World

JICA Study for Strategy and Guiding Policy on Advancing Low-carbon / Carbon Neutral Society in Developing Countries

Final Report

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Japan International Cooperation Agency（JICA）

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List of abbreviations

Abbreviation	Official Name
AC	Alternating Current
ACT	Accelerating Coal Transition
ADB	Asian Development Bank
AfDB	African Development Bank
AFOLU	Agriculture, Forestry and Other Land Use
AGC	Automatic Generation Control
AI	Artificial Intelligence
ASEAN	Association of South-East Asian Nations
AT &C Loss	Aggregate Technical and Commercial Loss
A-USC	Advanced-Ultra Super Critical Power Plant
BAU	Business as Usual
BECCS	Bioenergy with Carbon Capture and Storage
BEMS	Building Energy Management System
BESS	Battery Energy Storage System
BEV	Battery Electric Vehicle
BIG	Bangkok Industrial Gas Company Limited
BOO	Build-Own-Operate
BOOT	Build-Own-Operate-Transfer
Bp	British Petroleum
BPP	Biaya Pokok Penjualan
BTL	Biomass to liquid
CCGT	Combined Cycle Gas Turbine
CCS	Carbon dioxide Capture and Storage
CCUS	Carbon dioxide Capture, Utilization and Storage
CEA	Central Electricity Agency
CERC	Central Electricity Regulatory Commission
CIF	Climate Investment Funds
CIF	Cost Insurance and Freight
CN	Carbon Neutral
CNG	Compressed Natural Gas
COP26	Conference of the Parties (26th United Nations Climate Change conference)

CSP	Concentrating Solar Power
DAS	Distribution Automation System
DC	Direct Current
DEDE	Department of Alternative Energy Development and Energy
DPR	Detail Project Report
DR	Demand Response
EC	European Commission
EDC	Economic load Dispatching Control
EEP	Energy Efficiency Plan
EGAT	Electricity Generating Authority of Thailand
EGR	Enhanced Gas Recovery
EIB	European Investment Bank
EMS	Energy Management System
EOR	Enhanced Oil Recovery
EPC	Engineering, Procurement, and Construction
ERC	Energy Regulatory Commission
ETM	Energy Transition Mechanism
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
FIT	Feed In Tarif
FRT	Fault Ride Through
FS	Feasibility Study
GF	Governor-Free
GFL	Grid Following Inverter
GFM	Grid Forming Inverter
GHG	Green-House gas
GIZ	Deutshe Geselleschaft fuur Internationale Zusammenarbeit
GWEC	Global Wind energy Council
G2V	Grid to Vehicle
HEFA	Hydroprocessed Esters and Fatty Acids
HEMS	Home Energy Management System
HHV	Higher Heating Value

HTTR	High Temperature engineering Test Reactor
HVDC	High Voltage Direct Current
HVO	Hydrotreated Vegetable Oil
ICAP	International Carbon Action Partnership
ICT	Information and Communication Technology
IEA	International Energy Agency
IGCC	Integrated coal Gasification Combined Cycle
InSTS	In-State Transmission System
IOC	Indian Oil Corporation Limited
IPP	Independent Power Producer
IPPU	Industrial Processes and Product Use
IREC	International Renewable Energy Certificates
IRESEN	Institut de Recherche en Énergie Solaire et Énergies Nouvelles
ISTS	Inter State Transmission System
ITB	Institut Teknologi Bandung
IREDA	Indian Renewable Energy Development Agency Limited
JICA	Japan International Cooperation Agency
JNNSM	Jawaharlal Nehru National Solar Mission
JOGMEC	Japan Oil, Gas and Metals National Corporation
JPEA	Japan Photovoltaic Energy Association
LFC	Load Frequency Control
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land-Use Change and Forestry
MaaS	Mobility as a Service
MASEN	Moroccan Agency for Sustainable Energy
MCH	Methylcyclohexane
MEF	Minister for Environment and Forestry
MEMR	Ministry of Energy and Mineral Resources
METI	Ministry of Economy, Trade and Industry
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MoU	Memorandum of Understanding
MRV	Measurement, Reporting and Verification

NEDO	New Energy and Industrial Technology Development Organization
NTPC	National Thermal Power Corporation
MG	Motor Generator
NAPCC	National Action Plan on Climate Change
NDC	Nationally Determined Contributions
NITI	National Institution for Transforming India
NRE	New Renewable Energy
NREL	National Renewable Energy Laboratory
OECD	Organisation for Economic Co-operation and Development
OIL	Oil India Limited
ONEE	Office National de l'Electricité et de l'Eau Potable
ONGC	Oil and Natural Gas Corporation Limited
PAU	PT Panca Amara Utama
PCS	Power Conditioning System
PHEV	Plug in Hybrid Electric Vehicle
PLI	Production Linked Incentive
PLN	Perusahaan Listrik Negara
PMI	Partnership for Market Implementation
POSOCO	Power System Operation Corporation Limited
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PTT	PTT Public Company Limited
PV	Photovoltaics
RDSS	Revamped Distribution Sector Scheme
RE	Renewable Energy
RFP	Request for Proposal
RoCoF	Rate of Change of Frequency
RPO	Renewable Purchase Obligations
RUKN	Rencana Umum Ketenagalistrikan Nasional
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik
SC	Sub Critical Power Plant
SDS	Sustainable Development Scenario
SECI	Solar Energy Corporation of India Ltd.
SLDC	State Load Dispatch Centre

SMR	Small Modular Reactor
SOC	State Of Charge
TERI	The Energy and Resource Institute
TOD	Transit Oriented Development
TMI	Three Mile Island
TPA	Third Party Access
USAID	United States Agency for International Development
USC	Ultra Super Critical Power Plant
VPP	Virtual Power Plant
VQC	Voltage and reactive power Control
VRE	Variable Renewable Energy
VSG	Virtual Synchronous Generator
V2G	Vehicle to Grid
V2H	Vehicle to Home
WB	World Bank
WT	Wind Turbine
YSCP	Yokohama Sbart City Project
ZEV	Zero-Emission Vehicle

Summary

Under the Paris Agreement, parties are required to update and submit their Nationally Determined Contributions (NDCs) every five years in accordance with the decisions of the Conference of the Parties, which sets greenhouse gas reduction targets for each country. According to the results compiled by the Institute for Global Environmental Strategies by October 2021, 193 countries have submitted NDCs, providing a glimpse into the high level of awareness of countries regarding climate change. This study was conducted to examine the use of Japanese technologies related to low carbon emissions.

For the purpose of grasping the trends of energy policies for low carbonization and decarbonization in major developed countries and developing countries, we selected 17 countries based on certain criteria to conduct a study on long-term energy policies, renewable energy policies, and energy efficiency policies. As key points to consider for future cooperation in promoting low-carbonization and decarbonization, we discussed support measures for each country taking into account its energy use and policy trends in each country.

Low carbon and decarbonization technologies and services in the power and energy sector, transportation and transit, commerce, industry, and urban planning sectors, as well as their commercialization and commercialization trends, are summarized. Regarding the advantage of Japanese companies in the field of electric power and energy among low-/de-carbon technologies, Japanese companies have a certain technological advantage on pumped storage power generation and low-loss high-capacity transmission lines, but the high cost is their weakness. Applicable power systems in developing countries are limited. As for battery storage system, Japanese products have high quality, but high cost and low productivity are regarded as weak points. As for ammonia co-firing/mono-firing and hydrogen co-firing/mono-firing, R&D competition is underway, and at this point, Japanese technologies are not recognized to have firm advantages.

From the above, considering the aspect of cost, Japanese technologies do not have overwhelming advantages in each element. Therefore, it is necessary to promote marketing as comprehensive project from a long-term perspective, including provision of detailed operational technology. In the field of electric power sector, in particular, the impact of massive entry of variable renewable energy into power system is based on electrical theory and electric power engineering, and is basically considered to occur in any power system. Therefore, the menu of fundamental countermeasures is same. Matching with the actual situation of each power system will make it possible to deal with the issues more efficiently.

The current status and future prospects of elemental technologies and services that will become necessary and effective as countermeasures on the generation side, the grid side, and the demand side in conjunction with the mass introduction of variable renewable energy are analyzed. At the connection points with Large-scale VRE, it is necessary to solve issues such as voltage fluctuations and power flow fluctuations. Utilization of voltage adjustment equipment including battery system for power grid is a major countermeasure. Problems with massive VRE introduction into the power system are the issues of deterioration of inertia of power system and of frequency adjustment ability. The options of countermeasures include not only pumped storage power generation and installation of battery system in power grid but also introduction of GFM inverter that provide inertia and frequency adjustment ability, improvement of FRT function of VRE, flexible operation of power system through DR/VPP, and other various measures.

For Thailand, India, Indonesia, and Morocco, we identified the targets set by each country on the supply and demand sides, respectively, and created a roadmap for achieving these targets. The roadmap is a qualitative analysis and summary of each country's current status, challenges, measures to address those challenges, and support from other donors with respect to the supply-side and demand-side targets. The supply side is summarized in terms of low-carbon thermal power generation and promotion of renewable energy (including power system stabilization), while the demand side is summarized for the industry, transportation, and urban development sectors. Based on this roadmap, discussions were held with relevant organizations in each country, and the feedback obtained was reflected in the roadmap as well as in the draft cooperation program. Two to three cooperative program proposals were developed for the supply side and the demand side, respectively. Based on the draft cooperation program, discussions were held again with the relevant organizations in each country.

Last section summarizes the cooperation patterns in the hydrogen sector for developing countries around

the world, intending to provide a reference when considering future hydrogen-related cooperation projects for developing countries. The Study Team organized ideas for grouping countries targeted for support in the hydrogen sector, and for analyzing patterns of cooperation taking into account the status of the development of hydrogen strategies.

For Thailand, Indonesia, Morocco, and India, information was summarized with the aim of stimulating discussion on hydrogen use and related support, and estimated sector-specific hydrogen demand potentials up to 2050. In addition, we surveyed the support needs of each country regarding the use of hydrogen through a desktop survey and interviews with relevant local organizations.

1. Trends in the Energy Sector Based on the Paris Agreement

1.1 NDCs in the Paris Agreement and Long-Term Strategy Formulation Review

1.1.1 About the Paris Agreement

The Parties to the Paris Agreement have the aim of making ambitious efforts toward mitigating climate change and adapting to its impact. The Agreement stipulates that support will be strengthened so that the same efforts can be made by signatory developing countries. The central aims of the Paris Agreement are to keep the increase in the global average temperature to well within 2°C above pre-industrial levels and to continue to make efforts toward limiting the increase to 1.5°C. Achieving these ambitious targets requires suitable financial systems, technologies and capacity building.

As of November 2020, there are 197 Parties to the Paris Agreement, of which 188 have completed the ratification procedures. Despite ratifying the Paris Agreement in September 2016, the U.S. made a notification of withdrawal in November 2019, and the withdrawal was completed in November 2020 in line with the provisions of the Agreement. On the day of his taking office as the 46th President of the U.S. on January 20, 2021, President Biden signed a document to restore the U.S. to the Paris Agreement, and the U.S. rejoined the Agreement on February 19, 2021.

1.1.2 NDC Submission Procedures

In the Paris Agreement, the Parties to the Convention are required to revise and submit a Nationally Determined Contribution ("NDC") stipulating greenhouse gas emission reduction targets for the respective country every five years in line with decision 1/CP.21 and any relevant decisions of the Conference of the Parties ("COP")[1]. Ahead of COP21 in 2015, the Parties were invited to prepare Intended Nationally Determined Contributions ("INDCs"), which were converted into the final NDCs upon their acceptance of the Agreement (changes were made by some countries when transferring from the INDCs to the NDCs).

Table 1 NDC Submission Process

2016-17	2018	2019-20	2020	2023	2024-25	2025
• INDCs to NDCs	• INDCs to NDCs • FD 2018	• Submit NDCs • (9-12 months prior to CMA [2])	• Synthesis Report • Low Emissions Development Strategy (LEDS) • CMA for NDCs	• Global Stock Take (GST)	• Submit NDCs • (9-12 months prior to CMA)	• Synthesis Report • LEDS • CMA for NDCs

Source: Webinar presentation materials on UNFCCC NDC (https://unfccc.int/files/focus/application/pdf/ndc_cycle_webinar2.pdf)

According to results calculated by the Institute for Global Environmental Strategies (IGES) up to October 2021, 197 countries had submitted INDCs and 193 countries had submitted NDCs (see Figure 1). Figure 2 shows the reductions targets stated in the NDCs against global greenhouse gas emissions (2018). Annex I countries in the Figure are countries (developed countries and countries transitioning to a market economy) classified as having common but differentiated responsibilities stipulated in the United Nations Framework Convention on Climate Change (adopted in 1992) that have stated greenhouse gas emission reduction targets. Non-Annex I countries are other countries that have not

[1] The obligation to prepare, submit, and maintain an NDC on mitigation is set forth in the first sentence of Article 4.2, and the obligation to submit an NDC every five years is set forth in Article 4.9.

[2] Conference of the Parties serving as the meeting of the Parties to the Paris Agreement: CMA

stated greenhouse gas emission reduction targets. In the 1997 Kyoto Protocol, numerical targets for greenhouse gas emission reductions were imposed on Annex I countries. However, after the adoption of the Kyoto Protocol in 1997, some developing countries made rapid economic growth, and China accounted for the largest global share of greenhouse gas emissions. The fact that no obligation for reduction was imposed on developing countries led to a sense of injustice among participatory countries, and the validity of the Kyoto Protocol was also brought into question by the fact that it hadn't been ratified by the U.S. The Paris Agreement requires all participating countries and regions, including developing countries, to set greenhouse gas emission reduction and limitation targets for 2020 and thereafter.

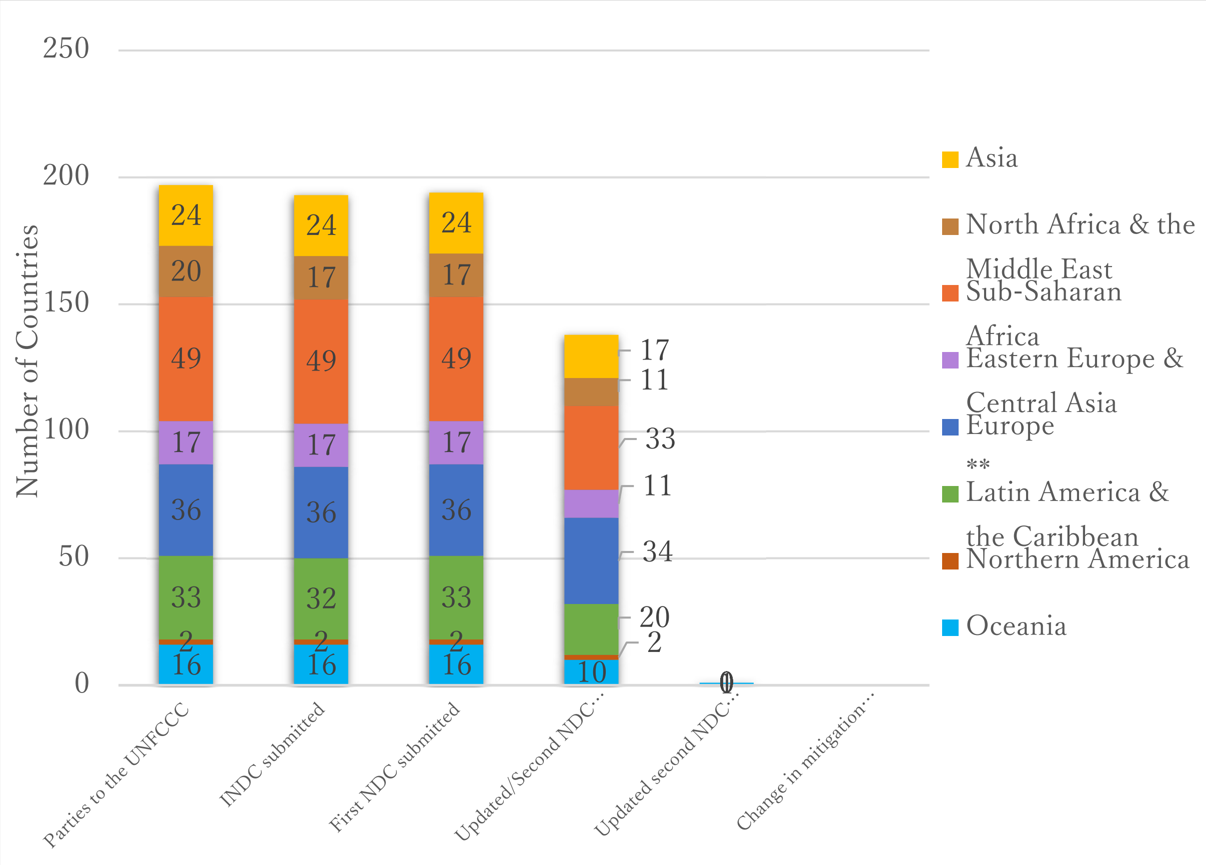

Figure 1 INDC and NDC Submission (no. of countries)

Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

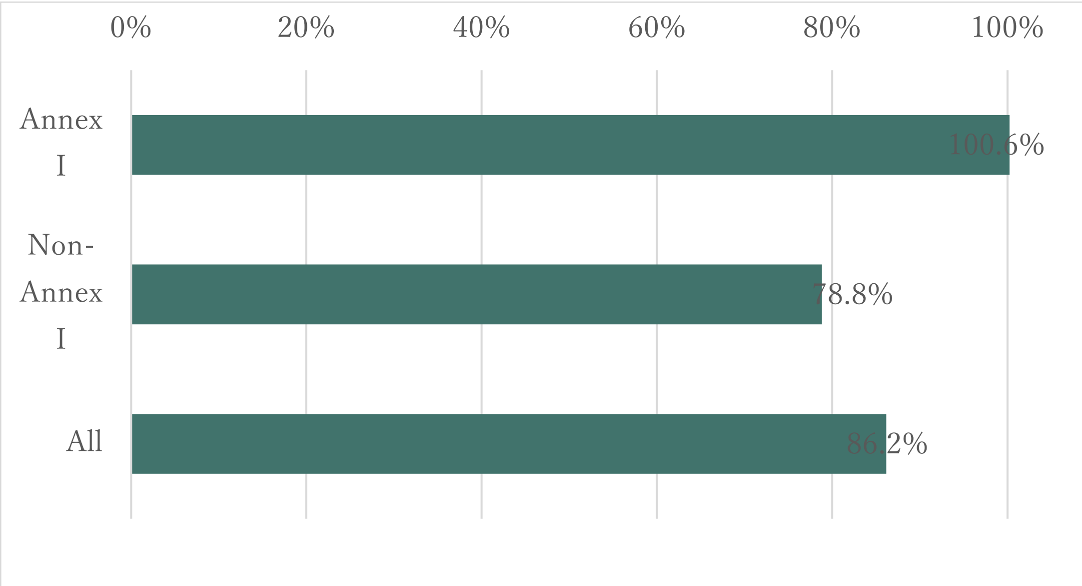

Figure 2　Ratio of Reduction Based on NDCs (%)

Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

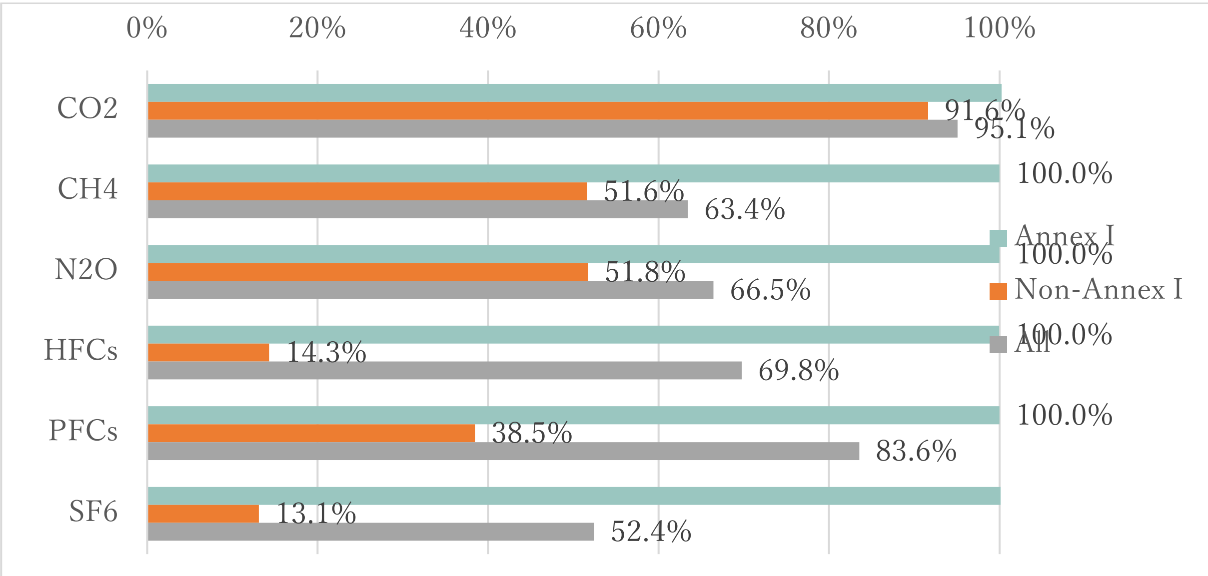

Figure 3　Ratio of Reduction in Types of Greenhouse Gases Based on NDCs (%)

Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

1.1.3 Analysis of Greenhouse Gas Emission Reduction Targets in NDCs

The overall trends based on the NDCs submitted by each country will now be described. First, the most common greenhouse gas covered by emission reduction targets is carbon dioxide followed by methane and then nitrous oxide (see Figure 4).

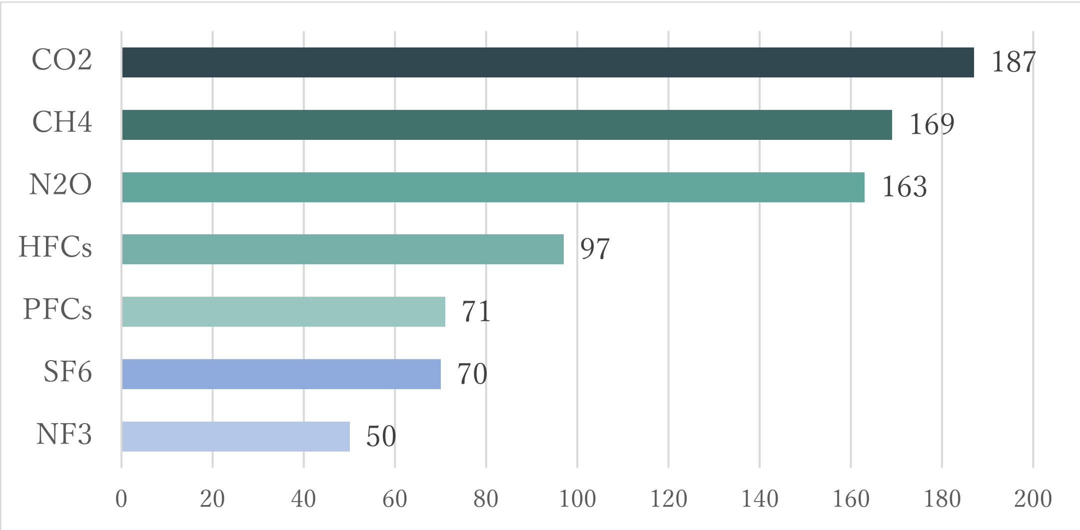

Figure 4 Types of Greenhouse Gas Covered by Emission Reduction Targets (no. of countries)
Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

In terms of the sectors covered by emission reduction targets, the energy sector is the most common sector followed by agriculture, and then transport (see Figure 5).

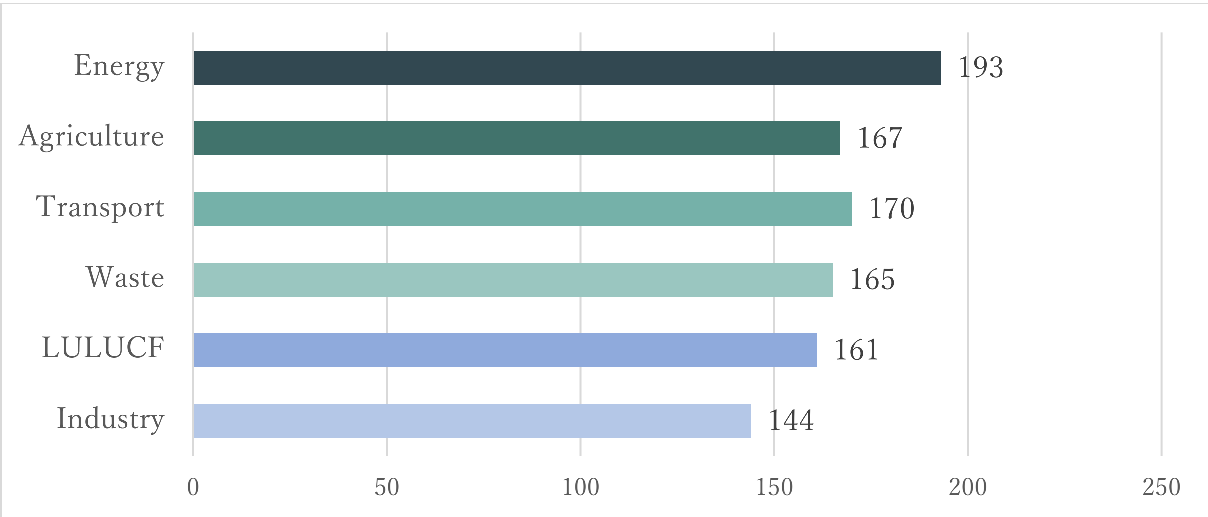

Figure 5 Sectors Covered by Emission Reduction Targets (no. of countries)
Source: IGES NDC Database (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

With reference to the IGES calculations, despite the use of the blanket term "greenhouse gas emission reductions," there are five main types of reduction in the NDCs. Among them, the types most commonly stated by the Parties are absolute emission reduction, which has the aim of reducing emissions compared to the base year, and relative emission reduction, which refers to the aim of reducing the amount of greenhouse gas in comparison to a BAU ("Business as usual") scenario, that is, the natural status in the case that no particular greenhouse gas reduction measures have been taken.

The other reduction types are carbon intensity reduction[3], peak of carbon emissions[4] and policies and actions.

The countries that have adopted carbon intensity reduction are China, India, Malaysia, Tunisia, Uruguay and Zimbabwe. The countries that have adopted peak of carbon emissions are Chile, Singapore and South Africa.

As shown below, a vast majority of countries have adopted absolute emission reduction or relative emission reduction.

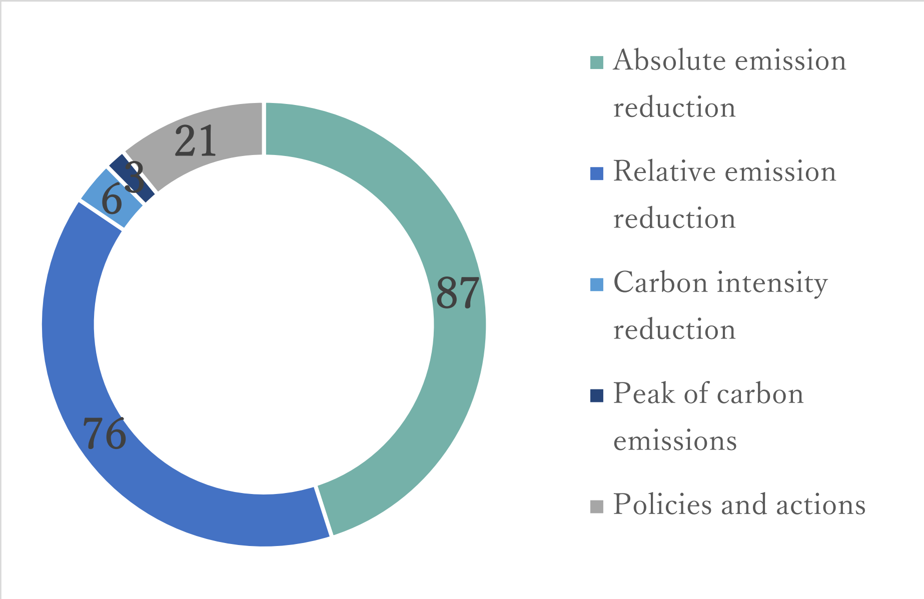

Figure 6 Type of Reduction (no. of countries)

Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

Furthermore, each country has set in its NDCs when it will achieve its reduction targets. As shown in Figure 7, the majority of countries have set 2030 as the target year.

[3] Carbon intensity = carbon dioxide emitted in the country / total primary energy supply. Smaller values are obtained when a higher percentage of renewable energy is used or more efficient technologies are introduced.

[4] For example, Chile has set a target of peaking out in 2025 and bringing total emissions to 95 million tCO_2 in 2030, while Singapore has set a target of peaking out at 65 million tCO_2 around 2030.

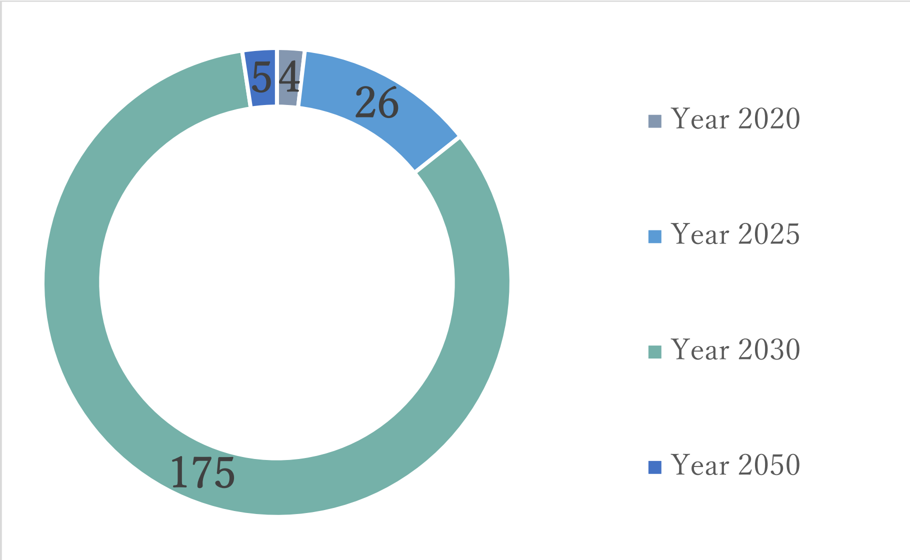

Figure 7 Target Year (no. of countries)

Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

Regarding GHG emission reduction targets, the results of an analysis of the correlation between various economic and energy-related data are shown in the following Table (the data used was from March 2021). With reference to this Table, although a slight positive correlation can be seen in the connection between the introduction of renewable energy and GHG emission reduction targets, other data has little connection to the GHG emission reduction targets. Except for Tuvalu, Vanuatu, Comoros, Namibia, and El Salvador, where the values are extreme, the correlation coefficient between renewable energy and the GHG emission reduction targets is below 0.433, showing that there is no direct correlation between GHG emission reduction targets and economic and energy-related data.

Table 2 Correlation between GHG Emission Reduction Targets and Energy-Related Data

	GHG emission reduction targets	Renewable energy target	Renewable energy target (NDB + Other)	Renewable energy share	Energy Intensity (2017)	GDP per capita	GNI per capita	GDP growth rate
GHG emission reduction targets	1.000							
Renewable energy target (Items stated in NDCs only)	0.504	1.000						
Renewable energy target (NDCs + other information sources (REN21))	0.397	1.000	1.000					
Renewable energy share	0.268	0.270	0.376	1.000				
Energy intensity (2017) (toe / USD 1000 (2010 PPP)	-0.127	-0.105	-0.002	0.223	1.000			
GDP per capita (Nominal USD)	0.090	-0.191	-0.142	0.242	-0.194	1.000		
GNI per capita (Nominal USD 2019)	0.091	-0.194	-0.113	0.319	-0.185	0.965	1.000	
GDP growth rate	0.132	0.085	0.018	-0.262	-0.043	-0.101	-0.102	1.000

*Renewable energy target (NDCs + other information sources (REN21)): In addition to the renewable energy target stated in the NDC, the targets for each country compiled in the REN21 "RENEWABLES 2020 GLOBAL STATUS REPORT" are listed in the case that the NDC does not include a renewable energy target.

Sources:
GHG emission reduction targets : NDC (data used was from March 2021)
Renewable energy target (Items stated in NDCs only): NDC
Renewable energy target (NDCs + other information sources (REN21)): NDC and REN21 (2020) "RENEWABLES 2020 GLOBAL STATUS REPORT"

Renewable energy share REN21 (2020) "RENEWABLES 2020 GLOBAL STATUS REPORT"
Energy Intensity: IEA website (https://www.iea.org/reports/sdg7-data-and-projections/energy-intensity)
GDP per capita: WB Economy & Growth website(https://data.worldbank.org/topic/economy-and-growth)
GNI per capita: WB Economy & Growth website(https://data.worldbank.org/topic/economy-and-growth)
GDP growth rate: WB Economy & Growth website(https://data.worldbank.org/topic/economy-and-growth)

The following Graph shows the connection between the renewable energy introduction targets stated in the NDCs and GHG emission reduction targets. As stated above, the values for Tuvalu, Vanuatu, Comoros, Namibia, and El Salvador are extreme.

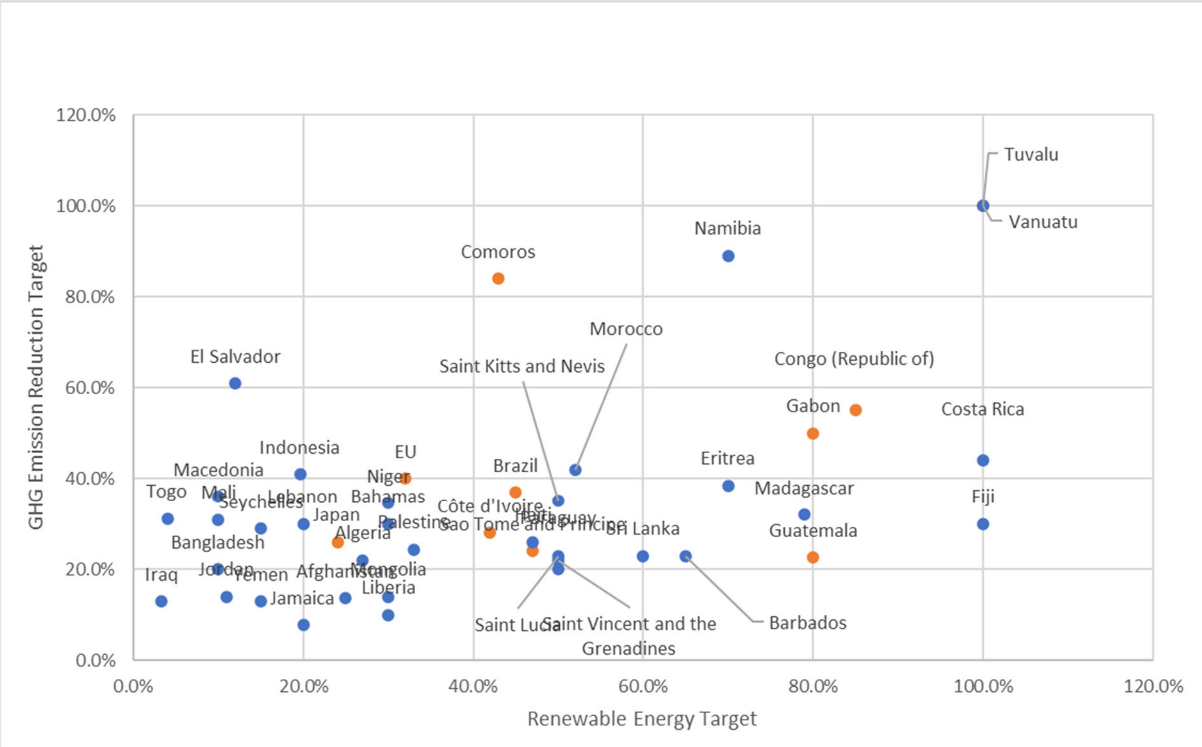

Figure 8　Connection between Renewable Energy and GHG Emission Reduction Targets

The following Graph shows the connection between renewable energy introduction targets and GHG emission reduction targets after using information in REN21 (2020) "RENEWABLES 2020 GLOBAL STATUS REPORT" to supplement the data of countries that do not have renewable energy introduction targets in their NDCs.

The targets for the introduction of renewable energy in European countries are difficult to see on the graph, as they are common for the entire EU, but, in concrete terms, the connection between renewable energy introduction targets and GHG emission reduction targets is not easily discerned.

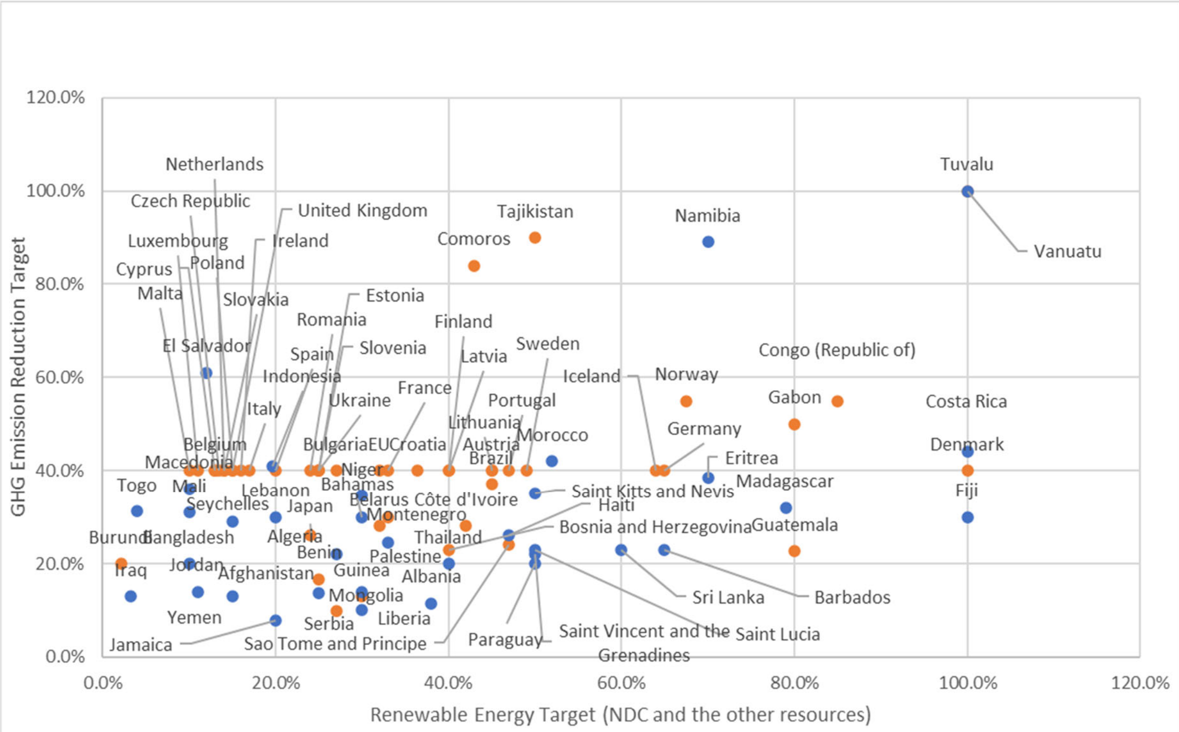

Figure 9 Renewable Energy Targets (inc. targets from a source other than the NDC) and GHG Emission Reduction Targets

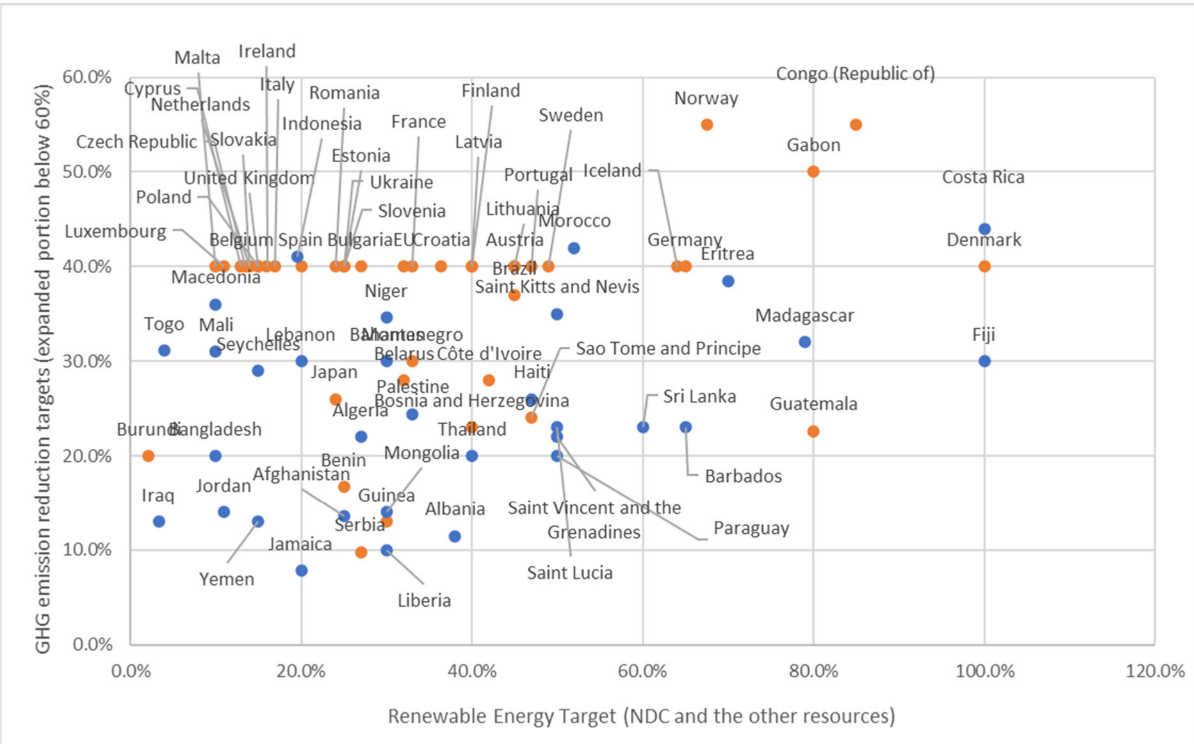

Figure 10 Renewable Energy Targets (inc. targets from a source other than the NDC) and GHG Emission Reduction Targets

*Expanded portion of GHG emission reduction target of 60% or less.

Based on the classification of developing countries in the OECD Development Assistance Committee ("OECD-DAC"), the ranges of the numerical emission reduction targets have been organized for each country with absolute and relative reductions on the following pages.

In addition to the above, Figures 11 and 12 show the renewable energy introduction targets in the NDCs.

	Least Deveoped		Other Low Income	Lower Middle Income		Upper Middle Income			Other (Developed)	
~100%	Tuvalu	Fa							New Zealand	Lg
~90%	Comoros	Kb		Tajikistan	Ab					
				Moldova (Republic of)	Ab					
~80%	Chad	Fb								
~70%										
~60%	Djibouti	Cb		Congo (Republic of)	Cf	Gabon	Ca	80%	Norway	Ab
~50%	Zambia	Fb				Marshall Islands	Fe	その他	Monaco	Ab
	Gambia	Fe				Dominica	Id	その他	Switzerland	Ae
~40%				Ukraine	Ab	Brazil	Da	45%	European Union	Ab
				Micronesia (Federated States of)	Ca	Grenada	Fe	その他	United Kingdom	Ab
						Azerbaijan	Ab	-	Iceland	Ab
									Liechtenstein	Ab
~30%	Solomon Islands	Je		Cameroon	Fc	Montenegro	Ab	-	Canada	Db
	Cambodia	Lb		Côte d'Ivoire	Gb	Belarus	Ab	-	Russian Federation	Ab
	Sao Tome and Principe	Db		Guatemala	Db	Dominican Republic	Fb	-	Australia	Db
	Mauritania	Fb				Kazakhstan	Ab	-	United States of America (USA)	Da
						Bosnia and Herzegovina	Ab	その他	Japan	Hb
						Ecuador	La	その他		
~20%	Burundi	Db				Equatorial Guinea	Fb	その他	San Marino	Db
	Congo (Democratic Republic of)	Cb				Botswana	Fb	-		
	Benin	Gb								
	Guinea	Bb								
	Burkina Faso	Eb								
~10%	Central African Republic	Fb		Uzbekistan	Fb	Serbia	Ab	-		

Figure 11 Connection between GHG Emission Reduction Targets in Each Country's NDC and Renewable Energy Introduction Targets (countries with absolute GHG emission reduction targets)

Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

Produced based on https://www.irena.org/Statistics/View-Data-by-Topic/Climate-Change/Renewable-Energy-in-the-NDCs

Graph legend

(Base year)

Base year	Mark
1990	A
1994	B
2000	C
2005	D
2007	E
2010	F
2012	G
2013	H
2014	I
2015	J
2030	K
Other	L

(Target year)

Target year	Mark
2025	a
2030	b
2035	c
2020,2025,2,030	d
2025,2030	e
2025,2035	f
2030,2050	g
Other	h

*Some countries set multiple target years.

(Renewable energy introduction target)

%	Color
100-80	
80-60	
60-40	
40-20	
20-0	
Other (e.g., generation facility capacity targets, etc.)	
Not stated in NDC	

	Least Deveoped		Other Low Income		Lower Middle Income		Upper Middle Income		Other (Developed)	
~100%	Vanuatu	1い								
~90%							Namibia	1い		
~80%										
~70%	Ethiopia	1い			Philippines	1い				
					El Salvador	1あ				
~60%										
~50%	Angola	1い	Korea (Democratic People's Republic of)	1い	Ghana	1い	Costa Rica	1い		
	Kiribati	1い			Nigeria	1い				
					Morocco	1い				
					Indonesia	1い				
~40%	Eritrea	2い			Kyrgyzstan	1い	Mexico	1い	Andorra	1い
	Lesotho	1い					Argentina	1い	Korea (Republic of)	1い
	Niger	1い					Macedonia	1い	Saint Kitts and Nevis	1お
	Madagascar	1い								
	Togo	1い								
	Mali	1い								
~30%	Haiti	1い			Kenya	1い	Colombia	1い	Bahamas	1い
	Uganda	1い			Georgia	1い	Fiji	1い	Seychelles	1お
	Senegal	1い			Viet Nam	1い	Lebanon	1い	Barbados	2お
					Palestine	1え	Mauritius	1い		
					Sri Lanka	1い	Peru	1い		
							Maldives	1い		
							Saint Lucia	1お		
							Algeria	1い		
							Saint Vincent and the Grenadines	1あ		
							Turkey	1い		
~20%	Bangladesh	1い			Pakistan	1い	Paraguay	1い	Trinidad and Tobago	1い
	Tanzania (United Republic of)	1い			Honduras	1い	Thailand	1い		
	Afghanistan	1い			Jordan	1い	Venezuela	1い		
	Yemen	1い					Iraq	1う		
					Mongolia	1い	Albania	1い		
~10%	Liberia	1か					Iran (Islamic Republic of)	1い	Oman	2い
							Jamaica	1い		

Graph legend

(Base year)

Base year	Mark
BAU	1
Other	2

(Target year)

Target year	Mark
2025	あ
2030	い
2035	う
2040	え
2025, 2030	お
2030, 2050	か

*Some countries set multiple target years.

(Renewable energy introduction target)

%	Color
100-80	
80-60	
60-40	
40-20	
20-0	
Other (e.g., generation facility capacity targets, etc.)	
Not stated in NDC	

Figure 12 Connection between GHG Emission Reduction Targets in Each Country's NDC and Renewable Energy Introduction Targets (countries with relative GHG emission reduction targets)

Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

Produced based on https://www.irena.org/Statistics/View-Data-by-Topic/Climate-Change/Renewable-Energy-in-the-NDCs

The following main points can be understood from Figures 11 and 12.

- ✓ More countries with relative emission reductions have specific numerical targets for the introduction of renewable energy than those with absolute emission reductions.
- ✓ For both GHG emission reduction and renewable energy introduction, developed countries do not always set a higher goal.

The countries that stand out in Figures 11 and 12 are as follows.

(Absolute emission reduction)

- Tuvalu (high emission reduction and renewable energy introduction targets)
  →Presumably because it is island nation where global warming is an urgent issue.
- Comoros (high emission reduction and renewable energy introduction targets)
  →Presumably because it is island nation where global warming is an urgent issue.
- Gabon (high emission reduction and renewable energy introduction targets)
- Republic of the Congo (high emission reduction and renewable energy introduction targets)

(Relative emission reduction)

- Vanuatu (high emission reduction and renewable energy introduction targets)
  →Presumably because it is island nation where global warming is an urgent issue.
- Namibia (high emission reduction and renewable energy introduction targets)
- Costa Rica (high emission reduction and renewable energy introduction targets)
  →Presumably because environmental policy is a material policy of the state.

Figures 13 and 14 have been created based on REN's "Renewable 2020 Global Status Report" with reference to the current share of renewable energy in total final energy consumption.

	Least Deveoped		Other Low Income		Lower Middle Income		Upper Middle Income		Other (Developed)	
~100%	Tuvalu	Fa							New Zealand	Lg
~90%	Comoros	Kb			Tajikistan	Ab				
					Moldova (Republic of)	Ab				
~80%	Chad	Fb								
~70%										
~60%	Djibouti	Cb			Congo (Republic of)	Cf	Gabon	Ca	Norway	Ab
~50%	Zambia	Fb					Marshall Islands	Fe	Monaco	Ab
	Gambia	Fe					Dominica	Id	Switzerland	Ae
~40%					Ukraine	Ab	Brazil	Da	European Union	Ab
					Micronesia (Federated States of)	Ca	Grenada	Fe	United Kingdom	Ab
							Azerbaijan	Ab	Iceland	Ab
									Liechtenstein	Ab
~30%	Solomon Islands	Je			Cameroon	Fc	Montenegro	Ab	Canada	Db
	Cambodia	Lb			Côte d'Ivoire	Gb	Belarus	Ab	Russian Federation	Ab
	Sao Tome and Principe	Db			Guatemala	Db	Dominican Republic	Fb	Australia	Db
	Mauritania	Fb					Kazakhstan	Ab	United States of America (USA)	Da
							Bosnia and Herzegovina	Ab	Japan	Hb
							Ecuador	La		
~20%	Burundi	Db					Equatorial Guinea	Fb	San Marino	Db
	Congo (Democratic Republic of)	Cb					Botswana	Fb		
	Benin	Gb								
	Guinea	Bb								
	Burkina Faso	Eb								
~10%	Central African Republic	Fb			Uzbekistan	Fb	Serbia	Ab		

Figure 13 Connection between GHG Emission Reduction Targets in each country's NDC and Current Renewable Energy Share (countries with absolute GHG emission reduction targets) (based on REN21 report)

Source: IGES NDC Database (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)
Produced based on REN21" Renewables 2020 Global Status Report"

Graph legend

(Base year)

Base year	Mark
1990	A
1994	B
2000	C
2005	D
2007	E
2010	F
2012	G
2013	H
2014	I
2015	J
2030	K
Other	L

(Target year)

Target year	Mark
2025	a
2030	b
2035	C
2020,2025,2,030	D
2025,2030	e
2025,2035	F
2030,2050	g
Other	h

*Some countries set multiple target years.

(Current renewable energy share)

%	Color
100-80	
80-60	
60-40	
40-20	
20-0	
Other (e.g., generation facility capacity targets, etc.)	
No data	

	Least Deveoped	Other Low Income	Lower Middle Income	Upper Middle Income	Other (Developed)
~100%	Vanuatu 1い				
~90%				Namibia 1い	
~80%					
~70%	Ethiopia 1い		Philippines 1い		
			El Salvador 1あ		
~60%					
~50%	Angola 1い	Korea (Democratic People's Republic of) 1い	Ghana 1い	Costa Rica 1い	
	Kiribati 1い		Nigeria 1い		
			Morocco 1い		
			Indonesia 1い		
~40%	Eritrea 2い		Kyrgyzstan 1い	Mexico 1い	Andorra 1い
	Lesotho 1い			Argentina 1い	Korea (Republic of) 1い
	Niger 1い			Macedonia 1い	Saint Kitts and Nevis 1お
	Madagascar 1い				
	Togo 1い				
	Mali 1い				
~30%	Haiti 1い		Kenya 1い	Colombia 1い	Bahamas 1い
	Uganda 1い		Georgia 1い	Fiji 1い	Seychelles 1お
	Senegal 1い		Viet Nam 1い	Lebanon 1い	Barbados 2お
			Palestine 1え	Mauritius 1い	
			Sri Lanka 1い	Peru 1い	
				Maldives 1い	
				Saint Lucia 1お	
				Algeria 1い	
				Saint Vincent and the Grenadines 1あ	
				Turkey 1い	
~20%	Bangladesh 1い		Pakistan 1い	Paraguay 1い	Trinidad and Tobago 1い
	Tanzania (United Republic of) 1い		Honduras 1い	Thailand 1い	
	Afghanistan 1い		Jordan 1い	Venezuela 1い	
	Yemen 1い			Iraq 1う	
			Mongolia 1い	Albania 1い	
~10%	Liberia 1か			Iran (Islamic Republic of) 1い	Oman 2い
				Jamaica 1い	

Graph legend

(Base year)

Base year	Mark
BAU	1
Other	2

(Target year)

Target year	Mark
2025	あ
2030	い
2035	う
2040	え
2025, 2030	お
2030, 2050	か

*Some countries set multiple target years.

(Current renewable energy share)

%	Color
100-80	red
80-60	orange
60-40	yellow
40-20	green
20-0	blue
Other(e.g., generation facility capacity targets, etc.)	grey
No data	

Figure 14 Connection between GHG Emission Reduction Targets in each country's NDC and Current Renewable Energy Share (countries with relative GHG emission reduction targets) (based on REN21 report)

Source: IGES NDC Database (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

Produced based on REN21" Renewables 2020 Global Status Report"

The following main points can be understood from Figures 13 and 14.

- ✓ REN21 collects the data of only a small number of countries which limits the countries that can be referenced.
- ✓ Of the countries that have stated absolute reduction targets, only lower-middle income countries or greater with emission reduction targets of 40% or more currently have renewable energy share of 40% or more.
- ✓ Among the countries that have stated relative reduction targets, there was no clear connection between the current renewable energy share, economic growth and the GHG emission reduction targets. Even among developing countries, some countries have a high renewable energy share.

The countries that stand out in Figures 13 and 14 are as follows.

(Absolute emission reduction)

- ➢ Tajikistan (high emission reduction targets and current renewable energy share)
- ➢ Gabon (high emission reduction targets and current renewable energy share)
- ➢ Norway (high emission reduction targets and current renewable energy share)

(Relative emission reduction)

- ➢ Madagascar (currently has a high renewable energy share among developing countries)
- ➢ Liberia (currently has a high renewable energy share among developing countries)

Furthermore, Figures 15 and 16 have been created based on the REN Renewable 2020 Global Status Report, and the difference between the introduction targets and the current amount of renewable energy introduced were classified according to color.

	Least Deveoped		Other Low Income		Lower Middle Income		Upper Middle Income		Other (Developed)	
~100%	Tuvalu	Fa							New Zealand	Lg
~90%	Comoros	Kb			Tajikistan	Ab				
					Moldova (Republic of)	Ab				
~80%	Chad	Fb								
~70%										
~60%	Djibouti	Cb			Congo (Republic of)	Cf	Gabon	Ca	Norway	Ab
~50%	Zambia	Fb					Marshall Islands	Fe	Monaco	Ab
	Gambia	Fe					Dominica	Id	Switzerland	Ae
~40%					Ukraine	Ab	Brazil	Da	European Union	Ab
					Micronesia (Federated States of)	Ca	Grenada	Fe	United Kingdom	Ab
							Azerbaijan	Ab	Iceland	Ab
									Liechtenstein	Ab
~30%	Solomon Islands	Je			Cameroon	Fc	Montenegro	Ab	Canada	Db
	Cambodia	Lb			Côte d'Ivoire	Gb	Belarus	Ab	Russian Federation	Ab
	Sao Tome and Principe	Db			Guatemala	Db	Dominican Republic	Fb	Australia	Db
	Mauritania	Fb					Kazakhstan	Ab	United States of America (USA)	Da
							Bosnia and Herzegovina	Ab	Japan	Hb
							Ecuador	La		
~20%	Burundi	Db					Equatorial Guinea	Fb	San Marino	Db
	Congo (Democratic Republic of)	Cb					Botswana	Fb		
	Benin	Gb								
	Guinea	Bb								
	Burkina Faso	Eb								
~10%	Central African Republic	Fb			Uzbekistan	Fb	Serbia	Ab		

Figure 15 Connection between GHG Emission Reduction Targets in each country's NDC and the Difference between Current Renewable Energy Share and the Renewable Energy Introduction Target (countries with absolute GHG emission reduction targets) (based on REN21 report)

Source: IGES NDC Database (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)
Produced based on REN21" Renewables 2020 Global Status Report"

Graph legend
(Base year)

Base year	Mark
1990	A
1994	B
2000	C
2005	D
2007	E
2010	F
2012	G
2013	H
2014	I
2015	J
2030	K
Other	L

(Target year)

Target year	Mark
2025	a
2030	b
2035	C
2020,2025,2,030	D
2025,2030	e
2025,2035	F
2030,2050	g
Other	h

*Some countries set multiple target years.

(Gap between renewable energy introduction target and current renewable energy share)

%	Color
20 or more	
20~15	
15~10	
10~5	
5 or less	
Other (e.g., generation facility capacity targets, etc.)	
No data	

	Least Deveoped		Other Low Income		Lower Middle Income		Upper Middle Income		Other (Developed)	
~100%	Vanuatu	1い								
~90%							Namibia	1い		
~80%										
~70%	Ethiopia	1い			Philippines	1い				
					El Salvador	1あ				
~60%										
~50%	Angola	1い	Korea (Democratic People's Republic of)	1い	Ghana	1い	Costa Rica	1い		
	Kiribati	1い			Nigeria	1い				
					Morocco	1い				
					Indonesia	1い				
~40%	Eritrea	2い			Kyrgyzstan	1い	Mexico	1い	Andorra	1い
	Lesotho	1い					Argentina	1い	Korea (Republic of)	1い
	Niger	1い					Macedonia	1い	Saint Kitts and Nevis	1お
	Madagascar	1い								
	Togo	1い								
	Mali	1い								
~30%	Haiti	1い			Kenya	1い	Colombia	1い	Bahamas	1い
	Uganda	1い			Georgia	1い	Fiji	1い	Seychelles	1お
	Senegal	1い			Viet Nam	1い	Lebanon	1い	Barbados	2お
					Palestine	1え	Mauritius	1い		
					Sri Lanka	1い	Peru	1い		
							Maldives	1い		
							Saint Lucia	1お		
							Algeria	1い		
							Saint Vincent and the Grenadines	1あ		
							Turkey	1い		
~20%	Bangladesh	1い			Pakistan	1い	Paraguay	1い	Trinidad and Tobago	1い
	Tanzania (United Republic of)	1い			Honduras	1い	Thailand	1い		
	Afghanistan	1い			Jordan	1い	Venezuela	1い		
	Yemen	1い					Iraq	1う		
					Mongolia	1い	Albania	1い		
~10%	Liberia	1か					Iran (Islamic Republic of)	1い	Oman	2い
							Jamaica	1い		

Graph legend

(Base year)

Base year	Mark
BAU	1
Other	2

(Target year)

Target year	Mark
2025	あ
2030	い
2035	う
2040	え
2025, 2030	お
2030, 2050	か

*Some countries set multiple target years.

(Gap between target and current renewable energy share)

%	Color
20 or more	
20~15	
15~10	
10~5	
5 or less	
Other	
No information	

Figure 16 Connection between GHG Emission Reduction Targets in each country's NDC and the Difference between Current Renewable Energy Share and the Renewable Energy Introduction Target (countries with relative GHG emission reduction targets) (based on REN21 report)

Source: IGES NDC Database (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)
Produced based on REN21" Renewables 2020 Global Status Report"

The following main points can be understood from Figures 15 and 16.

- ✓ REN21 collects the data of only a small number of countries which limits the countries that can be referenced.
- ✓ Among the countries that have stated absolute reduction targets, those that have a large gap between the reduction target and the current share of renewable energy are developing countries/regions with upper-middle income.
- ✓ Regarding the countries that have stated relative reduction targets, among developing countries/regions with low-middle income, upper-middle income, there were some countries with a huge gap, even though the reduction target was not high (Jordan and Jamaica).

The countries that stand out in Figures 15 and 16 are as follows.

(Absolute emission reduction)

- ➢ Belarus (huge gap between reduction targets and current renewable energy share)
- ➢ Bosnia-Herzegovina (huge gap between reduction targets and current renewable energy share)

(Relative emission reduction)

- ➢ Madagascar (Even among developing countries with low income, while high emission reduction targets have been set, there is a huge gap between the emission reduction targets and the current renewable energy share which is also high.)
- ➢ Jordan (Even though the reduction target is not high, there is a huge gap between the reduction target and the current renewable energy share.)
- ➢ Jamaica (Even though the reduction target is not high, there is a huge gap between the reduction target and the current renewable energy share.)

Furthermore, based on IEA data, the connection to energy intensity was also investigated.

	Least Deveoped			Other Low Income	Lower Middle Income			Upper Middle Income			Other (Developed)	
~100%	Tuvalu	Fa	-								New Zealand	Lg
~90%	Comoros	Kb	-		Tajikistan	Ab	0.128					
					Moldova (Republic of)	Ab	0.213					
~80%	Chad	Fb	-									
~70%												
~60%	Djibouti	Cb	-		Congo (Republic of)	Cf	0.116	Gabon	Ca	0.154	Norway	Ab
~50%	Zambia	Fb	0.196					Marshall Islands	Fe	-	Monaco	Ab
	Gambia	Fe	-					Dominica	Id	-	Switzerland	Ae
~40%					Ukraine	Ab	0.272	Brazil	Da	0.1	European Union	Ab
					Micronesia (Federated States of)	Ca	-	Grenada	Fe	-	United Kingdom	Ab
								Azerbaijan	Ab	0.094	Iceland	Ab
											Liechtenstein	Ab
~30%	Solomon Islands	Je	-		Cameroon	Fc	0.116	Montenegro	Ab	0.102	Canada	Db
	Cambodia	Lb	0.141		Côte d'Ivoire	Gb	0.122	Belarus	Ab	0.16	Russian Federation	Ab
	Sao Tome and Principe	Db	-		Guatemala	Db	0.111	Dominican Republic	Fb	0.057	Australia	Db
	Mauritania	Fb	-					Kazakhstan	Ab	0.2	United States of America (USA)	Da
								Bosnia and Herzegovina	Ab	0.172	Japan	Hb
								Ecuador	La	0.084		
~20%	Burundi	Db	-					Equatorial Guinea	Fb	-	San Marino	Db
	Congo (Democratic Republic of)	Cb	0.462					Botswana	Fb	0.08		
	Benin	Gb	0.225									
	Guinea	Bb	-									
	Burkina Faso	Eb	-									
~10%	Central African Republic	Fb	-		Uzbekistan	Fb	0.17	Serbia	Ab	0.166		

Figure 17 Connection between GHG Emission Reduction Targets in each country's NDC and the Current Energy Intensity (countries with absolute GHG emission reduction targets)

Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)

Produced based on https://www.iea.org/reports/sdg7-data-and-projections/energy-intensity

Graph legend

(Base year)

Base year	Mark
1990	A
1994	B
2000	C
2005	D
2007	E
2010	F
2012	G
2013	H
2014	I
2015	J
2030	K
Other	L

(Target year)

Target year	Mark
2025	a
2030	b
2035	C
2020,2025,2,030	D
2025,2030	e
2025,2035	F
2030,2050	g
Other	h

*Some countries set multiple target years.

(Energy intensity)

Toe / USD 1000 (2010PPP)	Color
0.462-0.2905	
0.2905-0.119	
0.119-0.08	
0.08-0.041	
No data	
Global average	0.119

	Least Deveoped		Other Low Income			Lower Middle Income			Upper Middle Income		Other (Developed)	
~100%	Vanuatu	1い										
~90%									Namibia	1い		
~80%												
~70%	Ethiopia	1い				Philippines	1い	0.074				
						El Salvador	1あ	0.09				
~60%												
~50%	Angola	1い	Korea (Democratic People's Republic of)	1い	0.148	Ghana	1い	0.08	Costa Rica	1い		
	Kiribati	1い				Nigeria	1い	0.157				
						Morocco	1い	0.077				
						Indonesia	1い	0.084				
~40%	Eritrea	2い				Kyrgyzstan	1い	0.186	Mexico	1い	Andorra	1い
	Lesotho	1い							Argentina	1い	Korea (Republic of)	1い
	Niger	1い							Macedonia	1い	Saint Kitts and Nevis	1お
	Madagascar	1い										
	Togo	1い										
	Mali	1い										
~30%	Haiti	1い				Kenya	1い	0.186	Colombia	1い	Bahamas	1い
	Uganda	1い				Georgia	1い	0.135	Fiji	1い	Seychelles	1お
	Senegal	1い				Viet Nam	1い	0.135	Lebanon	1い	Barbados	2お
						Palestine	1え	-	Mauritius	1い		
						Sri Lanka	1い	0.049	Peru	1い		
									Maldives	1い		
									Saint Lucia	1お		
									Algeria	1い		
									Saint Vincent and the Grenadines	1あ		
									Turkey	1い		
~20%	Bangladesh	1い				Pakistan	1い	0.107	Paraguay	1い	Trinidad and Tobago	1い
	Tanzania (United Republic of)	1い				Honduras	1い	0.146	Thailand	1い		
	Afghanistan	1い				Jordan	1い	0.117	Venezuela	1い		
	Yemen	1い							Iraq	1う		
						Mongolia	1い	0.145	Albania	1い		
~10%	Liberia	1か							Iran (Islamic Republic of)	1い	Oman	2い
									Jamaica	1い		

Graph legend

(Base year)

Base year	Mark
BAU	1
Other	2

(Target year)

Target year	Mark
2025	あ
2030	い
2035	う
2040	え
2025, 2030	お
2030, 2050	か

*Some countries set multiple target years.

(Energy intensity)

Toe / USD 1000 (2010PPP)	Color
0.462-0.2905	
0.2905-0.119	
0.119-0.08	
0.08-0.041	
No data	
Global average	0.119

Figure 18 Connection between GHG Emission Reduction Targets in each country's NDC and the Current Energy Intensity (countries with relative GHG emission reduction targets)

Source: IGES NDC Databook (https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en)
Produced based on https://www.iea.org/reports/sdg7-data-and-projections/energy-intensity

The following trends can be understood from Figures 17 and 18.

- ✓ There is no correlation between the NDC emission reduction targets and energy intensity.
- ✓ As income increases, the numerical values of energy intensity tend to decrease (increase in blue and green), but this is not the case in many countries.

The countries that stand out in Figures 17 and 18 are as follows.

(Absolute Targets: Countries with high energy intensity but high reduction targets)

- ✓ Tajikistan, Moldova

(Relative Targets: Countries with high energy intensity but high reduction targets)

- ✓ Ethiopia, North Korea, Nigeria

1.1.4 Case studies regarding NDCs

Target countries were selected for an analysis of the details of the NDC of the respective country. The target countries are shown below (the process of selection is described later in the study of cooperation strategies for energy and cross-sector initiatives).

These countries were analyzed with regard to the reporting year, scope of commitment, GHG emission reduction targets and renewable energy introduction targets, and means of commitment implementation (mainly mitigation measures).

Table 3 Targets of Detailed Analysis

High income	Upper-middle income	Lower-middle income	Low income
・EU(Covers European Commission policies and plans, not country by country) ・United States of America ・China	・Indonesia ・Thailand ・Peru ・South Africa	・India ・Morocco ・Egypt ・Cambodia ・Bangladesh ・Philippines ・Myanmar ・Vietnam ・Laos	・Mozambique

(1) EU

The main points of the EU's NDC are shown below.

Table 4 EU NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	March 2015 (INDC) *Date of submission on UNFCCC website: October 2016 December 2020 Updated version was submitted.	—
Target period	From January 1, 2021 to December 31, 2030	—
Scope of commitment	Energy Industry processes and product use	—

	Agriculture Waste Land use, land use changes and forestry (LULUCF) *Stated in more detail on the NDC. No changes in the updated version.	
Base year (Reference year or period)	1990	—
GHG emission reduction target	(2015 edition) At least 40% reduction in regional GHG emissions by 2030 (2020 edition) At least 55% reduction in regional GHG emissions by 2030	—
Renewable energy introduction target	(2015 edition) Not specified. (2020 edition) Increase the share of renewable energy in final energy consumption to 32% by 2030 *Based on the Directive (EU) 2018/2001[5]	—
Energy efficiency target	(2015 edition) Not specified. (2020 edition) The EU's final and primary energy consumption efficiency will be improved by 2030 at least 32.5% in comparison to the baseline. * The use of the term "will be" sounds more like an estimate than a target.	—
Renewable energy introduction volumes and its current share	(2015 edition) Not specified. (2020 edition) 17.5% renewable energy in final energy consumption (2017)	—
Energy intensity (current)	EU average 0.095 toe/USD 1 000 *Japan 0.089	IEA Report
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	Not specified.	—

Source: European Union First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

The EU NDC is a very simple 5-page document. The scope covers energy, industry processes and product use, agriculture, waste, land use, changes in land use and forestry, and there is detailed description of the scope of the NDC. This NDC is for the EU as a whole. It does not state anything regarding specific mitigation measures.

The EU submitted an updated version in December 2020. The updated NDC includes information regarding the action that was taken in order to implement the first NDC following the ratification of

5 Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

the Paris Agreement. The targets are more ambitious than those of the 2015 NDC. Specifically, while the target in the 2015 edition was at least a 40% reduction in regional GHG emissions by 2030, in the new version, the target is a reduction of at least 55% by 2030. The 2015 edition made no reference to renewable energy targets but the 2020 edition refers to numerical values from Directive (EU) 2018/2001.

(2) U.S.

The key points of the NDC of the U.S. are shown below.

Table 5 U.S. NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	September 2016 (INDC) *No dates are stated in the main text. Information taken from UNFCCC website April 2021 Updated version was submitted.	—
Target period	2025 as Target year	—
Scope of commitment	All sectors handled by IPCC	—
Base year (Reference year or period)	2005	—
GHG emission reduction target	(2016 edition) Reduction of 26-28% compared to 2005. (2021 edition) Reduction of 50-52% compared to 2005.	—
Renewable energy introduction target	Not specified.	—
Energy efficiency target	Not specified.	—
Renewable energy introduction volumes and its current share	Not specified.	No data in REN21 report.
Energy intensity (current)	0.124 toe/USD 1 000 *Japan 0.089, EU average 0.095	No data in IEA report.
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	(2016 edition) The content covers domestic laws, regulations, and measures relevant to implementation, and it merely introduces existing laws and regulations, and those then being prepared without any reference to other means of commitment implementation. (2021 edition) As noted above, there are brief references to sectoral approaches: power, transportation, buildings, and industry.	—

Source: US First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

The NDC of the U.S. is a very simple 5-page document. The content covers domestic laws, regulations, and measures relevant to implementation, and it merely introduces existing laws and regulations, and those then being prepared without any reference to other means of commitment implementation.

The United States submitted an updated version in April 2021. The updated NDC is 23 pages longer and includes a table with answers to the questions in Decision 4/CMA1. It also mentions adopting a sectoral approach to achieving the goals. For example, it includes the following.

- Electricity: switch to carbon emission-free electricity by 2035 through a range of cost-effective technologies and investments.
- Transportation: tailpipe emissions and efficiency standards; incentives for zero emission personal vehicles; funding for charging infrastructure to support multi-unit dwellings, public charging, and long-distance travel; and research, development, demonstration, and deployment efforts to support advances in very low carbon new-generation renewable fuels for applications like aviation, and other cutting-edge transportation technologies across modes, etc.
- Buildings: funding for retrofit programs, wider use of heat pumps and induction stoves, and adoption of modern energy codes for new buildings
- Industry: encourage renewable energy, nuclear energy, hydrogen from waste, and carbon capture.
- Agriculture and land: support scaling of climate smart agricultural practices (including, for example, cover crops), reforestation, rotational grazing, and nutrient management practices. Reduce the scope and intensity of catastrophic wildfires, and to restore fire-damaged forest lands.

(3) China

The key points of China's NDC are shown below.

Table 6 China NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	June 2015 (INDC) *Date of submission on UNFCC website: September 2016 October 2021 Updated version was submitted.	—
Target period	2030 as Target year	—
Scope of commitment	Not specified.	—
Base year (Reference year or period)	2005	—
GHG emission reduction target	(2015 edition) • To achieve the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early • To lower carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level • To increase the share of non-fossil fuels in primary energy consumption to around 20% • To increase the forest stock volume by around 4.5 billion cubic meters on the 2005 level (2021 edition) • Peak out CO2 emissions by 2030 and work toward achieving carbon neutrality by 2060.	—

	• To lower carbon dioxide emissions per unit of GDP by 65% or more from the 2005 level • To increase the share of non-fossil fuels in primary energy consumption to around 25% • To increase the forest stock volume by around 6.0 billion cubic meters on the 2005 level • To increase the total installed capacity of wind and solar power generation to more than 1.2 billion kW	
Renewable energy introduction target	(2015 edition) 20% (2030, share of non-fossil fuels in primary energy consumption) (2021 edition) 25% (2030, share of non-fossil fuels in primary energy consumption)	—
Energy efficiency target	Not specified.	—
Renewable energy introduction volumes and its current share	7.8% (2018)	REN21 Report
Energy intensity (current)	0.147 toe/USD 1 000 *Japan 0.089, EU average 0.095	IEA Report
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	(2015 edition) The commitment implementation methods are stated as follows from the viewpoints of A to O, below. A. Implementing Proactive National Strategies on Climate Change B. Improving Regional Strategies on Climate Change C. Building Low-Carbon Energy System D. Building Energy Efficient and Low-Carbon Industrial System E. Controlling Emissions from Building and Transportation Sectors F. Increasing Carbon Sinks G. Promoting the Low-Carbon Way of Life H. Enhancing Overall Climate Resilience I. Innovating Low-Carbon Development Growth Pattern J. Enhancing Support in terms of Science and Technology K. Increasing Financial and Policy Support L. Promoting Carbon Emission Trading Market M. Improving Statistical and Accounting System for GHG Emissions N. Broad Participation of Stakeholders O. Promoting International Cooperation on Climate Change (2021 edition) See the below	—

Source: China First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

China's NDC is written in both Chinese and English (the letter and main text in Chinese comprises 14 pages, the main text in English comprises 20 pages). China's NDC is characterized by the large portion devoted to commitment implementation methods. Specifically, descriptions (provided below) are given in the categories of “A. Implementing Proactive National Strategies on Climate Change” to “O. Promoting International Cooperation on Climate Change.”

An updated version was submitted in October 2021. The updated version emphasizes the accomplishments that China has achieved in the past with respect to climate change action, as evidenced by the use of the phrase "significant progress toward curbing greenhouse gas emissions."

Table 7 Methods of implementing the commitments in the NDC (2015 submission)

a) “Implementing Proactive National Strategies on Climate Change” includes strengthening laws and regulations on climate change, integrating climate-change-related objectives into the national economic and social development plans, and formulating China' s long-term strategy and roadmap for low-carbon development.
b) “Improving Regional Strategies on Climate Change” includes implementing regionalized climate change policies, strictly controlling greenhouse gas emissions in Urbanized Zones for Optimized Development, enhancing carbon intensity control in Urbanized Zones, and accelerating green and low-carbon transformation.
c) “Building Low-Carbon Energy Systems” includes enhancing the clean use of coal, increasing the share of concentrated and highly-efficient electricity generation from coal, expanding the use of natural gas, proactively promoting the development of hydro power, developing nuclear power in a safe and efficient manner, scaling up the development of wind power, accelerating the development of solar power, proactively developing geothermal energy, bio-energy, and marine energy, and initiatives in many other sectors. It is characterized by the references to the use of coal. Also, there are references to scaling up distributed energy and the enhanced construction of smart grids.
d) “Building Energy Efficient and Low-Carbon Industrial System” includes developing a circular economy, optimizing the industrial structure, revising the guidance catalogue of the adjustment of industrial structure, strictly controlling the total expansion of industries with extensive energy consumption and emissions, accelerating the elimination of outdated production capacity and promoting the development of service industry and strategic emerging industries. It also includes a wide-range of other details, such as formulating the Action Plan of Industries Addressing Climate Change (2012-2020) and carbon emission control target and action plans in key industries, and effectively controlling emissions from key sectors including power, iron and steel, nonferrous metal, building materials and chemical industries through energy conservation and efficiency improvement, phasing down the production and consumption of HCFC-22, promoting low-carbon development in agriculture, and promoting low-carbon development in the service industry.
e) “Controlling Emissions from Building and Transportation Sectors” includes integrating the low-carbon development concept in the entire process of urban planning, construction and management, promoting the urban form that integrates industries into cities, improving energy efficiency in construction and the quality of building construction, raising the share of green buildings in newly built buildings of cities and towns to 50% by 2020, developing a green and low-carbon transportation system, improving the quality of gasoline and promoting new types of alternative fuels, promoting the share of public transport and accelerating the development of smart transport and green freight transport.
f) “Increasing Carbon Sinks” includes enhancing afforestation, strengthening forest disaster prevention and forest resource protection, the protection and restoration of wetlands and restoring grassland from grazing land.
g) “Promoting the Low-Carbon Way of Life” includes enhancing education for all citizens on low-carbon way of life and consumption, encouraging the use of low-carbon products and improving waste separation and recycling systems.
h) “Enhancing Overall Climate Resilience” includes improving safe operation of infrastructure of water conservancy, transport and energy against climate change, implementing the strictest water management regulations, improving the construction of water conservation facilities for farmlands, enhancing resistance to marine disasters and management of coastal zones, improving national monitoring, early warning and communication systems on climate change, and strengthening the development of disaster reduction and relief management systems.
i) “Innovating Low-Carbon Development Growth Patterns” includes conducting low-carbon cities (towns) pilots, as well as low-carbon industrial parks, low-carbon communities, low-

carbon businesses and low-carbon transport pilots. It also includes low-carbon certified product pilots. j) "Enhancing Support in terms of Science and Technology" includes conducting research on climate change monitoring and forecasting, and strengthening research on the mechanisms and assessment methodology of climate change impacts and risks. It also refers to strengthening research and development (R&D) and commercialization demonstration for low-carbon technologies, such as energy conservation, renewable energy, advanced nuclear power technologies and carbon capture, utilization and storage. k) "Increasing Financial and Policy Support" includes exploring new investment and financing mechanisms for low-carbon development, such as public-private partnerships, implementing preferential taxation policies for promoting the development of new energy, and improving mechanisms of pricing, grid access and procurement mechanisms for solar, wind and hydro power. It also refers to improving green government procurement policy systems. l) "Promoting Carbon Emission Trading Market" includes implementing a nationwide carbon emission trading system. m) "Improving Statistical and Accounting System for GHG Emissions" includes strengthening personnel training, constantly improving the quality of data and strengthening the work on greenhouse gas emission inventory accounting. n) "Broad Participation of Stakeholders" includes enhancing the responsibility of enterprises for low-carbon development, encouraging them to explore low-carbon development modes that are resource-saving and environment-friendly and strengthening the role of public supervision and participation in low-carbon development. o) "Promoting International Cooperation on Climate Change" includes encouraging developed countries to offer funding to developing countries. It also includes establishing the Fund for South-South Cooperation on Climate Change, and providing assistance and support, within its means, to other developing countries including the small island developing countries, the least developed countries and African countries to address climate change.

Source: China First NDC (Archived)

The 2021 NDC provides the following direction for mitigation as a new initiative to achieve the new NDC goals, as shown in the table below.

Table 8 Methods of implementing the commitments in the NDC (2021 submission)

(i) Promote carbon neutrality in an integrated and orderly manner
1. Promote comprehensive green transformation of economic and social development
2. Thorough implementation of carbon peak out actions
3. Promote energy production and consumption revolution
4. Strengthening dual control of energy consumption intensity and total volume control
5. Actively promote green and low-carbon transformation in the industrial sector
6. Improving the level of green and low-carbon construction in urban and rural areas
7. Accelerating the construction of green and low-carbon transportation systems
8. Strong promotion of emission reduction and efficiency improvement in agriculture
9. Promoting a high level of ecosystem protection
10. Strengthening the establishment of market-based mechanisms such as carbon trading
11. Implement carbon neutral demonstration projects (pilot projects)
12. Continuous enhancement and increase of ecosystem carbon sinks
13. Effective control of greenhouse gas emissions other than CO2

Source: China First NDC (Updated submission)

(4) Indonesia

The key points of Indonesia's NDC are shown below.

Table 9 Indonesia NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	November 2016 July 2021 Submission of updated version	—
Target period	(2016 edition) Up to 2030	—
Scope of commitment	Energy, waste, industry processes and product use (IPPU), agriculture, and forestry	—
Base year (Reference year or period)	BAU (business as usual)	—
GHG emission reduction target	・【Unconditional】 29% reduction against BAU scenario by 2030 ・【Conditional】 41% reduction against BAU scenario by 2030	—
Renewable energy introduction target	The following targets have been set for the energy sector a) Introduction of at least 23% new renewable energy by 2025 and at least 31% by 2050. b) Less than 25% oil by 2025 and less than 20% by 2050. c) Coal 30% or below by 2025 and 25% or below by 2050. d) Natural gas 22% or below by 2025 and 24% or below by 2050. *The "Minimum●%" has been interpreted as meaning "● or below." *There were no changes between the 2016 edition and the 2021 edition.	—
Energy efficiency target	Not specified. *While no targets are stated, it does mention an unconditional target of 75% and a conditional target of 100% for the final energy consumption efficiency and the introduction of clean coal technology in power generation facilities as a prerequisite to GHG emission estimates for 2030. However, there is no statement about the meaning of 75% or 100%.	—
Renewable energy introduction volumes and its current share	6.2% (2018)	REN21 Report
Energy intensity (current)	0.084 toe/USD 1,000 *Japan 0.089, EU average 0.095	—
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	The basis for the estimates presented in the Annex indicates that the following initiatives are being planned. ●Energy sector 1.Increased efficiency of final energy consumption 2.Introduction of clean coal technology in power plants 3. Introduction of renewable energy for power production 4. Introduction of biofuels in transportation sector (B30 required). 5. Additional gas distribution lines 6. Additional compressed natural gas refueling stations (SPBG) ●Agriculture, Forestry and Other Land Use (AFOLU)	—

	・Deforestation countermeasures ●Agriculture 1. Use of low-emission crops 2. Greater water efficiency in water management 3. Fertilizer management as a biogas countermeasure 4. Feed management for livestock farming ●Waste 1. Increased recovery of LFG between 2010 and 2030 2. Improved waste utilization rate through composting and 3R 3. Increased ratio of PTLSa/RDF included in waste transport.	

Source: Indonesia First NDC for information not mentioned in "Sources other than NDC".

Indonesia's first NDC is 19 pages. Characteristically, the NDC states the basis of the estimates for each sector in the Annex in p.13-p.17.

There is also a chapter entitled "INDONESIA LOW CARBON AND CLIMATE RESILIENCE STRATEGY." However, while the enabling conditions are listed, as follows, it only states the importance of building resilience in each sector, and no specific details are provided.

- Reliability of space planning and land use
- Land tenure security
- Food security
- Water security
- Renewable energy

The basis for the estimates presented in the Annex indicates that the following initiatives are being planned.

● Energy sector
1.Increased efficiency of final energy consumption
2.Introduction of clean coal technology in power plants
3. Introduction of renewable energy for power production
4. Introduction of biofuels in transportation sector (B30 required).
5. Additional gas distribution lines
6. Additional compressed natural gas refueling stations (SPBG)

● AFOLU
1. Deforestation countermeasures

● Agriculture
1. Use of low-emission crops
2. Greater water efficiency in water management
3. Fertilizer management as a biogas countermeasure
4. Feed management for livestock farming

● Waste
1. Increased recovery of LFG between 2010 and 2030
2. Improved waste utilization through composting and 3R
3. Increased ratio of PTLSa/RDF included in waste transport.

In the July 2021 updated version, "V. NATIONAL REGISTRY SYSTEM AS THE BACKBONE OF TRANSPARENCY FRAMEWORK," "VI. MEANS OF IMPLEMENTATION" and "Annex 2.

Key programmes, Strategies, and Actions to achieve climate resilience targets" have been added. These are the major differences from the 2016 edition.

"V. NATIONAL REGISTRY SYSTEM AS THE BACKBONE OF TRANSPARENCY FRAMEWORK" has been included in connection to the implementation of Article 13 of the Paris Agreement[6]. Explanations are provided regarding the transparency frameworks of national reporting, as shown below.

(a) National registry system (Id. Sistem Registry Nasional/SRN) in connection to mitigation measures, adaptation measures, and the means of implementation based on domestic and international information sources
(b) National GHG inventory system (SIGN-SMART)
(c) MRV system for mitigation measures inc. REDD+
(d) Safeguard information system for REDD+ (SIS-REDD+)
(e) Information system in connection to vulnerabilities (SIDIK) and information system relating to community level climate change adaptation and mitigation actions (PROKLIM)

The following items are explained in "VI. MEANS OF IMPLEMENTATION."
6.1. FINANCE
6.2. TECHNOLOGY DEVELOPMENT AND TRANSFER
6.3. CAPACITY BUILDING

6.2. TECHNOLOGY DEVELOPMENT AND TRANSFER. On this point, reference is made to the fact that the first Technology Needs Assessment (TNA) was implemented in 2010 with a focus on mitigation and the second TNA was implemented in 2012 covering both mitigation and adaptation. However, there is no reference in specific terms to the promotion of technology transfer from particular sectors.

Regarding "6.3. CAPACITY BUILDING," the following focus points are given.

(a) Personnel training to form strong character[7]
(b) Regulatory reforms to increase the effectiveness and efficiency of capacity building programs and activities
(c) Increased investment in personnel training including revitalization of vocational training
(d) Creation of employment and business opportunities
(e) Use of technology to optimize capacity building

The following two items are presented as the means of capacity building in order to support the implementation of the NDC.

General means: Focusing on integrating climate change into national systems with regard to education, training, and other forms of capacity building.

Technical means: Focusing on capacity building programs for various stakeholders in connection to mitigation and adaptation.

The general means specifically address the following initiatives.

(a) Improving public awareness through outreach and campaigns
(b) Improving the provision of information accessible to the public on various knowledge levels related to climate change
(c) Strengthening stakeholder participation in climate policy formulation and actions
(d) Strengthening regional, national and international level cooperation and networking

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6 Article 13 of the Paris Agreement stipulates a framework for transparency and the provision of information on each country's current status and efforts related to emissions and absorption, mitigation, and adaptation, as well as information on the receipt of donor support

7 Although not defined in the text, it is assumed to refer to people who are concerned about climate change, etc., and have an awareness of the need to conserve energy, etc.

Reference is also made to improving a wider range of abilities in order to implement the transparency frameworks stipulated in Article 13 of the Paris Agreement.

In "Annex 2. Key programmes, Strategies, and Actions to achieve climate resilience targets (economic, social and livelihood, and ecosystem and landscape)," explanations are given regarding the main programs, strategies and activities for achieving adaptation targets.

(5) Thailand

The key points of Thailand's NDC are shown below.

Table 10 Thailand NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	Submission October 2015 (INDC) *Date of submission on UNFCCC website: September 2016 Submission of updated version October 2020	—
Target period	2021 – 2030	—
Scope of commitment	Entire economy (land use, land use changes and forestry to be determined later)	—
Base year (Reference year or period)	BAU emissions with 2005 as the base year (BAU scenario 2030: approx. 555 MtCO2e)	—
GHG emission reduction target	20% reduction in GHG emissions compared to BAU emissions estimated by 2030	—
Renewable energy introduction target	• In the Power Development Plan (PDP), the target is set for 20% power generation from renewable energy sources by 2036. • In the Alternative Energy Development Plan (AEDP), the target is set to increase the share of renewable energy in total final energy consumption to 30% by 2036. *In the 2020 updated version, the descriptions related to the specific targets have been removed.	—
Energy efficiency target	Refer to energy intensity (target) below	—
Renewable energy introduction volumes and its current share	Not specified.	—
Energy intensity (current)	0.125 toe/USD 1 000 (PPP 2010) (2017) *Japan 0.089, EU average 0.095	IEA Report
Energy intensity (target)	In the Energy Efficiency Plan (EEP), the target is set for energy intensity to be 30% or below of the 2010 level by 2036. *In the 2020 updated version, the descriptions related to the specific targets have been removed.	—
Means of commitment implementation (mainly mitigation measures)	No specific descriptions.	—

Source: Thailand First NDC for information not mentioned in "Sources other than NDC".

The NDC submitted by Thailand in September 2016 comprises 7 pages. Although a detailed basis for the estimates is not given, this NDC is characterized by the inclusion of targets for renewable energy, energy intensity and more. Also, it is characterized by the fact that just under three of the seven pages are dedicated to adaptation.

In October 2020, Thailand submitted an updated version. The updated version has 8 pages. While there is no change to the 20% reduction in greenhouse gas emissions compared to BAU estimated by 2030 in the updated version, the descriptions of the specific targets related to renewable energy and energy intensity have been removed. Also, in 4.2, a specific request is made for the transfer of technology from developed countries as a requirement for technology transfer. The description of mitigation includes the following technologies.

- The development of energy efficiency and renewable energy technology including advanced energy storage systems, and innovative and cost-efficient technologies and approach on the demand-side.
- Discovering the potential for maritime renewable energy power generation systems that can offer alternative energy sources.
- Smart power generation/dispatch (dispatch), smart power transmission, smart electric power consumption, smart grids, electric power grid industry development and smart grid environment construction.
- Promotion of the electrification of transportation, battery-charging technical support.
- Improvement of regional and local-level waste management technology and systems.

(6) Peru

The key points of Peru’s NDC are shown below.

Table 11 Peru NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	September 2015 (2015 edition) (INDC) *Date of submission on UNFCCC website: December 2016 Submission of updated version December 2020	—
Target period	From January 1, 2021 to December 31, 2030	—
Scope of commitment	The categories considered in the national GHG inventory in 2010 resemble the categories considered in BAU scenario estimates. In the BAU scenario estimates, there are no agreed calculation frameworks, which means that emissions from international aviation and cargo have not been taken into consideration. Also, there is only a small contribution to the sub-category of “transportation,” and no detailed information is given, which means that emissions from rail and sea transportation have not been taken into consideration. The solvent and product use category has zero emissions.	—
Base year (Reference year or period)	BAU scenario	—
GHG emission reduction target	(2015 edition) ・ A reduction in emissions corresponding to a 30% reduction is estimated with regard to BAU GHG emissions for 2030.	—

	• A 20% reduction will be implemented through domestic investment and expenditure using public and private resources (unconditional proposal) • The remaining 10% is dependent on the availability of international fundraising and favorable conditions (conditional proposal) (2020 updated version) • In the unconditional proposal, there is a 20-30% reduction in comparison to BAU by 2030 • In the conditional proposal, there is a 30-40% reduction in comparison to BAU by 2030	
Renewable energy introduction target	Not specified.	—
Energy efficiency target	Not specified.	—
Renewable energy introduction volumes and its current share	Not specified.	—
Energy intensity (current)	0.064 toe/ USD 1 000 *Japan 0.089, EU average 0.095	—
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	(2015 edition) There are no detailed references to implementation methods. In terms of initiatives being implemented, reference is made to various initiatives, such as switching fuel over to natural gas, enabling the conversion of national energy consumption and the power generation matrix, and the promotion of renewable energy sources, including wind power plants, solar power plants, and biomass power plants. (2020 edition) The National Registry of Mitigation Measures (RENAMI) was established on the basis of Law No. 30754, Framework Law on Climate Change that was promulgated in 2018. RENAMI is a digital platform onto which public and private GHG reduction initiatives can be registered, and where information relating to mitigation measures is stored.	—

Source: Peru First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

Peru's NDC submitted in 2016[8] has 12 pages in the Spanish version (including cover sheet) and 12 pages in the English version (including cover sheet) while the 2020 update has 29 pages.

A great deal of effort was put into the updated version, including its visual aspects. Also, in terms of content, major changes have been made to (1) target setting methods, and (2) the actual targets.

First, the approach was changed from relative targets based on BAU scenarios to the formulation of absolute targets. Fixed-value targets in CO2-eq units have been established.

[8] In the 2020 updated version, the 2015 edition is alluded to with reference not to the date of submission but to the production year.

The targets are also more ambitious. Originally, in connection to BAU GHG emissions estimated for 2030, while a reduction corresponding to 30% (20% unconditional, 10% conditional) was estimated, in the updated version, the values have been raised (after converting fixed-value targets in CO2-eq units to BAU) in the unconditional proposal to a reduction of 20-30% by 2030 in comparison to BAU, and in the conditional proposal to a reduction of 30-40% in comparison to BAU by 2030.

No information on how to realize the commitments is provided in the 2015 edition nor in the updated version. The National Registry of Mitigation Measures (RENAMI) was established on the basis of Law No. 30754, Framework Law on Climate Change that was promulgated in 2018. RENAMI is a digital platform onto which public and private GHG reduction initiatives can be registered, and where information relating to mitigation measures is stored.

(7) South Africa

The key points of South Africa's NDC are shown below.

Table 12 South Africa NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	November 2016 (INDC) * No date is given in the text. Information from UNFCCC website: September 2021. Submitted an updated edition	—
Target period	2025 – 2030	—
Scope of commitment	IPCC main categories: Energy, industry processes and product use (IPPU), waste, AFOLU (agriculture, forestry, and other land use).	—
Base year (Reference year or period)	None. *The 2021 edition responded that the base year is not applicable (Not Applicable) because the goal is not based on a base year. In the 2016 edition, it says "Commencement of peak, plateau and decline (PPD) showing a GHG emissions trajectory range after mitigation from the end of 2020."	—
GHG emission reduction target	(2016 edition) The timeframes within the PPD trajectory range are 2025 and 2030, in which emissions will be in a range between 398 and 614 Mt CO2–eq. *The expression used is "The time-frames within the PPD trajectory range that are communicated in South Africa's INDC are 2025 and 2030, in which emissions will be in a range between 398 and 614 Mt CO2–eq," which, rather than making a commitment, has the nuance of keeping emissions to a certain level within the expected range as a result of the efforts. (2021 edition) The 2025 target is expressed as "South Africa's annual GHG emissions will be in a range from 398-510 Mt CO2-eq." and the 2030 target is expressed as "South Africa's annual GHG emissions will be in a range from 350-420 Mt CO2-eq.".	—
Renewable energy introduction target	Not specified.	—

Energy efficiency target	Not specified.	—
Renewable energy introduction volumes and its current share	Not specified.	—
Energy intensity (current)	0.193 toe/USD 1 000 *Japan 0.089, EU average 0.095	—
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	(2016 edition) There are no structured explanations of the method of implementing the commitment. In the section that discusses cost, reference is made to some adaptation measures, as follows. o Necessary additional costs: Estimated additional cost for expanding the Renewable Energy Independent Power Producer Procurement Programme (REI4P) over the next 10 years: USD 3 billion per year Assumed total cost starting in 2010 for low-carbon electric power by 2050: USD 349 billion CCS: 23 MtCO2 from coal liquefaction plants: USD 450 million Electric vehicles from 2010 to 2050: USD 513 billion Hybrid electric vehicles: 20% by 2030: USD 488 billion (2021 edition) As with the 2016 edition, there is no explicit mention of specific approaches.	—

Source: South Africa First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

South Africa’s NDC comprises 11 pages.

South Africa’s NDC is characterized by the use of the expression “peak, plateau and decline (PPD)” that shows a GHG emissions trajectory range after mitigation. In addition, the country has transitioned its international mitigation commitment “from a relative ‘deviation from Business-as-usual’ to an absolute peak, plateau and decline greenhouse gas emissions trajectory range.” The expression “Deviating from BAU and transitioning to PPD” gives the impression of making a commitment to the utmost effort toward emission reduction itself rather than a commitment to achieving quantitative targets.

Regarding the targets, the expression used is “The time-frames within the PPD trajectory range that are communicated in South Africa’s INDC are 2025 and 2030, in which emissions will be in a range between 398 and 614 Mt CO2–eq,” which, rather than making a commitment, has the nuance of keeping emissions to a certain level within the expected range as a result of the efforts.

There are no structured explanations of the method of implementing the commitment. In the section that discusses cost, reference is made to some adaptation measures. Specifically, the following explanations are given for required additional costs.

① Estimated additional costs for expanding the Renewable Energy Independent Power Producer Procurement Programme (REI4P) over the next 10 years: USD 3 billion per year
② Assumed total cost starting in 2010 for low-carbon electric power by 2050: USD 349 billion
③ CCS: 23 MtCO2 from coal liquefaction plants: USD 450 million
④ Electric vehicles from 2010 to 2050: USD 513 billion

⑤ Hybrid electric vehicles: 20% by 2030: USD 488 billion

South Africa submitted an updated version in September 2021. The updated version is 32 pages and more voluminous.

(8) India

The key points of India's NDC are shown below.

Table 13 India NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	October 2016 (INDC) * No date is given in the text. Information from UNFCCC website:	—
Target period	2021 – 2030	—
Scope of commitment	All sectors, including agriculture	—
Base year (Reference year or period)	2005	—
GHG emission reduction target	33-35% reduction of emissions intensity against GDP by 2030 in comparison to 2005.	—
Renewable energy introduction target	Increase the cumulative electric power installed capacity from non-fossil fuel-based energy resources to approx. 40% by 2030.	—
Energy efficiency target	Refer to reduction targets	—
Renewable energy introduction volumes and its current share	9.9% (2018)	REN21 Report
Energy intensity (current)	(NDC) 15.02 g oil equivalent per GDP in rupees (2012) (IEA Report) 0.105 toe/USD 1 000 *Japan 0.089, EU average 0.095	IEA Report
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	Commencement of new initiatives in the following priority sectors 1) Introducing new, more efficient and cleaner technologies in thermal power generation. 2) Promoting renewable energy generation and increasing the share of alternative fuels in overall fuel mix. 3) Reducing emissions from transportation sector. 4) Promoting energy efficiency in the economy, notably in industry, transportation, buildings and appliances. 5) Reducing emissions from waste. 6) Developing climate resilient infrastructure. 7) Full implementation of Green India Mission and other programmes of afforestation.	—

	8) Planning and implementation of actions to enhance climate resilience and reduce vulnerability to climate change.	

Source: India First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

India's NDC is a voluminous, 38-page document. (However, a large font is used, and the line-spacing and margins are also large, which must be taken into consideration.)

India's NDC is characterized by the references to mitigation and adaptation strategies after mentioning the socio-economic situation of the country in "I. NATIONAL CIRCUMSTANCES," and the later references to specific commitments. The NDCs of other countries first state the commitments, and then the ways to realize these commitments (given later), but the order in India's NDC is different. The commitments are based on the emissions intensity[9]. Specifically, India's plan calls for a 33-35% reduction compared to 2005 in emissions intensity of its GDP by 2030. In addition, the following commitments are made.

- To achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 with the help of transfer of technology and low-cost international finance including from Green Climate Fund (GCF).
- To create an additional carbon sink of 2.5 to 3 billion tons of CO_2 equivalent through additional forest and tree cover by 2030.

Little space is given to specific ways to realize commitments. In order to realize the commitments, reference is made to the commencement of new initiatives in the following priority sectors.

① Introducing new, more efficient and cleaner technologies in thermal power generation.
② Promoting renewable energy generation and increasing the share of alternative fuels in overall fuel mix.
③ Reducing emissions from transportation sector.
④ Promoting energy efficiency in the economy, notably in industry, transportation, buildings and appliances.
⑤ Reducing emissions from waste.
⑥ Developing climate resilient infrastructure.
⑦ Full implementation of Green India Mission and other programmes of afforestation.
⑧ Planning and implementation of actions to enhance climate resilience and reduce vulnerability to climate change.

In "5. MEANS OF IMPLEMENTATION," the need for fundraising, technology transfer and capacity building is discussed (as follows).

Table 14 5. MEANS OF IMPLEMENTATION

5.1 CLIMATE CHANGE FINANCE REQUIREMENT ・ Estimates by NITI Aayog (National Institution for Transforming India) indicate that the mitigation activities for moderate low carbon development would cost around USD 834 billion till 2030 at 2011 prices. ・ India's climate actions have so far been largely financed from domestic resources. A substantial scaling up of the climate action plans would require greater resources. A preliminary estimate suggests that at least USD 2.5 trillion (at 2014-15 prices) will be required for meeting India's climate change actions between now and 2030. 5.2 REQUIREMENT FOR TECHNOLOGY TRANSFER & SUPPORT ・ India has advocated global collaboration in Research & Development (R&D), particularly in clean technologies and enabling their transfer, free of Intellectual Property Rights (IPR) costs,

[9] Emission rates of specific pollutants relative to the volume of specific activities or industrial production processes, in this case GHG emissions per GDP

to developing countries. IPR costs can also be borne from the GCF through a separate window.

- In its pursuit of low carbon growth, India would be focusing on technologies that need to be moved from lab to field and those that require targeted global research along with those that are still in the realm of imagination. One of the important areas of global collaborative research should be clean coal and fossil fuel, energy management and storage systems for renewable energy. Given the current stage of dependence of many economies on coal, such an effort is an urgent necessity. A preliminary and illustrative list of some of the technologies (which will evolve over time) is at Annexure A.

5. 3 CAPACITY BUILDING NEEDS

- India's efforts will require proper training and upgrading of skills across sectors.
- It is expected that the international mechanism will support such initiatives including formation of Thematic Knowledge Networks, further expand activities under Global Technology Watch Group, establishing more intensive state centric knowledge and awareness creating activities and training of professionals in different aspects of renewable energy and supporting research and development institutions for pre-competitive research.
- Rough estimates indicate that around 2.5% of Government's salary budget would be required for capacity building initiatives, while some part of it would need to be financed internationally.

Annexure A Illustrative list of some of the Technologies (Mitigation perspective)

Clean Coal Technologies (CCT)

- Pulverized Combustion Ultra Super Critical (PC USC)
- Pressurized Circulating Fluidized Bed Combustion, Super Critical, Combine Cycle (PCFBC SC CC)
- Integrated Gasifier Combined Cycle (IGCC)
- Solid Oxide Fuel Cell (SOFC), Integrated Gasifier Fuel Cell (IGFC)
- Underground Coal Gasification (UCG)

Nuclear Power

- Pressurized water reactor, Integral pressurized water reactor, Advanced Heavy Water Reactor (AHWR)
- Fast Breeder Reactor (FBR)
- Accelerated-driven systems in advanced nuclear fuel cycles

Renewable Energy

- Yeast /enzyme-based conversion to high quality hydrocarbon fuels
- Conversion of pre-treated biomass to fuels and chemicals
- Gasification technologies like fluidized bed, plasma induced etc. for power generation
- Wind Energy technologies:
- ✓ Development of smaller and more efficient turbines
- ✓ Wind turbines for low wind regime
- ✓ Designs of offshore wind power plants
- Solar PV technologies:
- ✓ Based on p-type silicon wafers and n-type silicon wafers
- ✓ Hetero junction with Thin Interfacial (HIT) Module, Back Contact Back Junction (BCBJ) Modules
- ✓ Crystalline silicon photovoltaic cells of > 24 % cell efficiency
- ✓ High efficiency Concentrating PV (CPV)
- ✓ Non-silicon based solar PV technologies
- Composite cylinders for on-board hydrogen storage
- Advanced biomass gasification technologies
- Low temperature Polymer Electrolyte Membrane Fuel Cell (PEMFC) for stationary power generation and for vehicular applications
- Energy storage technologies for bulk storage and Renewable Energy integration, frequency regulation, utility Transmission & Distribution applications and for community scale projects.

Source: India First NDC

(9) Morocco

The key points of Morocco's NDC are shown below.

Table 15　Morocco NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	September 2016 *No dates are stated in the main text. Information taken from UNFCCC website Submission of updated version June 2021	—
Target period	2010 – 2030 (Bau scenario)	—
Scope of commitment	•Power generation •Housing (residential and semi-public sectors) •Agriculture •Industry •Transportation •Waste •Forestry	—
Base year (Reference year or period)	2010 – 2030 (Bau scenario)	—
GHG emission reduction target	(2016 edition) (Conditional) 42% below BAU by 2030. (reduction of 527 Mt CO2e between 2020 and 2030) (Unconditional) 17% below BAU by 2030. (2021 edition) (Conditional) 45.5% GHG emissions reduction (64 771.5 Gg Eq CO2) for the entire economy in 2030 compared to the reference scenario (NAC). (Unconditional) 18.3% net reduction in GHG emissions (26 119.2 Gg Eq CO2) for the entire economy in 2030 compared to the reference scenario (NAC) by means of independent national efforts after receiving the same degree of international support as prior to 2020. *Higher targets than the 2016 edition.	—
Renewable energy introduction target	(2016 edition) Reach a share of 52% or more of renewable energy in installed electric capacity by 2030. *Reference is made in the NDC to the following points stipulated in the National Energy Strategy. Morocco aims to produce 52% of its electricity from renewable energy by 2030 (20% using solar energy, 20% wind and 12% hydropower). (2021 edition) No change to the content.	—

	- Reach a share of 52% of renewable energy in installed electric capacity by 2030 (20% using solar energy, 20% wind and 12% hydropower).	
Energy efficiency target	(2016 edition) Energy consumption will be reduced by 15% by 2030. * Reference is made in the NDC to the following points stipulated in the National Energy Strategy. Energy consumption in the building, industry, and transportation sectors will be reduced by 12% by 2020 and by 15% by 2030. The breakdown of expected energy saving by sector is 48% from industry, 23% from transport, 19% from residential and 10% from services. In addition, reference is made to making an improvement of 4.1% between 2010 and 2030 in GHG emissions intensity per unit of GDP. (2021 edition) - 20% energy conservation will be achieved by 2030 compared to trends[10]. - Energy consumption in the building, industry, and transportation sectors will be reduced by 5% by 2020 and by 20% by 2030. The breakdown of expected energy saving by 2030 by sector is 17% from manufacturing, 24.5% from transport, 14% from urban & residential and tertiary industries, and 13.5% from agriculture and maritime fisheries. - An additional capacity of 450MW will be introduced through composite cycle technology using imported natural gas by 2030. - Energy will be supplied to the main industries through pipelines that supply re-gasified imported natural gas.	—
Renewable energy introduction volumes and its current share	Not specified.	—
Energy intensity (current)	0.077 toe/ USD 1 000 *Japan 0.089, EU average 0.095	—
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	(2016 edition) 55 actions are listed in Annex I (see above). (2021 edition) 61 actions are listed in Annex I (see above).	—

Source: Morocco First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

(2016 edition)

The unconditional target is a 17% reduction in GHG emissions by 2030 in comparison to the BAU scenario. 4% are due to AFOLU actions. Without the AFOLU actions, the reduction target is 13%.

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10 The NDC only states "Réaliser une économie d’énergie de 20% d’ici 2030 par rapport à l’évolution Tendancielle, " and it is unclear what the trend refers to.

The conditional target includes an additional reduction of 25% that can be achieved under certain conditions. In this case, there would be a 42% total GHG reduction in comparison to BAU including the AFOLU actions by 2030. Without the AFOLU actions, the additional reduction would be 21%, making a conditional reduction target of 34%.

Other targets include those stated below.

- Reach a share of 52% or more of renewable energy in installed electric capacity by 2030
- Achieve 15% energy savings by 2030
- Based on reforms that have been taking place in recent years, major reductions in public fossil fuel subsidies.
- Greatly increase the use of natural gas through infrastructure projects that enable the importation of liquefied natural gas.

Regarding the means of commitment implementation, the NDC states 55 methods. The names of those methods are shown below (more details of the methods are stated in the NDC).

Table 16 Methods of realizing the commitments outlined in Morocco's NDC (2016 edition)

(Unconditional) 1. National Wind Plan for 2020 2. National Solar Plan for 2020 3. National Program for the Promotion of Photovoltaic 4. Hydroelectric Power Plants by 2030 5. Combined-Cycle Plants by 2025 6. Energy-Certification Labelling of Refrigerators 7. Energy-Efficient Building Wraps 8. Energy Efficiency in the Tourism Sector 9. Low-Carbon City 10. Private Wind Farms 11. Industrial Energy Efficiency 12. Extension of the Rabat Tram 13. Extension of the Casablanca Tram 14. Large Taxi Upgrade Plan 15. Olive Tree Program by 2020 16. Fruit Arboriculture Program (excluding citrus and olive trees) by 2020 17. Citrus Planting Program by 2020 18. Cactus Planting Program by 2020 19. Date Palm Tree Planting program by 2020 20. National Development of Rangelands Program and Regulation of Transhumant Flows: First phase by 2020 21. Afforestation and Reforestation Program 2010–2030 22. Program Combatting Silting 2010–2030 23. Management of Forestry Climate Risk 2010–2030 24. Energy Efficiency Cook-Stove Program 2010–2030 (Conditional) 25. National Wind Plan by 2030 26. National Solar Plan by 2030 27. Micro-Hydro Power Plants by 2030 28. Combined-Cycle Power Plants by 2030 29. National Development Plan of Solar Water Heaters 30. Low-energy lighting in residential housing 31. Installations of Photovoltaic Panels 32. Public Lighting Energy Efficiency Program

33. Natural Gas in the Industrial Sector by 2030 34. Biomass Valorization Program for Industry 35. Implementation Program of an Energy and Output Management System (EOMS), and of the ISO 50001 standard in Industry 36. Project for Energy Recovery from Compressors between 2021 and 2025. 37. Pilot Project on Implementation of Centralized Production of Utilities for an Integrated Industrial Park 38. Fly Ash Repurposing within Building Materials Industry 39. Polyvinyl Chloride (PVC) Recycling Project 40. National Strategy on Logistics Development 41. Upgrade of Utility Vehicles 20 Years and Older between 2025 and 2030 42. Mechanical biological treatment and co-incineration of household waste 43. Recycling of GHG Emissions from Wastewater Treatment Plants 44. Olive Tree Program 2020–2030 45. Fruit Arboriculture Program (excluding citrus and olive trees) 2020–2030 46. Citrus Planting Program 2020-2030 47. Argan Tree Planting Program 2020-2030 48. Cactus Planting Program 2020-2030 49. Fruit Tree-Planting Program 2020¬–2030 50. Date Palm Tree Planting Program by 2020–2030 51. National Development of Rangelands Program and Regulation of Transhumant Flows 2020–2030 52. Afforestation and Reforestation Program 2020–2030 53. Program Combatting Silting 2020–2030 54. Management of Forestry Climate Risk 2020–2030 55. Energy Efficiency Cook Stove Program 2020–2030

Source: Morocco First NDC (Archived)

2021 Edition

By means of independent national efforts after receiving the same degree of international support as prior to 2020, the targets have been become more demanding in the form of achieving an 18.3% net reduction in GHG emissions for the entire economy in 2030 compared to the reference scenario (NAC). Also, with even greater support, Morocco hopes to achieve a 45.5% emissions reduction compared to NAC.

The number of commitment implementation methods has increased in comparison to the 2016 edition, with a total of 61 methods listed. The names of the methods are given below (more details of the methods are stated in the NDC).

Table 17 Methods of realizing the commitments outlined in Morocco's updated NDC

1	National Wind Plan for 2020
2	National Solar Plan for 2020
3	Hydroelectric Power Plants by 2020
4	Combined-Cycle Plants by 2020
5	Combined-Cycle Plants by 2030
6	Hydroelectric Power Plants by 2030
7	National Wind Plan for 2030
8	National Solar Plan for 2030
Industry	
9	Industrial Energy Efficiency
10	Introduction of MEPS for electric motors of 75kW or more
11	Use of natural gas in industry by 2030

12	Biomass recovery program in industrial sector
13	Installation program for renewable energy (PV) self-sufficiency in industrial sector
Cement	
14	Recycling of used tires
15	WWTP sludge recovery
16	Domestic waste recycling
17	Olive pomace assessment
18	Fly ash assessment
19	Solar dehydration of phosphate
20	C02 separation and recovery from phosphorous chimneys
Phosphate	
21	Khouribga – Jorf Lasfar Slurry Pipeline
22	Co-generation
23	Solar energy
Building	
24	National solar water heater development plan for 2010 to 2020
25	Program to standardize LED lamps in housing by 2030
26	Refrigerator Minimum Energy Performance Standard (MEPS)
27	Air conditioner MEPS
28	Energy efficiency of outer façade of new buildings
29	Energy efficiency of tourist accommodation
30	Post 2020 National solar water heater development plan¥
31	Installation of solar powered generator for home use in the residential/semi-public sectors by 2030
32	Energy efficiency program for public lighting
Transportation	
33	Rabat tram extensions
34	Casablanca tram extensions
35	Improvement of automobile environmental standards
36	Bonus-malus system
37	Renewal and break program
38	Eco drive
39	Application of CO2 emissions performance standards for new automobiles and small commercial vehicles
Waste	
40	GHG recovery from WWTP
41	Mechanical biological processing and joint incineration of domestic waste
Agriculture	
42	Olive Tree program (Phase 1)
43	Fruit Arboriculture program (Phase 1)
44	Citrus Planting program (Phase 1)
45	Date Palm Tree Planting program (Phase 1)
46	National Development of Rangelands Program and Regulation of Transhumant Flows (Phase 1)
47	Cactus Planting program (Phase 1)
48	Olive Planting program (Phase 2)

49	Fruit Arboriculture program (Phase 2)
50	Date Palm Tree Planting program (Phase 2)
51	National Development of Rangelands Program and Regulation of Transhumant Flows (Phase 2)
52	Cactus Planting program (Phase 2)
53	Argon Tree Planting program
54	Dakhla 40MW wind power plants
Forests	
55	Ecosystem restoration activities (unconditional aspects)
56	Avoidance of deterioration (unconditional aspects)
57	Strengthening capacity for recovery of social ecosystems in vulnerable areas (unconditional aspects)
58	Activities for 2010 to 2020
59	Ecosystem restoration activities (conditional aspects)
60	Avoidance of deterioration (conditional aspects)
61	Strengthening capacity for recovery of social ecosystems in vulnerable areas (conditional aspects)

Source: Morocco First NDC (Updated submission)

(10) Egypt

The key points of Egypt's NDC are shown below.

Table 18 Egypt NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	June 2017 (INDC) * No date is given in the text. Information from UNFCCC website	—
Target period	Start year: not given. End year: not given.	—
Scope of commitment	Energy, agriculture, waste, industry	—
Base year (Reference year or period)	No specific numerical targets.	—
GHG emission reduction target	No specific numerical targets.	—
Renewable energy introduction target	25%	REN21 Report
Energy efficiency target	No specific details.	—
Renewable energy introduction volumes and its current share	4%	REN21 Report
Energy intensity (current)	0.092 toe/ USD 1 000 *Japan 0.089, EU average 0.095	IEA Data
Energy intensity (target)	Not specified.	—
Means of commitment implementation	Mitigation measures are described separately for the energy sector and non-energy sectors (see below).	—

(mainly mitigation measures)		

Source: Egypt First NDC for information not mentioned in "Sources other than NDC".

Egypt's NDC comprises 13 pages. Specific numerical targets are not given. Only the policies and approaches to be taken are described, such as how to promote countermeasures against GHG emissions.

Table 19 Mitigation Measures in Energy Sub-Sectors

Sector	Mitigation Measures
Business	Energy efficiency improvement
	Use of solar power for hot water supply
Transportation	Energy efficiency improvement
Passengers	Increased railroad passenger share
	Increased bus passenger share
	Increased minibus passenger share
	Increased river transport passenger share
	Cairo metro (Line 3 phase 3 and 4, and Line 4)
Freight	Road transport efficiency improvement
	Transition from road transport to river transport
	Transition from road transport to rail transport
Agriculture	Energy efficiency improvement
Domestic/commercial	Energy efficiency improvement
	Use of solar power for hot water supply
	Energy efficiency improvement
Electricity	Use of nuclear energy for power generation
	Use of renewable energy for power generation
Oil	Energy efficiency improvement

Source: Egypt First NDC

Table 20 Mitigation Measures in Non-Energy Sectors

Sector	Mitigation Measures
Agriculture	Intestinal fermentation
	Fertilizer management
	Rice crops
	Agricultural soil
	Agricultural residue burning
Waste	Solid waste
	Wastewater
	Incineration
	Encouraging waste management and recycling
Industrial processes	Optimize production rather than using cement, lime, iron/steel and ammonia
	Used for urea, nitrogen fertilizer, nitric acid
Oil and natural gas	Production and processing
	Vent and flaring (heat waste)

Source: Egypt First NDC

(11) Cambodia
The key points of Cambodia's NDC are shown below.

Table 21 Cambodia NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	February 2017 (INDC) * No date is given in the text. Information from UNFCCC website Submission of updated version December 2020 * No date is given in the text. Information from UNFCCC website	—
Target period	Start year: 2020 End year: 2030	—
Scope of commitment	Energy, transport, waste, LULUCF and industry	—
Base year (Reference year or period)	(2015 edition) Amount of CO2, CH4, and N2O compared to the baseline emissions of 11,600 GgCO2eq in 2030 (2020 edition) 213 million tCO2e /year in BAU scenario in 2030	—
GHG emission reduction target	(2015 edition) 27% below the baseline GHG emissions in 2030 (2020 edition) Emissions reduction of 64.6 million tCO2e/year expected by 2030. Corresponds to a 41.7% reduction from BAU scenario	—
Renewable energy introduction target	Not specified.	No data in the REN21 Report.
Energy efficiency target	No specific details.	—
Renewable energy introduction volumes and its current share	Not specified.	No data in the REN21 Report.
Energy intensity (current)	0.141 toe/ USD 1 000 *Japan 0.089, EU average 0.095	IEA Data
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	(2015 edition) The following mitigation measures for each sector are presented. Energy industry: Grid-connected renewable power generation (solar, hydro, biomass, biogas) and distributed renewable energy system that was connected to the grid system Off-grid electric power such as home solar system, and hydro power generation (pico, mini and micro) Promotion of end user energy efficiency Manufacturing industry: Reduction in emissions as a result of rice milling, garment manufacturing and brick making Transportation sector: Increased efficiency of automobile inspection, public transportation and rolling stocks	—

	Other sectors: Efficient cooking stoves, biodigesters and water filters Forestry: National forest cover increase up to 60% and maintain the level from 2030 onwards (2020 edition) List of 50 mitigation measures (see below) *51 items are listed, but the fourth item is missing.	

Source: Cambodia First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

The NDC submitted by Cambodia in 2015 comprises the following sections across 16 pages.

- Section 1: National context, presenting national circumstances relevant to the INDC
- Section 2: Adaptation, covering Cambodia's vulnerability to climate change and prioritized adaptation actions
- Section 3: Mitigation, including Cambodia's intended contribution to reduce greenhouse gas emissions, with information to ensure clarity, transparency and understanding, and consideration of fairness and ambition
- Section 4: Planning and implementation processes, with indications of the institutions, policies, strategies, and plans that will support the implementation of the INDC
- Section 5: Means of implementation, with information on the support needed for the implementation of the INDC.

The target is a 27% reduction against base emissions of 11,600 GgCO2eq.
Cambodia submitted an updated NDC to the UNFCCC in December 2020. The updated version reaches 158 pages with the following structure. The Annex covers p.90 onwards, which is quite voluminous.
1 Introduction
2 Mitigation Contribution
3 Adaptation Contribution
4 Cross-cutting areas
5 Governance and Implementation Processes
*6 N/A (incorrect numbering?)
7 Means of Implementation
8 Transparency
9 Sustainable Development
Appendix 1: Detailed mitigation measures
Appendix 2: Detailed adaptation measures
Appendix 3: Selected bibliography
Appendix 4: Emissions reduction estimates
Appendix 5: NDC scenarios

In the updated version, the target of a 27% reduction in GHG emissions against the base emissions by 2030 has been changed to a 41.7% reduction from BAU scenario. The BAU value and the calculation conditions are different, so it is difficult to make a straight comparison, but looking solely at the numbers, the target is more ambitious than that of 2015.

Table 22 Mitigation measures presented in 2020 edition

1 Urban planning tools for climate change mitigation and the urban planning solution in three sub cities
2 Improvement of process performance of EE by establishment of energy management in buildings/industries
3 Efficiency energy and pollution management in latex and rubber wood processing
4 New sanitary landfills with LFG extraction and LFG extraction at the Dangkor Landfill

5 Potential for private sector engagement in financing, constructing, and operating sanitary landfill and LFG systems 6 Composting of biodegradable organic fraction of MSW supplemented with separation of organic waste (at source). 7 Production of Refuse Derived Fuel (RDF) from either a) fresh MSW or b) old MSW mined from the Dangkor landfill. 8 Implementation of National 3R strategy 9 Bio-digesters construction (85% reduction compared to 2000)(Small size (2-3- 4m^3); Medium size (6-8- 10m^3), Large size(>10m^3) 10 Centralized recycling facility for industrial waste from the garment sector 11 Better management of industrial wastewater in the food & beverage sector 12 Application of electrical equipment labelling & MEPS (Lighting, Cooling & Equipment) 13 Public awareness campaigns 14 Building codes and enforcement/certification for new buildings and those undergoing major renovation 15 Introduction of efficient electrical industrial motors and transformer 16 Improve sustainability of charcoal production through enforcement of regulations 17 Increase energy access to rural area 18 Roadmap study on Integration of renewable energy resources (solar, wind, hydro, biomass) into energy mix 19 Diversification of household and community energy generation sources to reduce reliance on biomass as an energy source 20 Reducing GHG emission through off grid street lightening of rural municipality 21 Toward Battambang city to green city 22 Eco-payment based on changing behavior on fire wood use of community in Angkor and Kulen Conservation Park 23 Cooling of public sector buildings 24 Promote sustainable energy practices in manufacturing 25 Actions to promote sustainable sourcing of fuel wood in the garment industry 26 Implementation of National Cooling Action Plan 27 Inclusion of performance requirements of passive cooling systems in building energy code of Cambodia 28 Implementation of "passive cooling" measures in the cities (addressing urban heat island effect [UHIE]), public buildings and commercial buildings. 29 Promote integrated public transport systems in main cities 30 Enhance maintenance and inspection of vehicle (Piloting maintenance and emission inspections of vehicles) 31 E-mobility 32 Establish green belts along major roads for climate change mitigation 33 Shift long distance freight movement from trucks to train 34 Increasing the effectiveness and sustainability of agricultural land management techniques (Conservation Agriculture) 35 Organic input agriculture and bio-slurry; and deep placement fertilizer technology 36 Promote fodder production to improve high nutrient rich and high-quality forage feed value agriculture by products technology to support cattle production 37 Promote manure Management through compost making process to reduce carbon emission 38 Seedlings distribute to public and local community 39 REDD + 40 Promoting one tourist, one tree campaign 41 Practicing responsible travel manner in order to protect and conserve environment, biodiversity, culture and local livelihood improvement 42 Always remind and practice 3R in all tourist activities 43 Reducing energy use, improving energy efficiency, increasing the use of renewable energy, carbon offsetting, waste management and recycling, and water conservation 44 Operating sustainable destination management 45 Promoting adventure and green tourism activities 46 Installing air quality monitoring equipment in all provinces across the country and establishing air quality data monitoring center with mobile application for public information and access

47 Establishing air quality monitoring and broadcasting center 48 Improving urban environmental management through increasing green spaces in the city 49 Emission management from factories 50 Air quality management from construction sites 51 Development of a long-term low emission strategy

Source: China First NDC (Updated submission)

(12) Bangladesh

The key points of the Bangladeshi NDC are shown below.

Table 23 Bangladesh NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	September 2015 (INDC) *Date of submission on UNFCCC website: September 2016 December 2020 (Interim updated) Submitted an interim updated edition * No date is given in the text. Information from UNFCCC website December 2021 (Updated) Submitted an updated edition	—
Target period	Start year: 2020 End year: 2030	—
Scope of commitment	(2015 edition) Energy, agriculture, transport, waste, LULUCF and industry (2021 edition) Energy, industrial process and product use (IPPU); agriculture, forestry, and other land use (AFOLU); waste	—
Base year (Reference year or period)	(2015 edition) CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3 for the base year 1990 (2021 edition) 2012	—
GHG emission reduction target	(2015 edition) 20% reduction from BAU scenario (5% Unconditional/15% Conditional). (2021 version) In unconditional scenario, GHG emissions would be reduced by 27.56 Mt CO_2e (6.73%) below BAU in 2030 and in conditional scenario, GHG emissions would be reduced by 89.47 Mt CO_2e (21.85%) below BAU in 2030 in the respective sectors.	—
Renewable energy introduction target	10%	REN21 Report
Energy efficiency target	No specific details	—
Renewable energy introduction	0.2%	REN21 Report

volumes and its current share		
Energy intensity (current)	0.071 toe/ USD 1 000 *Japan 0.089, EU average 0.095	IEA Data
Energy intensity (target)	20% Reduction	—
Means of commitment implementation (mainly mitigation measures)	It is specifically described in the 2015 edition, the 2020 interim update, and the 2021 update, and is cited as below.	—

Source: Bangladesh First NDC (Archived, Interim updated submission and Updated submission) for information not mentioned in "Sources other than NDC".

The NDC submitted by Bangladesh in September 2015 comprises 15 pages. The mitigation measures and other content conform to the Energy Efficiency and Conservation Master Plan formulated with support from Japan. For that reason, it includes mitigation measures such as Super Critical (SU) Coal Fired Power Project.

Bangladesh submitted an interim updated edition in December 2020. The interim updated edition has 18 pages. Bangladesh's interim updated edition is simple, whereas other countries' updated editions are very voluminous. The interim updated edition does not present mitigation measures as structured as the 2015 edition, and the keyword “super critical (SU) coal fired power generation” has been removed.

In addition, Bangladesh has submitted an updated edition in December 2021. The updated edition is 32 pages long, and unlike the interim update, the updated edition is very specific in its mitigation measures. Specific mitigation measures are discussed below.

The table below shows the mitigation measures listed in the 2015 edition.

Table 24 Mitigation Measures Presented in 2015 Edition

Sector	Description
Power	• Ensure all new coal generation uses super-critical technology • Increased penetration of wind power • Implement grid-connected solar plant to diversify the existing electricity generation mix
Transport	• Modal shift from road to rail, delivered through a range of measures, including underground metro systems and bus rapid transit systems in urban areas. Co-benefits will include reduced congestion, improved air quality and improved traffic safety. • Reduced congestion and improved running of traffic. This will be achieved by a number of measures, including building of expressways to relieve congestion and public transport measures
Industry (energy related)	• Carry out energy audits to incentivize the uptake of energy efficiency and conservation measures in the main industrial sectors based on the Bangladesh Energy Efficiency and Conservation Master Plan
Hosueholds	• Put in place policy mechanisms to incentivize the uptake of improved (more efficient) gas cook stoves • Support the replacement of biomass with LPG for cooking purposes • Promoting policies to induce greater level of energy efficiency and conservation in the household sector based on the Bangladesh Energy Efficiency and Conservation Master Plan
Commercial buildings	• Promote policies to induce greater level of energy efficiency and conservation in the commercial sector based on the Bangladesh Energy Efficiency and Conservation Master plan • Incentivize rainwater harvesting in commercial buildings as a form of water and energy conservation

Agriculture (non-energy related)	• Increase mechanization in agriculture leading to a reduction in numbers of draft cattle (and therefore lower methane emissions) • Increase the share of organic manure in the used fertilizer mix • Scale up rice cultivation using alternate wetting and drying irrigation
Waste	• Increase composting of organic waste • Promote landfill gas capture and power generation
Land use, land use change and forestry	• Continuation of coastal mangrove plantation • Reforestation and afforestation in the reserved forests • Plantation in the island areas of Bangladesh • Continuation of Social and Homestead forestry

Source: Bangladesh First NDC (Archived)

The table below lists the mitigation measures listed in the 2020 edition (interim update).

Table 25 Mitigation Measures Presented in 2020 Interim Updated Edition (planned items)

• The government has set a target of generating 1,700 MW from Utility scale solar plants and 250 MW from solar home system by 2030. • Additionally, government is repowering old steam turbines to increase efficiency. Through the six registered CDM projects, approximately 118 MtCO2e will be reduced by 2030. Six million additional improved cook stoves are expected to be distributed in Bangladesh. Commercial buildings in Bangladesh have a 25% potential to reduce the GHG emission through the planned activities. • The major cities generate substantial amount of solid waste (of which 75% is bio-degradable) and they have the potential to reduce the waste by converting it to energy. Already two city corporations adopted the incineration technology to reduce waste and other two city corporations will also follow them and around 100 municipalities will establish bio-gas plant to reduce GHG emissions. These initiatives are gaining momentum and some of them will be implemented over the next few years. Bangladesh has already ratified the Kigali Amendment and by phasing out HCFCs and HFCs, around 2.4 million tons of GHG emission will be reduced by 2030. • In transportation sector, 10 000 hybrid and electric vehicles are planned to be introduced, introduction of broad gauge and electric locomotives, introducing good quality fuel and Euro III and IV engines, completing all highways with four lanes, withdrawal of 86,000 unfit vehicles from the roads and introducing Lithium-ion battery in all motor cycles and cars are planned.

Source: Bangladesh First NDC (Interim updated submission)

The 2021 version provides lists of mitigation measures, both for conditional and unconditional. However, while there are differences in the amount of renewable energy equipment installed and GHG emission reductions, the content is generally the same. The table below lists the mitigation measures for conditional scenario.

Table 26 Mitigation Measures Presented in 2021 Updated Edition (Conditional)

Sector	Description	Actions by 2030
Energy	**Power** • Implementation of renewable energy projects • Enhanced efficiency of existing power plants • Use of improved technology for Power generation	**Power** • Implementation of renewable energy projects of 4114.3MW • Grid-connected Solar-2277 MW, Wind-597 MW, Biomass-50 MW, Biogas-5 MW, New Hydro-1000 MW, Solar Mini-grid-56.8 MW, Waste to Electricity-128.5 MW • Coal power plant with Ultra super critical technology- 12147 MW • Installation of new Combined Cycle Gas based power plant (5613 MW) • Efficiency improvement of Existing Gas Turbine

	Transport • Improvement of fuel efficiency for transport sub-sector • Increase use of less emission-based transport system and improve Inland Water Transport System **Industry** • Increase energy efficiency in Industry sub-sector **Agriculture** • Enhanced use of solar energy in Agriculture **Brick Kilns** • Enforcement and Improved technology use **Residential and Commercial** • Enhanced use of energy-efficient appliances in household and commercial buildings **F-Gases** • Further reduction of Ozone Depleting Gases	power plant (570 MW) • Installation of prepaid meter • Bring down total T&D loss to a single digit by 2030 **Transport** • Improvement of road traffic congestion (15% improvement in fuel efficiency) • Widening of roads (2 to 4 lanes) and improving road quality • Construct NMT and bicycle lanes • Electronic Road Pricing (ERP) or congestion charging • Reduction of private cars and encourage electric and hybrid vehicles • Development of Urban Transport Master Plans (UTMP) to improve transport systems in line with the Urban Plan/ City Plan for all major cities and urban area • Introducing Intelligent Transport System (ITS) based public transport management system to ensure better performance, enhance reliability, safety and service • Establish charging station network and electric buses in major cities • Modal shift from road to rail (25% modal shift of passenger-km) through different Transport projects such as BRT, MRT in major cities, Multi-modal hub creation, new bridges etc. Purchase of modern rolling stock and signaling system for railway • Electrification of the railway system and double-track construction • Improved and enhanced Inland Water Transport (IWT) system (Improve navigation for regional, sub-regional, and local routes, improve maintenance of water vessel to enhance engine performance, introduce electric water vessel etc.) **Industry** • Achieve 20% Energy efficiency in the Industry sub-sector through measures according to the Energy Efficiency and Conservation Master Plan (EECMP) • Promote green Industry • Promote carbon financing **Agriculture** • Implementation of 4102 Nos. solar irrigation pumps (generating 164 MW) for agriculture **Brick Kilns** • 47% emission reduction through Banning Fixed Chimney kiln (FCK), encourage advanced technology and non-fired brick use **Residential and Commercial** • Use energy-efficient appliances in household and commercial buildings (achieve 19% and 25% reduction in emission respectively) **F-Gases** • Reduction of Ozone Depleting Gases (HCFCs) use in air conditioning after 2025.

	Fugitive Emission Gas leakage reduction	**Fugitive Emission** 51% emission reduction from Gas leakage through CDM projects
AFOLU	**Agriculture** Reduction of emission from Rice Field, Fertiliser User, Enteric Fermentation and Manure Management **Forestry** • Deforestation reduction • Reforestation/ Afforestation • Forest restoration • Maintain forest and tree cover	**Agriculture** *Methane emission reduction from Rice field* Upscaling Alternate Wetting and Drying (AWD) in dry season rice field in 100,000 ha of crop lands • Rice Varietal Improvement for 2,129,000 ha crop lands *Nitrous Oxide emission reduction from nitrogen-based Fertilizer* • 627,000 ha crop land Management (leaf color chart, soil test based fertilizer application, less tillage barn management etc.) • Improvement of fertilizer management (deep placement of urea in rice field, training, awareness) in 150,000 ha • Bringing more area under pulse cultivation *Methane emission from Enteric Fermentation* • Replacement of low-productive animals with high-producing crossbred cattle (Large Ruminant – 1.882 million and Small Ruminant – 1.776 million) • Feed improvement by using a balanced diet and beneficial micro-organisms for livestock (Large Ruminant 1.013 million and Small Ruminant – 1.355 million) *Methane and Nitrous Oxide emission from Manure management* • Improved manure management through promotion of mini biogas plants (107,000 nos.) • Expansion of awareness and training programme **Forestry** • Maintain the forest cover and tree cover through collaborative forest management, social forestry and other programs. • Forest conservation by Scale-up of alternative income-generating activity for forest-dependent communities- 55,000 nos. families • Co-management in Protected areas -72,000 ha • Additional coastal afforestation activities. • Maintain the restoration of degraded or deforested areas. • Plantation in roadsides, embankments, private lands etc.
Waste	• Improved Municipal solid waste management • Ensure 3R principle for waste management • Improvement of Sewerage treatment	• Establishment of Incineration plant in 3 Cities • Implementation of wastewater treatment plants in several cities • Expansion of Regional Integrated Landfill and Resource Recovery Facility in other cities

Source: Bangladesh First NDC (Updated submission)

(13) The Philippines

The key points of the Philippines' NDC are shown below.

Table 27 Philippines NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	April 2021	—
Target period	2020-2030	—
Scope of commitment	Agriculture, waste, industry, transportation, energy	—
Base year (Reference year or period)	—	—
GHG emission reduction target	75% below BAU (2.71% is unconditional, 72.29% is conditional)	—
Renewable energy introduction target	Not specified.	No data in the REN21 Report.
Energy efficiency target	No specific details.	—
Renewable energy introduction volumes and its current share	30% (in total primary energy consumption)	REN21 Report
Energy intensity (current)	0.074 toe/ USD 1 000 *Japan 0.089, EU average 0.095	IEA Data
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	Technology transfer from the international community is required.	—

Source: Philippines First NDC for information not mentioned in "Sources other than NDC".

The Philippines NDC is a very simple document comprising 5 pages. The key points are shown below.

With regard to mitigation measures, the focus is on the need for funding support and technology transfer from the international community, but there are no specific descriptions.

(14) Myanmar

The key points of the Myanmar's NDC are shown below.

Table 28 Myanmar NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	August 2015 (INDC) *Date of submission on UNFCCC website: September 2015 August 2021 Submitted an updated edition	—
Target period	Start year: Not specified.	—

	End year: 2030	
Scope of commitment	(2015 edition) Energy, agriculture, transport, waste, LULUCF and industry (2021 edition) Energy, Forestry and Other Land Use	—
Base year (Reference year or period)	(2015 edition) Not specified. (2021 edition) Different from sector. For example, the energy sector sets targets using BAU scenarios with 2005 - 2015 as the base year. Agriculture uses 2013 as its base year, and Forestry and Other Land Use uses 2005 - 2015 as its base year.	—
GHG emission reduction target	(2015 edition) Not specified (2021 edition) 244.52 million tCO2e reduction by 2030 for unconditional scenario, and a total of 414.75 million tCO2e reduction with conditions of international financial and technical assistance	—
Renewable energy introduction target	(2015 edition) 30% (rural electric power) (2021 edition) Increase the share of renewable energy (solar and wind) to 53.5% (2,000 MW to 3,070 MW) by 2030, reduce the share of coal to 73.5% (7,940 MW to 2,120 MW), etc.	—
Energy efficiency target	(2015 edition) No specific details. (2021 edition) The energy efficiency improvement targets for 2030 are Residential sector: 7.8% Industrial: 6.63 Commercial: 4%. Other sectors: 1.36	—
Renewable energy introduction volumes and its current share	(2015 edition) Not specified. (2021 edition) It is stated that the current capacity is 166.4 MW.	—
Energy intensity (current)	0.078 toe/ USD 1 000 *Japan 0.089, EU average 0.095	IEA Data
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	(2015 edition) Regarding rural electric power, at least 30% shall be from renewable energy sources. (2021 edition) Various projects are mentioned, both in terms of anticipated budgets. By sector, the following directions are also indicated.	—

	Energy Sector: Reduce the share of renewable energy (solar and wind) to 53.5% and coal to 73.5% by 2030, etc. Agriculture Sector: Promote afforestation and agroforestry Forest land and other land use sectors: Reduce deforestation by 50% by 2030 (conditional target)/25% by 2030 (unconditional target) Other: - Distribution of 5.1 million fuel-efficient cook stoves - Introduction of renewable energy - Improvement of energy efficiency	

Source: Myanmar First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

Myanmar's 2015 edition NDC comprises 18 pages. The key points are shown below.

While the specific actions are limited to the forestry and energy sectors, the introduction of hydro power generation and improved energy efficiency in the industry sector are included.

Myanmar submitted an updated version in August 2021. The updated version is 83 pages long and thick with content.

Table 29 Mitigation Measures Presented in Myanmar's NDC (2015 edition)

Sector	Measures/Actions
Forestry sector	
National Permanent Forest Estate Target	By 2030, Myanmar's permanent forest estate (PFE) target is to increase national land area as forest land with the following percent of total land area): ✧ Reserved Forest (RF) and Protected Public Forest (PPF) = 30% of total national land area ✧ Protected Area Systems (PAS) = 10% of total national land area
Energy Sector	
(1) Renewable energy - Hydroelectric power	Increase the share of hydroelectric generation within limits of technical Hydroelectric potential. Indicative goal - 9.4 GW by 2030
(2) Renewable energy - Rural electrification	To increase access to clean sources of electricity amongst communities and households currently without access to an electric power grid system. Indicative goal: Rural electrification through the use of at least 30% renewable sources as to generate electricity supplies.
(3) Energy efficiency - industrial processes	To mitigate GHG emissions in the rapidly developing industrial production sector by: (a) Improving energy efficiency within the Myanmar industry (b) Focusing on the implementation of energy management systems compatible with the international standard ISO50001 (c) Energy system optimization Indicative goal: To realize a 20% electricity saving potential by 2030 of the total forecast electricity consumption.
(4) Energy efficiency - Cook-stoves	To increase the number of energy efficient cook-stoves disseminated in order to reduce the amount of fuel wood used for cooking. Indicative goal: To distribute approximately 260 000 cook stoves between 2016 and 2031.

Source: Myanmar First NDC (Archived)

(15) Viet Nam

The key points of Viet Nam's NDC are shown below.

Table 30 Viet Nam NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	September 2015 (INDC) *Date of submission on UNFCCC website: November 2016 July 2020 Submitted an updated edition * Date of submission on UNFCCC website: September 2020	—
Target period	From January 1, 2021 to December 31, 2030	—
Scope of commitment	(2015 edition) Entire economy including the following sectors: 1. Energy a. Fuel combustion - Energy industries - Manufacturing industries and construction - Transport - Others: residential, agriculture and commercial services b. Fugitive emissions - Coal mining - Natural gas and oil 2. Agriculture - Enteric fermentation - Manure management - Rice cultivation - Agriculture soil - Prescribed burning of savannas - Field burning of agricultural residues 3. Land Use, Land Use Change and Forestry (LULUCF) - Forest land - Cropland - Grassland - Wetlands - Settlements - Other land 4. Waste - Solid waste landfills - Industrial wastewater - Domestic wastewater - Human waste - Waste incineration. (2020 edition) The following were added 5.Industrial processes (IP) - Construction materials - Chemical industry - HFC consumption	—
Base year (Reference year or period)	Comparison to BAU (2015 edition) BAU calculation are from 2010 (2020 edition) Calculation revised with the BAU standard set to 2014.	—
GHG emission reduction target	(2015 edition) (Unconditional)	—

	-By 2030 Viet Nam will reduce GHG emissions by 8% compared to BAU, in which: - Emission intensity per unit of GDP will be reduced by 20% compared to the 2010 levels; - Forest cover will increase to the level of 45%. (Conditional) The above-mentioned 8% contribution could be increased to 25% if international support is received through bilateral and multilateral cooperation, as well as through the implementation of new mechanisms under the Global Climate Agreement, in which emission intensity per unit of GDP will be reduced by 30% compared to 2010 levels. (2020 edition) (Unconditional: Use of domestic resources) ・ By 2025 Viet Nam will have reduced total GHG emissions by about 7.3% compared to the BAU scenario (equivalent to 52.9 million tons of CO2eq), ・ By 2030 Viet Nam will have reduced total GHG emissions by about 9% ・ BAU scenario (equivalent to 83.9 million tons of CO2eq). (Conditional: With international support) The above-mentioned 9% contribution can be increased to 27% by 2030 (equivalent to 250.8 million tons of CO2eq) with international support received through bilateral, multilateral cooperation as well as through the implementation of market and non-market mechanisms under Article 6 of the Paris Agreement.	
Renewable energy introduction target	Not specified.	—
Energy efficiency target	Reference is made to emissions intensity per unit of GDP as above.	—
Renewable energy introduction volumes and its current share	13.3% (2018)	REN21 Report
Energy intensity (current)	0.135 toe/ USD 1 000 *Japan 0.089, EU average 0.095	—
Energy intensity (target)	Not specified. Reference is made to emissions intensity per unit of GDP as above.	—
Means of commitment implementation (mainly mitigation measures)	(2015 edition) The following 9 items are referenced. 1) Strengthen the leading role of the State in responding to climate change 2) Improve effectiveness and efficiency of energy use; reducing energy consumption 3) Change the fuel structure in industry and transportation 4) Promote effective exploitation and increase the proportion of new and renewable energy sources in energy production and consumption 5) Reduce GHG emissions through the development of sustainable agriculture; improve effectiveness and competitiveness of agricultural production	—

	6) Manage and develop sustainable forest, enhance carbon sequestration and environmental services; conservation of biodiversity associated with livelihood development and income generation for communities and forest-dependent people 7) Waste management 8) Communication and awareness raising 9) Enhance international cooperation (2020 edition) (i) Improving energy saving and energy efficiency, and reducing energy consumption; (ii) changing the fuel and energy structure in industry and transportation; (iii) shifting passenger and cargo transportation models; (iv) promoting efficient exploitation of renewable energy sources and increasing their proportion in energy production and consumption; (v) reducing GHG emissions through sustainable agricultural development, and improving the effectiveness and competitiveness of agricultural production; (vi) managing and developing sustainable forests, enhancing carbon sequestration and environmental services; conservation of biodiversity associated with economic development and increasing incomes for forest-dependent communities and people; (vii) managing wastes; (viii) reducing GHG emissions by replacing construction materials and improving the cement and chemical production processes together with reducing the consumption of HFCs.	

Source: Viet Nam First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

The first NDC submitted by Viet Nam comprises 11 pages and was submitted in September 2015 (the UNFCCC website states that it was submitted in November 2016). The NDC submitted by Viet Nam in 2015 is characterized by the detailed description of the scope of commitment. As for the target, in addition to a reduction in GHG emissions compared to the BAU scenario, the NDC presents the target of a reduction in emissions intensity per unit of GDP.

On the other hand, in the text, the word "will" is used for the above target, which gives the impression that it is weak as a commitment.

Viet Nam submitted an updated NDC to the UNFCCC in September 2020. The updated edition has 46 pages. The main points of the changes are shown on p.3.

In the updated edition of the NDC, Viet Nam has:

(i) Reviewed, updated and adjusted its mitigation and adaptation contributions to be more in line with the country's current situation and latest socio-economic development forecasts for up to 2030; ensured that NDC implementation objectives are in line with the objectives of the Socio-Economic Development Strategy, the National Climate Change Strategy, the Viet Nam Green Growth Strategy, and the National Strategy for Natural Disaster Prevention, Response and Mitigation.

(ii) Followed several new requirements for the NDC adopted at COP24 that are suitable for Viet Nam's capacities.

(iii) Clarified issue of loss and damage and included Viet Nam's latest efforts in adaptation and mitigation.

(iv) Included impact assessment of the implementation of mitigation measures on socioeconomic development.

(v) Added the analysis of co-benefits of adaptation, mitigation, and sustainable development.

(vi) Supplemented appropriate indicators to facilitate regular monitoring and evaluation of NDC implementation progress.
(vii) Included a national system for measurement, reporting and verification (MRV) for mitigation actions and a monitoring and evaluation (M&E) system for adaptation actions in order to implement the NDC.
(viii) Clarified advantages, disadvantages and an implementation plan for the NDC given current international and national contexts as well as the appropriate measures to be taken.

The large increase in the number of pages in comparison to the 2015 edition is due to the added descriptions regarding (iii) to (viii).
Also, it is worth noting that in the updated edition the BAU calculations have been newly revised with the Base Year set as 2014. Furthermore, in the updated editon, there are additional changes regarding the mitigation measures.
Specifically, as shown on p.2, “1. Strengthen the leading role of the State in responding to climate change,” “8) Communication and awareness raising” and “9) Enhance international cooperation” were removed, and “(iii) shifting passenger and cargo transportation models” and “(viii) reducing GHG emissions by replacing construction materials and improving the cement and chemical production processes together with reducing the consumption of HFCs” were added. In addition, there were some changes in expression. However, in “2.4. Measures to achieve GHG reductions in different sectors” on p.10, there is a sector-by-sector organization of mitigation measures, which makes it more difficult to understand the key point with regard to the mitigation measures presented on p.2.
Revisions were also made to the targets. The unconditional target using domestic resources only has dropped from 8% to 7.3%, yet the target with international support has risen from 25% to 27%.

(16) Mozambique
The key points of Mozambique’s NDC are shown below.

Table 31 Mozambique NDC Key Points

	NDC	Sources other than NDC
Type	1st NDC	—
UNFCCC report year	June 2018 (INDC) *No dates are stated in the main text. Information taken from UNFCCC website December 2021 Submitted an updated version	—
Target period	(2018 edition) 2020 – 2030 (2021 edition) 2020-2025	—
Scope of commitment	(2018 edition) Energy (power generation, transport, Other–residential, commercial, business sectors), land use, land use changes and forestry (REDD +), waste (solid waste disposal and processing) (2021 edition) Agro-livestock, Sustainable Land Use, Waste Management, Energy Security and Sustainability of Industries, REDD+	—
Base year (Reference year or period)	(2018 edition) Covers a reduction in overall emissions in the period of 2020 to 2030, with no base year.	—

	(2021 edition) Comparison with the BAU scenario for the period 2020-2025, no base year.	
GHG emission reduction target	(2018 edition) Estimate total reduction of about 76.5 MtCO2eq in the period from 2020 to 2030, with 23.0 MtCO2eq by 2024 and 53.4 MtCO2eq from 2025 These reductions are estimates with a significant level of uncertainty and will be updated with the results from the BUR (Biennial Update Report) to be available by early 2018. (2021 edition) Reduce GHG emissions by about 40 Mt CO2eq between 2020 and 2025.	—
Renewable energy introduction target	Not specified.	—
Energy efficiency target	Not specified.	—
Renewable energy introduction volumes and its current share	Not specified.	—
Energy intensity (current)	Not specified.	—
Energy intensity (target)	Not specified.	—
Means of commitment implementation (mainly mitigation measures)	(2018 edition) The section explaining the means of implementation is limited to a description of the fact that Mozambique is participating in the Second Phase of the Technology Needs Assessment Project (TNA), that includes the production of a Technological Action Plan, but there are no specific details. (2021 edition) See bellow	—

Source: Mozambique First NDC (Archived and Updated submission) for information not mentioned in "Sources other than NDC".

Mozambique's NDC comprises 12 pages. Mozambique was slow to submit its NDC, doing so in 2018.

Mozambique has submitted an updated version in December 2021. The mitigation measures presented in Mozambique's updated NDC are listed in the table below.

Table 32 Mitigation measures proposed in the updated NDC

Sector	Measures
Improving access to renewable energy	Promotion of the use of renewable energy sources - hydro
	Technology Action Plan for Regular Hydro Turbine
	Technology Promotion of the use of renewable energy sources - wind
	Promotion of the use of renewable energy sources - Photovoltaic
Promoting the expansion of the national grid or the creation of energy distribution micro-grids	Expansion of the urban network, making new connections; promoting 100% coverage in the connection of domestic consumers in suburban areas, in the districts and interconnected to the national grid (SILE).
Development of projects and programmes for micro-energy generation in commercial and residential buildings -	Installation of 50,000 photovoltaic or wind turbine lighting systems
	Installation of 5,000 solar PV systems for pumping water for domestic, community or public use in isolated (SIE) or mixed (SILE/SIE) areas,

Increase energy efficiency	including agricultural irrigation and livestock waterin
Promotion of the use of efficient household appliances	Powering of 5,000 glaciers for domestic use, through photovoltaic technology or with wind turbines, in homes in areas isolated from the national electricity grid (SIE)
	Replacement of 2,500,000 incandescent lamps with efficient lamps in all domestic consumers in the country
	Productive use of energy - construction of 8 centres for fish conservation
Promotion of low carbon urbanisation	Construction of 450 MW thermal power plant based on natural gas: Technological Action Plan for Combined Cycle Natural Gas Technology
	Massification of LPG - Increasing the number of people with access to cooking gas to around 309.02% compared to today
	Massification of Natural Gas Use: Construction of 10 Compressed Natural Gas Supply Stations, • Importation of 150 CNG Buses • Import of 1,000 kits and respective conversion Cylinders for Natural Gas. • Conversion of 1,000 cars to NG
	Repair of 150 NG buses for public transport
Increased energy efficiency in travel	Expansion of Metrobus to the country's main capitals
Managing and recovering waste	Promotion of sustainable waste management in Mozambique (NAMA Waste)
	Implementation of the Technological Action Plan and Project Ideas for Solid Urban Waste Management and Treatment
Enhance and expand conservation agro-livestock farming techniques	Application and expansion of agricultural production techniques of a conservationist and soil protection nature, such as the use of direct planting.
Increased efficiency in the production and use of biomass fuels	Application and dissemination of production techniques and improved use of firewood and charcoal sustainability.
Reducing GHG emissions from Industry	Installation of solid waste recycling industries under PRONAL
	Creation of Industrial Research and Development Centers
	Encouraging investors to evaluate GHG emissions in investment projects
	Promotion of projects and programs of microgeneration of energy in the industrial sector

Source: Mozambique First NDC (Updated submission)

1.1.5 Long-Term Strategy Case Studies

The long-term strategies communicated by the Parties to the UNFCCC are available on the UNFCCC website. The countries that have published their strategies on the website as of February 17, 2021, are, in order of submission, Canada, Mexico, the U.S., Benin, Germany, Czech Republic, U.K., Ukraine, the Marshall Islands, Fiji, Japan, Portugal, Costa Rica, the EU, Slovakia, Singapore, South Africa, Finland, Norway, Latvia, Belgium, Spain, Sweden, the Netherlands, Australia, South Korea, Denmark, Switzerland, and France.

Of these, from among the countries that fall into the category of developing countries, the long-term strategies of Benin, the Marshall Islands, Fiji, Costa Rica, South Africa, China, Thailand, and Cambodia are summarized below alongside basic economic data.

For Indonesia, an overview of its long-term strategy is discussed below in Section 1.2.1 Low- and Decarbonizing Energy Policies and Long-Term Energy Plans in Major Developed/Developing Countries.

(1) Benin

(i) Industry Characteristics (basic information not provided in the long-term strategy)

First, although not provided in the long-term strategies, basic information on the countries to be surveyed was considered important for our analysis, and information about Benin was organized with reference to the website of the Japanese Ministry of Foreign Affairs (MOFA) and other sources.

Table 33 Industry Characteristics

Indicator	Figures/Details
(1) Area	112 622 km^2 (approx. one third of Japan)

(2) Population	11.49 million (2018, World Bank)
(3) Key industries	Agriculture (cotton, palm oil), Services (harbors)
(4) GDP (Nominal)	USD 14.25 billion (2018, World Bank)
(5) GNI per capita	USD 1 200 (2018, World Bank)
(6) Economic growth rate	Economic growth rate 6.7% (2018, World Bank)

Source: (1) to (6) Ministry of Foreign Affairs of Japan website. (7) World Bank

(ii) Elements that Constitute the Long-Term Strategy

The long-term strategy has 84 pages with the following elements.

1. Status of climate and climate scenarios: Becoming warmer with more precipitation
2. Adaptation and mitigation challenges and issues: Harmonizing economic development and environmental protection
3. Strategic diagnosis: Six economic development sectors that are vulnerable to climate change
4. Strategic foundations: Short-term and mid-term cross-sector strategy
5. Application strategy: Introducing measures for economic development with low carbon intensity and resilience against climate change
6. Processes and systematic frameworks for implementation and monitoring: Multi-centric implementation approach
7. Resource mobilization plan: Relying on the country's own resources in order to mobilize more specialist fundraising mechanisms[11]

Appendix

Six economic development sectors are identified as being vulnerable to climate change. They are:

1) Agriculture and rural development sector
2) Energy sector
3) Forestry and land use sector
4) Infrastructure and residence sector
5) Healthcare sector
6) Water resources sector

The situations of these sectors are analyzed based on the perspectives of basic programs and climate risk types and levels, and strategies are formulated via a process of forming the necessary sub-programs.

(iii) GHG Emissions Characteristics

GHG emissions in 2000 except for Land Use, Land Use Change and Forestry (LULUCF) were estimated to be 6251.03 Gg E-CO2. With LULUCF included, it is estimated to be -5082.11Gg E-CO2.

The contribution ratios to GHG emissions excluding LULUCF are 40%, 37%, and 23% for N2O, methane (CH4), and CO2, respectively.

Agriculture accounts for 68% of GHG emissions and the energy sector accounts for 30%.

Indirect GHG emissions from NOx, CO, and COVNM were estimated to be 896.37 Gg in 2000 excluding LULUCF. Of these, 55% is from agriculture, and 45% from the energy sector.

(iv) Characteristics of Mitigation Measures

The countermeasure consists of pillars and sub-programs (SP). The SP are more about an awareness of the effects than specific measures.

[11] Green Climate Funding (GCF)

Pillar 1: Local community and agriculture production system resilience strengthening
SP-1: SP to strengthen the resilience of the community and agricultural sector
SP-2: SP with the objective of establishing structural climate financial services
SP-8: SP to strengthen the capacity of regional communities with the objective of supporting regional development that is capable of recovery even when facing climate change
SP-11: Multi-purpose dam construction SP
SP-12: SP in connection to boreholes, reservoir construction, drinking water supply, and work community management.

Pillar 2: Reduction in artificial GHG emissions and potential for carbon sequestration
SP-3: Energy insufficiency transition support program
SP-4: SP to develop controls/regulator mechanisms for GHG emissions
SP-5: SP to enhance carbon sinks and to reduce emissions from deforestation and forest deterioration

Pillar 3: Climate risk reduction
SP-6: SP to establish and recover natural flow and rainwater drainage network
SP-7: SP to enhance early warning system for the purpose of climate information and natural disaster risk management
SP-9: Sub regional program to secure the coastline of West Africa
SP-10: SP for the control of disease-transmitting organisms that are easily impacted by the climate

Cross-section: Coordination, capacity building and knowledge management

(2) Marshall Islands
(i) Industry Characteristics (basic information not provided in the long-term strategy)

Table 34 Industry Characteristics

Indicator	Figures/Details
(1) Area	180 km^2 (roughly the same size as Kasumigaura)
(2) Population	58 413 (2018, World Bank)
(3) Key industries	Agriculture (copra, coconut palm oil) fishing
(4) GDP (Nominal)	USD 221 million (2018, World Bank)
(5) GNI per capita	USD 4 740 (2018, World Bank)
(6) Economic growth rate	3.6% (2018, World Bank)

Source: (1) to (6) Ministry of Foreign Affairs of Japan website.

(ii) Elements that Constitute the Long-Term Strategy
The Marshall Islands' long-term strategy comprises 76 pages, with the following elements.

Contents
The Marshall Islands - A context
Section 1-Executive Summary
Section 2–Greenhouse Gas Emissions
Section 3–Adaptation and Climate Resilience
Section 4–Means of Implementation
Section 5–Transparency, Environmental and Social Information
Section 6–Gender and Human Rights
Section 7–Health
Section 8–Education, Training and Public Awareness
Section 9–Approach and Future Perspectives
Section 10–Background to RMI 2050 strategy
Section 11–Methodologies, Baselines, Projections

Section 12–Acronyms
Section 13–Acknowledgments

In Section 2, about a quarter of the total (21 pages) is devoted to the long-term strategy. Also, Section 6 is characterized as the chapter regarding gender and human rights. The significance of the long-term strategy as to why it is necessary, is often described earlier in an introduction section as a general matter, but this strategy is unique in that it is discussed in Section 10 and later.

(iii) GHG Emissions Characteristics

As an island nation, the majority of GHG emissions are from power generation and waste.

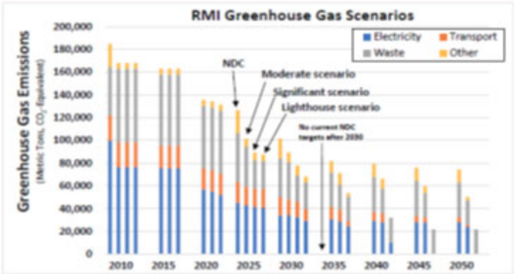


Figure 19 Snapshot Comparisons of Scenarios by Sector and Year

Table 35 The following points are included as new commitments.

Submit, by 2020 at the latest, a new NDC in which, in the context of the necessary means of implementation being available, RMI: • revises its quantified economy-wide target to reduce its emissions of GHGs to at least 32% below 2010 levels by 2025; • commits to a quantified economy-wide target to reduce its emissions of GHGs to at least 45% below 2010 levels by 2030; • communicates an indicative target to reduce its emissions of GHGs by at least 58% below 2010 levels by 2035; • reaffirms its aspiration to achieve net zero GHG emissions by 2050 at the latest; • commits to producing a National Adaptation Plan by the end of 2019 at the latest that sets out short, medium and long-term milestones to adapt to the impacts of climate change and transition to climate resilience, suggests implementation measures and includes a plan to generate the necessary financing; • commits to submitting an Adaptation Communication to the UNFCCC by 2020 at the latest; • commits to a gender-responsive and human rights-based approach in all NDC-related planning, programming and implementation; and • commits to using the latest Intergovernmental Panel on Climate Change (IPCC) Guidelines (currently 2006).

(iv) Characteristics of Mitigation Measures

The mitigation measures are as follows.

Table 36 Mitigation Measures

Sector	Sub-Sector	Mitigation Measures
Stationary electricity	**Power generation**	Diesel Generator Efficiency / Rapid Response
		Solar power
		Wind power
		Coconut Oil

	Storage **Energy efficiency**	Automated SCADA/Dispatch/ Forecasting
		Vehicle to Grid Battery Storage
		Battery Storage
		Thermal Storage
		Replace all A/C with Wet Cooling Towers / Seawater ASHPs
		Improve Building Codes / Enforcement
		Other
Waste	—	"Fukuoka" Landfill Site
		Incinerate Waste rather than Uncontrolled Burning
		Disposable Container Ban
		Improve Recycling, Education, Regulation Enforcement, Reducing Landfill Volumes
Transportation	—	Land Efficiency Improvements
		Electric Vehicles
		Multi-modal initiatives: Regular Island Shuttles; Electric Bikes
		Improve efficiency of maritime transportation
Other	—	Improve LPG efficiency
		Convert LPG Cooking to Electric

*Categorization is modified as there are some mistakes in original document
Source: Marshall Island (2018) Tile Til Eo – 2050 Climate Strategy "Lightning the way"

(3) Fiji
(i) Industry Characteristics (basic information not provided in the long-term strategy)

Table 37 Industry Characteristics

Indicator	Figures/Details
(1) Area	18 270 km^2 (roughly the same size as Shikoku)
(2) Population	Approx. 890 000 (2017, Fiji Bureau of Statistics)
(3) Key industries	Big three industries are tourism, garment and sugar
(4) GDP (Nominal)	USD 5.537 billion (2018, World Bank)
(5) GNI per capita	USD 5 860 (2018, World Bank)
(6) Economic growth rate	3.5% (2018, World Bank)

Source: (1) to (6) Ministry of Foreign Affairs of Japan website.

(ii) Elements that Constitute the Long-Term Strategy
Fiji's long-term strategy is very long at 232 pages, with the following elements.
1 Introduction
2 National Circumstances
3 Pathways Towards Low Emission Development and Deep Decarbonization in Fiji
4 Sector-Specific Targets and Measures
5 Climate Change Adaptation and Resilience
6 Social, Economic and Environmental Dimensions
7 Education, Capacity Building and Awareness Raising
8 Governance and Monitoring and Evaluation
Annex A. List of Prioritized Actions, with High-Level Costing and Timeline
References

In particular, more than half of the total volume is devoted to Chapter 4, at 143 pages. The target sectors in Chapter 4 are as follows.

1 Electricity and Other Energy Generation and Use
2 Land Transport
3 Maritime Transport
4 Domestic Air Transport
5 AFOLU (Agriculture, Forestry and Other Land Use)
6 Coastal Wetlands
7 Waste Sector
8 Cross-Cutting Sectors: Tourism, Commercial, and Industrial and Manufacturing Sectors

(iii) GHG Emissions Characteristics

There are major emissions from land transportation on the island and from AFOLU. The use of electric power and other energy accounts for about 10% of emissions but in the BAU scenario the ratio of the use of electric power and other energy by 2050 is expected to increase to almost 25%.

Table 38 CO2 emissions forecast by sector in Fiji

BAU Unconditional	2020	2025	2030	2035	2040	2045	2050
Electricity and Other Energy Use	237,124	219,734	282,652	430,975	603,157	834,329	1,121,791
Land Transport	817,396	937,084	1,112,908	1,277,184	1,416,260	1,531,237	1,623,846
Domestic Maritime Transport	198,500	229,900	267,200	317,500	379,100	454,000	545,300
Domestic Air Transport	21,000	27,000	34,000	41,000	50,000	58,000	68,000
AFOLU	870,681	870,729	864,670	858,614	852,554	846,498	840,439
Waste	200,167	226,948	251,061	279,504	301,603	323,293	344,682
Total	**2,344,868**	**2,511,395**	**2,812,491**	**3,204,777**	**3,602,674**	**4,047,357**	**4,544,058**

(iv) Characteristics of Mitigation Measures

In ANNEX A, there are various countermeasures for the energy sector, land transportation, domestic maritime transport, domestic air transport, AFOLU, wetlands and waste.

It is not possible to mention them all as there are so many countermeasures, but in the energy sector reference is made to various approaches, including biomass power generation, solar photovoltaic power generation, hydropower generation, wind power generation, thermal power generation, tidal power generation, improved energy efficiency in the business community and in the public sector, and Vehicle to Grid.

Regarding land transportation, reference is made to hybrid cars, electric vehicles and the use of biofuel.

Regarding domestic maritime transport, reference is made to 4-stroke engines, and fuel efficiency standards.

Regarding domestic air transport, reference is made to improved energy efficiency of aircraft, solar photovoltaic power generation, biofuel, and improved energy efficiency.

Regarding AFOLU, reference is made to reducing GHG emissions from the transport of timber, reducing forest logging, improving the efficiency of plantations, afforestation, intestinal fermentation countermeasures for domestic animals, domestic animal excrement countermeasures, and synthetic fertilizer countermeasures.

Regarding wetlands, reference is made to mangrove countermeasures.

Regarding waste, reference is made to the promotion of 3R, composting promotion, the establishment of relay points, waste power generation, and countermeasures for methane from disposal sites.

(4) Costa Rica

(i) Industry Characteristics (basic information not provided in the long-term strategy)

Table 39 Industry Characteristics

Indicator	Figures/Details
(1) Area	51 100 km^2 (an area the size of Kyushu and Shikoku combined)
(2) Population	Approx. 4 990 000 (2018, World Bank)
(3) Key industries	Agriculture (bananas, pineapple, coffee etc.), manufacturing (medical apparatus), tourism
(4) GDP (Nominal)	USD 60 100 million (2018, Central Bank)
(5) GNI per capita	USD 12 026 (2018, Central Bank)
(6) Economic growth rate	3.2% (2017, Central Bank)

Source: (1) to (6) Ministry of Foreign Affairs of Japan website.

(ii) Elements that Constitute the Long-Term Strategy

Costa Rica's long-term strategy has 112 pages, with the elements as follows.

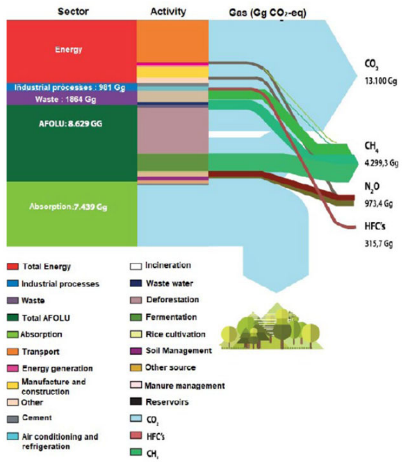
Presentation

Section 1: Executive Summary
Section 2: Costa Rica aspires to have a green, resilient and equitable economy without emissions.
Section 3: The Costa Rican economy and public policy created a pattern of emissions that reflects great successes, but also new challenges
Section 4: The goal of decarbonization planning is to go beyond an environmental agenda: it is to transform the economy
Section 5: Short-, medium- and long-term goals and actions for the decarbonization of the Costa Rican economy
Section 6: Institutional requirements and involvement for transformation
Section 7: Conclusions: Five priority actions
Annexes: Action Plan of the 10 decarbonization axes, for the period 2019-2022

Section 5 comprises 39 pages, roughly one third of the entire document. It defines the targets and actions for the 10 pillars described later.

(iii) GHG Emissions Characteristics

As an agricultural country, emissions from AFOLU (agriculture, forestry and land use) are high. Conversely, absorption from forests is also high.

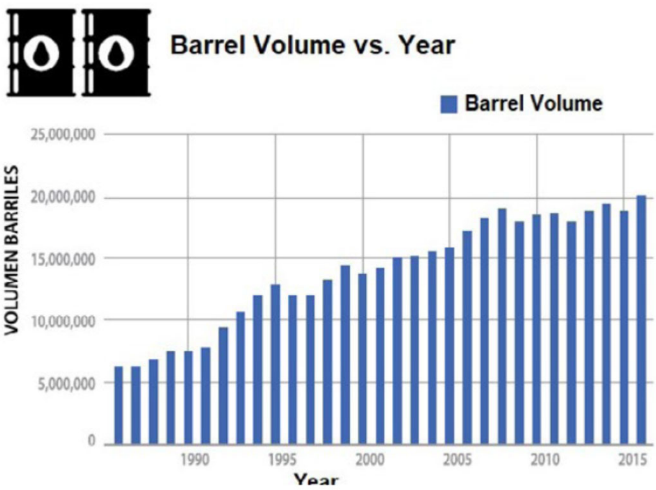


Source: National Inventory of Greenhouses Gases and Carbon Absorption 2012

Figure 20 CO2 emissions by sector in Costa Rica

In the energy sector, diesel is being increasingly used.

FIGURE 3: Oil barrel annually imported in Costa Rica (1985-2015)



Source: RECOPE

Figure 21 Oil Barrel Annually Imported in Costa Rica (1985-2015)

(iv) Characteristics of Mitigation Measures

After defining the 10 axes of the strategy, cross-sector countermeasures are established. The 10 axes of the strategy are as follows.

Table 40 The 10 Axes in the Decarbonization and Cross-Cutting Strategy

Table 7: The 10 axes in the decarbonization and cross cutting strategy

10 axes of the decarbonization	Cross-cutting strategies
1. Development of a mobility system based on safe, efficient and renewable public transport, and on active mobility schemes.	A. Comprehensive reform for the new institutionality of the Bicentennial.
2. Transformation of the light-duty vehicles fleet to have zero-emissions, sustained by renewable energy, not of fossil origin.	B. Green Tax Reform.
3. Promotion of a cargo transport that adopts modalities, technologies and sources of energy zero-emissions or the lowest emission possible.	C. Funding strategy and investments attraction for transformation.
4. Consolidation of the national electric system with capacity, flexibility, intelligence, and resilience necessary to supply and manage renewable energy at competitive cost.	D. Digitalization and Knowledge-based Economy Strategy.
5. Development of buildings for different uses (commercial, residential, institutional) under the standards of high efficiency and low emission processes.	E. Labor strategies of "just transition".
6. Transformation of the industrial sector through processes and technologies that use energy from renewable sources or other efficient and sustainable methods that have low or zero-emissions.	F. Inclusion, human rights and promotion of gender equality.
7. Development of an integrated waste management system based on the separation, reuse, revaluation, and final disposal of maximum efficiency and low GHG emissions.	G. Transparency, metrics and open data strategy.
8. Promotion of highly efficient agro-food systems that generate low-carbon local consumption and export goods.	H. Education and Culture Strategy: the Bicentennial Costa Rica free of fossil fuels.
9. Consolidation of an eco-competitive livestock model based on productive efficiency and reduction of GHG.	
10. Consolidation of a model of management for rural, urban, and coastal territories that facilitates the protection of biodiversity, the increase and maintenance of forest cover, and ecosystem services based on nature-based solutions	

(5) South Africa

(i) Industry Characteristics (basic information not provided in the long-term strategy)

Table 41 Industry Characteristics

Indicator	Figures/Details
(1) Area	1 220 000 km2 (Approx. 3.2 times greater than Japan)
(2) Population	57 780 000 (2018, World Bank)
(3) Key industries	(Agriculture) Dairy farming, maize, sugarcane, soy, citrus fruits, other vegetables, fruit, potatoes, wheat, wool, leather (Metals) Gold, platinum, iron ore, coal, copper, chrome, manganese, nickel, diamond, vanadium, titanium (Manufacturing/processing) Food, iron manufacture, chemicals, fibers, automobiles
(4) GDP (Nominal)	USD 366.3 billion (2018, World Bank)
(5) GNI per capita	USD 5 720 (2018, World Bank)
(6) Economic growth rate	0.6% (2018, World Bank)

Source: (1) to (6) Ministry of Foreign Affairs of Japan website.

(ii) Elements that Constitute the Long-Term Strategy

South Africa's long-term strategy (South Africa's Low-Emission Development Strategy 2050) has 69 pages, with the elements as follows.

(iii) GHG Emissions Characteristics

A large amount of GHG emissions in South Africa is from power generation at 42%, followed by industry emissions at 27%.

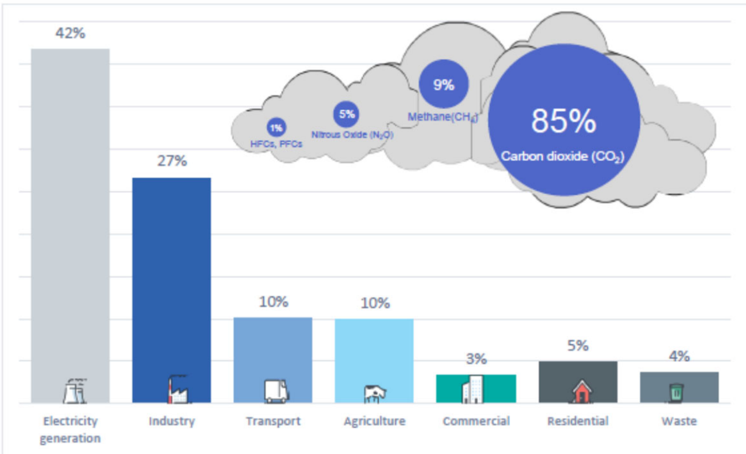


Figure 4: Total gross national GHG emissions by economic sector

Figure 22 Total Gross National GHG Emissions by Economic Sector

(iv) Characteristics of Mitigation Measures

Mitigation measures are listed by sector in Chapter 4 of the long-term strategy, "GHG EMISSIONS MITIGATION MEASURES."

Table 42 GHG emission mitigation measures described in South Africa's long-term strategy

4.1 Energy supply
4.1.1 Integrated Energy Plan
4.1.2 Integrated Resource Plan
4.1.3 Biofuels opportunities
4.2 Energy demand
4.2.1 National Energy Efficiency Strategy
4.2.2 Support for uptake of Solar Water Heaters
4.2.3 National Building Regulations and Buildings Standards Act
4.2.4 Promotion of Cleaner Mobility
4.3 Industry
4.3.1 Industrial Policy Action Plan (IPAP)
4.3.2 Tax incentives for green project development
4.4 Agriculture, Forestry and Land Use (AFOLU)
4.5 Waste
4.6 Cross-Cutting Measures
4.6.1 Carbon Tax
4.6.2 Sectoral Emissions Targets (SETs)

4.6.3 Carbon Budgets 4.6.4 Phasing out of inefficient fossil fuel subsidies/incentives

In "4.1.2 Integrated Resource Plan," reference is made to countermeasures in energy supply and demand.

Regarding supply, reference is made to hydropower generation, solar photovoltaic power generation, wind power generation, and other measures.

Characteristically, there are references to various measures on the demand side, as shown below.

Table 43　Characteristics of demand-side measures in South Africa (1)

Sector	Measures	Time frame
Public sector	Introduce mandatory Energy Performance Certificates in all rented properties and publicly accessible buildings	2 years
	Develop the public sector awareness raising campaign to facilitate the "leading by example" approach	5 years
	Introduce standards and labelling relevant for public sector appliances and equipment	2 years
	Announce a 15-year trajectory for the successive tightening of the energy performance component of building standards and successively tighten standards	5 years
	Roll-out the provision of energy and activity data to the public sector	1 year
Municipal sector	Develop municipal energy efficiency strategies	3 years
	Support the implementation of energy savings measures	5 years
Residential sector	Announce a 15-year trajectory for the successive tightening of minimum energy performance standards for household appliances and successively tighten standards	5 years
	Develop a strongly branded energy performance certification mark for household appliances (modelled on the "Energy Star" brand), in addition to the planned energy efficiency labels.	5 years
	Announce a 15-year trajectory for the successive tightening of the energy performance component of building standards for residential buildings and successively tighten standards	5 years
	Build on the existing awareness-raising activities targeting households and the school curriculum	5 years
	Roll-out the provision of energy and activity data from the residential sector	1 year
	Support technology innovation and dissemination of energy efficient cookstove technologies	5 years
Commercial sector	Introduce mandatory Energy Performance Certificates in all rented properties and publicly accessible buildings	2 years
	Revise 12L to ensure it provides an incentive to commercial property owners	4 years
	Introduce standards and labelling relevant for commercial sector appliances and equipment	2 years
	Roll-out the provision of energy and activity data from the commercial sector	1 year
	Adjust the 12L tax incentive scheme	4 years

Source: South Africa (2020) South Africa's Low Emission Development Strategy

Table 44 Characteristics of demand-side measures in South Africa (2)

Sector	Measures	Time frame
Industrial sector	Develop minimum energy performance standards for motors and motor-driven systems	4 years
	Provide targeted support and advice on energy efficiency to enterprises	3 years
	Incentivise enterprises to introduce Energy Management Systems and achieve ISO50001 certification standards	5 years
	Roll-out the provision of energy and production data from the manufacturing sub-sector	1 year
	Develop standardised tools for voluntary reporting of energy savings from initiatives in the mining sector	2 years
	Create technology/ learning hubs for energy efficiency	2 years
Agricultural sector	Explore the potential for savings in agricultural vehicle use, and develop appropriate awareness-raising material	2 years
	Develop targeted awareness-raising and training material on potential savings in motor-driven systems	2 years
	Provide direct grants to small farmers / smallholders for all or part of the cost of interventions	4 years
Transport sector	Develop fuel efficiency standards for light and heavy vehicles to improve the overall efficiency of the vehicle stock	5 years
	Improve systems for ensuring road worthiness	5 years
	Roll-out the provision of energy and activity data from the transport sector	1 year
Production and distribution sector	Develop the enabling framework for cogeneration and trigeneration	3 years
	Expand internal efficiency programmes for producers	3 years

Source: South Africa (2020) South Africa's Low Emission Development Strategy

(6) China

(i) Industry Characteristics (basic information not provided in the long-term strategy)

Table 45 Characteristics of Chinese Industries

Indicator	Figures/Details
(1) Area	Approximately 9.6 million square kilometers (about 26 times the size of Japan)
(2) Population	Approximately 1.4 billion people
(3) Key industries	Primary industry (7.3% of nominal GDP), secondary industry (39.4% of nominal GDP), tertiary industry (53.3% of nominal GDP) (Note) As the "world's factory" driven by labor-intensive and external demand-driven industries, the country has developed mainly through the secondary industry, but in 2012 the ratio of the tertiary industry reversed the ratio of the secondary industry. In 2015, the ratio of the tertiary industry exceeded 50%.
(4) GDP (Nominal)	Approximately 114,367 billion yuan (2021, National Bureau of Statistics of China) Approximately \$17,458 billion (2021, IMF (estimate))
(5) GNI per capita	Approximately 80,976 yuan (provisional value) (2021, National Bureau of Statistics of China) Approximately \$14,096 (2021, IMF (estimate)) GDP per capita
(6) Economic growth rate	8.1% growth (2021, National Bureau of Statistics of China)

Source: (1) to (6) Ministry of Foreign Affairs of Japan website.

(ii) Elements that Constitute the Long-Term Strategy

China's long-term strategy has 43 pages, with the elements as follows.

INTRODUCTION
CHAPTER 1. ADDRESSING CLIMATE CHANGE AND LOW-EMISSION DEVELOPMENT
1. Climate change is a severe threat to all mankind
2. Active response to climate change has become a global political consensus
3. Green and low-carbon transformation has become a general trend of global development
4. China has made positive contributions to combating the global climate change
CHAPTER 2. GUIDING PRINCIPLES AND STRATEGIC VISIONS
1. Guiding principles
2. Strategic visions
3. Technical pathways
CHAPTER 3. STRATEGIC PRIORITIES AND POLICY ORIENTATIONS
1. Foster a green, low-carbon and circular economic system
2. Build a clean, low-carbon, safe and efficient energy system
3. Establish a low GHG emission industrial system
4. Impel urban and rural construction in green and low-carbon manner
5. Form a low-carbon comprehensive transportation system
6. Achieve a substantial reduction in non-carbon dioxide GHG emission
7. Implement the Nature-Based Solutions
8. Inspire low-emission technology innovation
9. Create a new pattern of nationwide participation
10. Promote the modernization of climate governance system and governance capacity
CHAPTER 4. CHINA'S APPROACHES AND ADVOCATES FOR PROMOTING GLOBAL CLIMATE GOVERNANCE
1. Adhere to fairness and equity
2. Adhere to win-win cooperation
3. Adhere to the respect for science
4. Adhere to the commitments
CONCLUDING REMARKS

(iii) GHG Emissions Characteristics

China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy makes no mention of the overall status of GHG emissions. The only mention is that CO_2 emissions per GDP will be reduced by 48.1% in 2019 compared to 2005 levels, and that the share of non-fossil fuels in energy consumption will reach 15.3%.

(iv) Characteristics of Mitigation Measures

In China's Long-Term Strategy, policy direction is provided in Chapter 3, Strategic Priorities and Policy Intentions. Broadly, the following points are described.

1. promote an environmentally friendly, low-carbon, recycling-oriented economic system
2. building a clean, low-carbon, safe and efficient energy system
3. establishment of industrial systems with low GHG emissions
4. promoting urban and rural construction in an environmentally friendly and low-carbon manner
5. formation of a low-carbon integrated transportation system
6. significant reduction of GHG emissions other than carbon dioxide
7. implementation of nature-based solutions
8. promote innovation in low emission technologies
9. creation of new patterns of participation by the entire population
10. promote modernization of climate governance systems and governance capacity

(7) Thailand

(i) Industry Characteristics (basic information not provided in the long-term strategy)

Table 46 Characteristics of Thai Industries

Indicator	Figures/Details
(1) Area	514,000 square kilometers (about 1.4 times the size of Japan)
(2) Population	66.17 million (2021) (Ministry of Interior, Thailand)
(3) Key industries	Agriculture accounts for about 30% of the workers, but less than 10% of GDP. Manufacturing, on the other hand, accounts for about 15% of the workforce, but the highest share at about 30% of GDP.
(4) GDP (Nominal)	501.6 (billion dollars) (nominal, 2020, National Economic and Social Development Board of Thailand)
(5) GNI per capita	GDP per capita is $7,217 (2020, National Economic and Social Development Board, Thailand)
(6) Economic growth rate	-6.1% (2020, National Economic and Social Development Board of Thailand)

Source: (1) to (6) Ministry of Foreign Affairs of Japan website.

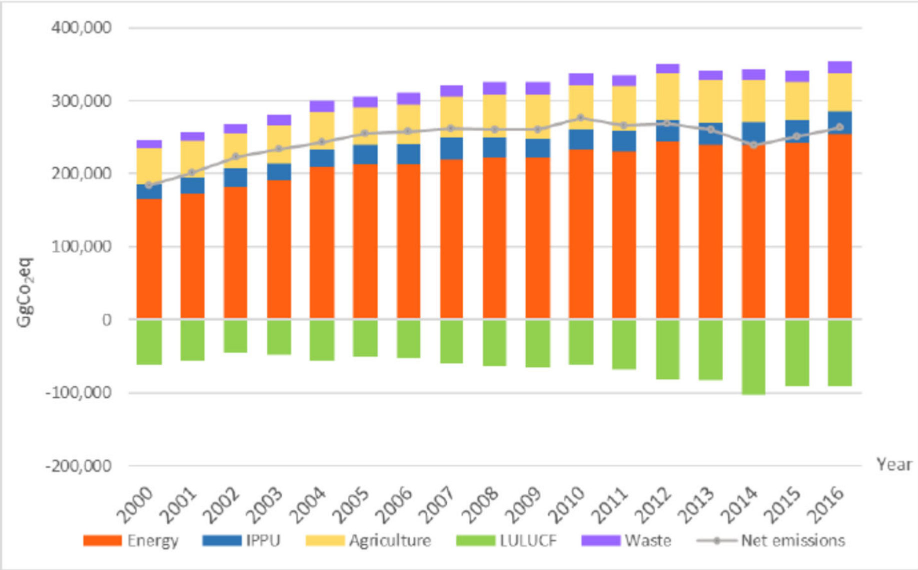
(ii) Elements that Constitute the Long-Term Strategy

Thailand's long-term strategy has 50 pages, with the elements as follows.

Preface
Executive summary
Chapter 1: National Circumstances
1.1 Country Profile
1.2 National GHG Emissions Profile
1.3 Thailand's Climate Change Policy and Institutional Arrangement
Chapter 2: Thailand's Mitigation Actions
2.1 Nationally Appropriate Mitigation Actions (NAMAs)
2.2 Nationally Determined Contribution (NDC)
2.3 Implementation of Mitigation Measures
Chapter 3: Long-term Low Greenhouse Gas Emission Development
3.1 Methodology for the Development of Long-term Low Greenhouse Gas Emission Pathways
3.2 Long-term Sectoral emissions
3.3 Macroeconomic Impact Assessment
3.4 Co-benefits of Long-term Low Emissions
3.5 Thailand Carbon Neutrality
3.6 Support Needs
3.7 Implementation Approach
Bibliography

(iii) GHG Emissions Characteristics

Thailand has the highest GHG emissions from the energy sector at 71.65%, followed by agriculture at 14.72%, industrial process and product use (IPPU) at 8.90%, and waste at 4.73%.



Source: Thailand Third Biennial Update Report, UNFCCC 2020.

Figure 23 CO2 emissions in Thailand by sector

Main location: Thailand (2021) "NDC Roadmap (2021-2030)"

(iv) Characteristics of Mitigation Measures

In 2017, the Thai government approved the NDC Roadmap (2021-2030), and the mitigation measures cited in said roadmap are also cited in the Mid-century, Long-term Low Greenhouse Gas Emission Development Strategy The mitigation measures cited in the roadmap are also cited in the mid-century, long-term Low Greenhouse Gas Emission Development Strategy. Specifically, the NDC Roadmap mitigation measures have been developed based on the following policies

- 12th National Economic and Social Development Plan 2017-2021, extended to 2022
  (12th National Economics and Social Development Plan 2017-2021, extended to 2022)
- Climate Change Master Plan 2015-2050 (Climate Change Master Plan 2015-2050)
- Power Development Plan 2015-2036 (Power Development Plan 2015-2036)
- Thailand Smart Grid Development Master Plan 2015-2036 (Thailand Smart Grid Development Master Plan 2015-2036)
- Energy Efficiency Plan 2015-2036 (Energy Efficiency Plan 2015-2036)
- Alternative Energy Development Plan 2015-2036 (Alternative Energy Development Plan 2015-2036)
- Environmentally Sustainable Transport System Plan 2013-2039 (Environmentally Sustainable Transport System Plan 2013-2030)
- National Industrial Development Master Plan 2012-2031 (National Industrial Development Master Plan 2012-2031)
- Waste Management Roadmap

The following is a list of mitigation measures outlined in the NDC Roadmap.

Table 47 Mitigation measures outlined in Thailand's NDC Roadmap (2021-2030)

sector	Mitigation measures	$MtCO_{2eq}$
1. energy	generation (e.g. power) 1. Improved power generation efficiency 2. Generation of electricity from renewable energy sources Energy consumption in the home 3. Improving energy efficiency in the home	72.0

	4. Use of renewable energy in the home Energy consumption in buildings (commercial and public) 5. Improving Energy Efficiency in Buildings	
2. transportation	1. Traffic flow avoidance/reduction 2. Conversion and maintenance of traffic modes 3. Improving energy efficiency in transportation	41.0
3. industrial process and product use (IPPU)	1. Alternative to clinker 2. Refrigerant renewal/conversion	0.6
4. waste management	Waste Management 1. Reduce the total amount of waste (e.g., reduce disposal rates, improve recycling and effective use of waste, etc.) wastewater management 2. Improved biogas production from industrial wastewater through the use of methane 3. Industrial Wastewater Management 4. Urban Drainage Management	2.0
total amount		**115.6**

Main location: Thailand (2021) "NDC Roadmap (2021-2030)"

(8) Cambodia

(i) Industry Characteristics (basic information not provided in the long-term strategy)

Table 48 Characteristics of Cambodian Industries

Indicator	Figures/Details
(1) Area	181,035 square kilometers
(2) Population	15.3 million (2019 Cambodian Census)
(3) Key industries	Agriculture (25.0% of GDP), Industry (32.7% of GDP), Services (42.3% of GDP) (2017, ADB data)
(4) GDP (Nominal)	Approx. 26 billion USD (2020, IMF estimate)
(5) GNI per capita	US$1,655 (2020, IMF estimate) GDP per capita
(6) Economic growth rate	No data

Source: (1) to (6) Ministry of Foreign Affairs of Japan website.

(ii) Elements that Constitute the Long-Term Strategy

Cambodia's long-term strategy has 47 pages, with the elements as follows.

Executive Summary
1. Introduction and Background
1.1. Global and local context of climate change
1.2. Developing Cambodia's long-term strategy
2. Cambodia's Vision for Carbon Neutrality
2.1. LTS4CN objectives and scenarios
2.1.1. The BAU scenario
2.1.2. The LTS4CN scenario

2.2. Economic costs and benefits
2.2.1. Public sector costs
2.2.2. Public financing plan
2.3. Technology and capacity needs
2.3.1. Agriculture sector
2.3.2. Energy sector
2.3.3. FOLU sector
2.3.4. IPPU sector
2.3.5. Waste sector
3. Socioeconomic Benefits
3.1. Costs and benefits of LTS4CN actions
3.2. Total economic costs and benefits
3.3. Public sector costs
3.4. Implications for investment, economic growth, gender and jobs
3.5. Adaptation and wider social and environmental benefits
3.6. Benefits of adaptation for economic growth
3.6.1. Sector adaptation co-benefits analysis
4. Governance, Measurement, Reporting and Verification
4.1. Governance structure
4.2. MRV indicators and tracking
4.2.1. MRV framework
4.2.2. Reporting responsibility

(iii) GHG Emissions Characteristics

The Long-Term Strategy for Carbon Neutrality for Cambodia does not include detailed data on current GHG emissions, but provides information in the form of long-term projections.

As of 2020, forestry and other land use (FOLU) will account for a large share of GHG emissions, but GHG emissions from energy use, such as electricity, are expected to grow significantly in the future. In addition, agriculture is expected to account for the next largest share of FOLU emissions in 2020, but the absolute amount of emissions from agriculture is expected to remain almost flat.

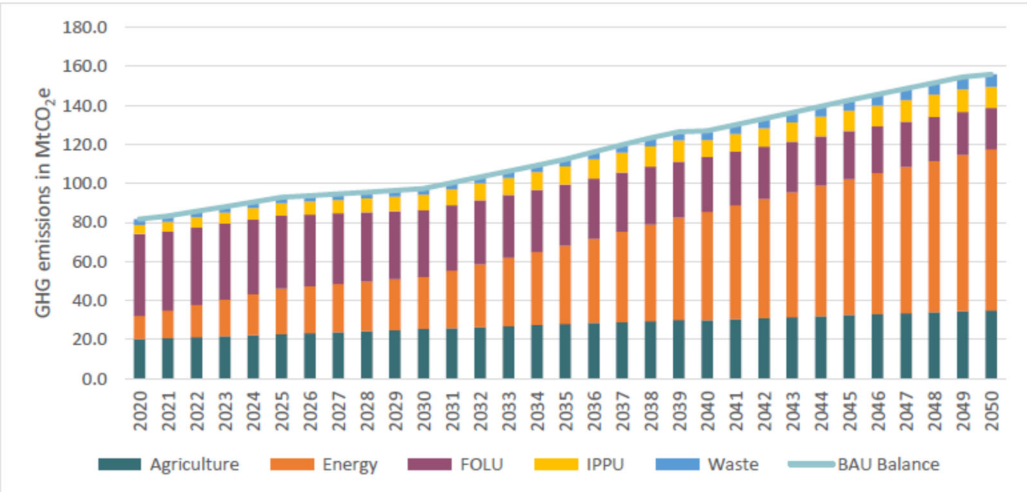


Figure 24Cambodia's GHG Emissions by Sector

Source: Kingdom of Cambodia Nation-Religion-King (2021), "Long-Term Strategy for Carbon Neutrality"

(iv) Characteristics of Mitigation Measures

Cambodia's long-term strategy outlines the following measures as mitigation measures

Table 49 Mitigation measures outlined in Cambodia's long-term strategy

agriculture	・ Utilization of rice varieties with low methane intensity ・ Direct seeding practices

	• Alternate Wetting and Drying • Promote organic fertilizers and deep fertilizer technology (Use of feed additives for cattle (to control methane production) • Improved feed management • Introduction of composting technology
Forestry and Other Land Use (FOLU)	• Reduce deforestation rate by 50% by 2030 • Stop deforestation by 2045 • Afforestation, improved forest management, reforestation • Agroforestry, commercial afforestation • Full implementation of investment plan for REDD+ by 2050
energy	• Prohibit construction of new coal-fired power plants, except for existing projects • Natural gas as a transition fuel with adjustable output • Investments in LNG imports, storage, and infrastructure • Increase solar, hydro, biomass, and other renewables to 35% by 2050, 12% of which will be solar • Investments in power grid modernization, flexibility, and storage • Energy efficiency measures in buildings and industry • Conversion of cooking fuels to electricity • Coal Substitution in the Industrial and Power Sectors
traffic	• Expand use of public transportation Increase modal share in urban areas to 30% by 2050 • Moderate penetration of electric vehicles 70% for motorcycles and 40% for cars and city buses by 2050 • Improved fuel efficiency of internal combustion engine vehicles • Railroads for freight and passenger transport • 80% compressed natural gas (CNG) penetration in interregional buses and 80% in trucks by 2050
Use of industrial processes and products	• Clinker substitution in cement production • Carbon capture and storage in cement kilns • Use of recycled aggregate concrete • Expand use of refrigerants with low global warming potential • Periodic inspections of refrigeration and air conditioning equipment, and recycling of used refrigerant
waste	• Increase trash collection rate to 85% by 2050 and reduce wildland fires • Implement reduce, reuse, and recycle strategies • Landfill Gas Management • Organic composting • Anaerobic Digestion and Wastewater Treatment

Source: Kingdom of Cambodia Nation-Religion-King (2021), "Long-Term Strategy for Carbon Neutrality"

Table 50 NDC and Long-Term Strategy Submission Status

Country		NDC				Long-term strategy
		INDC	First NDC	First NEC Revision	Second NDC	
High income	EU	○	○	○		
	U.S.	○	○			
	China	○	○			
	Indonesia	○	○			

Upper middle income	Thailand	○	○			
	Peru	○	○			
	South Africa	○	○			○
Lower middle income	India	○	○			
	Morocco	○	○			
	Egypt	○	○			
	Cambodia	○	○	○		
	Bangladesh	○	○	○		
	The Philippines	○				
	Myanmar	○	○			
	Vietnam	○	○	○		
	Laos	○	○			
Low income	Mozambique	○	○			

1.2 Organization of Trends in Low-carbon and Decarbonization Energy policies, Technologies, Services, Utilization and Commercialization in Major Developed/Developing Countries

For the purpose of grasping the trends of energy policies for low and decarbonization in major developed countries and developing countries, we conducted a study such as long-term energy policies, renewable energy policies, and energy efficiency policies of each 17 countries studied.

Table 51 17 Countries Studied (by Income Group)

High income	Upper-middle income	Lower-middle income	Low income
EU (*) United States China	Indonesia Thailand Peru South Arica	India Egypt Cambodia Bangladesh Philippines Viet Nam Myanmar Morocco Lao PDR	Mozambique

(*) Policies and plans by the European Commission, not by country.

Regarding the selection of countries to be studied, for major developed countries, the EU, which has set out advanced energy policies for low-carbon and decarbonization and is leading the discussion in global climate change negotiations, the United States and China, which account for a large proportion of global GHG emissions, were selected. For developing countries, the selection was made according to the following procedure.

【Target country selection process (developing countries)】

(1) Extract countries of the ranks that can be supported by JICA from the classification by income class of the World Bank.
(2) Each country is classified into 4 quadrants according to the low carbon intensity of energy consumption and the energy efficiency.
(3) Select the target country in consideration of various conditions in addition to the balance of income class and 4 quadrants.

(1) Extract countries of the ranks that can be supported by JICA from the classification by income class of the World Bank

First, from the World Bank's classification by income class, the countries of the class (Upper-middle income, Lower-middle income, Low income) that could be supported by JICA were extracted. However, countries without IEA data for "renewable energy ratio in power generation" and "energy intensity" used in the next process were excluded at this point.

Table 52 World Bank Income Class Classification (including countries with IEA data)

Upper-middle income		Lower-middle income		Low income
4,046 - 12,535		1,036 - 4,045		< 1,036
Costa Rica	Indonesia	Sri Lanka	Congo, Rep.	South Sudan
Venezuela	China	Angola	Kenya	Yemen
Dominican Republic	North Macedonia	Ghana	Tanzania	Eritrea
Cuba	Armenia	Philippines	Cambodia	Sudan
Peru	Malaysia	El Salvador	Mongolia	Tajikistan
Colombia	Azerbaijan	Bangladesh	Moldova	Niger
Argentina	Georgia	Morocco	Uzbekistan	Korea, Dem. People's Rep.
Ecuador	Thailand	Senegal	Zambia	Haiti
Mexico	Iraq	Bolivia	Zimbabwe	Ethiopia
Turkey	Bulgaria	Côte d'Ivoire	Benin	Mozambique
Brazil	Gabon	Egypt	Nepal	Syrian Arab Republic
Lebanon	Serbia	Tunisia	Kyrgyz Republic	Togo
Botswana	Kosovo	Honduras	Ukraine	Congo, Dem. Rep.
Namibia	Kazakhstan	Cameroon		
Paraguay	South Africa	Nicaragua		
Albania	Bosnia and Herzegovina	Nigeria		
Jamaica	Belarus	Lao PDR		
Suriname	Libya	Myanmar		
Guatemala	Russian Federation	Algeria		
Jordan	Iran	Pakistan		
Equatorial Guinea	Turkmenistan	India		
Montenegro		Vietnam		

Source: World bank, GNI per capita / IEA, IEA World Energy Balances

(2) Each country is classified into 4 quadrants according to the low carbon intensity of energy consumption and the energy efficiency

Next, in order to understand the characteristics of energy consumption in each country, each country was classified into four quadrants according to the carbon intensity of energy consumption (renewable energy ratio in the total power generation) and the energy (energy intensity). Figure 25). Figure 26 shows the distribution of each country in four quadrants by income group.

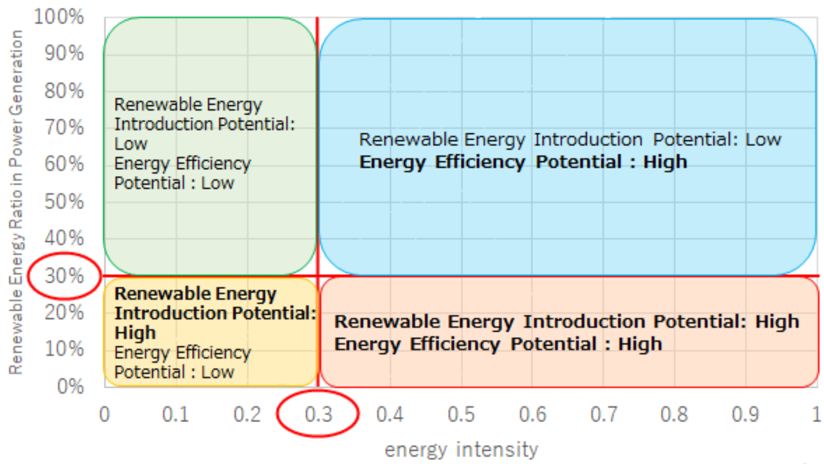


Figure 25 4-quadrant classification based on renewable energy ratio and energy intensity in total power generation

Note: The reference values for dividing the quadrants (renewable energy ratio of 30% in power generation, energy intensity 0.3) were set with reference to the average value of non-OECD countries and the median value of countries.
Source: JICA Study Team

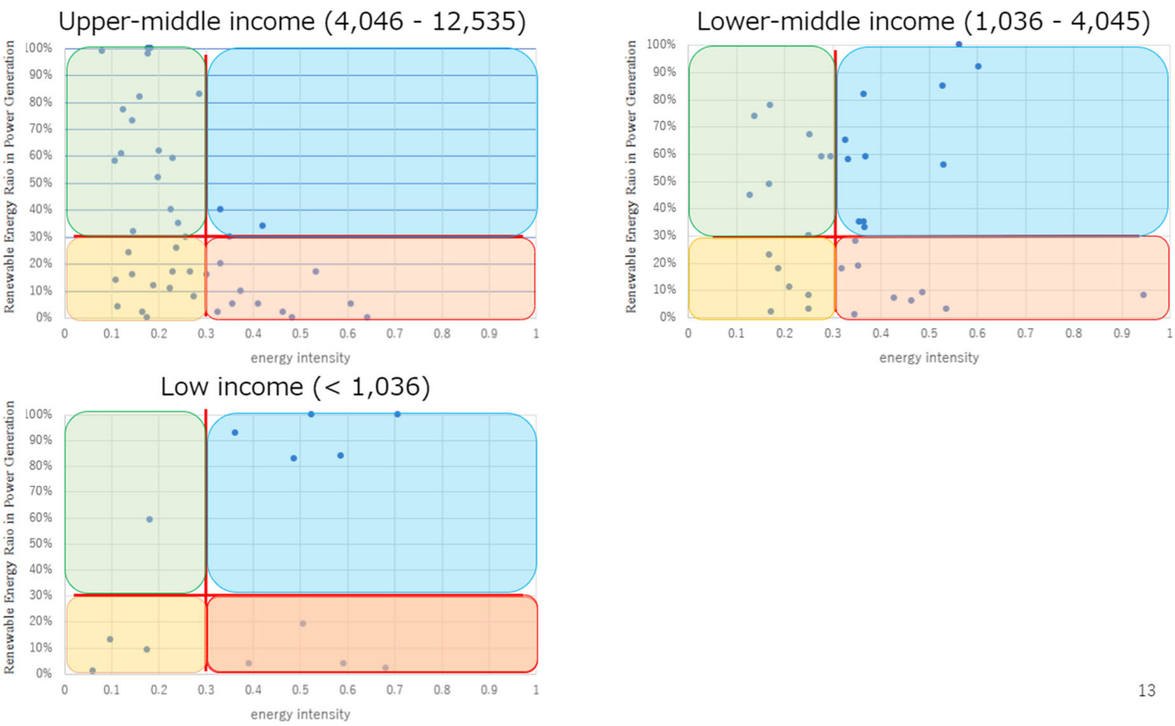


Figure 26　4-quadrant distribution by income group

Source; Author

(3) Select the target country in consideration of various conditions in addition to the balance of income class and 4 quadrants.

The selection of target countries was based on a well-balanced selection from the three income groups and four quadrants shown in Figure 26 in order to broadly understand trends in global energy policies toward low carbonization and decarbonization. In addition, the following points were also taken into consideration when selecting.

- Region to which the target country locates
- Priority of support
- Current status of energy supply and demand in each country
- Population

Regarding the regions to which the target countries locate, consideration was given so that the regional breakdown of the target countries studied would not be overly biased.

Regarding the priority of support, the existence of energy policy dialogue in bilateral relations with Japan and the past study and support results in this area by JICA were taken into consideration.

Regarding the current situation of energy supply and demand in each country, countries with extremely low potential for introducing renewable energy, such as countries where the ratio of renewable energy in electricity supply is close to 100% at present, are excluded from the target.

Regarding the population, in this study, in countries with high potential for low carbonization and decarbonization, the market size is considered which is above a certain level, in order to consider the formulation of a cooperation program (draft) and the implementation of pilot projects that can utilize the products or services of Japanese companies.

Table 53 Arrangement of selection criteria for developing countries (14 countries)

Country	Classification by income class	Res. ratio in total Power generation	Energy intensity	Others
Indonesia	Upper-middle income	17%	0.231	・Bilateral energy cooperation ・Environment policy dialogue ・Renewable energy study (JICA 2019)
Thailand		16%	0.302	・Bilateral energy cooperation (Energy policy dialog) ・Environment policy dialogue
Peru		61%	0.121	
South Africa		5%	0.412	
India	Lower-middle income	19%	0.353	・Bilateral energy cooperation ・Environment policy dialogue ・Renewable energy study (JICA 2019)
Egypt		8%	0.251	・Renewable energy study (JICA 2019)
Cambodia		59%	0.369	・Renewable energy study (JICA 2019)
Bangladesh		2%	0.173	・Bilateral energy cooperation ・Renewable energy study (JICA 2019)
Philippines		23%	0.169	・Environment policy dialogue ・Renewable energy study (JICA 2019)
Viet Nam		35%	0.356	・Bilateral energy cooperation ・Environment policy dialogue
Myanmar		58%	0.333	・Environment policy dialogue ・Renewable energy study (JICA 2019)
Morocco		18%	0.188	
Lao PDR		65%	0.328	
Mozambique	Low income	84%	0.587	・Bilateral energy cooperation

Note: "Bilateral energy cooperation" refers to countries where bilateral cooperation has been taken up in recent years in the "Energy White Paper" issued by the Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry.

1.2.1 Low-carbon and decarbonized energy policies and long-term energy plans in major developed/developing countries

(1) EU

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

Fossil fuels account for about 70% of the primary energy supply mix in the EU, with coal (12%), oil (33%), and natural gas (24%), but the share of renewable energy has gradually increased since 2000, rising from 1% in 1990 to 8% in 2019. The region has oil and natural gas reserves, mainly in the North Sea, and natural gas imports from Russia through pipelines also support the energy supply of the member states. The share of renewable energy is also increasing rapidly in the electricity generation mix, from 1% in 1990 to 24% in 2019. Fossil fuels account for 39% of the power source mix, which is large compared to other energy sources, but the EU as a whole can be said to have a well-balanced mix that is not heavily dependent on any particular power source.

The EU has set medium- and long-term goals for 2020, 2030, and 2050, but the authority to determine the energy mix (energy policy) rests with the member states. Therefore, it should be noted that the primary energy supply mix and the electricity generation mix differ significantly among the member states.

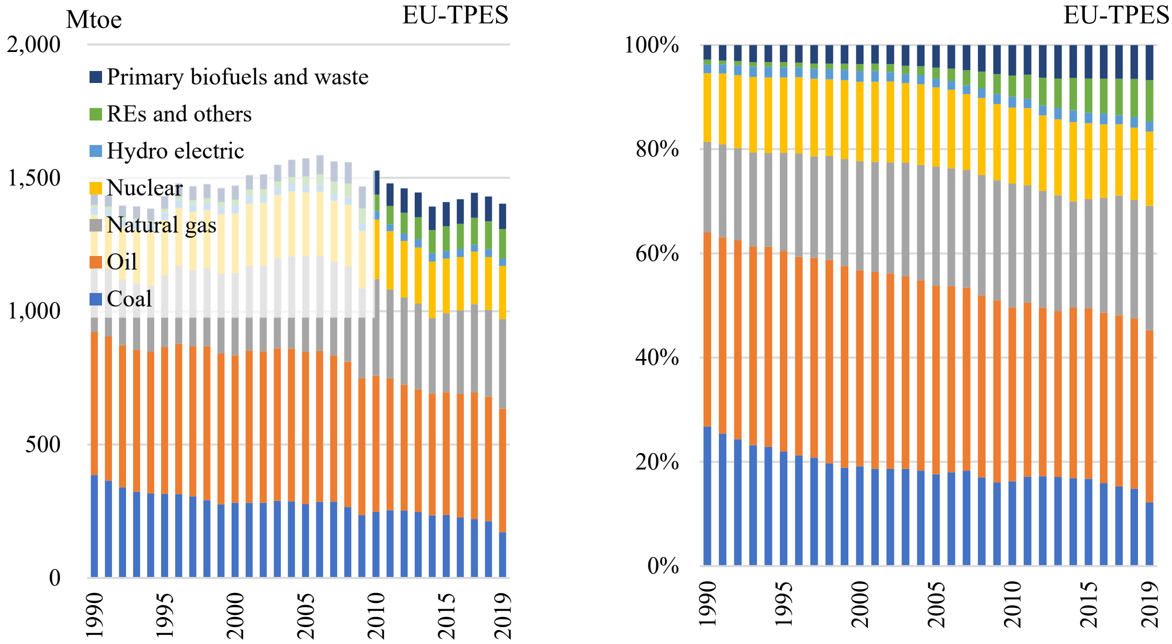


Figure 27 Primary Energy Supply in EU

Source: World Energy Balances 2021 extended edition database, IEA

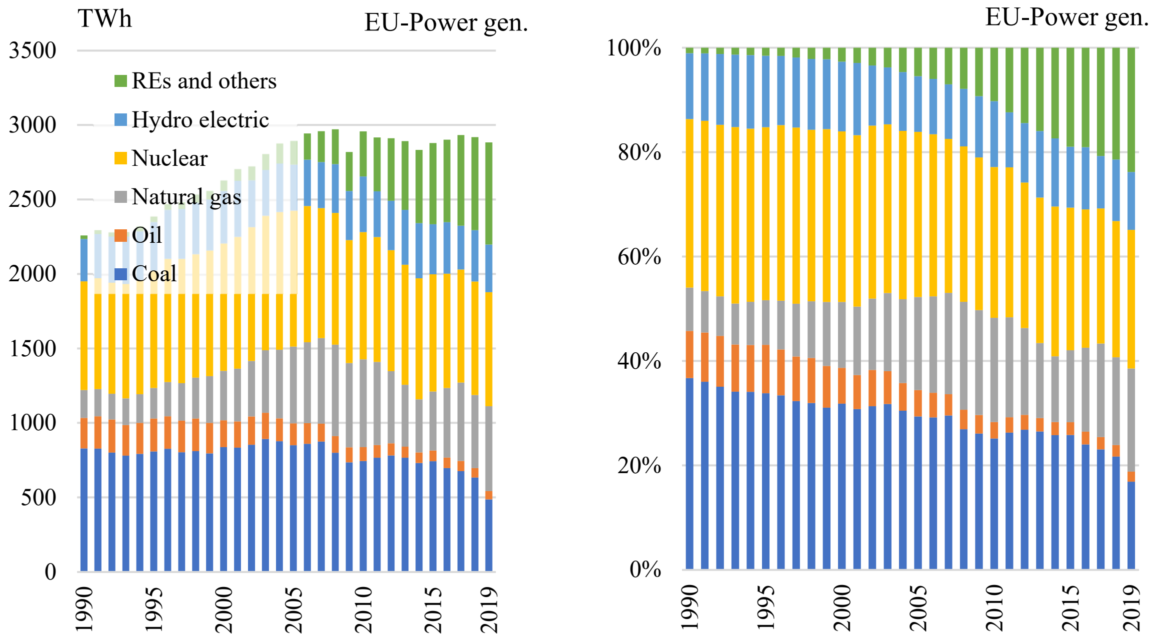


Figure 28 Fuel Mix of Electricity Generation in EU

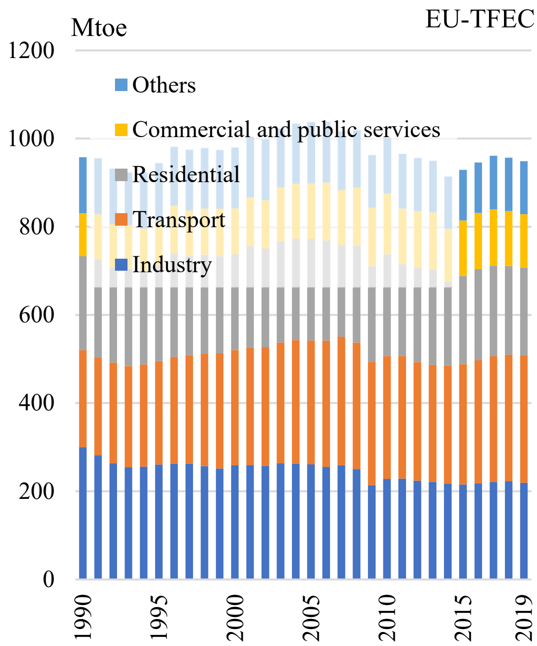
Source: World Energy Balances 2021 extended edition database, IEA

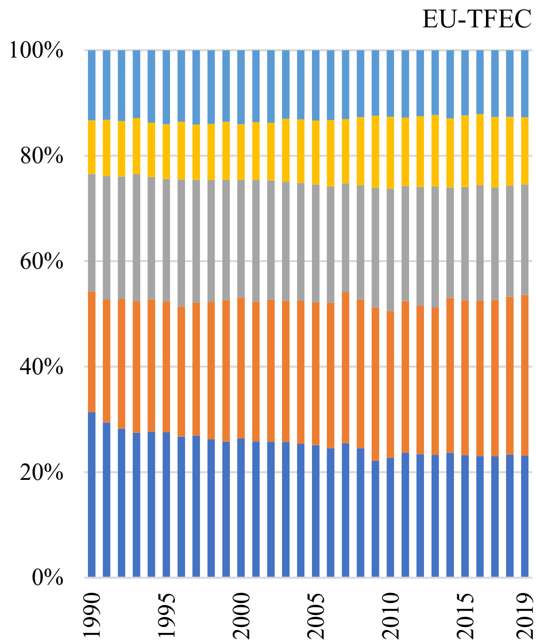
A breakdown of final energy consumption by sector shows the percentage of the transportation sector becoming larger in 2019, with the industry sector accounting for 23%, transportation 31%, residential 21%, and commercial/public services 13%. As for the average annual change from 2013 to 2019, the transportation sector had it the largest at 1.5%.

In the industrial sector, manufacturing accounts for about 90% of final energy consumption, with chemicals and petrochemicals taking up a particularly high share (23.7%, 2019). As of 1990, steel accounted for the second largest share of manufacturing (20.3%) after chemicals and petrochemicals, but by 2019 it had dropped to 11.9%, overtaken by non-metallic minerals and pulp and paper. Looking at final energy consumption in the industrial sector by energy source, electricity accounts for the largest share (37%) followed by natural gas (34%) as of 2019. Electricity exceeded natural gas in 2006, for the first time since 1990. The use of oil and coal is declining, with the share of renewable energy surpassing that of coal in 2018.

In the transportation sector, petroleum accounts for more than 90%, and road (automobile) use accounts for 93.4% of energy consumption in the transportation sector (2019). The prevalence of diesel vehicles is particularly high in Europe. Additionally, in the EU, the use of alternative fuels such as biodiesel has increased rapidly since 2005, accounting for 5.5% as of 2019. Although there are positive indications of efforts to introduce electric vehicles in order to lower the carbon footprint of the transportation sector, electricity accounts for only 2% as of 2019.

Natural gas demand remains high in the residential and commercial/public service sectors, with 40% and 30% (2019), respectively, as oil demand is being replaced by natural gas for heating applications. In the commercial/public services sector, electricity is ahead of natural gas at 52% (2019).





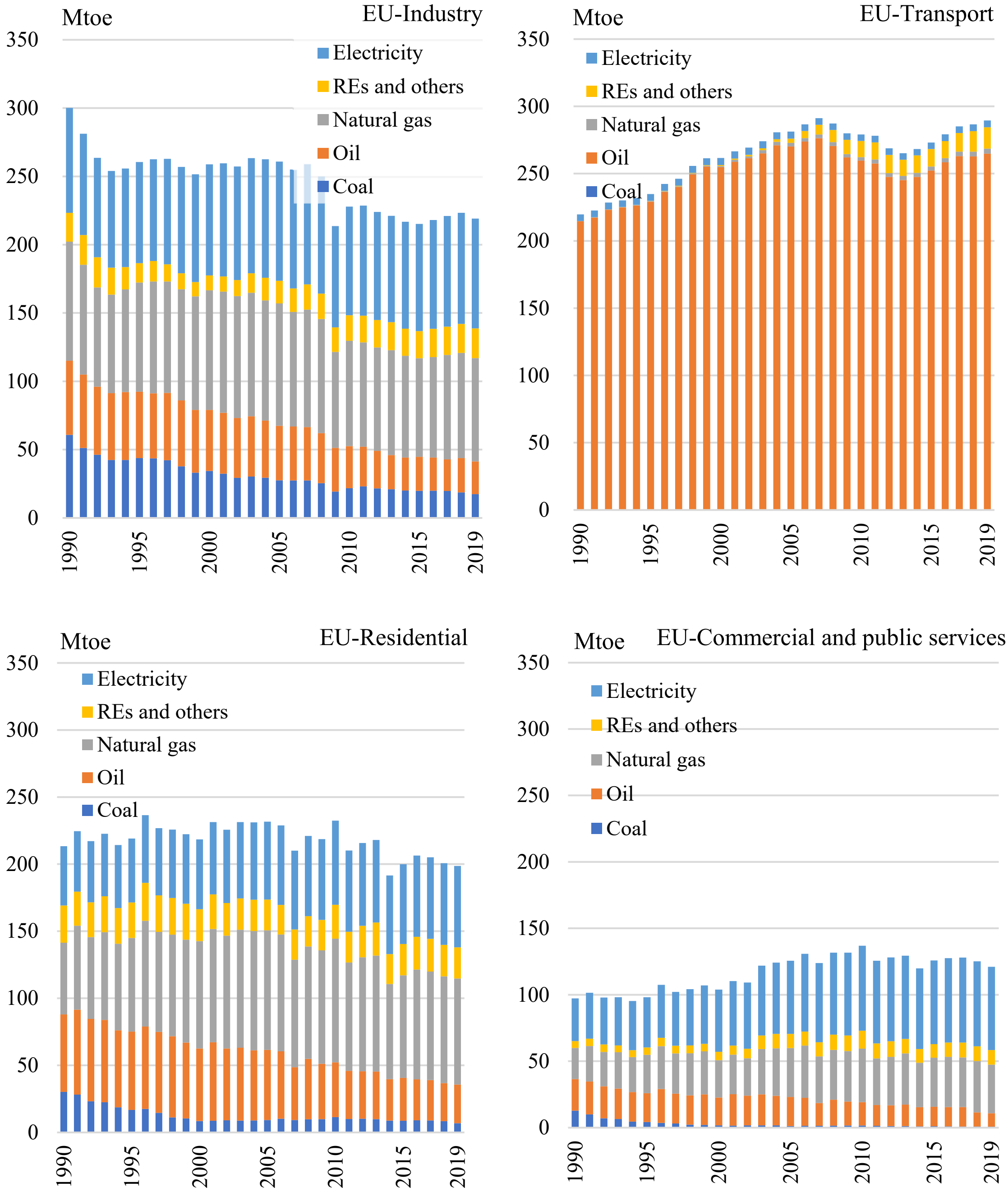


Figure 29　Final Energy Consumption of Major Sectors in EU

Excludes "Primary solid biofuels," "Non-specified primary biofuels and waste," and "Charcoal."
"Others" in TFEC includes agriculture, forestry, fisheries, other, and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP has been slightly decreasing since 1990, reaching 0.095 toe/$1,000 (2015 prices) in 2019 (0.090 in Japan). It can be said that improvements in energy efficiency have been gradually progressed.

The thermal efficiency of coal-fired power in the EU is hovering around 37-39%, and member states that use coal-fired power are working to increase the efficiency of low-efficiency coal-fired power plants. The thermal efficiency of gas-fired power generation has exceeded 50% since the mid-2000s, and very efficient natural gas-fired power generation is being used.

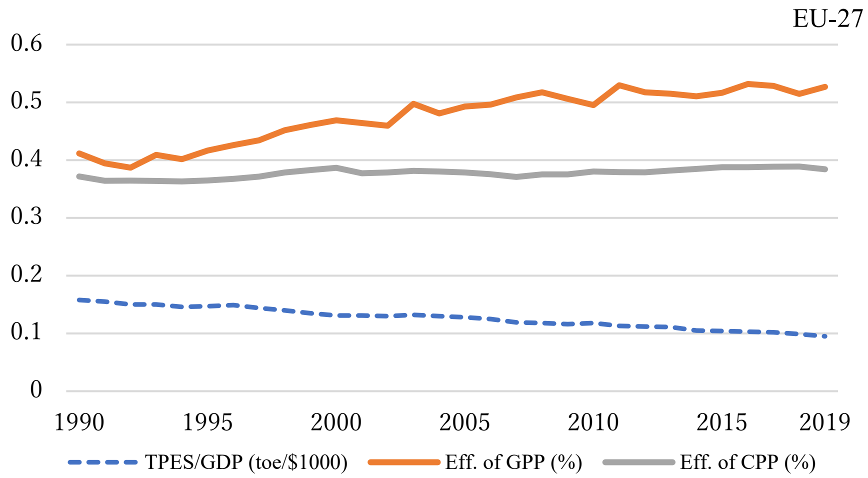


Figure 30　Energy Efficiency in EU

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant, CPP = coal power plant
GDP in 2015 price
Source: World Energy Balances 2021 extended edition database, IEA

(2) Primary energy mix and electricity mix planning

According to the IEA's World Energy Outlook 2021 (released in October 2021: Stated Policies Scenario), energy demand in the 27 EU states is expected to grow at a negative rate of -0.7%/year from 2020 over to 2050, becoming 1,078 Mtoe in 2050. By energy source, the share of coal, oil, natural gas, and nuclear power is expected to decrease, while the share of renewable energy is expected to increase significantly.

Table 54　Energy Demand Outlook in EU (Stated Policies Scenario)

(Unit: Mtoe)

	2020	2030	2035	2040	2045	2050
Coal	143	67	45	37	35	33
Oil	423	349	293	247	212	188
Natural gas	326	318	297	279	261	242
Nuclear	178	154	135	133	133	135
Hydro	30	33	34	34	35	36
Solar	17	46	55	60	64	66
Wind	34	69	91	103	110	113
Bioenergy	164	200	210	218	227	235
Other Renewables	7	11	15	19	23	26
Total	1,326	1,251	1,179	1,134	1,102	1,078

Source: World Energy Outlook 2021, IEA

According to the IEA's World Energy Outlook 2021 (released in October 2021: Stated Policies Scenario), total electricity generation in the 27 EU states is expected to grow at a rate of 0.9%/year through 2050, reaching 3,577 TWh in 2050. The potential for offshore wind power is particularly high, with wind power expected to grow at a remarkable rate (4.2%/year).

Table 55　Electricity Generation Outlooking EU-27 (Stated Policies Scenario)

(Unit: TWh)

	2020	2030	2035	2040	2045	2050
Unabated coal	386	110	35	16	17	15
Oil	47	19	14	8	5	5
Unabated natural gas	556	534	456	427	391	356
Nuclear	681	592	519	509	509	519
Hydro	347	381	391	399	408	417
Solar	142	421	495	523	533	541
Wind	398	844	1,108	1,248	1,323	1,365
Bioenergy	182	222	234	243	253	260
Other Renewables	12	21	36	57	78	98
Hydrogen and ammonia	0	0	0	0	0	0
Fossil fuels with CCUS	0	0	0	0	0	0
Total	2,757	3,145	3,289	3,432	3,520	3,577

Source: World Energy Outlook 2021, IEA

(b) Electric utility system

(1) Electricity supply system

In the electricity sector, the EU Electricity Directive and its amendments from 1996 to 2009 promoted electricity liberalization. The 1996 Directive mandated retail market liberalization for large consumers and accounting separation of generation, transmission, and distribution for vertically integrated companies. In 2003, it was mandated that the retail market be fully liberalized by 2007 and that the transmission and distribution sectors be legally separated. In 2009, member states were to choose from three options for unbundling (full ownership separation, ISO, or ITO). In June 2009, it was decided to establish the Agency for Co-operation of Energy Regulators (ACER) to further promote the reform toward energy market liberalization. Since then, efforts to integrate markets within the EU have progressed, and under the new "Electricity Market Regulation" that entered into force in August 2015, a comprehensive legal framework for electricity trading within Europe was established, making intra-regional market integration legally binding.

With the aim of ensuring that the energy system is able to accommodate an increased share of renewable energy, amendments to the Electricity Regulation, amendments to the Electricity Directive, amendments to the ACER Regulation, and new draft regulations on addressing risks in the energy sector have been proposed, and all the amended regulations and directives entered into force in May 2019.[12]

(2) Renewable electricity supply system

Within the electricity supply system based on the above-mentioned electricity regulations and electricity directives, each member state has established its own renewable energy electricity supply system.

(c) Policy on renewable energy

(1) Potential of renewable energy

In the EU region, wind conditions are very favorable in the northern offshore areas, mainly in the North Sea, the Baltic Sea, and the Norwegian Sea, and offshore wind power generation is expected to have a high potential among wind power generation. Note that, in 2019, onshore wind power had an installed capacity of 169,277 MW and generated 359,474 GWh of electricity, while offshore wind power had an installed capacity of 22,028 MW and generated 58,485 GWh of

12 European Commission, Commission publishes new market design rules proposal, 2016-12-1.

electricity.[13]

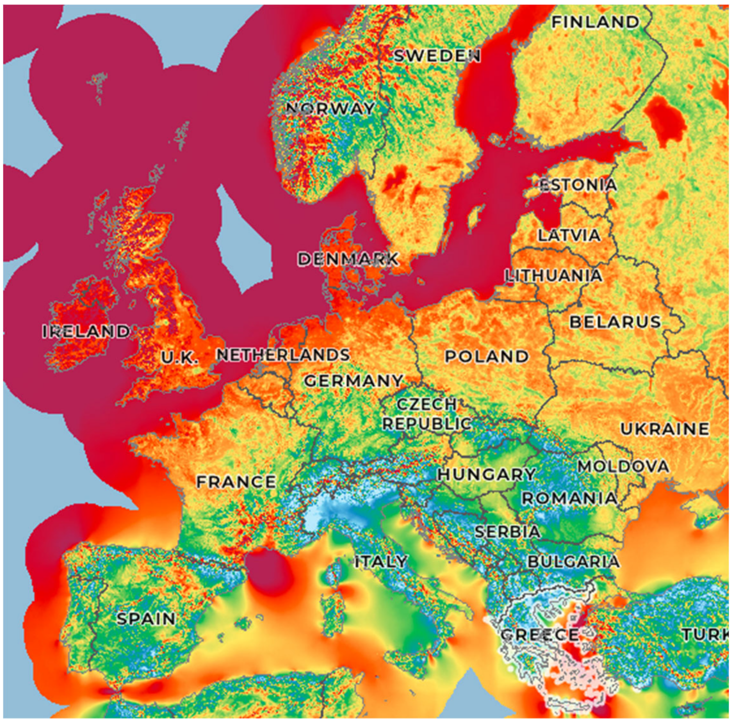


Figure 31　Wind Power Generation Potential in EU

Note: The mean wind speeds shown are the representative values at the elevation of 50 m. Red color indicates the fastest wind speed.

Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The Directorate-General for Energy of the European Commission has jurisdiction over the Commission's energy policy, including renewable energy. DG Energy is responsible for energy as well as climate action and environmental policies. Meanwhile, the European Commission's Directorate-General for Climate Action has jurisdiction over policies related to climate action and the environment.

(3) Development targets

The EU adopted the European Climate Law in June 2021, which includes legally binding targets of climate neutrality (net zero greenhouse gas emissions) by 2050 and at least a 55% reduction in net greenhouse gas emissions (from 1990 levels) by 2030. As part of the Fit for 55 package (policy package toward the 55% reduction), the EU-ETS Directive, the Renewable Energy Directive, and amendments to the Energy Efficiency Directive have been proposed. The revision of the Renewable Energy Directive proposes to increase the share of renewable energy in EU-wide final energy consumption to at least 40% by 2030.[14] Note that the current Revised Renewable Energy Directive, which entered into force in December 2018, sets a renewable energy target of 32% by 2030 (a binding target) and includes a review clause until 2023 to revise the new target upward.[15]

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[13] IRENA (2021) "Renewable Energy Statistics 2021".

[14] European Commission, European Green Deal: Commission proposes transformation of EU economy and society to meet climate ambitions, 2021-7-14, <https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541>.

[15] European Commission, Europe leads the global clean energy transition: Commission welcomes ambitious agreement on further renewable energy development in the EU, 2018-6-14, <http://europa.eu/rapid/press-release_STATEMENT-18-

As part of the European Green Deal, the European Commission presented the EU Offshore Renewable Energy Strategy in November 2020. The Strategy proposed to increase Europe's offshore wind power capacity from the current 12 GW to more than 60 GW by 2030 and 300 GW by 2050. To complement this, the European Commission aims to introduce other emerging technologies such as 40 GW of ocean energy and floating offshore wind and solar power by 2050.[16]

(4) Introduction promotion policy

Based on the Renewable Energy Directive, each member state has set its own targets for the introduction of renewable energy and has developed measures to support the introduction (RPS, feed-in tariffs, etc.).

The EU established priority feeding of renewable energy in the Renewable Energy Directive of 2001, and some member states have introduced the system. The Internal Electricity Market Regulation, which entered into force in May 2019, stipulates that renewable electricity from small generation facilities should be eligible for priority feed-in.[17]

In September 2020, the European Commission published the implementing rules for the new EU Renewable Energy Financing Mechanism, which will apply in early 2021. The Mechanism will make it easier for member states to work together to finance and deploy renewable energy projects, either as a hosting or contributing state. Energy generated counts toward the renewable energy goals of all participating states.[18]

(d) Energy conservation policy

(1) Institutions in charge of policy

DG Energy of the European Commission has jurisdiction over the Commission's energy policy, including energy conservation. DG Energy is responsible for energy as well as climate action and environmental policies.

(2) Targets

The Energy Efficiency Directive[19] entered into force in December 2012, and under Article 3 of the Directive, member states are obligated to submit their national energy efficiency targets to the European Commission.[20] The revised Energy Efficiency Directive came into effect in December 2018 and the new energy efficiency target for 2030 is 32.5%, including a review clause (upward revision) until 2023.[21] Based on the revised Directive, each member state has developed its own energy efficiency targets. The draft revised Energy Efficiency Directive included in the Fit for 55 package proposes energy efficiency targets of 36% for final energy consumption and 39% for primary energy consumption.[22]

4155_en.htm>.

16 European Commission, Boosting Offshore Renewable Energy for a Climate Neutral Europe, 2020-11-19, <https://ec.europa.eu/commission/presscorner/detail/en/IP_20_2096>.

17 Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity.

18 European Commission, European Green Deal: New financing mechanism to boost renewable energy, 2020-9-17, <https://ec.europa.eu/info/news/european-green-deal-new-financing-mechanism-boost-renewable-energy-2020-sep-17_en>.

19 The draft directive was published on 22 June 2011 and was informally agreed between the EU Council and the European Parliament on 14 June 2012. The Directive establishes a common framework for promoting energy efficiency within the EU to achieve the key goal of improving energy efficiency by 20% by 2020 and to pave the way for further improvements thereafter. Each member country is obliged to specify energy conservation targets based on either primary or final energy consumption, domestic primary or final energy savings, or energy intensity.

20 European Commission, Energy Efficiency, Energy Efficiency Directive.

21 European Commission, Energy efficiency first: Commission welcomes agreement on energy efficiency, 2018-6-19, <http://europa.eu/rapid/press-release_STATEMENT-18-3997_en.htm>.

22 European Commission, European Green Deal: Commission proposes transformation of EU economy and society to meet

(3) Promotion policy

For the private and commercial sectors, the 2012 Energy Efficiency Directive provides for the promotion of renovation of public buildings, obligating member states to renovate every year at least 3% of the gross floor area of buildings owned and occupied by the central government.

In addition, the Directive on the Energy Performance of Buildings was recast in 2009, adding new regulations such as “to bring the energy balance of new buildings constructed after 2021 to nearly zero” and “to use renewable energy for the majority of energy consumed,” and removing the restriction of “floor space of 1,000 m^2 or more.” The Directive was recast again in 2018, requiring the following items to be incorporated into the legislation in member states: formulation of long-term renovation strategies; improvement of access to finance for building renovations and linking between finance and renovation quality; transparency and comparability in the calculation of energy performance; improvement of collection, monitoring and inspection of data on conformity to standards; and requirements for the deployment of electric mobility infrastructure.[23]

Furthermore, in October 2020, the European Commission published the Renovation Wave Strategy to improve the energy performance of buildings. The Strategy aims to at least double the retrofit rate over the next decade to ensure that retrofits lead to greater energy and resource efficiency.[24]

For household appliances, the Ecodesign Directive provides the framework for rules establishing minimum ecodesign requirements (e.g., maximum annual energy consumption) for energy-related products distributed on the EU market. In addition, the Energy Labeling Framework Regulation specifies rules for setting energy labeling requirements for energy-related products. Specific requirements are set forth in the implementing rules adopted by the Commission.[25]

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

In October 2014, the European Council agreed on the 2030 Climate and Energy Framework,[26] which includes the following targets for the EU: a 40% reduction in greenhouse gas emissions from 1990 levels (binding), an increase in the EU-wide renewable energy share to at least 27% (binding), energy efficiency improvements of at least 27%, or 30% by 2030, and to complete the internal energy market and set a target of 15% for electricity interconnection among member states.[27] All eight decrees proposed in November 2016 under the name of “Clean Energy for All Europeans” were passed by May 2019, and the renewable energy percentage target for 2030 was revised upward to at least 32% and the energy efficiency target to at least 32.5%.[28] In September 2020, the European Commission announced plans to reduce EU's greenhouse gas emissions by at least 55% from 1990 levels by 2030.[29] In December of the same year, the European Council agreed to raise the greenhouse gas emissions target for 2030.[30] In June 2021, the EU adopted the European Climate Law, which includes legally binding targets of climate neutrality (net zero

climate ambitions, 2021-7-14, <https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541>.

23 IEA (2020), “European Union 2020 Energy Policy Review”, pp.100-101.

24 European Commission, Renovation Wave: doubling the renovation rate to cut emissions, boost recovery and reduce energy poverty, 2020-10-14, <https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1835>.

25 IEA (2020), “European Union 2020 Energy Policy Review”, p.107.

26 European Council, 23 and 24 October 2014, <http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf>.

27 European Commission, Energy and climate goals for 2030, <http://ec.europa.eu/energy/2030_en.htm>.

28 European Commission, 2030 climate & energy framework, <https://ec.europa.eu/clima/policies/strategies/2030_en>.

29 European Commission, State of the Union: Commission raises climate ambition and proposes 55% cut in emissions by 2030, 2020-9-17, <https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1599>.

30 European Council, European Council meeting (10 and 11 December 2020) – Conclusions, 2020-12-11, <https://www.consilium.europa.eu/media/47296/1011-12-20-euco-conclusions-en.pdf>.

greenhouse gas emissions) by 2050 and at least a 55% reduction in net greenhouse gas emissions (from 1990 levels) by 2030.

(2) Promotion policy

Efforts to reduce greenhouse gas emissions in the EU can be divided into two areas. One is the area covered by the EU Emission Trading System (EU-ETS) (power plants, industrial facilities, and airline operators operating flights to and from airports in the EEA), and the other is the national emissions target for each year for each member state, which is set based on each state's GDP and other factors under the Effort Sharing Decision (until 2020) and the Effort Sharing Regulation (until 2030).

The EU-ETS was officially launched in January 2005 and is divided into phases: first period (2005-2007), second period (2008-2012), third period (2013-2020), and fourth period (2021-2030).

Since 2009, a surplus of emission credits had been building up in the EU-ETS, mainly due to the economic crisis and the increase of international credit imports. In October 2015, the European Parliament and the Council of the European Union adopted a decision on the introduction of the Market Stability Reserve (MSR),[31] whereby the 900 million tons of emission credits left over from the 2014-2016 period will be transferred to the reserve, as well as those that were not assigned.[32] In April 2018, the revised EU-ETS Directive entered into force,[33] applicable for the period 2021-2030, and MSR will also be implemented under the Directive.

In addition, taxonomies for green growth have been discussed in recent years. In June 2020, the EU Taxonomy Regulation came into force, giving the European Commission the power to adopt technical screening criteria to define sustainable economic activities that contribute to one of six environmental objectives, including climate change mitigation (reduction) and climate change adaptation, and do not cause significant harm to other environmental objectives (Do No Significant Harm). In February 2022, the Commission issued a draft delegated act classifying nuclear power and natural gas as sustainable under certain conditions. In July 2022, the delegated act was published in the Official Journal and will apply as of January 2023. The following table shows overview of the technical screening criterion for nuclear and fossil gaseous-related activities. Note that nuclear-related activities covers pre-commercial stages of advanced technologies, construction and safe operation of new nuclear installations, (the construction permit issued by 2045), and modification of existing installations (approval for extension issued by 2040). Fossil gaseous-related activities include power generation, high-efficiency cogeneration, and heat production, but the table below describes only the technical screening criteria for power generation from fossil gaseous fuels.

Table 56 Overview of technical screening criteria for nuclear-related and fossil gaseous-related activities

Nuclear-related activity	Fossil gaseous-related activity (Electricity generation)
- Life cycle GHG emissions are below the threshold of 100 gCO2e/kWh - Compliance with the Euratom Treaty and with related legislation adopted on its basis - Establish a radioactive waste management fund and a nuclear decommissioning fund as	(a) Life cycle GHG emissions are below the threshold of 100 gCO2e/kWh (b) facilities for which the construction permit is granted by 31 December 2030 comply with all of the following:

[31] Decision (EU) 2015/1814 of the European Parliament and of the Council of 6 October 2015 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and amending Directive 2003/87/EC.

[32] European Commission, Market Stability Reserve, <https://ec.europa.eu/clima/policies/ets/reform_en>.

[33] European Commission, Revision for phase 4 (2021-2030), <https://ec.europa.eu/clima/policies/ets/revision_en>.

of the approval date of the project - Demonstrate the expected availability of funds for radioactive waste management and decommissioning at the end of operation - Have operational final disposal facilities for all very low, low, and intermediate level radioactive waste - Have a documented plan with detailed steps to operate a disposal facility for high-level radioactive waste by 2050 - Use accident-tolerant fuel (ATF) from 2025 (new construction and modification of existing installations)	(i) direct GHG emissions of the activity are lower than 270g CO2e/kWh of the output energy, or annual direct GHG emissions of the activity do not exceed an average of 550kgCO2e/kW of the facility's capacity over 20 years; (ii) the power to be replaced cannot be generated from renewable energy sources; (iii) the activity replaces an existing high emitting electricity generation activity that uses solid or liquid fossil fuels; (iv) the newly installed production capacity does not exceed the capacity of the replaced facility by more than 15 %; (v) the facility is designed and constructed to use renewable and/or low-carbon gaseous fuels and the switch to full use of renewable and/or low-carbon gaseous fuels takes place by 31 December 2035; (vi) the replacement leads to a reduction in emissions of at least 55 % GHG over the lifetime of the newly installed production capacity; (vii) where the activity takes place on the territory of a Member State in which coal is used for energy generation, that Member State has committed to phase-out the use of energy generation from coal and has reported this in its integrated national energy and climate plan.

Source: Commission Delegated Regulation (EU) 2022/1214 of 9 March 2022

(3) Transportation

The European Green Deal aims to reduce greenhouse gas emissions from the transportation sector by 90% by 2050. To transform the transportation sector, 75% of inland transportation currently by road must be shifted to rail and one million public charging and filling stations must be installed by 2025. To help achieve these goals, the European Commission published the Sustainable and Smart Mobility Strategy in December 2020. Specific phase-in targets include "at least 30 million zero-emission cars will be in operation on European roads" by 2030, "zero-emission large aircraft will become ready for market" by 2035, and "nearly all cars, vans, buses as well as new heavy-duty vehicles will be zero-emission" by 2050.[34] The Strategy is accompanied by an action plan consisting of 82 initiatives.

The 2009 Renewable Energy Directive obligated the EU and its member states to achieve a 10% renewable energy share in the transportation sector by 2020. Furthermore, the 2018 Renewable Energy Directive obligates member states to require fuel suppliers to supply at least 14% of the energy consumed in road and rail transportation from renewable energy sources by 2030. In addition, the share of road and rail transportation final energy consumption of biofuels derived from conventional agricultural crops will be limited to a maximum of 7%. The share of

[34] European Commission, A fundamental transport transformation: Commission presents its plan for green, smart and affordable mobility, 2020-12-9, <https://ec.europa.eu/commission/presscorner/detail/en/IP_20_2329>.

advanced biofuels and biogas is targeted at 14%.

EU regulations set binding 2025 and 2030 CO_2 emissions targets for new passenger cars and new light commercial vehicles. After 2021, the average emissions target for all new vehicles will be 95 gCO_2/km, after which emissions from passenger cars and light commercial vehicles must be reduced by 15% by 2025 and 37.5% by 2030 compared to the 2021 target. For light commercial vehicles, CO_2 emissions need to be reduced by 31% by 2030. In addition, the new heavy-duty vehicle standards will require manufacturers to achieve emissions reductions of 15% from 2025 and 30% from 2030 compared to the base period (July 2019 to June 2020) as of 2025, and manufacturers that fail to meet these targets will have to pay a financial penalty in the form of an excess emissions premium. [35]

(4) Urban development

The EU has incorporated the smart city concept into its Europe 2020 economic growth plan launched in 2010 as a way to realize a low-carbon society. Then in 2011, the Smart Cities and Communities Industrial Initiative was launched and began funding demonstration projects in the transportation and energy sectors. In July 2012, the European Innovation Partnership on Smart Cities and Communities was launched as a successor initiative to the said Initiative, including the information and communication technology sector this time.[36] In addition, the Smart City Marketplace has been established as a hub of information by merging two platforms, the the "Marketplace of the European Innovation Partnership on Smart Cities and Communities" and the "Smart Cities Information System".[37]

(f) Next generation technology, innovation

(1) Introduction targets

The Fuel Cells and Hydrogen 2 Joint Undertaking (a public-private partnership comprising the European Commission, Hydrogen Europe on behalf of industry and Hydrogen Europe Research on behalf of research institutions) published in January 2019 the Hydrogen Roadmap Europe, which estimates, in an ambitious scenario, approximately 2,250 TWh of hydrogen will be produced in the EU by 2050, equivalent to 24% of the EU's final energy demand.[38]

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35 IEA (2020), "European Union 2020 Energy Policy Review", pp.83-86.

36 Delegation of the European Union to Japan, EU MAG, https://eumag.jp/issues/c0215/.

37 European Commission, Smart cities, <https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en>.

38 Fuel Cells and Hydrogen 2 Joint Undertaking, "Hydrogen Roadmap Europe".

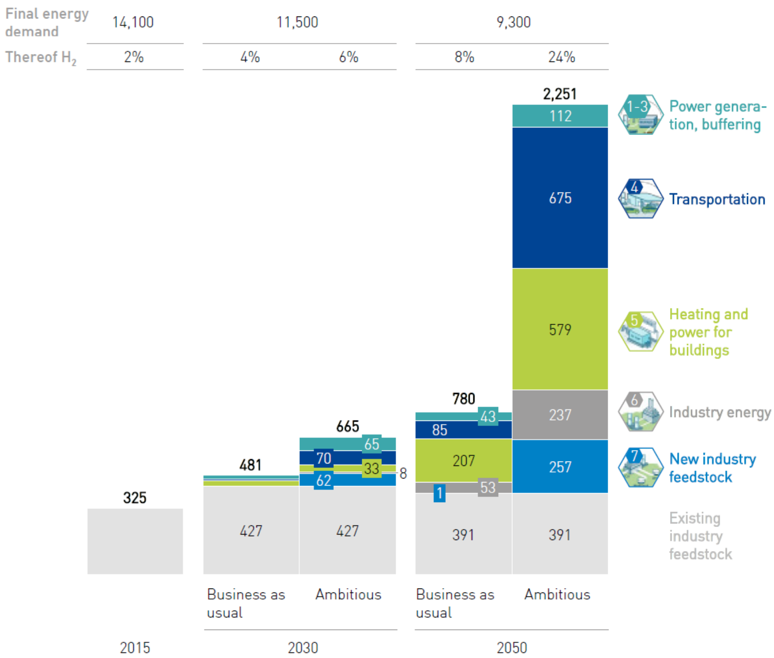

Figure 32 Outlook of Final Energy Consumption and Hydrogen Demand in EU (Unit: TWh)
Source: FCH 2 JU, Hydrogen Roadmap Europe

In July 2020, the European Commission published its Energy System Integration Strategy, presenting a vision of a smarter, more integrated, and optimized energy system that contributes to a low-carbon future for all sectors. It has three pillars: a more circular energy system, expanding the field of use of electricity derived from renewable energy sources, and promoting clean fuels.[39] The European Commission has positioned the introduction of hydrogen derived from renewable energy sources as a way to integrate sectors, and the Commission has also published a hydrogen strategy at the same time.

The EU Hydrogen Strategy noted that the EU's priority is to develop hydrogen from renewable energy sources, but low-carbon fossil fuel-derived hydrogen is also needed in the short to medium term. The Strategy presents a roadmap for building a hydrogen economy, in which the period from 2020 to 2050 is divided into three phases with the following goals.[40]

■ 2020-2024: Install at least 6 GW of renewable hydrogen electrolyzers to produce 1 million tons of hydrogen from renewable energy sources; increase production of large-scale water electrolyzers and introduce them to oil refineries and steel and chemical plants; decarbonize existing hydrogen production plants by introducing CCS technology

■ 2025-2030: Install at least 40 GW of renewable hydrogen electrolyzers; produce 10 million tons of hydrogen from renewable energy sources; expand application of hydrogen from renewable energy sources to steelmaking processes, trucks, trains, and ships in the transportation sector

■ 2030-2050: Make renewable energy-derived hydrogen technologies reach maturity; apply hydrogen at large scale to sectors that are difficult to decarbonize (e.g., aviation)

Concurrently with the release of the Hydrogen Strategy, the European Clean Hydrogen Alliance was launched. The Alliance includes industry, national and local public authorities, and other interested parties, and aims to achieve an ambitious deployment of hydrogen technology by 2030.[41]

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39 European Commission, EU strategy on energy system integration, <https://ec.europa.eu/energy/topics/energy-system-integration/eu-strategy-energy-system-integration_en>; European Commission, COM(2020) 299 final.

40 European Commission, COM(2020) 301 final.

41 European Commission, Hydrogen, <https://ec.europa.eu/energy/topics/energy-system-integration/hydrogen_en>.

Battery development is also being actively pursued in the EU. In October 2017, the EU established the European Battery Alliance with the aim of creating a competitive manufacturing value chain for sustainable battery cells in Europe.[42] In June 2019, the Batteries Europe platform was established in connection with the research and innovation of the European Battery Alliance. It is a research and innovation platform, involving public and private stakeholders along the entire battery manufacturing value chain.[43] The Batteries Europe platform has published its vision for short-term research and development priorities for the European battery sector in July 2020. The priorities range from sustainable battery raw materials processing, to advanced battery raw material classification and recycling methods, and to manufacturing, etc. of next-generation battery for e-mobility.[44] In addition, the European Commission has approved the first and second Important Projects of Common European Interest (IPCEI) to support research and innovation in the battery value chain, which were jointly prepared and submitted by several member states.[45]

Relating to batteries, the EU has also focused its efforts on raw materials. In September 2020, the European Commission published its Action Plan on Critical Raw Materials, the List of Critical Raw Materials 2020 and a study report on critical raw materials in strategic technologies and sectors as of 2030 and 2050.

(2) Development status of laws and regulations

The European Commission proposed amendments to the Battery Regulation in December 2020. The new regulations to be developed will address the ensured sustainability and safety of batteries, display of sustainability and service life statements through labeling, recovery targets and obligations by EPR, and the recycling efficiency and materials to be recovered. This Regulation is planned to be implemented in phases (2024: presentation of carbon footprint information for industrial/EV batteries; 2027: indication of cobalt, lead, lithium, and nickel recycling rates and stipulation of minimum recycling rates after 2030; 2026: indication of serviceability), and the proposed amendments state to introduce a mechanism to contribute to the traceability of large batteries as the “Battery Passport.” [46]

(2) United States

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

The United States is a resource-rich country for fossil fuels, with the world's ninth largest reserves of crude oil, fifth largest reserves of natural gas, and largest reserves of coal as of the end of 2020. As for nuclear power, as of the beginning of 2021, the U.S. is the world's leading powerhouse with 94 nuclear reactors and 100.4 GW of generation capacity. Petroleum is used primarily as transportation fuel and coal is used primarily for power generation. Some of crude oil, natural gas, and coal produced in the country are exported. In particular, hydraulic fracturing technology has increased the production of natural gas from shale formations, which has led to the construction of natural gas liquefaction terminals, export of LNG, and ever-growing export volumes. As a result of the expansion of the Panama Canal that reduced the number of voyage

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[42] European Commission, European Battery Alliance, <https://ec.europa.eu/growth/industry/policy/european-battery-alliance_en>.

[43] European Commission, Launch of the BatteRIes Europe Platform, 2019-6-25, <https://ec.europa.eu/info/news/launch-batteries-europe-platform-2019-jun-25_en>.

[44] European Commission, Batteries experts identify short-term research & innovation priorities, 2020-7-3, <https://ec.europa.eu/info/news/batteries-experts-identify-short-term-research-innovation-priorities-2020-jul-03_en>.

[45] European Commission, State aid: Commission approves €3.2 billion public support by seven Member States for a pan-European research and innovation project in all segments of the battery value chain, 2019-12-9; European Commission, State aid: Commission approves €2.9 billion public support by twelve Member States for a second pan-European research and innovation project along the entire battery value chain, 2021-1-26.

[46] European Commission, Green Deal: Sustainable batteries for a circular and climate neutral economy, 2020-12-10.

days from liquefaction terminals built on the Gulf Coast to Asia and pricing based on cheap domestic natural gas prices unlike non-U.S. LNG projects, Asia became the largest export destination for U.S. LNG in 2020.

The United States is a coal-producing country, and coal used to account for the largest share of electricity generation, exceeding 50% up until the 2000s. However, the share of natural gas increased in the 2010s due to lower natural gas prices and lower CO_2 emissions resulting from the shale gas revolution, and surpassed coal in 2018. Since the 1990s, the share of nuclear power has remained almost constant.

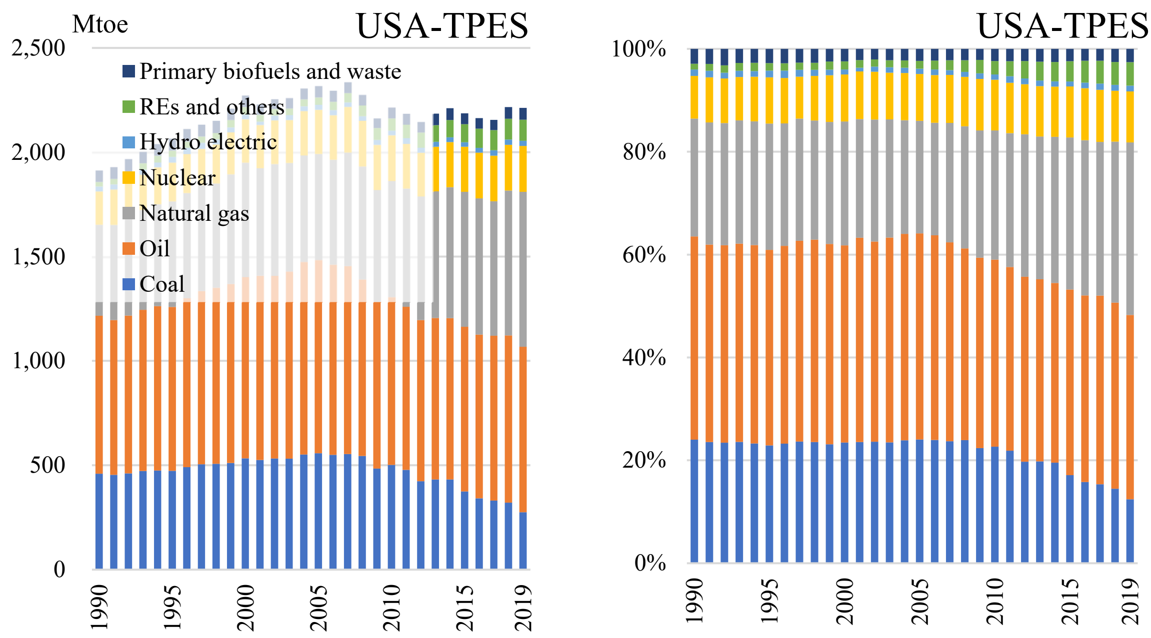


Figure 33 Primary Energy Supply in the U.S.

Source: World Energy Balances 2021 extended edition database, IEA

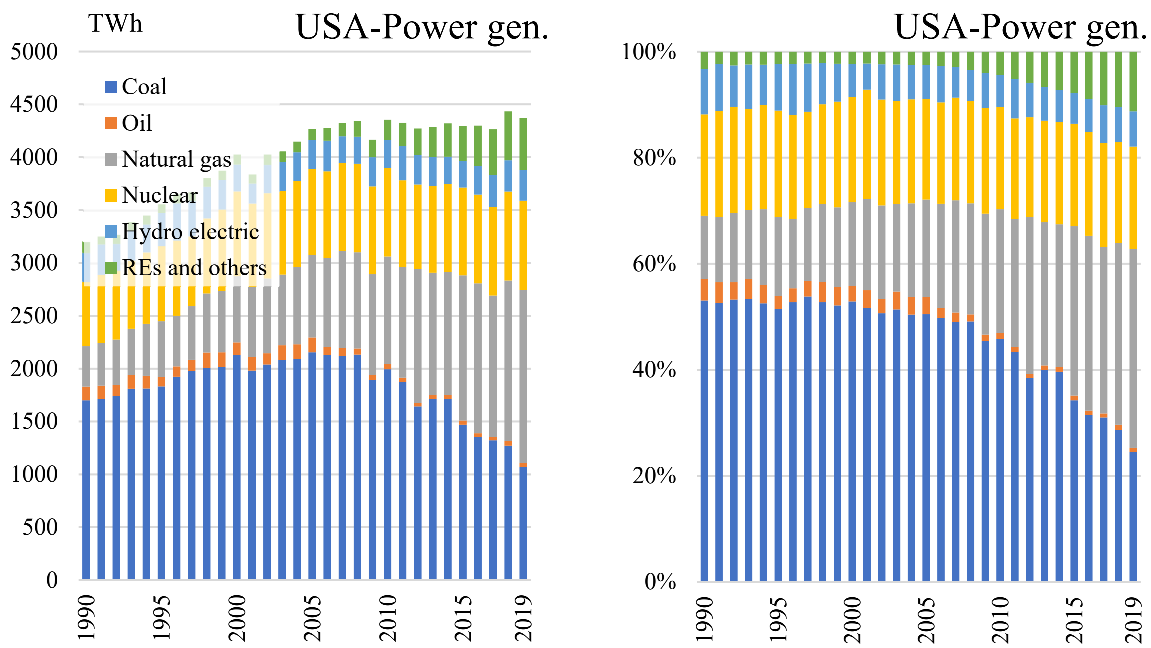


Figure 34 Fuel Mix of Electricity Generation in the U.S.

Source: World Energy Balances 2021 extended edition database, IEA

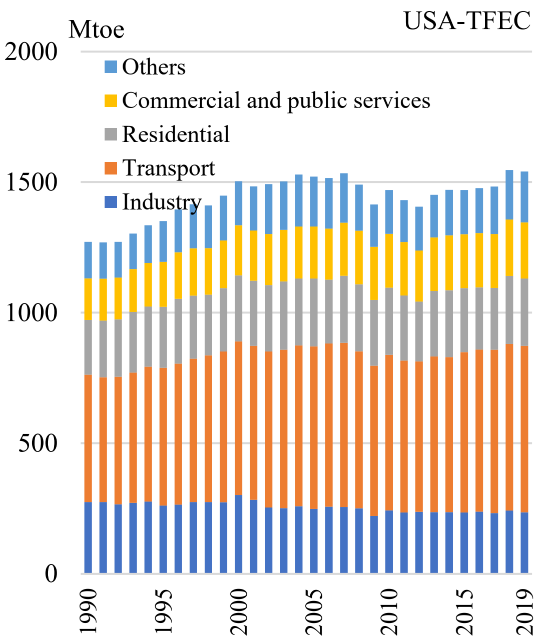
The U.S. has the highest energy consumption in the transportation sector due to its large land area and resultant high demand for transportation fuel. The sectoral breakdown of final energy consumption in 2019 was 15% for industry, 41% for transportation, 17% for residential, and 14% for commercial/public services. Looking at the five-year growth from 2014 to 2019, the growth rate in the transportation sector was 1.4%, making a huge contribution to the 0.9% average annual growth rate of final energy consumption over the same period.

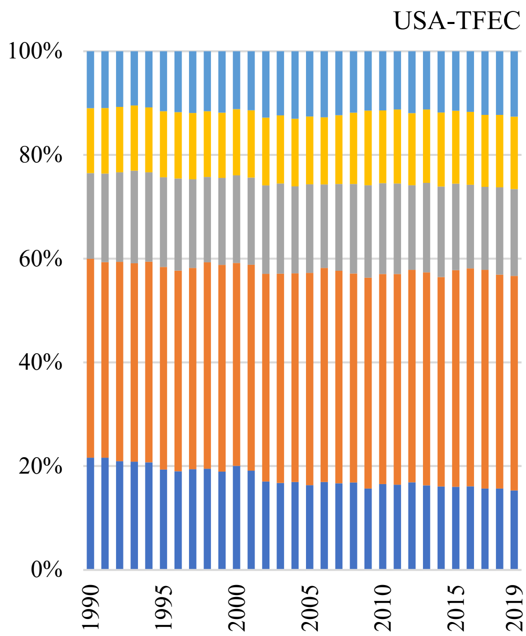
Industries are the largest consumers of natural gas in the U.S. because of the well-developed natural gas pipeline network. Especially in the 2010s, the shale gas revolution has increased natural gas production and lowered prices, causing coal to lose market share to natural gas. Large-scale ethylene crackers are also being constructed using ethane, a byproduct of the raw gas processing process.

Approximately 90% of transportation fuel is petroleum. The United States is a major agricultural country, and ethanol made from corn is blended with gasoline for use. Biodiesel is also used, and recently there has been a movement to convert small oil refineries into biodiesel production plants. Natural gas cars are becoming popular, and LNG trucks have recently begun to become more common.

In 2019, electricity and natural gas had a combined energy share of 90% in the residential sector, with electricity accounting for 46% and natural gas for 44%. Looking at the average annual growth rates for five years from 2014 to 2019, electricity drove energy consumption in the residential sector at 0.3%, while the residential sector as a whole was 0.0%.

In 2019, electricity and natural gas had a combined energy share exceeding 90% in the commercial/public services sector, with electricity accounting for 54% and natural gas for 38%. The average annual growth rate for five years from 2014 to 2019 was 0.5% for the commercial/public services sector as a whole, where the growth rate was 0.2% for electricity and 0.8% for natural gas, showing a notable increase in the consumption of natural gas.





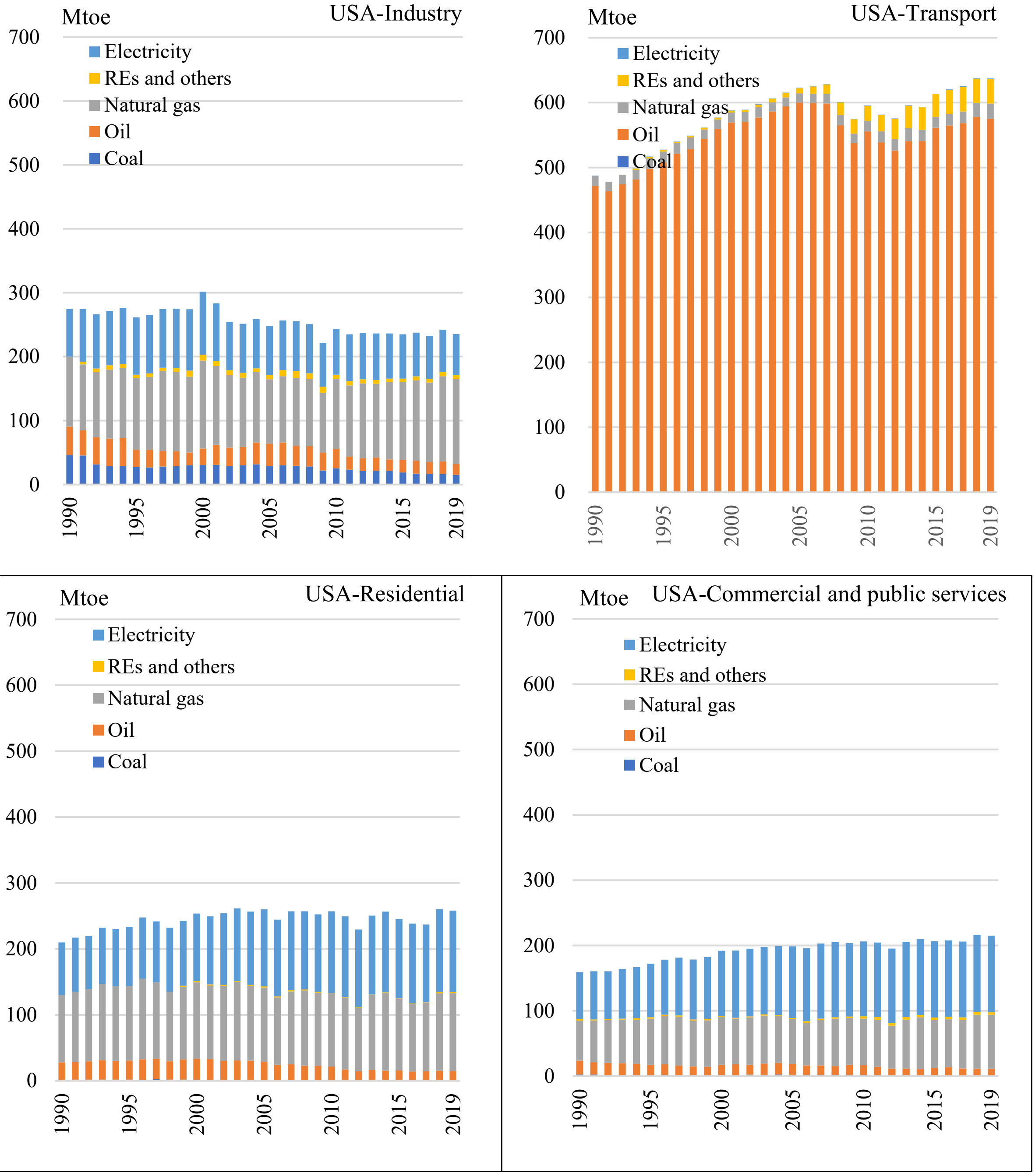


Figure 35 Final Energy Consumption of Major Sectors in the U.S.

Note: Excludes “Primary solid biofuels,” “Non-specified primary biofuels and waste,” and “Charcoal.”
“Others” in TFEC includes agriculture, forestry, fisheries, other, and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP improved from about 0.2 toe/\$1,000 in 1990 to about 0.1 toe/\$1,000 in 2019, approaching the Japanese level (0.090, 2015 prices).

With respect to the thermal efficiency of power generation, there has been no improvement in the efficiency of coal-fired power plants, while the efficiency of natural gas-fired power plants has been improving.

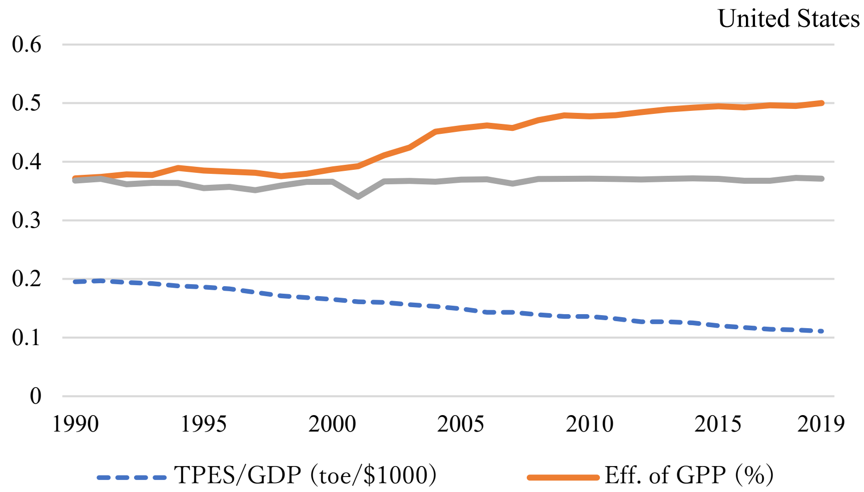


Figure 36 Energy Eficiency in the U.S.

Note: TPES = total primary energy supply; Eff. = thermal efficiency; GPP = gas-fired power plant; GDP is in 2015 U.S. dollar prices

Source: World Energy Balances 2021 extended edition database, IEA

(2) Primary energy mix and electricity mix planning

The figure below shows the outlook for energy consumption in the Reference case of the Annual Energy Outlook 2021 (AEO 2021) published by the U.S. EIA in February 2021.

By energy, petroleum and liquid fuels will be the most consumed in 2050, with a projected average annual increase of 0.5% between 2020 and 2050 to 39.08 quadrillion Btu and a share of 36.0%. The runner-up is natural gas, which is expected to increase by 0.5% to 36.70 quadrillion Btu with a 33.8% share. Coal is forecast to decline 1.0% to 6.60 quadrillion Btu with a 6.1% share. Looking at renewable energy, conventional hydropower is expected to decrease by 0.3% to 2.29 quadrillion Btu with a share of 2.1%, biomass is expected to increase by 0.4% to 3.40 quadrillion Btu with a share of 3.1%, and other renewable energies are expected to increase by 3.9% to 14.11 quadrillion Btu with a share of 13.0%.

By sector, the projected average annual growth rates between 2020 and 2050 are 0.1% for residential, 0.4% for commercial, 0.9% for industrial, 0.4% for transportation, and 0.5% for electricity generation.

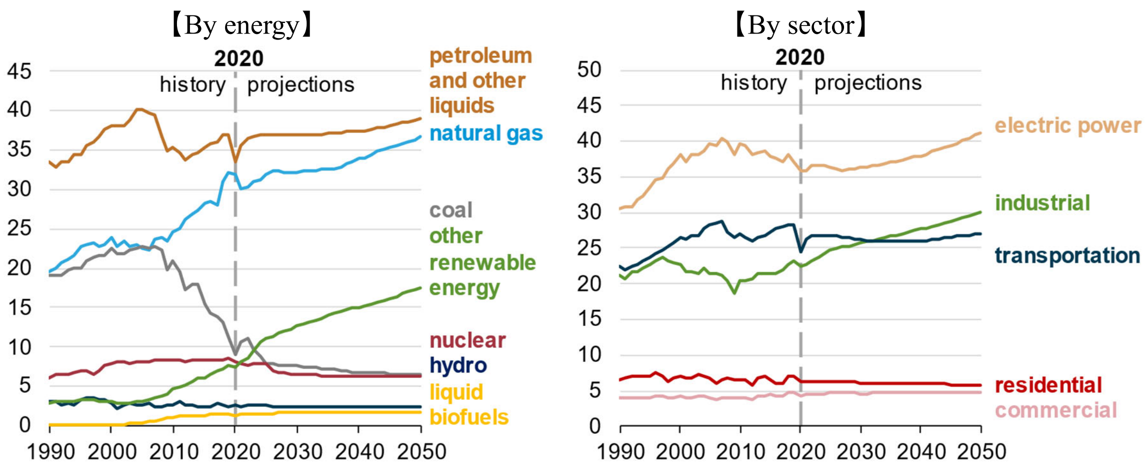


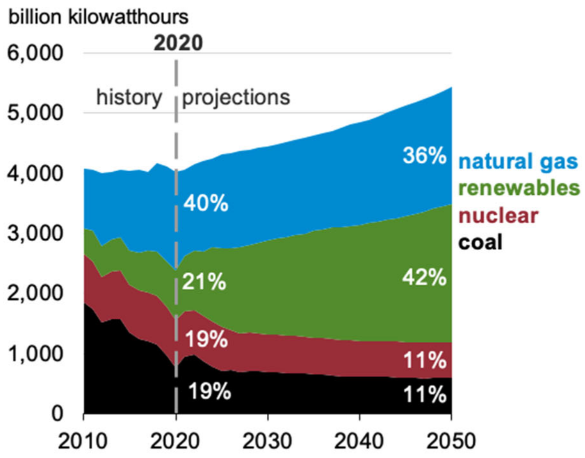
Figure 37 Outlook of Primary Energy Consumption in the U.S. (Reference Case, quadrillion Btu)

Source: Annual Energy Outlook 2021, DOE/ EIA

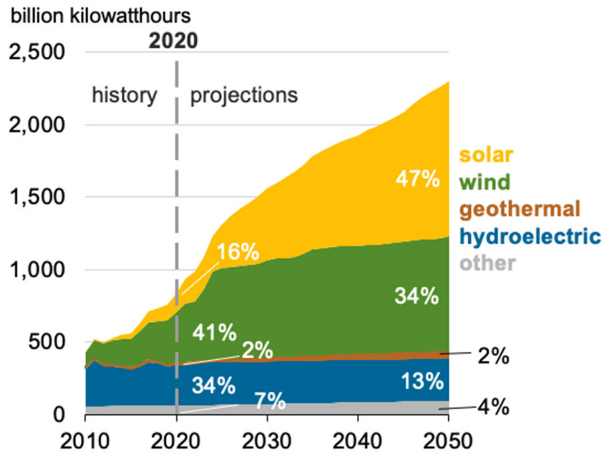
The figure below shows the projected power generation in the Reference case of AEO 2021.

By energy, coal is expected to decrease by an average of 0.9% per year between 2020 and 2050 to 593 TWh with a share of 11%; natural gas is expected to increase by 0.6% to 1,953 TWh with a share of 36%; nuclear is expected to decrease by 0.9% to 594 TWh with a share of 11%; and renewable energy is expected to increase by 3.4% to 2,298 TWh with a share of 42%.

The breakdown of renewable energy in 2050 shows that wind power is expected to have the highest share at 47%, followed by wind at 34% and hydro at 13%.



【By main fuel】



【By renewable energy】

Figure 38 Outlook of Electricity Generation in the U.S. (1000TWh)

Source: Annual Energy Outlook 2021, DOE/ EIA

(b) Electric utility system

(1) Electricity supply system (major players, status of deregulation of power generation, transmission and distribution, etc.)

The regulatory agencies for electric utilities are the FERC (regulates interstate transactions) and PUC (regulates intrastate transactions). The wholesale electricity market began to be liberalized when the Public Utility Holding Company Act (PUHCA) was amended in 1992, allowing IPPs to freely own and operate generating facilities and sell electricity. In 1996, the FERC mandated that electric utilities open their transmission lines and separate the functions of their power transmission and distribution divisions (while allowing for the recovery of unrecoverable costs from departing customers), and since then IPPs and other entities have been entering the market.

There are more than 3,000 electric utilities in the United States, with a variety of ownership types, including private, federal, local public, and cooperative-owned. Electric utilities traditionally engaged in integrated operation of generation, transmission, and distribution of electricity and were regulated in return for being granted exclusive operating privileges by local governments in certain regions, but the liberalization of the wholesale electricity market has led to the separation of generation, transmission, and distribution of electricity. On the other hand, non-electric power providers (IPPs) are differentiated into two groups: qualifying facility (QF) providers, for whom purchase of electricity by a power company is basically guaranteed, and providers without purchase guarantee.

(2) Renewable electricity supply system

In the U.S., there are few barriers to entry into renewable energy generation, except for safety and environmental regulations, and various players, including oil and natural gas majors, have entered the market.

(3) Method of selling/purchasing renewable electricity

As a developer of renewable energy generation, one has the option of selling to the local electricity wholesale market or entering into a PPA with a specific company. Companies such as

Google and Apple have signed PPAs with renewable energy generation developers or built their own renewable energy generation facilities in order to promote the low-carbonization of the electricity they use.

(c) Policy on renewable energy

(1) Potential of renewable energy

In areas with high solar potential, developers are developing solar projects, including rooftop ones. Solar accounted for 10% of the world's generating capacity as of 2019 and 15% of the world's electricity generation in 2019.

Table 57 Solar Power Generation Capacity and Generated Electricity in the U.S. (2019)

Country		Capacity (MW)		Generation (GWh)	
USA	Photovoltaic	60,540	(10.5%)	81,244	(14.8%)
	Concentrated solar power	1,758	(28.0%)	3,940	(32.3%)
	Total	62,298	(10.7%)	85,184	(15.2%)

Note: Figures in parentheses are global market shares.
Source: RENEWABLE ENERGY STATISTICS 2020, IRENA

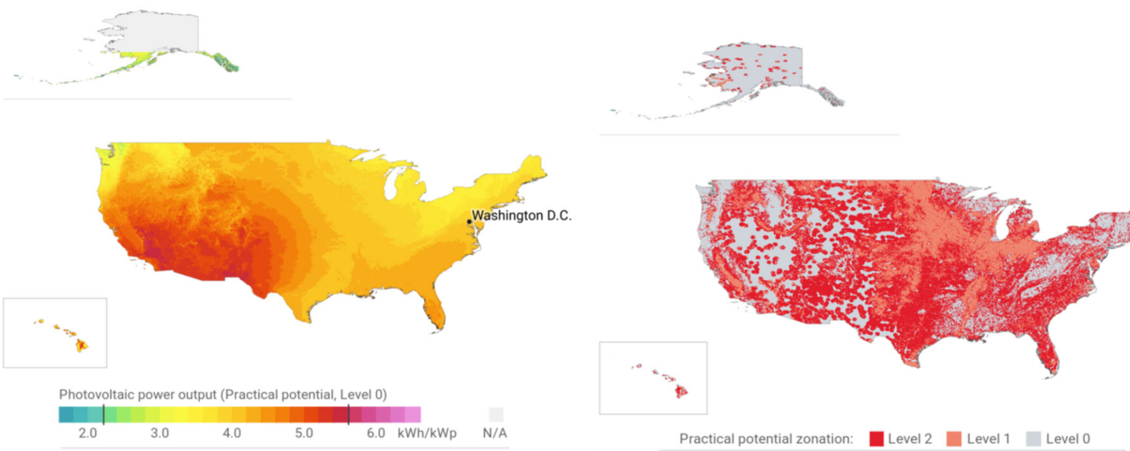


Figure 39 Solar Power Generation Potential in the U.S.

Note: Left = estimated power generation.
Right = potential zones; Level 0 = no constraints, Level 1 = excluding topographic constraints, Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

The U.S. accounted for 17% of the world's wind capacity as of 2019 and 22% of the world's wind electricity generation in 2019. Offshore wind power is being developed off the East Coast of the United States.

Table 58 Wind Power Generation Capacity and Generated Electricity in the U.S. (2019)

Country		Capacity (MW)		Generation (GWh)	
USA	Onshore	103,555	(17.4%)	275,732	(23.1%)
	Offshore	29	(0.1%)	102	(0.1%)
	Total	103,584	(16.6%)	275,834	(21.8%)

Note: Figures in parentheses are global market shares.
Source: RENEWABLE ENERGY STATISTICS 2020, IRENA

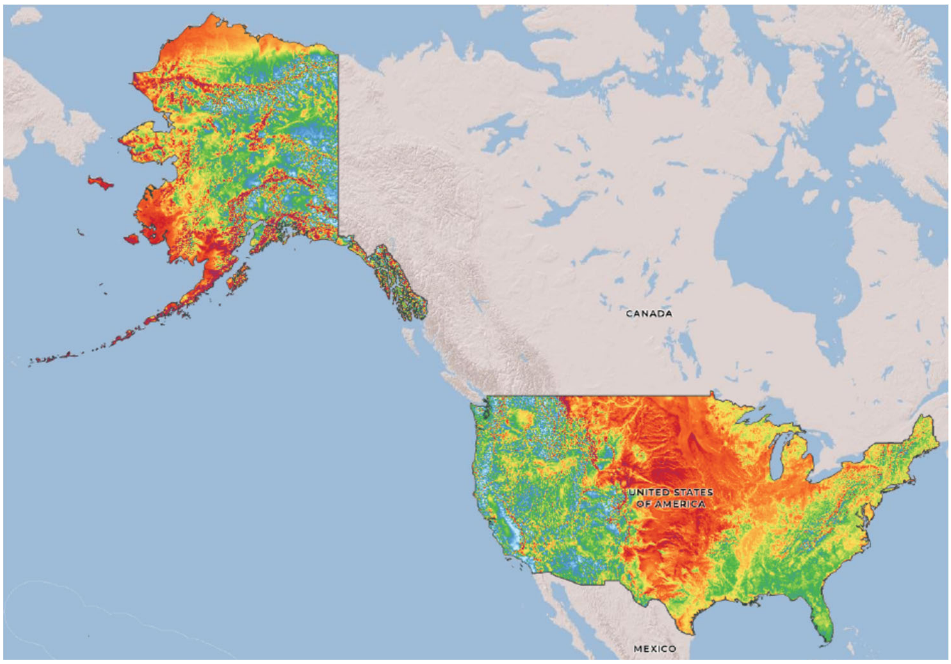


Figure 40 Wind Power Generation Potential in the U.S.

Note: The mean wind speeds shown are the representative values at the elevation of 50 m. Red color indicates the fastest wind speed.

Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

At the federal level, the Office of Energy Efficiency and Renewable Energy of the Department of Energy (DOE) has jurisdiction.

(3) Development targets

The AEO 2021's Reference scenario assumes a 42% market share for renewable energy generation in 2050.

(4) Introduction promotion policy

The major federal programs to support renewable energy deployment include the Production Tax Credit (PTC), Investment Tax Credit (ITC), direct subsidies, and debt guarantees.

As of July 2018, Washington D.C. and 29 states and 3 territories have adopted RPSs with target achievement obligations. Eight states and one territory, such as Kansas, have targets for renewable energy deployment, but are not obligated to meet the said targets.[47]

(d) Energy conservation policy

(1) Institutions in charge of policy

The DOE's Office of Energy Efficiency and Renewable Energy is primarily responsible for energy conservation policies, which are implemented jointly with other agencies such as the Environmental Protection Agency, Department of Transportation, and Department of Housing and Urban Development.

(2) Targets

Although there are no quantitative targets, DOE has been implementing the Better Buildings Initiative in public and private sectors since 2011.

[47] JAPAN ELECTRIC POWER INFORMATION CENTER, February 2019

(3) Promotion policy

According to the NDC submitted by the United States to the United Nations in 2015, under the Energy Policy Act and the Energy Independence and Security Act, DOE has developed 29 categories of product and equipment and commercial building construction standards to reduce emissions in the building sector, as well as the final draft of the energy conservation standards.

[Fuel efficiency standards for automobiles]

In 1975, the Energy Policy and Conservation Act was enacted, introducing the Corporate Average Fuel Economy (CAFE) for passenger cars and vans, which required improved average fuel economy for all new vehicles. In December 2007, the CAFE was amended under the Energy Independence and Security Act, mandating an average fuel economy of 35 miles per gallon by 2020.

In August 2012, the Obama administration announced a new automobile fuel economy standard of 54.5 miles per gallon by 2025.[48]

In March 2020, the Trump administration decided to lower the U.S. automobile fuel economy standard adopted under the previous Obama administration. The previous standard required automakers to improve fuel economy by 5% per year until 2026, but this has been reduced to 1.5% to approximately 40 miles per gallon. The Trump administration positioned this as the biggest step in its deregulation movement, stating that it would save automakers more than $100 billion in compliance costs. California and 22 other states have initiated legal battles.[49]

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

The INDC, submitted to the UN in 2015, targets a 26-28% reduction in CO_2 equivalent by 2025 compared to 2005 levels. In addition, for federal government operations, a Presidential Decree was issued in 2015 to reduce GHGs by 17% from 2005 levels by 2025, and this will be further increased to a 40% reduction.

In June 2017, President Trump announced the withdrawal of the U.S. from the Paris Agreement,[50] and in August of the same year, the Department of State formally notified the UN of its intention to withdraw from the Agreement.[51] In November 2019, the U.S. Department of State announced that it had formally notified the United Nations of its withdrawal from the Paris Agreement. The withdrawal process was completed on November 4, 2020, one year after the notification and the day after the U.S. presidential election.[52]

However, on January 20, the day of his inauguration, President Biden instructed the procedures for returning to the Paris Agreement. On February 19, 30 days after the application was filed, the U.S. Department of State officially announced its return to the Paris Agreement.

In April 2021, the United States submitted an NDC to the UNFCCC to reduce GHG emissions by 50-52% from 2005 levels by 2030. Also, in November 2021, the United States submitted to the UNFCCC its long-term strategy, “THE LONG-TERM STRATEGY OF THE UNITED STATES,” which lays out a pathway for emission reductions up to 2050. In the " THE LONG-TERM STRATEGY OF THE UNITED STATES," the target value (80% GHG reduction by 2050)

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48 Reuters, August 29, 2012.

49 Reuters, March 31, 2020. https://uk.reuters.com/article/us-usa-autos-emissions-idUKKBN21I25S

50 The White House, June 1, 2017. https://www.whitehouse.gov/the-press-office/2017/06/01/statement-president-trump-paris-climate-accord

51 https://www.state.gov/r/pa/prs/ps/2017/08/273050.htm

52 Department of State PR, November 4, 2019. https://www.state.gov/on-the-u-s-withdrawal-from-the-paris-agreement/

submitted during the Obama administration has been raised to net zero emissions, and the GHG reduction target by 2030 is set at 50-52% reduction (compared to 2005) is specified.[53]

(2) Promotion policy

The long-term strategy "THE LONG-TERM STRATEGY OF THE UNITED STATES" submitted to the UNFCCC in November 2021 states that the following five transitions are important to achieve net zero emissions in 2050.

DECARBONIZE ELECTRICITY

Driven by plummeting solar and wind costs, federal and state government promotion policies, and consumer demand, the transition to a clean power system has accelerated in recent years. Building on this success, the United States has set a goal of 100% clean electricity by 2035, a crucial foundation for net-zero emissions no later than 2050.

ELECTRIFY END USES AND SWITCH TO OTHER CLEAN FUELS

Replace cars, buildings and industrial processes with carbon-free electricity. Use clean fuels such as carbon-free hydrogen and sustainable biofuels in areas where electrification is technically difficult, such as aviation, ships and some industrial processes.

CUT ENERGY WASTE

This can be achieved through diverse, proven approaches, ranging from more efficient appliances and the integration of efficiency into new and existing buildings, to sustainable manufacturing processes.

REDUCE METHANE AND OTHER NON-CO2 EMISSIONS

There are many profitable or low-cost options to reduce non-CO2 sources, such as implementing methane leak detection and repair for oil and gas systems and shifting from HFCs to climate-friendly working fluids in cooling equipment. Through the Global Methane Pledge, the U.S. and partners seek to reduce global methane emissions by at least 30% by 2030.

SCALE UP CO2 REMOVAL

In the three decades to 2050, our emissions from energy production can be brought close to zero, but certain emissions such as non-CO2 from agriculture will be difficult to decarbonize completely by mid-century. Reaching net-zero emissions will therefore require removing carbon dioxide from the atmosphere, using processes and technologies that are rigorously evaluated and validated. This requires scaling up land carbon sinks as well as engineered strategies.

(3) Transportation

There are fuel efficiency standards for automobiles and the obligation to blend biofuels in transportation fuel.

[Transportation fuel]

The EPA has been implementing renewable fuel blending mandates (RFS) since 2007, imposing mandatory bioethanol and biodiesel use volumes on fossil fuel suppliers (e.g., petroleum refiners, petroleum importers, and petroleum fuel blending suppliers) for transportation, including gasoline and diesel fuel for automobiles. In addition, RFS2 has been in effect since 2010 to encourage cellulosic bioethanol, which is more effective in reducing greenhouse gas emissions than corn-based bioethanol by introducing sustainability criteria.

In November 2016, the Obama administration announced plans to install charging facilities on approximately 40,000 km of highways across 35 states in the U.S. mainland, among other things, in order to promote electric vehicles following the entry into force of the Paris Agreement.[54]

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[53] UNFCCC, November 1, 2021. https://unfccc.int/sites/default/files/resource/US-LongTermStrategy-2021.pdf

[54] Nihon Keizai Shimbun, November 4, 2026

In December 2018, the California Air Resources Board became the first case in the U.S. to adopt a policy requiring all newly introduced public buses to be electric by 2029.[55]

In September 2020, California Governor Gavin Newsom announced that the state plans to ban the sale of gasoline passenger cars and trucks starting in 2035. As the largest auto market in the U.S. (about 11% of U.S. auto sales), the state will shift to electric vehicles to reduce greenhouse gas emissions.[56]

(4) Urban development

The U.S. federal government embarked on a full-scale smart city buildout with the announcement in September 2015 of its $160 million Smart Cities initiative. The Smart Cities Council, the largest smart cities industry association in the U.S., is propelling cross-disciplinary activities involving a variety of companies, universities, and research institutions. Securing Smart Cities, an industry association of security companies, is collaborating on smart city security.[57]

(f) Next generation technology, innovation

(1) Introduction targets

Based on the Energy Policy Act of 2005, the DOE is promoting the Hydrogen and Fuel Cells Program under the leadership of the Energy Efficiency and Renewable Energy Office (EERE), with the participation of the Fossil Energy Office, Nuclear Energy Office, and Science Office.

In 2016, the Fuel Cell Technology Office (FCTO), which has jurisdiction over hydrogen technology at the DOE, released H2@Scale, a hydrogen technology deployment concept targeting the electric power sector.

In July 2020, the DOE released its Hydrogen Strategy (Enabling A Low-Carbon Economy), which identifies four priority R&D areas: 1) carbon-neutral hydrogen production using gasification and reforming technologies, 2) large-scale hydrogen infrastructure, 3) large-scale above-ground and underground hydrogen storage, and 4) hydrogen applications in power generation, fuel, and manufacturing.[58]

(2) Development status of laws and regulations

Safety and environmental laws and regulations are in place.

(3) Status of research and development of technologies

The figure below outlines the program for hydrogen.

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55 The New York Times, December 14, 2018. https://www.nytimes.com/2018/12/14/climate/california-electric-buses.html

56 Reuters, September 23, 2020. https://www.reuters.com/article/autos-california-emissions/california-sets-goal-to-ban-sale-of-new-gasoline-powered-passenger-vehicles-starting-in-2035-idUSKCN26F05M

57 JETRO https://www.jetro.go.jp/ext_images/_Reports/02/bbaea2a997300b76/reportsNY_201510.pdf

58 DOE, July 2020. https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf

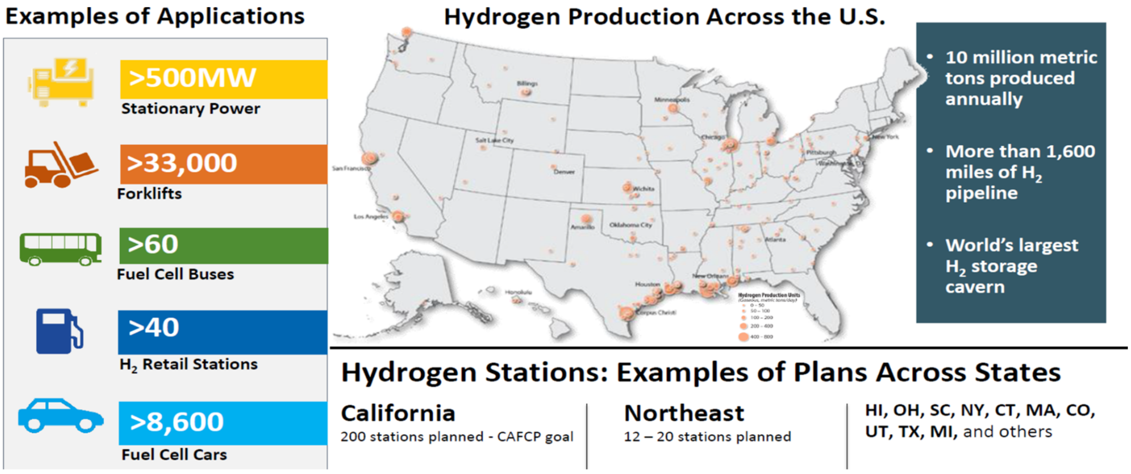


Figure 41 Snapshot of Hydrogen and Fuel Cells Applications in the U.S.

Source: Hydrogen and Fuel Cell Perspectives and Overview of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), DOE.[59]

In July 2020, the DOE announced a $118 million investment in the Coal FIRST (Flexible, Innovative, Resilient, Small, Transformative) Initiative to support carbon-neutral electricity generation and hydrogen production technologies from coal. It will inject $37 million into seven R&D projects and $81 million into new investment opportunity announcements. Coal FIRST power plants use coal, biomass, and waste plastics to generate clean, affordable, carbon-neutral electricity and hydrogen. Coal FIRST power plants can operate flexibly as required by the grid and are small-scaled compared to today's utility-scale coal-fired plants.[60]

In July 2020, the DOE announced an aid of $64 million in FY2020 for 18 projects that support the H2@Scale vision to make it easier to produce, store, transport, and use hydrogen. These projects will activate the R&D phase activities under H2@Scale as a multi-year initiative to fully realize the benefits of hydrogen to the economy.[61]

In November 2020, the DOE released its Hydrogen Program Plan, a strategic framework for the Department's hydrogen research, development, and demonstration (RD&D) activities. This program specifies the hydrogen and hydrogen-related technology goals necessary to make the market competitive with the technologies that are being developed.[62]

- ✓ Hydrogen production at $2/kg and terminal delivery for transportation equipment at $2/kg.
- ✓ $1/kg for industrial and stationary power generation facilities.
- ✓ 25,000-hour endurance fuel cell system for long-haul heavy-duty trucks at $80/kW.
- ✓ 2.2 kWh/kg and 1.7 kWh/l on-board hydrogen storage at $8/kWh.
- ✓ Water electrolysis capital cost for 80,000 hour durability and 65% system efficiency at $300/kW.
- ✓ Flexible fuel and high temperature stationary fuel cell system cost at $900/kW.

(3) China

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

China ranks fourth in the world in coal reserves and first in coal production, and coal is the

[59] DOE July 1, 2020. https://www.energy.gov/sites/prod/files/2020/07/f77/hfto-satyapal-gabi-workshop-jul20.pdf

[60] DOE PR, July 17, 2020. https://www.energy.gov/articles/doe-invests-118-million-21st-century-technologies-carbon-neutral-electricity-and-hydrogen

[61] DOE PR, July 20, 2020. https://www.energy.gov/articles/energy-department-announces-approximately-64m-funding-18-projects-advance-h2scale

[62] DOE PR, November 12, 2020. https://www.energy.gov/articles/energy-department-releases-its-hydrogen-program-plan3

dominant energy supply. China's energy consumption has gradually increased since its opening up and reform policy in 1978, and the growth increased sharply in 2003. China has been a net importer of crude oil since the mid-1990s and a net importer of coal as well since 2009. Natural gas imports began in 2006.

In 1995, China surpassed Japan to become the world's second largest producer of electricity, and in 2010 it surpassed the United States to become the world's largest producer of electricity. Coal-fired power plants play a key role in China's electricity supply, and 50 GW of new coal-fired power plants have been built every year to provide a stable supply of electricity to meet China's robust electricity demand. Coal-fired power generation has also contributed significantly to the economic development of various regions through the development of new power sources, coal mine development, and coal transportation and sales. For this reason, coal is the main source of power generation in China, and imported coal is used as well as domestic coal. The share of coal-fired power in 2019 was 65%.

Gas-fired power generation is increasing as imports of pipeline natural gas and LNG increase, but the share of gas-fired power remains at 3% in 2019.

Nuclear power generation began in 1993, and as of January 1, 2021, China had 48 nuclear reactors with a generating capacity of 49.9 GW, making it the third largest nuclear power in the world after the United States and France.

Non-hydro renewable energy generation, such as wind and solar, has increased rapidly since 2010, and the share of non-hydro renewable energy generation reached 10% in 2019.

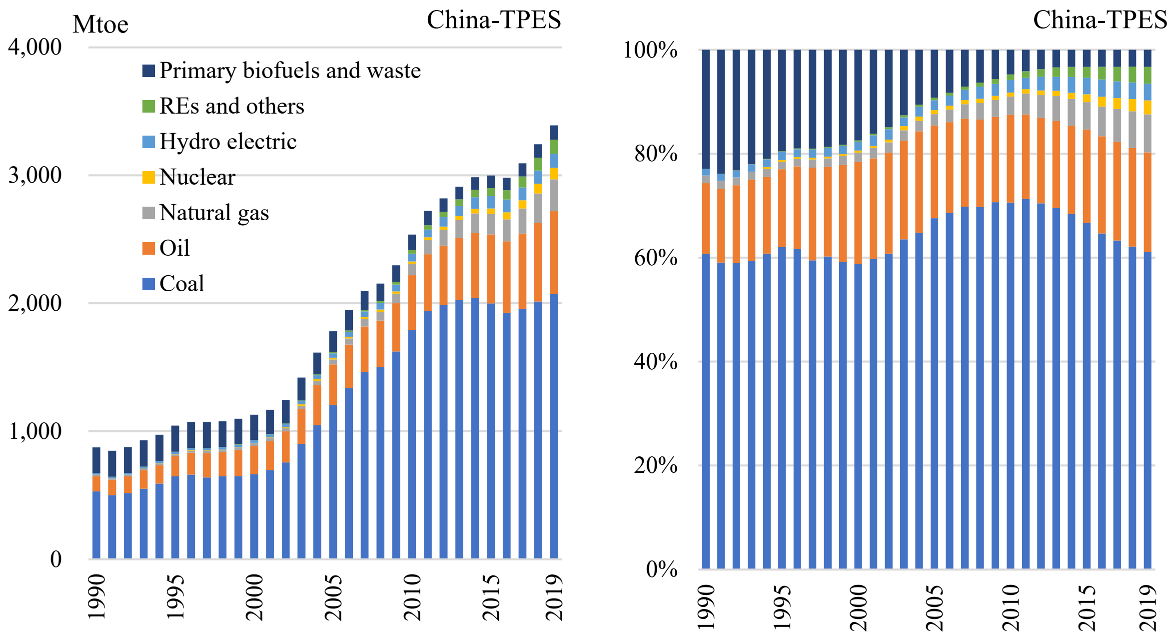


Figure 42 Primary Energy Supply in China

Source: World Energy Balances 2021 extended edition database, IEA

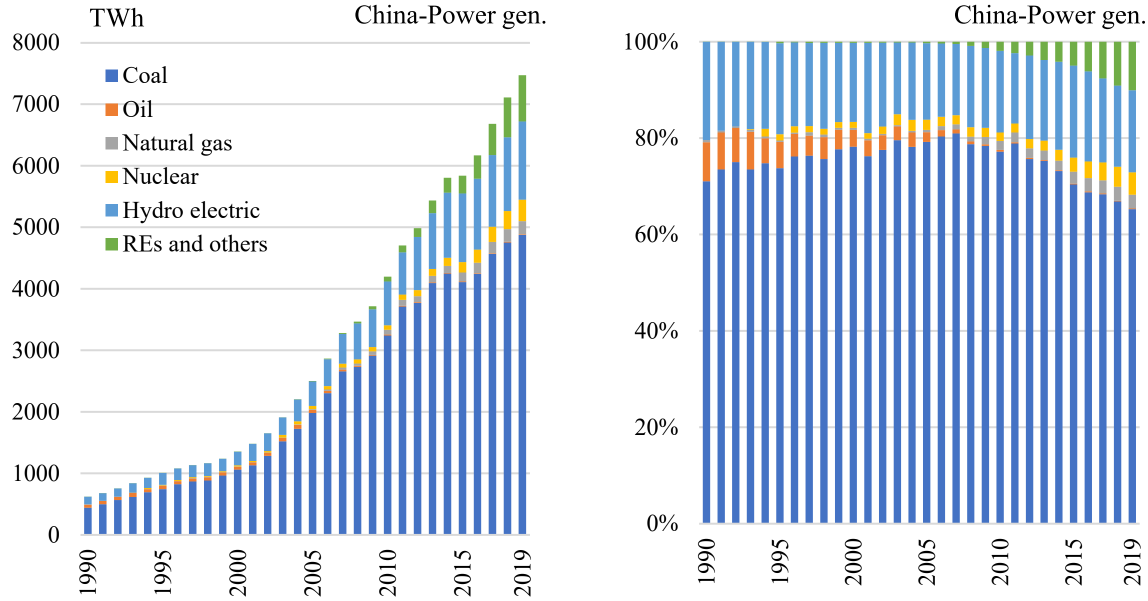


Figure 43 Fuel Mix of Electricity Generation in China

Source: World Energy Balances 2021 database, IEA

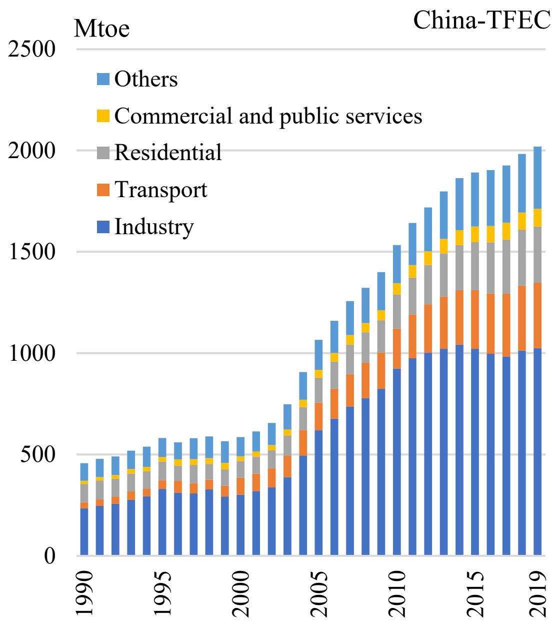
A breakdown of final energy consumption by sector shows that the industrial sector is the majority in 2019 with 51%, transportation 16%, residential 14%, and commercial/public services 4%. In the five-year growth from 2014 to 2019, residential had the largest growth at 5.3%, followed by transportation at 4.4%, while industry declined by 0.3%.

Coal is the main source of energy consumption in the industrial sector, with a 45% share in 2019, but it had been declining at an average annual rate of 5.9% over the five-year period from 2014 to 2019. After coal, electricity is the second largest source of energy, with a 33% share in 2019, and had an average annual increase of 3.6% over the five-year period from 2014 to 2019. China has a well-developed energy-intensive industry, and heat is the third largest source of energy after coal and electricity. In 2019, the share of heat was 7%, with an average annual increase of 6.0% over the five-year period from 2013 to 2018. The share of natural gas was only 9% in 2019, but had been increasing at an average annual rate of 17.4% over the five-year period from 2014 to 2019.

In 2019, the transportation sector's share of energy by type was 87% for oil, followed by natural gas at 8%. Since the 12th Five-Year Plan, China has adopted a low-carbon policy and is promoting the use of CNG and LNG in the transportation sector to combat air pollution in urban areas, which has led to the widespread use of natural gas vehicles. Another factor promoting the use of natural gas in the transportation sector is occasional subsidies by provincial and municipal governments when CNG or LNG is used for buses and cabs.

A variety of energy is used relatively evenly in the residential sector. The highest share was electricity, at 26% in 2019, which saw an average annual growth of 8.2% for the five-year period from 2014 to 2019. The share of energy other than electricity in 2019 was 10% for coal, 11% for oil, 12% for natural gas, 21% for biomass, 9% for heat, 6% for solar thermal, and 2% for biogas.

Also in the commercial/public services sector a variety of energy is used relatively evenly. The highest share was electricity, at 45% in 2019. In the five-year period from 2014 to 2019, the average annual growth rate was the highest for geothermal at 16.1%, followed by heat at 10.8% and electricity at 9.9%. Coal had a 14% share in 2019, but consumption is declining.


Mtoe
China-TFEC
2500
2000
1500
1000
500
0
Others
Commercial and public services
Residential
Transport
Industry
1990
1995
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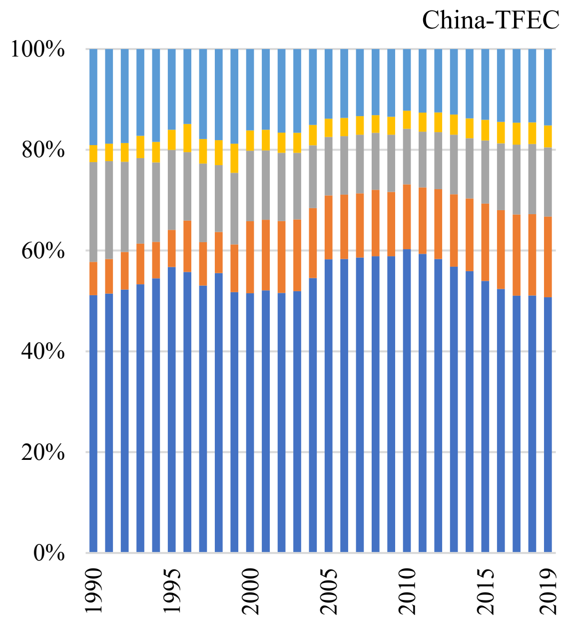
2019


China-TFEC
100%
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20%
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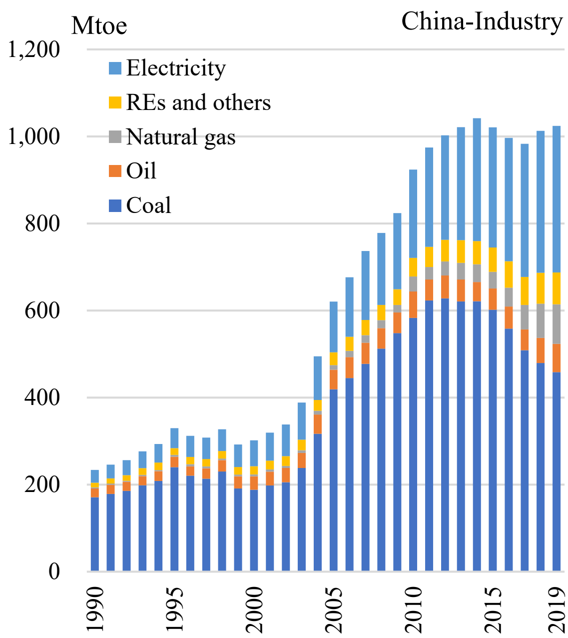
Mtoe
China-Industry
1,200
1,000
800
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Electricity
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Natural gas
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Coal
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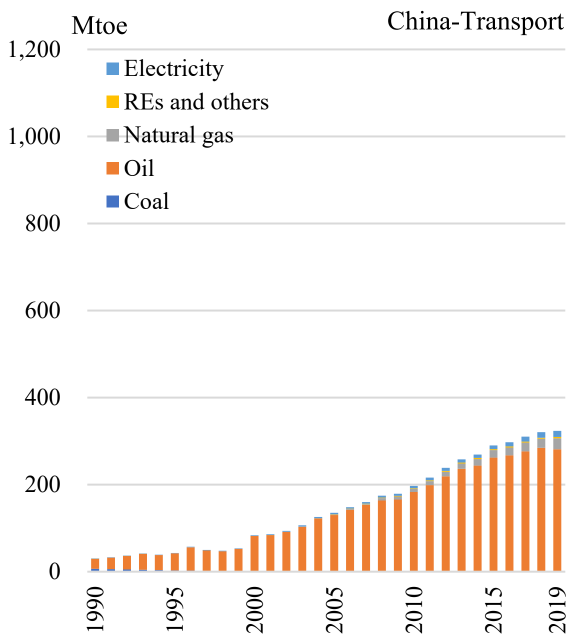
Mtoe
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1,200
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Electricity
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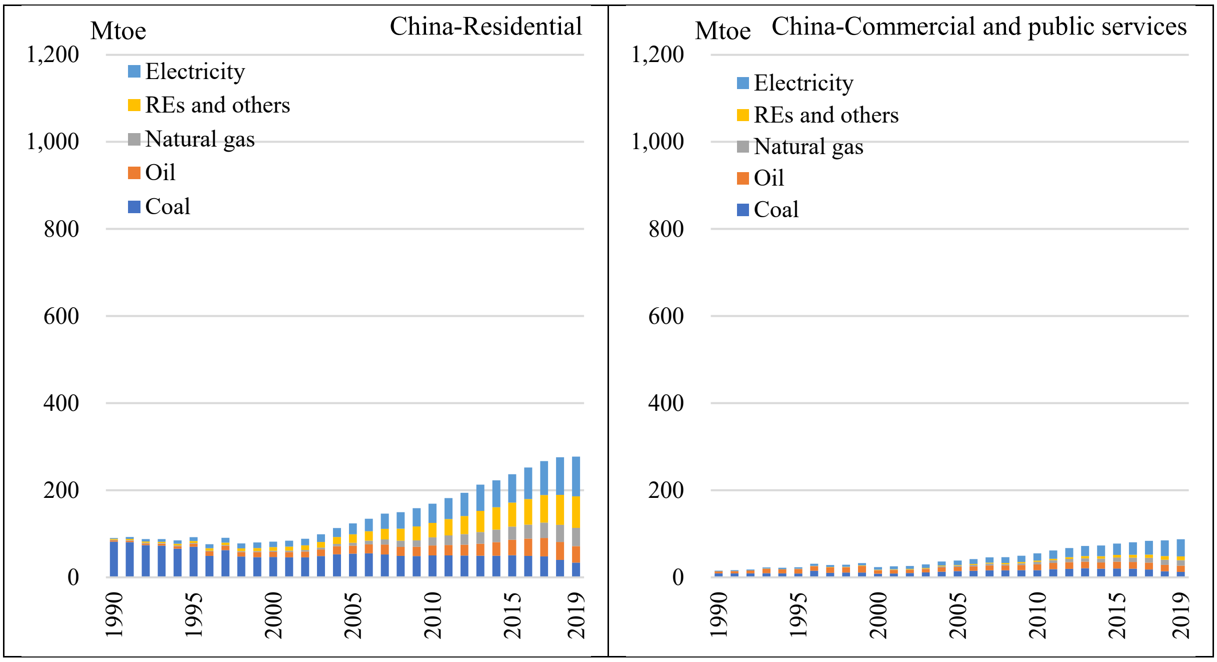

Figure 44 Final Energy Consumption of Major Sectors in China

Note: Excludes "Primary solid biofuels," "Non-specified primary biofuels and waste," and "Charcoal."
"Others" in TEFC includes agriculture, forestry, fisheries, other, and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP was above 1 toe/$1,000 (2015 prices) until the early 1980s, but has been below 1 since 1984, improving to 0.237 in 2019. This can be attributed to changes in industrial structure in addition to progress in energy conservation.

The thermal efficiency of coal-fired power plants has reached nearly 40% in 2019. The thermal efficiency of gas-fired power plants is getting closer to 60%.

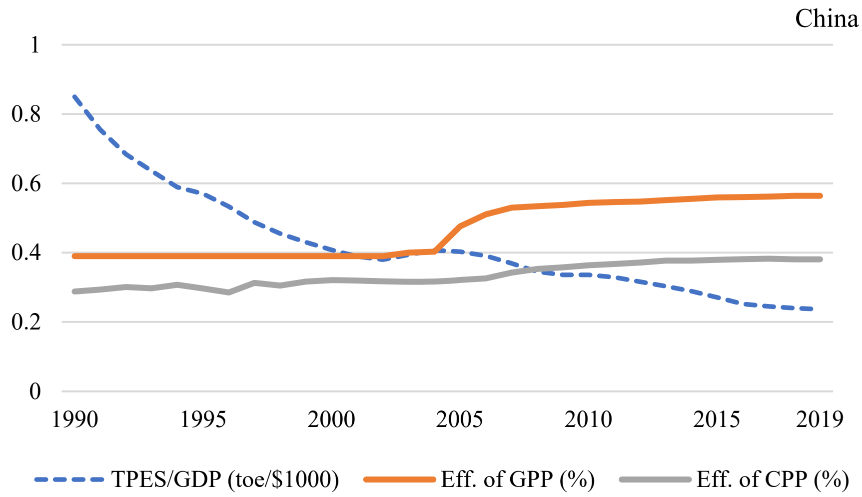

Figure 45 Energy Efficiency in China

Note: TPES = total primary energy supply; Eff. = thermal efficiency; GPP = gas-fired power plant; GDP is in 2015 U.S. dollar prices
Source: World Energy Balances 2021 extended edition database, IEA

(2) Primary energy mix and electricity mix planning

The main energy-related goals in the 13th Five-Year Plan for the National Economic and Social Development (announced in March 2016) and the 13th Five-Year Plan for Energy Development (announced in January 2017) are as shown below.

Table 59 Main Targets of China's 13th Five-Year Plan

Indicator		2020 Target
Total Primary Energy Consumption (tce)		Within 5 billion tons
	Share of Coal	58% or less
	Share of Non-Fossil Fuels	15%
	Share of Natural Gas	More than 10%
Nuclear Power Generation Capacity		Operation: 5.8 GW, Construction: 3GW
Natural Gas-Fired Generation Capacity		110 GW
Hydro Generation Capacity		380 GW
Wind Power Generation Capacity		290 GW
Solar Power Generation Capacity		160 GW
Geothermal Generation Capacity		42 million tce

Source: National Energy Administration, "Nogen Development 13.5 Plan", "Re-Energy Development 13.5 Plan / Guidance Opinion"

In December 2020, the National Energy Administration announced at its quarterly roundtable that it expects 120 GW of new wind and solar power capacity in 2021. China has indicated its targets of reducing CO_2 emissions per GDP by 65% from 2005 levels by 2030, increasing the ratio of non-fossil energy to primary energy consumption to 25%, and increasing its installed capacity of wind and solar power generation to more than 1,200 GW. Estimating according to these targets, 80 GW of solar power and more than 50 GW of wind power must be newly developed each year to achieve a non-fossil energy ratio of 20% in 2020-25. In addition, to raise the non-fossil energy ratio to 25% in 2026-30, 175 GW of solar power and more than 70 GW of new wind power will need to be newly developed each year.[63]

The outlook for China's power generation mix in the IEA's World Energy Outlook 2020 is as follows.

Table 60 Fuel Mix of Electricity Generation in China

	Stated Policies Scenario					
	Electricity generation (TWh)					
	2010	2018	2019	2025	2030	2040
Total generation	4 236	7 185	7 518	8 891	9 952	12 023
Coal	3 263	4 796	4 878	5 179	5 152	5 025
Oil	15	11	11	7	5	3
Natural gas	92	237	251	402	529	756
Nuclear	74	295	350	451	648	962
Renewables	791	1 846	2 029	2 852	3 618	5 277
Hydro	711	1 199	1 270	1 297	1 389	1 568
Bioenergy	34	104	128	229	289	390
Wind	45	366	406	725	979	1 545
Geothermal	0	0	0	1	2	12
Solar PV	1	177	224	597	944	1 722
CSP	0	0	2	3	14	39
Marine	0	0	0	0	1	2

Source: World Energy Outlook 2020, IEA

63 China Energy Network, December 24, 2020, https://www.china5e.com/news/news-1106860-1.html

(3) Current status and targets of electricity access (only for countries with poor access)

According to the IEA's Electricity Access Database, 99% of the population in both urban and rural China has access to electricity.

(b) Electric utility system

(1) Electricity supply system (major players, status of deregulation of power generation, transmission and distribution, etc.)

Currently, the power generation sector consists of five major power generation companies (Huaneng Group, Datang Group, Huadian Group, Guodian Group, and China Power Investment), a dozen or so large state-owned power companies, 1,200 thermal power companies, 1,200 hydroelectric power companies, 7 nuclear power companies, and 500 other power companies.[64] The reorganization of state-owned enterprises under the jurisdiction of the central government is underway, and in August 2017, the merger of Guodian Group, one of the five largest power companies, and Shenhua Group, a major coal company, was decided.[65]

The power transmission and distribution sector has three levels: the national power grid, the main regional power grid, and the provincial power grid, and "west-to-east power transmission," "north-south mutual supply," and "national power grid interconnection" are implemented. The State Grid Corporation purchases power from Russia and transmits power mainly to the North, Northeast, and Central China Power Grids.

(2) Renewable electricity supply system

The major players in renewable electricity are not yet to be investigated.

The method of selling/purchasing renewable electricity is also yet to be investigated.

(c) Policy on renewable energy

(1) Potential of renewable energy

China has high solar energy potential in inland areas. China's solar energy capacity as of 2019 ranks first in the world with a 35% share, and the amount of electricity it generates also ranks first in the world with a 30% share. It is no exaggeration to say that Chinese PV panels are dominating the world.

Table 61 Solar Power Generation Capacity and Generatred Elecricity in China (2019)

Country		Capacity (MW)		Generation (GWh)	
China	Photovoltaic	205,072	(35.4%)	170,062	(30.9%)
	Concentrated solar power	421	(6.7%)		
	Total	205,493	(35.1%)	170,062	(30.3%)

Note: Figures in parentheses are global market shares.
Source: RENEWABLE ENERGY STATISTICS 2020, IRENA

64 JAPAN ELECTRIC POWER INFORMATION CENTER, March 2015
65 Kyodo News, August 29, 2017

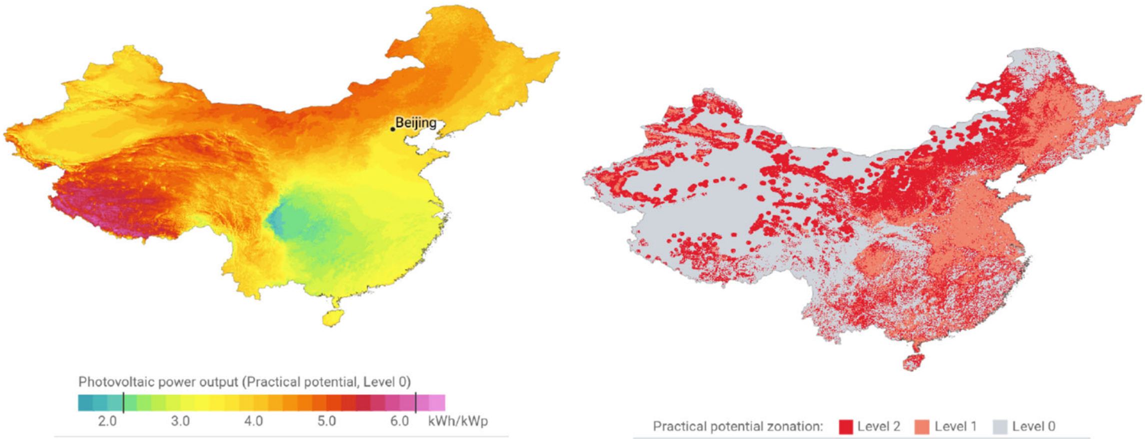

Figure 46 Solar Power Generation Potential in China

Note: Left = estimated power generation.
Right = potential zones; Level 0 = no constraints, Level 1 = excluding topographic constraints, Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

China has high potential for wind energy in inland areas. As of 2019, China's wind power capacity is the largest in the world with a 34% share, and the amount of electricity it generates also is the largest in the world with a 29% share.

Table 62 Wind Power Generation capacity and Generated Electricity in China (2019)

Country		Capacity (MW)	Generation (GWh)
China	Onshore	204,548 (34.4%)	357,340 (29.9%)
	Offshore	5,930 (21.1%)	9,112 (13.4%)
	Total	210,478 (33.8%)	366,452 (29.0%)

Note: Figures in parentheses are global market shares.
Source: RENEWABLE ENERGY STATISTICS 2020, IRENA

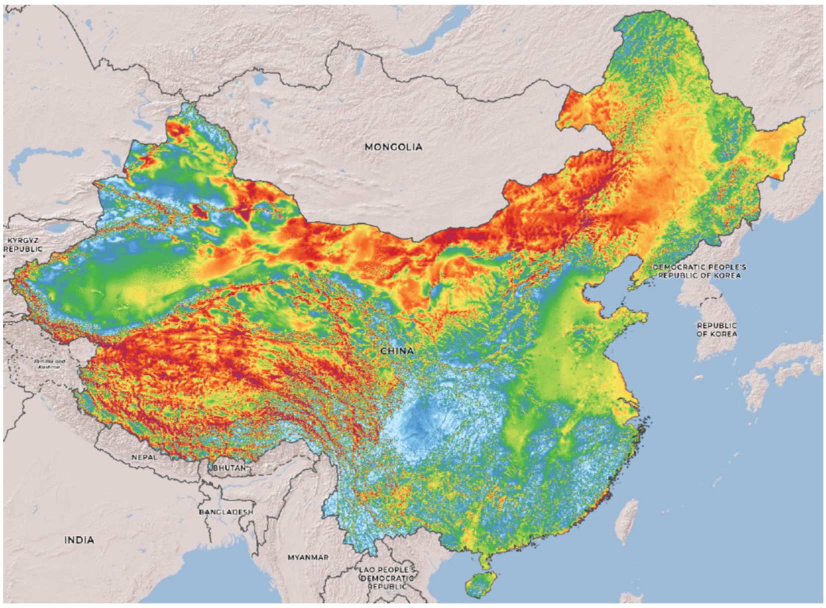

Figure 47 Wind Power Generation Potential in China

Note: The mean wind speeds shown are the representative values at the elevation of 50 m. Red color indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The agency in charge of renewable energy policy is the National Energy Administration.

(3) Development targets

In July 2017, the National Energy Administration issued the Guiding Opinion on Implementation of the 13th Renewable Energy Development Five Year Plan. In addition to explaining the path of development of renewable energies, the Administration announced the three documents: "New Construction Plan for Wind Power," "New Construction Plan for Photovoltaic Power," and "Composition of the 13th Five-Year Plan for Biomass Energy Development" for 2017-2020, specifying the scale of development of each power source for the four-year period from 2017 to 2020. With this announcement, the amount of renewable energy development in the 13th Five-Year Plan has been revised significantly upward.[66]

In December 2020, the National Energy Administration announced at its quarterly roundtable that it expects 120 GW of new wind and solar power capacity in 2021. China has indicated its targets of reducing CO_2 emissions per GDP by 65% from 2005 levels by 2030, increasing the ratio of non-fossil energy to primary energy consumption to 25%, and increasing its installed capacity of wind and solar power generation to more than 1,200 GW. Estimating according to these targets, 80 GW of solar power and more than 50 GW of wind power must be newly developed each year to achieve a non-fossil energy ratio of 20% in 2020-25. In addition, to raise the non-fossil energy ratio to 25% in 2026-30, 175 GW of solar power and more than 70 GW of new wind power will need to be newly developed each year.[67]

(4) Introduction promotion policy

A renewable energy use quota (RPS) system was introduced for power generators. The system mandates operators with a concession capacity (installed capacity of 100% owned power plants + installed capacity of power plants invested in × investment ratio) of 5 GW or more to increase the ratio of installed renewable energy capacity (other than hydro) to total power generation capacity to 3% by 2010 and to 8% or more by 2020.[68]

In March 2016, the National Development and Reform Commission of the People's Republic of China (NDRC) issued the Management Method for the Purchase of All Guaranteed Renewable Energy Power Generation to improve the utilization rate of renewable energy, under which wind and solar power generation was divided into the guaranteed purchase portion and market trading portion, and the government set annual guaranteed operating hours and required power grid companies to purchase such power generation.[69]

In November 2019, the National Energy Administration released the Law on Guaranteeing Purchase of All Renewable Energy by Electric Grid Enterprises. This is to guarantee purchase of all electricity generated under government approval from non-hydro renewable energy sources such as wind, solar, biomass, geothermal, and marine energy, excluding market traded electricity. If the grid company does not purchase such electricity, the grid company must immediately provide the renewable energy power price subsidy to the relevant renewable energy company.

In January 2020, China's Ministry of Finance announced that it would stop providing subsidies for new offshore wind and concentrating solar power generation projects and begin trading green certificates in 2021. The policy is to encourage increased consumption of clean energy by increasing income for renewable energy providers and increasing costs for those with high greenhouse gas emissions.[70]

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[66] The national energy administration, July 19, 2017

[67] Energy Information And Consulting Service Provider, December 24, 2020, https://www.china5e.com/news/news-1106860-1.html

[68] JAPAN ELECTRIC POWER INFORMATION CENTER, March 2012

[69] National Energy Administration, March 28, 2016

[70] Reuters, January 23, 2020, https://jp.reuters.com/article/china-renewables-subsidy-idJPKBN1ZM0W7

(d) Energy conservation policy

(1) Institutions in charge of policy

The agency in charge of energy conservation policy is the National Energy Administration.

(2) Targets

The revised Energy Conservation Law went into effect on April 1, 2008.

In January 2017, the State Council released the 13th Five-Year Comprehensive Energy Conservation and Emission Reduction Plan, which outlined national energy conservation and emission reduction efforts. Specifically, by 2020, energy consumption per 10,000 yuan of GDP was to be reduced by 15% from the 2015 level, and total energy consumption was to be controlled to be not more than 5 billion tons of standard coal equivalent. In addition, to reduce the environmental burden, the government was to promote the optimization of the industrial structure and energy structure, and develop low-carbon industries such as eco-cars, new energy, energy conservation and environmental protection to the scale of 10 trillion yuan as one of the strategic emerging industries that would be the new pillars of the economy.[71]

In December 2016, the National Energy Administration released the 13th Five-Year Plan for Energy Development and announced a target to reduce the average coal consumption of all thermal power plants below 310 g/kWh in 2020 in order to achieve energy conservation and environmental impact reduction through reduced coal consumption.[72]

China achieved its 13th Five-Year Plan's targets for ultra-low emission and energy-saving revamps of coal-fired power generation two years ahead of schedule, and built the world's largest clean coal-fired power generation system. China has been promoting ultra-low emission and energy-saving revamp projects for coal-fired power generation since 2014, and completed ultra-low emission revamps on a cumulative total of 700 GW of facilities by the third quarter of 2018. As for energy-saving revamps, China completed it for a total of 650 GW.[73]

(3) Promotion policy

In China, energy conservation policies are spelled out in five-year plans.

Major energy-saving initiatives in the 13th Five-Year Plan are:

- ✓ accelerate the elimination of lagging production capacity;
- ✓ Implement priority projects for energy conservation and emissions reduction;
- ✓ Implement nationwide energy conservation action plans;
- ✓ Develop a multitude of actions for priority energy use units;
- ✓ Act as a pioneering energy efficiency leader;
- ✓ Conduct energy conservation pilot tests for public institutions.

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

China submitted its INDC to the United Nations Framework Convention on Climate Change (UNFCCC) in June 2015. The main contents are:

- ✓ peak out CO_2 emissions by 2030;
- ✓ reduce CO_2 emissions per GDP by 60-65% relative to 2005 levels;
- ✓ increase the share of non-fossil fuels in primary energy to about 20%;
- ✓ increase forest stocks by 4.5 billion m^3 to 2005 levels.

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71 Xinhua News Agency, January 6, 2017

72 NDRC, December 2016, http://www.ndrc.gov.cn/gzdt/201701/W020170117348373245462.pdf#search=%27%E8%83%BD%E6%BA%90%E5%8F%91%E5%B1%95%E5%8D%81%E4%B8%89%E4%BA%94%E8%A7%84%E5%88%92%27

73 Energy Information And Consulting Service Provider, February 123, 2019, https://www.china5e.com/news/news-1051454-1.html

In September 2016, the Chinese government ratified the Paris Agreement.

In November 2016, China's State Council released a Work Plan for Controlling Greenhouse Gas Emission During the 13th Five-Year Plan Period, presenting a work plan for reducing CO_2 and other greenhouse gases over the next five years. The overall goal is to reduce CO_2 emissions per GDP by 18% from 2015 levels.

In December 2020, President Xi Jinping announced at a United Nations conference on climate change China's goal of reducing CO_2 emissions per GDP by at least 65% by 2030 compared to 2005 levels. President Xi also stated that the ratio of non-fossil energy to primary energy consumption would be raised to around 25%, the amount of energy stored by forests would be increased by 6 billion m^3 from 2005 levels, and wind and solar power generation capacity would be increased to more than 1,200 GW.[74]

In December 2020, the Central Economic Work Conference was held and President Xi Jinping called for the promotion of decarbonization in the 14th Five-Year Plan, which would start the following year, with the goal of peaking CO_2 emissions by 2030 and achieving carbon neutrality by 2060. President Xi also instructed control of energy consumption by adjusting the industrial structure, promoting energy structure reform, curbing coal consumption, developing new energy sources, and building a national carbon market.[75]

(2) Promotion policy

[Emission trading]

Since 2011, China has promoted emission trading model projects in seven provinces and cities: Beijing, Shanghai, Tianjin, Chongqing, Hubei, Guangdong, and Shenzhen. According to Li Gao Si, head of the Department of Climate Change at the Ministry of Ecology and Environment, by March 2021, nearly 3,000 key emitting companies in more than 20 industries will be covered, with a cumulative trading volume of 440 million tons. The transaction value was 10.47 billion yuan.[76]

In December 2020, the Ministry of Ecology and Environment announced the Measures for the Administration of National Carbon Emission Trading (Trial), which would become the regulations for the greenhouse gas emissions trading system. A nationwide unified greenhouse gas emissions trading market will be launched, leading to the realization of a decarbonized society that will reduce greenhouse gas emissions to virtually zero by 2060. The effective date was February 1, 2021. The types of greenhouse gases and target industries dealt in the emissions trading market will be determined by the Ministry of Ecology and Environment, and will be announced as soon as determined. In addition, companies with high emissions are listed as "key emission entities" and are required to report regularly on their emissions and the scale of their transactions. Key emission entities are:

- ✧ industries specified by the national emissions trading market;
- ✧ companies with annual emissions of more than 26,000 tons-CO_2.

Emission quotas are determined by the Ministry of Ecology and Environment based on economic growth, industrial structure, energy structure, and other factors, and distributed to each region. Each region then allocates quotas to key emission entities.[77]

(3) Transportation

Since 2009, policies have been implemented in China to promote new energy vehicles (NEV)

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74 Energy Information And Consulting Service Provider, December 14, 2020, https://www.china5e.com/news/news-1106019-1.html

75 Energy Information And Consulting Service Provider, December 21, 2020, https://www.china5e.com/news/news-1106535-1.html

76 Jetro, 2021 年 6 月 3 日、https://www.jetro.go.jp/biznews/2021/06/b2380d09243a2971.html

77 State Council of the People's Republic of China, December 31, 2020, http://www.gov.cn/zhengce/zhengceku/2021-01/06/content_5577360.htm

and the development of related industries. NGVs are defined by the Chinese government as three types: electric vehicles (EV), plug-in hybrid vehicles (PHV), and fuel cell vehicles (FCV).

China has introduced a subsidy policy to promote NGVs. In 2010, under the leadership of the government, subsidies were also started to be issued to individuals who purchased, registered, and owned EVs and PHEVs in five cities: Shanghai, Changchun, Shenzhen, Hangzhou, and Hefei. Since 2012, new energy vehicles have been exempted from automobile purchase tax in addition to subsidies. The subsidy provided by the government was originally scheduled to end in 2020, but has been extended until the end of 2022.

In November 2020, the General Office of the State Council of China announced the New Energy Automobile Industry Development Plan (2021-2035). The "Development Plan" sets goals to raise the percentage of NGVs in new vehicle sales from the current 5% to around 20% by 2025, and to make EVs the mainstay of new vehicle sales by 2035. As measures to achieve the goals, (1) improvement of technological innovation capacity, (2) construction of a new industrial ecosystem, (3) promotion of industrial integration, (4) strengthening of infrastructure development, and (5) deepening of openness and cooperation were indicated.[78]

(Hydrogen)

Vehicle emission regulations are also yet to be investigated.

In its White Paper on China's Hydrogen Energy and Fuel Cell Industry, the China Hydrogen Energy Alliance predicted, "During 2020-25, China's hydrogen energy industry output will reach 1 trillion yuan, hydrogen fuel cell vehicles will reach 50,000, and hydrogen stations will reach 200. During 2026-35, the output will reach 5 trillion yuan, hydrogen stations will reach 1,500, and hydrogen fuel cell vehicles will reach 15 million."[79]

According to statistics from the Orange Group Research Institute, as of the end of December 2020, China has built 118 hydrogen stations and has built/plans to build 167 stations. The number of new hydrogen stations built in 2020 was 47. This exceeded the goal of "100 hydrogen stations by 2020" in the Energy Saving and New Energy Vehicle Technology Roadmap.[80]

(4) Urban development

With regard to smart city promotion plans, in China, smart cities are being promoted as part of the national development strategy. The concept was approved by President Xi Jinping in 2015 and explicitly included in the 13th Five-Year Plan (2016-2020). The central government is promoting smart city development across China, with a total of 500 smart city projects in the preparation stage or under construction as of January 2019.[81]

(f) Next generation technology, innovation

(1) Introduction targets

(Battery)

In 2015, the Chinese government launched the policy of "automotive power battery industry standard conditions". The condition lists the battery manufacturers that can be installed in EVs, and only EVs that use batteries from the manufacturers on this list are eligible to receive subsidies at the time of purchase. The list of battery manufacturers was published four times in 2016, but none of the 57 listed were foreign companies. As a result, Chinese manufacturers such as CATL and BYD have emerged as global battery manufacturers.

However, in June 2019, the "automotive power storage battery industry standard conditions"

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78 Mizuho Research & Technologies, December 15, 2020, https://www.mizuho-rt.co.jp/publication/mhri/research/pdf/china-bri/cb201215.pdf

79 People.cn, October 9, 2020, http://japanese.china.org.cn/business/txt/2020-10/09/content_76789150.htm

80 Energy Information And Consulting Service Provider, January 6, 2021, https://www.china5e.com/news/news-1107550-1.html

81 ISS, May 14, 2020, https://www.iss.europa.eu/content/towards-urban-decoupling-china’s-smart-city-ambitions-time-covid-19

were abolished, allowing EV manufacturers to use batteries made by foreign manufacturers.

There are the following support measures for battery factories in China.

Income tax rate reduction (25% → 15%) for companies that meet certain criteria

Various support measures by local governments

At the automotive battery industry forum held in July 2022, Mr. Ouyang Minggao, a professor at Tsinghua University and a member of the Chinese Academy of Sciences, the highest research institute under the direct control of the Chinese government, explained the global shipment volume of automotive batteries. predicted to exceed 1TWh in 2023. Furthermore, in 2025, he expects China shipments alone to surpass 1TWh.

(hydrogen)

In March 2016, the NDRC and the National Energy Administration released the Innovation Action Plan of Energy Technological Revolution (2016-2030). It stated China would develop technologies for mass production and storage of hydrogen, transportation, and technologies related to hydrogen stations.[82] In addition, the China National Institute of Standardization and the China Electric Appliance Industry Association released the Blue Book on China Hydrogen Energy Industry Infrastructure Development (2016). A roadmap from 2020 to 2050 was presented.

2020: Hydrogen production capacity of 72 billion m^3/year, 100 hydrogen stations
200 MW fuel cell power generation, 10,000 fuel cell vehicles

2030: Hydrogen production capacity of 100 billion m^3/year, more than 1,000 hydrogen stations
100 GW fuel cell power generation, 2 million fuel cell vehicles

2050: Hydrogen energy is a key component of the energy mix
Hydrogen industry grows to one of the key industries in Chinese manufacturing,
10 million fuel cell vehicles[83]

(2) Development status of laws and regulations

(Safety of EV)

In May 2020, the Ministry of Industry and Information Technology formulated the "Electric Vehicle Power Storage Battery Safety Requirements", "Electric Vehicle Safety Requirements" and "Electric Bus Safety Requirements", which were approved by the State Administration for Market Supervision and the National Standardization Administration. , applicable from January 2021. These three standards were formulated based on current relevant recommended national standards. In accordance with the United Nations Global Technical Regulations for Vehicles (GTR), which is said to have been led by China, the safety technology requirements for EVs and in-vehicle direct batteries have been strengthened and optimized.[84]

(Safety of hydrogen)

At present, technical standards, laws and regulations, and policy systems that support the development of China's hydrogen energy industry are still underdeveloped, and some point out that they are hindering the development of the industry.[85]

(3) Status of research and development of technologies

The following five basic decisions were compiled for the development of the hydrogen industry in the 14th Five-Year Plan.

- ✓ The hydrogen energy industry is in its early stages, and the 14th Five-Year Plan will bring new opportunities for development. The cost of hydrogen production will be significantly

82 NDRC, March 2016, https://www.ndrc.gov.cn/fggz/fzzlgh/gjjzxgh/201706/t20170607_1196784.html

83 Battery China net, November 18, 2016, http://www.cbea.com/html/www/xnyqc/201611/ff808081582e4546015842287342030a.html

84 Ashu Business, May 14, 2020, https://ashu-chinastatistics.com/news/603595-86404813060

85 The Japan Research Institute, June 8, 2021, https://www.jri.co.jp/page.jsp?id=39034

lowered, and the groundwork for the development of the hydrogen industry will be laid.

- ✓ The government subsidy policy will be continued and extended to speed up the cost reduction of hydrogen energy in transportation rates.
- ✓ Hydrogen stations will be developed on a large scale and constructed primarily by state-owned capital. In some areas, gas stations and hydrogen stations will be shared, and profits from gasoline sales will be used to supplement hydrogen station operations.
- ✓ Research and development in the county will be promoted in order to reduce fuel cell prices.
- ✓ The use of hydrogen is to be expanded, and its application in other areas such as natural gas will be promoted.[86]

In September 2020, the Ministry of Finance announced that it would focus on the development of hydrogen fuel cell vehicles and deploy new support measures to strengthen the industry's supply chain and improve technology. While the current policy supports NEV manufacturers in the form of sales subsidies, the new policy will focus on supporting companies that have or are developing breakthrough technologies. The emphasis will be on supporting the development of heavy-duty trucks and other long-haul transport vehicles. In addition, local governments are encouraged to work with local businesses to develop the hydrogen fuel cell vehicle industry to build a more mature supply chain.[87]

In September 2020, China Petrochemical Corporation (Sinopec) announced that its subsidiary, Sinopec Shanghai Gaoqiao Petrochemical Corporation, had begun operating a test production facility for high-purity hydrogen for fuel cell vehicles (FCVs).

In December 2020, the State Council of China released a white paper titled "Energy in China's New Era." The white paper explained that China is promoting the transformation of its energy consumption system and building a multi-sourced clean energy supply system. It said that the country is implementing an innovation-driven development strategy, constantly deepening the reform of its energy system, and continuously promoting international cooperation in the energy sector. It also said that China will promote the development of clean low-carbon energy, actively participate in global energy governance, and seek new ways to accelerate the sustainable development and promotion of global energy together with other countries.[88]

(4) Bangladesh

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

Bangladesh has experienced significant economic growth in recent years, with real GDP growth rates of approximately 5-8% since 2000. The real GDP growth rates have been steadily increasing especially from FY 2013 to FY 2019, and recorded the all-time high (8.2%) in FY 2019. During that time, primary energy supply has more than doubled. The country has natural gas reserves and has responded to the increasing demand for primary energy and electricity by utilizing natural gas. In recent years, however, with the increase in demand for natural gas and the depletion of natural gas fields, it has become impossible to meet domestic demand for natural gas through domestic production. To this end, the government is promoting measures to promote natural gas development, develop infrastructure for LNG imports, and expand the use of renewable energy.

In terms of power generation, gas-fired thermal has been the main source of power, and in recent years, the use of oil-fired thermal power has been promoted. In the future, it is envisioned that oil-fired power generation will be reduced and gas- and coal-fired power generation, as well as electricity imports, will be the main sources of power to meet the expected further increase in

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[86] Energy Information And Consulting Service Provider, June 5, 2020, https://www.china5e.com/news/news-1091152-1.html

[87] Reuters, September 7, 2020, https://www.reuters.com/article/us-china-autos-hydrogen/china-to-roll-out-new-supportive-policies-for-hydrogen-fuel-cell-vehicles-official-says-idUSKBN25W07V

[88] Xinhua News Agency, December, 2020, http://jp.xinhuanet.com/2020-12/22/c_139608632.htm

electricity demand. However, although coal was previously regarded as an important energy source to replace natural gas, public sentiment has grown stronger, and the current policy is to place limits on the amount of coal-fired power development in the future. Regarding electricity imports, the country currently imports from India and is considering importing clean electricity generated by hydroelectric power from Bhutan and Nepal in the future.

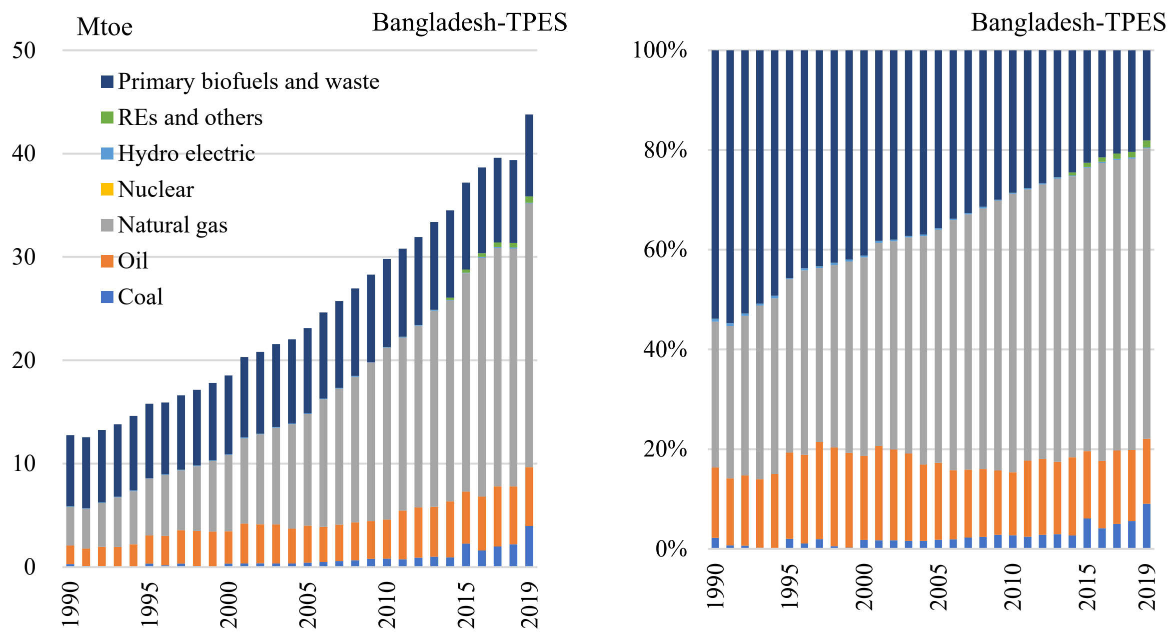

Figure 48 Primary Energy Supply in Bangladesh

Source: World Energy Balances 2021 extended edition database, IEA

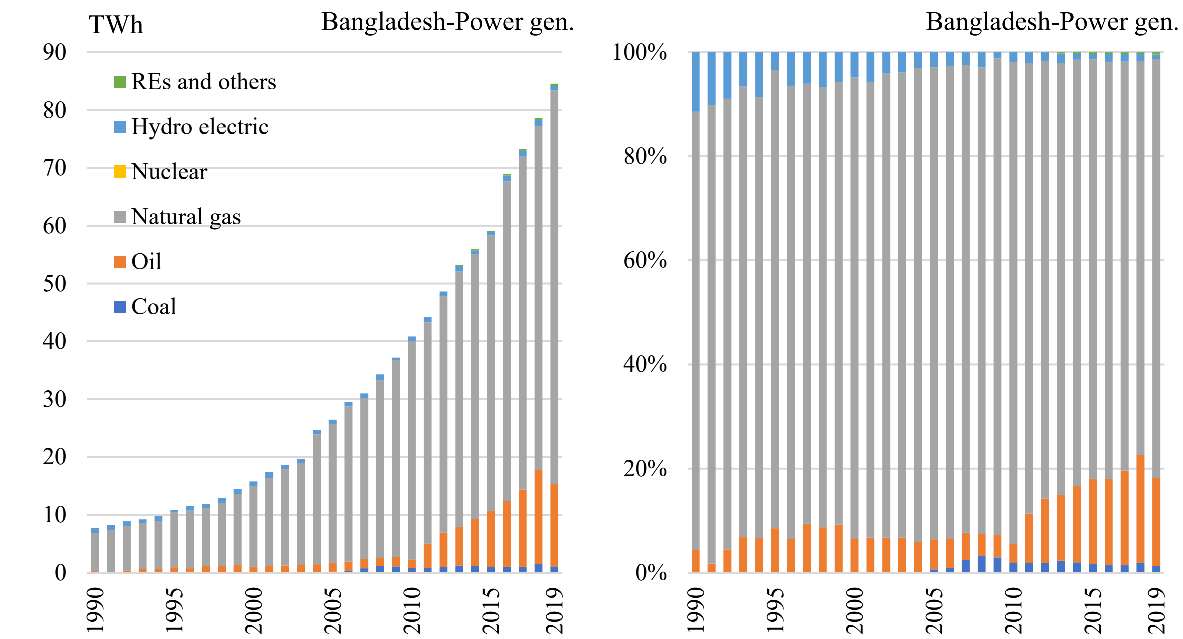

Figure 49 Fuel Mix of Electricity Generation in Bangladesh

Source: World Energy Balances 2021 database, IEA

A breakdown of final energy consumption by sector shows that, in 2019, consumption was the largest in industry at 43%, with transportation 16%, residential 27%, and commercial/public services 3%. The five-year growth from 2014 to 2019 was 11.4% for industry, the primary energy consumer, followed by commercial/public services at 11.4% as well and residential at 10.3%.

Industry mostly uses coal, natural gas, and electricity, with coal use in particular on the rise. Bangladesh's main industry is the clothing and sewn product industry, and energy consumption has been increasing in recent years as Chinese and other foreign companies have been transferring their production bases.[89] In addition, the country is focusing on the development of special economic zones to promote industrialization through attraction of new industries.[90] In Bangladesh, in-house power generation is used well because the price of natural gas for in-house power generation is set at a low level, making it cheaper than purchasing electricity from the grid. Energy efficiency and energy conservation measures in major industries where energy consumption is expected to increase will be necessary in the future.

In the transportation sector, 74% was oil and the remaining 26% was natural gas (2018). Currently, energy consumption is low in the sector, but future economic growth and rising incomes are expected to increase automobile use. It is said that when GDP per capita exceeds $3,000, motorization will accelerate and automobile penetration will increase, and according to IMF assumptions, Bangladesh's GDP per capita will approach $3,000 by the late 2020s.[91] In other words, there is a possibility of a rapid increase in automobile penetration in subsequent decades and an associated increase in GHG emissions. As indicated in the NDC submitted in August 2021, various measures to improve fuel efficiency of automobiles, a modal shift from automobiles to public transportation, and widespread use of hybrid and electric vehicles in the future will be likely necessary.

In the residential sector, the use of natural gas is the main source of electricity, while the use of electricity is gradually increasing. The reality is that biomass, mainly firewood, is widely used for cooking purposes, especially in rural areas, causing environmental pollution and health hazards. For the time being, improvement is expected to be made through the measures that have been promoted, such as the policy to electrify by introducing the Solar Home System (SHS) and mini-grids using renewable energy, introduction of efficient gas cooking stoves, and replacement of biomass with LPG. In the future, there may arise a need for systematic development of power grids. Consumption in the commercial/public services sector is currently negligible.

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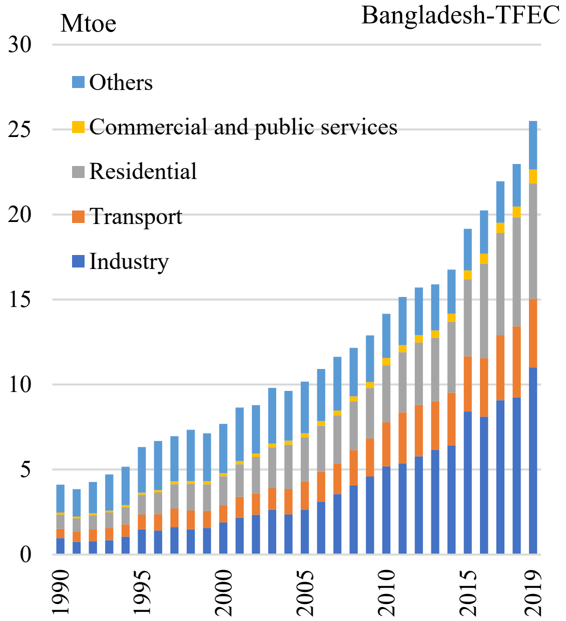
89 JETRO, May 31, 2019, https://www.jetro.go.jp/biznews/2019/05/a32f12196547b3e1.html

90 Bangladesh Economic Zone Authority, https://www.beza.gov.bd/investing-in-zones/incentive-package/

91 IMF, World Economic Outlook Database, April 2021



Mtoe
Bangladesh-TFEC
30
25
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5
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Others
Commercial and public services
Residential
Transport
Industry
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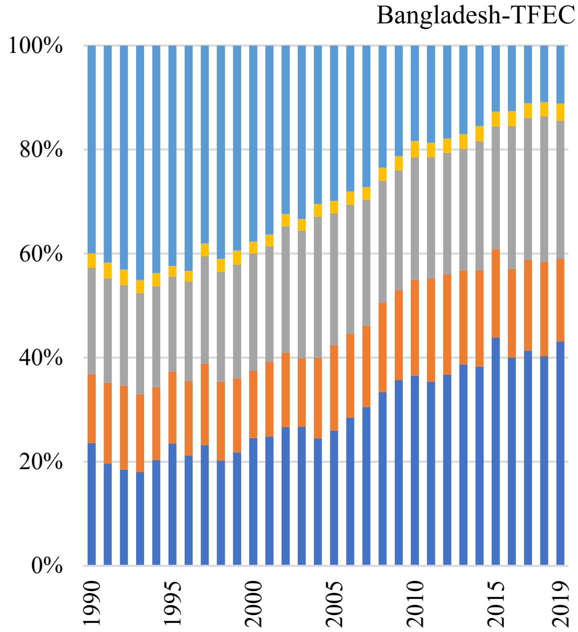
2015
2019



Bangladesh-TFEC
100%
80%
60%
40%
20%
0%
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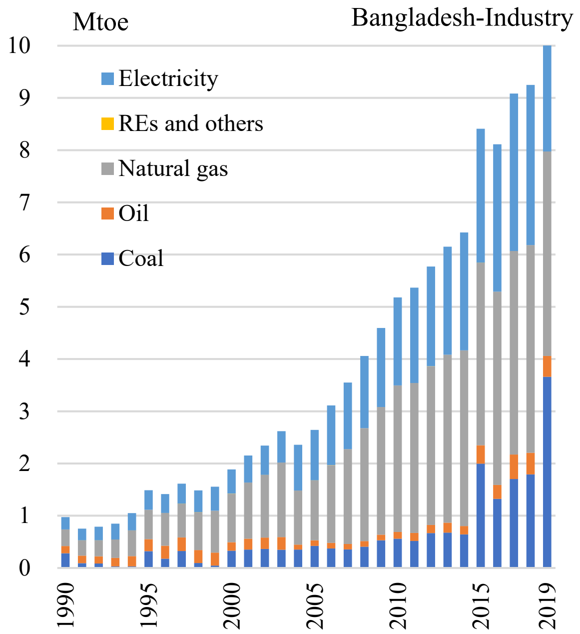
2019



Mtoe
Bangladesh-Industry
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7
6
5
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3
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Electricity
REs and others
Natural gas
Oil
Coal
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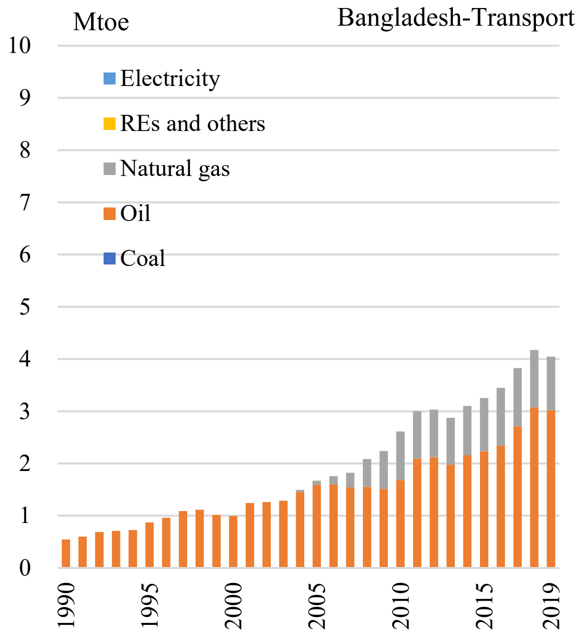

Mtoe
Bangladesh-Transport
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9
8
7
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Electricity
REs and others
Natural gas
Oil
Coal
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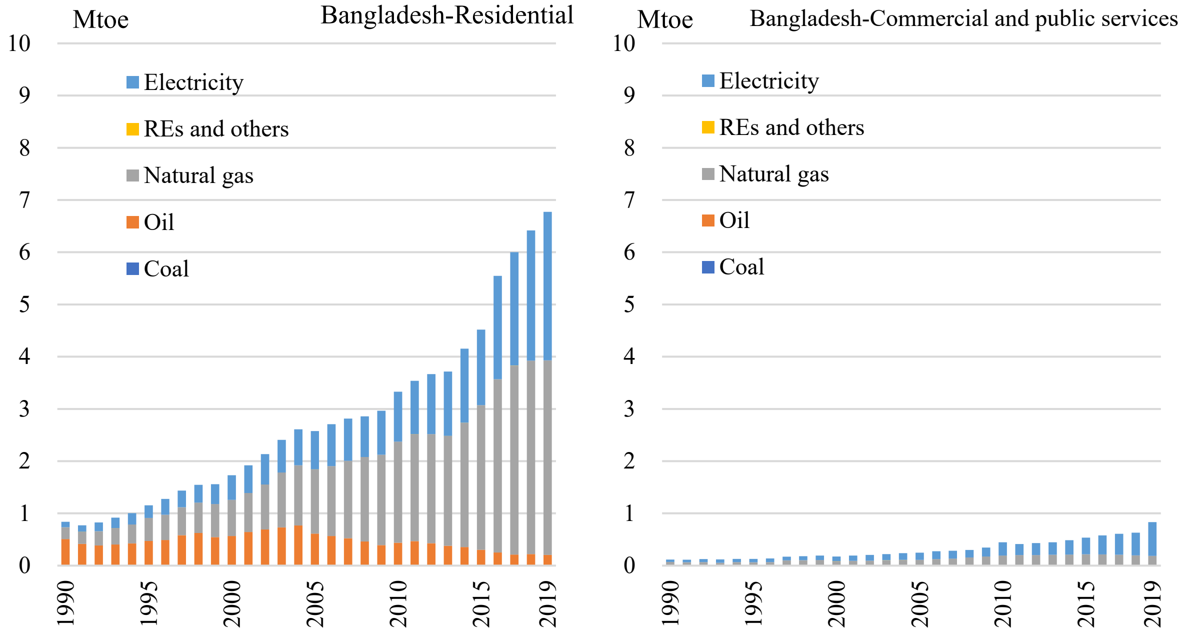

Figure 50 Final Energy Consumption of Major Sectors in Bangladesh

Excludes "Primary solid biofuels," "Non-specified primary biofuels and waste," and "Charcoal."
"Others" in TEFC includes agriculture, forestry, fisheries, other, and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP in Bangladesh has been slowly declining in recent years and was 0.167 toe/$1000 in 2019 (0.090 in Japan). Although this is a low figure among emerging economies, this is due to the low energy supply and the fact that the country's own gas resources had been the main source of supply. With energy consumption expected to increase rapidly in the future, various measures will be necessary.

The average thermal efficiency of gas-fired power plants is 41%, and that of coal-fired power plants is about 33%. Since thermal power generation is expected to be actively utilized in the future, CO_2 emissions may be reduced by replacing aging thermal power plants and building new high-efficiency thermal power plants. Meanwhile, in June 2021, the government halted plans to build 10 coal-fired power plants with a capacity of 9.3 GW due to financial difficulties and environmental concerns. Making the role of coal-fired power in the electricity mix a key in future low-carbonization and decarbonization of electricity.

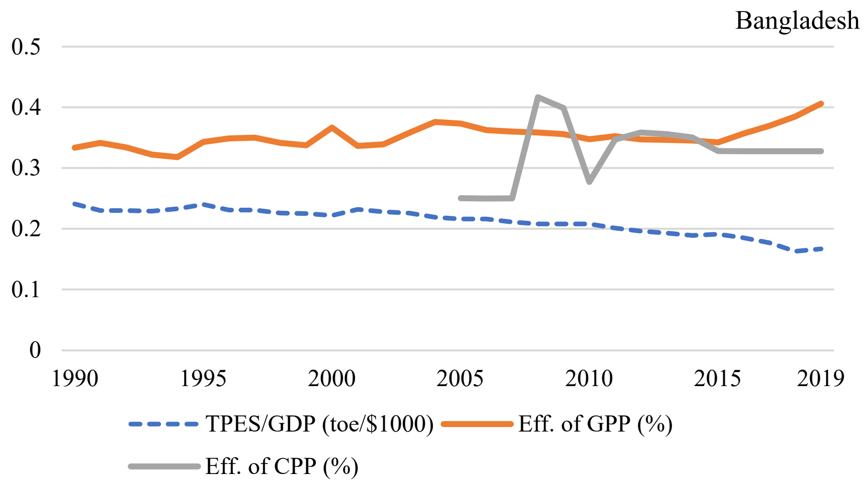

Figure 51 Energy Efficiency in Bangladesh

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant, CPP = coal power plant, GDP in

2015 price
Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options Bangladesh could take to reduce its CO_2 emissions in the future and their CO_2 reduction effects.

Table 63 Examples of Low-carbon/ Decarbonization Potential in Bangladesh

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		92.7 mton-CO2
	【Example of CO2 Emission Reduction Option】	【Reduction Effect】
Generation	Substitute 50% of Oil for Renewable Energy	4.66mton-CO2
Industry	Substitue 50% of Oil and Coal for Natural Gs	3.10 mton-CO2
Transport	Substitue 25% of Diesel Cars for NGV	0.69 mton-CO2
Residential	10% Improvement in Energy Efficiency	2.43 mton-CO2

Note: 2019 actual = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICA Study Team

(2) Primary energy mix and electricity mix planning
[Primary energy mix]
According to the Bangladesh Survey on Power System Master Plan (PSMP) 2016, primary energy demand will increase by an annual average of 4.8% between 2014 and 2041. The country has been relying on its abundant natural gas reserves for energy supply, but in order to cope with increasing demand for natural gas and the worsening natural gas field depletion issue, the country aims to promote natural gas development, develop infrastructure for LNG import, and expand the use of renewable energy. As a result, natural gas, which accounted for 57% of the total in 2014, is expected to decline to 38% in 2041, while coal is expected to increase from 3% in 2014 to 20% in 2041.[92]

Table 64 Primary Energy Supply Outlook of Bangladesh in 2041

Primary Energy Sources	2014		2041		Annual growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,728	(57%)	49,783	(38%)	3.3% p.a.
Oil (Crude oil + refined products)	6,060	(17%)	32,162	(25%)	6.4% p.a.
Coal	1,038	(3%)	25,401	(20%)	12.6% p.a.
Nuclear power	-	-	12,029	(9%)	-
Hydro, solar, wind power and others	36	(0%)	199	(0%)	6.6% p.a.
Biofuel and waste	8,449	(23%)	4,089	(3%)	-2.7% p.a.
Power (Export)	377	(1%)	6,027	(5%)	10.8% p.a.
Total	35,880	(100%)	131,151	(100%)	4.8% p.a.

Source: PSMP 2016

[Natural gas]
The GAS SECTOR MASTER PLAN BANGLADESH 2017 was published in 2018.[93] The

92 Power Division, "Bangladesh Survey on Power System Master Plan 2016", https://powerdivision.portal.gov.bd/sites/default/files/files/powerdivision.portal.gov.bd/page/4f81bf4d_1180_4c53_b27c_8fa0eb11e2c1/(E)_FR_PSMP2016_Summary_revised.pdf

93 Petrobangla, PowerCell, "GAS SECTOR MASTER PLAN BANGLADESH 2017", https://mpemr.gov.bd/assets/media/pdffiles/Bangladesh_GSMP_Final_Report.pdf

report is based on the PSMP 2016, but incorporates actual results since the PSMP 2016 was formulated and examines multiple gas demand scenarios. Scenario A (Modified PSMP2016) is a scenario in which large-scale coal-fired power development takes place with an emphasis on gas self-sufficiency, similar to the PSMP 2016; Scenario B (High Growth) is a scenario in which energy consumption accelerates and gas imports increase along with economic growth; and Scenario C (Climate Change) is a scenario in which coal-fired power decreases and gas-fired power and renewable energy increase from a climate change perspective. The Scenario A reflects growth in gas demand in the power generation sector compared to the assumptions in the PSMP 2016, as older gas-fired plants are not being decommissioned as expected, new coal-fired plants are being built more slowly, and cheaper LNG is being utilized.

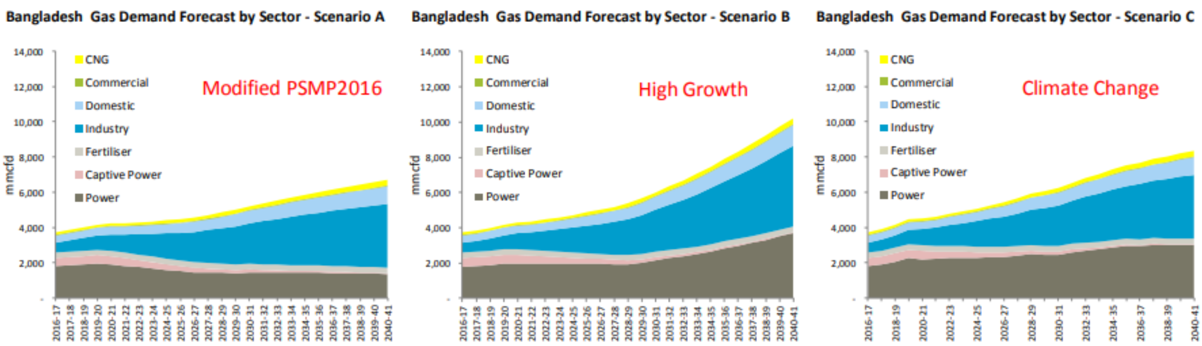

Figure 52　Gas Demand Outlook for Each Scenario up to 2041 in Bangladesh

Source: GAS SECTOR MASTER PLAN BANGLADESH 2017

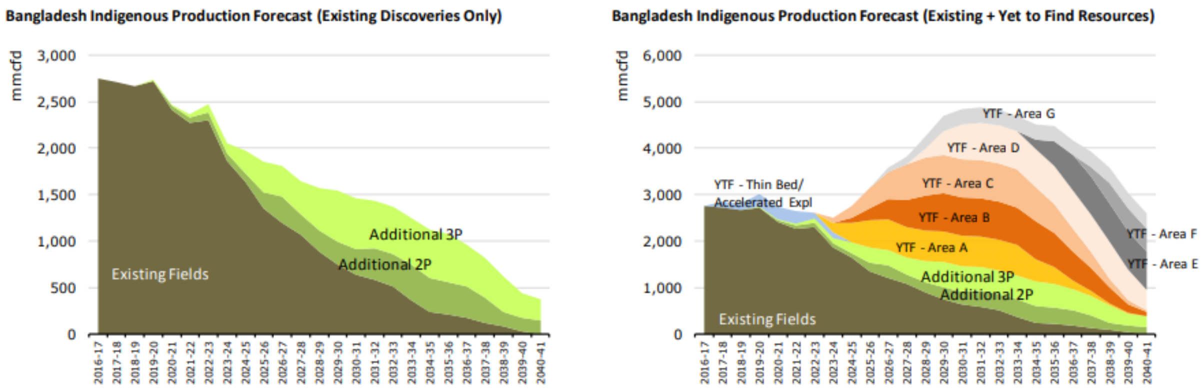

Figure 53　Domestic Natural gas Production Potential up to 2041 in Bangladsesh

2P＝Proven + Probable、3P＝Proven + Probable + Possible

Additional 2/3P is production that does not exist in the current development plan and may be added by future development.

Source: GAS SECTOR MASTER PLAN BANGLADESH 2017

As can be seen by comparing the gas demand assumptions (Figure 52) and the potential for domestic natural gas production (Figure 53), a large amount of gas imports will be required in the future, especially if no new gas fields are successfully developed. Figure 54 shows the gas supply-demand balance up to 2030 under Scenario C with moderate gas demand. If domestic gas field development is not successful, approximately 4,500 mmcfd of imports will be required in 2030.

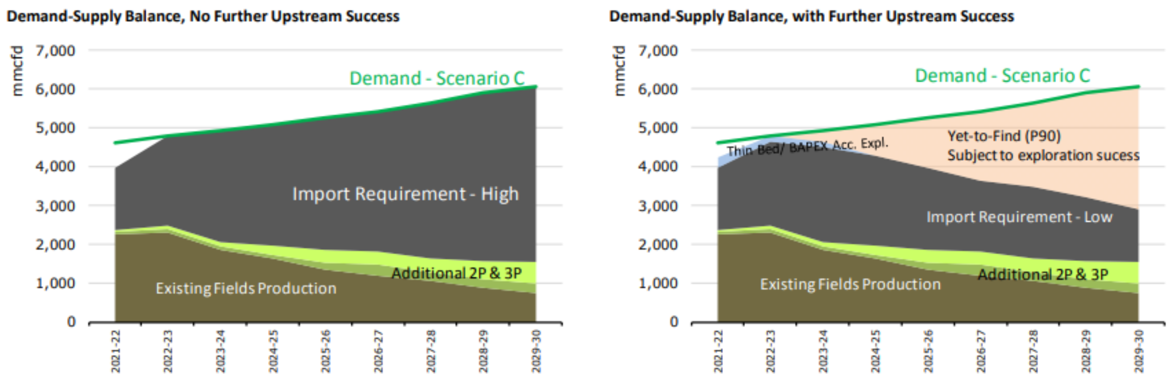

Figure 54 Gas Supply and Demand Balance by 2030 in Bangladesh (scenario C)

Source: GAS SECTOR MASTER PLAN BANGLADESH 2017

This situation has prompted Bangladesh to expand its LNG import facilities. Currently, two floating LNG storage and regasification units (FSRUs) are in operation, each with a rated capacity of 3.8 million tons per year. The first LNG imports from Qatar began in 2018, followed by imports from Omar in 2019. In 2020, LNG is being procured from the spot market for the first time. The construction of onshore LNG receiving terminals is also currently under consideration.[94] For topographical reasons, imports can only be made from Moheshkhali in the south, which is far from the demand area. The future challenge will be to expand the infrastructure from the import facilities to the consumption area (around Dhaka). Another option to address the gas shortage in Bangladesh is to import gas through a pipeline from Myanmar, and an expansion of the existing gas pipeline is planned.

Table 65 FSRU of Bangladesh in Operation

Location/ Shipowner	Gasification Capacity	Charterer	Operation
Moheshkhali/ Excelerate Energy	3.8 million ton/yr	Petrobangla	2018
Moheskhali/ Excelerate Energy	3.8 million ton/yr	Summit Power International	2019

Source: GIIGNL, Annual Report 2021[95]

In both cases of LNG imports and pipeline imports, supply costs are expected to be higher compared to the use of domestically produced gas. In that case, major challenges will be how to reflect the increase in supply costs on domestic gas prices and how to gain public understanding about it.

[Power mix]

For power generation, the Revisiting Power System Master Plan (PSMP) 2016,[96] published in 2018, provides assumptions and plans through 2041. Three cases are shown for peak demand: High, Base, and Low. In the Base case, peak demand is expected to increase from 10,707 MW in 2017 to 62,032 MW in 2041, a 5.8-fold increase. The power source mix (excluding renewable energy) is shown below for the High and Low cases, and it is assumed that the increasing power demand will be met by coal-fired power and electricity imports in addition to gas-fired power, which is currently the main source of energy (renewable energy is discussed below). Regarding

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[94] Tokyo Gas, January 29, 2021, https://www.tokyo-gas.co.jp/Press/20210129-01.html

[95] GIIGNL, Annual Report 2020, https://giignl.org/sites/default/files/PUBLIC_AREA/giignl_2021_annual_report_apr27.pdf

[96] https://solar.sreda.gov.bd/doc/Revisiting%20PSMP%202016%20(full%20report).pdf

electricity imports, Bangladesh currently imports 1,160 MW from India and is ready to import 500 MW of hydropower electricity from Nepal. Bangladesh is also reportedly having discussions with Bhutan on electricity imports.[97]

Table 66 Fuel Mix of Elecricity Generation Outlook by 2040 in Bangladesh (Generation Capacity, Share)

High Case	2025		2030		2035		2040	
	MW	%	MW	%	MW	%	MW	%
Coal	13,506	31	24,462	40	28,510	39	30,166	32
Gas/ LNG	18,143	42	22,803	37	28,924	39	40,661	43
Oil	7,157	17	5,894	10	2,096	3	2,186	2
Nuclear	1,116	3	2,232	4	4,464	6	6,696	7
Hydro	230	1	330	1	330	0.4	330	0.4
Imports	2,996	7	6,121	10	9,121	12	14,121	15

Low Case	2025		2030		2035		2040	
	MW	%	MW	%	MW	%	MW	%
Coal	9,913	25	17,969	34	23,940	37	25,596	32
Gas/ LNG	18,960	47	23,744	45	28,292	44	34,165	43
Oil	6,778	17	5,591	11	1,636	3	1,840	2
Nuclear	1,116	3	2,232	4	3,348	5	5,580	7
Hydro	230	0.6	230	0.4	330	0.5	330	0.4
Imports	2,996	8	3,496	7	7,496	12	11,996	15

Source: Revisiting Power System Master Plan (PSMP) 2016

(3) Current status and targets of electricity access

According to the IEA, the electrification rate of Bangladesh as of 2019 was 83%, with 93% in urban areas and 77% in rural areas.[98] In addition, the 8th Five Year Plan (July 2020 to June 2025), approved in December 2020, stated that the country had achieved an electrification rate of 97% as a 2020 result.[99]

(b) Electric utility system

(1) Electricity supply system

Under the jurisdiction of the Ministry of Power, Energy and Mineral Resources (MPEMR), the Power Division oversees the electric power business. Under its umbrella is the Bangladesh Power Development Board (BPDB), and power plants, IPPs, and private power producers, which are either divisionalized or spun off from BPDB, are engaged in power generation. As shown in figure below, DPDC, DESCO, REB, WZPDC, NESCO, and BPDB are responsible for the power transmission and distribution network, while in rural areas, rural electric cooperatives (PBS) supply electricity to consumers.

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[97] The Daily Star, 2019.11.22, https://www.thedailystar.net/business/news/500mw-be-bought-nepal- 1830388

[98] IEA, Access to electricity, https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

[99] General Economic Division, "8th FIVE YEAR PLAN JULY2020 - JUNE2025", http://www.plancomm.gov.bd/sites/default/files/files/plancomm.portal.gov.bd/files/68e32f08_13b8_4192_ab9b_abd5a0a62a33/2021-02-03-17-04-ec95e78e452a813808a483b3b22e14a1.pdf

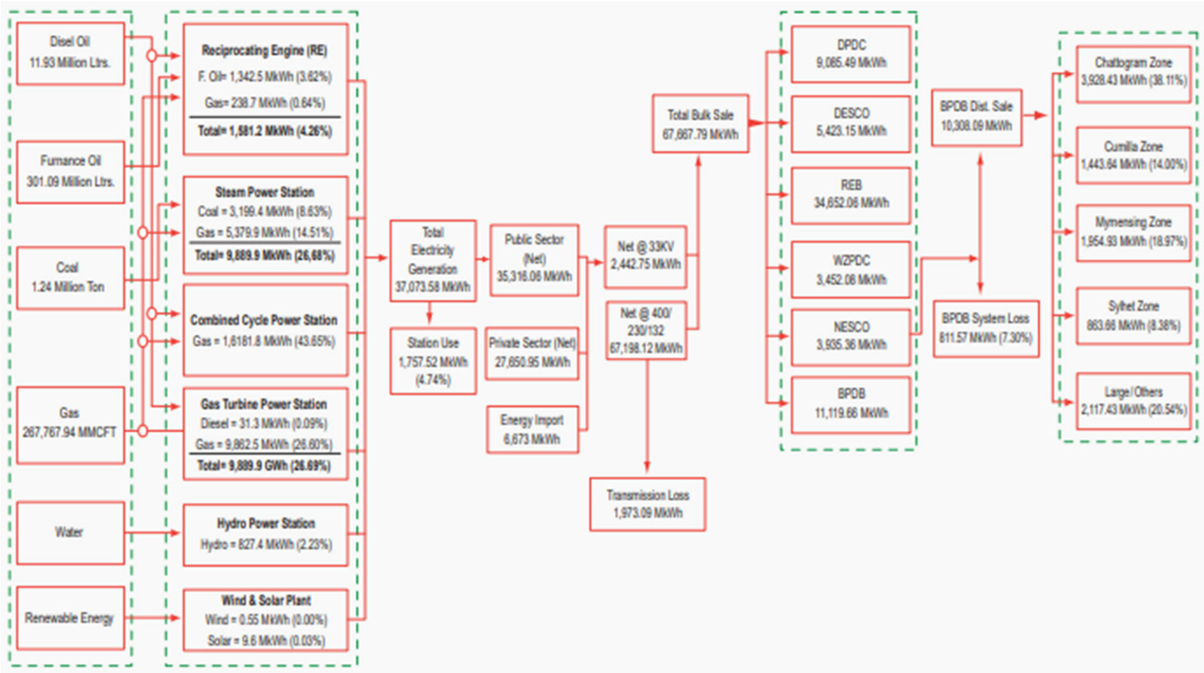

Figure 55 Electricity Supply Structure and Supplied Electricity in Bangladesh (FY2019)

DPDC: Dhaka Power Distribution Company Ltd.
DESCO: Dhaka Electric Supply Company Ltd.
REB: Rural Electrification Board
WZPDC: West Zone Power Distribution Company Ltd
NESCO:
BPDB: Bangladesh Power Development Board
Source: BPDB, Annual Report 2019-2020[100]

(2) Renewable electricity supply system[101]

The most of the renewable energy that is currently used is SHS in non-electrified areas. For SHS, the government agencies (SREDA and IDCOL) described below are developing various support programs with the assistance of international organizations. NGO-type operators such as Grameen and BRAC are responsible for setting up equipment on site.

There are three types of cases for large-scale projects such as solar parks: government-led, public-private partnership (PPP) with the government, and wholesale power projects (IPP) by the private sector. In the case of IPP, foreign companies from the U.S., China, Malaysia, Korea, and other countries often proceed in partnership with local companies.

(c) Policy on renewable energy

(1) Potential of renewable energy

As for photovoltaic power generation, there is potential with relatively good sunlight throughout the country. On the other hand, the potential for wind power is limited to certain areas, such as coastal areas.

[100] BPDB, Annual Report 2019-2020, https://www.bpdb.gov.bd/bpdb_new/resourcefile/annualreports/annualreport_1605772936_AnnualReport2019-20.pdf
[101] JICA report, August 2016, https://www.jica.go.jp/bangladesh/bangland/pdf/report-report24-renewable-energy.pdf[102] SREDA, http://www.sreda.gov.bd/

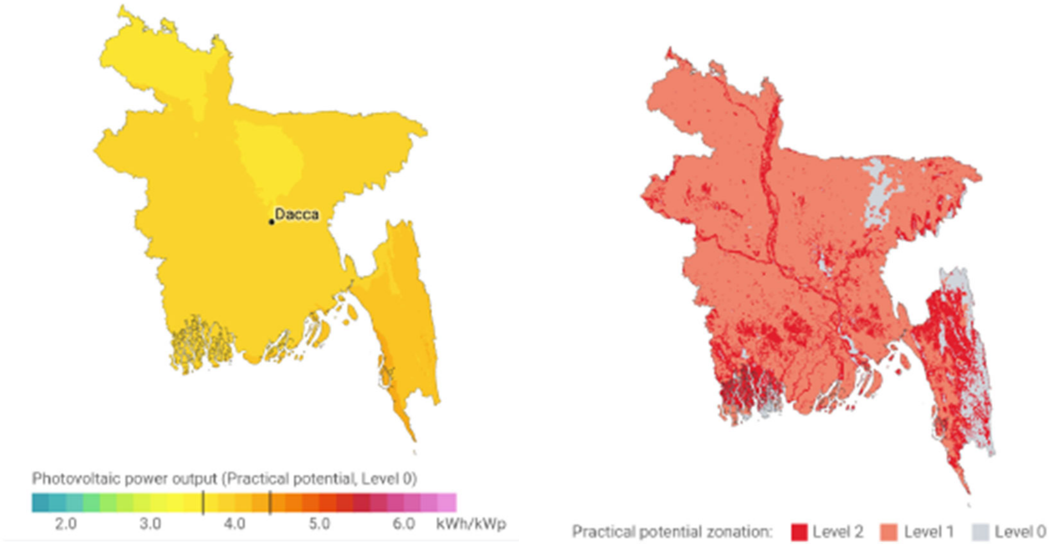

Figure 56 Solar Power Generation Potential in Bangladesh

Note: Left = estimated power generation.
Right = potential zones; Level 0 = no constraints, Level 1 = excluding topographic constraints, Level 2 = excluding topographic and regulatory constraints.

Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

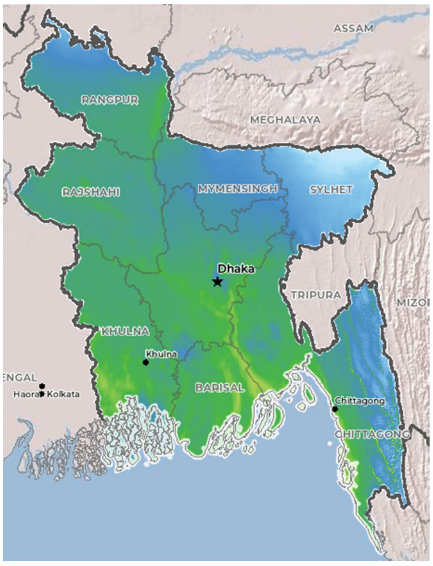

Figure 57 Wind Power Generation Potential in Bangladesh

Note: The mean wind speeds shown are the representative values at the elevation of 50 m. Red color indicates the fastest wind speed.

Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The MPEMR is responsible for energy policy. Under its subordinate Power Division, the Sustainable and Renewable Energy Development Authority (SREDA)[102] is responsible for renewable energy and energy conservation policy. The Infrastructure Development Company (IDCOL) and Bangladesh Infrastructure Finance Fund Limited (BIFFL) are policy finance institutions that invest in and finance infrastructure and renewable energy related projects. The country has received funding from the World Bank and other international organizations to

[102] SREDA, http://www.sreda.gov.bd/

develop renewable energy-related programs such as SHS.

(3) Development targets

In the Renewable Energy Policy published in 2008, the country targeted renewable energy development to meet 5% of total electricity demand by 2015 and 10% by 2020,[103] but the 8th Five Year Plan (July 2020 to June 2025) approved in December 2020 stated that the share of renewable energy in electricity generated in 2020 was only 3.05% compared to the target of 10% and mentioned the need to revise the target.[104]

The Revisiting PSMP 2016, published in 2018, states that the new renewable energy development plan from 2018 to 2035 is 2,322 MW of solar, 510 MW of wind, and 1 MW of biomass (2,833 MW in total). On the other hand, the National Solar Energy Action Plan (draft version) published in October 2020[105] calls for the introduction of 8 GW of solar PV by 2041 for BAU, 25 GW for a medium level, and 40 GW for the most advanced deployment, and lists the barriers to renewable energy deployment including land acquisition, climate, lack of human resources, need for grid reinforcement, and lack of policy and regulatory frameworks.

Table 67 Solar Power Generation Introduction Target up to 2041 in Bangladesh

Component	until 2020	2021-2030	2031-2041	Cumulative
	MW	MW	MW	MW
Solar Power Hub (Utility + IPP)	0	0	1,500	1,500
Solar PV power capacity addition by Utilities	15	485	1,000	1,500
Solar PV power capacity addition by solar IPPs	160	640	1,200	2,000
Rooftop solar PV systems	50	700	1,250	2,000
Solar irrigation pumps	40	205	360	605
Solar mini-/micro-/nano-grids	6	10	0	16
Solar home systems	275	5	0	280
Solar-powered telecom towers	9	10	11	30
Solar street lights	11	8	10	30
Solar charging station	1	10	20	31
Other solar-powered systems	2	3	4	9
Total	**569**	**2,076**	**5,355**	**8,000**

Source: National Solar Energy Action Plan Draft Final Report

(4) Introduction promotion policy[106]

The Renewable Energy Policy also provides for financial incentives, including a 15% VAT exemption on equipment and raw materials for renewable energy projects.

The government began working with international organizations around 2010 to spread SHSs to areas without electricity, and had installed about 4.13 million SHSs by January 2019.[107] Following the spread of SHS, the government has been focusing on the development of solar-

[103] Ministry of Power, Energy and Mineral Resources, "RENEWABLE ENERGY POLICY OF BANGLADESH" http://www.sreda.gov.bd/d3pbs_uploads/files/policy_1_rep_english.pdf

[104] General Economic Division, "8th FIVE YEAR PLAN JULY2020 - JUNE2025", http://www.plancomm.gov.bd/sites/default/files/files/plancomm.portal.gov.bd/files/68e32f08_13b8_4192_ab9b_abd5a0a62a33/2021-02-03-17-04-ec95e78e452a813808a483b3b22e14a1.pdf

[105] SREDA, "Draft Final Report National Solar Energy Action Plan, 2021-2041" http://old.sreda.gov.bd/files/Draft%20Final%20Report%20-%20National%20Solar%20%20Energy%20Action%20Plan,%202021-2041.pdf

[106] JICA Report, https://www.jica.go.jp/bangladesh/bangland/pdf/report-report24-renewable-energy.pdf

[106] JICA Report, https://www.jica.go.jp/bangladesh/bangland/pdf/report-report24-renewable-energy.pdf

[107] IDCOL, https://idcol.org/home/solar

powered mini-grids, specifically promoting the replacement of diesel-fueled irrigation pumps with solar power. The development of mini-grids is an initiative of IDCOL, with support from the World Bank, which is facilitating an incentive program to support entrepreneurs who wish to launch solar power-related businesses. In addition, the installation of stand-alone PV systems has increased dramatically in recent years due to lower PV system prices and microcredit schemes (where a portion of the installation cost is paid directly by the owner and the remainder is covered by a loan).[108] Further, the country started purchase of solar power by net metering in 2018.

With regard to large-scale development, the Guidelines for the Implementation of the Solar Power Development Program was formulated in 2013 to identify guidelines for solar parks and other large-scale developments.[109] In February 2021, the government issued draft guidelines for the installation of onshore wind farms. [110]

(d) Energy conservation policy[111]

(1) Institutions in charge of policy

Like renewable energy, SREDA is responsible for energy conservation policy. IDCOL and BIFFL are also responsible for investing in related projects.

(2) Targets

In May 2016, SREDA published the Energy Efficiency and Conservation Master Plan up to 2030 (EECMP). The EECMP set the goals to reduce primary energy consumption per GDP by 15% by 2021 and 20% by 2030 compared to FY 2013 levels (vs. BAU case) and specified detailed action plans.[112]

(3) Promotion policy

The following is a summary of efforts to achieve the goals in the EECMP. The main action plans include an energy management system, an energy efficiency labeling system, a system to promote energy efficiency in buildings, and a financial incentive system.

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[108] NEDO, https://www.nedo.go.jp/content/100904841.pdf

[109] Asia Pacific Energy Portal, BANGLADESH: Guidelines for the Implementation of the Solar Power Development Program, 2013, https://policy.asiapacificenergy.org/node/218

[110] Financial Express, 2021.2.6, https://thefinancialexpress.com.bd/trade/bangladesh-drafts-guidelines-for-wind-power-projects-1612153018

[111] JICA, February 2016, https://openjicareport.jica.go.jp/pdf/12253209.pdf

[112] JICA, " Energy Efficiency and Conservation Master Plan up to 2030 (March 2015)", https://openjicareport.jica.go.jp/pdf/12231247.pdf

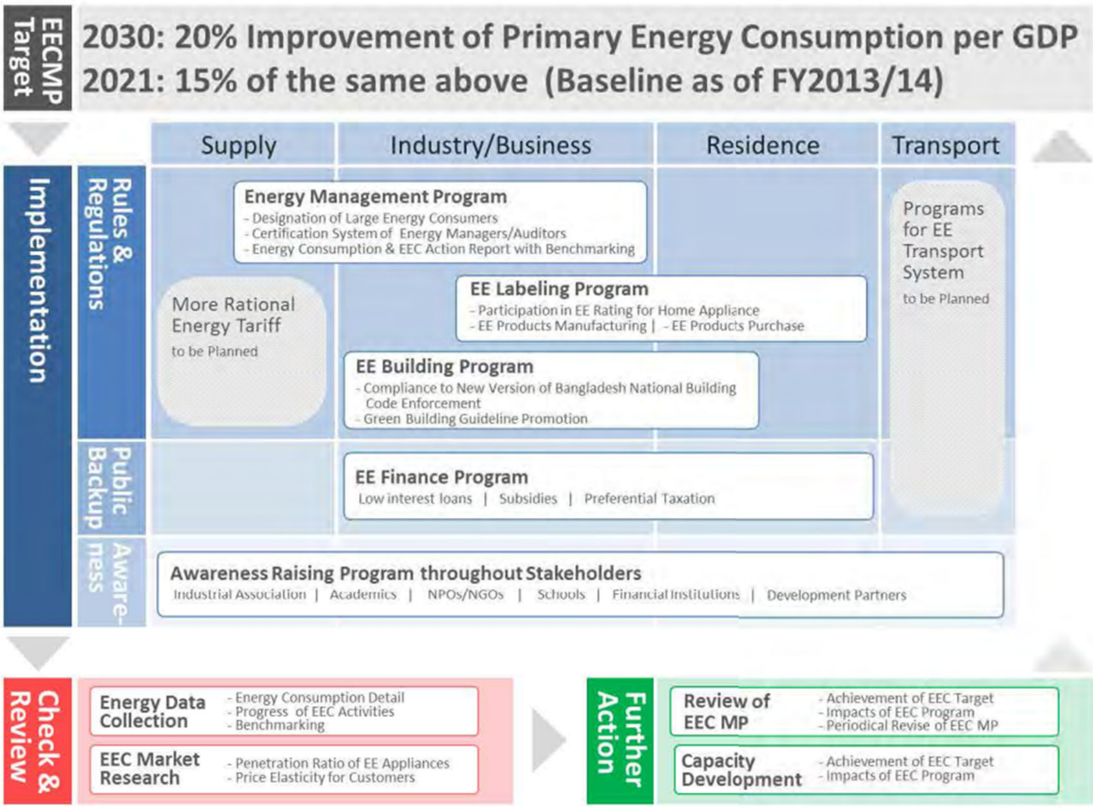

Figure 58 Outline of Bangladesh EECMP Outline of Bangladesh EECMP

Source: Energy Efficiency and Conservation Master Plan up to 2030

In 2018, the SREDA Standard and Labelling (Appliances & Equipment) Regulation-2018 was introduced, and the rules and procedures for 'Prescribing minimum energy performance standard (MEPS)' and 'Labeling of appliances & equipment' were summarized. In accordance with the rules, BSTI (Bangladesh Standards and Testing Institution) will determine MEPS and publish the details of implementation phases in the future. The labeling system covers ceiling fans, LED lamps, room air conditioners, refrigerators and refrigerator/freezers.[113]

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

The updated NDC submitted to the UN in August 2021 sets a target of reducing greenhouse gas emissions by 27.56 $MtCO_2$ (6.73%) relative to BAU by 2030, based on 2012 levels, and 61.9 $MtCO_2$ (15.12%) with international support. The reductions primarily target the power sector, with measures including the introduction of renewable energy (mainly solar power), introduction of CCGT power plants, and increasing the efficiency of existing gas-fired power plants.[114]

In November 2021, at the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26), the government also stated that if it could invest US$175.9 billion with international support, it could reduce greenhouse gas emissions from the 2012 level by 89.47 million ton-CO_2 (21.85%) by 2030, compared to BAU. [115]

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113 IEA, Policies database, https://www.iea.org/policies/6802-sreda-standard-and-labelling-appliances-equipment-regulation-2018

114 UNFCCC, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Bangladesh%20First/NDC_submission_20210826revised.pdf

115 The Daily Star 2021.11.1 https://www.thedailystar.net/news/bangladesh/news/cutting-co2-emission-fifth-bangladesh-needs-176b-2030-2210946

(2) Promotion policy

The Bangladesh Climate Change Strategy and Action Plan 2009 has identified the potential impacts of climate change and an action plan to address climate change. The Action Plan is organized in six pillars: (1) food security and social security; (2) comprehensive disaster management; (3) infrastructure; (4) research management; (5) mitigation and low carbon technologies; and (6) capacity building, with a total of 44 specific actions under the pillars.[116]

(3) Transportation

[Electric vehicles]

Currently, there are few EVs in Bangladesh, but electric motorcycles are in daily use. However, no guidelines exist to regulate electric vehicles. In January 2021, the government began working on a set of guidelines that will include the development of EV charging stations, proper disposal of spent batteries, and measures to combat illegally spreading electric tricycles.[117]

In September 2021, the government released the country's first automotive policy, Automobile Industry Development Policy 2021. To achieve the vision of building Bangladesh into a regional hub for the automotive industry by 2030, the Policy outlined financial and other incentives for the next 10 years.[118]

In terms of corporate developments, Bangladesh Auto Industries Ltd, a local automotive company, has announced plans to begin manufacturing electric vehicles in the Mirsarai economic zone in Chattogram starting in 2020 with an initial investment of US$200 million (announced postponing by one year due to COVID-19). With 80% of the planned US$200 million investment to be provided as local procurement and the rest as foreign direct investment, the factory plans to manufacture almost 60% of the vehicle's components, including lithium batteries, motors, software platforms, and bodies.[119]

(4) Urban development

There is no national-level development plan for smart cities, and urban development is proceeding on a project basis. In the capital city of Dhaka, the development of Mass Rapid Transit (MRT) and Bus Rapid Transit (BRT) to ease traffic congestion and reduce CO_2 emissions is conducted as major projects. The Purbachal New Town planned for the northeastern part of Dhaka is considered to be the first smart city in Bangladesh, and infrastructure development (urban facilities, transportation network, residential areas, educational institutions, etc.) is underway.[120]

(f) Next generation technology, innovation

The Oil and Gas Climate Initiative (OGCI) has published the CO_2 Storage Resource Catalogue. This was prepared by Pale Blue Dot Energy with support from the Global CCS Institute and evaluates the potential for CCS in various countries and regions.[121]

Checking the details for Bangladesh shows that 'Undiscovered inaccessible' is assessed to be

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[116] Ministry of Environment and Forests, "Bangladesh Climate Change Strategy and Action Plan 2009", http://nda.erd.gov.bd/files/1/Publications/CC%20Policy%20Documents/BCCSAP2009.pdf

[117] The Daily Star, 2021.1.17, https://www.thedailystar.net/backpage/news/electric-vehicles-guideline- talks-start-after-2-year-pause-2028977

[118] The Financial Express, 2021.9.26, https://www.thefinancialexpress.com.bd/trade/govt-issues-automobile-policy-with-fiscal-perks-1632373886

[119] DATABD.C, 2020.4.23, https://databd.co/stories/bangladeshs-road-to-adoption-of-electric-vehicles- 10947

[120] DhakaTribune, 2019.11.26, https://www.dhakatribune.com/business/real-estate/2019/11/26/the- eastern-expansion-of-purbachal

[121] https://co2storageresourcecatalogue.com/compare/

20,000 Mt and ‘Discovered inaccessible’ 1,133 Mt. ‘Undiscovered’ means storage suitability cannot be confirmed, and ‘Discovered’ means storage suitability can be confirmed. ‘Inaccessible’ means that CO_2 storage is not available at the time of assessment, but may be available for use depending on future regulatory and technological changes, although commercialization is difficult. In other words, Bangladesh has "1,133 Mt" of capacity that cannot be used for CO_2 storage at this moment, but may be stored in the future, albeit difficult to commercialize.

(g) Points to consider for future cooperation in promoting low-carbonization and decarbonization

- Natural gas is the key of energy supply in Bangladesh. Currently, plans are being formulated and implemented for LNG imports and pipeline development in order to ascertain domestic gas production potential and increase gas imports. Also, how to reflect future increases in gas supply costs on gas prices has become an issue, and there is likely a high need for support in this field.
- Photovoltaic power has been used as a substitute of biomass for household energy in the form of SHS and mini-grids that utilize renewable energy. While the introduction of large-scale PV is being considered, various issues such as land acquisition, securing human resources, the need for grid reinforcement, and the development of policies and regulations are likely to arise in the future, and the need for support for the expansion of renewable energy, especially PV, is expected to increase.
- As the demand for electricity is expected to increase further in the future along with advancement of industrialization, it will be important to improve the efficiency of gas-fired power generation (CCGT) and expand heat utilization on the supply side and to improve the efficiency of energy use on the demand side in order to achieve low-carbonization and decarbonization of electricity. The below are examples of possible measures to improve the efficiency of energy use.
  - ✓ Formulate energy efficiency benchmarks for the industrial sector
  - ✓ Implement energy management in energy-heavy industries
  - ✓ Introduce minimum efficiency standards for equipment
  - ✓ Expand the scope of labeling system to cover a wider range of equipment

(5) India

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

India's economy has grown significantly in recent years, with annual GDP growth rates exceeding 8% in some years since 2000, and primary energy supply has increased approximately 2.2 times and electricity supply 2.9 times over 20 or so years. In addition, its population, the second largest in the world (approximately 1.37 billion people), is expected to overtake China to become the world's largest by around 2027,[122] and it is expected that economic and population growth will continue to increase energy demand and associated GHG emissions.

India has coal and natural gas reserves and has made use of coal in its energy supply especially. However, domestic production has not kept pace with the rapid growth of domestic demand, and fossil fuel imports are on the rise. In particular, the country's dependence on oil imports is around 80%, making it one of the most important policy issues in terms of energy security.

In terms of electricity supply, the country is responding to the rapidly increasing electricity demand by developing coal-fired power generation, which accounted for 73% of electricity generated in 2019. In recent years, India has been promoting the introduction of renewable energy, particularly solar power generation. One challenge for future low-carbonization and decarbonization in the power sector will be reduction of CO_2 emissions from existing coal-fired power plants. As for the development of coal-fired power generation in India, the plants currently

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[122] United Nations, World Population Prospects 2019, https://population.un.org/wpp/Download/Standard/Population/

under construction are expected to be completed in the next few years, and no new construction is planned thereafter. However, existing coal-fired power plants are poor in the efficiency, averaging 35%, while they are still new with 15 years of operation in average. Therefore, the challenge would be how to reduce CO_2 emissions from these plants through measures such as early retirement, fuel switching, flexible operation, and CCS. In addition, with the increase in solar and wind power, there is a growing need to increase the flexibility of the power system, including flexible operation of thermal power generation, development and upgrading of transmission and distribution networks, and the use of storage technologies.

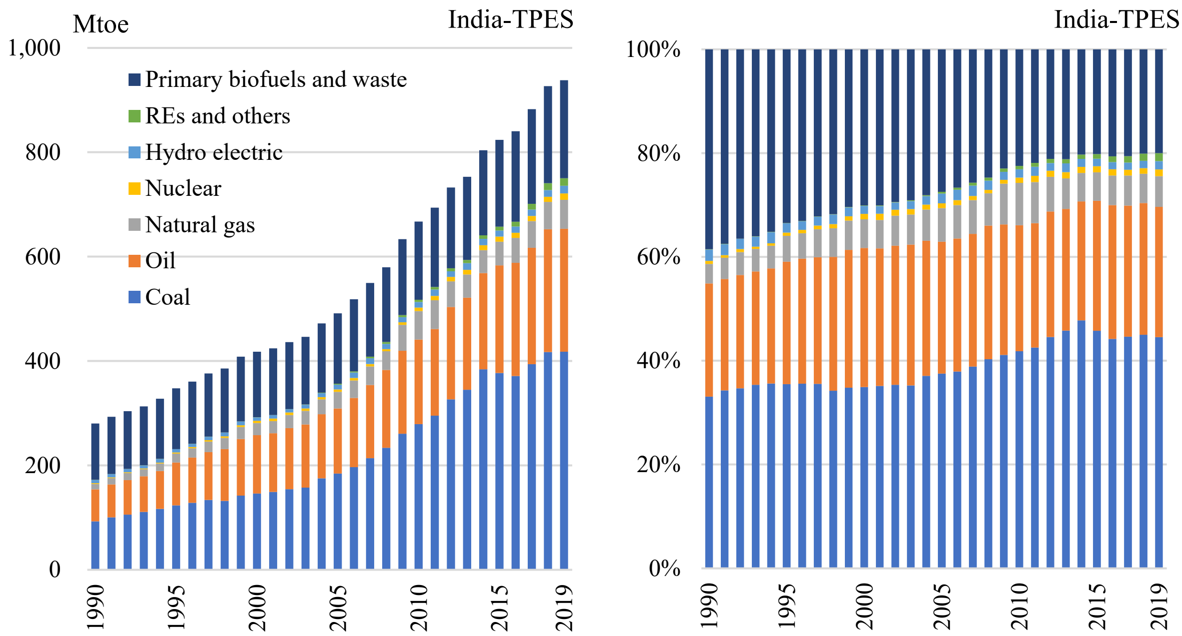


Figure 59 Primary Energy Supply in India

Source: World Energy Balances 2021 extended edition database, IEA

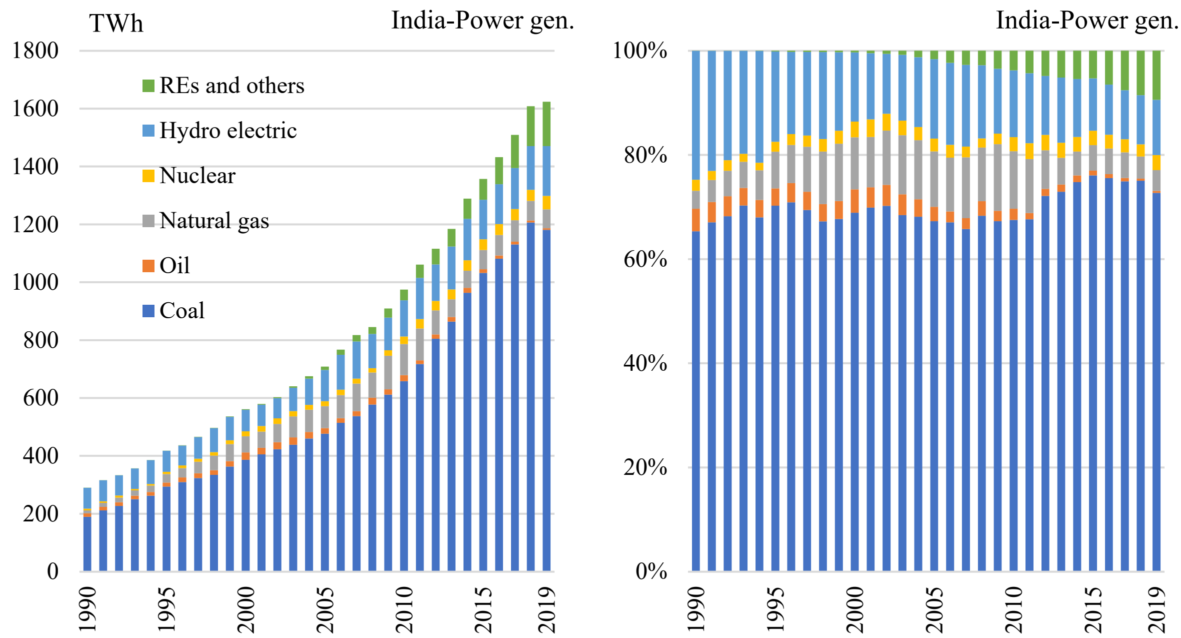


Figure 60 Fuel Mix of Electricity Generation in India

Source: World Energy Balances 2021 database, IEA

A breakdown of final energy consumption by sector shows that consumption was the largest in industry at 38%, followed by transportation 23%, residential 13%, and commercial/public services 4% in 2018. In term of the five-year growth from 2013 to 2018, commercial/public services had the largest growth with 7.7%, albeit small in the current consumption, followed by transportation at 5.7%.

What is characteristic about the industry is the increasing use of coal and electricity. India is expected to undergo rapid urbanization, with the urban population expected to grow by about 270 million within 20 years, more than doubling demand for cement, a construction material, and almost tripling demand for steel.[123] Toward low-carbonization and decarbonization of industry in the future, it will be necessary to use natural gas instead of coal, promote electrification, and increase the efficiency of energy use, as well as reduce the amount of raw materials required.

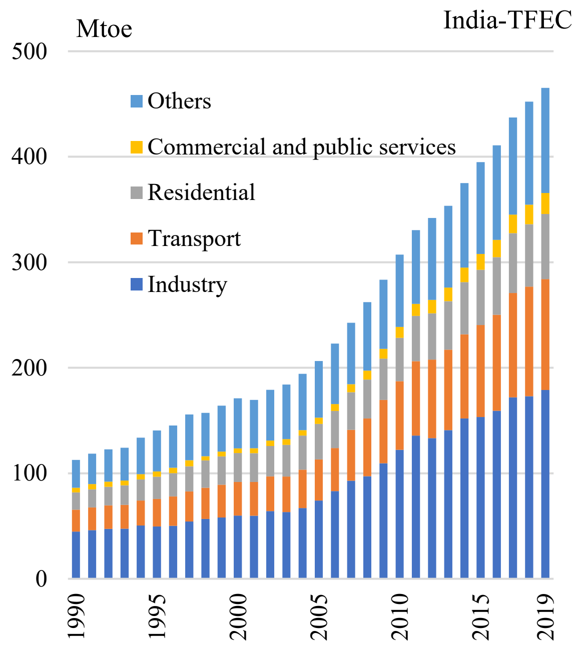
The transportation sector has experienced the largest increase in demand in recent years compared to other sectors. While more than three-quarters of India's stock vehicles consist of 2- and 3-wheelers, the largest CO_2 emitters are passenger cars and trucks.[124] The government is concerned about air pollution caused by automobiles, and introduced the Bharat Stage VI (BS-6, equivalent to EURO VI) automobile emission norms throughout India in April 2020. Demand for automobiles is expected to continue to increase associated with economic growth, and a modal shift to public transportation will be necessary to achieve low-carbonization and decarbonization, along with the use of LPG vehicles and EVs, which the government is promoting.

What is characteristic about residential and commercial/public services is that electricity use has increased over the years. As a matter of fact, biomass has been used very heavily as household energy, especially in rural areas, and has caused environmental pollution and health hazards. To address that, the government has been working in recent decades to electrify rural areas, popularize LEDs, and promote clean-energy cooking appliances. Regarding electrification, the government has announced the completion of electrification of all villages in 2018, but the promotion of clean-energy cooking appliances is still a political challenge. In addition, ownership of home appliances is expected to increase. Especially, ownership and energy consumption of air conditioners are expected to grow rapidly.[125] In the future, it will be likely necessary to introduce and disseminate energy conservation standards in housing and home appliances.

[123] IEA, India Energy Outlook 2021, https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf

[124] IEA, India Energy Outlook 2021, https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf

[125] IEA, India Energy Outlook 2021, https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf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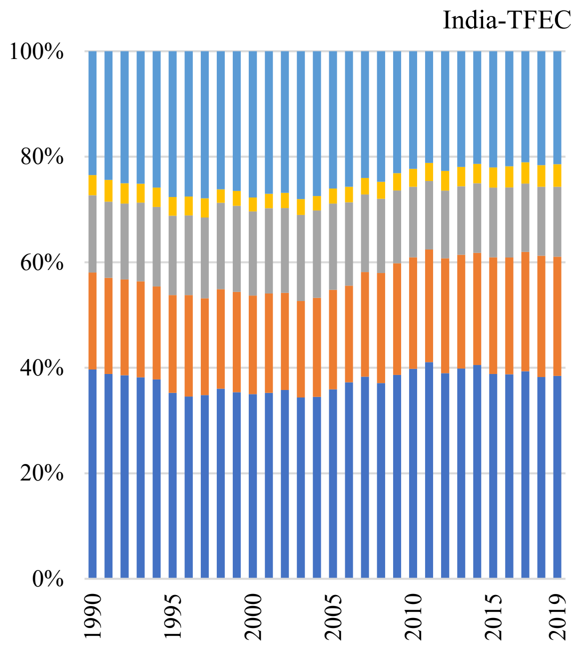
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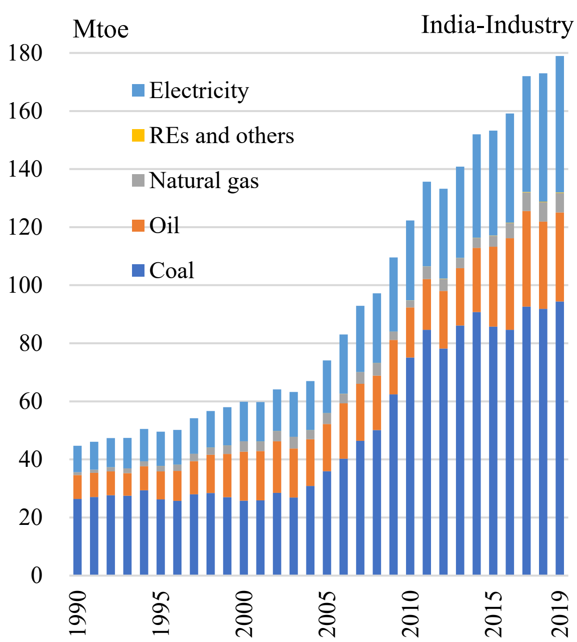
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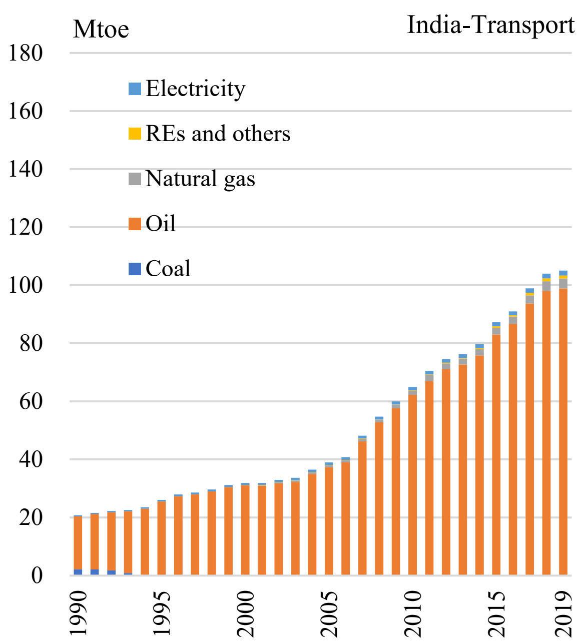
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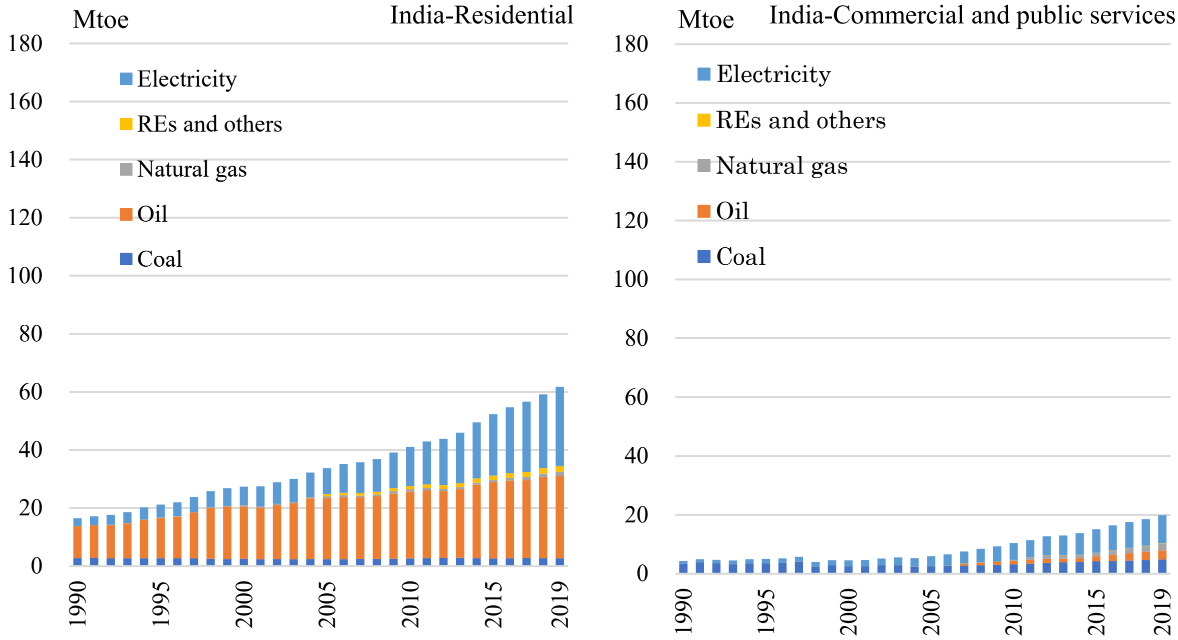

Figure 61 Final Energy Consumption of Major Sectors in India

Excludes "Primary solid biofuels," "Non-specified primary biofuels and waste," and "Charcoal."
"Others" in TEFC includes agriculture, forestry, fisheries, other, and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP has been declining year by year and was 0.345 toe/$1000 in 2019 (0.090 in Japan). The decline to date has been due to policies aimed at transitioning energy from biomass and improving energy efficiency (e.g., strict fuel efficiency standards in transportation), as well as the large share of the service industry in GDP, which leaves significant room for further improvement.

The average thermal efficiency of gas-fired power plants is about 41%, and that of coal-fired power plants is about 35%. As mentioned above, many coal-fired power plants have operated only for a short period of time, and how to utilize them (replacement, cogeneration, etc.) or decommission them early will be the key to achieve low-/de-carbonization of the power sector.

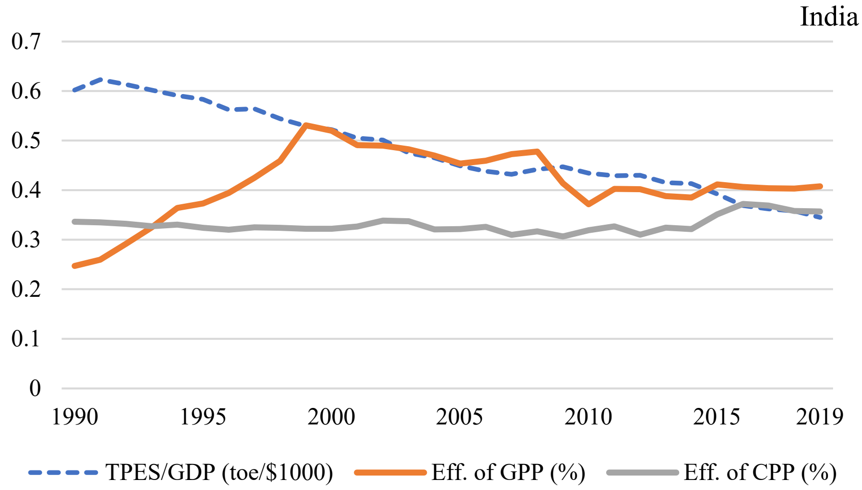

Figure 62 Energy Eiifciency in India

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant, CPP = coal power plant, GDP in

2015 price
Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options India could take to reduce its CO_2 emissions in the future and their CO_2 reduction effects.

Table 68 Examples of Low-carbon/ Decarbonization Potential in India

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		2,371.9 mton-CO2
	【Example of CO2 Emission Reduction Option】	【Reduction Effect】
Generation	Substitute 15% of Coal for Natural Gas, and 15% of Coal forRenewable Energy	275.18 mton-CO2
Industry	Substitue 25% of Coal for Natural Gas	38.04 mton-CO2
Transport	Substitue 25% of Diesel Cars for NGV	17.66 mton-CO2
Residential	Substutie 50% of LPG for Natural Gas	3.80 mton-CO2

Note: 2019 actual = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICA Study Team

(2) Primary energy mix and electricity mix planning
[Primary energy mix]
In the primary energy mix, strengthening energy security against increasing energy demand is a key issue, with emphasis on fuel switching and energy conservation to reduce dependence on oil imports, increasing domestic production of coal, and increasing the use of renewable energy. India also intends to increase the share of natural gas in primary energy supply, with the goal of increasing its share from the current 6% to 15% by 2030.[126]
The outlook from the Institute of Energy Economics, Japan, assumes that primary energy supply will increase at an average annual rate of 2.7%, based on an assumed GDP growth rate (2010 prices) of 5.3% from 2019 to 2050. Demand for coal is expected to increase for power generation, while demand for oil is expected to increase due to the progress of motorization.

Table 69 Primary Energy Consumption Outlook in India (Reference Case)

Unit: Mtoe

	2018	2030	2040	2050	Average annual growth rate (%) 2019-2050
Coal	418	588	767	894	2.5
Oil	235	344	476	637	3.3
Natural Gas	55	105	167	224	4.6
Nuclear	12	41	51	65	5.6
Hydro	15	21	28	35	2.8
Solar, Wind, etc.	11	34	55	82	6.5
Biomass, Wastes	191	233	234	224	0.5
Total	938	1,367	1,776	2,158	2.7

Source: IEEJ Energy Outlook2022

[Power mix]
In the power mix, NITI Aayog, the premier policy think tank of the Government of India, has

126 The Week, 2019.11.22, https://www.theweek.in/news/biz-tech/2018/11/22/PM-Modi-unveils-vision-for-a-gas-based-economy.html

published the Draft National Energy Policy, and has formulated the NITI Ambition Scenario with BAU and Ambitious Target for the year 2040.[127] A comparison of the two scenarios shows that the goal is to reduce coal-fired power in the electricity mix and to increase gas-fired power and solar power.

Table 70 Electricity Generation Capacity Outlook up to 2040 in India

GW	2012	2022		2040	
		BAU	Ambitious	BAU	Ambitious
Gas Power Stations	24	34	39	46	70
Coal power stations	125	266	251	441	330
Carbon Capture Storage (CCS)	0	1	1	26	26
Nuclear power	5	12	12	23	34
Hydro Power Generation	41	61	61	71	92
Solar PV	1	59	59	237	275
Solar CSP	0	4	5	28	48
Onshore Wind	17	62	62	168	181
Offshore Wind	0	2	2	19	29
Distributed Solar PV	0	36	36	102	120
Other Renewable Sources	8	18	20	43	56
Total	221	555	548	1204	1261

Source: Draft National Energy Policy

[International power transmission interconnection]

India has international interconnected transmission lines with Nepal, Bhutan, Bangladesh, and Myanmar, and exports electricity to all countries except Bhutan. As for exports, India exports 400 MW to Nepal and 500 MW to Bangladesh, and has a very small-scale interconnection with Myanmar. In addition, India is conducting a demonstration test of a submarine cable with Sri Lanka. As for imports, India imports electricity from three hydroelectric power plants built in Bhutan (1.5 MW in total), with three more hydroelectric power plants (2.91 MW in total) and a 400 kV direct current interconnection line under construction.[128]

(3) Current status and targets of electricity access

In April 2018, the government announced that it had completed the electrification of all Indian villages under the rural electrification program (named DDUGJY) launched in 2015.[129] However, biomass is the main source of energy in rural areas, and improving access to electricity and providing clean cooking fuels in rural areas is a major policy agenda.

(b) Electric utility system

(1) Electricity supply system

Electric utilities are broadly divided into the central sector, the state sector, and the private sector. The central sector is responsible for policy making at the national level and for multi-state power generation and transmission operations. State governments are responsible for policy making and the generation, transmission, and distribution of electricity within their respective states. Independent regulatory commissions have been established at the central and state sectors to regulate rates, write rules, and resolve disputes. State governments are given limited

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[127] NITI Aayog, "Draft National Energy Policy", http://niti.gov.in/writereaddata/files/new_initiatives/NEP-ID_27.06.2017.pdf

[128] Overseas Electric Power Industry Statistic I 2019-2, JAPAN ELECTRIC POWER INFORMATION CENTER

[129] REUTERS 2018.4.29 https://www.reuters.com/article/us-india-power/india-says-electrified-all-villages-ahead-of-prime-ministers-deadline-idUSKBN1I0094

involvement in nuclear and coal policies, but are given the freedom to develop and implement their own policies in the areas of electricity and renewable energy deployment.

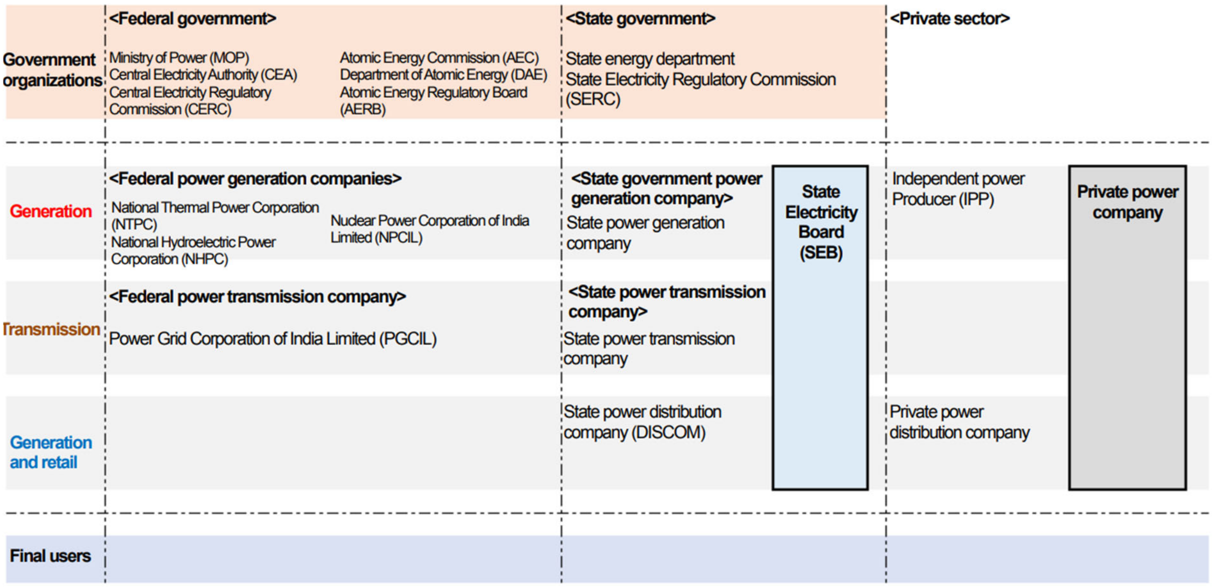

Figure 63 Electricity Supplr Structure in India

Source: IEEJ[130]

(2) Renewable electricity supply system

In renewable energy generation, central government agencies and state governments undertake procurement from private power producers under central government plans. As for private operators, major players include local companies Acme Solar Holdings, Renew Power, Adani, and Greenko Energy Holdings.

(c) Policy on renewable energy

(1) Potential of renewable energy

Regarding photovoltaic power generation, India has great potential because of the good sunlight conditions throughout the country. Large-scale solar parks are already being built and planned throughout the region, and the cost of power generation is among the lowest in the world. With regard to wind power, there is high potential in the southern and western coastal areas, especially in the southern state of Tamil Nadu, which is actively developing wind power.

130 Analysis on Indian Power Supply Situation and Policies, July 2018, https://eneken.ieej.or.jp/data/8002.pdf

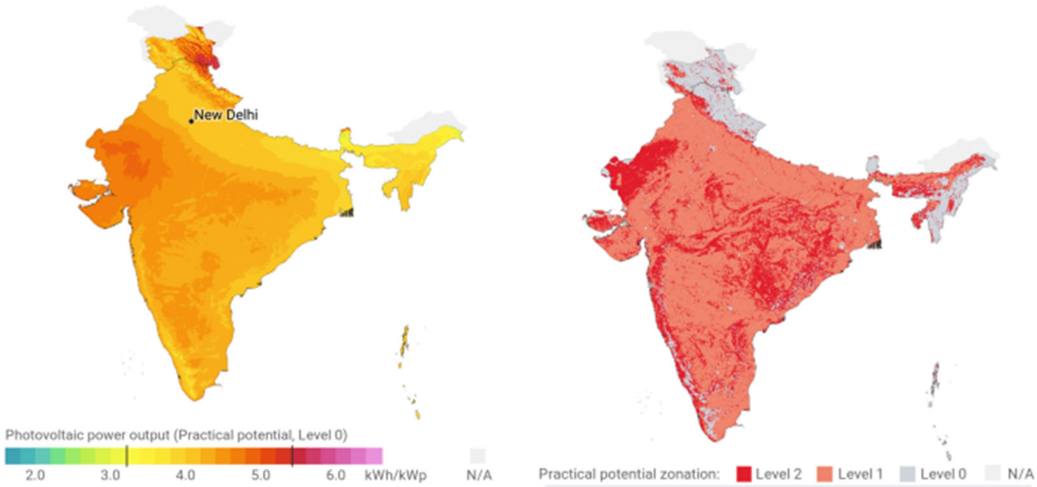

Figure 64　Solar Power Generation Potential in India

Note: Left = estimated power generation.
Right = potential zones; Level 0 = no constraints, Level 1 = excluding topographic constraints, Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

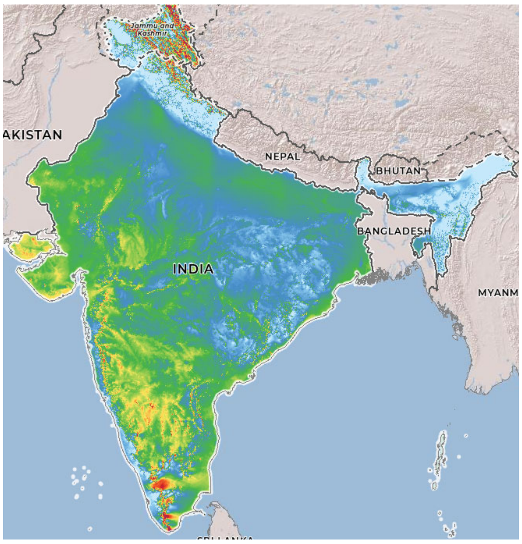

Figure 65　Wind Power Generation Potential in India

Note: The mean wind speeds shown are the representative values at the elevation of 50 m. Red color indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The Ministry of New and Renewable Energy (MNRE) is responsible for renewable energy. Under the umbrella of MNRE are the Indian Renewable Development Agency (IREDA), which provides financial support for renewable energy projects, and the Solar Energy Corporation of India (SECI), an implementing agency for solar power procurement.

(3) Development targets

In 2014, the government announced a target of 175 GW of renewable energy to introduce by 2022. The breakdown is 100 GW for solar, 60 GW for wind, 10 GW for biomass, and 5 GW for small hydro. For solar, 60 GW is to be supplied from large-scale solar power plants (solar parks, etc.) and 40 GW from rooftop-mounted solar (rooftop).[131] In November 2021, Prime Minister Narendra Modi announced a target to develop 500 GW of non-fossil power generation, mainly solar, by 2030 and to increase the share of non-fossil power generation in the installed capacity to 50%.[132] In June 2018, MNRE announced its intention to conduct tendering for 40 GW of renewable energy (30 GW solar and 10 GW wind) annually until 2028.[133]

(4) Introduction promotion policy

[FIT system and tendering system]

In 2009, India introduced a feed-in tariff (FIT) system. Purchase prices used to be set at each state by the state electricity regulatory commissions with reference to the FIT system set at the national level by the Central Electricity Regulatory Commission (CERC). However, the FIT system has been replaced by a tendering system for solar power generation, and some states have also introduced a tendering system for wind power generation.

Solar and wind power projects use a tendering system known as a reverse auction, in which a business operator with the lowest bidding price wins. In recent years, Indian renewable energy prices have fallen sharply and are now among the lowest in the world. Since 2018, the country is also tendering hybrid systems of solar PV and wind power with the aim of compensating for the intermittency of renewable energy and increasing grid stability.[134]

[Renewable energy procurement obligation system (RPO)]

In 2010, India started a system (Renewable Purchase Obligations: RPO system) that obligates electric power distribution companies and other entities in each state to procure a certain percentage of renewable energy. If the procurement obligations cannot be met, the purchase of Renewable Energy Certificates (RECs) is allowed as a substitute. RECs are traded at the country's two wholesale power exchanges (IEX and PXIL). The RPO targets set by the central government are as follows.

Table 71 RPO Target set by Central Government in India

	2016	2017	2018	2019	2020	2021
Non-solar RPO	8.75%	9.50%	10.25%	10.25%	10.25%	10.50%
Solar power RPO	2.75%	4.75%	6.75%	7.25%	8.27%	10.50%
Total	11.50%	14.25%	17.00%	17.50%	18.52%	21.00%

Source: NATIONAL PORTAL FOR RENEWABLE PURCHASE OBLIGATION (RPO)

[Initiatives to increase photovoltaic power generation][135]

In 2010, the government announced the Jawaharlal Nehru National Solar Mission (JNNSM). The Mission is to increase mega solar power generation through a tendering system in three phases over the period from 2010 to 2022. At the time of the Mission's formulation, the target for PV installation was 22 GW by 2022, but this was revised upward to 100 GW in the 2015 revision. In 2014, a solar park program (Development of Solar Parks and Ultra Mega Solar Power Projects) was initiated as one of the means to promote the achievement of the JNNSM. The program calls for bids to solar parks of 500 MW or more (with exceptions), while the central government will provide support for site acquisition, grid connection, etc. to reduce the burden on operators. More than 50 solar parks

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131 CEA, National Electricity Plan, https://cea.nic.in/wp-content/uploads/2020/04/nep_jan_2018.pdf

132 BBC, 2021.11.2, https://www.bbc.com/news/world-asia-india-59125143

133 The Economic Times of India 2018.6.30 https://economictimes.indiatimes.com/industry/energy/power/india-to-auction-40-gw-renewables-every-year-till-2028/articleshow/64806075.cms

134 IEA, India 2020 Energy Policy Review, https://www.iea.org/reports/india-2020

135 MNRE, Annual Report 2020-2021, https://mnre.gov.in/img/documents/uploads/file_f-1618564141288.pdf

(with a total generation capacity of 40 GW) are planned to be installed by FY2021. Regarding rooftop PV, the country has introduced a net metering system and a subsidy policy for installation costs (Roof Top Solar Programme). For solar power generation projects, preferential measures such as investment permits and tariff exemptions for foreign investment are also in place.

[Development of power transmission and distribution network]

In 2012, the Green Corridor Project, a plan to develop power grids across India, was launched with a view to expanding the introduction of renewable energy in the future. The Project is financially supported by the German Reconstruction Finance Corporation (KfW) and the Asian Development Bank (ADB), and includes strengthening intrastate transmission lines in states with high renewable energy potential,[136] strengthening interstate interconnection lines to export electricity to other states, and establishing renewable energy management centers.[137] Regardless of renewable energy, one of the challenges for the Indian power sector is to improve the efficiency and financial health of the power distribution sector. The Aggregate Technical and Commercial (AT&C) losses in India were about 20%, which is high compared to the OECD average of about 6%. The government has launched a plan to strengthen the distribution of electricity to urban and rural areas,[138] aiming to improve the profitability of electricity distribution companies by reducing losses as well as increasing the electrification rate. Many state-owned electric distribution companies (DISCOMs) have huge accumulated deficits because their electricity tariff levels are kept lower than the cost of supply, and they are also incurring uncollected electricity charges and other costs. The government has been implementing a debt reduction program (UDAY: Ujjwal DISCOM Assurance Yojana) for power distribution companies since 2015, which requires management improvements, including installation of smart meters and reduction of AT&C losses, as a condition for assisting fiscal consolidation.[139]

[Bioenergy][140][141]

The government has been promoting the use of biofuels as an alternative to domestically produced crude oil that leads to a reduction in dependence on oil imports, as a clean energy source that reduces GHG emissions, and from the aspect of increasing farmers' income and creating jobs. Biofuels are used most in the transportation sector, followed by the construction and energy sectors.

The most recent biofuel adoption targets are specified in the National Policy on Biofuels 2018,[142] which aims to achieve a 20% bioethanol blending rate in gasoline and a 5% biodiesel blending rate in diesel by 2030 (the blending rates as of 2018 were 2% and less than 0.1%, respectively). The measures to achieve this include promotion of EBP, increase of domestic biofuel production, and research and development and commercialization of second-generation biofuels. On the other hand, no mandates for biofuel production have been made.

As part of previous efforts, the Ethanol Blending Program (EBP) was introduced in 2003 to promote the sale of E5 (gasoline blended with 5% bioethanol). In the EBP, the goal is to reach E10 by 2022, and the EBP is being implemented in 21 states and four federal territories. In addition, the government restricts imports and exports of biofuels in order to promote domestic production and consumption of biofuels (no restrictions on ethanol for industrial and chemical use

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136 Eight states are covered: Tamil Nadu, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh, and Madhya Pradesh.

137 METI, March 2018, https://www.meti.go.jp/meti_lib/report/H29FY/000562.pdf

138 It refers to the Integrated Power Development Scheme (IPDS) for urban areas and the Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY).

139 IEA, India 2020 Energy Policy Review, https://www.iea.org/reports/india-2020

140 METI, FY2018, https://www.meti.go.jp/meti_lib/report/H30FY/000306.pdf

141 METI, March 2018, https://www.meti.go.jp/policy/alcohol/pdf/h29fychousahoukokusho_india.pdf

142 Ministry of Petroleum and Natural Gas, “National Policy on Biofuels 2018”, http://petroleum.nic.in/sites/default/files/biofuelpolicy2018_1.pdf

or on imports of raw materials for producing biofuels). While the policy is to increase ethanol demand, there are supply issues. Bioethanol in India is mainly refined from sugarcane residue (molasses), but the raw material is subject to various influences such as climate change and food security policies. The government is focusing on second-generation ethanol (cellulosic bioethanol), given the difficulty of supplying the amount needed to meet the target with molasses-derived ethanol alone.

In the power generation sector, biomass cogeneration and biomass power generation are being promoted. As of the end of June 2021, biomass IPP: 1,836 MW, cogeneration (bagasse): 7,562 MW, and cogeneration (non-bagasse): 772 MW have been installed. [143] India also promotes small-scale biogas power generation in rural areas, with about five million units installed by the end of March 2019. In 2018, the government launched a promotion program (NNBOMP: New National Biogas and Organic Manure Program) to subsidize the installation of biogas power generation, with the goal of 600,000 units in FY2020, but actual installation remained at 8,483.[144]

(d) Energy conservation policy

(1) Institutions in charge of policy

The Bureau of Energy Efficiency (BEE) is responsible for energy conservation policy. In addition, Energy Efficiency Services Limited (EESL),[145] a publicly owned energy service company (ESCO), conducts projects that contribute to improving the energy efficiency in a wide range of sectors, including lighting, buildings, electromobility, smart metering, and agriculture.

(2) Targets[146]

The National Mission for Enhanced Energy Efficiency (NMEEE), formulated in 2009, consists of the following four energy conservation initiatives, with a goal of saving 23 million oil equivalent tons of energy each year (reducing greenhouse gas emissions by 98.55 million tons each year).

1) Perform Achieve and Trade(PAT)
   Energy conservation certificate trading scheme for energy-heavy industries
2) Energy Efficiency Financing Platform (EEFP)
   Development and promotion of ESCO market in terms of financial and human resource. Creation of an energy conservation financing platform.
3) Framework for Energy Efficient Economic Development(FEEED)
   Establishment of a partial risk guarantee fund for energy conservation projects and an energy conservation venture capital fund.
4) Market Transformation for Energy Efficiency (MTEE)
   Utilization of international funds for promotion of energy conservation. Utilization of CDM in promotion of energy conservation.

(3) Promotion policy[147]

The Energy Conservation Act 2001 was enacted in 2001 and came into effect in March 2002. BEE was established in the central government as an agency to formulate and promote energy conservation policies, and state-designated agencies were established in the states. The Energy Conservation Act stipulates: establishment of a system of energy managers and energy auditors; designation of energy-intensive industries as Designated Consumers (DCs) and mandating appointment of energy managers, submission of annual reports, and implementation of energy audits, etc.; establishment of state-level energy conservation promotion organizations;

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[143] MNRE, https://mnre.gov.in/bio-energy/current-status

[144] MNRE, https://mnre.gov.in/img/documents/uploads/file_f-1618564141288.pdf

[145] It is being promoted by the Ministry of Power as a joint venture of four public sectors: NTPC Limited, Power Finance Corporation Limited, REC Limited, and POWERGRID Corporation of India Limited.

[146] METI, FY2018, https://www.meti.go.jp/meti_lib/report/H30FY/000199.pdf

[147] BEE, https://beeindia.gov.in/content/pat-read-more

formulation of energy conservation regulations for buildings; and establishment of energy standards and mandatory labeling for energy-consuming equipment.

[Industrial sector]

The Energy Conservation Act obligates business establishments that consume energy above a certain scale to submit annual reports, conduct energy diagnosis, and appoint energy managers. The PAT Scheme launched in 2012 seeks to achieve improved energy efficiency in energy-intensive industries in a cost-effective manner through the use of market mechanisms. Specifically, the Scheme is to set a specific energy consumption amount for each designated energy consumer in each industry stipulated in the Energy Conservation Act, and if the energy conservation exceeds the target, this amount is converted into tradable energy conservation certificates (ESCerts), and specific consumers can purchase the ESCerts to achieve their own energy conservation targets. The PAT Scheme has been implemented in three-year cycles since FY 2012, with the sixth cycle (FY 2020-2022) underway as of 2021. The industries covered in the sixth cycle are cement, commercial buildings (hotels), steel, oil refineries, pulp and paper, and textiles.

[Consumer sector]

The Energy Conservation Building Code (ECBC) was implemented as a voluntary system based on the Energy Conservation Act, which stipulates energy efficiency standards in design and construction for commercial buildings with a power load of 500 kW or contracted power of 600 kVA or more.[148] In 2017, the ECBC was updated to stipulate energy efficiency standards in design and construction for commercial buildings above a certain scale.[149]

In 2009, BEE began implementing the Scheme for BEE star rating for office buildings to promote the application of ECBC. The program targets office buildings with a power load of 100 kW or more, and grades energy efficiency levels on a 1-5 star scale based on annual power consumption per unit area of the building.

In addition, formulation of mandatory or voluntary efficiency standards and implementation of labeling programs for machinery and equipment are taking place. Mandatory equipment includes air conditioners, refrigerators, televisions, and LEDs, and the subjects are regularly updated.[150]

(e) Environmental policy

(1) Greenhouse gas emission reduction targets[151]

The NDC submitted to the UN in October 2016 set a target to reduce GHG emissions by 33-35% per unit of GDP by 2030, using 2005 as the base year. It added, however, that realization will depend on ambitious global agreements that include implementation measures provided by developed countries. The NDC also stated that the share of non-fossil power sources in the installed capacity of power generation will be at least 40% by 2030.

To achieve the targets, the country aims to (1) introduce highly efficient and clean thermal power generation technologies, (2) promote the use of renewable energy and alternative fuels, (3) reduce emissions in the transportation sector, (4) promote energy conservation in all sectors, (5) reduce emissions from waste, (6) build climate-resilient infrastructure, (7) fully implement the Green India Mission and other tree planting programs, (8) plan and implement climate resilience measures.

In November 2021, at COP26 held in the UK, Prime Minister Modi declared that the country

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[148] IEA, India 2020 Energy Policy Review, https://www.iea.org/reports/india-2020

[149] Ministry of Power, BEE," Energy Conservation Building Code 2017", https://beeindia.gov.in/sites/default/files/BEE_ECBC%202017.pdf

[150] BEE, Standards & Labeling, https://beeindia.gov.in/content/standards-labeling

[151] UNFCCC, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/India%20First/INDIA%20INDC%20TO%20UNFCCC.pdf

aims to achieve carbon neutrality by 2070.[152]

(2) Promotion policy

In the National Action Plan on Climate Change (NAPCC) released in 2008, India presented policies to address climate change issues. The plan called for action plans to be formulated for the following eight items: (1) promoting solar power generation, (2) improving energy efficiency, (3) developing sustainable habitat, (4) improving water use efficiency, (5) sustaining ecosystems in the Himalayan region, (6) greening the land, (7) realizing sustainable agriculture, and (8) disseminating strategic knowledge on climate change. All these eight items have national action plans formulated and put into practice.[153]

(3) Transportation

[Electric vehicles][154]

India is promoting the spread of EVs against a backdrop of worsening air pollution and increasing dependence on oil imports. As a specific measure, the National Electric Mobility Mission Plan 2020 (NEMMP2020) was released in 2013. NEMMP2020 is a comprehensive plan to promote the spread of BEVs and HEVs, integrating various policies to gradually increase xEV sales in India to 6-7 million units by 2020 (mostly expected to be electric motorcycles, followed by HEVs and BEVs).[155]

In 2015, India introduced the Faster Adoption and Manufacturing of Hybrid & Electric Vehicles in India (FAME) I with the aim of supporting the EV and HV market development and manufacturing ecosystem, and has provided purchase subsidies for BEVs, HEVs, and PHEVs and capital investment in the relevant infrastructure and other constructions. The second phase (FAME II) began in 2019, and the country mentioned the electrification of buses and the expansion of EV charging stations. Under FAME II, a budget of 100 billion rupees is allocated for incentives for the purchase of xEVs and support for the introduction of charging infrastructure. Approximately 86% of the budget is planned to be allocated to the former.[156] The governmental think tank NITI Aayog noted that if policies such as FAME II are successful, EV sales could reach 30% of passenger cars, 70% of commercial vehicles, 40% of buses, and 80% of two and three wheelers by 2030.[157] Under the National E-Mobility Progamme formulated in March 2018, Energy Efficiency Services Limited (EESL) affiliated to the Ministry of Power has completed the EV procurement process (10,000 EVs) for government agencies to date, with an additional 10,000 EVs planned to be procured.[158] Other than these, each state is implementing its own measures to promote EVs.

In July 2019, the government announced tax incentives for EVs, reducing the Goods and Services Tax (GST) on electric vehicles from the current 12% to 5%, as well as an income tax credit for loans for the purchase of electric vehicles and the elimination of duties on certain EV components.[159] In February 2021, the Ministry of Power launched the Go Electric campaign, led by BEE. It aims to raise awareness at the national level about the benefits of e-mobility, charging,

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[152] BBC 2021.11.2 https://www.bbc.com/news/world-asia-india-59125143

[153] Overseas Electric Power Industry Statistic I 2019-2, JAPAN ELECTRIC POWER INFORMATION CENTER

[154] MARKLINES, https://www.marklines.com/ja/report/rep1745_201807 (Access, February 16, 2021)

[155] Department of Heavy Industries, “NEMMP2020”, https://dhi.nic.in/writereaddata/Content/NEMMP2020.pdf

[156] Ministry of Heavy Industries, “About FAME II”, https://fame2.heavyindustry.gov.in/content/english/1_1_AboutUs.aspx

[157] NITI Aayog and RMI (2019) “India’s Electric Mobility Transformation”, http://niti.gov.in/writereaddata/files/document_publication/NITI-RMI-Report.pdf

[158] The Economic Times, 2018-3-7, “Ministry of Power Launches National E-Mobility Programme in India”, https://auto.economictimes.indiatimes.com/news/industry/ministry-of-power-launches-national-e-mobility-programme-in-india/63203748

[159] NNA ASIA, 2019.7.9, https://www.nna.jp/news/show/1924070

and electric cooking appliances.[160]

The government is also focusing on domestic production of EVs and lithium-ion batteries as part of its "Make in India" manufacturing promotion policy. Currently, almost all lithium-ion batteries for automotive use are imported from China and other countries, but in recent years, major local rechargeable battery manufacturers have begun developing lithium-ion batteries for automotive use in partnership with foreign companies. In addition, there are moves toward local production among foreign companies, such as the construction of India's first automotive lithium-ion battery plant jointly established by Suzuki, Toshiba, and Denso[161].

[Vehicle emission regulations]

Air pollution in India has become so severe that, in November 2019, authorities in the Delhi metropolitan area asked citizens to refrain from going out and restricted vehicular traffic as it reached "harmful" levels that could cause respiratory diseases.[162]

In April 2020, all of India moved to Bharat Stage VI (BS-6, equivalent to EURO VI) vehicle emission standards (implemented in the capital Delhi in 2018).[163]

(4) Urban development

Since 2015, India has implemented the Smart Cities Mission[164] to establish 100 smart cities in the country to absorb the population influx from rural areas to urban areas and to accommodate the growing middle class. The total investment is expected to be more than 2 trillion rupees (about 3.2 trillion yen), of which 480 billion rupees (about 768 billion yen) is expected to be covered by subsidies from the central government, while the rest is to be covered independently by the provincial and municipal governments through various schemes including PPPs (public-private partnerships). Target cities were selected through four rounds of selection from January 2016 to June 2018. The project completion date was originally set to be within five years, but has been extended to June 2023 based on the impact of COVID-19.[165] The special website shows the progress of activities at each city (completed, underway, or tendering), and the progress varies from city to city.[166]

The Centre for Policy Research, an Indian think tank focused on public policy, selected 60 representative cities from the "Smart Cities Mission" target cities, surveyed and analyzed the energy initiatives of each city, and found that almost all cities have adopted the initiatives related to "energy supply," "energy production," and "lighting and equipment." With regard to "energy supply," which had the largest budget, most of the specific efforts were for basic infrastructure development, such as power distribution network development, and less than 18% of the budget was used for smart grids and smart meters that utilize ICT. As for "energy production," the majority of the allocated budget was used on installation of photovoltaic power generation (mainly rooftop solar).

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160 Ministry of Power, 2021-2-19, “Transport Minister Shri Nitin Gadkari launches ‘Go Electric’ Campaign in the august presence of Power Minister Shri RK Singh”, https://pib.gov.in/PressReleasePage.aspx?PRID=1699386

161 SankeiBiz, 2020.7.27, http://www.sankeibiz.jp/macro/news/200727/mcb2007270500007-n1.htm

162 BBC, 2019.11.4, https://www.bbc.com/japanese/50285251

163 DieselNet, Emission Standards, https://dieselnet.com/standards/in/ld.php

164 SMART CITIES MISSION, http://smartcities.gov.in/content/

165 The Indian Express, 2021.12.2, https://indianexpress.com/article/india/govt-extends-smart-cities-mission-timeline-to-2023-7653203/

166 Smart City, https://smartcities.gov.in/cities-profiles

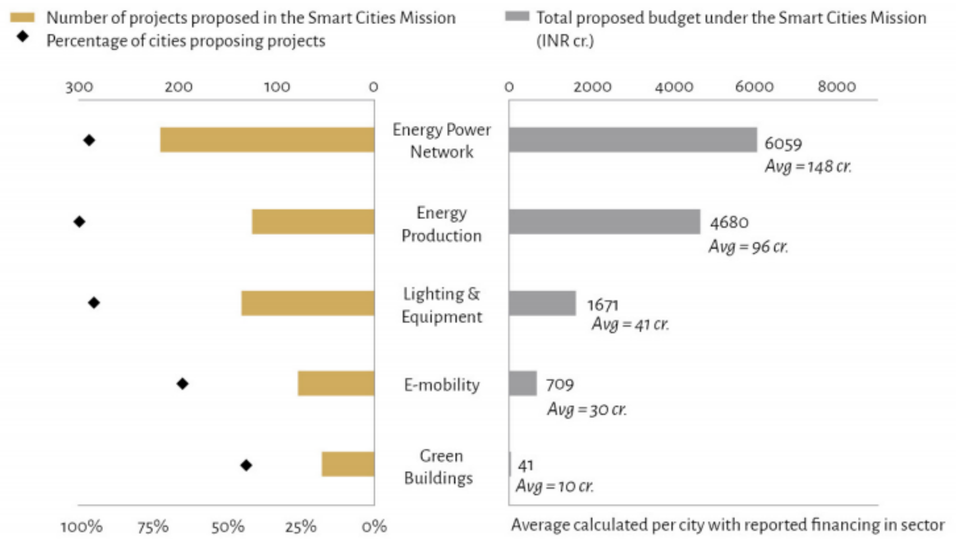

Figure 66 Energy Initiatives of Smart City Development in India (Ratio of cities adopting each category and budget allocation by category)

Source: NEW POWERS: HOW INDIA'S SMART CITIES ARE GOVERNING AND TRANSITIONING TO LOW-CARBON ENERGY

The initiatives adopted outside of basic infrastructure development, such as solar power, LEDs, and e-mobility, are already covered by nationwide support programs implemented by the central government, and only some of the cities are taking their own actions. This is due to the fact that there are no specific guidelines for initiatives that require complex sector- and system-wide discussions or coordination with the central and state governments, which tend to be avoided, and also due to concerns about the quality of services that may be degraded if the city decides to outsource to the private sector.[167]

(f) Next generation technology, innovation

[Hydrogen]

In 2006, The National Hydrogen Energy Board approved the National Hydrogen Energy Road Map - 2006. Although it set out numerical targets for hydrogen-based vehicles and power generation facilities with setting 2020 as the target year, no evaluation of plans had been conducted. Therefore, in June 2020, the Federation of Indian Chambers of Commerce and Industry (FICCI) published the India Roadmap on Low Carbon and Sustainable Mobility[168] and in that report, with regard to hydrogen energy, made medium- and long-term recommendations for the use of hydrogen. In December 2020, the Energy and Resources Institute of India (TERI) published The Potential Role of Hydrogen in India.[169] The report cites a five-fold increase in demand for hydrogen by 2050 and the fact that the cost of green hydrogen production in India could be competitive with the cost of production from natural gas by 2030, and recommends the encouragement of domestic production of electrolysis systems and the establishment of government initiatives from research and development to commercialization of hydrogen-related technologies.

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[167] Centre for Policy Research, JULY 2019, NEW POWERS: HOW INDIA'S SMART CITIES ARE GOVERNING AND TRANSITIONING TO LOW-CARBON ENERGY, https://cprindia.org/sites/default/files/New%20Powers_%20Working%20Paper_28%20Aug.pdf

[168] FICCI, "India Roadmap on Low Carbon and Sustainable Mobility", https://static.investindia.gov.in/s3fs-public/2020-06/India-Roadmap.pdf

[169] TERI, 2020.12.16, https://www.teriin.org/press-release/cost-hydrogen-renewables-could-fall-more-50-2030-says-teri-projects-five-fold-demand

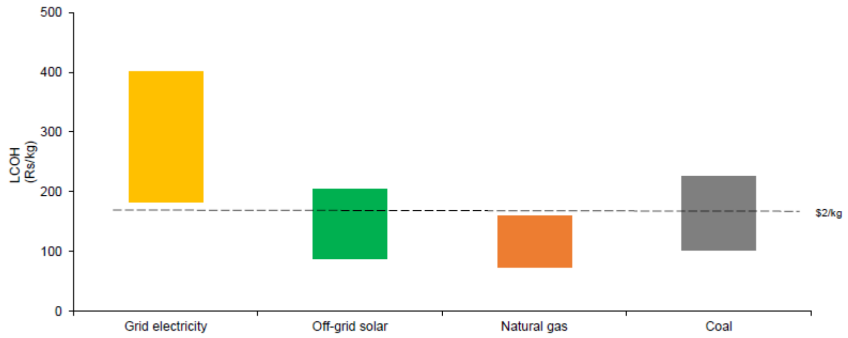

Figure 67 Hydrogen Production Cost Range by 2030 in India

Source: The Potential Role of Hydrogen in India

In August 2021, Prime Minister Modi announced in his Independence Day speech the launch of the National Hydrogen Mission, which aims to make India a green manufacturing and export hub. The government is considering a proposal to obligate fertilizer plants and oil refineries to purchase green hydrogen as part of hydrogen utilization.[170]

Under these circumstances, there has been a flurry of activity related to hydrogen in both the state and private sectors. As major initiatives related to hydrogen in state-owned enterprises, the National Thermal Power Corporation (NTPC) conducts the green hydrogen mobility project (introduction of fuel cell buses) in Ladakh, a federal district in the north,[171] a joint demonstration project with Gujarat Gas on blending natural gas and hydrogen in the city gas supply network,[172] and a project to develop a stand-alone microgrid using hydrogen fuel cells.[173] IOC is working with the Italian company Snam on hydrogen and gas value chain development (Adani group and Greenko are also participating),[174] construction of a green hydrogen plant at the Mathura refinery,[175] etc. The private sector has also been active, with Reliance setting a goal of lowering the cost of green hydrogen production[176] and ACME signing a memorandum of understanding with Omani company Tatweer to develop green hydrogen and ammonia production facilities in Oman.[177]

(g) Points to consider for future cooperation in promoting low-carbonization and decarbonization

- In India, coal-fired power generation has a large share in the power sector. While the country has indicated policies to reduce coal-fired power generation and expand gas-fired power generation and renewable energy, it has not provided a long-term roadmap consistent with the 2070 carbon neutrality goal. Currently, coal-fired power generation is relatively new and the use of coal-fired power is expected to continue to a certain extent from the

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170 Mint, 2021.8.15, https://www.livemint.com/news/india/independence-day-pm-modi-announces-national-hydrogen-mission-11629002077955.html

171 Energyworld, 2021.7.13, https://energy.economictimes.indiatimes.com/news/renewable/ntpc-to-set-up-indias-first-green-hydrogen-mobility-project-in-ladakh/84368914

172 The Economic Times of India, 2021.10.12, https://energy.economictimes.indiatimes.com/news/oil-and-gas/ntpc-gujarat-gas-blend-hydrogen-for-homes/86939821

173 NNA ASIA, 2021.12.17, https://www.nna.jp/news/show/2276964

174 Snam, 2020.11.6, https://www.snam.it/en/Media/news_events/2020/Snam_enters_the_Indian_market_low_carbon_mobility_hydrogen.html

175 Financial Express, 2021.7.24, https://www.financialexpress.com/industry/indian-oil-corporation-to-build-green-hydrogen-plant-at-mathura-refinery/2296759/

176 Financial Express, 2021.9.4, https://www.financialexpress.com/industry/clean-hydrogen-reliance-industries-bets-big-on-green-energy/2323714/

177 FuelCells, 2021.3.25, https://fuelcellsworks.com/news/india-acme-signs-us-2-5-billion-investment-deal-in-oman-with-tatweer-to-set-up-green-hydrogen-ammonia-plant/

perspective of effective utilization of domestic coal reserves. Toward the low-carbonization of electricity in India, Japan may be able to provide support for the formulation of a long-term roadmap and for the introduction of clean coal technologies, such as higher efficiency coal-fired power generation and ammonia co-firing.

- With the expansion of renewable energy, India has been developing its power grid, represented by the Green Energy Corridor Project in collaboration with Germany. In addition to this, the implementation of tendering for renewable energy + storage facilities is being conducted, and there is a need to utilize storage batteries and upgrade the operation of power distribution networks for the integration of renewable energy into the grid, and some support in this field would be warranted. In addition, the country aims to expand the use of EVs, the integration of EVs into the power system (and their impact on the grid), along with renewable energy, is considered to be an area of high interest.
- Energy demand is expected to increase in the future, especially in the transportation sector. In consideration of reducing oil imports and environmental burden, it will be important to develop transportation infrastructure and modal shift to public transportation, in addition to promoting EVs and alternative fuels. Japan may be able to provide support for sustainable urban development in areas in which Japan has a wealth of experience and expertise, such as public transportation-oriented development (TOD) and environmental symbiosis.
- India is set to undergo rapid urbanization in the future, and energy demand in buildings is expected to increase. The need for improving energy efficiency and the introduction of high-efficiency equipment will likely increase due to the strengthening and spread of energy conservation management and standards in buildings (residential and office buildings) and labeling systems for home appliances.
- Since mid-2020, there has been a flurry of activity related to hydrogen, with both state and private companies entering into partnerships with European companies for hydrogen research and development, backed by government encouragement. The National Hydrogen Mission is scheduled to be announced in 2022, and there is room for Japan to consider the possibility of cooperation in hydrogen-related fields.

(6) Myanmar

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

Myanmar's energy demand has increased dramatically along with economic development, especially since 2010. Biomass accounts for just under 50% of the primary energy supply, but this share has been declining since 2010, and the increasing energy demand has been met by oil and its natural gas reserves.

As for power generation, the country takes advantage of its abundant hydroelectric resources, with hydroelectric power generation accounting for approximately 50% of the electricity generated. However, hydropower development has stalled lately due to concerns about negative social and environmental impacts, and development prospects are uncertain. In recent years, Myanmar has also been developing gas-fired power generation, but because natural gas is a valuable means of earning foreign currency, as of 2016, approximately 80% of domestic production was exported to Thailand and China[178] and Myanmar is not fully utilizing its reserves within the country. Currently, natural gas production is on a downward trend and one of the challenges is to restore the production. According to ERIA, electricity demand is expected to quadruple over the next 30 years to 2050, making the development of power sources an urgent need.[179]

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[178] Information Center for Petroleum Exploration and Production（ICEP）, January 2017, http://www.icep.or.jp/02_zigyou/jinzai_link/icep290131.pdf

[179] ERIA, Energy Outlook and Energy Saving Potential in East Asia 2020, https://www.eria.org/publications/energy-outlook-

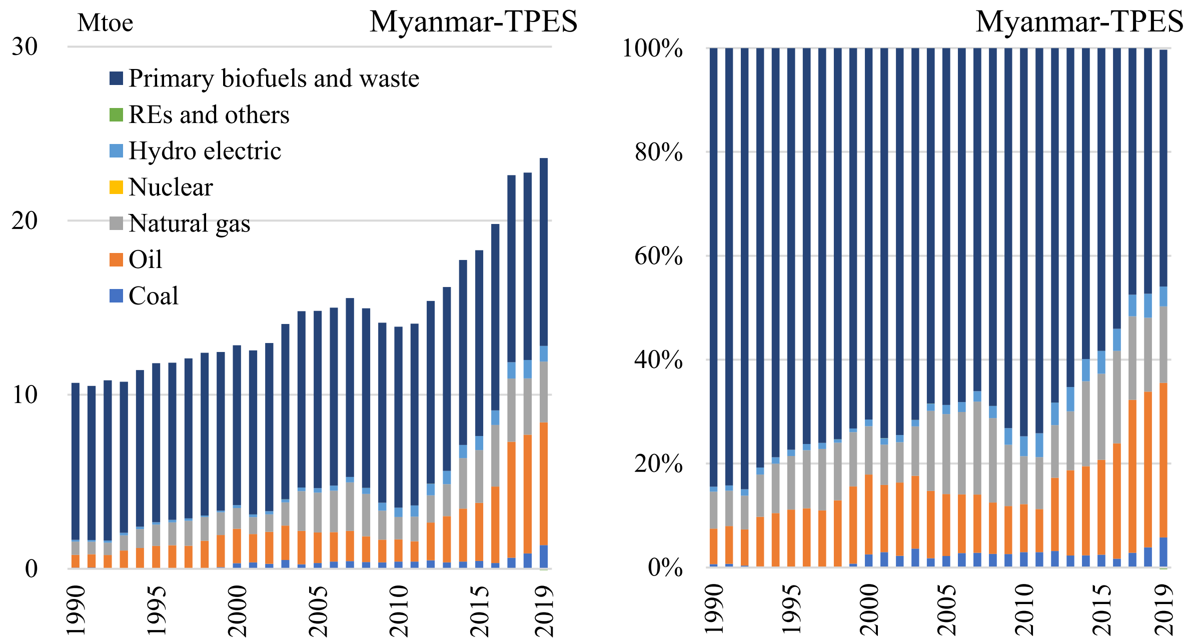


Figure 68 Primary Energy Supply in Myanmar

Source: World Energy Balances 2021 extended edition database, IEA

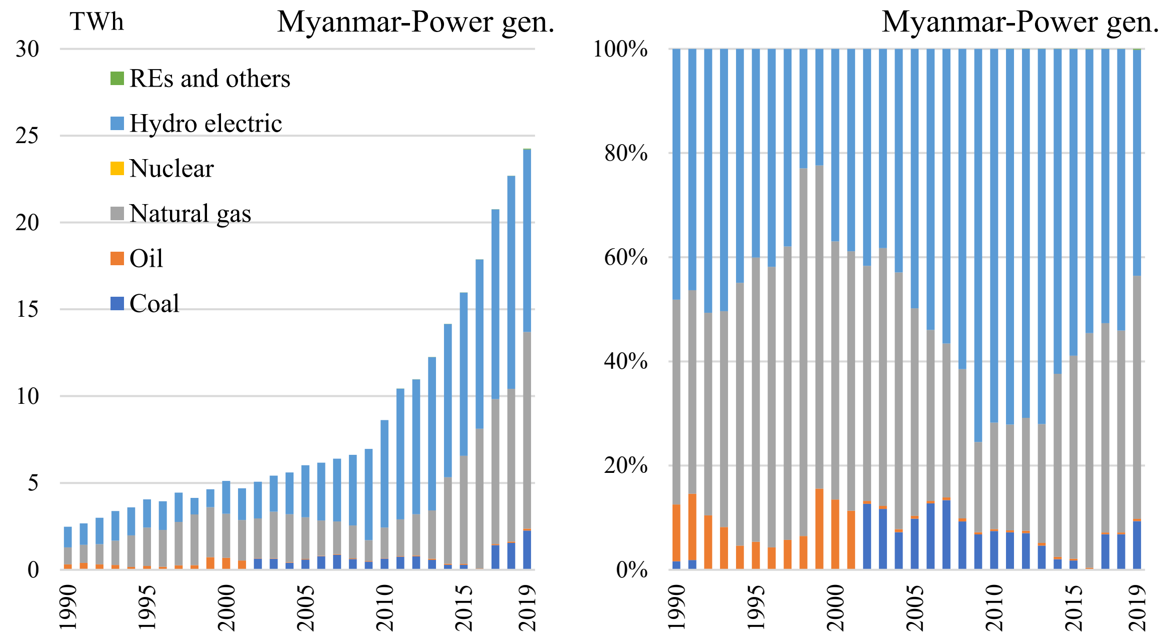


Figure 69 Fuel Mix of Elecrricity Gneration in Myanmar

Source: World Energy Balances 2020 database, IEA

A breakdown of final energy consumption by sector shows 36% for industry, 23% for transportation, 8% for residential, and 8% for commercial/public services in 2019. In the five-year growth from 2014 to 2019, commercial/public services, although smaller in consumption,

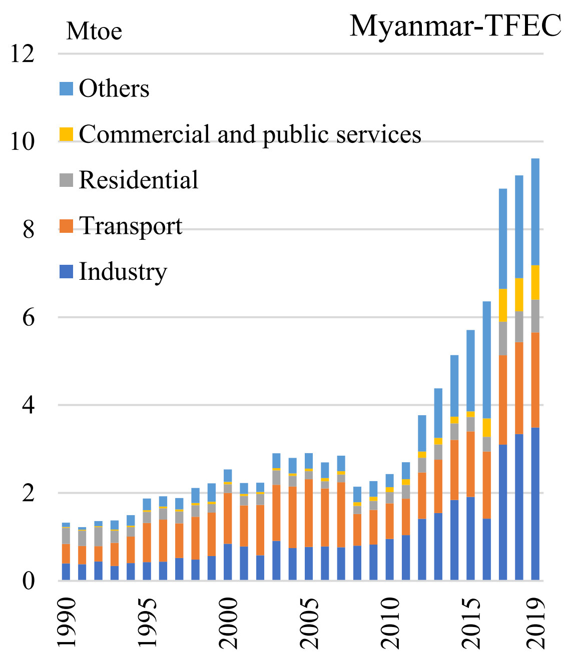
and-energy-saving-potential-in-east-asia-2020/

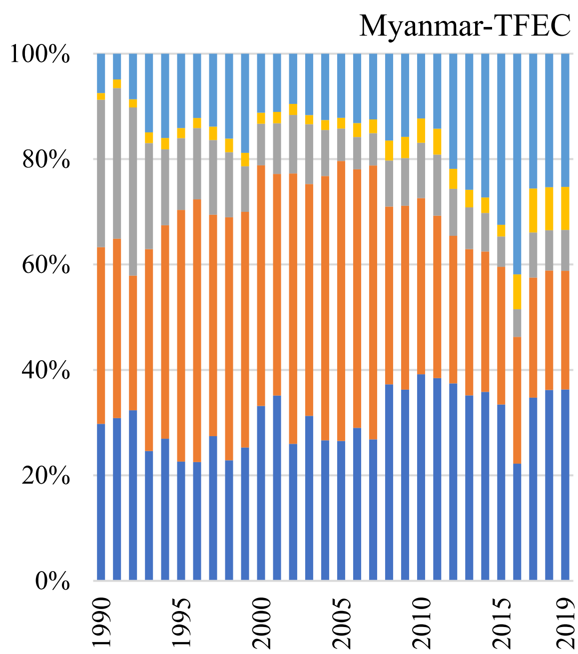
grew rapidly at 38.8%, followed by industry at 13.6% and housing at 14.7%.

What is characteristic about the industry is the increase in consumption and use of petroleum since around 2010. One of Myanmar's major industries is the clothing and sewn product industry, and this increase in consumption is likely due to foreign companies having been transferring their production bases to Myanmar in recent years, backed by its inexpensive labor costs compared to other ASEAN countries. It is considered necessary to introduce high-efficiency equipment and energy conservation measures in major industries where energy consumption is expected to increase in the future.

In transportation, 92% is oil and the remaining 8% is natural gas. Myanmar's GDP per capita is $1.53 thousand (2019),[180] which is one of the lowest levels in ASEAN, along with Cambodia, and the car ownership rate is low.

Although the use of electricity is increasing in the residential sector, the reality is that biomass, primarily firewood, is the main source of energy for household use, causing environmental pollution and health hazards. The government has been working with international organizations to promote the use of more energy-efficient biomass cooking appliances. Possible further measures include transition to LPG and promotion of electrification, but a balanced approach is needed that takes into account the increasing cost of fuel imports, energy security issues due to increased import dependence, and uncertainties surrounding power plant development.





180 IMF, Myanmar, Country Data, https://www.imf.org/en/Countries/MMR#countrydata

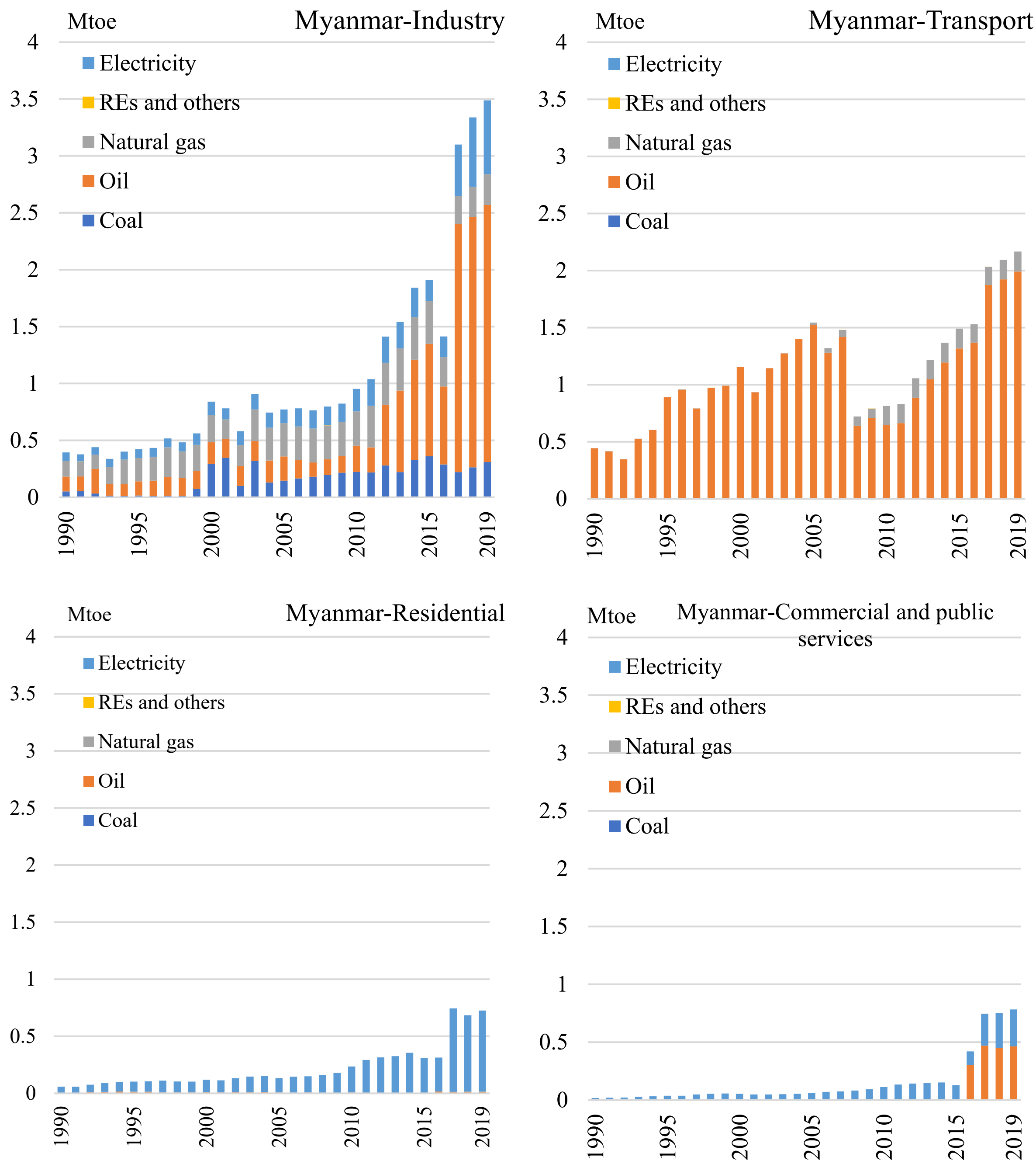


Figure 70 Final Energy Consumption of Major sectors in Myanmar

Excludes "Primary solid biofuels," "Non-specified primary biofuels and waste," and "Charcoal."
"Others" in TEFC includes agriculture, forestry, fisheries, other, and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP has been decreasing year by year and was 0.281 toe/$1000 in 2019 (0.090 in Japan). There is much room for improvement, including thermal efficiency improvements in thermal power generation and energy conservation measures in all sectors.

The average thermal efficiencies are at low levels, around 26% for gas-fired thermal and around 28% for coal-fired thermal. In the future, thermal power development is expected to take place associated with an increase in electricity demand, and the introduction of high-efficiency thermal power generation will contribute to a stable energy supply and low-carbon power generation in Myanmar. It is also important from the perspective of low-carbon electricity and energy security for Myanmar to find a balance between exports and domestic use of its natural gas reserves.

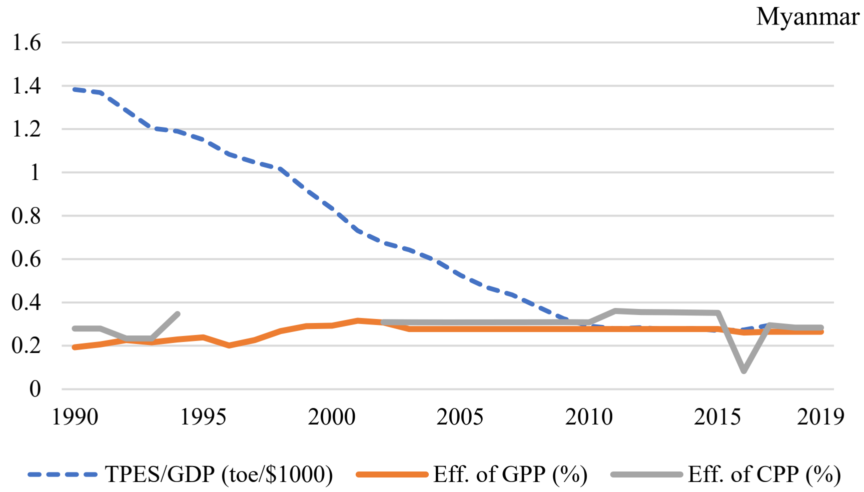


Figure 71 Energy Efficiency in Myanmar

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant, CPP = coal power plant, GDP in 2015 price

Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options Myanmar could take to reduce its CO_2 emissions in the future and their CO_2 reduction effects.

Table 72 Examples of Low-carbon/ Decarbonization Potential in Myanmar

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		39.3 mton-CO2
	【Example of CO2 Emission Reduction Option】	【Reduction Effect】
Generation	Substitute 15% of Gas for Renewable Energy	1.30mton-CO2
Industry	Substitue 50% of Oil for Natural Gas	0.85 mton-CO2
Transport	10% Improvement of Fuel Mileage	0.55 mton-CO2
Residential	SubstitueBiomass for LPG/ Electrification	—

Note: 2019 actual = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES

Source: JICA Study Team

(2) Primary energy mix and electricity mix planning

[Primary energy mix]

According to the Myanmar Energy Master Plan (MEMP) released in January 2016, the average annual economic growth rate through 2030 is 7.1% and final energy consumption is expected to grow from 12.6 Mtoe in 2012 to 21.9 Mtoe in 2030.[181] On the supply side, it is envisioned to reduce dependence on biomass by promoting electrification, and to expand the use of oil and natural gas.

[181] The Government of the Republic of the Union of Myanmar National Energy Management Committee(NEMC), "Myanmar Energy Master Plan (December 2015)", http://www.burmalibrary.org/docs22/2015-12-Myanmar_Energy_Master_Plan.pdf

Table 73 Final Energy Consumption outlook up to 2030 in Myanmar

	2012	2015	2018	2021	2024	2027	2030
TFC	12.6	14.2	15.3	16.5	17.9	19.6	21.9
Coal	0.1	0.1	0.2	0.2	0.3	0.4	0.6
Oil	2.5	3.4	3.6	4.0	4.4	4.9	5.5
Gas	0.6	0.9	1.2	1.5	2.0	2.5	3.2
Electricity	0.7	1.0	1.3	1.8	2.4	3.2	4.3
Biomass Type II	8.8	8.9	9.0	9.0	8.8	8.6	8.4
Shares (%)							
Coal	0.6	0.8	1.1	1.4	1.7	2.1	2.5
Oil	19.3	23.9	23.7	23.9	24.5	24.8	25.0
Gas	5.0	6.2	7.7	9.3	11.0	12.7	14.4
Electricity	5.5	6.7	8.7	10.9	13.5	16.4	19.6
Biomass Type II	69.6	62.3	58.8	54.5	49.2	43.9	38.5

Source: Myanmar Energy Master Plan

According to ERIA's Natural Gas Master Plan for Myanmar[182] (published in 2017), total natural gas production in Myanmar is on a declining trend, and even taking into account the development of new gas fields, it is not enough to compensate for the depletion of existing gas fields and the total production is expected to be about half of the 2020 levels by around 2030. Currently, LNG imports and LNG-fired power generation development projects are underway to meet growing domestic energy demand, and in July 2020, a group of Japanese companies received exclusive development rights from the Ministry of Electricity and Energy (MOEE) for the Thilawa LNG To Power project in Thilawa District, Yangon Region. The project involves the construction, ownership and operation of a 1,250 MW gas-fired thermal power plant and onshore LNG storage and regasification facility, the largest of its kind in Myanmar.[183]

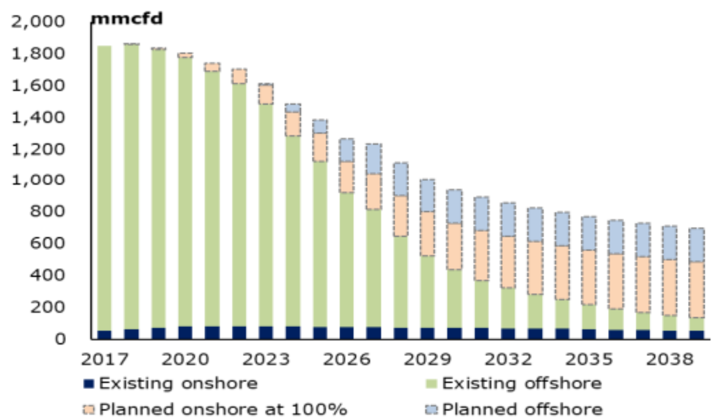


Figure 72 Domstic Natural Gas Production Outlook in Myanmar
Source: Natural Gas Master Plan for Myanmar

[Power mix]

According to the MEMP released in January 2016, for 2030, hydropower will continue to be the main source of energy, with coal-fired power generation development planned to meet the increasing demand for electricity. The power source mix in 2030 is expected to be hydropower 57%, coal 30%, gas 8%, and solar 5%.[184] On the other hand, the latest NDC updated in August

182 ERIA, “Natural Gas Master Plan for Myanmar”https://www.eria.org/uploads/media/RPR_FY2017_17_fullreport.pdf
183 Sumitomo Corp., July 27, 2020, https://www.sumitomocorp.com/ja/jp/news/release/2020/group/13600
184 The Government of the Republic of the Union of Myanmar National Energy Management Committee(NEMC), “Myanmar Energy Master Plan (December 2015)”, http://www.burmalibrary.org/docs22/2015-12-

2021 sets the 2030 power source mix target (Conditional Target) to be hydro 31%, coal-fired 11%, gas-fired 33%, renewable energy (other than hydro) 17%, and imports 8% if international support is provided, which, compared to the MEMP, indicates a direction toward decreasing hydro and coal power and increasing gas power. This is due to growing environmental awareness and concerns about the social and environmental impacts of large-scale hydropower development.[185]

Source:

(3) Current status and targets of electricity access

According to the IEA, the electrification rate in 2019 was 51%, with 76% in urban areas and 39% in rural areas.[186] In rural un-electrified areas, biomass is the main source of energy, and the government has made supplying alternative energy sources (LPG, electrification, etc.) to the region one of its key policies. With support from the World Bank, Myanmar is pursuing the National Electrification Plan (NEP), which aims to increase the electrification rate to 75% by 2025 and to 100% by 2030.[187]

(b) Electric utility system

(1) Electricity supply system

In the electric power business, the generation, transmission, and distribution sectors are separated. The 1994 revision of the Foreign Investment Law allowed the introduction of private capital, but at present IPP projects are being implemented only in the power generation sector. The transmission sector is dominated by the Department of Power Transmission and System Control (DPTSC), and the distribution sector by the Yangon Electricity Supply Corporation, Mandalay Electricity Supply Corporation, and Electricity Supply Enterprise.

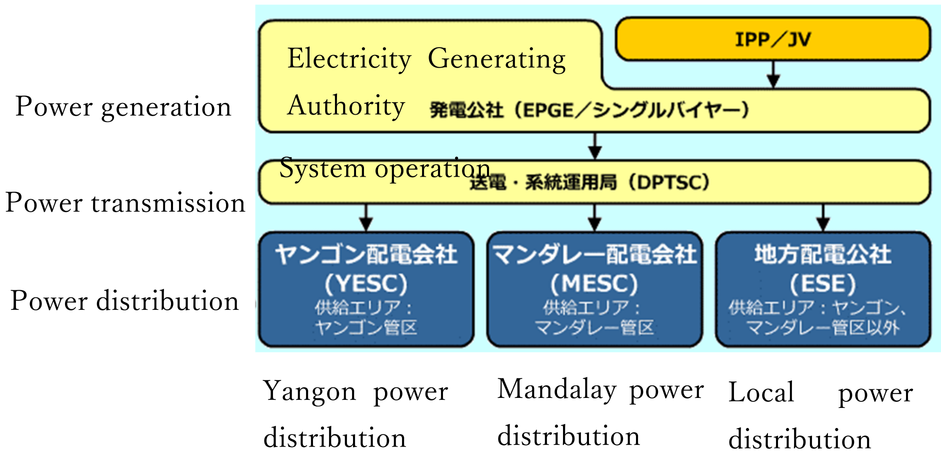


Figure 73 Electricity Supply Structure in Myanmar

Source: Overseas Electric Power Industry Statistic[188]

(2) Renewable electricity supply system

The use of solar power in rural SHS and mini-grids is led by the government, supported by

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Myanmar_Energy_Master_Plan.pdf

[185] UNFCCC, Myanmar, Nationally Determined Contributions, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Myanmar%20First/Myanmar%20Updated%20%20NDC%20July%202021.pdf

[186] IEA, Access to electricity, https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

[187] IEA, Policies, https://www.iea.org/policies/6287-myanmar-national-electrification-project-nep

[188] JAPAN ELECTRIC POWER INFORMATION CENTER, https://www.jepic.or.jp/data/asia08mymr.html

various international organizations. For larger projects, the Ministry of Electricity and Energy (MOEE) conducts a tendering process to select the solar power generation provider. The successful bidder will operate the solar power plant on a 20-year BOO (build, own, operate) basis and sell electricity to the Electric Power Generation Enterprise under the Ministry of Electricity and Energy.[189]

(c) Policy on renewable energy

(1) Potential of renewable energy

Regarding photovoltaic power generation, Myanmar has great potential due to its sunny conditions throughout the country, especially at the central area. For wind power, there is potential in some areas, including coastal and central areas

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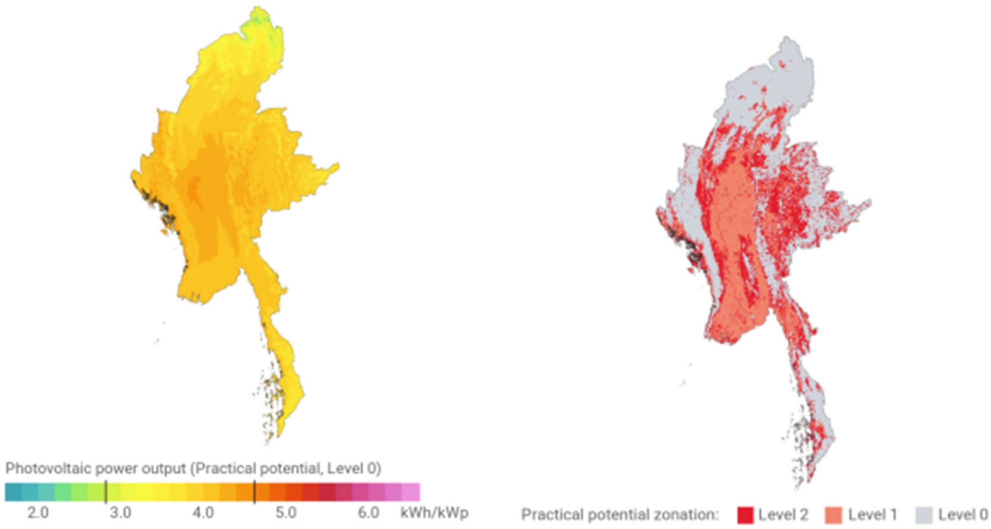

Figure 74 Solar Power Generation Potential in Myanmar

Note: Left = estimated power generation.
Right = potential zones; Level 0 = no constraints, Level 1 = excluding topographic constraints, Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

189 NNA Asia, 2020.5.20, https://www.nna.jp/news/show/2045682

Figure 75 Wind Power Generation Potential in Myanmar

Note: The mean wind speeds shown are the representative values at the elevation of 50 m. Red color indicates the fastest wind speed.

Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

MOEE has jurisdiction over the energy sector, including renewable energy.

(3) Development targets

Myanmar is moving toward renewable energy development, with the first commercial-scale solar power operations beginning in 2019, but the government has not provided clear deployment targets or roadmaps for individual energy sources.

In the latest NDC updated in July 2021, the share of renewable energy (excluding hydropower) in the power supply mix based on installed capacity in 2030 is assumed to be 11% (2,000 MW) if Myanmar works alone (unconditional) and 17% (3,070 MW) if international support is provided (conditional), and the country showed its policy to promote use of energy with receiving international support. Regarding the status of renewable energy development, the NDC stated that 40 MW of solar PV is in operation, 8.25 MW is under construction, 1,060 MW is in the tendering process, and 30 MW of wind power is in the feasibility study stage.[190]

In September 2020, the results of the first tender by the Ministry of Electricity and Energy to select the operator of 29 solar power plants (totaling over 1,000 MW) were announced, with Chinese companies winning 28 of the bids and German companies winning the remaining one. The project had an agreement with the government to complete the facility within six months of receiving project approval.[191]

(4) Introduction promotion policy

In April 2017, the list of promoted investment sectors (MIC Notification No. 13/2017, Classification of Promoted Sectors) promulgated under the Investment Law granted preferential treatment in 20 sectors, including tax incentives and long-term lease of land, covering renewable energy production as well as power generation, transformation and transmission.[192]

[190] UNFCCC, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Myanmar%20First/Myanmar%20Updated%20%20NDC%20July%202021.pdf

[191] NNA Asia 2021.1.4 https://www.nna.jp/news/show/2137445

[192] JETRO、December 10, 2020, https://www.jetro.go.jp/world/asia/mm/invest_03.html

The Ministry of Electricity and Energy is in the process of developing a renewable energy law to promote the introduction of renewable energy, and the bill intends to procure 8% and 12% of domestic electricity supply from renewable sources by 2021 and 2025, respectively.[193]

(d) Energy conservation policy

(1) Institutions in charge of policy

The Ministry of Industry is responsible for energy conservation policy.

(2) Targets[194]

The updated NDC submitted to the UN in July 2021 calls for a 20% reduction in energy demand as of 2030 from the baseline (target conditional on international support: cumulative 133,000 tCO_2 reduction). The sectoral energy conservation targets are 6.63% for industrial, 4% for commercial, 7.8% for residential, and 1.36% for other, as shown in Figure below.

In addition, the National Energy Efficiency and Conservation Policy, Strategy and Roadmap for Myanmar, formulated by the Ministry of Industry with ADB support in 2016, provides energy conservation targets and roadmaps for each sector. The overall goal is to reduce energy intensity by 12% by 2020, 16% by 2025, and 20% by 2030 from the 2012 baseline.[195]

Table 74 Energy Efficiency Target by 2030 in Myanmar

Sector	Weighted Average Saving Potential (%)	Achievable Target by 2020 (%)	EE Policy Target – 2020 (%)	Achievable Target by 2025 (%)	EE Policy Target – 2025 (%)	Achievable Target by 2030 (%)	EE Policy Target – 2030 (%)
Industry	8.84%	40	3.54	60	5.31	75	6.63
Commercial / Public	4.97%	40	1.99	60	2.98	80	3.98
Residential	9.70%	55	5.36	70	6.82	80	7.80
Other	1.7%	40	0.68	60	1.02	80	1.36
Total	**25.26%**		**11.7**		**16.1**		**19.77**
EE Policy Targets			12		16		20

Source: National Energy Efficiency and Conservation Policy, Strategy and Roadmap for Myanmar

193 Myanmar Times 2018.9.19 https://www.mmtimes.com/news/renewable-energy-law-works-speed-development.html

194 ASEAN-German Energy Programme, https://agep.aseanenergy.org/country- profiles/myanmar/myanmar-ee-sector/#1524895511136-18f61953-fecd870d-185982b1-30e2

195 ADB, "National Energy Efficiency and Conservation Policy, Strategy and Roadmap for Myanmar", https://www.adb.org/sites/default/files/project-documents/46389/46389-001-tacr-en.pdf

Table 75 Energy Efficiency Potential by Sector in Myanmar

Sector	Sub-Sector	Main Fuel Used	Saving Potential (%)			EE Technologies Proposed
			Min	Max	Ave	
Industry	Iron and Steel	Electricity	5	65	45	Cogeneration, EE Boiler, Waste Heat Recovery, EE Furnace, High Efficiency Motors
	Cement	Electricity	3	43	23	High Efficiency Motors, EE Kilns, Cogeneration, Waste Heat Recovery, Variable Speed Drives
	Pulp and Paper	Electricity	50	80	65	Cogeneration, EE Boiler, Waste Heat Recovery, EE Furnace, High Efficiency Motors
	Textile	Electricity	5	20	12.5	High Efficiency Motors, EE Boilers, EE Lighting, EE Air Conditioners
	Thermal Power Plants	Diesel / Electricity	3	5	4	High Efficiency Motors, Cogeneration, Combined Cycle Gas Turbine
	Sugar Mills	Bagasse / Electricity	25	45	35	Boilers, Waste Heat Recovery, Cogeneration, High Efficiency Motors
	Rice Mills	Electricity / Rice husks		35		Cogeneration, EE Boilers
	Ceramic and Brick	Biomass / Electricity	15	25	20	Cogeneration, Waste Heat Recovery, EE Kilns, High Efficiency Motors
Commercial	Office Buildings	Electricity	20	30	25	HE Lighting, ACs, Office Equipment through MEPS
	Restaurants	Electricity / LPG	20	35	25	HE Lighting, ACs, LPG cooking, Solar water heating
	Hotels	Electricity / LPG	20	35	30	HE Lighting, ACs, LPG cooking, solar water heating
Residential	Urban Households	Electricity / LPG / Biomass	25	40	30	HE Lighting, refrigeration, MEPS for appliances, SHW, LPG cooking
	Rural Households	Electricity / Biomass	25	40	30	HE Lighting, refrigeration, MEPS for appliances
Public Sector	Public Buildings	Electricity	20	30	25	HE Lighting, ACs, Office Equipment through MEPS
	Hospitals	Electricity / LPG	20	35	30	HE Lighting, ACs, LPG cooking, SWH, cogeneration
	Schools	Electricity / LPG	20	30	25	HE Lighting, ACs, Office Equipment through MEPS, Boilers, SWH
	Public Lighting	Electricity	35	65	50	LED, HPS street lighting

Source: National Energy Efficiency and Conservation Policy, Strategy and Roadmap for Myanmar

(3) Promotion policy

The National Energy Policy published in 2014 referred to energy conservation. Specifically, it stated the need to develop laws and regulations on energy conservation, establish a department specializing in energy conservation, accumulate experience through collaboration with international organizations, and develop a funding mechanism to implement energy conservation programs. In addition, the abovementioned roadmap formulated in 2016 provided a policy for initiatives in the industrial, commercial, utility, and residential sectors, which are prioritized for implementation.

(e) Environmental policy

(1) Greenhouse gas emission reduction targets[196]

The updated NDC submitted to the United Nations in July 2021 indicated that GHG emission reduction targets by 2030 would be 244.52 million tCO_2 as an unconditional target and 414.76 million tCO_2 as a conditional target with international support.

(2) Promotion policy

The Ministry of Natural Resources and Environmental Conservation (MONREC) is responsible for environmental policies.

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196 UNFCCC, The Republic of the Union of Myanmar NATIONALLY DETERMINED CONTRIBUTIONS, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Myanmar%20First/Myanmar%20Updated%20%20NDC%20July%202021.pdf

In 2019, the government formulated the Myanmar Climate Change Policy (MCCP) (2019), Myanmar Climate Change Strategy (MCCS) (2018-2030), and the Myanmar Climate Change Master Plan (MCCMP) (2018-2030) in order to reflect measures against climate change on short-, medium-, and long-term national development plans and policies. The MCCP outlines long-term goals to promote adaptation and mitigation in response to climate change, consistent with the Paris Agreement, and to realize a climate-resilient, low-carbon society. The MCCS and MCCMP are guidelines in the implementation of adaptation and mitigation, and provide short-, medium-, and long-term action plans. The below are the six priority sectors. [197]

- ➢ Climate-smart agriculture, fisheries, and livestock for food security
- ➢ Sustainable management of natural resources for healthy ecosystems
- ➢ Resilient, low-carbon transportation and industrial systems for sustainable growth
- ➢ Resilient, inclusive, and sustainable cities
- ➢ Climate risk management for people's health and well being
- ➢ Education, science, and technology for a resilient society

(3) Transportation

[Electric vehicles]

In November 2018, the Ministry of Industry agreed with Green Power Myanmar to promote a project to produce electric buses and install charging stations to spread EVs. Green Power Myanmar has a partnership with Hungary and plans to promote the spread making use of Hungary's technology. In September, Chinese automaker Yue Di and local Khaing Khaing Sang Da Motorcar (KSD) announced a joint venture to assemble and produce EVs in the Yangon Region.[198] In addition, in January 2019, the Minister of Industry announced that it would be encouraging domestic EV production. Attention needs to be paid to the future development.

(4) Urban development

Yangon, Nay Pyi Taw, and Mandalay were selected for the ASEAN Smart Cities Network (ASCN)[199] launched in 2018. In 2019, the Minister of Construction announced a national policy to promote the transformation of the three cities into smart cities, especially the Korea-Myanmar Industrial Complex (KMIC) and Smart District Project in Yangon, the New Mandalay Resort City in Mandalay, and the Yadanabon Cyber City.[200]

(f) Next generation technology, innovation

N/A.

(g) Points to consider for future cooperation in promoting low-carbonization and decarbonization

- Myanmar is working to develop LNG receiving terminals and LNG-fired power stations, as the depletion of domestically produced natural gas and the consequent need to secure energy supply capacity has become major issues for the country. Although the country plans to utilize coal in the future, the need for support related to the effective use of domestic

[197] UNFCCC, The Republic of the Union of Myanmar NATIONALLY DETERMINED CONTRIBUTIONS, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Myanmar%20First/Myanmar%20Updated%20%20NDC%20July%202021.pdf

[198] BayCurrent、https://www.baycurrent.co.jp/our- insights/pdf/Potential%20of%20Myanmar.pdf (Access, February 16, 2021)

[199] In April 2018, the lead of Singapore, which was the presidency of the ASEAN Summit, aims to overcome various social issues brought about by rapid urbanization in ASEAN with technology and digital solutions and improve the quality of life of residents. The "ASEAN Smart City Network (ASCN)" initiative has begun. Twenty-six cities have been selected from 10 ASEAN countries, aiming to promote smart city development projects through collaboration with private companies and other countries.

[200] NNA 2019.12.19 https://www.nna.jp/news/show/1988210

natural gas and LNG imports is expected to be higher, given the possible growing demand for low-carbonization.

- Myanmar is working on electrification, especially in rural areas, and is promoting energy transition from biomass, current major source of energy, to electricity and LPG. Although the electrification rate has improved significantly over the past few years, it is still just over 50% and continued support will be required in this area including the introduction of mini-grids that utilize renewable energy (mainly solar and hydro).
- The country also started developing large-scale PV: the first large-scale PV installation became operational in 2019, and tenders for a total capacity of 1,060 MW began in 2020. However, the renewable energy market is underdeveloped and facing many challenges, and Myanmar could use help toward the establishment of a support system by the government and financial institutions (e.g., clarification of development targets, enactment and operation of a renewable energy law, and establishment of systems to promote private investment).
- The demand for energy is expected to increase in line with economic growth in the future. The energy conservation roadmap specifically outlines a roadmap for each sector, and various forms of support during the implementation phase of this roadmap may contribute to low-carbonization and decarbonization in the medium to long term.

(7) Indonesia

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

As of 2020, Indonesia's population is approximately 270 million, making it the fourth largest in the world, and it has the largest GDP among ASEAN countries. Real GDP growth has remained above 5% in recent years, and energy demand has been increasing year after year. Java Island has the largest energy demand, followed by Sumatra Island.

Indonesia has abundant energy reserves, and is one of the world's largest exporters when it comes to coal. In terms of primary energy supply, oil has the largest share of 31% (2019), but coal and renewable energy have been increasing since around 2000. Renewable energies such as geothermal and hydropower have great overall potential, although the resources are scattered throughout the country, and there are plans to continue to utilize them.

With regard to power generation, in response to the recent increase in electricity demand, the country has been shifting from oil-fired power generation, whose production has declined, to coal-fired power generation, which accounted for 59% of the total electricity generated in 2019. From the perspective of environmental measures, the country set forth a policy is to reduce dependence on coal-fired power generation and to develop renewable energy in the future. One of the key points of low-carbonization and decarbonization in electricity is the expansion of geothermal power generation, which has one of the highest potentials in the world as renewable energy but has not yet been developed.

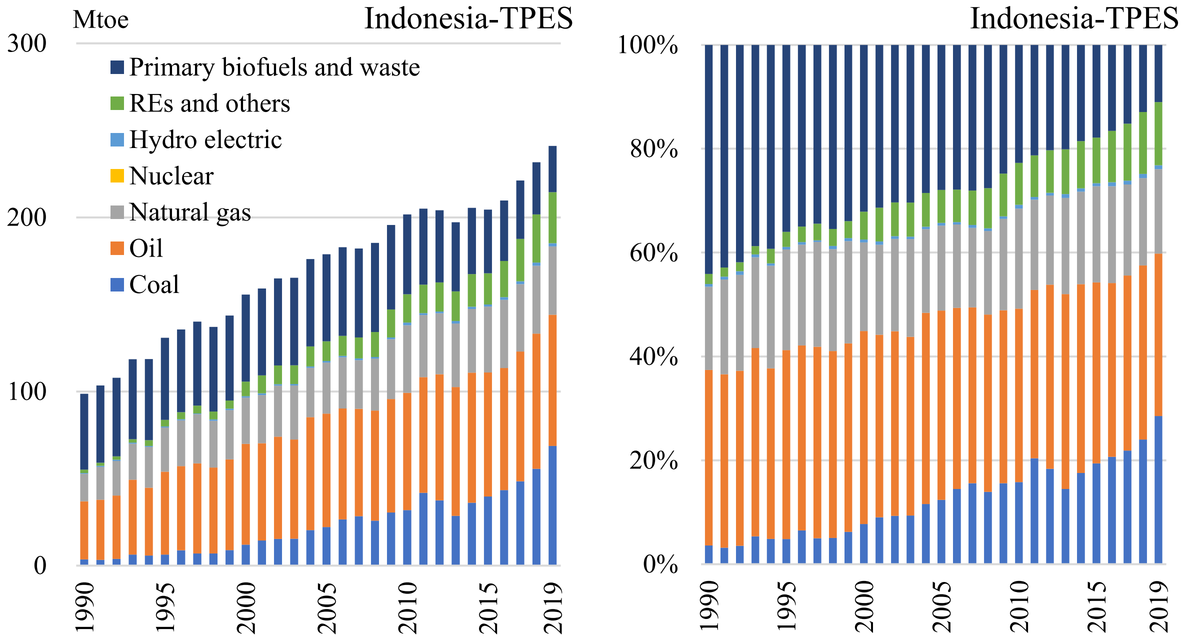


Figure 76 Primay Energy Supply in Indonesia

Source: World Energy Balances 2021 extended edition database, IEA

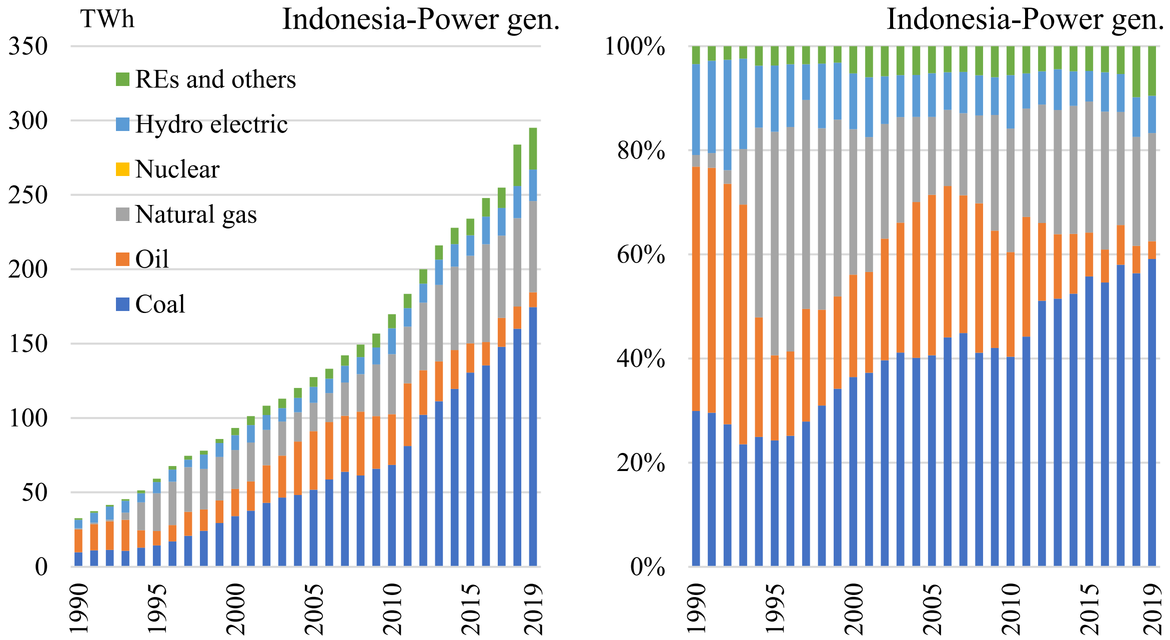


Figure 77 Fuel Mix of Electricity Generation in Indonesia

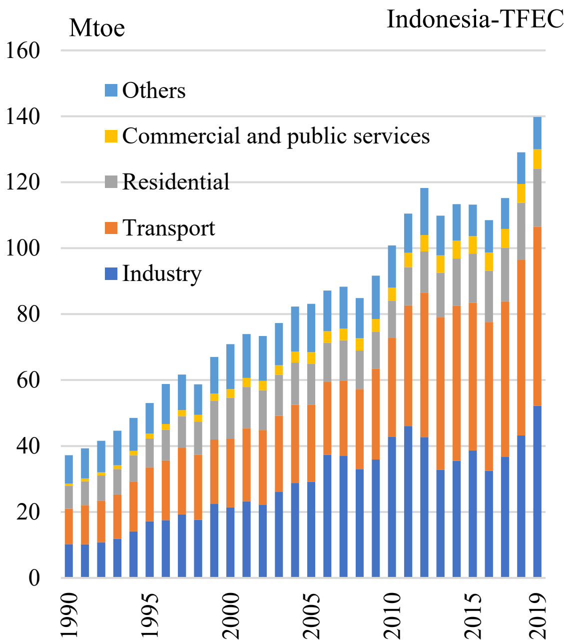
Source: World Energy Balances 2021 database, IEA

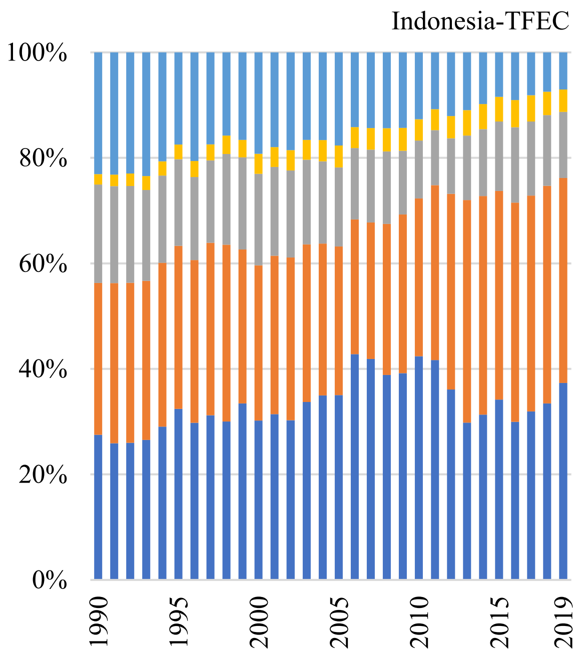
The sectoral breakdown of final energy consumption is characterized by a high share of transportation in 2019: 37% for industry, 39% for transportation, 13% for residential, and 4% for commercial/public services. In terms of five-year growth from 2014 to 2019, industry had the largest growth at 8.0%, followed by residential at 4.1% and transportation at 2.9%.

What is characteristic about the industry is the intermittent increase in energy consumption, which may be attributable to the transition of major industries. Looking at the share of GDP by industry, Indonesia has been focusing on manufacturing since the oil crisis, and the share of manufacturing in GDP rose to nearly 30% around 2000. Since about 2010, the services sector, which had accounted for about 40% of GDP, has expanded further, and the share of the manufacturing sector has declined.[201] With regard to the low-carbonization of the manufacturing industry, Japanese companies are working on the introduction of high-efficiency equipment and heat utilization initiatives through JCM, and ongoing energy efficiency improvement and energy conservation measures are considered necessary in the future.

In the transportation sector, oil accounted for 92%, with the remaining 7% coming from renewable energy and other sources (2019). The consumption started to increase considerably in around 2010, and is expected to keep growing. However, traffic congestion and air pollution caused by the increase in the number of automobiles, especially in urban areas, are becoming an issue. In the future, in addition to the government's various measures to utilize biofuels and improve fuel efficiency of automobiles, it will be necessary to improve transportation infrastructure and modal shift to public transportation.

In the residential and commercial/public services sectors, use of electricity is on the rise. As further urbanization is expected to increase cooling demand in particular, the introduction and spread of an energy efficiency labeling system for home appliances, including air conditioners, which has already been introduced, could be an effective measure toward a low-carbon society. While the country's overall electrification rate is 99.5% (2019), some remote islands and rural areas far from towns have no other choice but to use diesel and gasoline generators to generate electricity, and biomass is also widely used. Microgrid projects using renewable energy in such regions will also likely contribute to the promotion of low-carbonization and decarbonization.





201 JETRO, October 2017, https://www.ide.go.jp/library/Japanese/Researchers/pdf/yuri_sato_1710.pdf

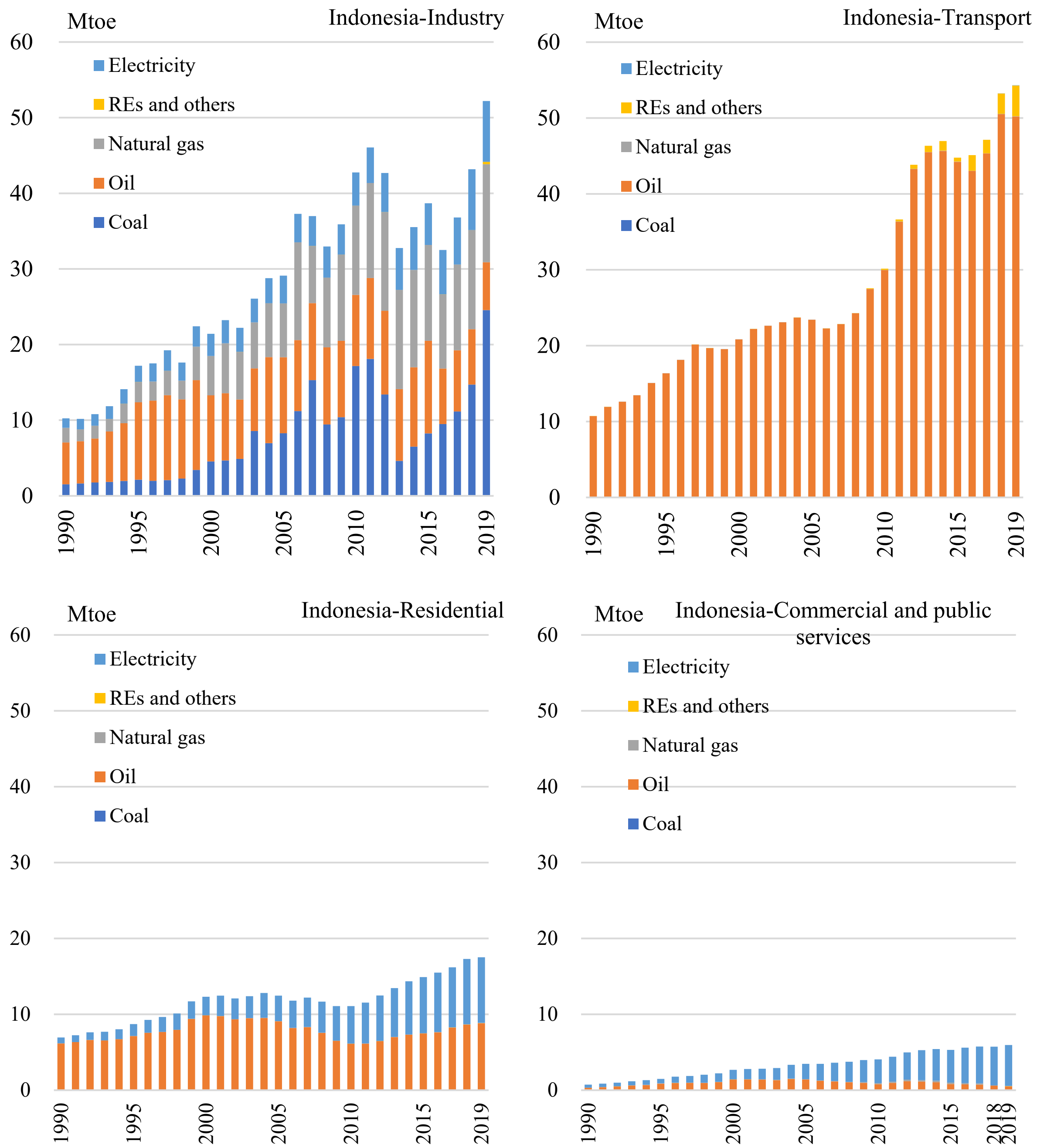


Figure 78　Final Energy Consumption of Major Sectors in Indonesia

Excludes "Primary solid biofuels," "Non-specified primary biofuels and waste," and "Charcoal."
"Others" in TEFC includes agriculture, forestry, fisheries, other, and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP showed an increasing trend from 1990 to 2000 due to the emerging manufacturing sector, but has been declining since 2000 and was 0.230 toe/$1000 in 2019 (0.090 in Japan). The decrease since 2000 is thought to be due to a shift to the service industry, and continued energy conservation measures in each sector will be necessary in the future.

The average thermal efficiency of gas-fired power plants is just under 40%, and that of coal-fired power plants is just under 35%. Since thermal power generation will continue to be the main source of electricity supply, the adoption of clean coal technologies, such as higher efficiency and fuel switching, and the use of CCS will be necessary toward low-carbonization and decarbonization in the power sector.

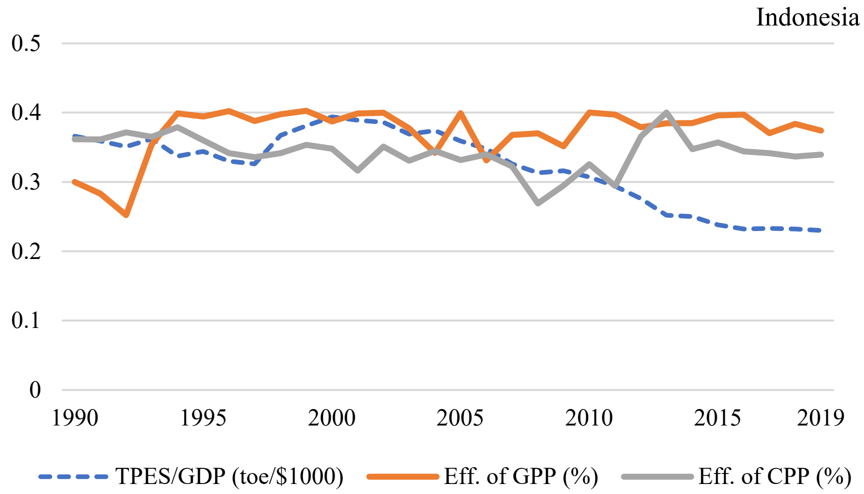


Figure 79 Energy Efficiency in Indonesia

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant, CPP = coal power plant, GDP in 2015 price

Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options Indonesia could take to reduce its CO_2 emissions in the future and their CO_2 reduction effects.

Table 76 Examples of Low-carbon/ Decarbonization Potential in Indonesia

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		596.3 mton-CO2
	【Example of CO2 Emission Reduction Option】	【Reduction Effect】
Generation	Substitute 25% of Coal for Renewable Energy	44.45mton-CO2
Industry	Substitue 50% of Oil and Coal for Natural Gas	22.92 mton-CO2
Transport	10% Improvement of Fuekl Mileage	14.14 mton-CO2
Residential	10% Improvement of Energy Efficiency	9.87 mton-CO2

Note: 2019 actual = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES

Source: JUICA Study Team

(2) Primary energy mix and electricity mix planning

[Primary energy mix]

In terms of the primary energy mix, although the country will continue to utilize natural resources in a well-balanced manner, it intends to decrease the ratio of oil and coal and promote renewable energy, out of consideration in the environmental aspects.

In the National Energy Policy (Kebijakan Energi Nasional: KEN) formulated in October 2014, Indonesia created two scenarios for future energy projections: the Business as usual case (BAU) scenario and the national energy scenario (KEN). In KEN, Indonesia set the targets of reducing the share of oil and coal in primary energy supply and increasing the share of new and renewable energy[202] to at least 23% in 2025 and at least 31% in 2050, which indicates that the country is aiming to shift to cleaner energy.

[202] New energy: coal liquefaction, coal bed methane, coal gasification, nuclear, hydrogen, other methane, renewable energy: geothermal, hydro, biomass, solar, wind, tidal, ocean temperature difference

Table 77 Primary Energy Supply Straucture Outlook of National Energy Policy in Indonesia

	2020	2025	2030	2035	2050
Coal	30%	30%	30%	29%	25%
Gas	23%	22%	23%	23%	24%
Oil	29%	25%	22%	21%	20%
New and Renewable Energy	19%	23%	25%	27%	31%

Source: JOGMEC, February 2018[203]

Indonesia has also set the goal of virtually zero greenhouse gas emissions by 2060, and mentioned an ambitious primary energy mix that will further promote low-carbonization and decarbonization to achieve the goal (see (e) Environmental policy).

[Power mix]

As for electricity development plans, MEMR will formulate a comprehensive 20-year plan, the National Electricity Master Plan (RUKN), and PLN, the state-owned electricity utility, will formulate a detailed 10-year plan, the Electricity Supply Business Plan (RUPTL), based on RUKN.[204]

In October 2021, the latest RUPTL 2021-2030 was published. Regarding the composition of electricity generation up to 2030, it presented a "least cost" scenario which emphasizes cost minimization (but takes into account a 23% share of renewable energy in primary energy supply by 2025) and a "low carbon" scenario which emphasizes low-carbonization. The composition of electricity generation in 2030 in each scenario is coal 64%, gas 13%, hydro 10%, geothermal 10%, and other renewable energy 2% in the "low cost" scenario, and coal 59%, gas 15%, hydro 10%, geothermal 8%, and other renewable energy 6% in the "low carbon" scenario. Both scenarios aim to reduce dependence on coal and expand renewable energy, mainly geothermal and hydroelectric.[205]

Meanwhile, discussions are being held to further reduce the carbon intensity of power sources toward the 2060 net-zero goal (see (e) Environmental policy).

(3) Current status and targets of electricity access

According to the IEA, the electrification rate as of 2019 was 99.5%, with 100% in urban areas and 98.8% in rural areas.[206] Some remote islands and rural areas far from towns have no power transmission and distribution network and have no other choice but to use diesel or gasoline generators for limited power generation. PLN stated it would proceed with the development of microgrids, mainly using solar power, for areas without power distribution lines.[207]

(b) Electric utility system

(1) Electricity supply system

In Indonesia, PLN (including its subsidiaries) and independent power producers (IPPs) are

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203 http://coal.jogmec.go.jp/content/300354637.pdf

204 JOGMEC, March 2018, http://coal.jogmec.go.jp/content/300354637.pdf

205 RUPTL PLN 2021-2030, Ministry of Energy and Mineral Resources, https://gatrik.esdm.go.id/frontend/download_index/?kode_category=ruptl_pln

206 IEA, Access to electricity, https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

207 PLN, Renewable Energy Penetration:Challenges for Indonesia(2018 年 11 月) , http://www.iesr.or.id/wp-content/uploads/2019/04/Suroso-Isnandar.pdf

responsible for the power generation sector, while PLN is basically responsible for the transmission, distribution, and retail sectors. However, in areas that are not connected to PLN's grids, resident organizations called village cooperatives (KUDs) provide off-grid electricity supply.[208]

(2) Renewable electricity supply system

The sale of renewable energy generation is subject to a direct appointment and tendering system by PLN (see below for details). The operators are mainly local companies, but there are also cases where foreign companies such as Singaporean and European companies are participating.[209]

(c) Policy on renewable energy

(1) Potential of renewable energy

[Solar and wind power generation]

Regarding photovoltaic power generation, Indonesia has great potential due to its sunny conditions throughout the country, especially on the island of Java. According to the ERIA, LCOE of PV in Indonesia is expected to decline from $0.11/kWh in 2020 to $0.08/kWh in 2040, which is as low a level as Thailand in ASEAN countries.[210] As for wind power, some parts of Java Island have potential, but overall it is not very great.

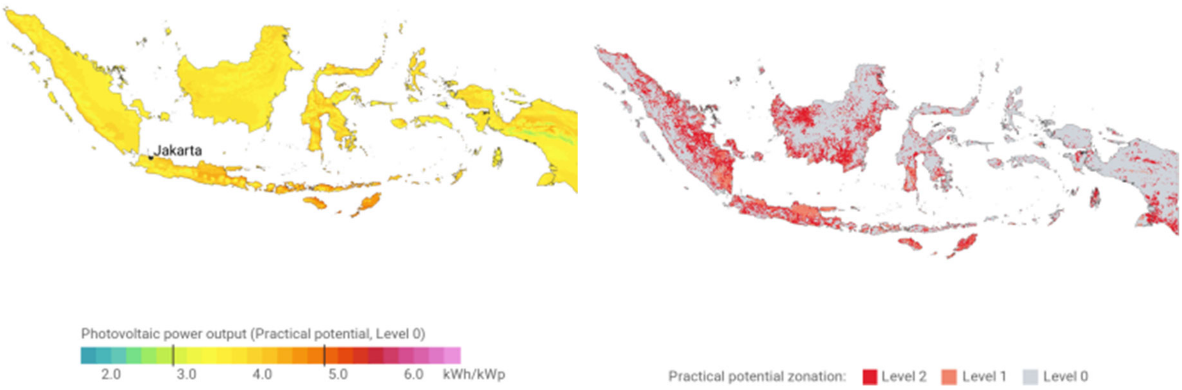

Figure 80 Solar Power Generaton Potential in Indonesia

Note: Left = estimated power generation.

Right = potential zones; Level 0 = no constraints, Level 1 = excluding topographic constraints, Level 2 = excluding topographic and regulatory constraints.

Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

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[208] Japan Electric Power Information Center, Inc.

[209] METI Ministry of Economy, Trade and Industry, https://www.meti.go.jp/meti_lib/report/H29FY/000562.pdf

[210] ERIA, LCOE Analysis for Grid-Connected PV Systems of Utility Scale Across Selected ASEAN Countries, https://www.eria.org/uploads/media/discussion-papers/LCOE-Analysis-For-Grid-Connected-PV-Systems-Of-Utility-Scale-Across-Selected-ASEAN-Countries.pdf

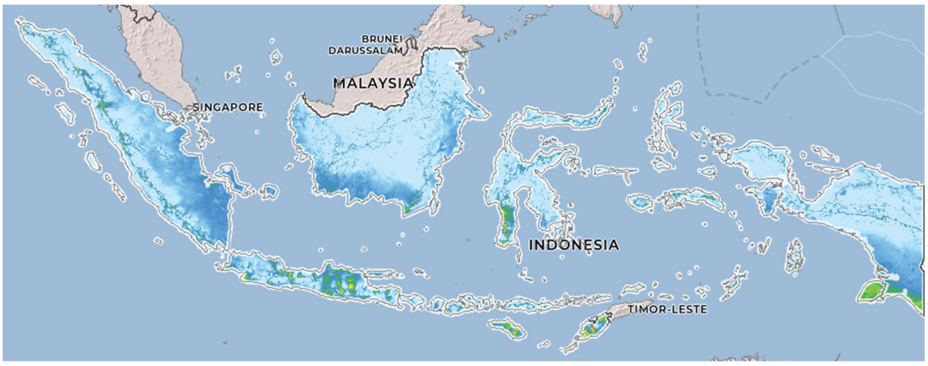

Figure 81 Wind Power Generation Potential in Indonesia

Note: The mean wind speeds shown are the representative values at the elevation of 50 m. Red color indicates the fastest wind speed.

Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

[Geothermal power generation]

Indonesia is one of the world's largest geothermal resource countries. The latest National Electricity Master Plan (RENCANA UMUM KETENAGALISTRIKAN NASIONAL: RUKN) 2019-2038, published in 2019, states that the geothermal power potential is about 29 GW, with a relatively high development potential reserve (cadangan) of about 17.5 GW.

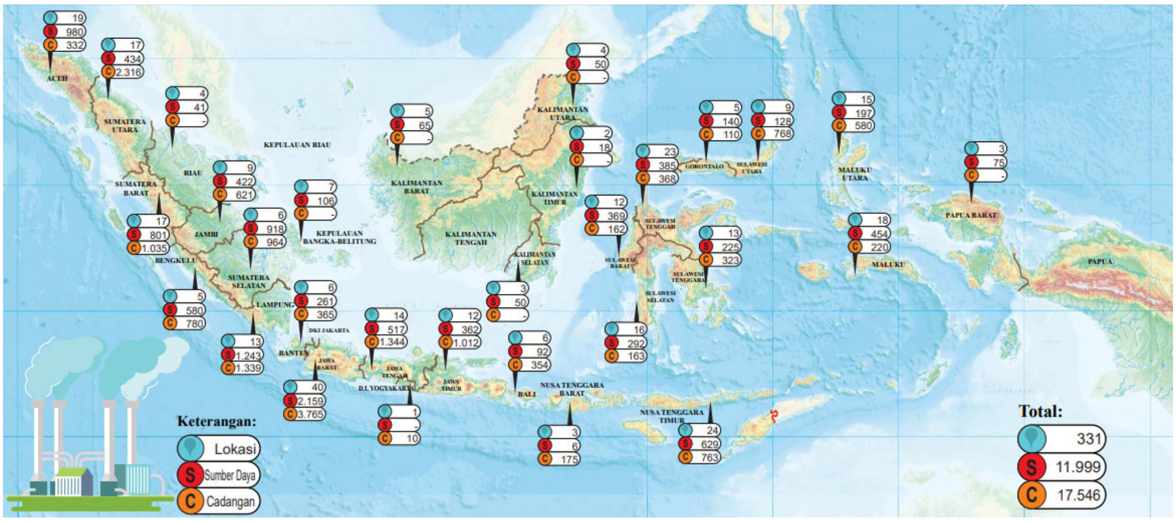

Figure 82 Geothermal Resourcs in Indonesia(MW)

Cadangan = reserve, sumber daya = resource, lokasi = location (existing geothermal power plant)

Source: RUKN2019 - 2038

[Hydroelectric power generation]

According to RUKN 2019-2038, the potential for hydropower is very large, with about 96 GW of large-scale hydropower and 19 GW of small-scale hydropower. More than 40% of the potential is concentrated on Kalimantan Island, and although not all of the potential can be utilized due to the balance between supply and demand, further expansion is expected in the future.

Figure 83 Large Scale Hydro Resources in Indonesia (MW)

Source: RUKN2019 - 2038

Figure 84 Small Scale Hydro and Ocean Power Resources in Indonesia (MW)

Source: RUKN2019 - 2038

(2) Institutions in charge of policy

The Directorate General of New and Renewable Energy and Energy Conservation of the Ministry of Energy and Mineral Resources (MEMR) has jurisdiction.

(3) Development targets

The basic approach to the energy policy in Indonesia, including targets for the introduction of renewable energy, has been laid out by the aforementioned KEN and the National Energy General Plan (RUEN: Rencana Umum Energi Nasional). The target for the introduction of renewable energy is to increase the share of renewable energy in primary energy supply to 23% by 2025. In the RUPTL 2021-2030, the share of renewable energy in the development of power sources for the 10 years to 2030 is 51.6%, with individual development targets of 10.4 GW for hydro, 4.7 GW for solar, 3.4 GW for geothermal, etc.[211]

[211] DISEMINASI RUPTL PT PLN 2021-2030, Ministry of Energy and Mineral Resources, https://gatrik.esdm.go.id/assets/uploads/download_index/files/dc45f-mesdm-diseminasi-ruptl-pln-2021-2030.pdf

(4) Introduction promotion policy

In 2006, the government mandated PLN, the only off-taker of grid electricity in Indonesia, to purchase all small- and medium-scale renewable energy (1-10 MW). Subsequently, the government set and reviewed the purchase price for small- and medium-scale renewable electricity, and published a new regulation for renewable energy purchase (MEMR Regulation No. 50/2017) in 2017. Under the new regulation, a benchmark price is set based on the average cost of generation (BPP) for each region, and a purchase price below that price is set. In central regions such as Java, Bali, and Sumatra, low BPPs due to the introduction of inexpensive thermal power generation has kept the purchase price cap low, making renewable energy less viable. The MEMR Regulation also adopted the Build Own Operate Transfer (BOOT) method, whereby IPPs transfer their business to PLN at the end of the contractual term (20 years) of Power Purchase Agreement (PPA).[212]

Table 78 Renewable Energy Purchase Prices in Indonesia (MEMR Regulation No.50/2017)

Power source type	Terms and Conditions for Power Purchase	Purchase price	
		Regional BPP > Nationwide BPP	Regional BPP ≦ Nationwide BPP
Solar	Direct Selection by Capacity Allocation	Maximum purchase price is 85% of the local generation cost (BPP)	Agreements between businesses (B to B)
Wind			
Marine (tidal)	Direct Selection		
Biomass			
Biogas			
Hydro	Direct Selection	Maximum purchase price is 85% of the local generation cost (BPP)	Agreements between businesses (B to B)
Geothermal	Bidding method defined in a separate system		
Waste			

※The figures for Regional BPP and Nationwide BPP shall be the BPP for the previous year as determined by the (MEMR) Minister.

Sourse：Feasibility Study on Power Generation for Microgrid Utilizing Energy Management System for Stable Supply of Renewable Energy, Indonesia[213]

Since then, frequent improvements have been made to the procurement system, and in MEMR Regulation No. 4/2020, published in March 2020, it was decided to abolish the existing BOOT system and shift to a BOO system for renewable energy projects with a capacity of 10 MW or less, and the transfer of facilities to PLN after the PPA contract term ends is no longer required. The MEMR Regulation also changed the procurement method by PLN from "direct selection" to "direct appointment," allowing PLN to designate specific electricity suppliers without going through a tendering process, which is expected to stimulate future project development.[214]

In November 2018, MEMR Regulation No. 49/2018 made it possible for rooftop solar PV installations to sell excess electricity to PLN upon prior application to and approval by PLN of the customer number, panel standards, and other necessary information.

[Geothermal]

Indonesia is one of the world's largest geothermal resource countries, but at present, the development rate is only about 5% of the reserves, due to the risk of well drilling failure, high initial investment, and low purchase price.

In 2003, the Geothermal Law was enacted, allowing private companies to participate in geothermal development, which had been the responsibility of state-owned companies. In

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212 METI, February 28, 2019, https://www.meti.go.jp/meti_lib/report/H30FY/000673.pdf

213 METI, February 2019, https://www.meti.go.jp/meti_lib/report/H30FY/000673.pdf

214 The secretariat of the Carbon Markets Express / Overseas Environmental Cooperation Center (OECC), https://www.carbon-markets.go.jp/wp-content/uploads/2020/06/JCM-report-JPN_PV@IDN_0602_OECC.pdf

addition, the "Geothermal Development Roadmap" formulated in 2005 set a geothermal power development target of 9,500 MW for 2025.

JICA's 2007 Master Plan Study for Geothermal Power Development identified specific timelines and measures to achieve the goals, including upgrading geothermal development technologies, human resource development, and reserves surveys by the government to address the "risk of well drilling failure," and measures such as the provision of economic incentives (securing policy funds) and the promotion of measures to reduce development costs to address the "high initial investment." In a subsequent study, JICA proposed the establishment of an exploratory drilling fund by the government to reduce the risk of exploratory drilling, etc., and institutional design is underway.[215]

Based on the above, the KEN (released in 2014) clearly stated that priority areas include ensuring the sustainability of geothermal energy utilization and strengthening the capacity of industries related to geothermal exploration and power generation. In 2014, the Geothermal Law was amended to remove geothermal development from the "mining" category, allowing geothermal development in protected forests. It also removed the upper limit on the field area the government grants project rights to developers, which is expected to lead to progress in geothermal development and an increase in large-scale projects in areas with strict environmental regulations.[216]

In recent years, many Japanese companies have participated in large-scale projects, including Sarulla (330 MW), Muara Laboh (220 MW), and Rantau Dedap (220 MW) in Sumatra among IPP projects.

[Hydroelectric power generation]

As mentioned above, Indonesia has abundant hydropower resources, but development has not progressed due to differences between the distribution of resources and the areas of high demand, as well as environmental and social impacts of development (adverse effects on forests and ecosystems, resettlement of residents due to development, etc.), and the development rate is about 7% of the total resources.

In past development plans, the directionality has been to use hydropower as much as possible in areas with such potential, as a source of clean domestic energy, along with geothermal energy. In the RUKN (2008-2027), the share of hydropower in electricity generated was scheduled to remain almost unchanged from 7% in 2008 to 6% in 2018, indicating that new investment in hydropower was scheduled to continue at a rate comparable to demand growth.

[Biofuel]

One of Indonesia's main policies in the energy sector is to reduce its dependence on fossil fuels and switch to biofuels made from home-grown palm oil. The biofuel blending mandate was enacted in 2008 and most recently revised in March 2015. In addition to the transportation sector, the regulation sets targets for biofuel blending in the industrial and power generation sectors, as shown below. The main use of biodiesel is for transportation, while efforts on bioethanol have not progressed due to lack of financial support, expensive raw materials, and limited domestic production capacity.

Table 79 Biofuel Blending Mandatory Target in Indonesia

Item	Target in 2025
Biodiesel Blending Ratio Target	
Transport Fuel (Subsidized)	30%
Transport Fuel (Non-subsidized)	30%
Industrial Fuel	30%

215 JICA, September 2007, https://openjicareport.jica.go.jp/pdf/11864535_01.pdf

216 Daiwa Institute of Research, February 25, 2016, https://www.dir.co.jp/report/asia/asian_insight/20160225_010657.html

Power Generation Fuel	30%
Bioethanol Blending Ratio Target	
Transport Fuel (Subsidized)	20%
Transport Fuel (Non-subsidized)	20%
Industrial Fuel	20%

Source: USDA Foreign Agricultural Service, "Indonesia Biofuels Annual Report 2021"より作成[217]

In September 2018, the government mandated the use of B20, a 20% biodiesel blend of diesel fuel.[218] In addition, in January 2020, the use of B30, a 30% biodiesel blend, became mandatory.[219]

(d) Energy conservation policy

(1) Institutions in charge of policy

As with renewable energy, the Directorate General of New and Renewable Energy and Energy Conservation of the Ministry of Energy and Mineral Resources has jurisdiction.

(2) Targets

The National Energy Conservation Master Plan (RIKEN) has been established in alignment with the National Energy Policy (KEN) that comprehensively defines energy policy. RIKEN has set two goals: (1) to reduce the energy elasticity (growth in energy consumption/economic growth) to not more than 1 by 2025, and (2) to improve energy GDP intensity by 1% every year until 2025. According to RIKEN, the energy saving potential in each sector from the time the master plan was formulated to 2025 is 17% for industry, 15% for business, 20% for transportation, and 20% for households.[220]

(3) Promotion policy

As noted above, the goals and direction of Indonesia's energy conservation policy are set by KEN and RIKEN. The National Energy General Plan (Presidential Regulation No. 22/2017) formulated by the Ministry of Energy and Mineral Resources in 2017 aims to promote energy efficiency through four main activities.[221]

- Launch of energy services companies responsible for implementing energy efficiency projects
- Implementation of energy audits and management programs
- Creation of incentive programs for industries that have implemented energy efficiency measures
- Conduct of educational activities on energy efficiency (energy developers, general public)

As a specific initiative, the industrial sector has introduced an energy management system, establishing obligations for businesses with annual energy consumption of more than 6,000 toe to appoint an energy manager, formulate an energy conservation program, implement periodic energy conservation diagnosis (energy audit), make proposals based on the results of energy conservation audits, and periodically report the implementation status of energy conservation measures.[222] For individual machines, the Minimum Energy Performance Standards (MEPS) and

217 USDA Foreign Agricultural Service, "Indonesia Biofuels Annual Report 2021" https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Biofuels%20Annual_Jakarta_Indonesia_7-31-2015.pdf

218 Nihon Keizai Shinbun, August 16, 2018, https://www.nikkei.com/article/DGKKZO34197650V10C18A8FFJ000/

219 NNA Asia, January 14, 2020, https://www.nna.jp/news/show/1994582

220 METI, February 2018, https://www.meti.go.jp/meti_lib/report/H29FY/000587.pdf

221 ASEAN-German Energy Programme, https://agep.aseanenergy.org/country-profiles/indonesia/indonesia-ee-sector/

222 METI, February 2017, https://www.meti.go.jp/meti_lib/report/H28FY/000073.pdf

labeling systems have been introduced. Energy efficiency labeling for fluorescent lamps began in October 2011, and labeling has since become mandatory for lighting lamps and air conditioners, but the rest is on a voluntary basis. The labeling standard for room air conditioners is a double standard for inverter and non-inverter machines to protect local businesses. Therefore, the market share of inverter air conditioners, the highest priority energy-saving technology in cooling, remains below 10%, one of the lowest in the world, which is a major concern.

MEPS are mandatory standards for fluorescent light bulbs and air conditioners, and voluntary standards for other equipment. The country plans to expand its scope to include refrigerators, fans, electronic ballasts, electric motors, LED bulbs, washing machines, pumps used for well pumping, irons, and TVs.[223]

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

In July 2021, the government submitted its long-term strategy and updated NDC to the UNFCC. The updated NDC stated that greenhouse gas emissions would be virtually zero by 2060. The existing 2030 target of a 29% reduction in GHG emissions (a 41% reduction with the use of international assistance) against the base year 2010 remains unchanged, but the BAU for comparison are set more strictly. In terms of sectoral reduction targets, the forestry and other land use sectors account for 24%, and the energy sector for 16%.

Table 80 GHG Emission Reduction Targets for Each Sector in Indonesia NDC

Sector	GHG Emission Level 2010* (MTon CO_2e)	GHG Emission Level 2030 MTon CO_2e			GHG Emission Reduction MTon CO_2e		GHG Emission Reduction % of Total BaU		Annual Average Growth BAU (2010-2030)	Average Growth 2000-2012
		BaU	CM1	CM2	CM1	CM2	CM1	CM2		
1. Energy*	453.2	1,669	1,355	1,223	314	446	11%	15.5%	6.7%	4.50%
2. Waste	88	296	285	256	11	40	0.38%	1.4%	6.3%	4.00%
3. IPPU	36	70	67	66	3	3.25	0.10%	0.11%	3.4%	0.10%
4. Agriculture**	111	120	110	116	9	4	0.32%	0.13%	0.4%	1.30%
5. Forestry and Other Land Uses (FOLU)***	647	714	217	22	497	692	17.2%	24.1%	0.5%	2.70%
TOTAL	**1,334**	**2,869**	**2,034**	**1,683**	**834**	**1,185**	**29%**	**41%**	**3.9%**	**3.20%**

Notes: **CM1**= Counter Measure 1 (*unconditional mitigation scenario*)
CM2= Counter Measure 2 (*conditional mitigation scenario*)
*) Including fugitive.
**) Only include rice cultivation and livestock.
***) Including emission from estate crops plantation.

Source: UPDATED NATIONALLY DETERMINED CONTRIBUTION REPUBLIC OF INDONESIA

(2) Promotion policy

The Long -Term Strategy for Low Carbon and Climate Resilience 2050, submitted in July 2021, established three development pathways as low carbon and climate resilience scenarios (LCCR). The three pathways are: (1) current policy scenario (CPOS), (2) transition scenario (TRNS), and (3) low carbon scenario compatible with Paris Agreement target (LCCP), where CPOS is a scenario that follows the unconditional scenario of the NDC and the transition scenario bridges transition from the CPOS to LCCP. It also has long-term guidelines for energy that include (1) implementation of energy efficiency measures, (2) use of decarbonized electricity in the transportation and building sectors, (3) shift from coal use to natural gas and renewable energy use in the industrial sector, and (4) promotion of renewable energy in the electricity,

223 METI, February 2017, https://www.meti.go.jp/meti_lib/report/H28FY/000073.pdf

transportation, and industrial sectors.[224]

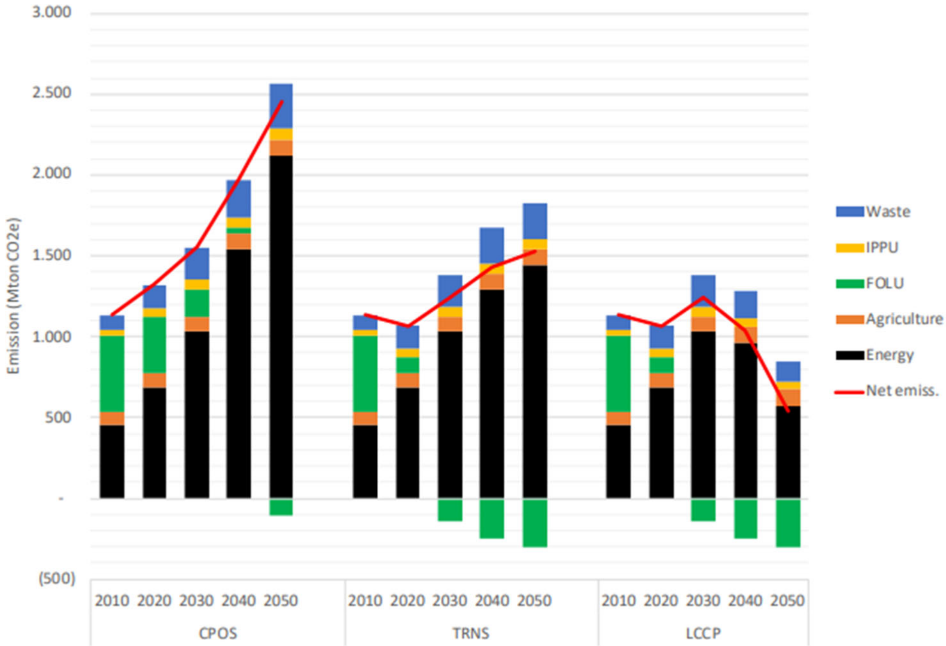

Figure 85 Estimated CO2 Emissions by Sector in Each Scenario of Long-Term Strategy in Indonesia

Source: Long -Term Strategy for Low Carbon and Climate Resilience 2050

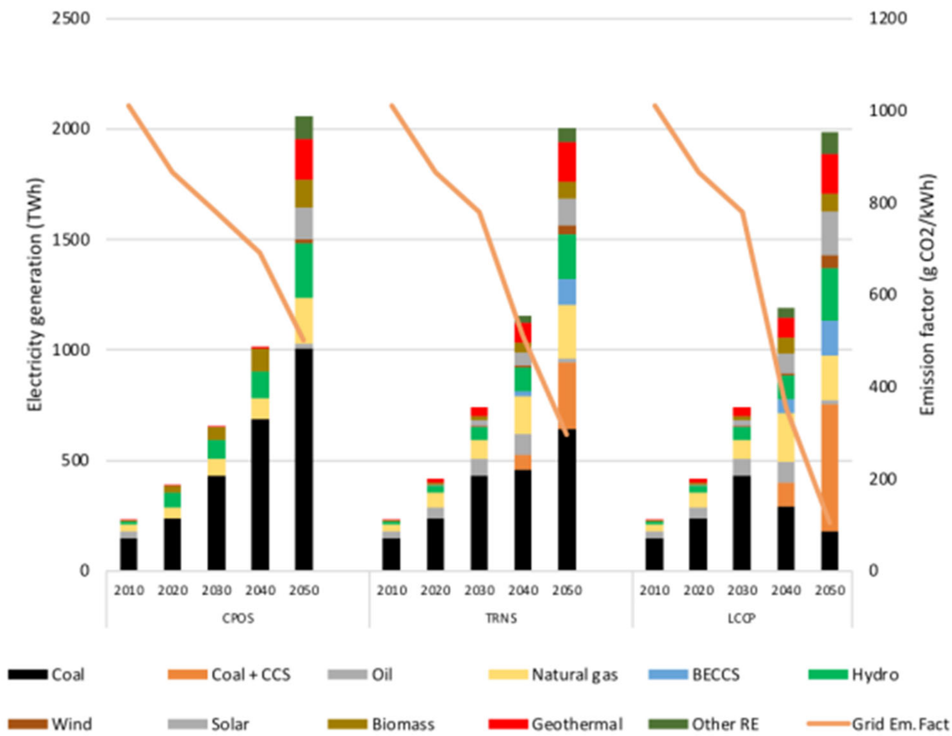

Figure 86 Estimated Electricity Generation Structure and Grid Emission Factor in Each Scenario of Long-Term Strategy in Indonesia

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[224] UNFCCC," INDONESIA Long-Term Strategy for Low Carbon and Climate Resilience 2050", https://unfccc.int/sites/default/files/resource/Indonesia_LTS-LCCR_2021.pdf

Source: Long -Term Strategy for Low Carbon and Climate Resilience 2050

In October 2021, the Ministry of Energy and Mineral Resources (MEMR) announced that it was preparing a roadmap toward net zero emissions (NZE) by 2060. The five key points listed were: increased use of renewable energy, reduced use of fossil fuels, use of EVs, promotion of electrification in the residential and industrial sectors, and use of CCS. MEME also set forth the following policies regarding the energy mix. [225]

Table 81 Roadmap Policy for 2060 NZE in Indonesia (Extract from the Part Related to the Energy Mix)

Year	Policy
2021	・ Publication of Presidential Decree regarding the abolition of Coal-fired power generation (No new Coal-fired power plants will be built, except for Coal-fired power plants under contract or under construction)
2025	・ NRE share will increase to 23% (mostly the share of solar)
2027	・ Halt importing gas
2030	・ NRE share will increase to 42% (the largest share: Solar) ・ 2 million EVs and 13 million Electric Motorcycles will be widespread
2031	・ Implementation of the first stage of early abolition of subcritical coal-fired power generation
2035	・ NRE share will increase to 57% (the lagst share: solar, hydro, and geothermal)
2040	・ NRE share will increase to 71%, diesel power generation not in operation ・ Considering the construction of nuclear power generation in the next 5 years (considering the introduction of 35GW of nuclear power generation from 2045 to 2060)
2050	・ NRE share will increase to 87%
2060	・ The share of NRE will reache 100% (the largest share: solar and hydro)

Source: MEMR PR

[Carbon tax and emission trading system (ETS)]

In October 2021, the government provided for the introduction of a carbon tax in the Taxation Harmonization Law (No. 7/2021). A tax of 30 rupiah (approx. 0.2 yen) per kg of CO_2 equivalent emissions will be levied. Introduction will begin at coal-fired power plants on April 1, 2022. [226]

In November 2021, the government announced that the President had signed a Presidential Regulation on carbon pricing (No. 98/2021). According to documents obtained by Reuters, the Presidential Regulation also stipulated a pay-per-performance system according to CO_2 reductions, implementation of an emission trading system inside and outside the country, and establishment of a carbon trading market[227]. The government had been studying implementation of a domestic ETS for the power and industrial sectors and had been conducting pilot projects.[228]

(3) Transportation

[Electric vehicles]

The RUEN presents an action plan for the transportation sector. The targets for electric vehicles are to have 2,200 electric and hybrid vehicles and 2.1 million electric motorcycles by 2025. It also

[225] MEMR, 2021.10.8, https://www.esdm.go.id/en/media-center/news-archives/road-map-to-carbon-neutrality-is-being-prepared-says-energy-minister

[226] NNA ASIA, 2021 年 11 月 4 日, https://www.nna.jp/news/show/2258630

[227] NNA ASIA, November 17, 2021, https://www.nna.jp/news/show/2263915

[228] World Bank, State and Trends of Carbon Pricing 2020(May 2020) , https://openknowledge.worldbank.org/bitstream/handle/10986/33809/9781464815867.pdf?sequence=4&isAllowed=y

plans to install 1,000 public charging stations by 2025, with the target of increasing the share of electric vehicles in urban traffic vehicles to 10% by 2025.

In August 2019, the government announced a long-term plan to create a regional hub for EV production and to start full-scale EV manufacturing in 2022, with targets of making Low Carbon Emission Vehicles (LCEVs) to be 20% of total vehicle production (400,000 vehicles) in 2025 and 30% (1.2 million vehicles) in 2035.[229][230] In the same month, the Presidential Regulation No. 55/2019 was issued to promote BEVs and their industry, establishing five major policies ((1) promotion of the domestic BEV industry, (2) provision of incentives, (3) development of charging infrastructure and electricity rates for BEVs, (4) compliance with BEV technology-related regulations, and (5) environmental protection).[231]

In June 2021, the Minister of Energy and Mineral Resources announced goals to make all motorcycles sold after 2040 to be electric and all new vehicles sold after 2050 to be electric.[232] In October 2021, the Ministry of Transportation announced a plan to electrify 90% of urban buses and other mass transit systems by 2030[233] .

[Emission regulations, etc.]

Emission regulations in Indonesia are under the jurisdiction of the Ministry of Environment and Forestry. The regulation values vary by the type of vehicle, with Euro 2 equivalent applied to passenger cars, vans, and heavy-duty vehicles, and Euro 3 equivalent applied to motorcycles. Euro 4 is planned to be implemented in 2021, and furthermore, it has been adopted that Euro 5 will be implemented by 2025. [234]

(4) Urban development

Since 2017, seven ministries including the Ministry of Communication and Information Technology, the Ministry of Finance, and the Ministry of National Development Planning have collaborated on the 100 Smart Cities project. Each city is to formulate a master plan for becoming a smart city, and the government will dispatch experts and provide budgetary assistance. It is also unique in that a satisfaction survey of citizens is planned to be conducted as a means of measuring the achievement level of the project.[235] DKI Jakarta, Banyuwangi, and Makassar were selected for the ASCN launched in 2018, with development targets based on regional characteristics.

(f) Next generation technology, innovation

【CCS/CCUS】

CCS has attracted attention in Indonesia as one of the measures to reduce CO_2 emissions, but there was no mention of CCS in the National Energy General Plan released in 2017 or other plans.

However, several feasibility studies (FS) and demonstration projects on CCUS are under consideration in Indonesia (examples below).

- Gundih CCUS Project: FS implemented (June 2020 to February 2021); demonstration project planned to be implemented from 2021 to 2025. Participating organizations include METI, J-Power, and JGC Corporation.
- Sukowati CO2-EOR Project: FS planned to be implemented in the future

229 BEV、HEV/PHEV、FCEV & Advanced/ Bio Diesel を含む。

230 Ministry of Industry, "GOVERNMENT POLICY ON FUTURE AUTOMOTIVE TECHNOLOGY(July 2019) ", https://www.gaikindo.or.id/wp-content/uploads/2019/07/01.-Dirjen-Ilmate_-Sesi-Siang-GOVERNMENT-POLICY-ON-FUTURE-AUTOMOTIVE-TECHNOLOGY-GIIAS-Conference-240719.pdf (access, February 16, 2021)

231 Ministry of Investment/BKPM, https://www.bkpm.go.id/images/uploads/printing/Electric_Vehicle_Brochure_2020.pdf

232 Reuters,June 14, 2021, https://jp.reuters.com/article/indonesia-electric-idJPKCN2DQ0SU

233 NNA ASIA,Nivember 2, 2021, https://www.nna.jp/news/show/2257531

234 METI, March 2019, https://www.meti.go.jp/policy/voc/h30kaigai_taikikisei.pdf

235 JETRO, August 30, 2019, https://www.jetro.go.jp/biz/areareports/special/2019/0801/74b72efc489b22d1.html

(implementation agreement signed in June 2021). A pilot project (250 ton-CO_2/day) is scheduled for 2022, and a full-scale project (5,500 ton-CO_2/day) for 2028. Participating organizations include Pertamina, LEMIGAS, and JAPEX.

- Tangguh CCUS Project: FS implemented in 2020, scheduled to be operational in 2026. Participating organizations include bp, LEMIGAS, ITB, and Japan business federation.

In relation to Japan, Japanese companies are carrying out a number of studies on the feasibility of CCUS in Indonesia with the support of the Japanese government. The major issue is economic non-viability due to high equipment CAPEX (especially CO_2 pipelines). The FY2018 International Institution Collaboration Project for Measures against Global Warming (Collaboration Project toward International Contribution using CCS Technology in Japan) by the Ministry of Economy, Trade and Industry proposed a regional CO_2 management concept based on hubs and clusters[236] in Indonesia, based on the results of a CO2-EOR study in South Sumatra carried out by JGC under a NEDO project, and stated continued studies on the scale, schedule, and economics of each project.[237]

(g) Points to consider for future cooperation in promoting low-carbonization and decarbonization

- The country intends to continue to utilize its coal reserves to a certain extent in power generation, and the adoption of clean coal technologies, such as improvement of efficiency of existing facilities and fuel transition, and the use of CCS could contribute significantly to the low-carbonization of electric power.
- Although the country is one of the world's largest geothermal resource-rich countries, it has not been able to effectively utilize its potential. Considering JICA's support in the past, it is possible for Japan to provide continued support for geothermal development.
- Some remote islands and in rural areas far from towns have no other choice but to use diesel or gasoline generators for limited power generation. For that, Japan may be able to provide support for microgrid projects that combine solar and small-scale hydropower with local resources.
- The transportation sector accounts for a large share of primary energy consumption and the share is expected to increase further. The government has made curbing oil consumption a key task as domestic production slumps, and there is growing interest in energy conservation in the transportation sector, which accounts for the majority of oil consumption, and there is likely to be a need for support in this area. Specific possible supports are as shown below.
    - ✓ Support for promotion of vehicle fuel transition (EV, biodiesel)
    - ✓ Support for smart city development with a focus on transportation infrastructure that leads to low-carbonization and decarbonization
    - ✓ Support for smart grid projects utilizing EVs
- Although labeling systems and minimum energy performance standards (MEPS) have been introduced for energy efficiency and conservation in buildings, most of them are voluntary standards, and support could be provided to organize the necessary policies and regulations to further promote energy efficiency and conservation. In particular, regarding the spread of inverter air conditioners, support by Japanese companies is strongly desired to achieve breakthroughs (see (d) Energy conservation policy (3) Promotion policy).

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236 Utilize CO2 in the region at multiple points by developing a CO2 transport infrastructure "core CO2 transport pipeline" that connects one or more CO2 emission sources and multiple oil fields centered on hub oil fields. Mechanism to enable "Regional CO2 management".

237 METI, https://www.meti.go.jp/meti_lib/report/H30FY/000497.pdf

(8) Vietnam

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

Vietnam's economy has been growing remarkably in recent years, with real GDP growth rates of approximately 5-8% since 2000, and primary energy supply has tripled. The rapid increase in demand is being met by the use of fossil fuels, mainly coal, with coal accounting for 51% of primary energy supply, followed by oil at 24% (2019). Vietnam has hydropower resources throughout its land area, coal in the north, and oil and natural gas resources in the south, and exports crude oil in particular to neighboring countries with large energy demand, such as China and Thailand. However, imports of coal and petroleum are on the rise as domestic energy demand increases.

In terms of power generation, the country has traditionally focused on hydropower, which has abundant resources, but with the rapid increase in electricity demand since 2000, it has been developing thermal power generation, mainly coal, and as of 2019, coal-fired power generation accounts for 50% and hydropower for 28% of total electricity generated. However, coal power generation, which has been the mainstay of electric power development, has recently been running into a lot of flak from a viewpoint of global environmental issues, especially the trend to curb CO2 emissions, and some plans have been cancelled due to opposition from local residents and governments. Low-carbon and decarbonized electricity will require a shift from coal-fired to gas-fired and renewable energy sources.

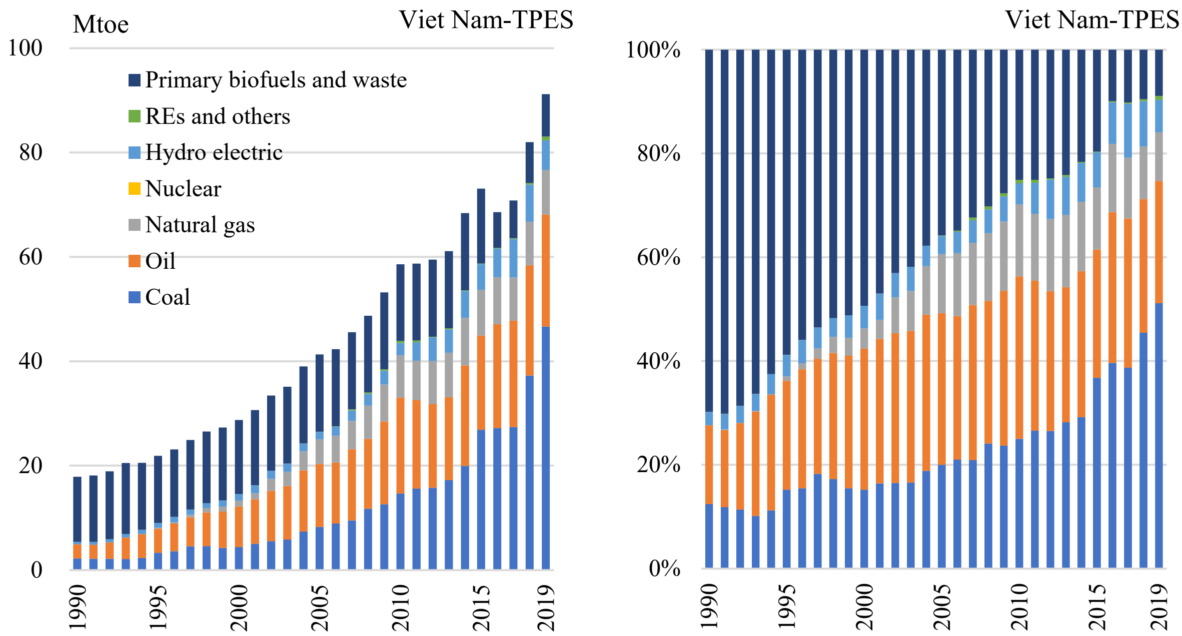

Figure 87 Primary Energy Supply in Viet Nam

Source: World Energy Balances 2021 extended edition database, IEA

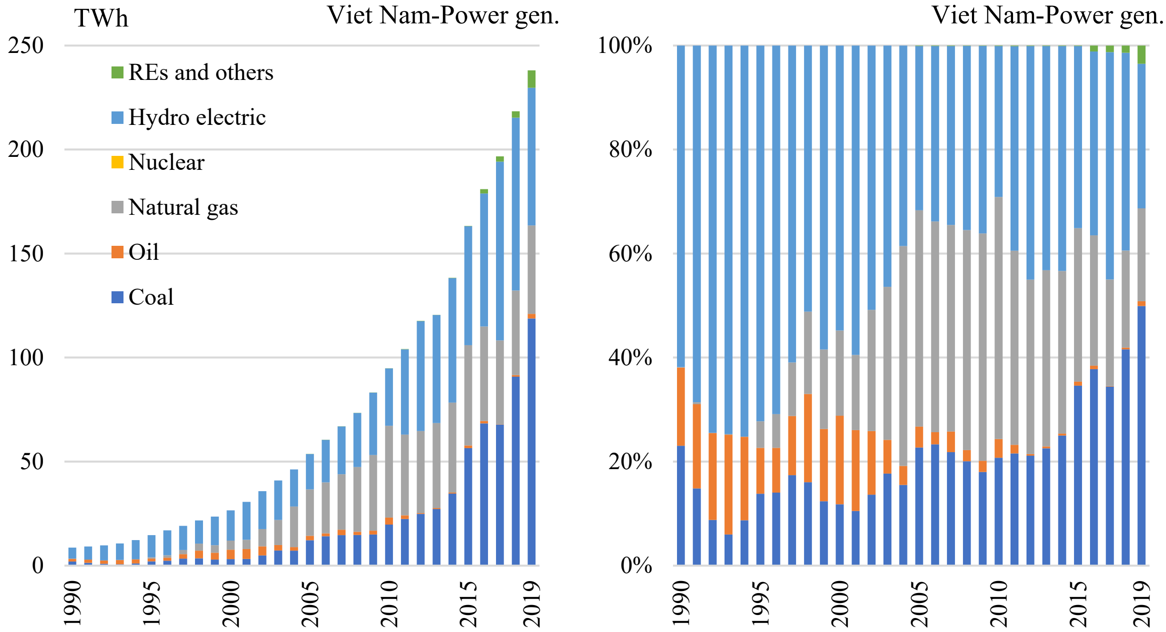

Figure 88 Fuel Mix of Electricity Generation in Viet Nam
Source: World Energy Balances 2021 database, IEA

A breakdown of final energy consumption by sector shows that industry accounts for 51%, transportation 25%, residential 13%, and commercial/public services 5% in 2019. Industry had the largest overall five-year growth from 2014 to 2019 at 7.7%, followed by transportation at 7.1% and residential and commercial/public services at 3.9%.

Industry, with a very high growth rate, is dominated by the use of coal, but the use of electricity has also been increasing since around 2010. This may be due in part to the fact that South Korea's Samsung began operating a cell phone manufacturing plant in Vietnam in 2009 and is increasing the number of plants for related parts and other products. The industrial sector has been growing at a high rate as a result of the Doi Moi (reform) policy, which began in the late 1980s and focused on the introduction of a market economy system and opening up to the outside world. In recent years, Chinese and other foreign companies have been expanding into the sewing industry, which is a major industry. Energy conservation targets have been set for each industrial sector for 2019 (see below), and specific efforts to implement energy conservation measures will be important in the future.

In transportation, oil accounts for 98%, while natural gas and renewable energy and others each account for 1% (2019). Vietnam's per capita GDP is about US$1,000, significantly lower than the US$3,000 that is expected to accelerate motorization, and the car ownership rate is low at this time. However, Vietnam has the third largest population among ASEAN countries (approximately 96.5 million: [238]in 2019) after Indonesia and the Philippines, and is experiencing high economic growth rates, which is expected to create a large automobile market in the long run. Since the government is also active in public transportation in urban development, it will be important to develop urban development and transportation infrastructure with an eye toward future sustainability.

Residential use of electricity has been growing each year, reaching 74% as of 2019. In recent years, the introduction of MEPS and labeling systems for home appliances has been actively promoted.

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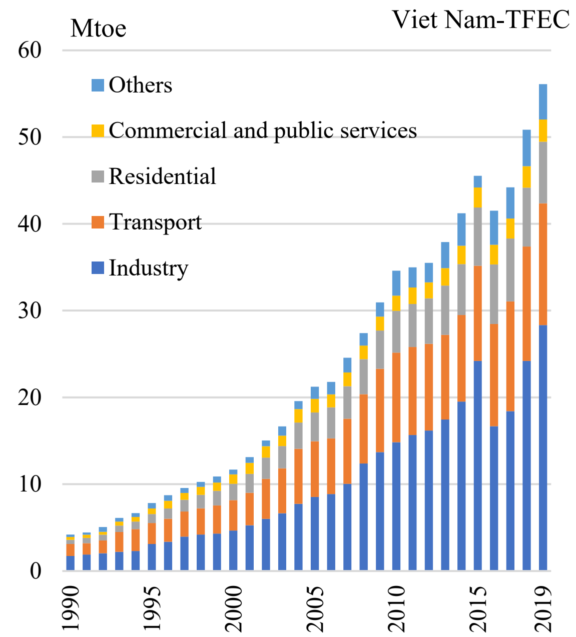
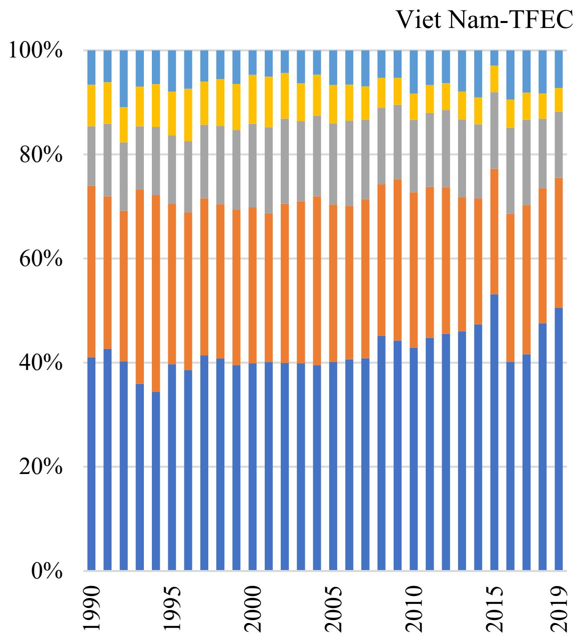
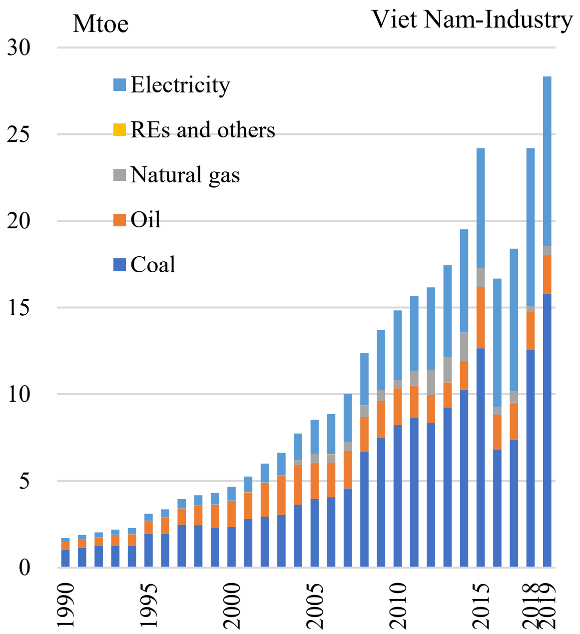
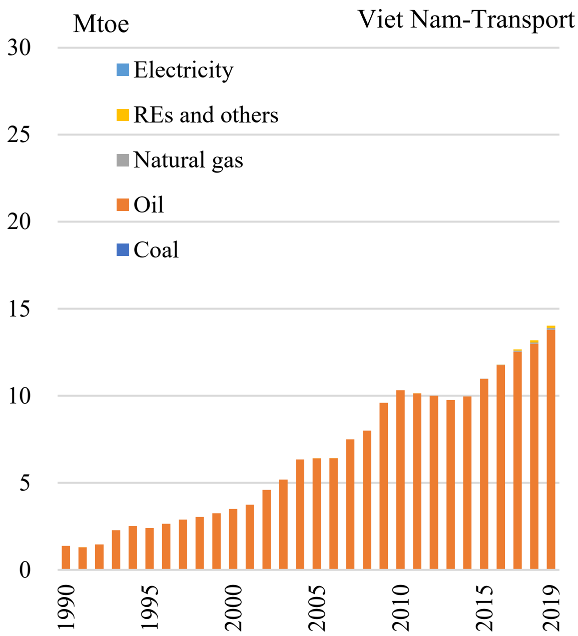
[238] The World Bank, Vietnam, https://data.worldbank.org/country/vietnam?view=chart


Mtoe
Viet Nam-TFEC
60
50
40
30
20
10
0
Others
Commercial and public services
Residential
Transport
Industry
1990
1995
2000
2005
2010
2015
2019


Viet Nam-TFEC
100%
80%
60%
40%
20%
0%
1990
1995
2000
2005
2010
2015
2019


Mtoe
Viet Nam-Industry
30
25
20
15
10
5
0
Electricity
REs and others
Natural gas
Oil
Coal
1990
1995
2000
2005
2010
2015
2018
2019


Mtoe
Viet Nam-Transport
30
25
20
15
10
5
0
Electricity
REs and others
Natural gas
Oil
Coal
1990
1995
2000
2005
2010
2015
2019

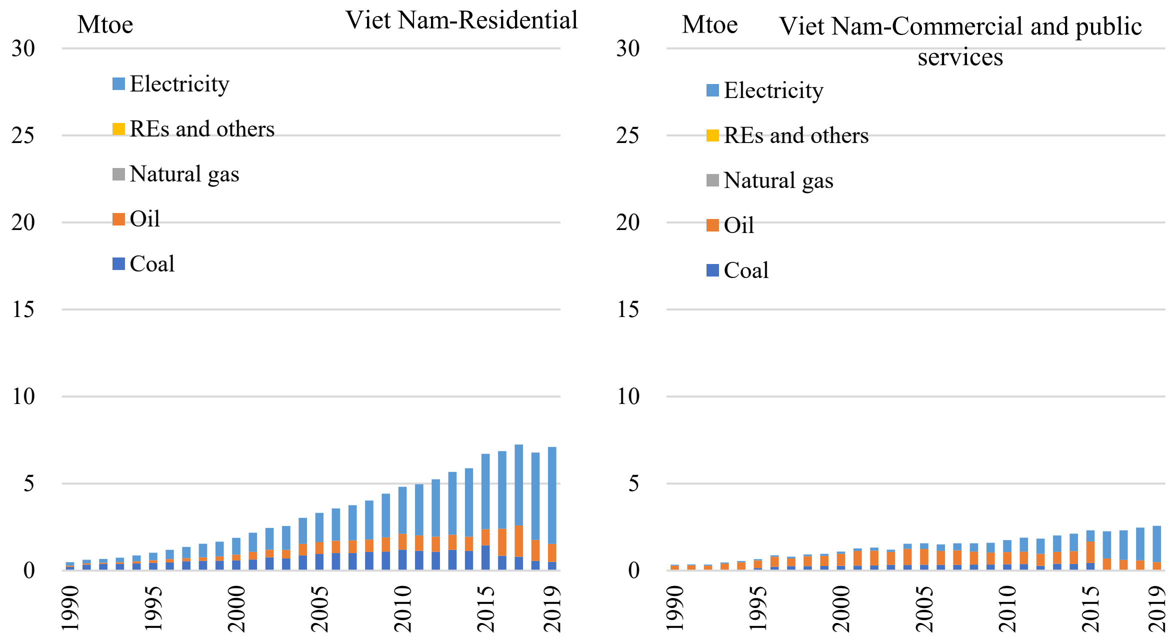


Figure 89 Final energy Consumption of Major sectors in Viet Nam

"Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal" are excluded.
"Others" in TEFC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP had been declining since about 1970, but has not changed much since 2000 from 0.4 toe/$1000. Subsequently, it was 0.363 toe/$1000 in 2019 (0.090 in Japan) following a downward trend over the past few years, but it is still relatively high among ASEAN countries and there is much room for improvement.

The average thermal efficiency of gas-fired and coal-fired power plants is 52% and 44%, respectively. The thermal efficiency of gas-fired power plants is particularly high compared to other ASEAN countries. The future policy is to prioritize the use of gas-fired thermal power and limit coal-fired thermal power to an appropriate level. However, coal-fired thermal power will continue to be a major source of electricity supply, and higher efficiency thermal power generation will make a significant contribution to the low-carbonization of electricity.

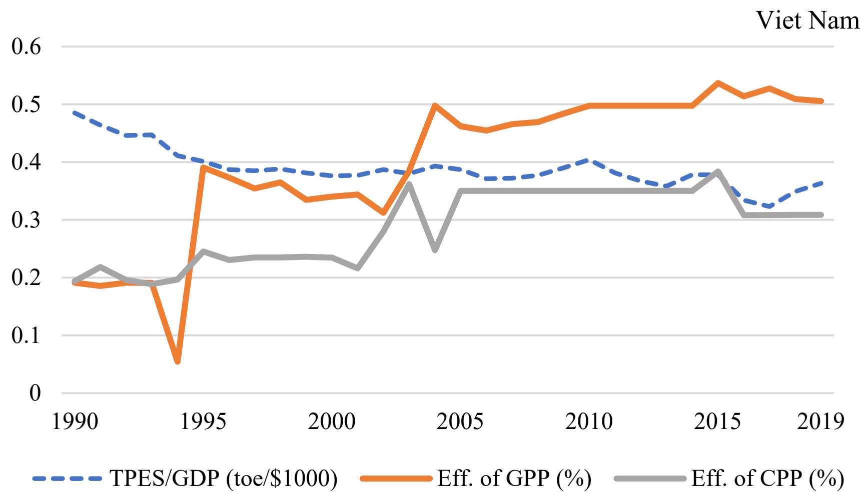


Figure 90 energy efficiency in Viet Nam

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant, CPP = coal power plant, GDP in 2015 price

Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options that could be adopted to reduce CO_2 emissions in Vietnam in the future and their CO_2 reduction effects.

Table 82 Examples of Low-carbon/ Decarbonization Potential in Viet Nam

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		285.5 mton-CO2
	【Example of CO2 Emission Reduction Option】	【Reduction Effect】
Generation	Substitue 15% of Coal-fired Generation for Natural Gas, 15% of Coal-fired Generation for Renewable Energy	28.68mton-CO2
Industry	Substitue 50% of Coal for Natural Gas	13.23mton-CO2
Transport	10% Improvement of Fuel Mileage	3.86mton-CO2
Residential	10% Improvement of Energy Efficiency	3.40mton-CO2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICA Study Team

(2) Primary energy mix and electricity mix planning

[Primary energy mix]

In December 2007, the Cabinet approved the National Energy Development Strategy up to 2020, with a Vision to 2050. Its basic policies include diversification of energy resources, promotion of energy conservation, efficient use of domestic resources and international cooperation to ensure energy security, and development of clean energy.

The Ministry of Industry and Trade (MOIT) of Vietnam, through its energy partnership program with the Danish Energy Agency (DEA), has developed Vietnam Energy Outlook through a long-term scenario analysis. The Energy Outlook published for 2019 analyzes the outlook for primary energy supply and installed generation capacity based on various scenarios. There are five scenarios in the following.

Table 83 Conditions for Various scenarios of Long-Term Energy Outlook in Viet Nam

	RE Target	Restriction of Coal-fired Generation	EE Technology
C0	Unachieved	No restriction	Not prevailed
C1	Achieved	No restriction	Not prevailed
C2	Achieved	No new investment after 2025	Not prevailed
C3	Achieved	No restriction	Prevailed
C4	Achieved	No new investment after 2025	Prevailed

Note: The ratio of renewable energy (including hydroelectric power) is 32% in 2030, 38% in 2040, and 43% in 2050. The 2030 and 2050 targets were established in the Renewable Energy Development Strategy (REDS).
Source: VIETNAM ENERGY OUTLOOK REPORT 2019[239]

Looking at the outlook for primary energy supply, coal supply is expected to increase sequentially through 2050 in the C0, C1, and C3 scenarios, while it is expected to begin to decline as of 2050 in the C2 and C4 scenarios.

[239] Ministry of Foreign Affairs of Denmark, VIETNAM ENERGY OUTLOOK REPORT 2019, https://ens.dk/sites/ens.dk/files/Globalcooperation/vietnam_energy_outlook_report_2019.pdf

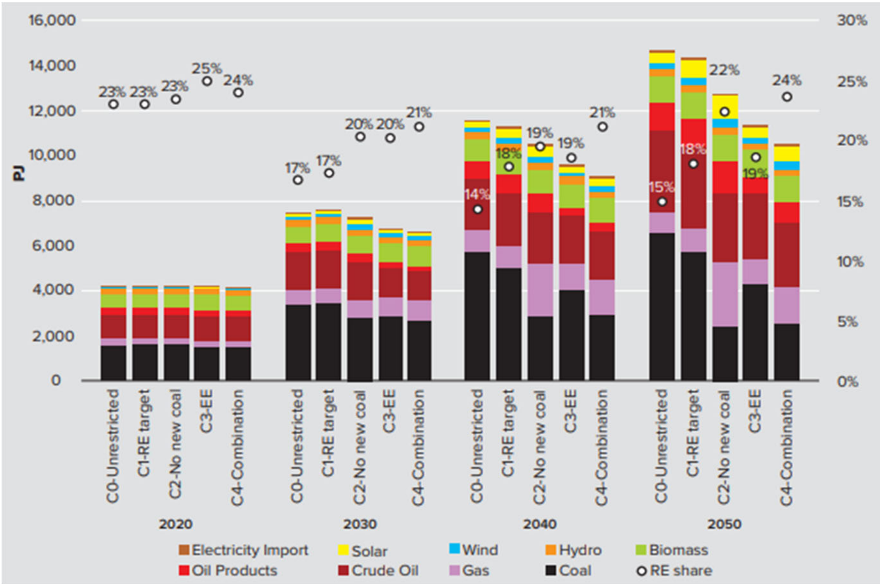


Figure 91 Primay Energy Supply Outlook in Viet Nam

Source: VIETNAM ENERGY OUTLOOK REPORT 2019

The outlook for installed generation capacity shows that solar power generation is expected to increase significantly through 2050 in both scenarios. In C2 and C4, where coal-fired power generation is restricted, imported LNG and large amounts of solar power generation will be needed to replace coal-fired power generation in C2, where energy-saving technologies are not widely used, while in C4, where energy-saving technologies are widely used, domestic resources are expected to be used more efficiently.

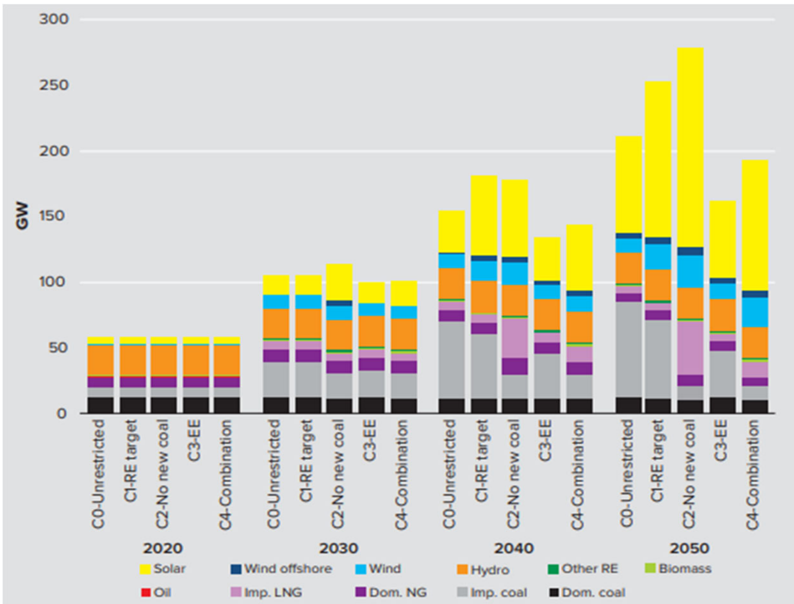


Figure 92 Electricity Generation Capacity Outlook in Viet Nam

Source: VIETNAM ENERGY OUTLOOK REPORT 2019

In February 2020, the Communist Party issued Politburo Resolution No. 55 (55-NQ/TW), "National Energy Development Strategy to 2030 and Vision to 2045," setting targets for renewable energy and greenhouse gas reduction. Specifically, the ratio of renewable energy to total primary energy supply will be approximately 15-20% in 2030 and 25-30% in 2045, and the reduction rate of greenhouse gas emissions from the energy sector (compared to a normal development scenario) will be 15% in 2030 and 20% in 2045. [240]

[Power Mix]

With regard to the power mix, the "(Power Development Plan 7: revised PDP7" announced in March 2016 aims to promote the development of renewable energy sources such as wind and solar power, and plans to operate nuclear power plants in case primary energy sources in Japan are depleted in the future. The generation mix in 2030 in the revised PDP7 is 12.4% hydro, 53.2% coal-fired, 16.8% gas-fired, 10.7% renewable, 5.7% nuclear, and 1.2% electricity imports. With power supply development, demand for coal for power generation will be 5.8 times higher in 2025 than in 2015, and imported coal has increased rapidly after 2018. In 2025, imported coal is expected to account for about 40% of the total.

If power supply development is implemented according to the schedule in the revised PDP7, a stable supply of electricity is expected, while delays in power supply development and higher-than-expected demand growth are risk factors. In particular, the southern part of the country has seen a sharp increase in power receiving since 2011, and power is being supplied from the northern and central parts of the country. According to the electricity supply and demand outlook published by the Ministry of Industry and Trade in 2019, there could be electricity shortages in southern Vietnam after 2021 due to delays in the construction of thermal power plants in southern Vietnam. [241]

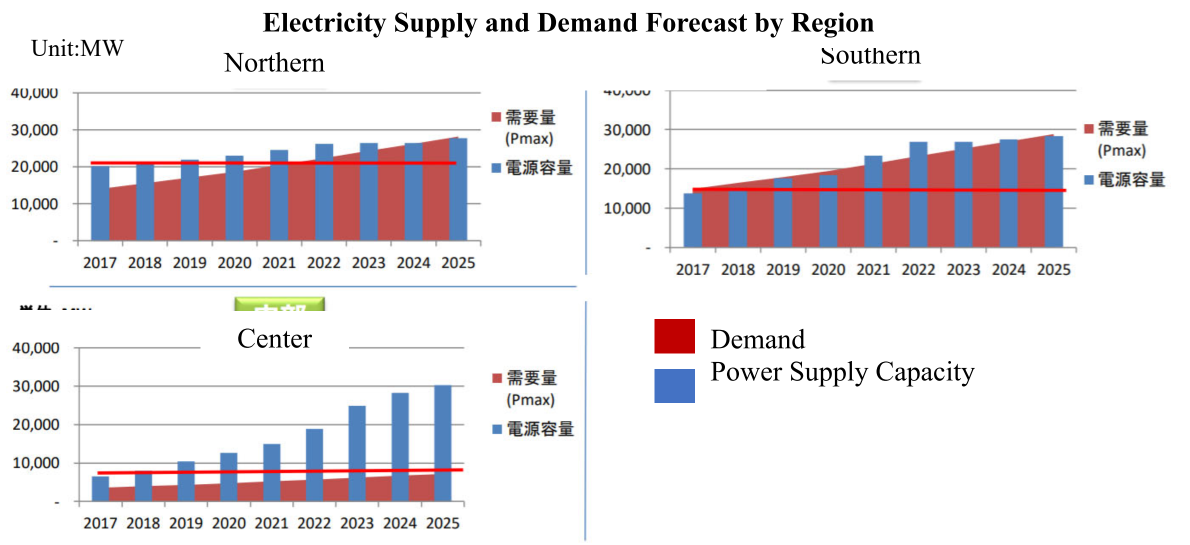


Figure 93 Electricity Supply and Demand Outlook for 2017-2025 (by Region)

Source: JETRO[242]

The future direction of energy policy is set out in the aforementioned "National Energy Development Strategy to 2030 and Vision to 2045" (55-NQ/TW). With regard to electricity supply, it states that coal-fired power generation will be kept to an appropriate limit and the share of renewable energy will be increased by drawing up an appropriate roadmap to prioritize the development of gas-fired power generation and reduce the share of coal-fired power generation.[243] Based on this Politburo resolution, the Ministry of Industry and Trade is preparing to promulgate the 8th National Electricity Master Plan (PDP8). It was originally intended to be

240 JETRO, April 28, 2021, https://www.jetro.go.jp/biz/areareports/special/2021/0401/95af12c1d66af1b4.html

241 JETRO, Jule 9, 2019, https://www.jetro.go.jp/biznews/2019/07/0cc0ca55dc03beab.html

242 JETRO, March 2019, https://www.jetro.go.jp/ext_images/_Reports/02/2019/3f14818917585e2a/201903-rpvn.pdf

243 Viet Nam Energy Partnership Group, http://vepg.vn/wp-content/uploads/2020/03/CPCs-Resolution-55.NQ-TW-on-Energy-Development-Strategy-to-2030-and-outlook-to-2045.pdf

formulated and published by the end of 2021, but is now being reviewed again in light of the carbon neutrality declaration by 2050 announced at COP26 and the schedule is expected to be significantly delayed.

(b) Electric utility system

(1) Electricity supply system

Vietnam Electricity (EVN), as a holding company, owns and manages major power plants, feeder stations, transmission companies, and distribution companies. Specifically, the National Power Transmission Corporation (NPTC), the National Load Dispatch Center (NLDC), [244]the Electric Power Trading Company (EPTC), and five power distribution and retail companies [245](Power Corporation: PC): (1) Northern Power Distribution Company, (2) Southern Power Distribution Company, (3) Central Power Distribution Company, (4) Ho Chi Minh City Power Distribution Company, and (5) Ha Noi City Power Distribution Company. For the power generation sector, liberalization has been underway since 2015, with wholesale electricity liberalization officially beginning in 2019 (MOIT Decision No. 8266/QD-BCT dated August 10, 2015). [246]

(2) Supply system of renewable electricity

The FIT system has been introduced, and the standard template prepared by the Ministry of Industry and Trade (MOIT) is used to contract EVN. Local companies are the main developers, but foreign companies are also moving into the area, mainly German companies for wind power and Korean companies for solar power. [247]

(c) Policy on renewable energy

(1) Renewable energy potential

The potential for both solar and wind power is very high in the southern region, and development projects are currently concentrated in the southern provinces of Binh Thuan and Ninh Thuan. With regard to wind power, a World Bank and Danish Energy Agency report published in 2020 states that Vietnam has an estimated potential of 160 GW of offshore wind capacity within 5 km to 100 km of the coast and could have up to 10 GW of offshore wind in operation by 2030. [248]

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244 It acts as a window for EVN electricity transactions such as the conclusion of an electricity sales contract (PPA).

245 In addition to the distribution and retail companies (PCs), there are nearly 9,000 "Commune Operators" and small distribution companies called "Local Distribution Units (LDUs)" .

246 JETRO Vietnam Electricity Survey 2017, https://www.jetro.go.jp/ext_images/_Reports/02/2018/ccf4d530ac1e7574/vha20180315_mic.pdf

247 METI Ministry of Economy, Trade and Industry, https://www.meti.go.jp/meti_lib/report/H29FY/000562.pdf

248 IEEFA, https://ieefa.org/world-bank-study-sees-potential-for-10gw-of-offshore-wind-in-vietnam-by-2030/

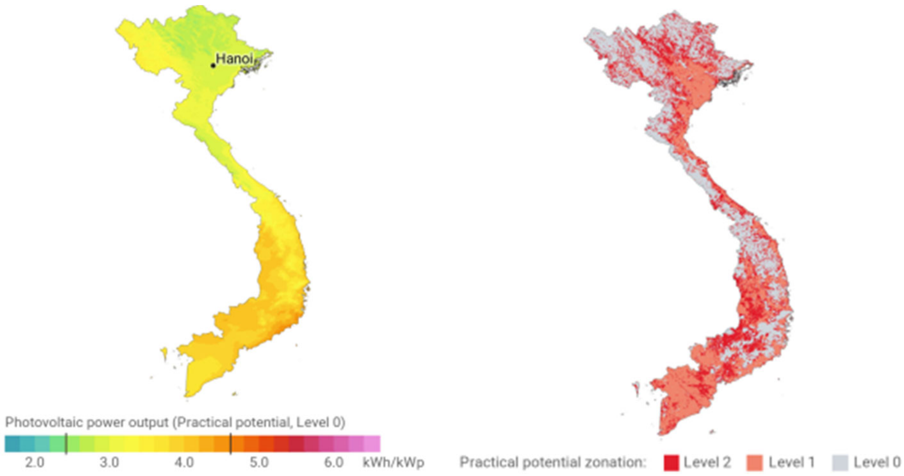

Figure 94 Solar Power Generarion Potential in Viet Nam

Note: Left = Estimated power generation
Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints; Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

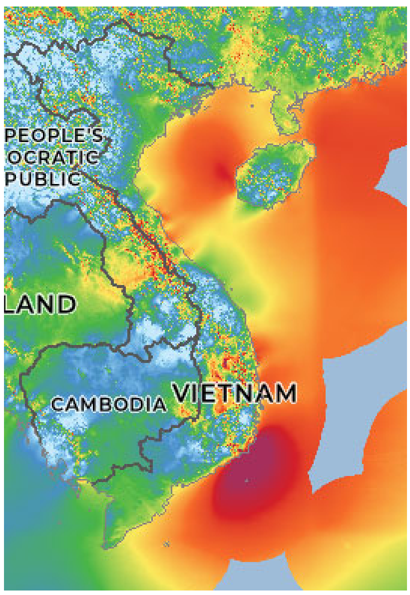

Figure 95 wind Power Generation Potential in Viet Nam

Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

MOIT will oversee all energy industries, including renewable energy.

(3) Development goals

The revised PDP7 states that future renewable energy development plans call for increasing the share of renewable energy to 21% of installed capacity and 10.7% of power generation by 2030, with 2030 targets for individual technologies: 6 GW of wind power (2.1% share of power generation), 12 GW of solar power (3.3% share of power generation), and biomass (2.1% share of power generation). The plan is to develop at least 1 GW of renewable energy each year starting in

2019 and 3 GW starting in 2028. [249]

(4) Policies to promote introduction[250]

The FIT system is in place, covering solar, wind, biomass, and waste power generation, with a guaranteed purchase for 20 years, but there are plans to shift to a bidding system in the future, starting with wind power.

Wind power generation has been developed based on the Prime Minister's Decision (No. 37/2011/QD-TTg) dated June 2011, which sets FIT electricity sales prices, tax incentives, and other promotion measures. In September 2018, the Prime Minister's Decision (No. 39/2018/QD-TTg) was issued (supplement to No. 37/2011/QD-TTg), which provides for an increase in the purchase price of wind power, reflecting requests from companies for a higher purchase price. The legislation, which took effect in November 2018 and is time-limited until November 1, 2021, increases the purchase price per kWh from the previous VND1,614 (about 7.8 cents) per kWh to VND1,928 (8.5 cents) for onshore generation and VND2,223 (9.8 cents) for offshore generation. The new buyback price will be valid for 20 years, with the condition that commercial operation must begin before November 1, 2021 and be connected to the national grid. [251] The new application of FIT to wind power generation will end at the end of October 2021, and it is intended to shift to a bidding system that covers the entire range of renewable energies, including solar power. [252]

Solar power generation has been developed based on the Prime Minister's Decision dated April 2017 (No. 11/2017/QD-TTg), which sets FIT electricity sales prices, tax incentives, and other promotional measures. The Prime Minister's Decision (No. 13/2020/QD-TTg), dated April 2020, established a new purchase price, ranging from VND1,644 to VND1,943 (7.09 to 8.38 cents) per kWh, depending on installation location. Eligible projects are those that receive approval prior to November 23, 2019 and begin commercial operation between July 1, 2019 and December 31, 2020, and a bidding system is expected to apply to solar that does not meet the requirements. [253] Since the application of the FIT system, the amount of solar power generation installed has increased rapidly (from 105 MW in 2018 to 16,504 MW in 2020 [254]), and the accompanying lack of development of power transmission and distribution network infrastructure and other issues have become a challenge. In May 2021, the National Load Dispatching Center (NLDC) announced its intention to continue to curtail the output of solar and other renewable energy power plants to avoid overloading the power grid. [255] For biomass power generation, the purchase price has been increased by the Prime Minister's Decision dated March 2020 (No. 8/2020/QD-TTg) due to the government's intention to encourage investment. [256]

(d) Energy conservation policy

(1) Institutions in charge of policy

The Energy Efficiency and Sustainable Development Department, under MOIT, is responsible for energy conservation policies.

(2) Target

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[249] JETRO, March 2018, https://www.jetro.go.jp/ext_images/_Reports/02/2018/ccf4d530ac1e7574/vha20180315_mic.pdf

[250] METI, March 2018, https://www.meti.go.jp/meti_lib/report/H29FY/000562.pdf

[251] JETRO, September 25, 2018, https://www.jetro.go.jp/biznews/2018/09/a9562f218fe64045.html

[252] NNA ASIA, December 28, 2021, https://www.nna.jp/news/show/2265572

[253] JETRO, April 14, 2020, https://www.jetro.go.jp/biznews/2020/04/73851908d63cd34f.html

[254] IRENA, Trends in Renewable Energy, https://public.tableau.com/views/IRENARETimeSeries/Charts?%3Aembed=y&%3AshowVizHome=no&publish=yes&%3Atoolbar=no (access, January 7, 2022)

[255] NNA ASIA, May 13, 2021, https://www.nna.jp/news/result/2187541

[256] JETRO, April 14, 2020, https://www.jetro.go.jp/biznews/2020/04/73851908d63cd34f.html

The National Energy Efficiency Programme (VNEEP) for the period 2019-2030, published in 2019, aims to save 5-7% of energy consumption in the period 2019-2025 and 8-10% in the period of 2019-2030. Targets for each industrial sector are as follows (average energy consumption reduced)[257]

Table 84 Energy Efficiency Targets of Industry Sector by 2030 in Viet nam

(base Year: 2015-2018)	2019-2025	2019-2030
Iron and Stell	3-10%	5-16.50%
Chemical	Min7%	Min10%
Plastic Production	18.00-22.46%	21.55-24.81%
Cement	min7.5%	Min10.89%
Textile and Clothing	Min5%	Min6.80%
Alcohol-Beverage	3.00-6.88%	4.6-8.44%
Paper and Pulp	8.00-15.80%	9.90-18.48%

Source: National Energy Efficiency Programme (VNEEP) for the period of 2019 – 2030

(3) Promotion policy[258]

In January 2011, the Law Concerning the Energy Saving and the Efficient Use of Energy (Energy Conservation Law) came into effect. The bill organizes the energy management and reporting system, labeling system, and measures to promote the introduction of energy-saving equipment, which have been established based on government decisions and notifications, etc., and also attempts to shift from a voluntary participation type system to a mandatory system. The systems under the Energy Conservation Law are as follows

- Introduction of financial subsidies and an energy labeling system to promote energy efficiency and conservation.
- Establishment of responsibilities and obligations for the development and implementation of energy saving plans for business operators.
- Designation of "Priority Energy Users" with high total annual energy consumption.
- Establishment of priority business operators for energy use, including the formulation of annual and five-year plans for energy use rationalization and the designation of energy managers.
- Introduction of labeling on equipment selected for energy labeling.
- Tax incentives for the production of energy-saving products (reduction or exemption of import/export tax and corporate income tax), and exemption of tariffs on equipment used in research for energy-saving technology development and energy-saving products that cannot be produced domestically.

(e) Environmental policy

(1) Greenhouse gas emission reduction targets[259]

The updated NDC submitted to the UN in September 2020 aims to reduce GHG emissions by 9% (83.9 million tons) from the BAU level by 2030, based on 2014 levels, and by 27% (250.8 million tons) if new or additional financial support, technology transfer and capacity building from abroad are received. Sectoral emission reduction targets are as follows.

[257] ASEAN, National Energy Efficiency Programme (VNEEP) for the period of 2019–2030, https://aeds.aseanenergy.org/policy/national-energy-efficiency-programme-vneep-for-the-period-of-2019-2030/

[258] METI, February 29, 2016, https://www.meti.go.jp/meti_lib/report/2016fy/000471.pdf

[259] UNFCCC, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Viet%20Nam%20First/Viet%20Nam_NDC_2020_Eng.pdf

Table 85 Emission Reduction Targets for Each Sector in Vietnam's NDC

Unit: Reductio nratio (%), Reduction amount (million ton-CO2)

Sector	Domestic effort		Including international aid	
	Ratio	Amount	Ratio	Amount
Energy	5.5	51.5	16.7	155.8
Agricaulture	0.7	6.8	3.5	32.6
LULUCF*	1.0	9.3	2.3	21.2
Wastes	1.0	9.1	3.6	33.1
Indutrial process	0.8	7.2	0.9	8.0
Total	9.0	83.9	27	250.8

*Includes absorption of greenhouse gases.
Source: UPDATED NATIONALLY DETERMINED CONTRIBUTION (NDC)を基に調査団作成

Specific initiatives in the energy sector, which has the largest GHG emissions and the highest reduction targets, are presented below.

-Promotion of energy efficiency and conservation in all sectors
-Development of renewable energy
-Restructuring of freight transportation model
-Promotion of use of public transportation
-Shift from conventional fuels to bio-combustion, natural gas, and electricity
-Reduction of GHG emissions in cement production
-Development and utilization of energy-saving building materials and green materials in the residential and commercial sectors, etc.

In November 2021, at COP26 in the UK, it was also announced that the country will be carbon neutral by 2050. [260]

(2) Promotion policy

Vietnam has actively introduced domestic measures related to climate change.

In 2011, the National Climate Change Strategy was developed to provide a long-term vision along with scenarios in climate change and sea level rise in Vietnam and to serve as a foundation for other strategies. Vietnam is one of the countries most affected by climate change, and the overall goal of the strategy is to "simultaneously address climate change adaptation and measures to reduce greenhouse gas emissions by utilizing all of the country's capabilities." [261]

In addition, in 2012, the government enacted the National Green Growth Strategy for the period up to 2020. Strategic issues include reducing the intensity of greenhouse gas emissions (target set by 2020), increasing the share of high technologies and green technologies in GDP (43-45%), and promoting green lifestyles and sustainable consumption. [262] In October 2021, the "Revised Green Growth Strategy (National Green Growth Strategy for 2021-2030 with a view to 2050)" was released to achieve carbon neutrality. [263] This year's event particularly emphasized the green economy, which aims for economic prosperity, sustainability in the environment, and equality in society, as well as reductions in global warming and CO2 emissions. The specific targets are 15% reduction in greenhouse gas emissions in 2030 and 30% reduction in 2050 compared to 2014. For each item of the greening process based on (1) reducing the intensity of

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[260] Online Newspaper of the Government, http://news.chinhphu.vn/Home/Viet-Nam-to-take-stronger-measures-to-achieve-netzero-emissions-by-2050/202111/46000.vgp

[261] Government Portal, National strategy on climate change, http://www.chinhphu.vn/portal/page/portal/English/strategies/strategiesdetails?categoryId=30&articleId=10051283

[262] GIZ, Viet Nam National Green Growth Strategy, https://www.giz.de/en/downloads/VietNam-GreenGrowth-Strategy-giz2018.pdf

[263] Government Portal, http://vanban.chinhphu.vn/portal/page/portal/chinhphu/hethongvanban?class_id=2&_page=1&mode=detail&document_id=204226

greenhouse gas emissions, (2) greening each industry, (3) promoting green living and sustainable consumption, and (4) greening based on the principles of equality, inclusion, and resilience, the specific numerical targets are provided[264].

[Carbon tax and emissions trading]

In November 2020, Vietnam's National Assembly passed an amendment to the Law on Environmental Protection to legislate an emissions trading scheme. The effective date is January 1, 2022. Details of the targets, schedule, and target industries will be announced by government notification at a later date. National greenhouse gas emissions inventories and MRV of emissions will also be legislated. Enhancement of free trade with the EU is also expected by the adoption of carbon pricing.[265]

(3) Transportation

[Electric vehicles]

At this time, there are no comprehensive EV support measures in place. However, some domestic and foreign automakers are moving forward with their plans in anticipation of higher demand in the near future.

For example, in 2018, Mitsubishi Motors signed a memorandum of understanding with the Vietnamese government on expanding the use of EVs and other electric vehicles. As air pollution becomes an issue in Vietnam, we will work with the country's Ministry of Industry and Trade (MOIT) to collaborate on efficient electric vehicle use and public policy programs.[266] Also in 2019, Vinfast[267], the country's first automaker established in 2017, announced plans for a manufacturing project at its Haiphong plant with technology transfer from BMW [268]and the first EV sales in Vietnam in December 2021. It is also planned to begin sales in Europe and the United States in 2022. [269] A policy was also announced to install EV charging stations in a total of 40,000 locations in 63 provinces and cities in the country by the end of 2021. [270] The government is considering tax incentives for EVs, and future trends will be closely watched.

(4) Urban development

Ha Noi, Da Nang, and Ho Chi Minh City were selected for the ASCN launched in 2018. In August 2018, Deputy Prime Minister Trinh Dinh Dung promulgated Prime Minister Decision No. 950/QD-TTg approving "Vietnam's Sustainable Smart City Development Plan for the period 2018-2025 and Policy until 2030". According to the plan, the goals for the period up to 2020 are: the creation of the legal basis for smart city development and preparatory work for pilot development investments; the creation of a legal framework for sustainable smart city development and the promulgation of the institutions applicable to the pilot districts; the creation of an overall system of national standards applicable to sustainable smart city development. The goals by 2025 include the development of various regulations based on the results of the pilot implementation and the promulgation of national standards applicable to the pilot construction of smart cities (with priority given to urban management, transportation, sewerage, power grids, etc.). [271]

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264 Tepia Corporation Japan, http://www.tepia.co.jp/tepiamonthly/report/tepia-monthly20211019r.pdf

265 East Asia Forum, November 19, 2020, https://www.eastasiaforum.org/2020/11/19/vietnam-pioneers- post-pandemic-carbon-pricing/

266 Itmedia NEWS, January 16, 2018, https://www.itmedia.co.jp/news/articles/1801/16/news082.html

267 Vinfast is a subsidiary of the major local conglomerate Vingroup.

268 JETRO, May 13, 2019, https://www.jetro.go.jp/biznews/2019/05/76a6f98b4cf2df66.html

269 Nihon Keizai Shinbun, December 25, 2021, https://www.nikkei.com/article/DGXZQOGM2525Z0V21C21A2000000/

270 NNA ASIA, November 23, 2021, https://www.nna.jp/news/show/2266233

271 VIETJO, August 6, 2018, https://www.viet-jo.com/news/economy/180804082719.html

(f) Next generation technology, innovation

N/A.

(g) Points to consider for future cooperation in promoting low carbon and decarbonization

- The potential for solar and wind power generation is large, and the direction of future energy policy indicates that the use of renewable energy sources will be promoted. However, the investment decisions for solar power generation have greatly exceeded targets due to preferential treatment, which has given rise to concerns about the development of the power grid, especially in the southern region where resources are concentrated. On the other hand, the southern region is concerned about power shortages due to delays in coal-fired power development, and support for the development of power transmission and distribution networks and resilience enhancement may be considered in consideration of the expansion of renewable energy.
- The industrial sector accounts for a large share of energy consumption and is expected to increase further in the future. Energy conservation targets have been set for each industrial sector for 2019, and there will likely be a need for assistance in developing specific roadmaps for the implementation of energy conservation measures. In the consumer sector, the Heat Pump and Thermal Storage Center is currently exchanging information with Hanoi University of Technology on the conversion of boilers to heat pumps within the Asian Heat Pump and Thermal Storage Technologies Network (AHPNW), and may provide support based on Japanese companies entering the market.
- The momentum toward low carbon and decarbonization is growing, and smart city development has begun in many regions. Some Japanese companies have advanced into Hanoi, including a consortium led by Sumitomo Corporation that is developing a smart city in Hanoi, and support in this area may be considered based on the needs of each city and the advancement of Japanese companies in the area. With urbanization and motorization expected in the future, it will be important to develop urban development and transportation infrastructure with an eye toward future sustainability.
- JICA has been supporting the industrial sector, which is the largest energy consuming sector, to insert energy management systems for large energy consumers, and MOIT has expressed a desire to extend this to SMEs in order to further promote energy conservation in the industrial sector.

(9) Thailand

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

Thailand has experienced various economic slowdowns in recent years, including the Asian currency crisis, the global financial crisis, and the 2011 floods that caused extensive damage across a vast area. In addition, the economy has been growing at a sluggish rate of 3-4% in real GDP growth over the past few years due to political instability, including a military coup in May 2014 and the continuation of military rule until general elections in March 2019. Energy demand has been increasing rapidly since around 1980 due to industrialization, but there has been no significant change in the past few years. Thailand has abundant natural gas resources, which, along with petroleum, is the country's main source of energy. However, as natural gas consumption in the electric power sector increases, domestic reserves are reaching a plateau, and production is expected to decline in the future. As for electricity, gas-fired power is the main source, with gas-fired power generation accounting for 64% of electricity generated in 2019. However, as noted above, domestic production of natural gas is on the decline, and natural gas imports are on the rise. Currently, imports from Myanmar are the main source of LNG. However, there are concerns that imports may decrease in the future as Myanmar's own demand increases, so the company is considering expanding LNG imports from the Middle East and other countries. In addition, renewable energy generation has been increasing since around 2010, accounting for 14% of electricity generated in 2019.

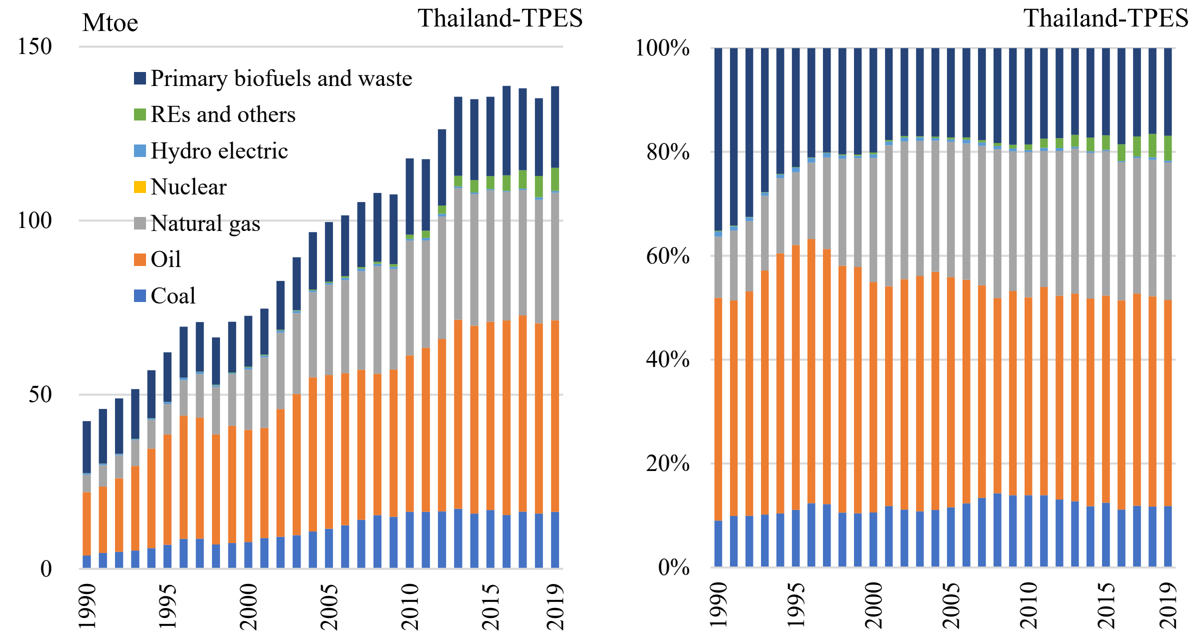


Figure 96 Primary energy Supply in Thailand

Source: World Energy Balances 2021 extended edition database, IEA

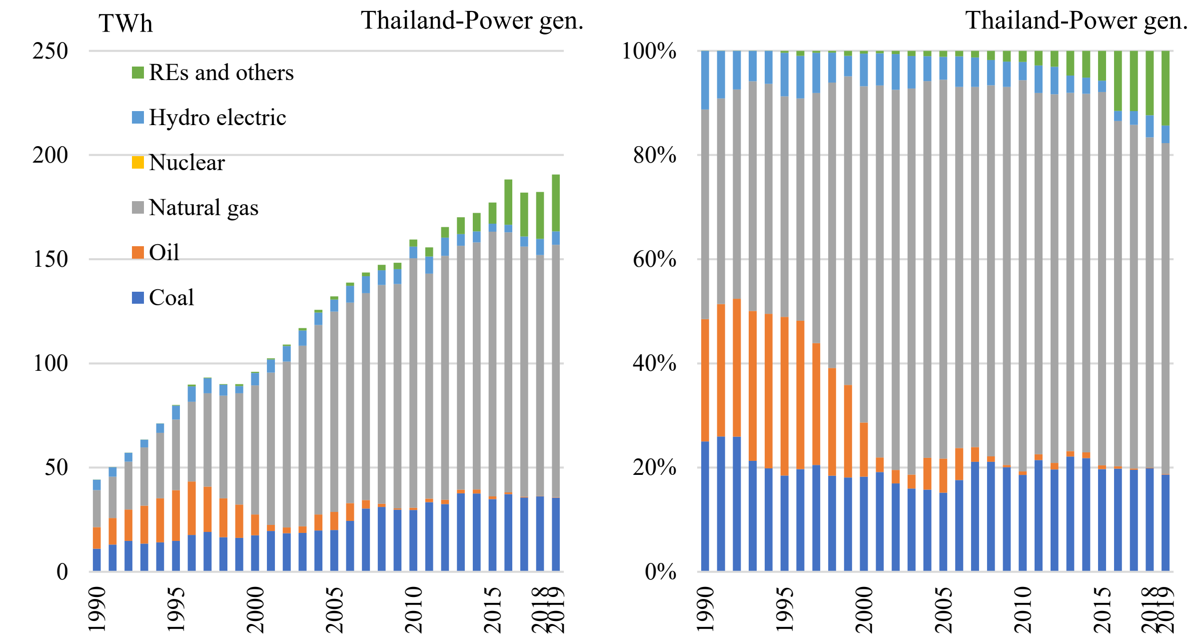


Figure 97 Fuel Mix of Electricity Generation in Thailand

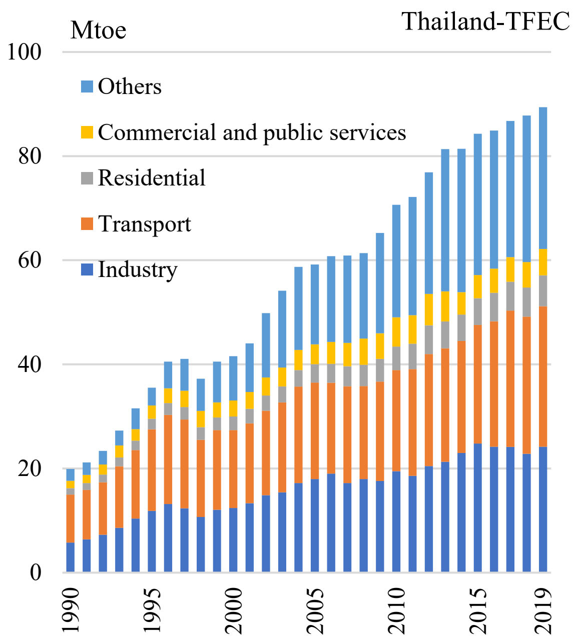
Source: World Energy Balances 2021 database, IEA

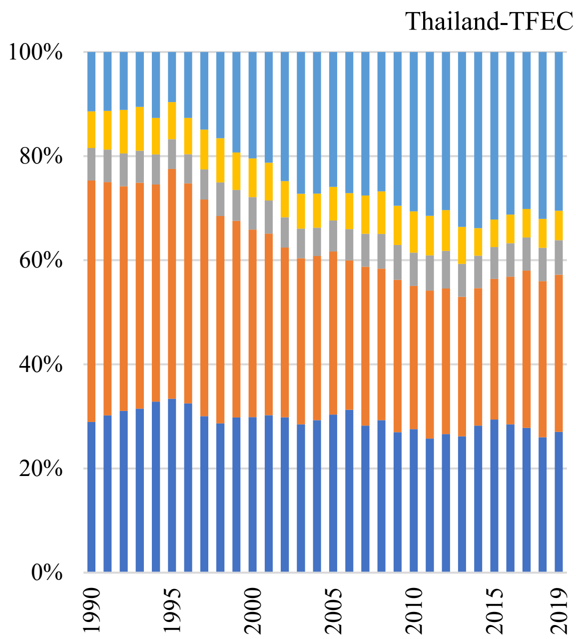
A breakdown of final energy consumption by sector shows that industry, transportation, residential, commercial/public services account for 27%, 30%, 7%, and 6% of final energy consumption in 2019, respectively, indicating that consumption in industry and transportation is dominant. Transportation has the largest five-year growth from 2014 to 2019 at 4.7%, followed by commercial/public services at 3.3% and residential at 3.1%.

The industry has been stagnant since 2015, but electricity use is on the rise. The industrial policy "Thailand 4.0," announced in 2016, aims to shift from the previous emphasis on heavy industry and industrial product exports to the development of a digital economy and the nurturing of new-generation industries (next-generation automobiles, smart electronics, robotics, etc.)[272], which could further increase demand for electricity in the future.

In the transportation sector, 86% is petroleum, 8% is renewable energy and others, and 6% is natural gas. Thailand has introduced strict emission regulations ahead of other ASEAN countries and is also making efforts to promote the use of biodiesel. Also related to the industrial sector, the country has indicated a policy to develop its country as an EV production hub in the ASEAN region by 2025, and is considering promoting EVs domestically as well. In addition to the implementation of further fuel efficiency regulations and the use of biodiesel, efforts to promote EVs in conjunction with the low-carbonization of electric power are likely in the future.

In residential and commercial/public services, electricity is the power mainly used.





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[272] Thailand Board of Investment, https://www.boi.go.th/upload/osaka181226/Article_EEC_181222.pdf

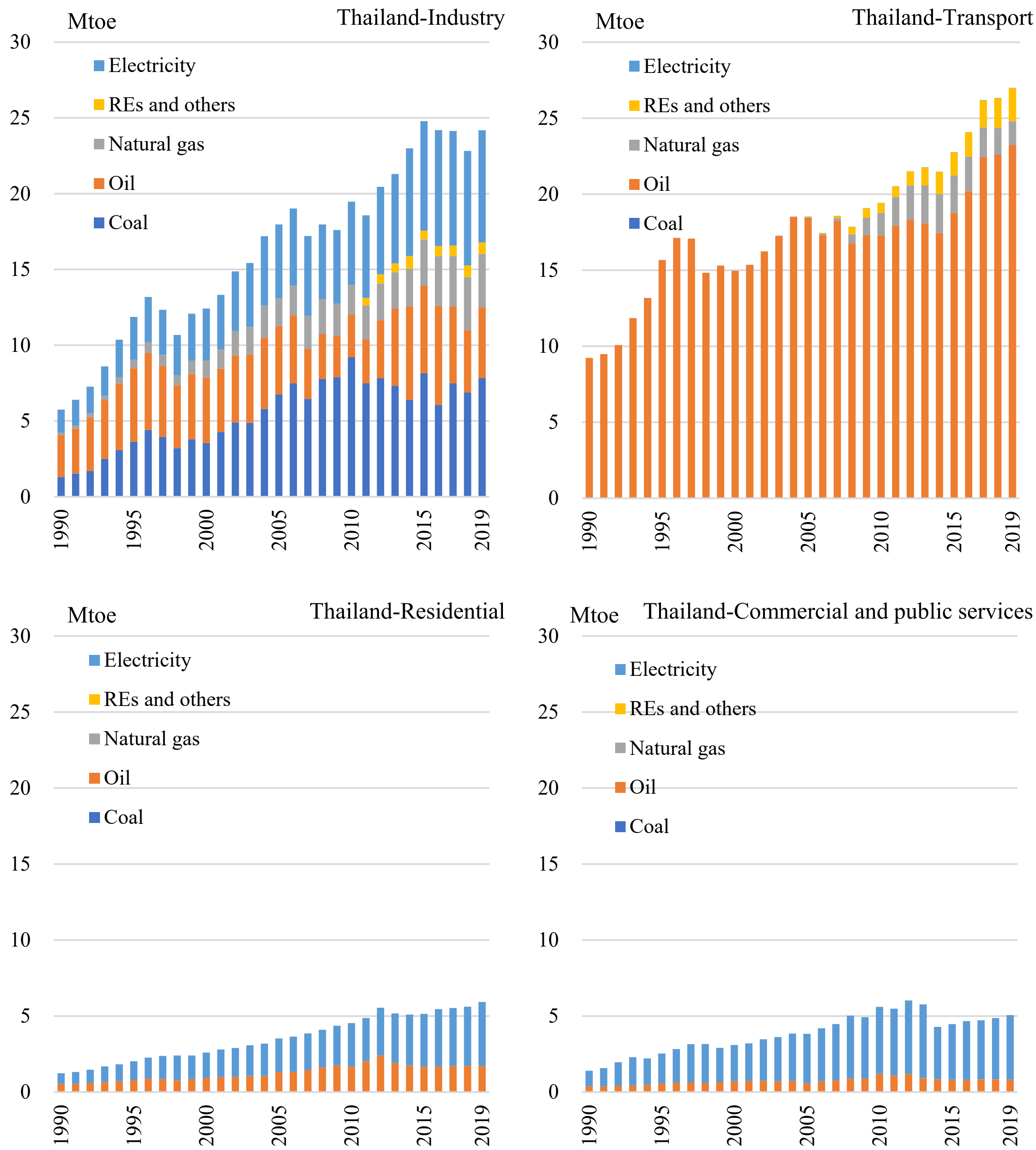

Figure 98 Final energy Consumption of Major Sectors in Thailand

Excluding "Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal".
"Others" in TEFC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2020 extended edition database, IEA

Primary energy consumption per GDP was on a declining trend in the 1970s and 1980s, but began to rise in the late 1980s and was 0.301 toe/$1,000 in 2019 (0.090 in Japan). This indicates that Thailand is not making progress in decoupling economic growth from energy consumption, i.e., improving energy efficiency.

The average thermal efficiency of gas-fired power plants is 46%, while the average thermal efficiency of coal-fired power plants is around 36%. The average thermal efficiency of gas-fired power plants is relatively high, which is due to the fact that many CCGTs have been introduced as a mainstream power source development. CCGTs have high operational flexibility and will play an important role in grid stabilization as further renewable energy is introduced in the future.

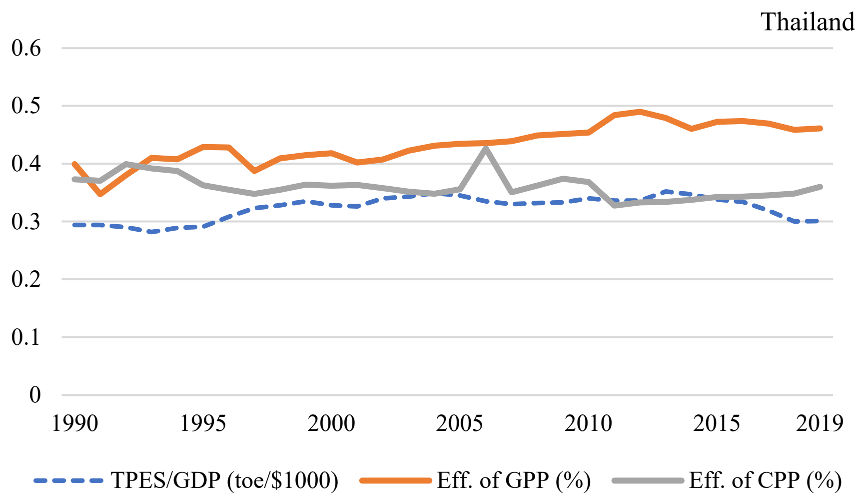

Figure 99 Energy Efficiency in Tnailand

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant, CPP = coal power plant, GDP in 2015 price

Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options that could be adopted to reduce Thailand's CO2 emissions in the future and their CO2 reduction effects.

Table 86 Examples of Low-carbon/ Decarbonization Potential in Thailand

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		256.9 mton-CO2
【Example of CO2 Emission Reduction Option】		【Reduction Effect】
Generation	Substitue 25% of Coal-fired Generation foe Renewable Energy	9.19 mton-CO2
Industry	Substitute 50% of Oil and Coal for Natural Gas	8.06mton-CO2
Transport	10% Improvement of Fuel Mileage	6.44 mton-CO2
Residential, Commercial and Public Services	10% Improvement of Energy Efficiency	5.30mton-CO2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES

Source: JICA Study Team

(2) Primary energy mix and electricity mix planning

[Primary energy mix]

The table below shows Thailand's primary energy consumption forecast to 2050 by the Institute of Energy Economics, Japan. Based on an assumed GDP growth rate (2010 prices) of 3.1% for the period 2018-2050, primary energy consumption is projected to increase at an average annual rate of 1.4%. In energy sources in 2050, oil and natural gas will continue to dominate, but renewable energy sources are also expected to expand.

Table 87 Primary Energy Supply Outlook in Thailand (Reference case)

Unit: Mtoe

	2019	2030	2040	2050	Annual Growth rate (%) 2019-2050
Coal	16	16	16	15	-0.3
Oil	55	60	66	70	0.8
Natural Gas	37	38	40	39	0.2
Nuclear	-	-	1.8	6.2	n.a.
Hydro	0.6	0.8	0.9	0.9	1.7
Solar, Wind, etc.	0.8	2.4	4.6	7.2	7.5
Biomass, Wastes	27	38	46	54	2.2
Total	139	159	182	199	1.2

Source: IEEJ Outlook 2022

[Power Mix]

With regard to the electricity mix, there are concerns about the peaking out of domestic natural gas production and a decrease in imports from Myanmar due to Myanmar's increasing demand for its own natural gas. Therefore, LNG imports, diversification of energy sources, and further promotion of energy conservation are called for. Electricity imports through transmission line interconnection with Laos and Myanmar are also being considered (Laos is already connected).In October 2020, the government approved the Power Development Plan 2018-2037 Revision 1 (PDP2018 Rev1) at the Cabinet meeting. PDP2018 Rev1 reflects some content revisions to PDP2018 (published April 2019). It is characterized by an emphasis on securing stable supply and energy security, while at the same time emphasizing a shift away from coal and renewable energy, and a further focus on low carbon emissions. In addition, the "Settlement Power Plant Policy for Grassroots Economy" presented by the government in 2019 aims to ensure that energy development generates jobs and income for residents at the grassroots level in the country (Energy for all). In order to ensure consistency with the policy, which emphasizes the generation of electricity in the villages by clean energy fuels that can be procured within the area and used within the area in power development, consideration is given to the development of installed capacity and transmission networks in each region to enable energy independence by region. For the 2018-2037 power supply development plan, the total power supply capacity will remain unchanged from PDP2018 and will increase from 46,090 MW in 2017 to 77,211 MW. A total of 25,310 MW of power plants will be shut down by the end of 2037, which means that an additional 56,431 MW will be needed to achieve the goal. The following table shows the planned development of new power sources and the assumed generation capacity by type of power generation until 2037.

Table 88 New Power Development Plan 2018-2037 in Thailand (MW)

Renewable power generation plant	18,833
Village power plant	1,933
Circulating hydro power plant	500
Co-generation plant	2,112
Combind Cycle generation plant	15,096
Coai/ Lignite-fired power plant	1,200
Electricity imports	5,857
New/ Alternative power plant	6,900
Energy conservation measures (energy efficiency)	4,000
Total	**56,431**

Source: PDP2018 Rev1

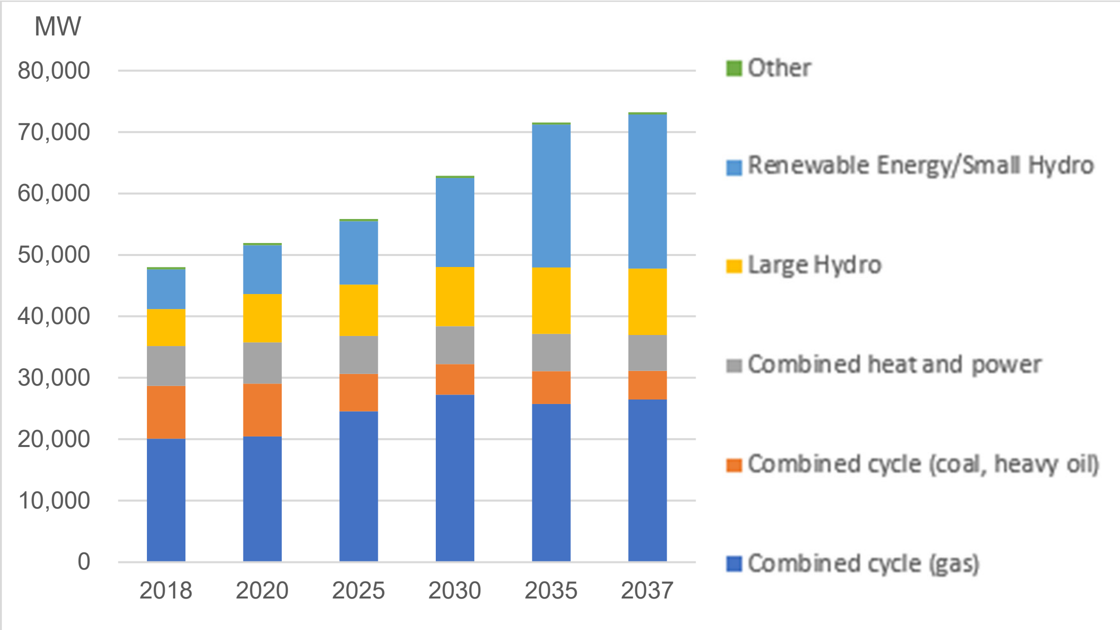

Figure 100 Estimated Electricity Generation Capacity 2018-2037 in Thailand (by Fuel) (MW)
Source: PDP2018 Rev1

(b) Electric utility system

(1) Electricity supply system

In the power sector, the Electricity Generating Authority of Thailand (EGAT), the Metropolitan Electricity Authority (MEA), which is in charge of power distribution in the metropolitan area, and the Provincial Electricity Authority (PEA), which is in charge of power distribution in other areas, have dominated the generation, transmission, and distribution sectors. However, in 1992, the participation of private companies such as IPPs and SPPs (Small Power Producers) was promoted in the power generation sector. The Thai government authorized the establishment of the Electricity Generating Company (EGCO) in 1992 and Ratchaburi Electricity Generating Holding Public Company Limited (RATCH) in 2000 to encourage competition in the power generation sector.

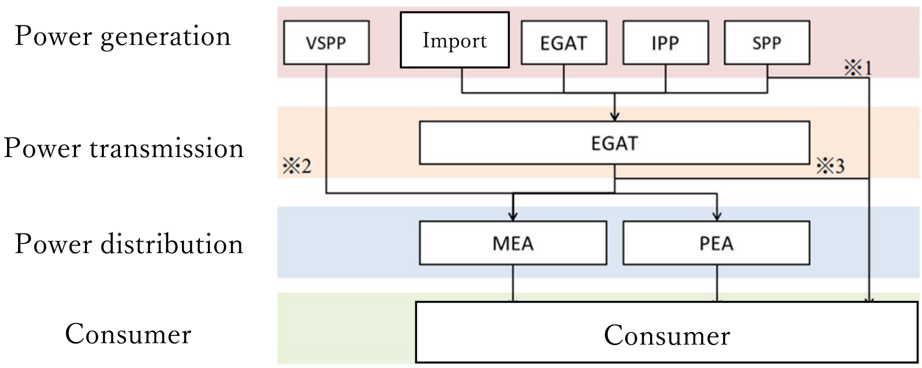

Figure 101 Electricity Supply Structure in Thailand
Note: VSPP stands for Very Small Power Producers. They are renewable energy power producers with an installed capacity of less than 10,000 kW of electricity sold, and cogeneration is included in the power generation facilities.
Source: METI, March 2019[273]

[273] https://www.meti.go.jp/meti_lib/report/H30FY/000663.pdf

With respect to electricity generation, as of December 2020, the percentages per operator are 32% (EGAT), 29% (IPP), 19% (SPP), 8% (VSPP), and 12% (imports). However, in the PDP 2018 Rev1, the percentage of each operator in 2037 is assumed to be 24% (EGAT), 15% (IPP), 11% (SPP), 25% (VSPP), 11% (import), and 9% (other), with a large increase in the percentage of VSPPs that mainly focus on small-scale renewable energy. Therefore, strengthening of power system management and operation is required. [274]

(2) Renewable electricity supply system[275]

The FIT system is in place and applies to power producers of less than 9 MW for solar power and 10 WM for wind power. For larger sizes, the market is progressing on the initiative of the private sector, and there are plans to move to bidding in the future. As private operators, local companies have a strong presence in the solar power generation business, and there have been cases of development in cooperation with overseas companies. In addition, foreign companies are expanding their presence in panel supply, and many companies have local manufacturing bases. In the wind power generation business, development is centered on EGAT and Wind Energy Holding, the largest local wind turbine manufacturer. As for wind turbine manufacturers, European companies are increasing their presence.

(c) Policy on renewable energy

(1) Renewable energy potential

As for photovoltaics, the potential is high throughout the country, especially in the eastern region. As for wind power generation, areas with good wind conditions are concentrated in the eastern mountainous regions (areas far from demand areas), and the potential is not very high.

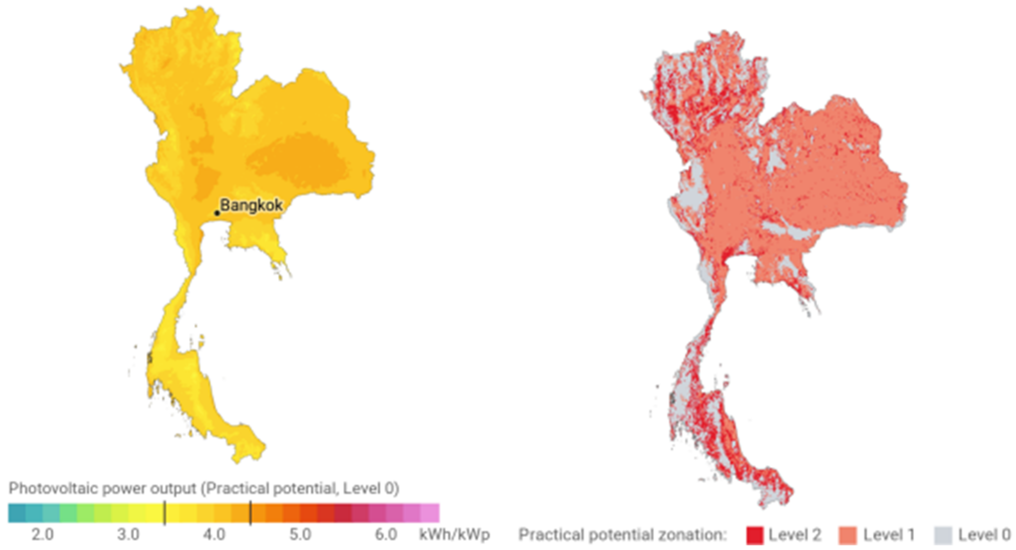

Figure 102 Solar Power Generation Potential in Thailand

Note: Left = Estimated power generation
Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints; Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

[274] Energy Policy and Planning Office, The direction of electricity policy in Thailand, http://www.sgtecheng.nu.ac.th/wp-content/uploads/2021/03/04-EPPO.pdf

[275] METI, March 2018, https://www.meti.go.jp/meti_lib/report/H29FY/000562.pdf

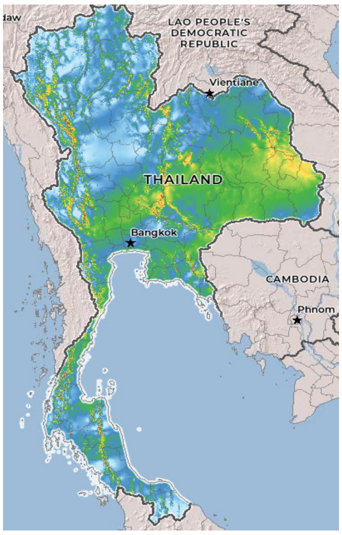

Figure 103 WindPower Generation Potential in Thailand

Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The Energy Policy and Planning Office (EPPO) and the Department of Alternative Energy Development and Efficiency (DEDE) under the Ministry of Energy (MOE) are responsible for renewable energy.

(3) Development goals

The Thailand Alternative Energy Development Plan (AEDP) 2018-2037, approved by the Cabinet in October 2020, states that by 2037, 30% (38,284 ktoe) of final energy consumption will be supplied from alternative and new energy.[276] The cumulative introduction targets for each type of power generation by 2037 include 3 GW of wind power, 14.9 GW of solar power (including water-based solar power), 5.8 GW of biomass, and 1.6 GW of biogas, etc. The share of alternative and new energies in the power source composition in 2037 is expected to be 34.23%.

[276] Alternative and new energy include solar, wind, biomass, biogas, residential waste, industrial waste and small and large hydro.

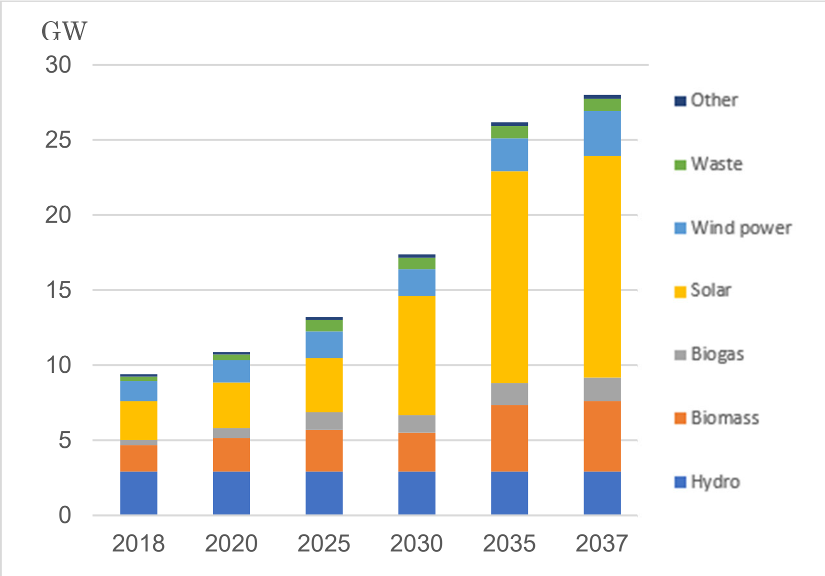

Figure 104 Estimated Renewable Power Generation Capacity 2019-2037 in Thailand
Source: PDP2018 Rev1

(4) Policies to promote introduction[277]

In 2007, a purchase price surcharge (Adder) for renewable energy generation was introduced, followed by a transition from Adder to Feed-In-Tariff (FIT) in 2011, and the FIT system was launched in 2013.

With regard to solar power generation, there are two main categories: large-scale solar power generation and distributed solar power generation (e.g., roof-mounting type projects). The preferential treatment system was initially intended mainly for large-scale PV, but amid concerns about restrictions on construction sites and grid capacity limitations, the FIT system mainly targets power plant projects of less than 9 MW, known as solar farms, and roof-mounted solar power projects. The allocation for solar farms has already ended, and the market is now planned to become a private-sector-driven market via bidding, along with large solar farms of 9 MW or more (only projects for government agencies and agricultural cooperatives are expected to continue under the FIT). On the other hand, the FIT is expected to continue for roof-mounted solar power projects, although the allocation has ended at this time (detailed timing has not yet been determined). Also in 2015, a net metering system (NMS) was introduced for roof-mounted solar power installers, allowing them to sell excess electricity. The FIT system has led to a rapid increase in roof-mounted solar power generation, mainly for residential use, and the government is promoting solar power generation for private consumption, taking into account its impact on the grid. There are two types of in-house power generation: In-Plant Utilities (IPUs), which generate and consume their own power without using the EGAT or MEA/PEA distribution system, and Industrial Power Suppliers (IPSs), which sell surplus power after in-house consumption not to EGAT or EMA/PEA, but to industrial customers in nearby industrial parks.

As for wind power generation, very small power producers (VSPPs) of less than 10 MW have been subject to the FIT since its initial introduction. For wind power generation projects of 10 MW or more, the market has been progressing under the initiative of the private sector, and the policy will shift to bidding in the future.

To promote the introduction of renewable energy, the government offers incentives to businesses, including corporate tax exemptions for up to eight years and import duty exemptions for machinery and materials needed to manufacture the products. ESCO funds are also provided

[277] METI, March 2018

by DEDE (e.g., low-interest soft loans provided, equity participation, equipment leasing, etc.) and various data are provided (e.g., solar radiation, wind, potentials, etc.).

As a recent development, in July 2019, based on the Cabinet's key policy on energy, the energy policy will establish mechanisms to engage residents in energy, promote economic development, and generate jobs and income for residents at the grassroots level in the country (Energy for all). For power development, emphasis is placed on the generation and use of clean energy fuels that can be procured and used within the community. In 2019, a resolution was passed to agree to the introduction of a FIT system and a purchase price framework for very small-scale power producers (VSPPs) for village power generation projects for grassroots economies. The new power generation capacity targets for new village power plants for grassroots economies in PDP2018 Rev1 are 550 MW of solar, 600 MW of biomass, 600 MW of biogas (energy plants), and 183 MW of biogas (wastewater/waste) cumulatively through 2024.

In October 2020, EGAT also announced that it will introduce Thailand's first renewable energy certificate (REC) issuance and trading system. [278]

[Biomass]

As mentioned above, Thailand is facing the depletion of its main energy source, natural gas, and its high dependence on oil imports in response to increasing energy demand, making diversification of energy sources an urgent priority. Among these, biomass is attracting attention as an important alternative energy source in Thailand, which has abundant agricultural resources.

In power generation, solar power will be the main focus of renewable energy expansion in the future. However, according to the new generation capacity targets in "Village Power Plants for Grassroots Economy" under PDP 2018 Rev1, biomass and biogas power generation are the main focus in village power generation (600 MW of biomass and 783 MW of biogas out of a total of 1,933 MW of cumulative development targets from 2020 to 2024).

In heat production, biomass accounts for 90% of heat production from alternative energy sources, especially bagasse in the sugar industry. AEDP2018 sets a target of 41.61% for the share of heat production from alternative energy sources to the national heat energy demand in 2037, which is higher than the target in AEDP2015 (36.67%).

The transportation sector has promoted bioethanol and biodiesel, produced from the remaining products of domestic consumption and export, as alternative fuels. However, in light of recent fuel efficiency improvements in the transportation sector and the development of electric vehicle technology, the demand for fuel oil in the transportation sector is expected to decline, and the biomass fuel use target in AEDP2018 has been lowered compared to AEDP2015. (The national biomass fuel percentage target for transportation sector fuel decreased from 25.04% in AEDP2015 to 9.99% in AEDP2018.)

(d) Energy conservation policy

(1) Institutions in charge of policy

As with renewable energy, the DEDE has jurisdiction over energy conservation policies.

(2) Target

The Energy Efficiency Plan (EEP) 2018-2037, approved by the Cabinet in October 2020, sets a goal of reducing the economic efficiency (Energy Intensity) of energy by 30% in 2037 compared to 2010 levels. The energy conservation targets for 2037 by sector are as follows: the regulatory sector includes the introduction of energy conservation standards and tax measures for the transportation sector, while the promotion sector includes the introduction of a proactive labeling system and investment support for the implementation of energy conservation measures.

[278] Jiji Press Asia Business Information, October 8, 20208

Table 89 Energy Consumption Reduction Target by Sector in Thailand (2037) (ktoe)

Sector	Regulated sector	Promoted sector	Total
1.Industry	11,291	9,846	21,137
2.Commercial	3,165	3,253	6,418
3.Residential	114	3,186	3,300
4.Agriculture	37	490	527
5.Transport	3,809	13,873	17,682
Total	18,416	30,648	49,064
%	38	62	100

Source：EEP2018-2037

(3) Promotion policy[279]

In 1992, the Energy Conservation Promotion Act B.E. 2535 was enacted to promote energy conservation, making it one of the first countries in ASEAN to make energy conservation efforts. The 2007 revision is based on the basic policy of paying attention not only to technical initiatives (e.g., facilities and equipment) but also to initiatives that include human resource development. The main systems in place are as follows.

-Obligation for owners of factories and buildings above a certain size to appoint an energy manager and submit an annual energy conservation report.

-Establishment of ENCON Fund

-Establishment of advanced and minimum energy efficiency performance standards for equipment, facilities, and materials

-Introduction of labeling system (air conditioners, refrigerators, TVs, washing machines, fluorescent lamps, etc.) [280]

-Establishment of a new ministerial ordinance on energy-saving design for new buildings or renovated buildings with a total floor area of 2000 m2 or more (Building Energy Code).

In addition, the labeling standard for room air conditioners is a double standard for inverter and non-inverter machines to protect local businesses. Therefore, it is a major challenge that the market share of inverter air conditioners, the highest priority energy-saving technology in cooling, remains below 10%, which is one of the lowest in the world.

(e) Environmental policy

(1) Greenhouse gas emission reduction targets[281]

In December 2014, the Nationally Appropriate Mitigation Actions submitted to the UNFCCC Secretariat set a voluntary target for the energy and transportation sector for GHG emission reductions of 7-20% below BAU by 2020.[282]

The NDC, updated in October 2020, calls for a 20% reduction in GHG emissions relative to BAU by 2030, based on 2005 levels, and a 25% reduction if financial assistance, technology transfer, and capacity-building support necessary to promote climate action are received from developed countries.[283] In October 2021, Thailand submitted a long-term strategy to the UNFCC. The goal is to achieve virtually zero CO_2 emissions by 2065 and virtually zero GHG emissions by 2090. [284] Furthermore, in November 2021, Thai Prime Minister Prayuth

[279] METI, February 29, 2016, https://www.meti.go.jp/meti_lib/report/2016fy/000471.pdf

[280] IEA, DC2016: Philippine Standards and Labelling Program, https://www.iea.org/policies/6807-dc2016- philippine-standards-and-labelling-program?country=Philippines%2CIndonesia%2CIndia&jurisdiction=National&region=Asia%20Pacific&sector=Transport%2CRoad%20transport&status=In%20force

[281] UNFCCC, https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Thailand/1/Thailand_INDC.pdf

[282] UNFCCC, Thailand Submits NAMA, https://unfccc.int/news/thailand-submits-nama

[283] The NDC submitted in October 2015 described specific targets for the introduction of renewable energy and the reduction of energy intensity, but it has been deleted in the latest version in October 2020.

[284] UNFCCC, https://unfccc.int/sites/default/files/resource/Thailand_LTS1.pdf

announced at the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26) a new target to achieve virtually zero CO2 emissions by 2050 and virtually zero GHG emissions by 2065. [285] The goal has been further raised from the long-term strategy.

(2) Promotion policy

The Climate change master plan (CCMP) 2015-2050, the latest version of the Climate change master plan, describes the overall concept, including medium-term goals and promotion policies to achieve the long-term goals.The mid-term goals (by 2020) include a 7-20% reduction in GHG emissions from the energy and transportation sectors by 2021 compared to 2005 with international support, and at least 25% of final energy consumption to be renewable energy. Long-term goals (2020-2050) include reducing energy consumption per unit of GDP by at least 25% below BAU by 2030. [286]

The government is also in the process of enacting a Climate Change Act to strengthen climate change measures, which has reportedly been approved by the National Committee for Climate Change (NCCC) in March 2021. The law requires the industrial sector to record greenhouse gas emissions data and clarify the method for calculating emissions, among other things.

In terms of industrial policy, in January 2021, Prime Minister Prayut announced that the BCG (bio, circular, and green) economy would be the national strategic model (BCG model). The BCG model will focus on four areas: (1) food and agriculture, (2) medicine and health, (3) bioenergy, (4) biomaterials and biochemicals, (4) tourism, and the creative economy, with an emphasis on biodiversity and cultural diversity. The relevant sectors are entitled to tax benefits and other advantages. [287] In addition, in September of that year, the BOI approved a new incentive benefit for reducing greenhouse gas emissions and also announced expanded benefits for next-generation vehicle manufacturing. [288]

[Carbon tax]

The importance of carbon markets was noted in the 11th National Economic Development Plan (2012-2016) and the National Climate Change Master Plan (2015-2050). As a founding member of the Market Mechanism Reserve Fund (PMR) led by the World Bank, the country is considering an emissions trading scheme. In October 2014, the Voluntary Emissions Trading Scheme (Thailand V-ETS) was introduced. In the future, the study may be deepened with a focus on emissions trading systems. [289]

(3) Transportation

[Electric vehicles]

The Board of Investment of Thailand (BOI) has been vigorously pursuing investment policies aimed at promoting electric vehicles since 2015. In February 2020, the government launched the National Electric Vehicle Policy Committee and announced its policy to develop Thailand as an EV production hub in the ASEAN region by 2025. It also aims to increase domestic EV production to 250,000 units by the same year, and to expand EV production to 750,000 units, or 30% of domestic vehicle production, by 2030. [290]

Currently, as a measure to promote EVs, the excise tax on EVs is being reduced. An exemption is applied from January 2020 to December 2022 and 2% tax is applied after 2022 for companies

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[285] JETRO 2021.11.8 https://www.jetro.go.jp/biznews/2021/11/31957a2537a226eb.html

[286] The Office of Natural Resources and Environmental Policy and Planning / Ministry of Natural Resources and Environment(July 2015), "Climate Change Master Plan 2015-2050", https://climate.onep.go.th/wp-content/uploads/2019/07/CCMP_english.pdf

[287] JETRO, January 21, 2021, https://www.jetro.go.jp/biznews/2021/01/338924c725245424.html

[288] JETRO, September 10, 2021, https://www.jetro.go.jp/biznews/2021/09/d9f57b6f154a54f7.html

[289] Ministry of Environment, Government of Japan, July 2018, https://www.env.go.jp/policy/policy/tax/mat-4.pdf

[290] MARKLINES, September 28, 2020, https://www.marklines.com/ja/report/rep2057_202009

that have received preferential treatment from the Board of Investment of Thailand (BOI). (8% for companies that have not received preferential treatment). Corporate tax exemptions for manufacturers of finished vehicles and key components, as well as a 90% reduction in import duties on raw materials for storage batteries for two years are also provided. [291]

In the short term, the government plans to promote the use of EVs, promote the installation of charging stations and battery test centers, and establish an environmentally friendly battery waste management plan, etc. In the next one to five years, the excise tax will be restructured to take into account the amount of vehicle bodies and parts procured locally, and EV and battery waste will be managed in line with international environmental standards with high safety standards.[292]

[Emission regulations, etc.]

Thailand has been ahead of other Asian countries in adopting strict emission regulations, and Euro 4 equivalent regulations have been applied to passenger cars and light trucks since 2012.[293] It is planned to introduce more stringent Euro 5 equivalent regulations in the future, but due to the new coronavirus, this is expected to be postponed from the original 2024 to 2025. [294]

(4) Urban development

In Thailand, smart cities are defined in terms of seven categories: environment, economy, mobility, energy, people, living, and governance.

Thailand's smart city development initiative was launched in 2017 with the establishment of the National Smart City Committee, chaired by the Prime Minister, and is rapidly being developed. Initially, under the Thailand 4.0 initiative[295], three cities, Phuket in the south, Chiang Mai in the north, and Khon Kaen in the northeast, were to be developed, but in November 2017, a target of 100 smart cities to be developed by 2022 was presented [296]. Particular priority is given to the development of three cities that have been selected as candidate cities for the ASCN: Bangkok, Chonburi (part of the Eastern Economic Corridor: EEC 297), and Phuket.

(f) Next generation technology, innovation

[Smart Grid]

Thailand has developed a "Smart Grid Development Master Plan 2015-2036," which is a phased plan with short term (2017-2021), medium term (2022-2031), and long term (2032-2036) segments.

[291] Nihon Keizai Shinbun, November 5, 2020, https://www.nikkei.com/article/DGXMZO65896870V01C20A1FFE000/

[292] JETRO, March 30, 2021, https://www.jetro.go.jp/biznews/2021/03/e9f8ef14f352bbd9.html

[293] METI, March 2016, https://www.meti.go.jp/meti_lib/report/2016fy/000441.pdf

[294] MARKLINES, July 17, 2020, https://www.marklines.com/ja/news/241988

[295] Thailand 4.0: An ambitious long-term vision that aims to shift Thailand to a value-added society by accelerating the digitization of the economy and society, and to become a developed country in the next 20 years.

[296] SMART CITY Thailand, “Annual Smart City Thailand Report 2018”, https://smartcitythailand.or.th/web?download

[297] Known as the EEC (Eastern Economic Corridor) concept. This is a central project to realize Thailand 4.0, and the government will take the initiative in developing intensive infrastructure in the three eastern provinces of Bangkok (Chonburi, Chachoengsao, and Rayong).

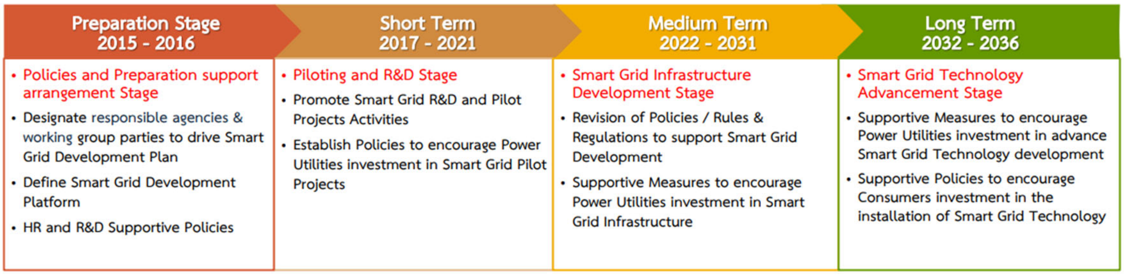


Figure 105 Outline of Smart Grid Development Master Plan 2015-2036

Source: Energy Policy and Planning Office[298]

Based on this master plan, EGAT and MEA and PEA have each developed their own plans for smart grid development. EGAT's plan is as follows.

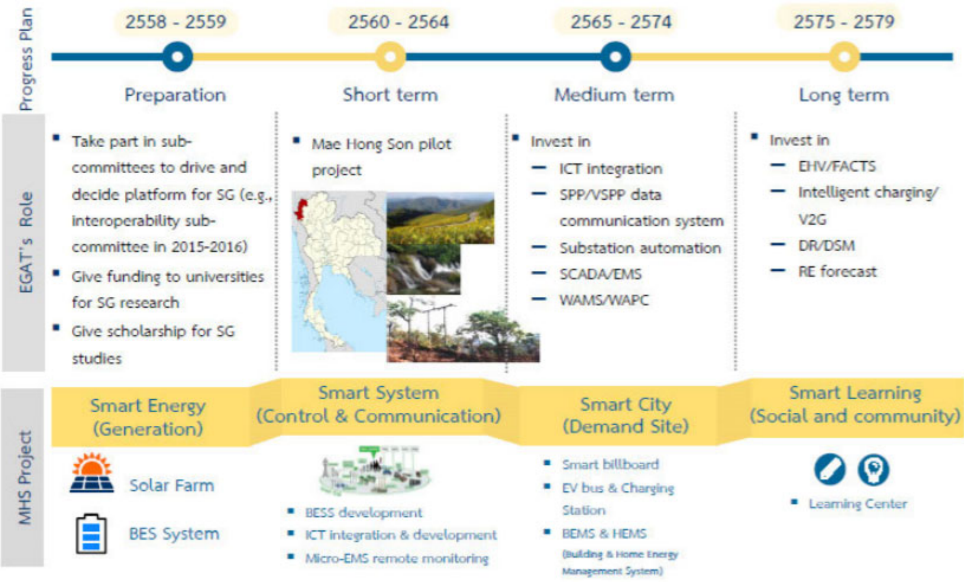


Figure 106 Smart Grid Road Map of EGAT in Thailand

*The year is presented according to the Buddhist calendar. (The year minus 543 gives A.D.).

Source: METI[299]

PDP2018rev1 mentions projects for the development of electric power facilities based on the master plan, which include the combination of solar power generation and battery energy storage systems (BESS) to improve the stability of electricity supply, control of electricity use through demand response and the use of EMS, power users' participatory in-building energy management, and other projects.

【CCS】

The Department of Mineral Fuels (DMF) has developed a roadmap for CCS. The CCMP 2015-2050 also states that implementation of CCS technology may be considered to reduce GHG emissions from coal-fired power generation but is not currently commercially viable and that risks such as CO_2 storage potential and CO_2 leakage need to be investigated.

298 Energy Policy and Planning Office, The direction of electricity policy in Thailand, http://www.sgtecheng.nu.ac.th/wp-content/uploads/2021/03/04-EPPO.pdf

299 METI, March 18, 2019, https://www.meti.go.jp/meti_lib/report/H30FY/000663.pdf

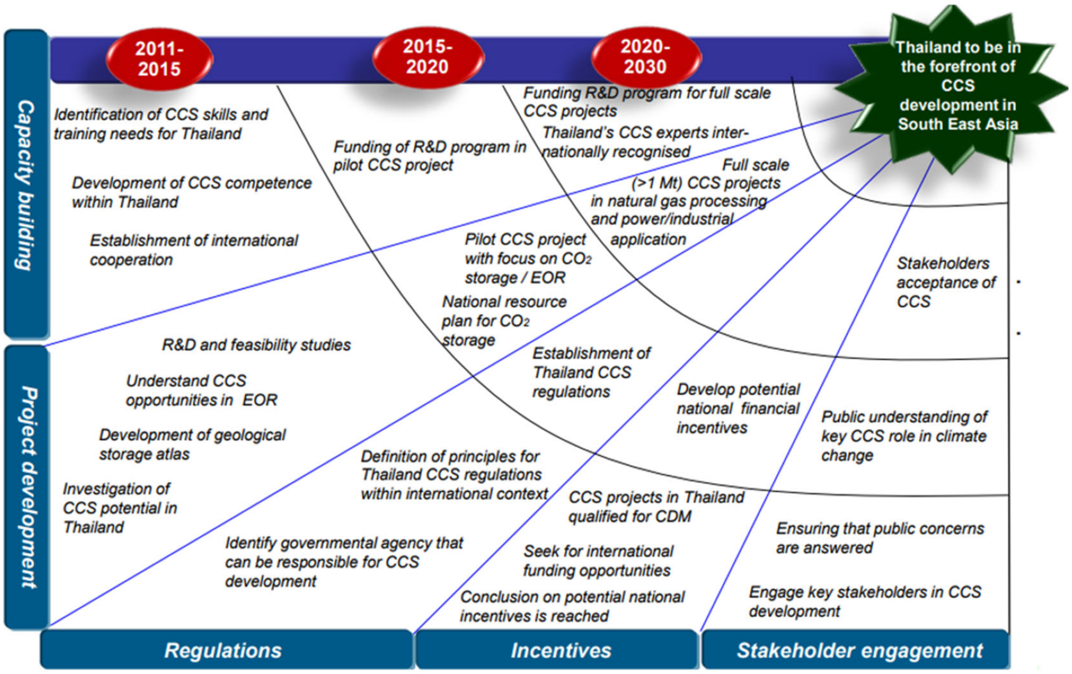


Figure 107　CCS Road map in Thailand

Source: Department of Mineral Fuel[300]

Regarding CO_2 storage potential, many of Thailand's potential storage formations extend over neighboring countries, especially in western Thailand, where there are large deep underground formations off the coast of Sumatra, Indonesia. As for Thailand's own storage potential, a study published by ADB in 2013 estimated it to be over 10 GtCO2. [301] The deep saline water layers in the Greater Thai Basin and Pattani Basin off the eastern coast of Thailand are expected to have a potential of 8.9 $GtCO_2$ and the gas fields and oil fields in the region have a potential of 1.4 $GtCO_2$. Both gas and oil fields in Thailand are on the verge of depletion, so demand for EOR is likely to be high. [302]

[300] Department of Mineral Fuel, "CCSM-National Coordinator Meeting (M2) Country Presentation: Thailand" , http://www.ccop.or.th/ccsm/data/28/docs/TH-CCS_Update_Thailand_Feb_2016.pdf

[301] ADB, "Prospects for carbon capture and storage in Southeast Asia" https://www.adb.org/sites/default/files/publication/31122/carbon-capture-storage-southeast-asia.pdf

[302] METI, March 27, 2020, https://www.meti.go.jp/meti_lib/report/2019FY/000271.pdf

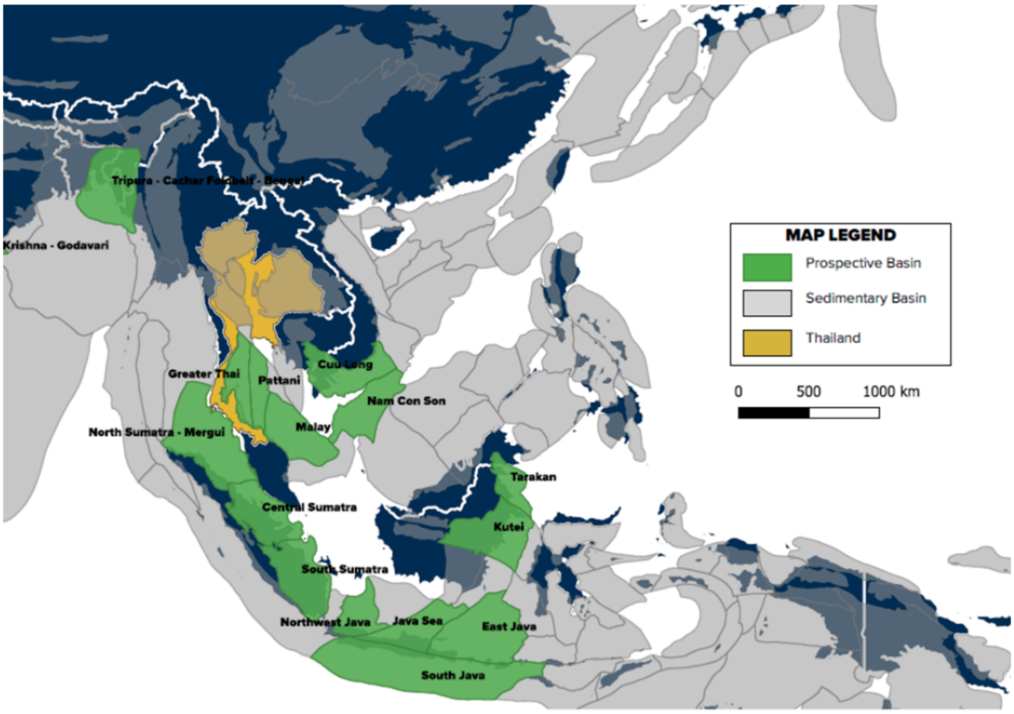


Figure 108 Deep Underground Formations with Potential CO2 Storage around Thailand
Source: METI[303]

(g) Points to consider for future cooperation in promoting low carbon and decarbonization

- One of Thailand's challenges is to strengthen its energy security in the face of its domestic gas production headway, and the country is promoting the expansion of renewable energy and energy conservation. On the supply side, the impact of the increase in renewable energy on the grid is becoming more pronounced. On the demand side, measures utilizing DR and storage batteries are being examined, and support for maintaining grid stability, including EVs which will be discussed later, and support for advanced operation are being considered.

[Reference]

In the Thailand Renewable Grid Integration Assessment published in 2018, the IEA identified the following grid measures for grid integration of renewable energy.

- ✓ Creation of nationally uniform grid codes

  Codes differ among EGAT, MEA, and PEA, preventing effective system operation.
- ✓ Establishment of a national renewable energy management center

  Enables real-time VRE generation data and short-term generation forecasts.
- ✓ Increase of operational flexibility of existing power plants (e.g., load change rates, start-up times, etc.)
- ✓ Promotion of demand side measures (DSM, V-charging, batteries, etc.)

- As part of Thailand 4.0, Thailand is promoting a plan to make Thailand a production base for electric vehicles with the aim of popularizing electric vehicles in the country and expanding exports. Currently, EV penetration in the country is not progressing due to the price of EVs and the state of infrastructure development. However, new services in automobiles such as MaaS and connected services are beginning to spread, including those by Japanese companies, and support in areas such as EV penetration in the country and optimal installation of charging infrastructure can be made.
- In the consumer sector, the Heat Pump and Thermal Storage Center is in the process of

303 METI, March 27, 2020, https://www.meti.go.jp/meti_lib/report/2019FY/000271.pdf

exchanging information with DEDE and King Mongkut's University of Technology on the conversion of boilers to heat pumps within the Asian Heat Pump Thermal Storage Technologies Network (AHPNW). In 2019, JICA also supported the conversion of boilers to heat pumps in factories in Bangkok under a private partnership scheme, and a proposal for a support scheme in conjunction with these efforts could be considered.

- With regard to energy conservation in buildings, the need to make Thailand's Building Energy Code a ZEB code that meets international standards in the future, and the need for a mechanism to promote the ZEB concept in the Thailand (e.g., government support for building owners and developers) are recognized. There is a ZEB/ZEH support scheme in Japan, which may be useful for Thailand, and information exchange would be effective. In particular, regarding the spread of inverter air conditioners, support by Japan is strongly desired to achieve breakthroughs (see (d) Energy conservation policy (3) Promotion policy).

(10) Philippines

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

In the past, the Philippines has experienced political instability and a long period of economic stagnation. However, political stabilization began around 2010, and since then real GDP growth has continued at 6-7%, with a rapid increase in energy demand. The Philippines is rich in domestic resources such as geothermal, hydropower, coal, and natural gas. On the other hand, imports of oil and coal are increasing as energy consumption rises, and the development of domestic energy resources has become one of the key policies.

The increase in energy demand has been responded since around 2010 with the use of coal. The expansion of coal-fired power in electricity is significant, with the share of coal-fired power in electricity generated expanding from 37% in 2010 to 55% in 2019. In addition, geothermal power, which has the second largest installed capacity in the world after the U.S., and hydroelectric power, which has great potential, account for a high percentage of renewable energy. The company has indicated a policy of expanding solar power generation in the future.

In December 2021, a major typhoon in Cebu Island disrupted the power grid in the industrial park of MEP21, resulting in a two-month power outage. This caused significant damage in the industrial park, and this has increased the importance of resilience, securing alternative power sources, and momentum for the introduction of renewable energy.

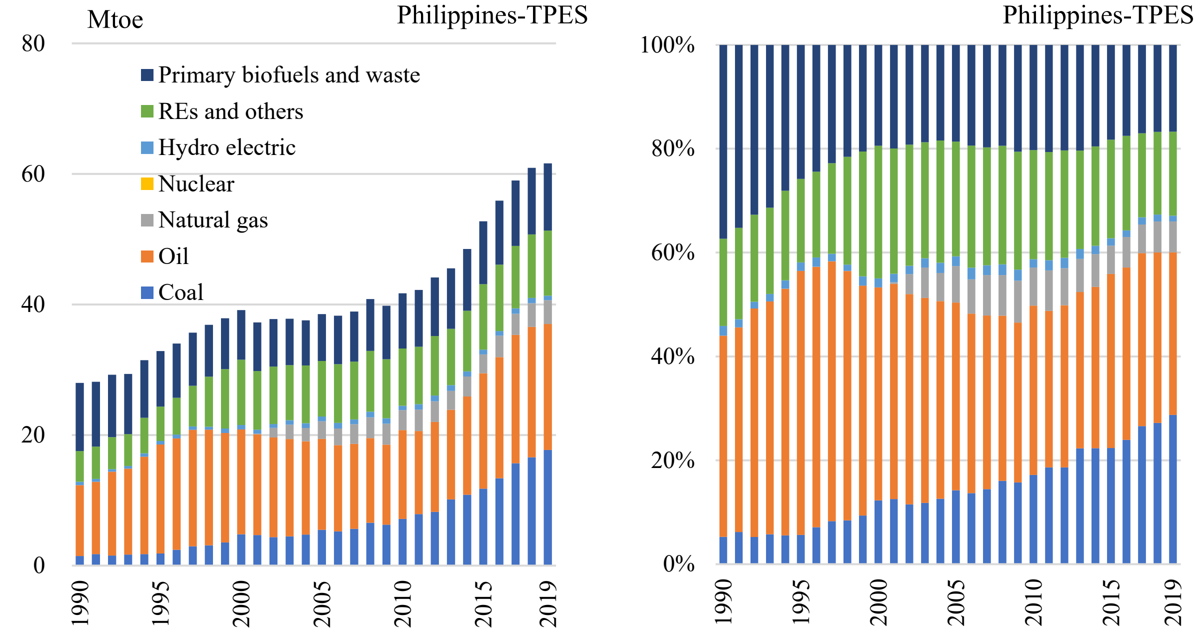


Figure 109 Primary Energy Supply in Philippines
Source: World Energy Balances 2021 extended edition database, IEA

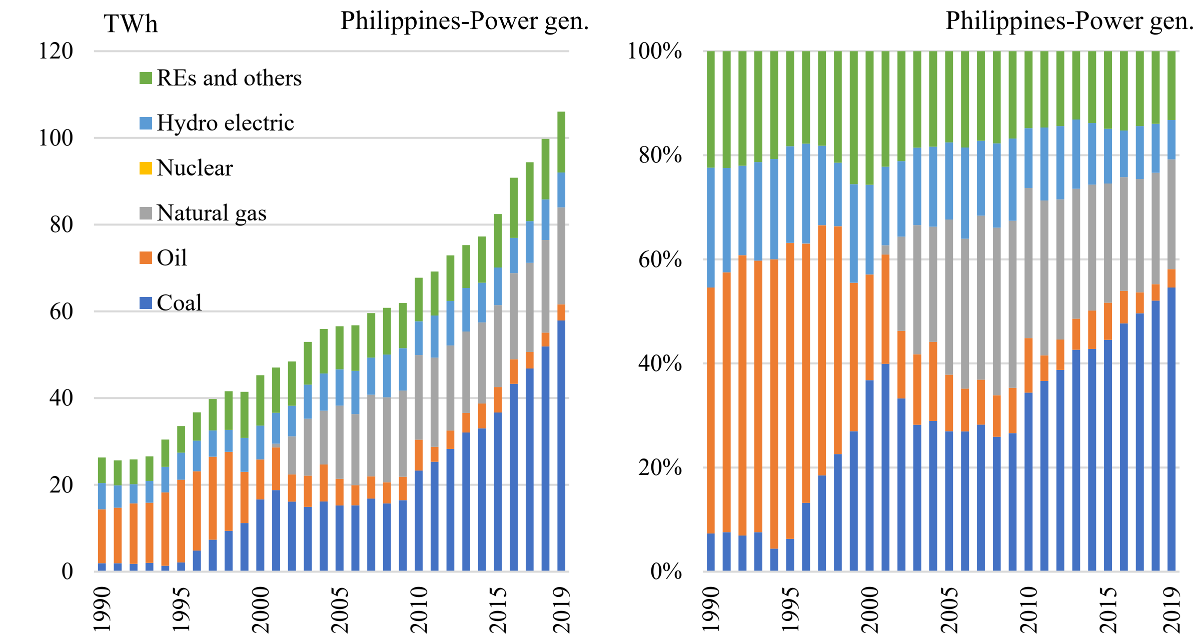


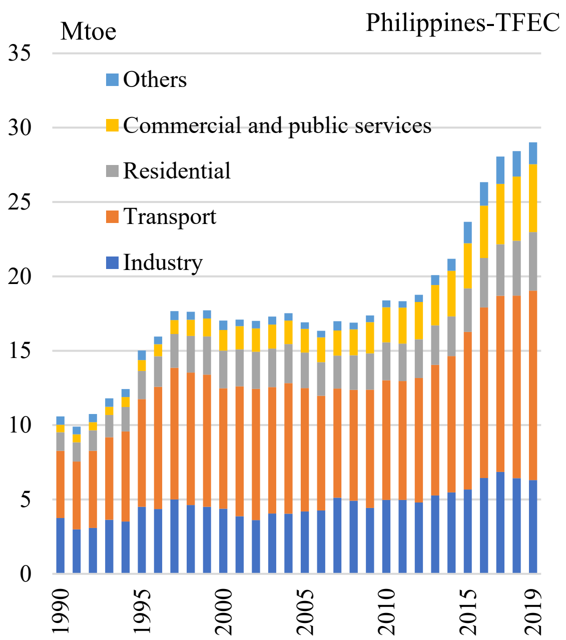
Figure 110 Fuel Mix of ElecricityGeneration in Philippines
Source: World Energy Balances 2021 database, IEA

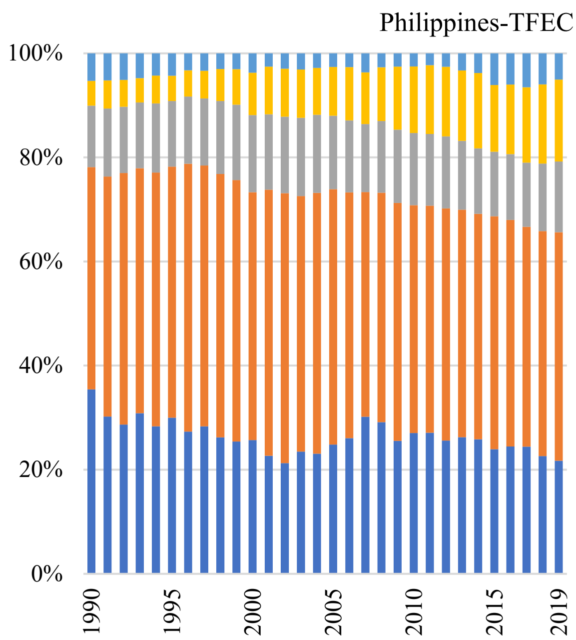
The sectoral breakdown of final energy consumption is characterized by a large share of transportation in 2019: 22% for industry, 44% for transportation, 14% for residential, and 16% for commercial/public services. Commercial/public services had the largest five-year growth of 8.3% from 2014 to 2019, followed by residential of 8.1% and transportation of 6.8%.

Growth in industrial energy consumption is not as large as in other sectors. The Philippines has a large services sector that accounts for just under 60% of GDP, which is due to the fact that the Philippines is less industrialized than Thailand and Indonesia and is in the process of industrialization in Southeast Asia.

Petroleum accounts for 96% of energy consumption in the transportation sector, with renewable energy and others making up the remainder. In the Philippines, dependence on oil imports is an energy security issue, and measures to reduce oil consumption in the transportation sector, such as improving fuel efficiency and using alternative fuels, are considered important. In addition, traffic congestion is a major issue due to the significant concentration of population in Metro Manila and inadequate transportation infrastructure. In addition, an estimated 60,000 jeepneys are part of the public transportation system in Metro Manila, but many of them are aging and, along with traffic congestion, contribute to air pollution. [304] The Philippines has the second largest population among ASEAN countries (approximately 110 million) after Indonesia, and since population growth is expected to continue and further expansion of automobile use is anticipated, appropriate transportation infrastructure development is considered necessary.

In residential and commercial/public services, the growth rate of energy consumption in recent years has been significant, with oil and electricity being most commonly used. In addition, there are also un-electrified areas on remote islands and in rural areas far from towns, where biomass is also utilized. As economic development and population growth continue, energy consumption, including cooling demand, is expected to further increase, creating demand for the establishment and dissemination of energy conservation standards for housing and home appliances.





[304] METI, march 2017, https://dl.ndl.go.jp/view/download/digidepo_11273986_po_000593.pdf?contentNo=1&alternativeNo=

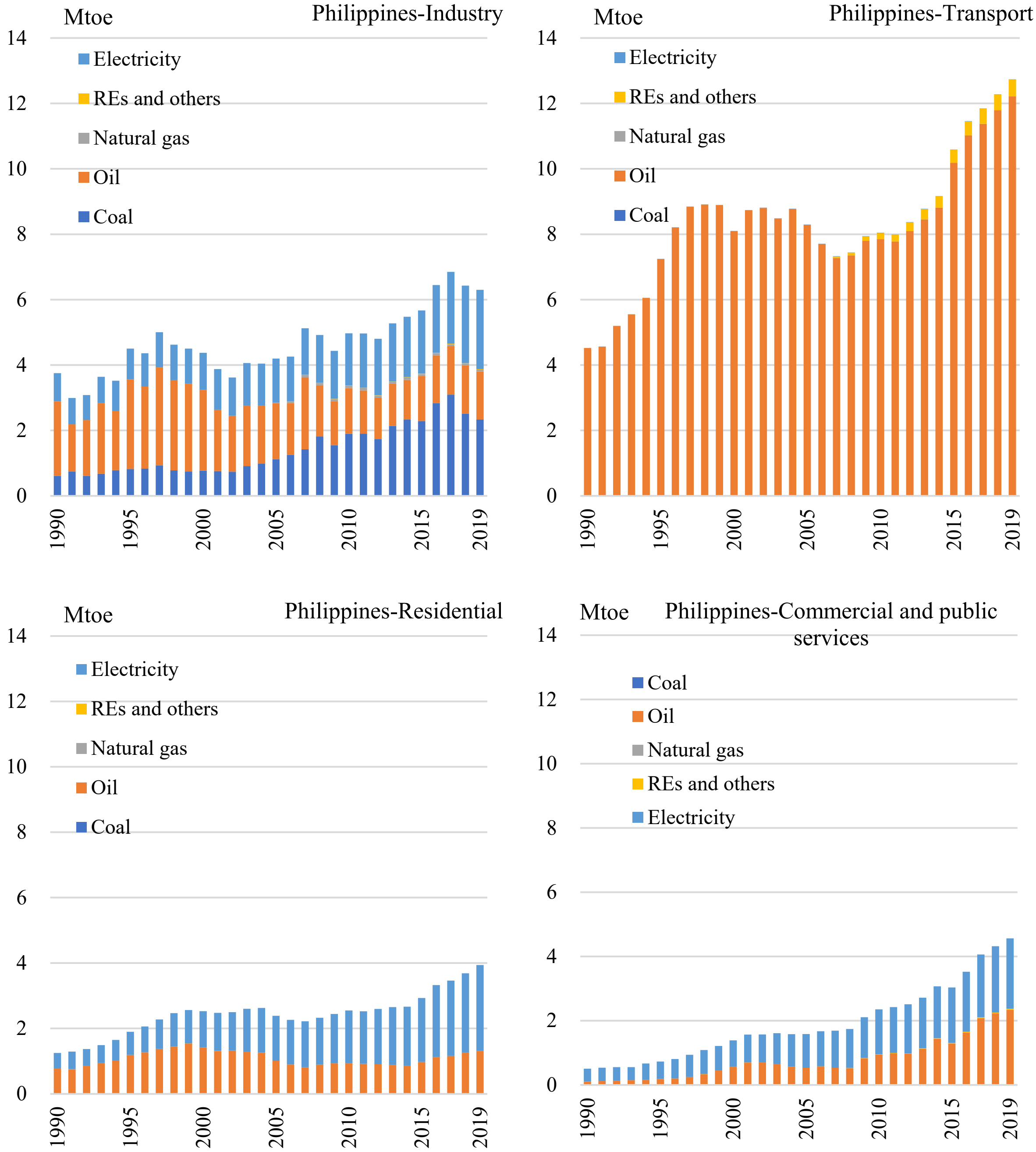


Figure 111 Final Energy Consumption of Major Sectors in Philippines

"Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal" are excluded.
"Others" in TEFC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP did not change significantly until around 2000 and remained around 0.33 toe/$1,000 (2015 prices), but has been declining since 2000 and was 0.156 in 2019 (0.090 in Japan). This can be attributed to the fact that since 2010, GDP has grown mainly in the service sector, which consumes less energy.

The average thermal efficiency of gas-fired and coal-fired power plants is 56% and 33%, respectively, which is low despite the fact that coal-fired power plants account for more than 50%

of the electricity generated. The Philippines intends to continue to utilize coal-fired power to a certain extent, and the introduction of more efficient existing thermal power generation and high-efficiency gas-fired power generation could contribute to the low-carbonization of electricity.

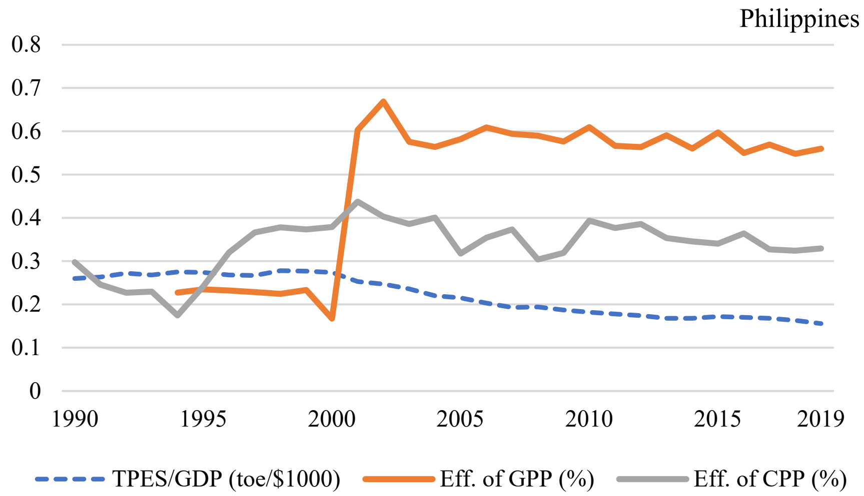


Figure 112 Energy Efficiency in Philippines

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant, CPP = coal power plant, GDP in 2015 price

Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options that could be taken to reduce CO2 emissions in the Philippines in the future and their CO2 reduction effects.

Table 90 Examples of Low-carbon/ Decarbonization Potential in Philippines

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		138.8 mton-CO2
	【Example of CO2 Emission Reduction Option】	【Reduction Effect】
Generation	Substitue 15% of Coal-fired generation for Natural Gas,15% of Coalk-fired generation for Renewable Energy	15.32mton-CO2
Industry	Substitue 50% of Oil and Coal for Natural Gas	3.80mton-CO2
Transport	10% Improvement of Fuel Mileage	3.44mton-CO2
Residential, Commercial and Public Services	10% Improvement of Energy Efficiency	4.90mton-CO2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES

Source: JICA Studt Team

(2) Primary energy mix and electricity mix planning

[Primary energy mix]

The Philippine Energy Plan (PEP2020-2040), released in October 2021, presents two scenarios for the energy supply and demand outlook for 2040: the Reference Scenario (REF) (=Business as Usual Scenario (BAU)) and the Clean Energy Scenario (CES). The REF is a reference case based on current government policy. On the other hand, CES actively promoted the expansion of renewable energy and natural gas in the power generation sector and the improvement of energy use efficiency on the demand side. Primary energy supply in the Philippines is projected to expand by an average of 5.21% per year from 2018 to 2040 in the REF. Petroleum will be the most widely used energy, and geothermal will be the most widely used renewable energy. [305]

Table 91 Primary Energy Supply Outlook in Philippiens (2040) (Mtoe)

Energy	2020	2040	
		REF	CES
Oil	16.45	56.40	51.49
Coal	17.34	33.06	30.15
Natural Gas	3.29	26.50	16.85
Geothermal	9.25	13.92	13.92
Hydro	1.79	12.83	15.72
Solar	0.12	4.56	6.19
Wind	0.09	0.44	1.87
Biomass	7.56	6.17	6.40
Biofuels	0.48	1.75	2.29
Total	56.37	155.62	144.88
Energy Self-sufficiency	56.6%	40.4%	63.5%

Source: Department of Energy(DOE) , PEP2020-2040(P269) を基に調査団作成

[Power Mix]

The PEP 2018-2040, published in October 2021, projects that electricity use in the REF will increase from 91,369 GWh in 2020 to 335,691 GWh in 2040. In addition, the installed capacity of power generation is expected to increase from 26,250 MW in 2020 to 95,670 MW in 2040. By energy source, natural gas will be the most widely used, and among renewable energy sources, solar will be the most widely used. In the previous PEP2018-2040, the difference between the REF and CES was how to convert coal-fired power to gas-fired power and renewable energy; in PEP2020-2040, coal-fired power will only increase slightly in both the REF and CES, and the difference between the two scenarios is how to convert gas-fired power to renewable energy. In particular, solar and wind power saw significant growth at CES. In 2020, the DOE will temporarily freeze construction permits for coal-fired power plants (with exceptions for expansion plans for existing plants, etc.), and there are signs that the DOE is trying to steer a course toward reducing coal dependence in the power mix. [306]

Table 92 Electricity Generation Capacity in Philippines (2040) (MW)

Energy	2020	2040	
		REF	CES
Coal	10,944	13,585	13,585
Oil	4,237	4,618	4,618
Natural Gas	3,453	24,263	18,883
Geothermal	1,928	2,408	2,408
Hydro	3,779	15,426	20,176
Solar	1,019	32,590	46,137
Wind	443	2,027	11,830
Biomass	447	753	933
Total	26,250	95,670	118,570

[305] DOE, "PHILIPPINE ENERGY PLAN 2020-2040", https://www.doe.gov.ph/sites/default/files/pdf/pep/PEP-2020-2040.pdf

[306] DOE, https://www.doe.gov.ph/announcements/advisory-moratorium-endorsements-greenfield-coal- fired-power-projects-line-improving

Source: DOE, PEP2020-2040(P182,192)

(3) Current status and goals of electricity access

The country's overall electrification rate is 96.4% (2019), with 99.8% in urban areas and 93.4% in rural areas. [307] The government is promoting the development of renewable energy sources such as solar power and the electrification of non-electrified areas through the development of power transmission and distribution networks. DOE aims to achieve electrification in all households by 2022. [308]

(b) Electric utility system

(1) Electricity supply system[309]

The National Power Corporation of the Philippines (NPC) used to monopolize the power generation and transmission sectors, but following an electric utility reform in 2001, NPC and IPPs took over the power generation business, while the National Grid Corporation of the Philippines (NGCP) took over the power transmission business. All of NPC's power generation assets, real estate, and IPP contracts will be sold to the private sector, with the sale expected to be completed by 2022. NPC is currently responsible for the operation of existing power plants and the electrification of areas far from the transmission and distribution system through small-scale generation projects until privatization. For the power transmission business, the state-owned National Transmission Corporation (TRANSCO) owns the assets and the private National Grid Corporation of the Philippines (NGCP) has a monopoly. In addition, the electric distribution business consists of private electric distribution companies, local government-owned companies, and electrification cooperatives. The metropolitan area is supplied by Manila Electric Company (Meralco), the Philippines' largest private power distribution company. The retail business is subject to deregulation for customers with 750 kW or more, and expansion to 500 kW or more is under consideration.

(2) Supply system of renewable electricity

Private operators have a high share of the power generation sector in the Philippines, and renewable energy is also sold to transmission and distribution companies through the wholesale power spot market.

(c) Policy on renewable energy

(1) Renewable energy potential

Regarding solar power generation, the entire country is relatively sunny, and the potential is especially large in the northern part of the country. As for wind power generation, there is a certain amount of potential in coastal areas, which could be developed in conjunction with the development of power grids to power demand areas.

[307] IEA, Access to electricity, https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

[308] The Manila Times, September 4, 2017, https://www.manilatimes.net/2017/09/04/business/doe-eyes-100-electrification-2022/348495

[309] Overseas Electric Power Industry Statistic I 2019-2, JAPAN ELECTRIC POWER INFORMATION CENTER

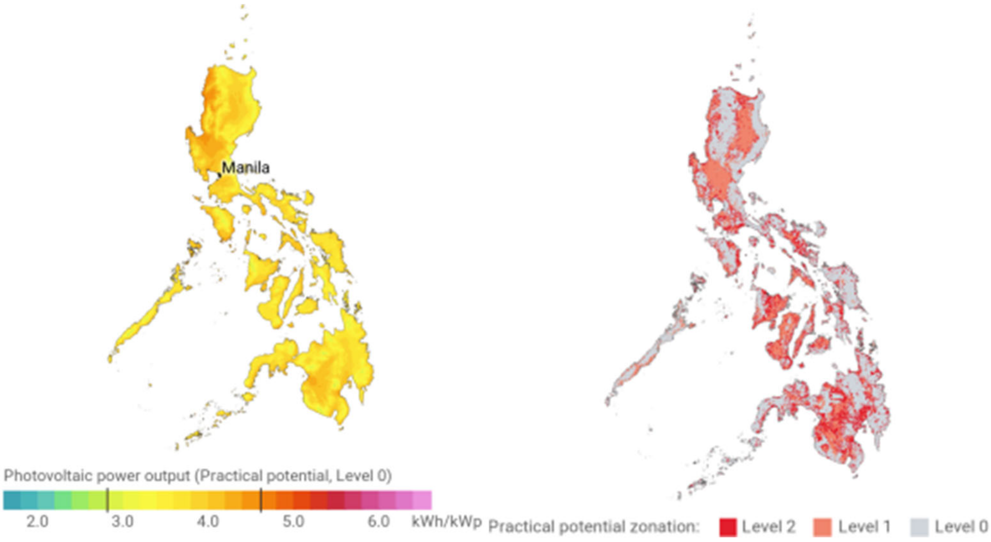


Figure 113 Solar Power Generation Potential in Philippines

Note: Left = Estimated power generation
Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints; Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

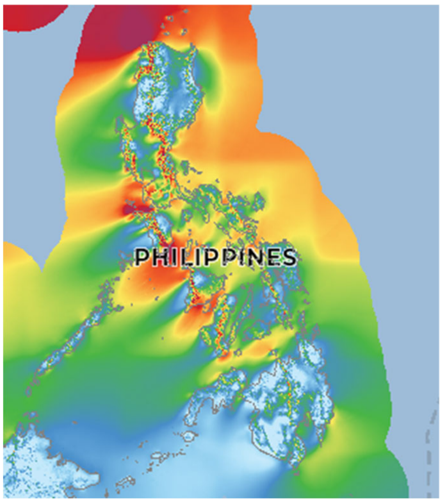


Figure 114 Wind Power Generation Potential in Philippines

Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The Department of Energy (DOE) is responsible for overall energy policy, and the National Renewable Energy Board (NREB), which is under the DOE, promotes the introduction of renewable energy in the private sector, and encourages the use of CDM and research and development.

(3) Development goals

In February 2012, the National Renewable Energy Program (NREP) was established under the Renewable Energy Act, with the goal of expanding renewable energy installations to 15,304 MW by 2030 (about three times the 2010 level). [310]

[310] DOE, https://www.doe.gov.ph/national-renewable-energy-program?ckattempt=1

In addition, NREP 2017-2040 sets a goal of expanding renewable energy to more than 20,000 MW by 2040, with hydroelectric, geothermal, and wind power as the primary energy sources.

The latest target in PEP2020-2040 published in October 2021 aims to increase the share of renewable energy in electricity generated to 35% by 2030 and 50% by 2040. [311] NREP 2020-2040 is currently being developed and is expected to include the same goals. [312]

(4) Policies to promote introduction

In December 2008, the Renewable Energy Act of 2008 (RA 9513) was enacted to promote the development, use, and commercialization of renewable energy. This Act provides financial incentives such as income tax exemptions and import duty exemptions, and non-financial incentives such as FIT and RPS programs.

The FIT system was introduced in 2012, and the Energy Regulatory Commission (ERC) announced the purchase price and introduction targets. However, goals for solar and wind power have already been achieved due to a rapid increase in applications for connection (target: solar, wind, biomass, and hydro).[313] The RPS system was introduced in 2018 and required distribution utilities and retail electricity suppliers to source at least 1% of their electricity sales from renewable energy sources. [314]

Table 93 Feed-in-Traiff in Philippines

		Purchase price [peso/kWh]	Introduction target [MW]
Wind	Published in 2012	8.53	200
	Published in 2015	7.40	200
Biomass	Published in 2012	6.63	250
Solar	Published in 2012	9.68	50
	Published in 2015	8.69	450
Hydro(run-of-river)	Published in 2012	5.90	250

Source: Overseas Electric Power Industry Statistic I 2019-2 (P197), JAPAN ELECTRIC POWER INFORMATION CENTER

In September 2018, the Competitive Renewable Energy Zone (CREZ) was introduced. DOE has selected areas with high potential for renewable energy generation as "CREZs" and will systematically install and expand the power grid in these areas. [315]

In June 2021, the DOE, with support from the World Bank Group, launched an offshore wind roadmap project, aiming at identifying areas with high potential for offshore wind development and setting short- and long-term offshore wind energy targets. [316]

[Biofuel]

Biofuels Act of 2006 (RA 9367, effective in January 2007) mandates the blending of biofuels in motor fuels. Biodiesel is to be blended at 1% within three months of the law's entry into force and at 2% within two years of the same; bioethanol is to be blended with gasoline fuel at 5% two years after the law's entry into force and at 10% after four years. [317]

The PEP2020-2040, published in October 2021, targets a 5% blend of biodiesel and a 10%

311 DOE, PEP2020-2040, https://www.doe.gov.ph/sites/default/files/pdf/pep/PEP-2020-2040.pdf

312 Philippines News Agency, November 13, 2021, https://www.pna.gov.ph/articles/1159659

313 Overseas Electric Power Industry Statistic I 2019-2 (P197), JAPAN ELECTRIC POWER INFORMATION CENTER

314 DOE, https://www.doe.gov.ph/press-releases/sec-cusi-pushes-continued-strengthening-re-sector-ph?ckattempt=1

315 JETRO, April 28 2021, https://www.jetro.go.jp/biz/areareports/special/2021/0401/ea819ae8074ff2d0.html

316 NNA, June 23, 2021, https://renews.biz/70487/philippines-sets-out-offshore-wind-roadmap/

317 DOE https://www.doe.gov.ph/laws-and-issuances/rules-and-regulations-implementing-ra-9367-biofuels-act-2006

blend of bioethanol by 2040. [318] In addition, the following targets for expansion of biofuel production capacity are indicated.

Table 94 Biofuel Production Expansion Targets up to 2040 in Philippines (MLPY) **

Year	Biodiesel	Bioethanol***
2020	707.90*	380.50*
2025	1,086.78	944.15
2030	1,086.78	1,354.26
2035	1,331.93	1,913.05
2040	1,733.04	2,579.34

* Existing capacity
** Cumulative/PEP2020-2040 Clean Energy Scenario (CES)
*** Assumes all bioethanol supply requirements are produced locally.
Source: DOE, PEP2020-2040(P81)

Measures to support bioethanol include import duty reductions and exemptions and preferential value-added tax treatment. Bioethanol operators are eligible for import duty and value-added tax exemptions on raw materials, agricultural supplies, and equipment imported with respect to bioethanol production. [319] In October 2019, the DO announced that it will develop guidelines to remove foreign investment restrictions on the ownership and operation of biomass power plants and to allow 100% ownership by foreign-owned companies. [320]

(d) Energy conservation policy

(1) Institutions in charge of policy

The DOE is in charge of energy conservation policy.

(2) Target

The Energy Efficiency and Conservation Roadmap 2017-2040 summarizes energy conservation measures by sector for transportation, industry, households, business, and agriculture by short term (2017-2020), medium term (2021-2030), and long term (2031-2040)[321]. The Roadmap sets a target of 24% reduction in energy consumption in 2040 compared to BAU (80% increase in energy consumption between 2017 and 2040).

Table 95 Energy Efficiency Targets by Sector up to 2040 in Philippines

	Annual reduction	Total reduction ration by 2040	Annual rrduction ratio
Transport	4,500 ktoe	25%	1.9%
Industry	3,000 ktoe	15%	1.3%
Residential	1,000 ktoe	20%	1.2%
Commercial	1,200 ktoe	25%	1.9%
Agricaulture	300 ktoe	10%	0.9%
Total	10,000 ktoe	24%	1.6%

Source: DOE, Energy Efficiency and Conservation Roadmap 2017-2040

(3) Promotion policy[322]

The National Energy Efficiency and Conservation Program (NEECP), established in 2004, lays out the principles of energy conservation policy. A key policy is to reduce the impact of higher

[318] DOE, PEP2020-2040, https://www.doe.gov.ph/sites/default/files/pdf/pep/PEP-2020-2040.pdf
[319] METI, March 2019, https://www.meti.go.jp/meti_lib/report/H30FY/000306.pdf
[320] JETRO, October 29, 2019, https://www.jetro.go.jp/biznews/2019/10/bc1f796b30044424.html
[321] DOE, "Energy Efficiency and Conservation Roadmap2017-2040", https://www.doe.gov.ph/sites/default/files/pdf/energy_efficiency/ee_roadmap_book_2017-2040.pdf
[322] METI, February 29, 2016, https://www.meti.go.jp/meti_lib/report/2016fy/000471.pdf

petroleum product prices on the economy through proper management of petroleum product demand. The main energy conservation policies are as follows.

-Ministry of Energy Order on DSM (Demand Side Management) Program

The ministerial order, issued in August 2014, orders all electricity consumers (especially households, industries, and business organizations) to implement DSM and other energy conservation measures to reduce electricity consumption, with the exception of hospitals, military facilities, airport-related and other critical facilities, in order to address the tight power supply and demand. It also mandates that electricity suppliers, as well as consumers, provide full support for DSM implementation.

-Energy management system

Under the system, the Ministry of Energy requires (1) companies and facilities that consume 1,000 kl or more of fuel oil equivalent per year to submit a quarterly energy consumption report (QECR) and (2) companies and facilities that consume 2,000 kl or more of fuel oil equivalent per year to submit an annual report with more detailed and varied information in addition to the QECR. However, it is not legally enforceable.

-Minimum energy efficiency performance standards (MEPS) for equipment

-Labeling system

In May 2019, the Energy Efficiency and Conservation Act of 2019 was passed, institutionalizing energy conservation efforts by government agencies and private companies. [323] In December of the same year, the Act's implementation bylaws were published. They specify the creation and implementation of Minimum Energy Performance (MEP), an energy conservation standard that energy-intensive products such as appliances, lighting, electrical equipment, machinery, and transportation vehicles must meet at a minimum, and Fuel Economy Performance (FEP), an environmental standard for transportation vehicles. [324]

In February 2021, the DOE issued a notice requiring the use of solar power and other renewable energy sources for new construction and expansion of large buildings. In the same notice, guidelines for the use of energy conservation in the design of buildings were established. [325]

(e) Environmental policy

(1) Greenhouse gas emission reduction targets[326]

The NDC was submitted in April 2021. The INDC submitted in October 2015 targeted a 70% reduction in GHG emissions in 2000-2030 compared to BAU, while the latest NDC aims for a 75% reduction (2.71% without conditions, 72.29% with conditions of international support).

(2) Promotion policy[327]

The Philippines is considered to be highly vulnerable to climate change. In 2009, the Climate Change Act came into effect, integrating and organizing the efforts made to date and establishing the Climate Change Commission (CCC), chaired by the President, as the sole policy-making body on climate change issues. In 2010, the CCC established the National Framework Strategy on Climate Change (NFSCC) 2010-2022 as a specific guideline and the National Climate Change Action Plan (NCCAP) 2011-2028 as an action plan. Based on these efforts, the CCC promotes energy efficiency and conservation, develops renewable energy, promotes the use of biofuels in the transportation sector, and introduces new technologies.

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[323] DOE https://www.doe.gov.ph/eec-act-primer

[324] JETRO, December 2019, https://www.jetro.go.jp/biznews/2019/12/a633344f4302c50a.html

[325] JETRO, February 24, 2021, https://www.jetro.go.jp/biznews/2021/02/6eed7365dfe6bd87.html

[326] UNFCCC, https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Philippines/1/Philippines%20-%20Final%20INDC%20submission.pdf

[327] Overseas Electric Power Industry Statistic I 2019-2, JAPAN ELECTRIC POWER INFORMATION CENTER

In November 2021, the Philippines became a target country for the ADB's new Energy Transition Mechanism (ETM), a mechanism to accelerate the transition from fossil fuels to clean energy by working with developing countries and using market-based approaches, and ADB and the Philippines have launched a new partnership to create the ETM. [328]

(3) Transportation
[Electric vehicles]

In the Philippines, air pollution is a serious problem, especially in urban areas, and the government is trying to promote EVs as one of the solutions. It is also expected to reduce imports of diesel and gasoline, which are highly import-dependent, thereby providing economic benefits.

In July 2021, the Electric Vehicle Federation of the Philippines announced that it would raise its target for electric vehicle penetration in the country to 1 million vehicles by 2030. The Federation’s former goal was 300,000 vehicles by 2030, and the present goal is more than three times higher. [329]

At this time, most EV vehicles in the Philippines are electric tricycles and electric motorcycles. In 2017, the Public Utility Vehicle Modernization Program (PUVMP) was initiated as part of an effort to improve the quality of vehicles used in public transportation, with the intention of introducing vehicles with a lower environmental impact. As a result, EVs have become more popular in public transportation. [330]

The "EV and Charging Stations Bill" (Senate Bill 1382) was introduced in 2020 to support the EV industry. It provides a basic framework for institutional and government policies regarding EV use, including measures such as providing incentives to manufacturers in the EV industry and requiring EV chargers to be installed at gas stations and in new buildings. In addition, the Electric Vehicle Alliance of the Philippines (EVAP) and the Bureau of Product Standards (BPS) of the Department of Trade and Industry are collaborating to study various standards and regulations for EVs, and the Board of Investment (BOI) has formulated the EV Incentive Strategy Program (EVIS), which provides incentives to the EV industry and promotes investment. [331]

(4) Urban development

There is no national-level development plan for smart cities, and planning is proceeding on a project basis. Manila, Cebu city, and Davao City have been selected for the ASCN launched in 2018, but New Clark City (NCC) is being watched closely, which is considered the first environmentally friendly smart city in the Philippines. In order to decentralize the economic concentration and population concentration in Metro Manila, the government is promoting urban development in the surrounding area, one of which is NCC with an international airport. In developing the project, the Philippines Bases Conversion and Development Authority (BCDA), a government agency, and Japan Overseas Infrastructure Investment Corporation for Transport and Urban Development (JOIN) [332]jointly prepared the master plan, and many Japanese companies, including Marubeni, Kansai Electric Power Co. and Chubu Electric Power Company, are involved.

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328 ADB, November 3, 2021, https://www.adb.org/ja/news/adb-indonesia-philippines-launch-partnership-set-energy-transition-mechanism

329 MANILA BULLETIN, July 14, 2021, https://mb.com.ph/2021/07/14/industry-upgrades-ev-adoption-target-to-1-million-units-in-2030/

330 JETRO, May 25, 2021, https://www.jetro.go.jp/biz/areareports/2021/7292509f6fb49f92.html

331 JETRO, May 25, 2021, https://www.jetro.go.jp/biz/areareports/2021/7292509f6fb49f92.html

332 JOIN: Utilizing the knowledge, technology and experience accumulated in Japan,it will supply funds, dispatch experts and other support to those who are engaged in transport business and urban development business overseas, and enter the market of domestic businesses, it was established with the purpose of promoting the entry of overseas markets.

333 The Oil Information Center, IEEJ, February 2018, https://www.enecho.meti.go.jp/category/resources_and_fuel/distribution/report/pdf/international_market_2017.pdf, pp.22-25.

(f) Next generation technology, innovation

N/A.

(g) Points to consider for future cooperation in promoting low carbon and decarbonization

- While the Philippines has indicated that its power source mix will continue to be centered on coal-fired power generation, there are also moves to steer a course toward reducing coal dependence in the power mix, such as the announcement of temporal termination of the approval of the construction of coal-fired power plants. In addition to geothermal and hydroelectric power, which have been developed to date, support for the formulation of a comprehensive roadmap for the effective utilization of renewable energy sources such as solar and wind power is being considered.
- Unelectrified areas also exist on remote islands and in rural areas far from towns. Possible support for microgrid projects utilizing solar and other renewable energy sources and storage batteries can be considered.
- With the increase in energy consumption, oil and coal imports are increasing year by year, and the promotion of energy conservation is an important issue. However, it has been pointed out that information provision to the public may not be sufficient, as there is a lack of awareness of the significance and effects of energy conservation in the industrial sector and a low level of recognition of the energy conservation labeling system, etc. Support for identifying issues to increase the effectiveness of existing energy conservation measures and formulating policies to promote further energy conservation is considered.

(11) Cambodia

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

In Cambodia, an agricultural country, agricultural products such as rice chaff and rice straw, and biomass energy such as firewood and charcoal have been utilized. While biomass and petroleum make up the bulk of the primary energy supply, the use of subbituminous coal began around 2009, mainly for power generation, and has gradually expanded since 2013 in line with the growth in energy demand. However, the use of biomass and petroleum is likewise on the rise. In particular, with regard to petroleum, it can be pointed out that the demand for petroleum is growing, especially for automobiles. Cambodia has almost no fossil fuel resources and relies on imports of coal and petroleum products from ASEAN countries.

In the power generation sector, oil dominated until around 2011, but the use of hydropower has expanded since 2012 and coal since 2013, and the share of oil-fired power generation has shrunk to 4% in 2018. Supply capacity is being strengthened, particularly coal-fired thermal power, to meet increasing demand for electricity. Since coal-fired power generation first surpassed hydropower in 2015, the trend has continued. However, in 2018, hydropower surpassed coal-fired power. In addition to domestic electricity supply, Cambodia imports electricity from Thailand, Vietnam, and Laos, with electricity imports of 1.6 TWh in 2018, up 6.3% from the previous year. Since the amount of electricity generated by hydroelectric power generation declines during the dry season from November to April, electricity imports from neighboring countries tend to increase during this period.

Given this supply structure, it will be important to improve the efficiency of coal-fired power utilization, to lower carbon emissions, and to switch fuels from coal to natural gas in order to achieve low carbon and decarbonization in the future.

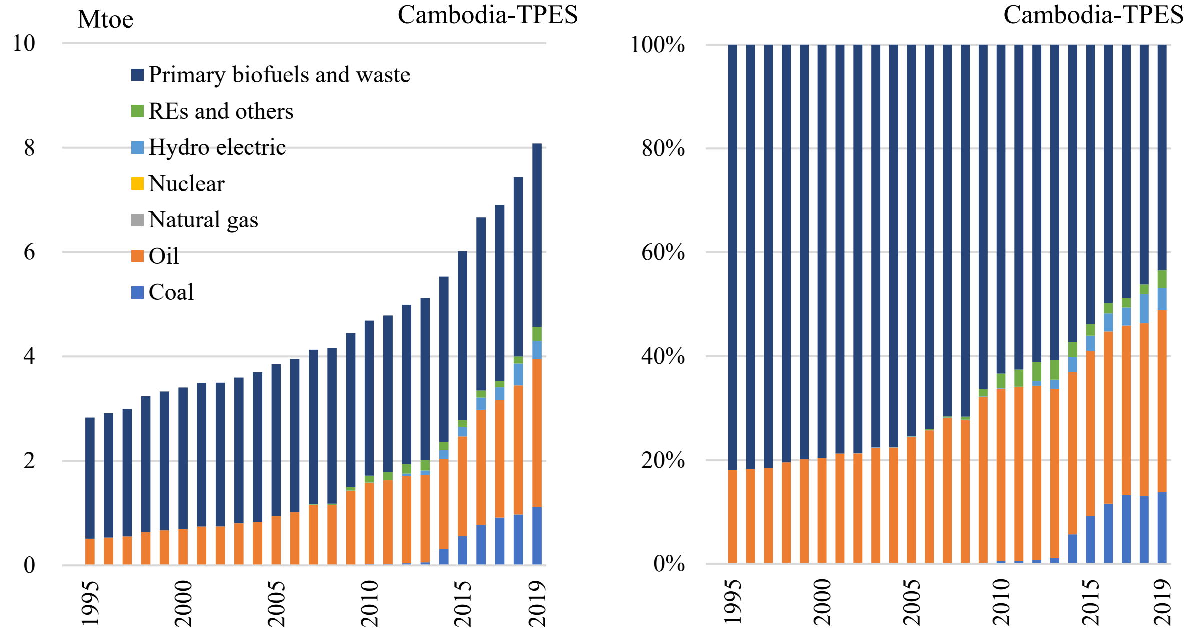


Figure 115 Primary Energy Supply in Cambodia

Source: World Energy Balances 2021 extended edition database, IEA

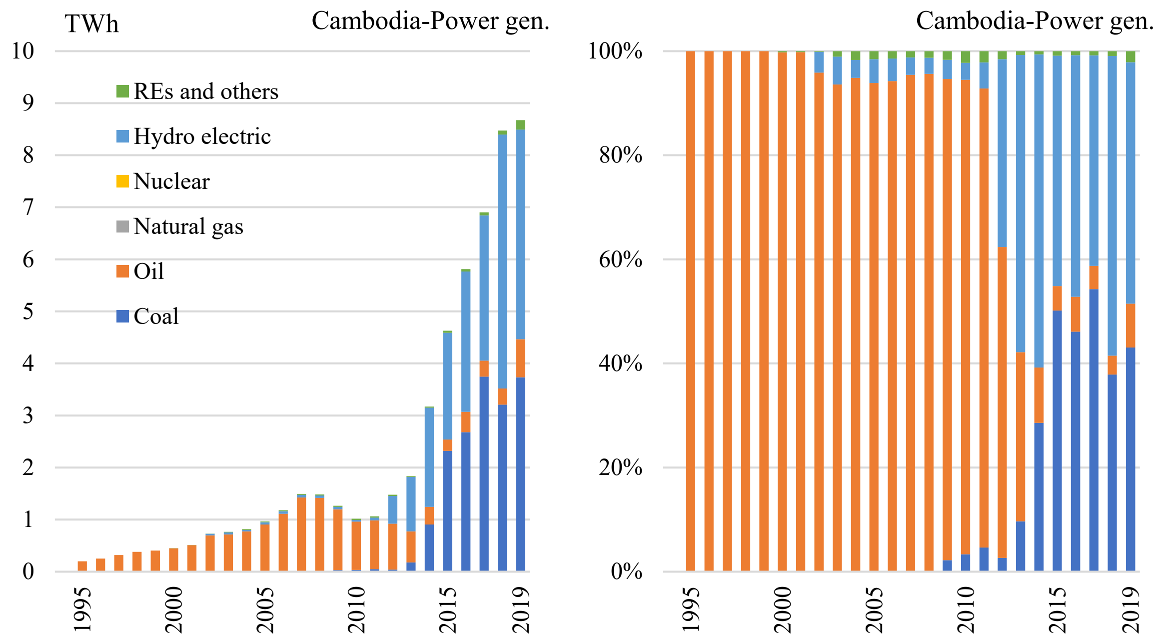


Figure 116 Fuel Mix of Electricity Generation in Cambodia

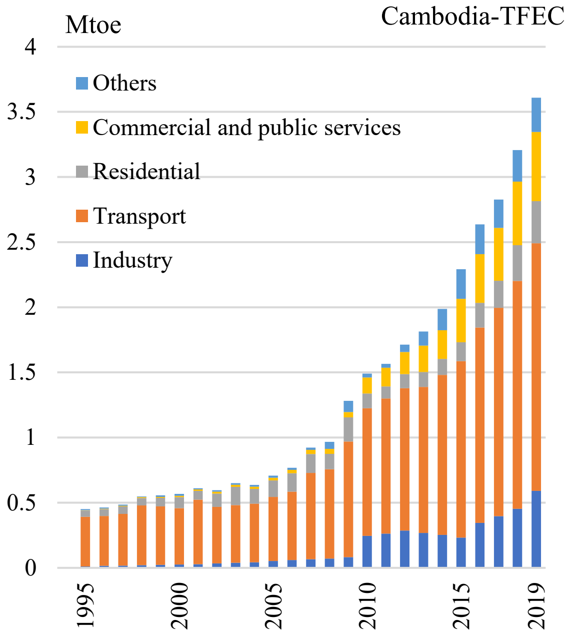
Source: World Energy Balances 2021 database, IEA

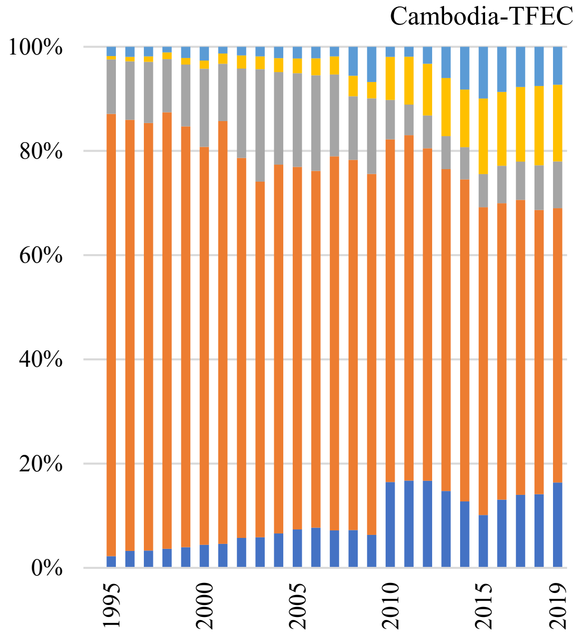
A breakdown of final energy consumption by sector shows that the transportation sector accounted for 12%, transportation 61%, residential 11%, and commercial/public services 13% in 2018. Commercial/public services had the largest average annual change of 38.4% from 2013 to 2018, followed by industry (change of 22.4%).

In the industrial sector, it can be read that the electrification of demand has gradually progressed in recent years, particularly in the manufacturing sector. Assuming that this trend will further develop in the future, it will be necessary to realize low carbon power sources and decarbonized power sources.

Petroleum accounts for 100% of the transportation sector, and road (automobile) use accounts for nearly 85% of the transportation sector's energy consumption (2018). In Cambodia, car use is likely to continue to increase as the economy grows and incomes rise. To realize low carbon and decarbonization, in addition to improving the fuel efficiency of conventional internal combustion engines, the transportation sector must increase the use of electric vehicles and expand the use of railroads (for logistics and intra- and inter-city public transportation), which currently only accounts for about 10% of the transportation sector.

In the residential sector, electricity accounts for 79% (2018), excluding biomass use. Petroleum, which accounts for 20%, is LPG, and a small amount is used for cooking purposes. [333] According to ERIA, commercial and public services account for about 88% of LPG demand [334] and LPG is dependent on imports from Vietnam and Indonesia. In the commercial/public services sector, oil accounts for 37% and electricity 63% (2018). Realizing low carbon and decarbonized energy demand in the residential and commercial/public service sectors will require low-carbonization of power sources, such as fuel conversion from coal-fired to natural gas-fired power, use of high-efficiency coal-fired power, and use of renewable energy sources such as solar power, as electricity consumption in both sectors is growing.





[333] The Oil Information Center, IEEJ, February 2018, https://www.enecho.meti.go.jp/category/resources_and_fuel/distribution/report/pdf/international_market_2017.pdf, pp.22-25.

[334] ERIA, “Energy Demand and Supply of Cambodia 2010-2018”, February 2020, https://www.eria.org/uploads/media/Research-Project-Report/Energy-Demand-and-Supply-of-Cambodia-2010-2018.pdf, pp.13-21.

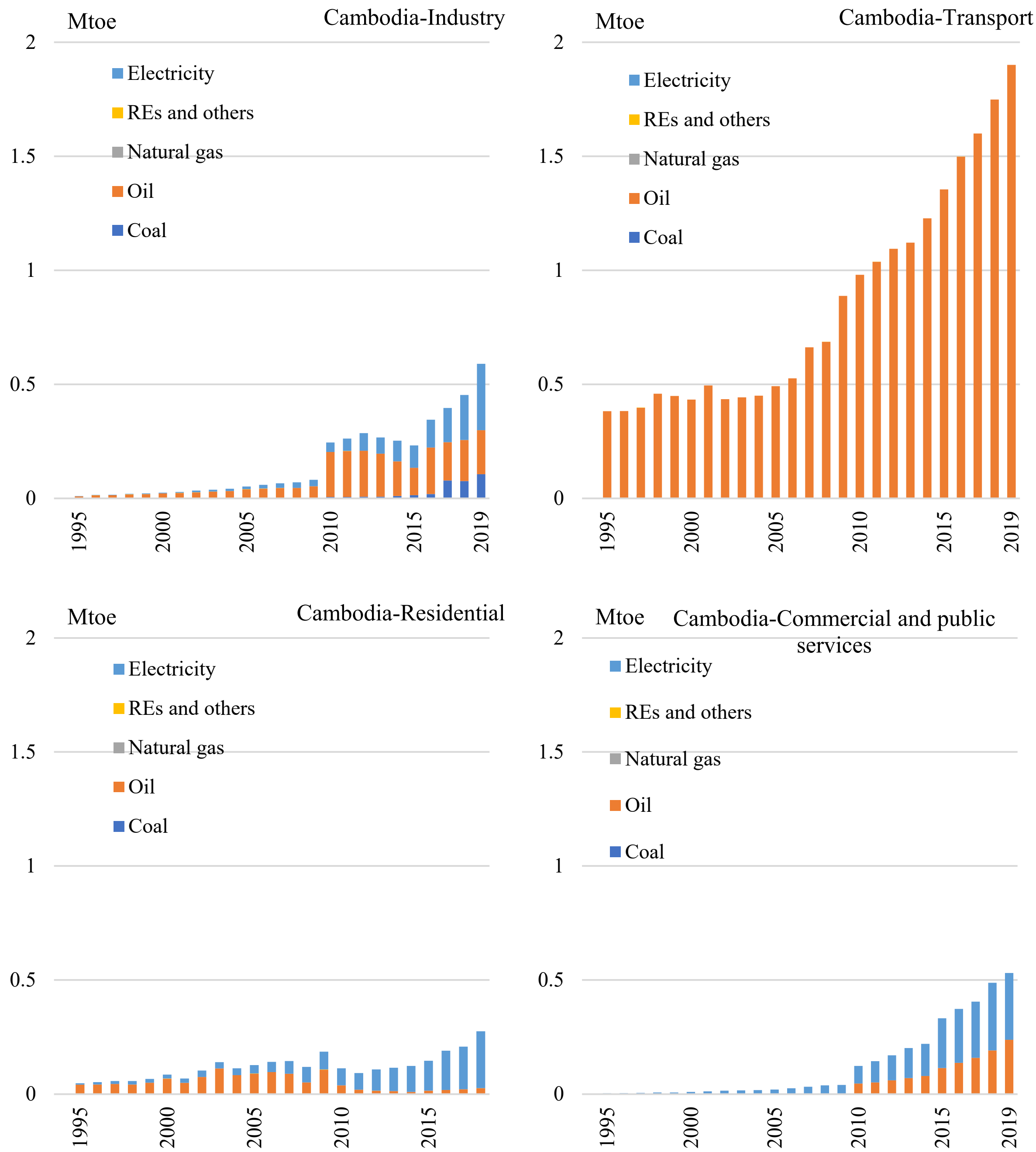


Figure 117 Final Energy Consumption of Major Sectoers in Cambodia

"Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal" are excluded.
"Others" in TFEC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP declined significantly from 1995 to the mid-2000s, falling to 0.286 toe/$1,000 (2015 prices) in 2008. In 2019, it is 0.340 (0.090 in Japan). This represents a decoupling of economic growth and energy consumption until 2008, after which improvements in energy efficiency have stalled.

In addition, the thermal efficiency of coal-fired power generation in Cambodia is hovering around 30-35%. The thermal efficiency of ultra-supercritical pressure power plants currently in practical use is 42%. Japan, for example, is developing technologies such as advanced ultra-supercritical pressure thermal power plants (thermal efficiency: 46%) and combined cycle coal gasification power plants (thermal efficiency: 46-50%). The use of more efficient technologies for new coal-fired power plants to be built in the future will also contribute to improved energy efficiency.

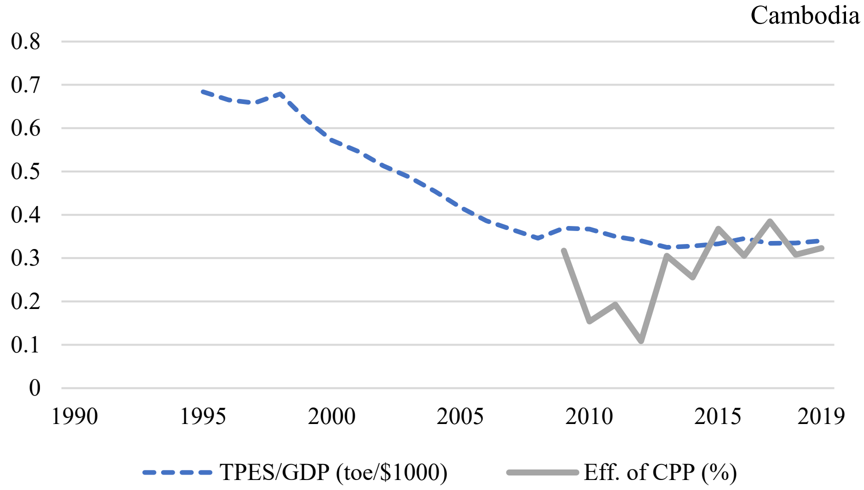


Figure 118 Energy Efficiency in Cambodia

TPES = total primary energy supply, Eff. = thermal efficiency, CPP = coal power plant
GDP in 2015 price
Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options that could be adopted to reduce Cambodia's CO_2 emissions in the future and their CO_2 reduction effects.

Table 96 Examples of Low-carbon/ Decarbonization Potential in Cambodia

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		13.9 mton-CO2
【Example of CO2 Emission Reduction Option】		【Reduction Effect】
Generation	Substitue 50% of Coal-fired Generation for Natural Gas	1.21 mton-CO2
Industry	Substitue 100% of Coal for Natural Gas, 50% of Oil for Elecrricity	0.32 mton-CO2
Transport	10% Improvement of Fuel Mileage	0.51 mton-CO2
Residential	10% Improvement of Energy Efficiency	0.15 mton-CO2
Commercial and public Services	10% Improvement of Energy Efficiency	0.20 mton-CO2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICA Study Team

(2) Primary energy mix and electricity mix planning

According to the Economic Research Institute for ASEAN and East Asia's (ERIA) Energy Outlook 2020, Cambodia's primary energy supply and electricity generation mix for 2050 is projected as shown in the figure below. Primary energy supply is projected to grow at an average annual rate of 5.6% from 2018 to 2050, with the composition by energy source in 2050 being 28.8% coal (16.5% in 2018), 35.9% oil (41.8% in 2018), 22.8% natural gas (0% in 2018), 5.7% hydro (7.1% in 2018), renewable energy excluding biomass 0.8% (0% in 2018). The growth in energy demand is expected to be met by coal and natural gas.

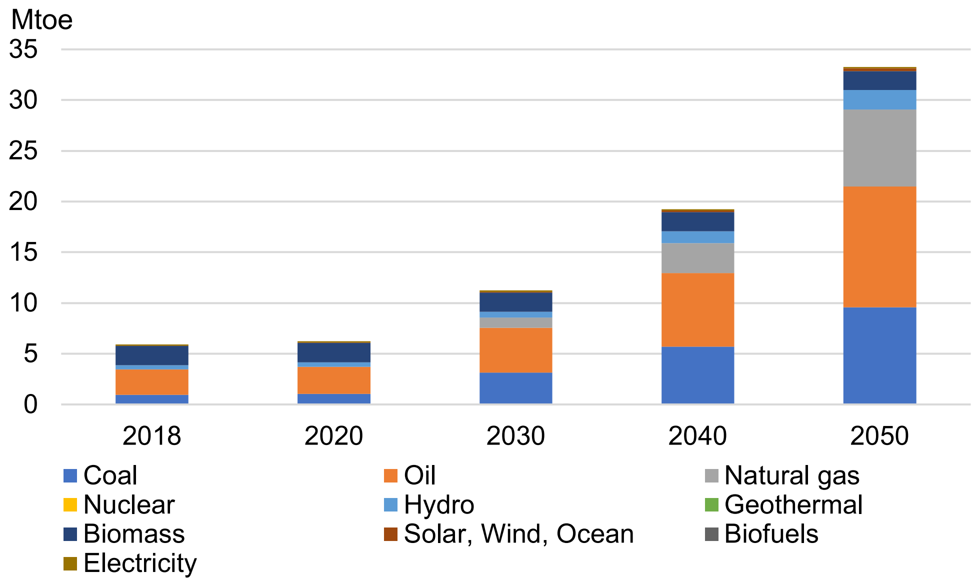


Figure 119 Primary Energy Supply Outlook in Cambodia (2018-2050)

Source: ERIA energy Outlook 2020

By 2050, Cambodia's electricity generation is expected to increase by 8.0% per year, and the increase in electricity demand is expected to be met by additional hydropower and coal-fired power generation, and in the long term by new natural gas-fired power generation. Oil is entirely dependent on imports from outside the country, and the use of oil-fired power plants, with their high generating costs, is expected to gradually decline. Cambodia's hydropower potential is estimated to be about 10,000 MW[335]. Since Cambodia's first hydropower plant started operation in 2002, hydropower projects have been developed mainly by Chinese companies. After 2030, natural gas-fired power generation is expected to increase rapidly and is estimated to exceed coal-fired and hydroelectric power generation by 2050, accounting for 46% of the power source mix. Although there are currently no natural gas-fired power plants in the country, it can be inferred that there are high expectations for the introduction of natural gas-fired power generation from the perspective of combating air pollution and climate change.

In addition, as mentioned above, Cambodia imports electricity from Thailand, Vietnam, and Laos, which plays an important role in meeting its rapidly growing electricity demand. In September 2019, the Electricity Authority of Cambodia signed a 30-year power purchase agreement with Laos for 2,400 MW of electricity, which will be supplied starting in 2024.[336]

Cambodia, with the support of the Asian Development Bank (ADB), is in the process of developing a master plan for power development for the year 2040[337], which is expected to be completed around July 2021. In the future, it is expected that power supply development and distribution plans will be carried out in accordance with the said master plan.

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[335] Ministry of Mines and Energy, General Department of Energy, https://www.mrcmekong.org/assets/Uploads/1.-Hydropower-plan-Cambodia.pdf

[336] Khmer Times, Cambodia and Laos to sign 2,400-megawatt power deal today, 2019-9-12, https://www.khmertimeskh.com/642313/cambodia-and-laos-to-sign-2400-megawatt-power-deal-today/.

[337] The Phnom Penh Post, 2021 a crucial year for electricity decisions in Cambodia, 2021-2-22, https://www.phnompenhpost.com/opinion/2021-crucial-year-electricity-decisions-cambodia.

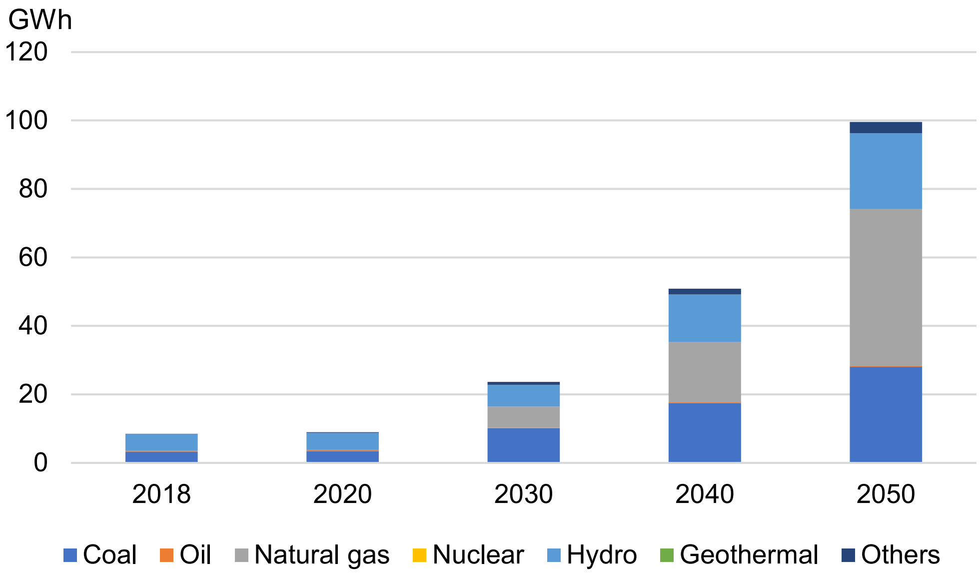

Figure 120 Electricity Generation Outlook by Fuel in Cambodia

Source: ERIA Energy Outlook 2020

(3) Current status and goals of electricity access

In its National Strategic Development Plan 2014-2018, the Cambodian government stated that by 2018 it would increase electricity generation to 10,823 GWh and annual per capita electricity consumption to 544 kWh. [338] The Plan's power supply development emphasizes increasing electricity supply capacity to enhance competitiveness, economic growth, energy security, and living standards, and one of its priorities is the implementation of policies to achieve the goal of 100% village electrification by 2020. In addition, the National Strategic Development Plan 2019-2023 published in 2019 showed lack of human and financial resources (lack of staff and funds for general operations for management and development of mining, oil and energy) as a challenge in implementing the 2014-2018 version in the minerals and energy sector. [339] The NDC submitted to the United Nations in December 2020 also pointed to expanding access to energy as an initiative, with at least 90% of households gaining access to the electricity grid by 2030. [340] The company plans to increase access in stages to 80% by 2020, 85% by 2025, and 90% by 2030.

According to the IEA, Cambodia's electrification rate as of 2019 is 74.8%. [341]

(b) Electric utility system

(1) Electricity supply system

Cambodia is encouraging private and foreign capital investment to expand its electricity supply. The government has developed a legal system, including the 1994 Investment Law, to provide incentives to promote investment. Of Cambodia's total installed generation capacity (2019), the national company Electricité du Cambodge (EDC) owns only 4.6%, while IPP owns 94%. [342] EDC supplies power generated by itself and imported from IPPs and neighboring countries in major urban areas including Phnom Penh, while off-grid power distribution in areas outside of major urban areas is provided by IPPs.

There are no restrictions on foreign participation in the electric utility industry, but any

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338 Royal Government of Cambodia (2014) "National Strategic Development Plan 2014-2018".

339 Royal Government of Cambodia (2019) "National Strategic Development Plan 2019-2023".

340 Kingdom of Cambodia (2020), "Cambodia's Updated Nationally Determined Contribution".

341 International Energy Agency (2020) "Electricity Access Database".

342 EAC (2019) "Report on Power Sector of the Kingdom of Cambodia".

domestic or foreign operator must obtain a license from the EAC. There are eight types of licenses (generation, transmission, distribution, combined (combination of dispatch and distribution), dispatch, wholesale, retail, and subcontracting) depending on the nature of the business. [343]

(2) Supply system of renewable electricity

Cambodia does not have a defined method of selling and purchasing renewable electricity such as RPS or feed-in tariffs. [344] (Not confirmed as of February 2021)

(c) Policy on renewable energy

(1) Renewable energy potential

Cambodia has relatively good sunlight throughout the country, and the potential for solar power generation is high. However, given geographic and institutional constraints, only a limited number of areas can be developed without constraints. For example, a national solar park project is underway with ADB support in Kampong Chhnang Province near Phnom Penh, where a 100 MW solar park, a substation, and transmission facilities connecting to Phnom Penh, the demand site, will be built. [345] In 2019, the installed solar power capacity was 99 MW and 43 GWh of electricity was generated. [346]

On the other hand, wind conditions are poor throughout the entire region, except for some points in the east, and there is little potential for wind power generation. There are no wind power installations in 2019. [347]

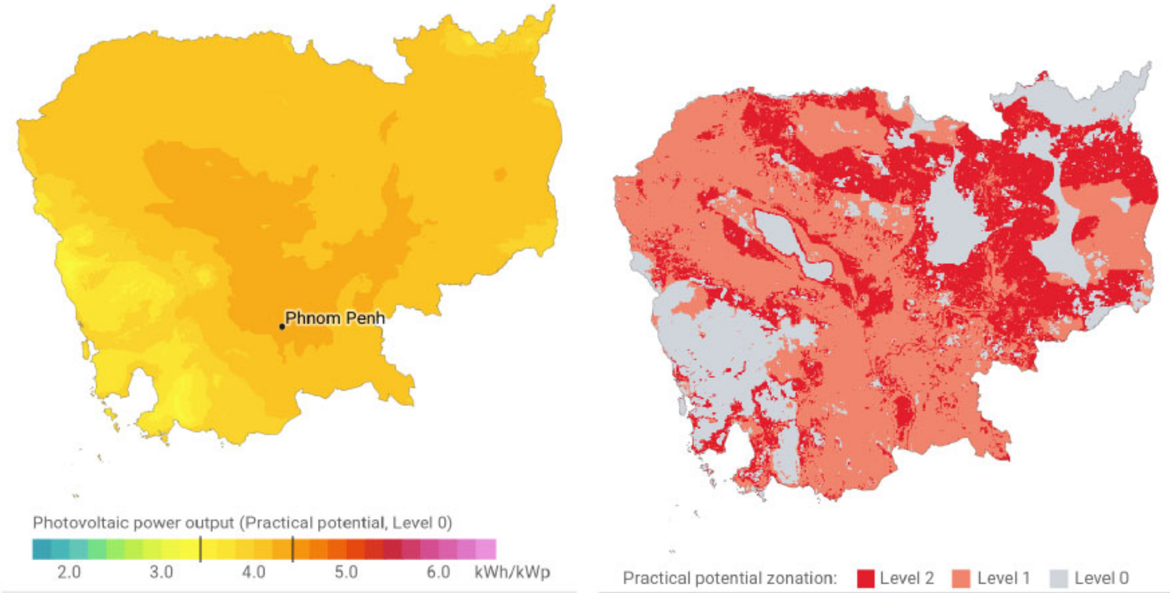

Figure 121 Solar Power Generation Potential in Cambodia

Note: Left = Estimated power generation
Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints; Level 2 = excluding topographic and regulatory constraints.

Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

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343 EAC (2019) "Report on Power Sector of the Kingdom of Cambodia".

344 Economic Research Institute for ASEAN and East Asia (2019) "Cambodia Basic Energy Plan".

345 ADB, National Solar Park Project: Initial Environmental Examination, March 2019, https://www.adb.org/projects/documents/cam-51182-001-iee.

346 IRENA (2020) "Renewable Energy Statistics 2020".

347 IRENA (2020) "Renewable Energy Statistics 2020".

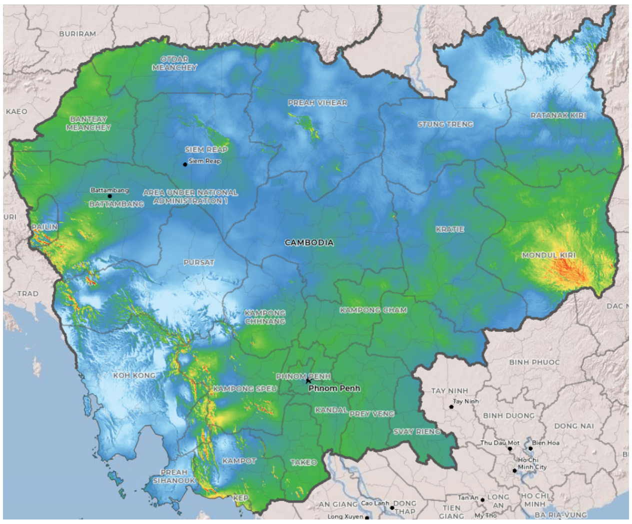

Figure 122 Wind Power Generation Potential in Cambodia

Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The New and Renewable Energy Department, under the General Department of Energy of the Ministry of Mines and Energy, has jurisdiction over policies related to renewable energies. The General Department of Energy is responsible for planning, consumption, and data collection in the power and energy sector, and houses the Energy Development Department, the New and Renewable Energy Department, the Hydropower Department, and the Nuclear Energy Technology Department.

(3) Development goals

In October 2017, ASEAN countries, including Cambodia, signed a strategic partnership with the International Renewable Energy Agency (IRENA), aiming for 23% renewable energy deployment by 2023. [348] In October 2018, they entered into a new partnership aimed at expanding renewable energy deployment and making progress in the transition to sustainable energy. Under the partnership, ASEAN aims to achieve a target of 23% renewable energy share in primary energy by 2025. [349]

Based on the Cambodia Energy Outlook, the most probable 2030 electricity mix is expected to be 55% hydro and 10% other renewables (6.5% biomass and 3.5% solar), with 26.2 TWh of electricity generated. [350] In a September 2020 press report, the EDC announced its intention to add 372 MW of solar power generation in 2021 and 60 MW in 2022, with about 1,815 MW installed by the end of 2030, and the EDC Secretary mentioned that 17% of peak demand would be met by solar power. [351] In November 2021, the Ministry of Mining and Energy revealed plans to operate seven solar power plants with a total output of 495 MW by 2023. [352] As a result, the share of solar power generation in Cambodia's power supply mix is expected to reach 20% by 2023.

The NDC submitted to the United Nations in December 2020 included a "Roadmap Study on the Integration of Renewable Energy Resources (Solar, Wind, Hydro, and Biomass) into the

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[348] PV-tech, October 2, 2017

[349] IRENA, October 30, 2018, https://irena.org/newsroom/pressreleases/2018/Oct/IRENA-Signs-Partnership-with-Southeast-Asian-Countries-as-Region-Looks-to-Scale-Up-Renewable-Energy

[350] Economic Research Institute for ASEAN and East Asia (2019) “Cambodia Basic Energy Plan”.

[351] NNA ASIA, September 23, 2020, https://www.nna.jp/news/show/2096941

[352] NNA ASIA, November 4, 2021, https://www.nna.jp/news/show/2258530

Energy Mix" as one of the mitigation measures, aiming to have 25% of the power supply mix be from renewable energy sources by 2030. Regarding biomass use, the NDC also states that it will promote diversification of household and community energy sources to reduce dependence on biomass as an energy source.

(4) Policies to promote introduction

As mentioned above, Cambodia has not introduced incentives such as a renewable electricity purchase program or tax benefits.

(d) Energy conservation policy

(1) Institutions in charge of policy

The Ministry of Mining and Energy has jurisdiction over energy conservation policy.

(2) Target

In May 2013, the Ministry of Mining and Energy, with the support of the EU's Energy Initiative Partnership Dialogue Facility and others, developed the National Policy, Strategy and Action Plan on Energy Efficiency. The goal is to reduce energy demand by 20% relative to BAU and CO2 emissions by 3 million tons by 2035. [353] The breakdown of 20% reduction is 2.24% for industry, 1.65% for buildings, 3.68% for end-user products, 11.93% for biomass, and 0.85% for REE (Rural Energy Entrepreneurs).

In addition, according to Cambodian government press releases, ongoing targets for energy conservation include a 10% reduction in total energy consumption in all sectors relative to BAU by 2030, transmission and distribution losses to be less than 8%, a 15% reduction in energy intensity in the industrial sector by 2030, and a 15% increase in bus engine efficiency by 2030. [354]

(3) Promotion policy

The National Strategic Plan 2019-2023 identified strengthening energy technologies and electricity standards in buildings and homes as a strategic action for the Ministry of Mining and Energy to pursue. [355]

In addition, the "Cambodia Energy Conservation Master Plan" published by ERIA in July 2020 summarizes the government's efforts in five policies and programs: training of ESCO operators and energy managers, standards and labeling systems, education, campaigns, and preparation of energy efficiency indicators. It also presents a five-year (2020-2025) roadmap.

In the NDC submitted to the UN in December 2020, the following measures related to energy conservation were mentioned (1) Improvement of process performance of energy efficiency through the establishment of energy management in the industrial sector (0.1MtCO2e GHG reduction per year through the implementation of mandatory energy audit for companies with annual energy consumption above a certain amount and through a voluntary scheme for small-to-medium-sized enterprise to reduce by 10% in 2030), (2) Increase of the share of high-efficiency equipment in the market by applying electronic equipment labeling and Minimum Energy Performance Standards (MEPS) (for lighting and cooling equipment) (1.2 TWh (29.7%) of electricity consumption reduction in 2030 and 1 $MtCO_2e$ GHG reduction per year), (3) raising public awareness (providing basic information necessary to understand energy efficiency and implementing about 25 awareness programs per year, resulting in a reduction of 0.03 $MtCO_2e$ per

[353] METI, March 2016; Ministry of Industry, Mines and Energy (2013) “National Policy, Strategy and Action Plan on Energy Efficiency in Cambodia”.

[354] Ministry of Mines and Energy, General Department of Energy, The Development of the 6th ASEAN Energy Outlook (AEO6)The 2ndAEO6 Workshop (Working Meeting on Scenarios), March 26-28, 2019.

[355] Royal Government of Cambodia (2019) National Strategic Development Plan 2019-2023.

year), (4) building codes and certifications for new buildings and buildings undergoing major renovations (10% reduction in electricity consumption by 2030 and a reduction of kWh/mWh of energy demand in new buildings and buildings undergoing major renovations), (5) introduction of highly efficient electric industrial motors and transformers (reduction of current electricity consumption by 2.3% in 2030 and 0.08 MtCO2e per year), and (6) promotion of sustainable energy initiatives in the manufacturing sector.

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

The INDC, submitted to the UN in September 2015, calls for a reduction of 3,100 Gg-CO_2eq in greenhouse gas emissions in the energy, manufacturing, transport and other sectors by 2030 compared to BAU (11,600 Gg-CO_2eq). It also calls for a forest covering of at least 60% of the national land area, which would lead to a reduction of 7,897 Gg-CO_2eq in greenhouse gas emissions in a LULUCF (land use, land-use change, and forestry sectors) by 2030 compared to 2010 (18,492 Gg-CO_2eq).

The NDC submitted to the UN in December 2020 set a goal of reducing greenhouse gas emissions in the sectors including FOLU (forestry and other land use), by approximately 64.6 million tCO2 by 2030 (a 41.7% reduction from BAU). [356]

(2) Promotion policy

Policies regarding environmental and carbon taxes are not identified.

The NDC submitted to the UN in December 2020 mentions improving the sustainability of charcoal production through the introduction of regulations and the implementation of a National Cooling Action Plan (reducing GHG emissions by 1.09 MtCO_2e by 2030).

(3) Transportation

In the NDC submitted to the UN in December 2020, E-mobility is listed as one of the mitigation measures, but no specific target values are given. As a baseline, the project assumes that nine electric vehicles have been registered by 2020. Also noted is the shift of long-distance transportation from trucks to rail, but as with e-mobility, no specific targets or other information are provided.

(4) Urban development

In April 2018, the ASEAN Smart Cities Network (ASCN) was established at the 32nd ASEAN Summit and 26 pilot cities were selected from member countries. In Cambodia, three cities have been selected: the capital Phnom Penh, Siem Reap in the northwest, and Battambang in the west. [357]

Phnom Penh has three strategic goals in its Smart City Action Plan: improving sidewalks, redesigning public spaces, and improving the efficiency of Phnom Penh public bus service to 50% modal share. Based on the goals, (1) 11 sidewalk rehabilitation projects and (2) improving the efficiency of Phnom Penh public transportation are presented as smart city projects. In addition to funding and technical assistance, assistance is requested for (1) in particular, for transportation system specialists who can work with limited transportation data and for engagement management of stakeholders, including all key stakeholders. [358]

Siem Reap has four strategic goals in its Smart City Action Plan: Development of an integrated data system that links drainage, sidewalk, vehicle traffic, and security data with waste management by 2025; Development of smart waste management and cleaning by 2021; Installation of CCTV at key tourist and traffic spots by 2021; and Installation and activation of

[356] Kingdom of Cambodia (2020), "Cambodia's Updated Nationally Determined Contribution".

[357] ASEAN, ASEAN Smart Cities Network, https://asean.org/asean/asean-smart-cities-network/

[358] ASEAN, ASEAN Smart Cities Network, Phnom Penh, https://asean.org/wp-content/uploads/2019/02/Phnom-Penh.pdf

drainage and flood control sensors by 2021. Smart city projects include (1) smart visitor management systems and (2) solid waste and wastewater management, for which infrastructure development support and financial assistance are requested. [359]

Battambang has proposed seven goals with 2025 as the year of achievement: Provision of at least 2,800 young people with tangible employment skills; Transition 50% of street vendors to formal retail stores and markets; Turning at least 3 informal settlements/urban areas into formal settlements; Development of a citywide drainage system; Building 2 wastewater treatment plants; Installation of sewage treatment systems in 85% of city villages; and Raising asphalt roads from 17% in 2016 to 40% in 2025. Smart city projects included (1) urban street and public space management and (2) solid and liquid waste management. [360]

The NDC submitted to the UN in December 2020 mentions efforts to transform Battambang into a green city, integrating the five Battambang towns into a green city, and implement financial management, institutional arrangements, and policy reforms by 2025.

(f) Next generation technology, innovation

N/A.

(g) Points to consider for future cooperation in promoting low carbon and decarbonization

- Cambodia has a high interest in energy conservation due to relatively high electricity rates, and has great energy conservation potential. Mandatory energy audits in the industrial sector and the introduction of standards and labeling systems are being considered as policy directions, but they must be concretized and steadily implemented, and when standards are established, they must be periodically reviewed (by updating the standards). It will also be necessary to formulate a roadmap for energy conservation beyond 2025. The following points may be considered as energy conservation programs.
    - Development of energy efficiency benchmarks for the energy conversion and industrial sectors
    - Introduction of energy management obligations in the industrial sector, training of energy managers
    - Introduction of fuel efficiency standards for automobiles
    - Improvement of public transportation network, introduction of electric vehicles
    - Development of Building Standard Law
    - Introduction of building insulation standards
    - Introduction of minimum efficiency standards for equipment
    - Introduction of equipment labeling system and expansion of applicable equipment
- In the transportation sector, fuel efficiency standards for conventional diesel and gasoline vehicles could be introduced or raised. In the mid- to long-term, options for low-carbon and decarbonization include the introduction of electric vehicles for private cars, together with the development of charging infrastructure, and for long-distance transportation, the development of railroads and the use of biofuels in heavy-duty vehicles.
- While promoting the suppression of electricity demand while utilizing the energy conservation programs mentioned above, CO2 emissions from the power generation sector could be significantly reduced by increasing the efficiency of existing coal-fired power plants in the short term and by converting from coal to natural gas in the long term. However, natural gas import infrastructure will need to be developed.
- Among renewable energies, there are advantages to solar power generation at points where it can be developed adjacent to demand areas. At this time, the Cambodian government has not formulated a specific roadmap for 2030, and its formulation was pointed out as a measure in the NDC. In conjunction with climate change risk impact analysis of existing

[359] ASEAN, ASEAN Smart Cities Network, Siem Reap, https://asean.org/wp-content/uploads/2019/02/Siem-Reap.pdf

[360] ASEAN, ASEAN Smart Cities Network, Battambang, https://asean.org/wp-content/uploads/2019/02/Battambang.pdf

hydropower plants and power infrastructure, which is mentioned as an adaptation measure, there is a possibility of cooperation by Japan.

(12) Laos

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

Biomass energy, including firewood, has been used in Laos. There has been no significant change in the amount of biomass used from 2000 to the present, as confirmed by IEA statistics. The increase in energy demand primarily comes from the increased use of coal, with coal accounting for 60% of the primary energy supply mix in 2018 and biomass for 28%. Petroleum tends to increase slightly, which can be attributed to the growing demand for petroleum, especially for automobiles. There are no oil or natural gas resources in Laos, and the country is 100% dependent on imports for petroleum products. Coal is distributed throughout Laos, with lignite coal reserves estimated at 540 million tons and anthracite coal reserves at 62.25 million tons. [361] Most coal resources are used for domestic industrial and power generation purposes.

In the power generation sector, hydroelectric power was the main source of electricity supply until 2015, when the Hongsa coal-fired power plant was put into operation. Since 2015, the use of coal has expanded rapidly. By 2018, hydropower accounted for 65% of the power supply mix and coal-fired power increased to 35%. Although there is still ample hydropower potential that can be developed in Laos, the use of coal-fired power generation is expected to expand in order to meet the rapid growth in electricity demand in the future.

Given this supply structure, the first step toward future low carbon and carbonization is to improve the efficiency of coal-fired power utilization. Although a fuel shift from coal to natural gas is expected to advance the low-carbon economy, natural gas will have to be imported. It should also be noted that Laos is a landlocked country, so even if LNG is imported using ports in neighboring countries, it is necessary to lay pipelines for transportation from the ports.

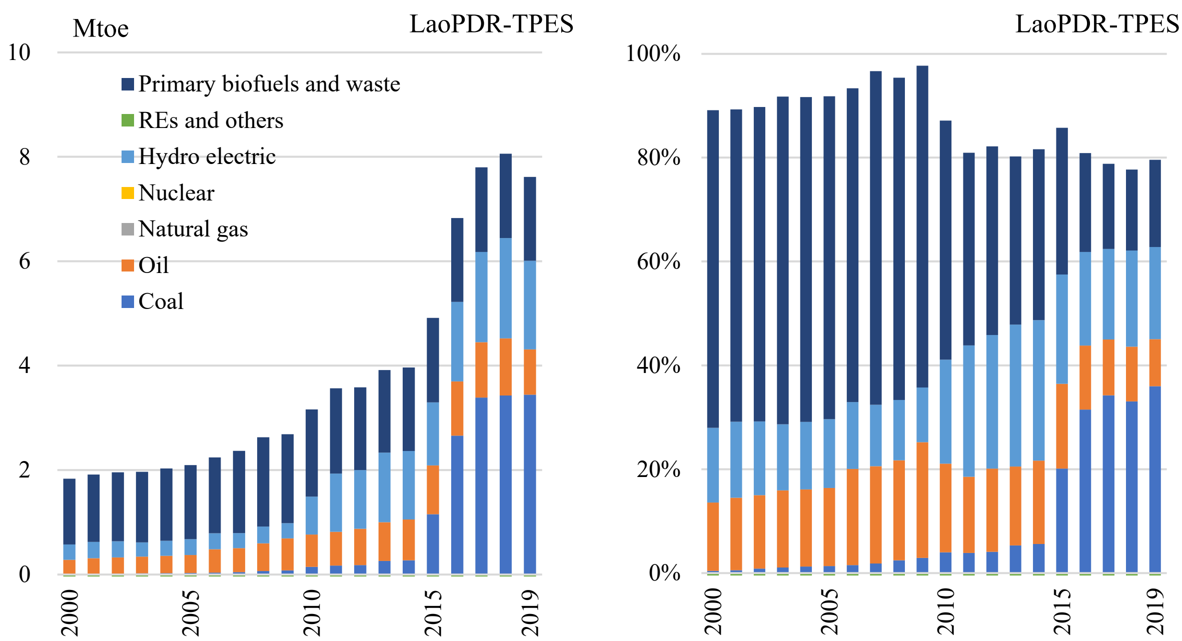


Figure 123 Primary Energy Supply in Lao PDR

Source: World Energy Balances 2021 extended edition database, IEA

361 JOGMEC(2014)

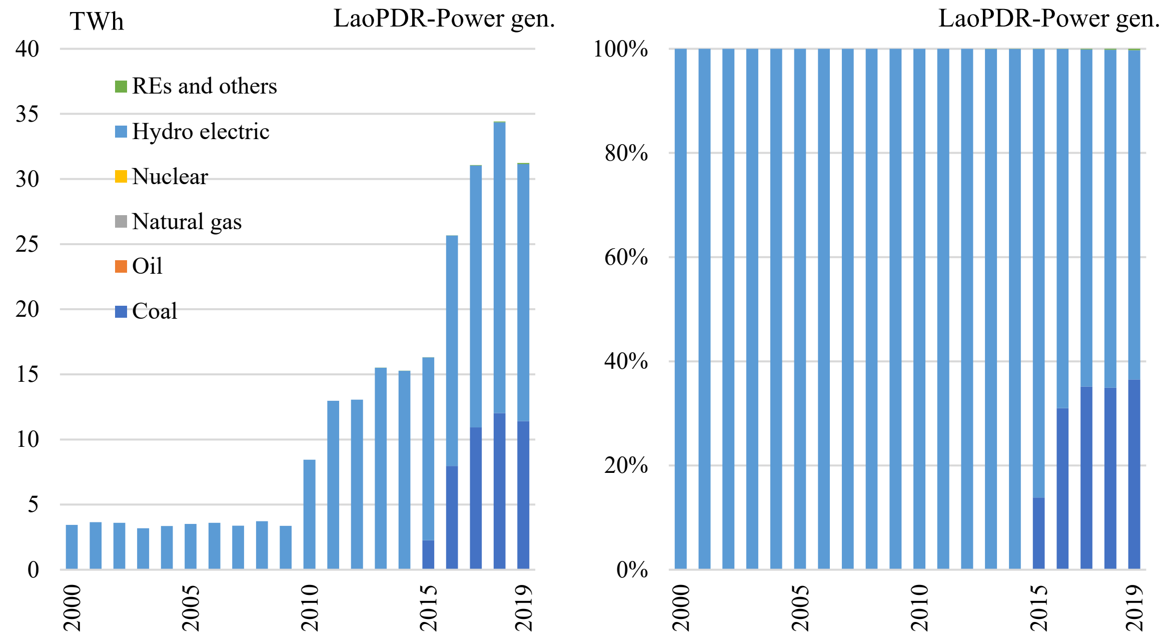


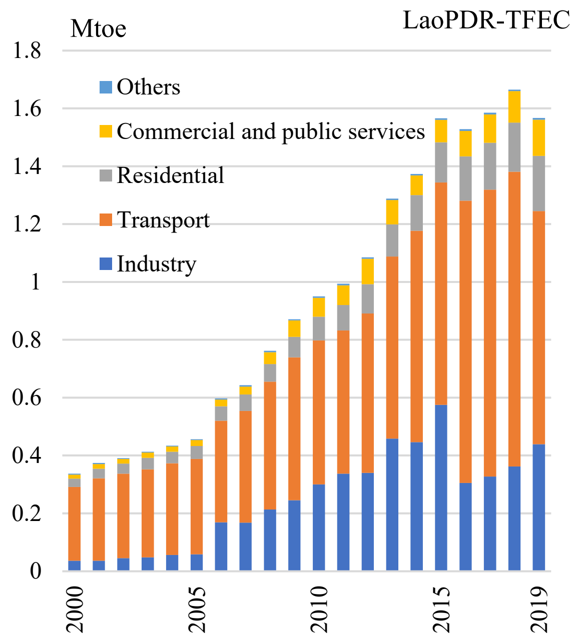
Figure 124 Fuel Mix of Electricity Generation in Lao PDR
Source: World Energy Balances 2021 database, IEA

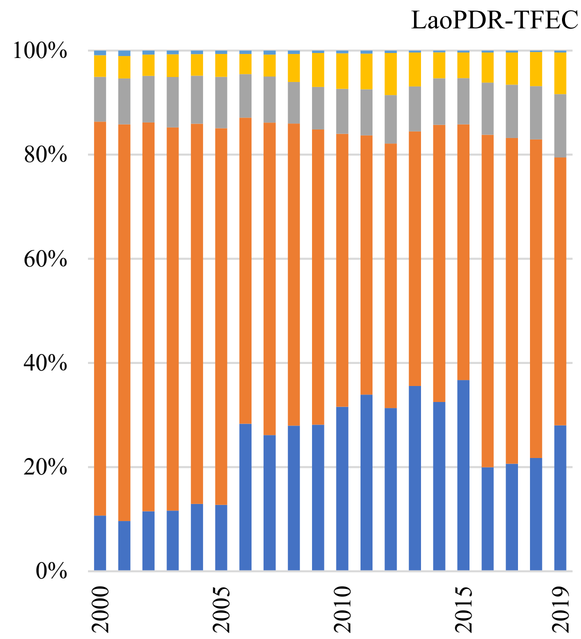
A breakdown of final energy consumption by sector shows that the transportation sector accounted for 22%, transportation 61%, residential 10%, and commercial/public services 7% in 2018. Transportation had the largest average annual change from 2013 to 2018 at 10.1%, followed by housing at 8.9%.

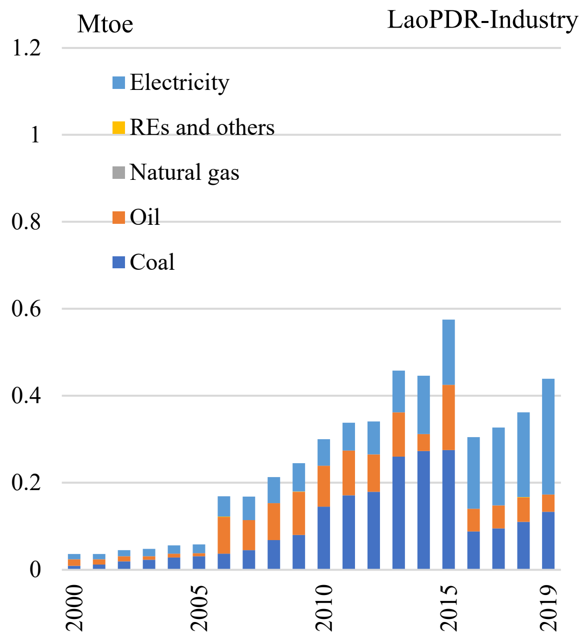
In the industrial sector, electricity demand is gradually increasing, and assuming this trend strengthens, power sources will need to be low-carbon and decarbonized.

Petroleum accounts for 100% in the transportation sector, and road (automobile) use accounts for almost all energy consumption in the transportation sector (2018). In Laos, car use is likely to continue to increase as the economy grows and incomes rise. To realize low carbon and decarbonization, in addition to improving the fuel efficiency of conventional internal combustion engines, the transportation sector must secure sufficient low-carbon power supply, with introduction of electric vehicles with sufficient low-carbon power sources and use of biofuels and other heavy-duty vehicles.

Excluding biomass uses such as firewood and charcoal, electricity accounts for 96% in the residential sector and 92% in the commercial/public service sector (2018). LPG use in both sectors has increased slightly since around 2015, but the shares are only 4% and 8%, respectively. Since biomass used for cooking and heating applications still dominates the market share, it is essential to improve the efficiency of cooking and heating equipment. In the mid- to long-term, conversion of LPG to electricity could be considered.


Mtoe
LaoPDR-TFEC
Others
Commercial and public services
Residential
Transport
Industry
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2000
2005
2010
2015
2019


LaoPDR-TFEC
100%
80%
60%
40%
20%
0%
2000
2005
2010
2015
2019


Mtoe
LaoPDR-Industry
Electricity
REs and others
Natural gas
Oil
Coal
1.2
1
0.8
0.6
0.4
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0
2000
2005
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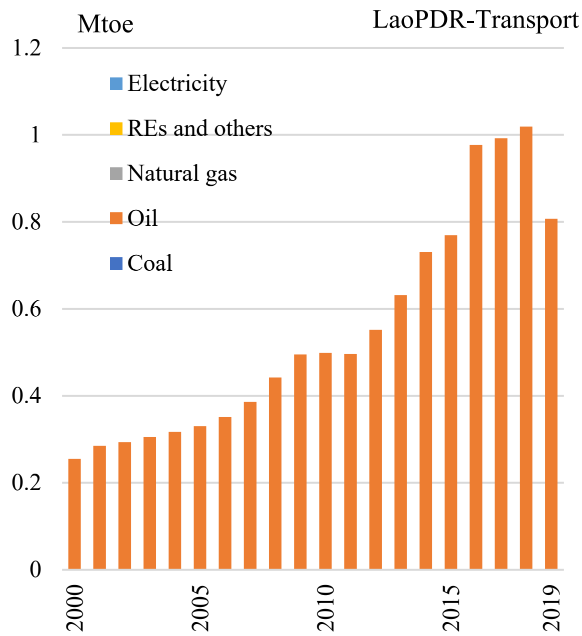
2019


Mtoe
LaoPDR-Transport
Electricity
REs and others
Natural gas
Oil
Coal
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2000
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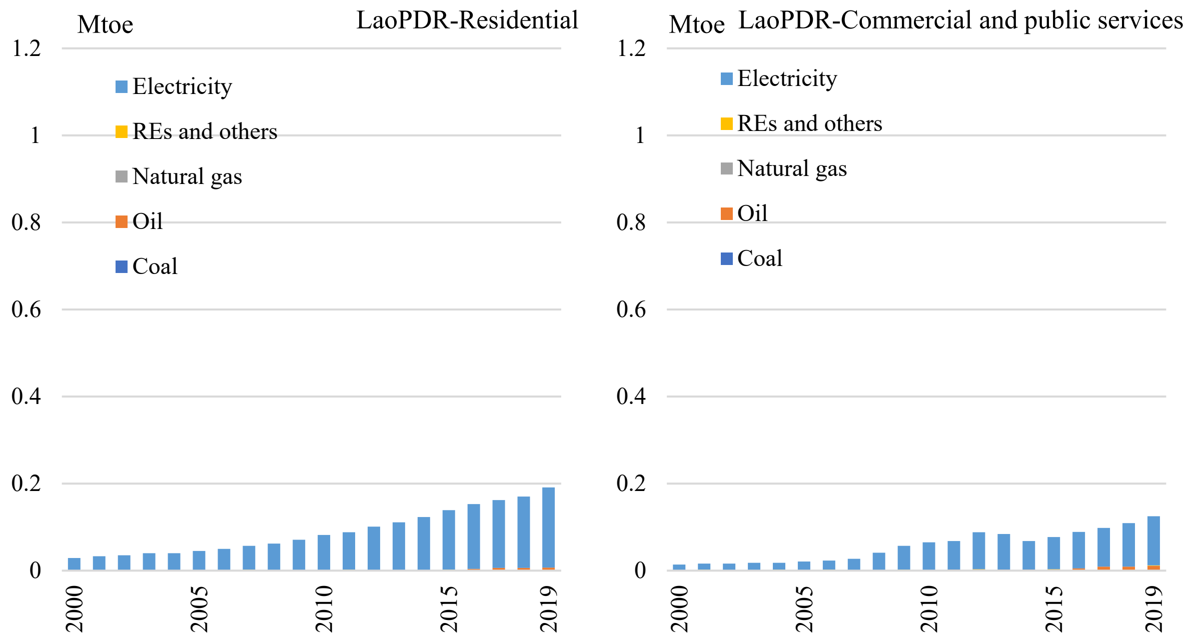

Figure 125 Final Energy Consumption of Major Sectors in Lao PDR

"Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal" are excluded.
"Others" in TFEC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP has been slowly declining, falling to 0.229 toe/$1,000 (2015 prices) in 2014. In 2019, it is 0.309 (0.090 in Japan). It is likely that energy efficiency has deteriorated due to the further acceleration of economic growth since 2015 and the increased introduction of coal-fired power generation, which is inferior to hydroelectric power in terms of power generation efficiency.

In addition, the thermal efficiency of coal-fired power generation in Laos is about 30%. The thermal efficiency of ultra-supercritical pressure power generation facilities currently in practical use is 42%, and the use of more efficient technology for new coal-fired power plants to be built in the future will also contribute to improved energy efficiency.

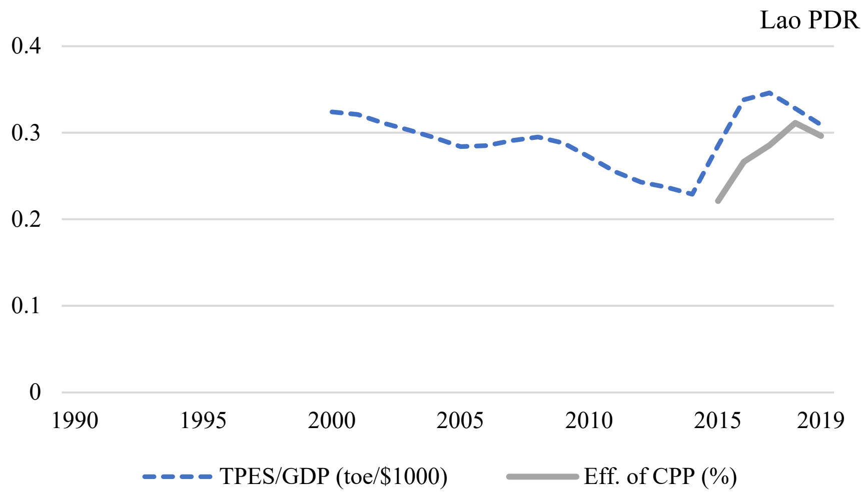

Figure 126 Energy Efficiency in Lao PDR

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant
GDP in 2015 price
Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the followings are examples of options that could be adopted to reduce CO2 emissions in Laos in the future and their CO2 reduction effects.

Table 97 Examples of Low-carbon/ Decarbonization Potential in Lao PDR

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		17.8 mton-CO2
【Example of CO2 Emission Reduction Option】		【Reduction Effect】
Generation	10% Improvement of Coal-fired Generation Thermal Efficiency	1.34 mton-CO2
Industry	Substitue 50% of Coal for Elecrtricity	0.15 mton-CO2
Transport	10% Improvement of Fuel Mileage	0.25 mton-CO2
Residential	10% Improvement of Energy Efficiency	0.092 mton-CO2
Commercial and Public Services	10% Improvement of Energy Efficiency	0.059 mton-CO2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICA Study Team

(2) Primary energy mix and electricity mix planning

According to the Energy Outlook 2020 of the Economic Research Institute for ASEAN and East Asia (ERIA), Laos' primary energy supply and electricity generation mix for 2050 is expected to be as follows. With regard to primary energy supply, it is projected to grow at an average annual rate of 3.0% from 2017 to 2050, with the composition by energy source in 2050 being 47.8% coal (69.9% in 2017), 29.9% oil (17.1% in 2017), 25.1% hydropower (31% in 2017), 11.7% biomass (22.6% in 2017), and 1.6% other renewable energy (0.1% in 2017). Fossil fuels such as coal and oil are expected to provide the majority of energy demand.

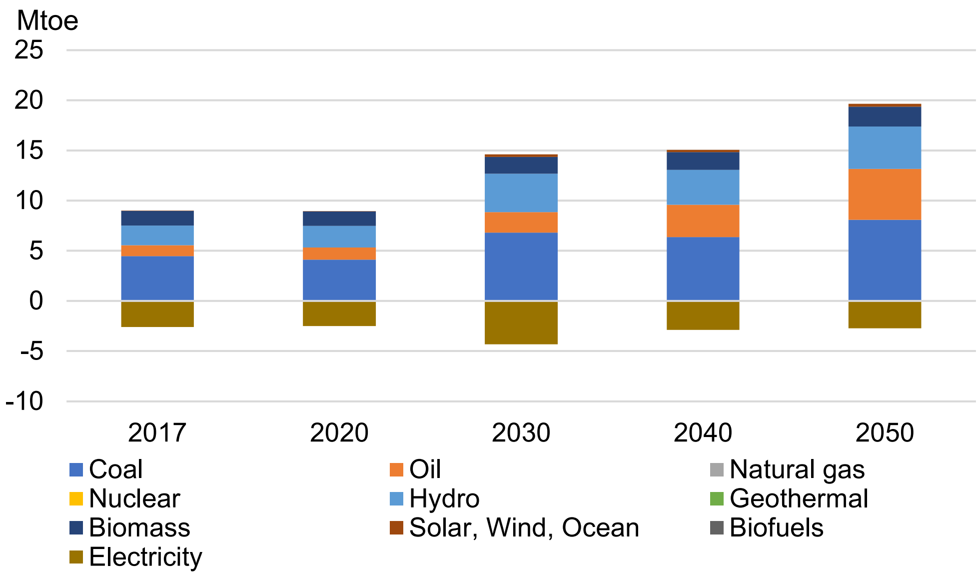

Figure 127 Primary Energy Supply Outlook in Lao PDR (2017-2050)

Source: ERIA Eenrgy Outlook 2020

By 2050, the amount of electricity generated in Laos is expected to increase by 2.2% per year, and the increase in electricity demand is expected to be met primarily by additional coal-fired and hydroelectric power generation. The composition of power sources was 62.6% hydropower and 37.1% coal in 2017, but by 2050, the share of hydropower will slightly increase to 65.1% and the share of coal-fired power generation will slightly decrease to 29.9%. The developable hydropower potential in Laos is estimated at 23,000 MW [362], with a hydropower capacity of 9,531 MW as of 2019 [363].

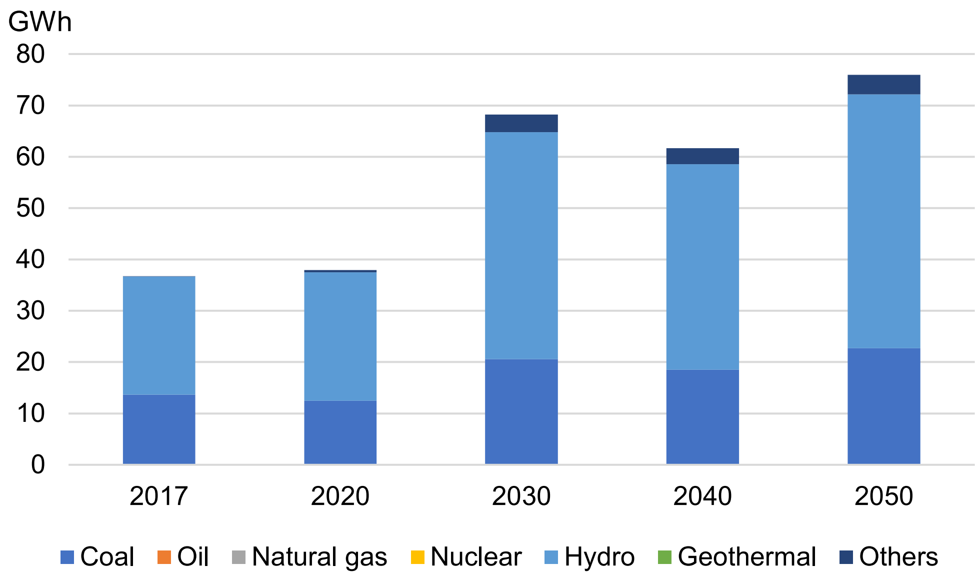

Figure 128 Electricity generation Outlook in Lao PDR (2017-2050)

Source: ERIA Energy Outlook 2020

(3) Current status and goals of electricity access

The government has set a target electrification rate to be 90% of households by 2020. [364]

The Lao government prepared a Rural Electrification Master Plan in 2010[365]. The goal is to supply electricity to 90-95% of households by 2020 (90% grid-supplied, 5% off-grid). Grid expansion is limited and will be supplemented by off-grid, utilizing solar home systems and small hydropower. The Vision 2030, approved in 2016, lists the goal of reaching the electrification rate 98% of all households at a reasonable cost. [366] According to the World Bank, the electrification rate in 2018 was 97.9%. [367] According to the IEA, Laos has an electrification rate of 94.8% as of 2019. [368]

(b) Electric utility system

(1) Electricity supply system

The Lao government allows private capital to participate in power development (hydropower development through IPP) in the form of BOT and BOOT. In the case of development through IPP, many projects are designed to transfer power facilities to the government after 20 to 30 years. In the supply system, EDL has a monopoly on transmission and distribution of electricity. Although few barriers to foreign investment are seen, the Electricity Law amended in 2011 includes a point where foreign investment is not allowed in small hydropower projects of 15 MW

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[362] Asian Development Bank (2019) "Lao People's Democratic Republic Energy Sector Assessment, Strategy, and Road Map", November 2019.

[363] JETRO, January, 2020, https://www.jetro.go.jp/biznews/2020/01/a7376fa0f6eb601e.html.

[364] Asian Development Bank (2011). Country Partnership Strategy: Lao PDR, 2012-2016, Sector Assessment (Summary): Energy.

[365] The Renewable Energy and Energy Efficiency Partnership, Policy and Regulatory Overviews: Lao PDR (2012).

[366] METI (2017).

[367] World Bank, Data, Access to electricity (% of population) – Lao PDR, https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=LA

[368] International Energy Agency (2020) "Electricity Access Database".

or less. [369] IPP dominate the installed generation capacity (2017) with IPP accounting for 89% (21% for domestic use and 67% for export), the Lao Power Generation Corporation (EDL-GEN) spun off from EDL for 11%, small power producers for 0.9%, and EDL for 0.1%. [370]

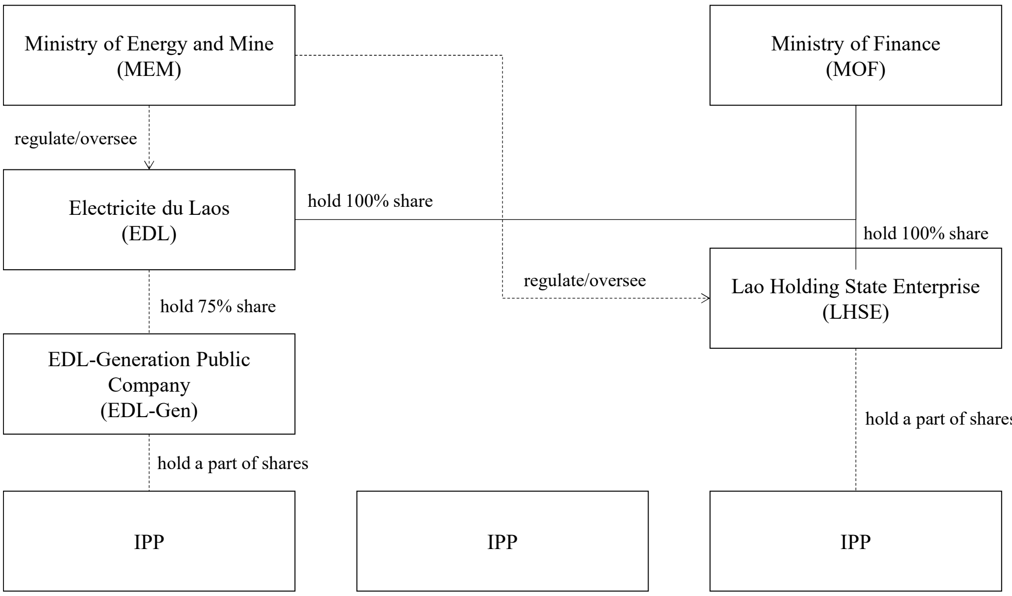

Figure 129 Electricity Related Organizaition in Lao PDR

Source: METI (2017)

Lao Holding State Enterprise (LHSE) is a 100% government-owned state enterprise under the jurisdiction of the Minister of Finance, which invests in IPP projects on behalf of the government. IPP for export power supplies is the main investment target. Electrical Construction and Installation State Enterprise (ECI) is a government-owned construction company under the jurisdiction of the MEM and is responsible for power projects in Laos and abroad. It is also empowered to cooperate with domestic and foreign investors, build energy resources (power sources) such as hydropower and solar power, and invest in JVs that manufacture power facilities and equipment.

(2) Supply system of renewable electricity

In Laos, there is no defined method for selling and purchasing renewable electricity such as RPS or feed-in tariffs. (Not confirmed as of February 2021)

(c) Policy on renewable energy

(1) Renewable energy potential

Laos has relatively good sunlight throughout the country, and the potential for photovoltaic power generation is high. However, given geographic and institutional constraints, only a limited number of areas can be developed without constraints. In 2019, the installed solar power capacity was 22 MW and 19 GWh of electricity generated. [371]

Wind conditions are poor except in some southern areas. In the southern provinces of Seakorn and Attapeu, Thailand's BCPG has announced the construction of a 600 MW wind farm[372], which

[369] JETRO, February 18, 2015

[370] JICA, August 21, 2018, https://www.jica.go.jp/priv_partner/information/field/2018/ku57pq00002ml5f3-att/20180817_01.pdf

[371] IRENA (2020) "Renewable Energy Statistics 2020".

[372] Bangkok Post, "BCPG eager to build Asean's largest wind farm in Laos", 2020-7-29, https://www.bangkokpost.com/business/1959159/bcpg-eager-to-build-aseans-largest-wind-farm-in-laos.

is expected to start operation in 2023 and export the generated power to Vietnam. [373]

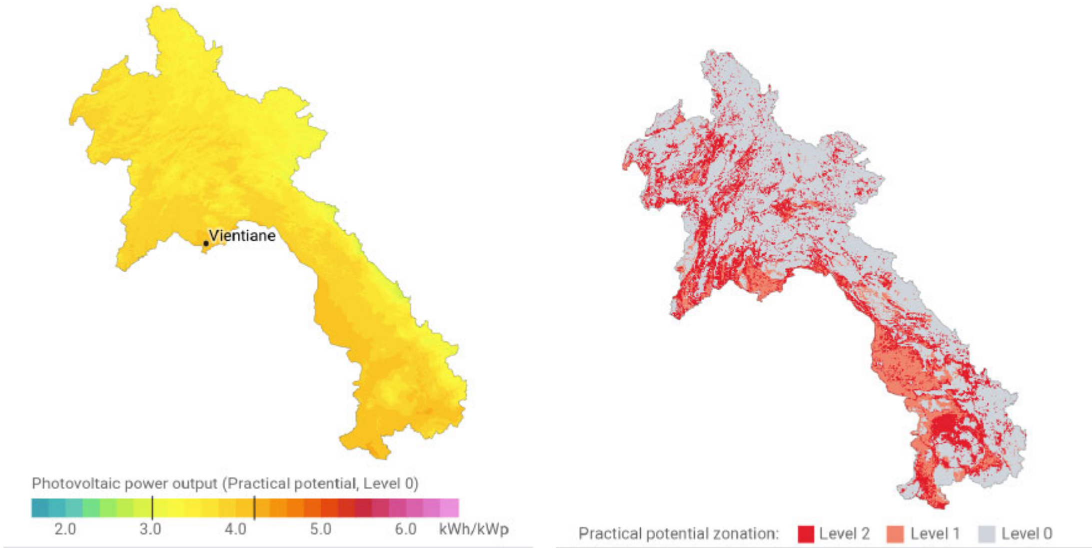

Figure 130 Solar Power Generation Potential in Lao PDR

Note: Left = Estimated power generation
Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints;
Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

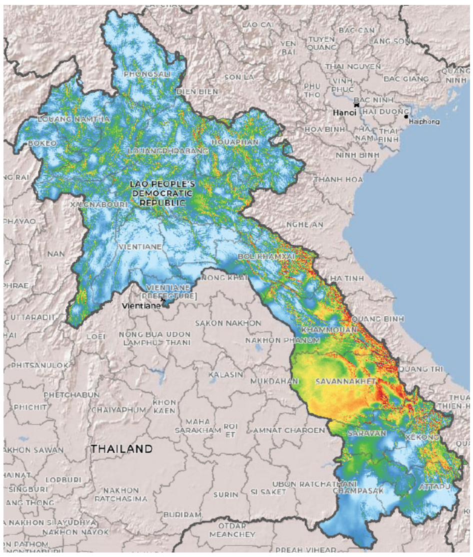

Figure 131 Wind Power Generation Potential in Lao PDR

Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The Institute of Renewable Energy Promotion (IREP) promotes renewable energy and energy conservation based on the Renewable Energy Strategy and Development Plan.

(3) Development goals

The Lao government has set a goal of 30% of its energy consumption to come from renewable

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[373] BCPG, Wind Power, https://www.bcpggroup.com/en/our-business/wind-power.

energy sources by 2025.

The Renewable Energy Strategy and Development Plan calls for 728 MW of renewable energy generation by 2025 (400 MW from small hydro, 33 MW from solar, 73 MW from wind, 58 MW from biomass, 51 MW from biogas, 36 MW from waste), 450 ML of biofuels (150 ML of ethanol, 300 ML of biodiesel), 400 ktoe of heat (113 ktoe from biomass, 178 ktoe from biogas, 109 ktoe of solar thermal) as potential development resources. [374]

(4) Policies to promote introduction

With regard to the renewable energy development targets mentioned above, the introduction of a reasonable feed-in tariff is being considered, but incentives such as renewable electricity purchase schemes and tax incentives are not currently identified.

(d) Energy conservation policy

(1) Institutions in charge of policy

The Institute of Renewable Energy Promotion (IREP) has jurisdiction.

(2) Target

As an energy conservation policy at the national level, a proposed roadmap to 2030 is under consideration. The main goals are (1) to reduce domestic energy demand by 10% relative to BAU in 2030, (2) to reduce the current 4% annual growth rate of energy consumption to 3.5%, and (3) to reduce greenhouse gas emissions. [375]

(3) Promotion policy

The Lao government has not yet developed a framework of laws and regulations for energy conservation. [376] In December 2019, the Energy Conservation Center held the (second) workshop to support the establishment of a legal framework for energy conservation in Laos. The main topics of discussion at the meeting were finalization of the draft Prime Minister's Order on Energy Conservation and the draft Standards and Labeling System, consideration of the establishment of an energy management system through industry-government-academia model project activities, and guidance for the compilation of a pilot energy audit report. [377]

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

The INDC, submitted to the UN in October 2015, presents six goals.

i) Reduction of 60,000-69,000 kt-CO_2e by increasing the share of forests in the territory to 70% by 2020 (base year 2000). The implementation of the REDD+ program (from around 2007), a development framework for the forest sector in the country; the implementation of the Voluntary Partnership Agreement (VPA), a bilateral trade agreement between the EU and non-EU timber exporting countries (currently under negotiation[378]); the continued implementation of the EU Forest Law Enforcement, Governance and Trade (FLEGT) (supported by Germany) are noted as plans to achieve the goal.

ii) Reduction of 1,468,000 kt-CO_2e by increasing the share of renewable energy in energy consumption to 30% by 2025 and expanding 10% of transportation fuel demand to biofuels (base year 2011). The goal will be achieved through the implementation of the Renewable Energy

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374 Lao People's Democratic Republic (2011). Renewable Energy Development Strategy in Lao PDR.

375 JAPAN ELECTRIC POWER INFORMATION CENTER, April 2015

376 ECCJ/AEEC, Lao PDR, https://www.asiaeec-col.eccj.or.jp/archive/eec-policy-country/laopdr/; Asian Development Bank (2019) "Lao People's Democratic Republic Energy Sector Assessment, Strategy, and Road Map", November 2019.

377 ECCJ/AEEC, Implementation of Energy Conservation support project (Second workshop) for Lao PDR, 2020-1-22, https://www.asiaeec-col.eccj.or.jp/201912-ajeep-lao/.

378 EU FLEGT Facility, Q&A Lao-EU Voluntary Partnership Agreement, https://www.euflegt.efi.int/q-and-a-laos

Strategy and Development Plan formulated in 2011. The first step in implementation will be to evaluate and update the renewable energy strategy. Specifically, the following analyses are to be conducted: Analysis identifying gaps and opportunities related to technology choices and resources for renewable energy (covering the following categories: (1) political, legal, regulatory, and organizational; (2) economic, fiscal, and market; and (3) technology, human resource development, and infrastructure); analysis of the current level of renewable energy deployment and management; analysis of alignment between current supply targets and demand forecasts; analysis of supportive policies such as feed-in tariffs, tax incentives, and tariffs; and analysis of market readiness to promote private sector investment.

iii) Reduction of 63 kt-CO_2/year by raising the electrification rate in village areas to 90% by 2020 (base year 2010). The plan to achieve the goal is to implement Nationally Appropriate Mitigation Actions (NAMA) in developing countries with the support of the United Nations Development Program.

iv) Reduction of 33 kt-CO_2/year by road network expansion and 158 kt-CO_2/year relative to BAU by promoting public transportation use. As with (3), it aims to achieve the same goals as part of the NAMA.

v) Reduction of 16,284 kt-CO_2/year between 2020 and 2030 (base year 2015) through increased use of large hydropower generation. The project aims to earn foreign currency and create jobs by exporting electricity derived from hydroelectric power generation to neighboring countries. The goal will be achieved by implementing an electricity export agreement in line with the progress of the NAMA and preparing for future carbon market mechanisms.

vi) Implementation of the Climate Change Action Plan (no target).

Note that Laos signed the Paris Agreement in April 2016 and ratified it in September 2016. In May 2021, Laos updated its NDC and submitted it to the UN. In this context, an unconditional target to reduce GHGs by 60% relative to BAU by 2030 and a conditional target to reduce GHGs by 63.5% relative to BAU were presented. [379]

(2) Promotion policy

Policies regarding environmental and carbon taxes are not identified. It has been reported that the government is considering introducing an environmental protection tax to curb the production of pollutants and hazardous waste by industry, while at the same time taxation is being considered to support energy conservation and the efficient use of natural resources. [380]

(3) Transportation

In its renewable energy strategy, the Lao government aims to replace 10% of its transportation fuel consumption with biofuels by 2025.

(4) Urban development

In April 2018, the ASEAN Smart Cities Network (ASCN) was established at the 32nd ASEAN Summit and 26 pilot cities were selected from member countries. In Laos, two cities have been selected, Vientiane and Luang Phabang. [381]

Vientiane has five strategic goals for its Smart City Action Plan: a quality health system, easy access to public services through e-government applications, affordable housing schemes, a clean environment, and urban living spaces with reduced flooding frequency. Smart city projects include (1) construction of drainage systems and (2) sustainable transportation planning, and in addition to funding, technical assistance for master planning and support for the development of a

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[379] UNFCCC, Lao People's Democratic Republic, https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party=LAO&prototype=1

[380] The Star, Lao government considers tax to protect environment, 2020-3-12, https://www.thestar.com.my/news/regional/2020/03/12/lao-government-considers-tax-to-protect-environment

[381] ASEAN, ASEAN Smart Cities Network, https://asean.org/asean/asean-smart-cities-network/

strategic roadmap are requested. [382]

The following four goals were identified in Luang Phabang's Smart City Action Plan: Implementation of replicable municipal waste management and sewerage solutions in a public-private partnership; development of appropriate solid waste disposal systems; restoration of all wetlands in the city and preservation of natural spaces along the Mekong and Nam Khang Rivers; and accommodation of anticipated growth in tourism while maintaining World Heritage values. Smart City projects include (1) wetland restoration for urban green space and habitat, and (2) construction of concrete roads and sidewalks, for which technical advice and financial assistance are requested. [383] Note that Luang Phabang is the target of the first phase of the Japanese government's Smart City Project Support Measures in ASEAN (Smart JAMP) announced in December 2020. [384]

(f) Next generation technology, innovation

N/A.

(g) Points to consider for future cooperation in promoting low carbon and decarbonization

- In Laos, laws and standards related to energy conservation are not yet in place, and the first step is to establish a law that will serve as a foundation for energy conservation measures. Then, the following points can be considered as countermeasures.
    - Development of energy efficiency benchmarks for the energy conversion sector
    - Introduction of energy management obligations in the industrial sector, training of energy managers
    - Introduction of fuel efficiency standards for conventional internal combustion engine vehicles and introduction of electric vehicles
    - Introduction of minimum efficiency standards for equipment
    - Introduction of equipment labeling system
- In the transportation sector, the low-carbon and decarbonization strategy may include the introduction or increase of fuel efficiency standards for conventional diesel and gasoline vehicles as well as the introduction of electric vehicles for private vehicles. In addition, the use of biofuels could be a means for heavy vehicles for long-distance transportation.
- Since there are no natural gas resources in the landlocked country and it is not easy to import LNG from overseas, so it is assumed that there are many challenges in converting to natural gas. Although coal-fired power generation will be used as a backup, strong promotion of energy conservation so that hydroelectric power and renewable energy sources can meet energy demand will contribute significantly to low carbon and decarbonization. Support for the introduction of Japanese technology for energy conservation is considered effective.
- For renewable energy, solar power generation at developable sites adjacent to demand areas is considered to be effective. However, as noted by the INDC, the renewable energy strategy must first be evaluated and updated. In particular, analysis to identify gaps and opportunities related to renewable energy technology choices and resources, as well as analysis of the alignment of current supply targets with demand projections, are critical to the implementation of long-term decarbonization goals and are important points of collaboration.
- Ammonia co-firing in coal-fired power plants may attract attention in order to utilize domestic coal resources and avoid stranding coal-fired assets. Ammonia can be produced from green hydrogen derived from abundant domestic hydroelectric power generation to realize low carbon and decarbonization in the energy conversion sector without increasing import dependence.

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382 ASEAN, ASEAN Smart Cities Network, Vientiane, https://asean.org/wp-content/uploads/2019/02/Vientiane.pdf

383 ASEAN, ASEAN Smart Cities Network, Luang Prabang, https://asean.org/storage/2020/01/ascn/Luang-Prabang.pdf

384 The Daily engiuneering and Construction News, January 8, 2021, https://www.decn.co.jp/?p=118044

(13) Peru

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

Peru began producing natural gas domestically in the late 1990s, increasing the share of natural gas from its traditional oil-centric energy mix. With the development of the economy, the consumption of conventional biomass and other materials is declining. Peru's challenge is to replace expensive imported LPG with domestically produced natural gas.

A common characteristic of South American countries is the high share of hydropower in power generation. However, when a drought occurs, the output of hydropower falls and power becomes scarce. For this reason, Peru has a very small share of coal-fired power, which has increased its share of natural gas-fired power as a result of domestic natural gas production. Peru is promoting the supply of electricity through PV panels as a measure to electrify areas with high poverty rates and difficulties in connecting to the power grid.

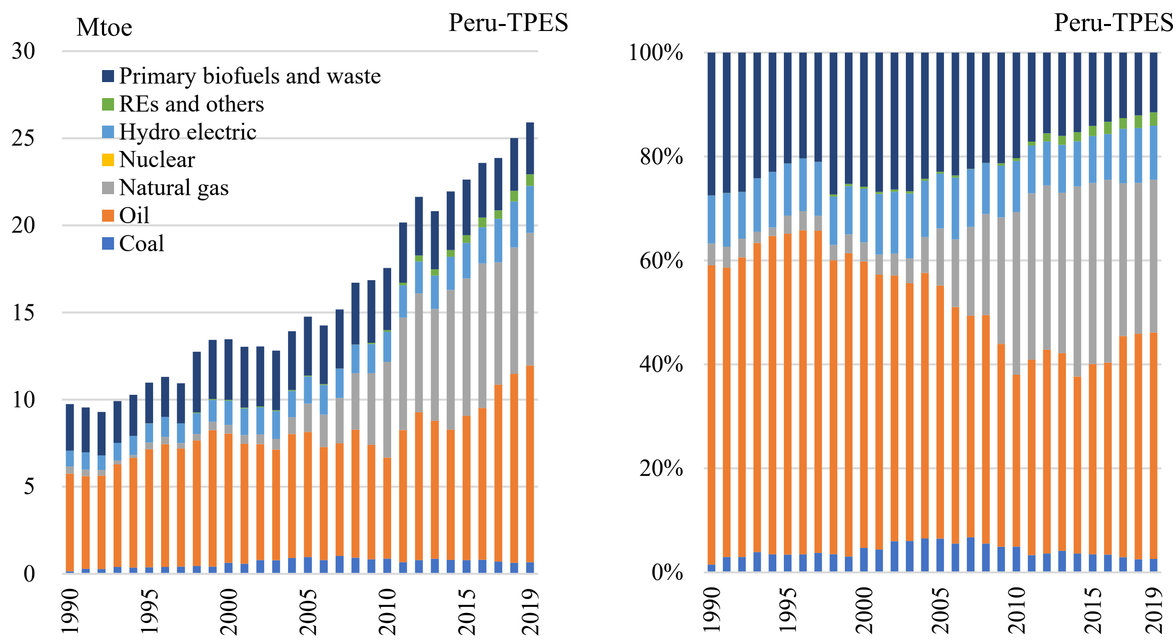


Figure 132 Primay Energy Supply in Peru

Source: World Energy Balances 2021 extended edition database, IEA

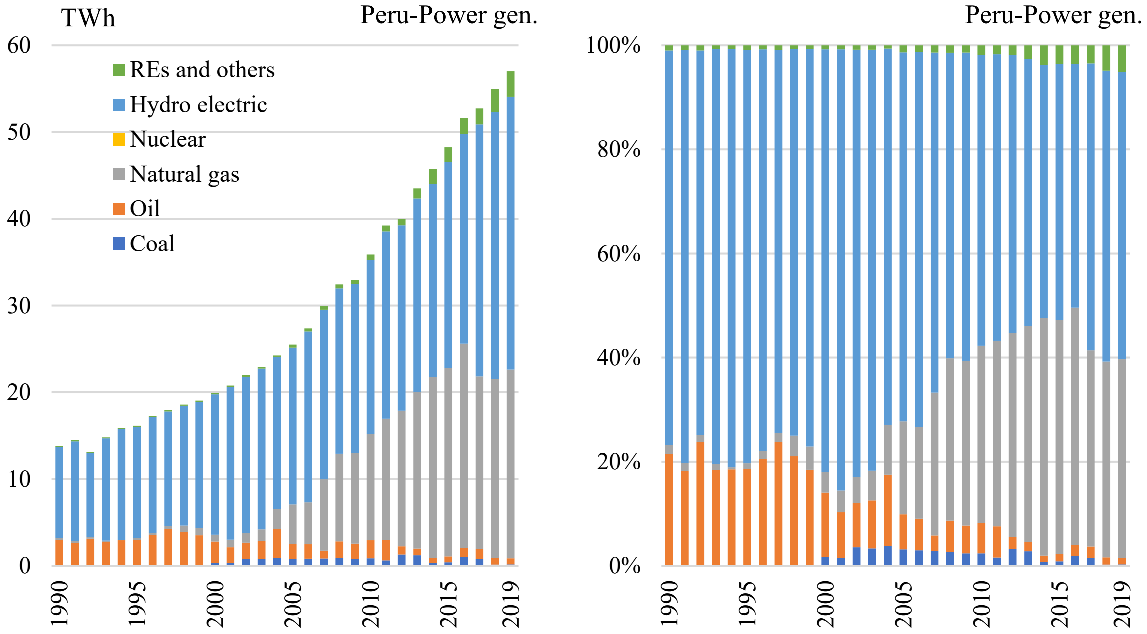


Figure 133 Fuel Mix of Electricity Generation in Peru

Source: World Energy Balances 2021 database, IEA

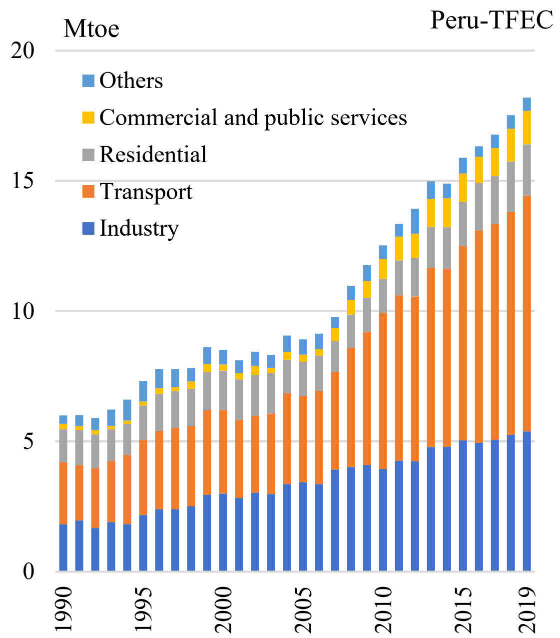
The sectoral breakdown of final energy consumption is 30% for industry, 50% for transportation, 11% for residential, and 7% for commercial/public services in 2019. Namely, the transportation sector consumes the most in 2019. Transportation had the highest five-year growth of 5.8% from 2014 to 2019, followed by housing at 4.1%.

Peru has a low share of fossil fuels due to the lack of developed energy-intensive industries and low demand for heat. The energy with the highest share in Peruvian industry is electricity, with a share of 42% in 2019. In the five years from 2014 to 2019, coal and oil had negative growth, while natural gas and electricity grew at an average annual rate of 6.3% and 5.7%, respectively.

In 2019, the transportation sector's share by energy was 88% for oil, 8% for natural gas, and 4% for ethanol and biodiesel. Currently, Peru is promoting the use of domestically produced natural gas to reduce expensive gasoline imports, and there is a subsidy program for conversion from gasoline-powered vehicles.

In 2019, biomass had the highest share of residential energy at 47%, followed by oil (LPG) at 24%, electricity at 22%, and natural gas at 4%. Looking at the average annual growth rate over the five-year period from 2014 to 2019, the trend of a steady switch from conventional biomass to commercial energy can be read as 32.0% for natural gas and 2.8% for electricity. Although Peru has adopted a policy of replacing expensive imported LPG with domestically produced natural gas, LPG consumption has also increased with an average annual growth rate of 2.5% over the past five years as living standards have improved.

Looking at the share of commercial/public services by energy in 2019, electricity has the highest share at 57%, followed by oil (mainly diesel/gas oil) at 18% and natural gas at 15%. Looking at the five-year growth from 2014 to 2019, the average annual growth rates for electricity, oil, and natural gas are 3.4%, 3.5%, and 1.0%, respectively.


Mtoe
Peru-TFEC
Others
Commercial and public services
Residential
Transport
Industry
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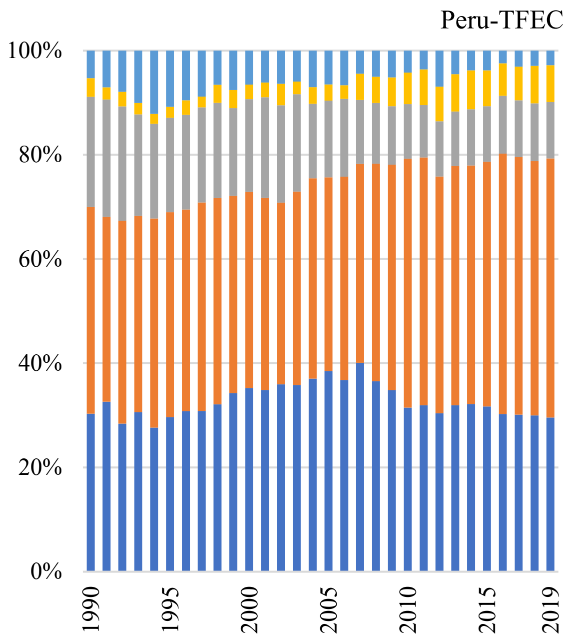
2015
2019


Peru-TFEC
100%
80%
60%
40%
20%
0%
1990
1995
2000
2005
2010
2015
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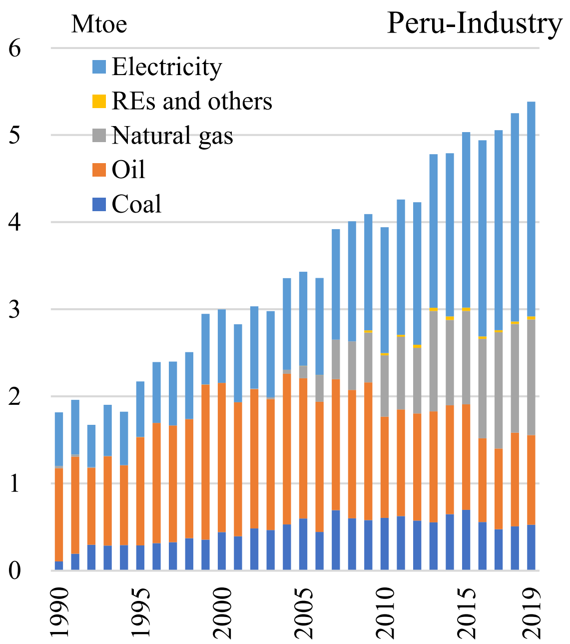
Mtoe
Peru-Industry
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REs and others
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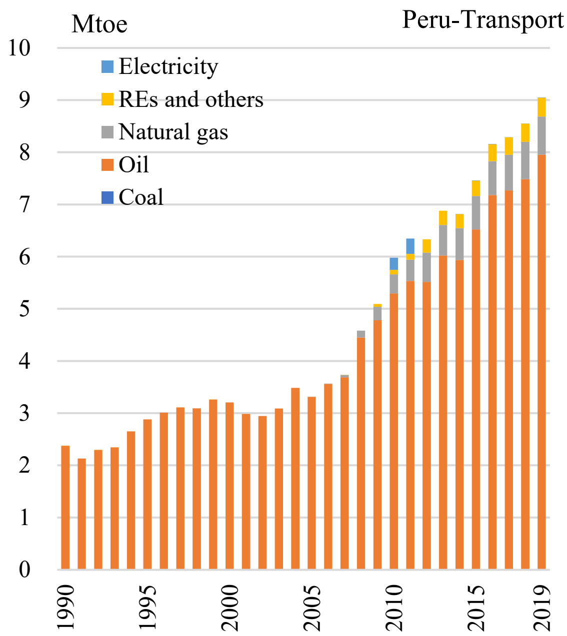
Mtoe
Peru-Transport
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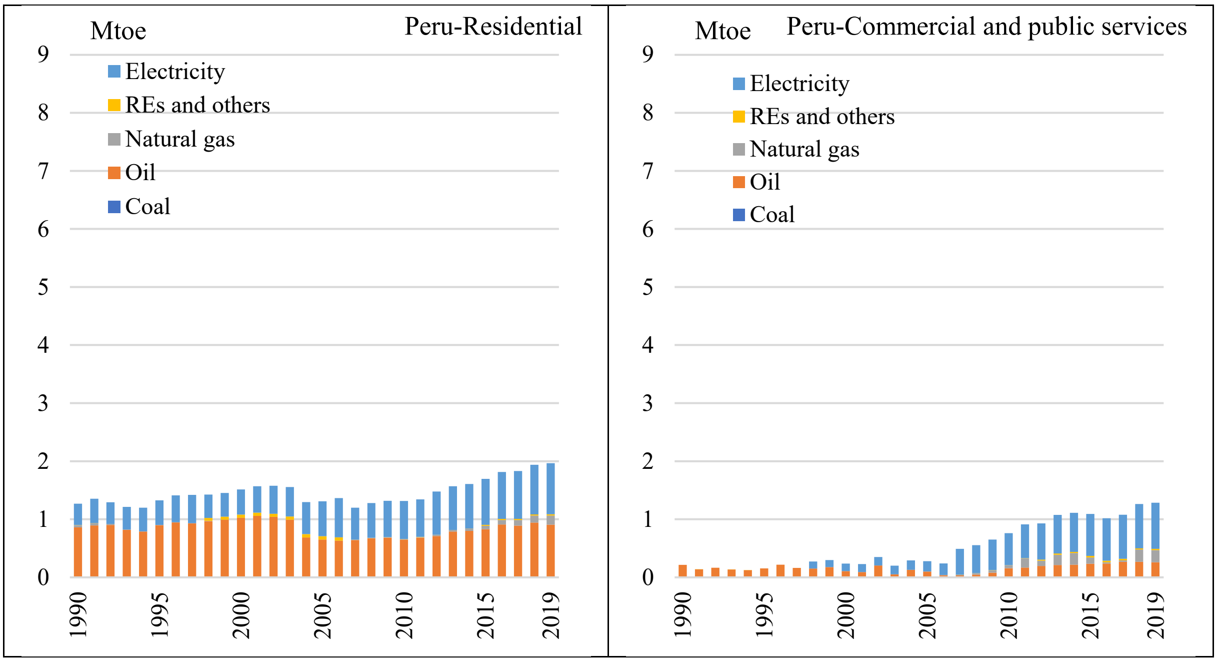

Figure 134 Final Energy Consumption of major Sectors in Peru

Note: Excluding "Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal".
"Others" in TEFC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Peru's primary energy consumption per GDP in 2019 (0.121 toe/$1,000 2015 prices) is about half the average for non-OECD countries (0.264) and close to the average for OECD countries (0.105).

Coal-fired power in Peru is only self-generated and generates little electricity

Natural gas-fired power generation efficiency has been above 40% since the late 2010s, although there was a period of temporary deterioration in the mid-2010s. This is likely due to the fact that Peru's natural gas-fired power plants were built in and after a relatively recent period (late 1990s), resulting in the introduction of relatively high-efficiency equipment.

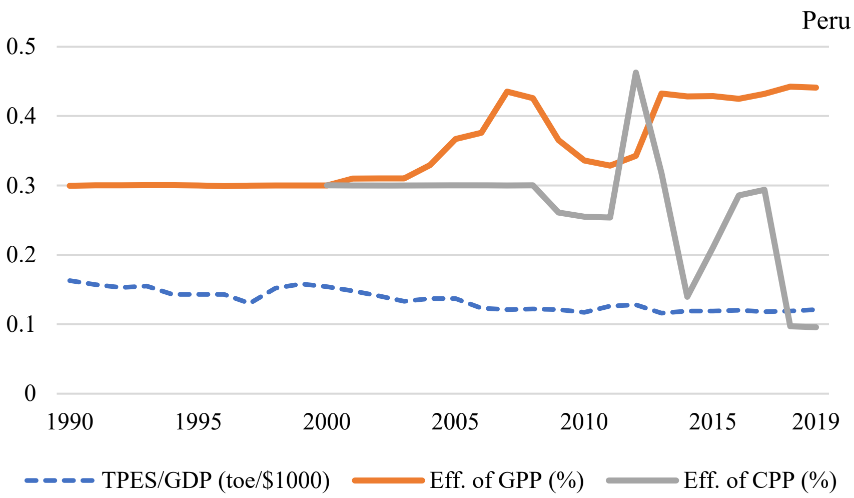

Figure 135 Energy Efficiency in Peru

Note: TPES = Total primary energy supply; Eff. = thermal efficiency; GPP = gas-fired power plant; GDP = 2015 U.S. dollar prices
Source：World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options that could be adopted to reduce Peru's CO_2 emissions in the future and their CO_2 reduction effects.

Table 98 Examples of Low-carbon/ Decarbonization Potential in Peru

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		53.8 mton-CO_2
【Example of CO2 Emission Reduction Option】		【Reduction Effect】
Generation	No option	-
Industry	Substitue 50% of Oil for Natural Gas	0.39 mton-CO_2
Transport	Substitue 25% of Diesel cars for NGV Substitue 50% of Gasoline cars for NGV	9.14 mton-CO_2
Building	Substitue 50% of LPG for Natural Gas	0.13 mton-CO_2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICSA Study Team

(2) Primary energy mix and electricity mix planning

According to the energy demand outlook by APEC, a common characteristic of South American countries is the high share of hydropower in power generation. However, when a drought occurs, the output of hydropower falls and power becomes scarce. For this reason, Peru has increased its share of natural gas-fired power generation as domestic natural gas production has begun.

With regard to primary energy supply, all three scenarios are expected to focus on oil and natural gas, and renewable energy is not projected to increase significantly even in the 2-Degrees Celsius scenario.

In terms of the power generation mix, the BAU and Target scenarios are expected to be dominated by hydropower and natural gas, as in the current situation, while the 2-Degrees Celsius scenario is expected to see a significant decrease in natural gas and an increase in the introduction of renewable energy sources other than hydropower.

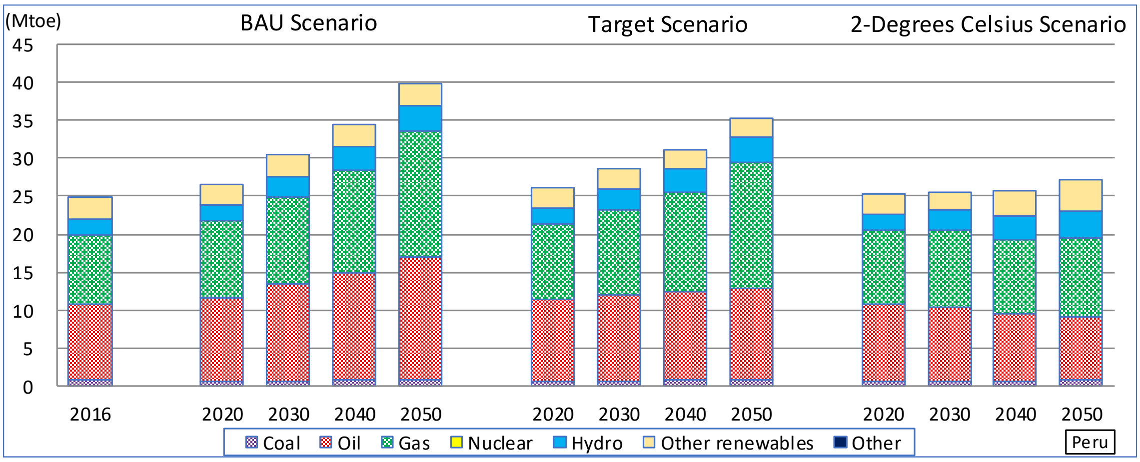

Figure 136 Primay Energy supply Outlook up to 2050 in Peru

Source: APEC Energy Demand and Supply Outlook 7th Edition, May 2019

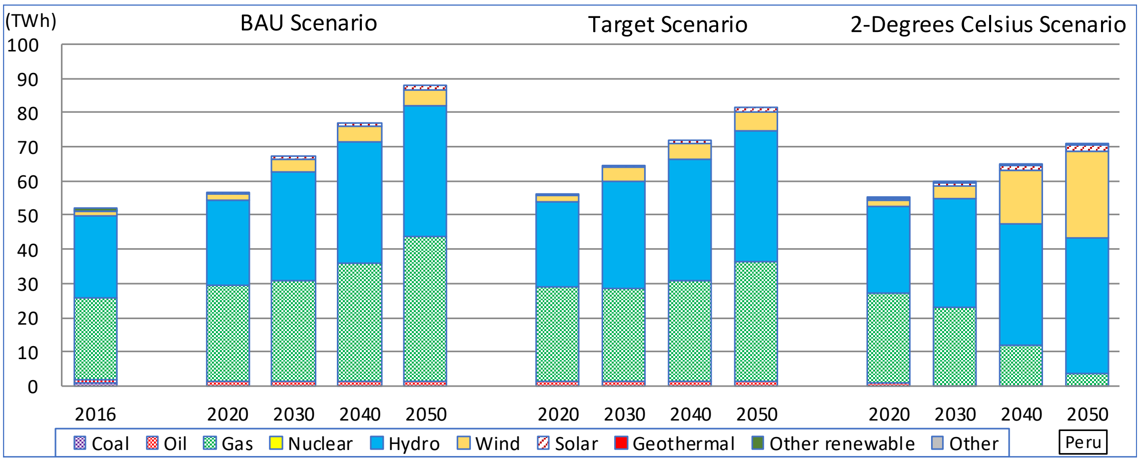

Figure 137 Electricity Generation Outlook up to 2050 in Peru

Source: APEC Energy Demand and Supply Outlook 7th Edition, May 2019

(3) Current status and targets for electricity access (only for countries with low access)

Peru initiated its rural electrification policy in 1992. Each year, policies and electrification projects are reviewed for the next 10 years. The latest version is the Plan Nacional de Electrificación Rural (PNER) 2016-2025, a rural electrification plan approved by the Ministry of Energy and Mines in January 2016. [385]

Peru is using distributed generation with solar panels to increase electrification rates. As of the end of September 2019, 19 rural electrification projects had been completed with an investment of 170.4 billion soles, benefiting 18,000 households and 72,800 people with electricity. More than 160 projects are underway in Peru, and the electrification rate is expected to approach 100% by 2022. [386]

By 2021, the plan is to install PV panels in 100,000 households in areas with high poverty rates and difficulty connecting to the electricity grid.

(b) Electric utility system

(1) Electricity supply system (major players, status of deregulation of power generation, transmission and distribution, etc.)

The framework for the electric utility business in Peru is based on the Electricity Utilities Act of 1992. The law allows private operators to freely enter the market within a competitive and efficient framework. Generation, transmission, and distribution of electricity are separated from each other, making it impossible for the same company to enter multiple sectors.

The law provides for liberalization of pricing in order to introduce the principle of competition in the power distribution business, but also allows for the application of a controlled pricing system if necessary. While power generation and retail are left to free competition, transmission and distribution are subject to price controls in order to protect consumers from oligopoly and increase economic efficiency through the overall optimization of social infrastructure, because of the huge investment costs and economies of scale of the transmission line network, which naturally lead to monopoly status.

Excluding private use, as of 2017, Peru had 81 generating companies, 17 transmission companies, and 23 distribution companies. [387]

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[385] La Republica.pe, 2 January 2016「MEM aprueba Plan Nacional de Electrificación Rural 2016-2025」

[386] Andina, 14 November 2019 https://andina.pe/agencia/noticia-paneles-solares-se-instalarian-colegios-oficinas-y-condominios-773962.aspx

[387] Capitulo 3, 4 and 5, ANUARIO EJECUTIVO DE ELECTRICIDAD 2017

(2) Supply system of renewable electricity

Basically, the bidding is done by the government, and currently the players are mostly Western developers.

There is no wholesale power market and the developer who wins the bid will sign a PPA with the power company.

(c) Policy on renewable energy

(1) Renewable energy potential

Peru's solar energy potential is high on the eastern side of the Andes, especially in the south. Inland is the Amazon rainforest, with little potential or demand. The use of solar energy is just beginning in Peru, where PV panels are being installed in homes, mainly for rural electrification. The southern part of the country has high potential for solar energy, but the central part, around the capital, is the demand area. The southern part has poor energy infrastructure, and transmission capacity needs to be strengthened if large solar power plants are to be built.

Table 99 Solar Power Generation Capacity and Generated Electricity in Peru (2019)

Country		Capacity (MW)		Generation (GWh)	
Peru	Photovoltaic	326	(0.1%)	797	(0.1%)
	Concentrated solar power				
	Total	326	(0.1%)	797	(0.1%)

Note: Share of global market in parentheses
Source: RENEWABLE ENERGY STATISTICS 2020, IRENA

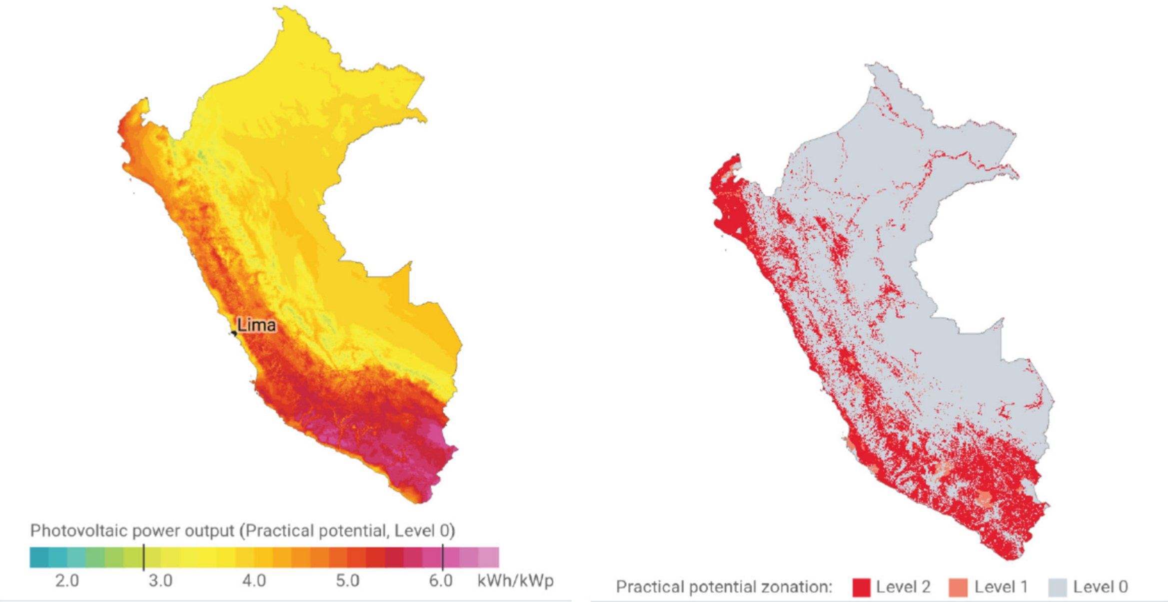

Figure 138 Solar Power Generation Potential in Peru

Note: Left = Estimated power generation
Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints; Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

As shown in the figure below, wind speeds in Peru are not generally fast, and there are only a limited number of areas with fast wind speeds. Wind speeds will be relatively fast in the Andes Mountains, but transmission will be a challenge even if large wind farms are built.

Table 100 Wind Power Generation capacity and Generated Electricity in Peru (2019)

Country		Capacity (MW)		Generation (GWh)	
Peru	Onshore	372	(0.1%)	1,502	(0.1%)
	Offshore				
	Total	372	(0.1%)	1,502	(0.1%)

Note: Share of global market in parentheses
Source: RENEWABLE ENERGY STATISTICS 2020, IRENA

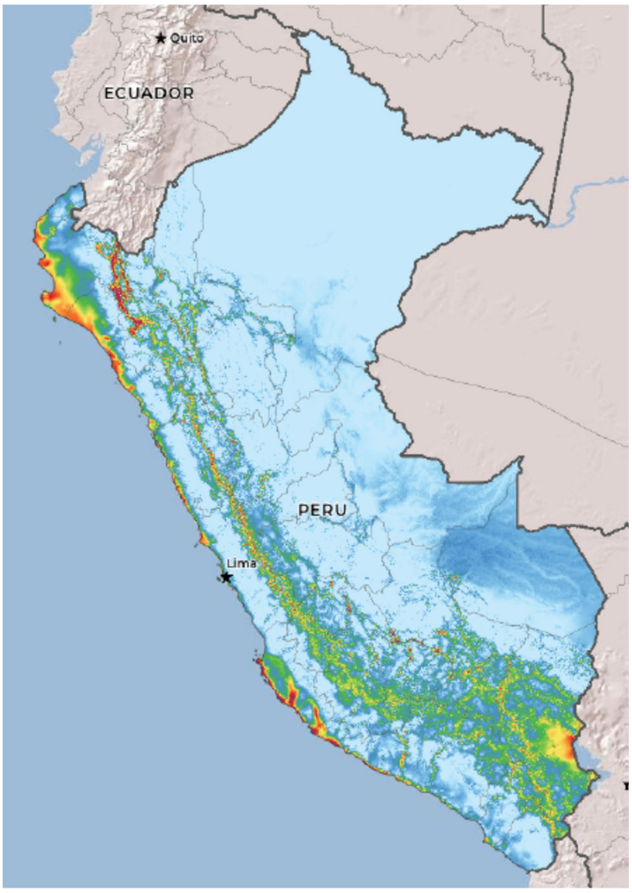

Figure 139 Wind Power Generation Potential in Peru

Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The agency in charge of policy is the Ministry of Energy and Mines.

(3) Development goals

In May 2008, the Law on Promotion of Power Generation from Renewable Energies (Decree) was enacted. Eligible projects include biomass, wind, solar, geothermal, tidal, and small hydropower of less than 20 MW. The main policies are as follows.

- ✓ A target percentage of renewable energy generation, excluding hydroelectricity, will be set every five years, with 5% for the first five years.
- ✓ In renewable energy generation bid, the successful bidder will be guaranteed a fixed price (the price offered in the bid) for the supply to the domestic grid for the term of the supply contract, which can be up to 20 years.
- ✓ Access to the power transmission and distribution network shall be a top priority.

(4) Policies to promote introduction

Tax incentives include accelerated depreciation of up to 20% per year for power generation projects using renewable energy, as well as tax incentives for renewable resources in the Value Added Tax Early Refund Program. [388]

[Biofuel]

Peru enacted a biofuel promotion law in 2003. Peruvian organizations related to biofuels include Proinversion, which created the "Probiocom" biofuel promotion program; the Ministry of Agriculture, which develops agricultural products for biofuel production; the Ministry of Industry, which provides biofuel production equipment; the Ministry of Energy and Mines, which provides product standards for biofuels; the Organization of Supervising for. Investments in Energy and Mines, which is the regulatory and financial institutions.

For gasoline, a 7.8% ethanol blend became mandatory throughout Peru in 2010, and for diesel, a 2% biodiesel blend has been mandatory since January 2009, and a 5% blend since January 2011.

(d) Energy conservation policy

(1) Institutions in charge of policy

In Peru, the Dirección General de Eficiencia Energética (DGEE) has been established within the Ministry of Energy and Mines as the agency in charge of energy conservation policy to develop energy conservation policies and standards (with the Deputy Minister in charge).

(2) Target

Peru enacted the Law on the Promotion of Efficient Use of Energy (Ley N°27345) in September 2000. In July 2006, the Law on the Development of Energy Efficiency and Conservation of Electricity was enacted, in October 2007, the Law on the Regulation of Energy Efficiency and Conservation, and in June 2008, the Revised Standards for Electricity-Using Equipment.

In October 2009, the Ministry of Energy and Mines announced its 2009-18 Energy Conservation Plan, which targets 15% or 60 MW savings over 10 years. This would save $5.291 billion and reduce CO_2 emissions by 35 million tons-CO_2. The specific reduction includes replacing 1 million conventional stoves with more efficient ones, modernizing the lighting in homes, installing solar hot water systems, and installing labeling systems. [389]

In line with the National Energy Policy 2010-2040, published in November 2010, projects in the transportation and household sectors were announced in May 2015.

In April 2016, the Ministry of Energy and Mines announced the launch of an energy efficiency labeling program. Seven items were selected for the first stage: refrigerators, washing machines, dryers, air conditioners, hot water heaters, electric motors, and boilers. [390]

In January 2019, the Ministry of Energy and Mines launched a summer energy conservation campaign for the general public. It aims to spread energy conservation awareness, create a culture that promotes the efficient use of energy, and contribute to climate change mitigation. [391]

In March 2019, the Deputy Minister of Energy and Mines said at a peer review on energy conservation in Peru that the country is currently formulating an energy policy that promotes the efficient use of energy and production within a sustainable development framework with a long-term perspective. The deputy minister said our task is to implement energy-saving labeling. The deputy minister also said energy audits, type approval formats, and evaluation of electric vehicle

[388] Cámara de Comercio e Industria Peruano Japonesa, November 2010

[389] BNamericas, 19 November 2009

[390] Andina, 30 April 2016

[391] Andina, 21 January 2019 https://andina.pe/agencia/noticia-ministerio-energia-y-minas-lanza-campana-para-promover-ahorro-energia-739923.aspx

technologies must be conducted. [392]

(3) Promotion policy

Energy-intensive industries are not as developed as in developed countries, and the transportation sector promotes natural gas vehicles. Therefore, energy savings are mainly targeted at the residential and commercial sectors.

Promotional policies are labeling systems for equipment and buildings, energy conservation publicity and awards.

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

In September 2015, Peru submitted an INDC to the UN in advance of COP21. The points are as follows.

- ✓30% reduction compared to BAU by 2030
  - ✧ Unconditional 20% reduction (in domestic public and private combined investment and spending)
  - ✧ The remaining 10% is contingent on the availability of international financial assistance.

In July 2016, Peru ratified the Paris Agreement.

(2) Promotion policy

The development of the National Adaptation Plan (NAP) began in the fourth quarter of 2015, and 91 adaption measures were launched in March 2020.

The INDC submitted to the UN in September 2015 does not include specific initiatives regarding energy.

(3) Transportation

For Peru, the alternative fuel to oil is domestically produced natural gas, and the country is promoting natural gas vehicles.

In October 2018, the Ministry of Energy and Mines announced a plan to promote the conversion of passenger cars to natural gas specifications through the Social Energy Comprehensive Fund FISE. The program is expected to result in the conversion of 15,000 passenger cars to natural gas vehicles annually in 11 cities, including the capital Lima. The payment of the modification costs announced by the financial institution is in installments of up to 5 years, with an interest rate of 3%, which is significantly lower than the usual 14%-40%. The Ministry of Energy and Mines is working to make natural gas available throughout the entire country.

In October 2020, the Ministry of Energy and Mines and the Urban Transport Authority for Lima and Callao (ATU) signed an agreement to switch urban transit from diesel to natural gas. The government's priority policy of increasing the use of natural gas is now being extended to the transportation sector. The Ministry of Energy and Mines is looking to expand its BonoGas Vehicular program as a means of providing financial support for upgrading engines with light oil specifications to engines using natural gas. In addition, switching from diesel oil to natural gas is expected to reduce fuel costs by more than 50%. The BonoGas Vehicular program allows engine renewal costs to be paid in 5-year installments with an interest rate of less than 1.6%.

(4) Urban development

There is a consortium of 10 institutions called Smart City Perú. ! There are four projects: GLIPS (GeoLocation Interface Position System) & SAVIA (Surveillance and Alarm for gender

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[392] Andina, 19 March 2019 https://andina.pe/ingles/noticia-peru-develops-policy-to-promote-efficient-energy-use-and-production-745877.aspx

VIolence Application), PyMach, SnorUNI and BeeGOns[393].

(f) Next generation technology, innovation
No special note.

(g) Points to consider for future cooperation in promoting low carbon and decarbonization
In Peru, hydroelectric power generation has a share of over 50%, and thermal power generation has a high share of natural gas. Based on IEA statistics, Peru's CO_2 emissions per kWh of electricity generated in 2018 were 0.199 kg-CO_2, which is significantly lower than the global average of 0.504 kg-CO_2. Incidentally, the Stated Policy Scenario, the standard scenario of the IEA's World Energy Outlook 2021, also shows a global average of 0.311 kg-CO_2 in 2040, and the above figure is still low compared to this value. Against this backdrop, there are currently no active low-carbon initiatives.

Peru's basic energy policy is to promote the use of domestic natural gas instead of expensive imported fuels. Therefore, the following cooperation is possible.

- ✓ Promotion of the use of natural gas vehicles, especially LNG trucks
- ✓ Southern Peru has no natural gas pipeline, so LNG is transported by lorry to demand areas in the south to build a city gas network.

(However, this assumes that existing Peru LNG facilities can be used and that LNG can be sold to the domestic market.)

Peru does not have a well-developed energy-intensive industry, and in terms of energy conservation, the labeling system currently in place will be enhanced.

(14) Egypt
(a) Long-term energy policy
(1) Current status of primary energy mix and electricity mix

Egypt has abundant natural gas resources, which are used in many sectors with the exception of transportation. Natural gas production was in serious decline from 2010 to around 2015, putting domestic supply in jeopardy. Therefore, at that time, in addition to emergency evacuation measures such as the suspension of LNG exports, the government took steps to secure the domestic supply of natural gas and to diversify energy supplies by starting LNG imports and developing coal-fired thermal power generation. However, the subsequent development of the large Zohr gas field has led to a rapid recovery in natural gas production, which recovered to a record high in 2018. With the recovery of supply capacity, the position of natural gas as the mainstay of energy supply is expected to remain unchanged in the foreseeable future.

The same is true for power generation. Hydroelectric and oil (diesel engines) used to be primary sources of power generation, but capacity enhancements in response to increased demand for electricity have been centered on gas-fired power generation. However, as of 2019, 13% of the electricity supply is still expensive oil. In addition, demand for petroleum, especially for automobiles, continues to increase. On the other hand, coal use is marginal and renewable energy supplies are increasing but as a small percentage of primary energy supply.

Given this supply structure, the first step toward future low-carbon and decarbonization is to improve the efficiency of oil and natural gas use and to switch fuels from oil to natural gas.

393 http://www.smartcityperu.org

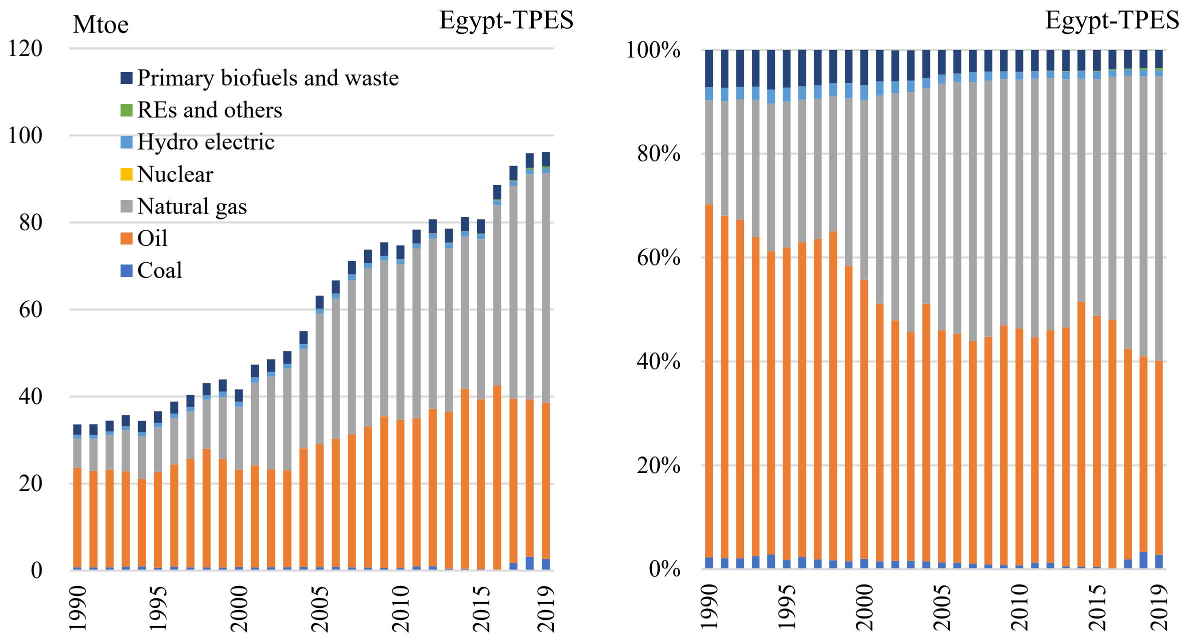


Figure 140 Primar Energy Supply in Egypt

Source: World Energy Balances 2021 extended edition database, IEA

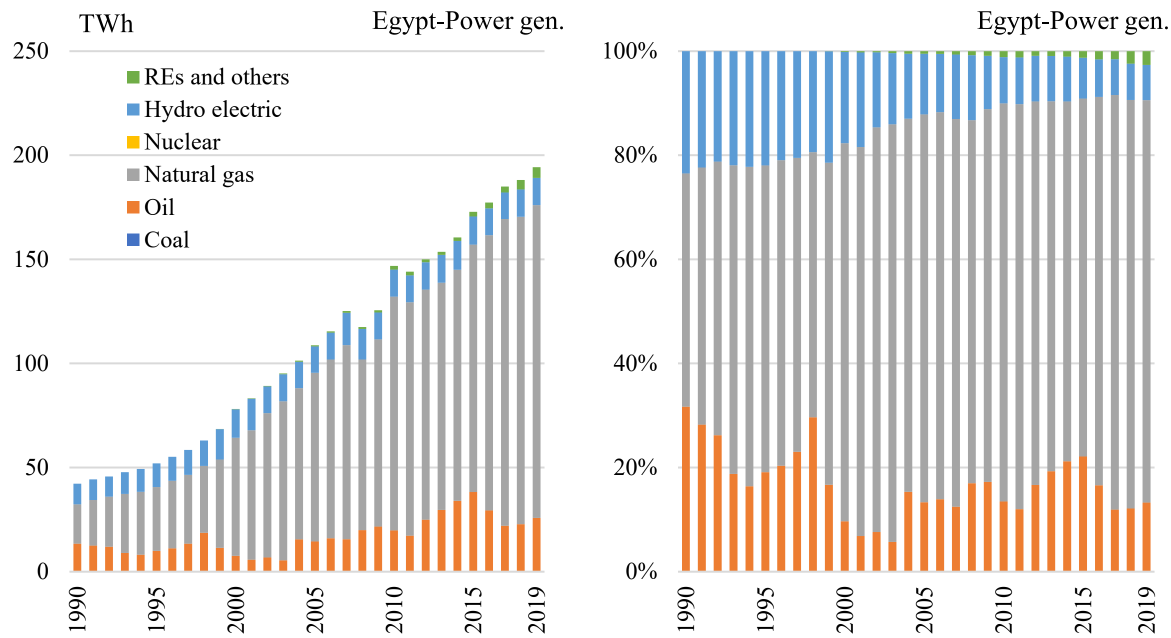


Figure 141 Fuel Mix of Electricity Generation in Egypt

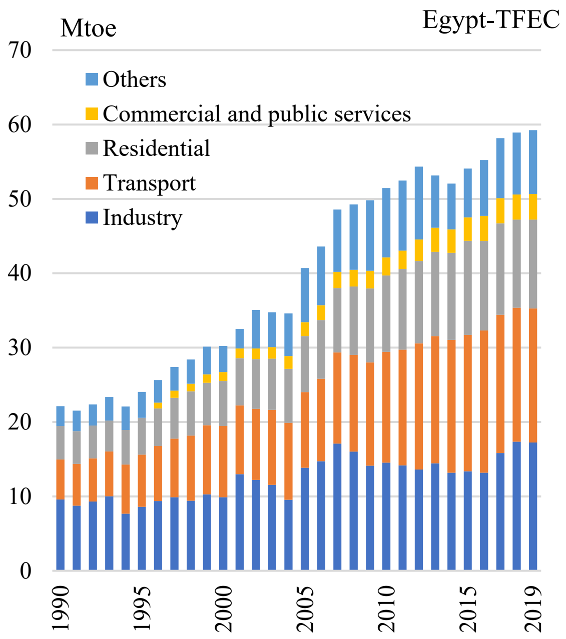
Source: World Energy Balances 2021 database, IEA

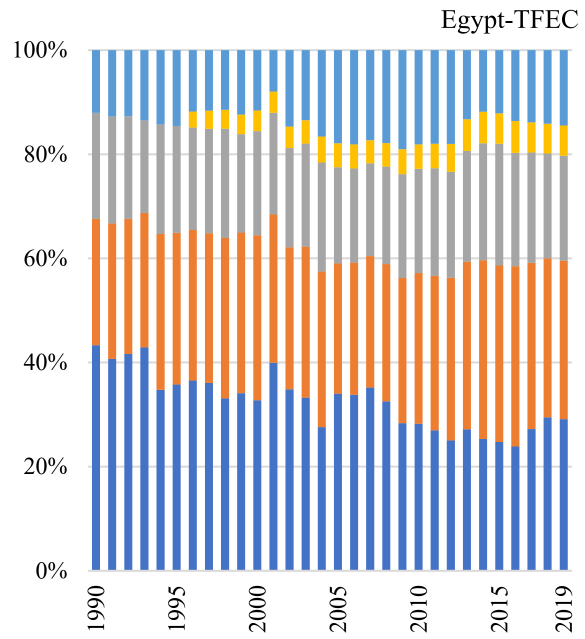
A breakdown of final energy consumption by sector shows that in 2019, industry accounted for 29%, transportation 30%, residential 20%, commercial/public services 6%, and other 14%. Industry had the largest five-year growth from 2014 to 2019 at 3.7%. Transportation, on the other hand, had negative growth for two consecutive years in 2017 and 2018, but began to increase in 2019.

A distinctive feature of the industry is the increased use of coal since 2015. Demand for ceramic soil and stone is increasing rapidly, and this fuel conversion is expected to be one of the key points for low-carbon and decarbonization in the future. In other energy sources, the use of electricity is increasing while that of petroleum is decreasing, which peeks out at the increasing shift of demand to electricity in the industrial sector as well. Assuming that demand will continue to trend toward electric power, it is essential that electricity be low-carbon and decarbonized.

In the transportation sector, 98% is oil and the remaining 2% is natural gas (2019). Although higher prices for petroleum products due to the elimination of subsidies are likely to suppress demand to some extent, economic growth and rising incomes are likely to increase the use of automobiles in the future. In addition, non-automotive energy consumption is very small, and both logistics and passengers are highly dependent on automobiles. In addition to various measures to improve fuel efficiency of automobiles, the transportation sector must realize low carbon and decarbonization by expanding the use of vehicles fueled by natural gas and electricity, and by increasing the share of intra- and inter-city travel by public transportation.

Residential and commercial/public services use electricity the most, at 39% and 100% respectively (both in 2019). Traditionally, LPG has been used for heat supply, but this is gradually declining, and conversely, the use of natural gas is increasing. Since LPG is highly dependent on imports and expensive, while natural gas is self-sufficient, it can be inferred that policy is encouraging a switch from LPG to natural gas. In order to realize low carbon and decarbonization of the heat supply of buildings from the current status, the carbon intensity of electricity needs to be significantly reduced, and high-efficiency heat pumps need to be installed. Both of these measures require time and money, and direct combustion of natural gas is expected to be a realistic option for the time being.





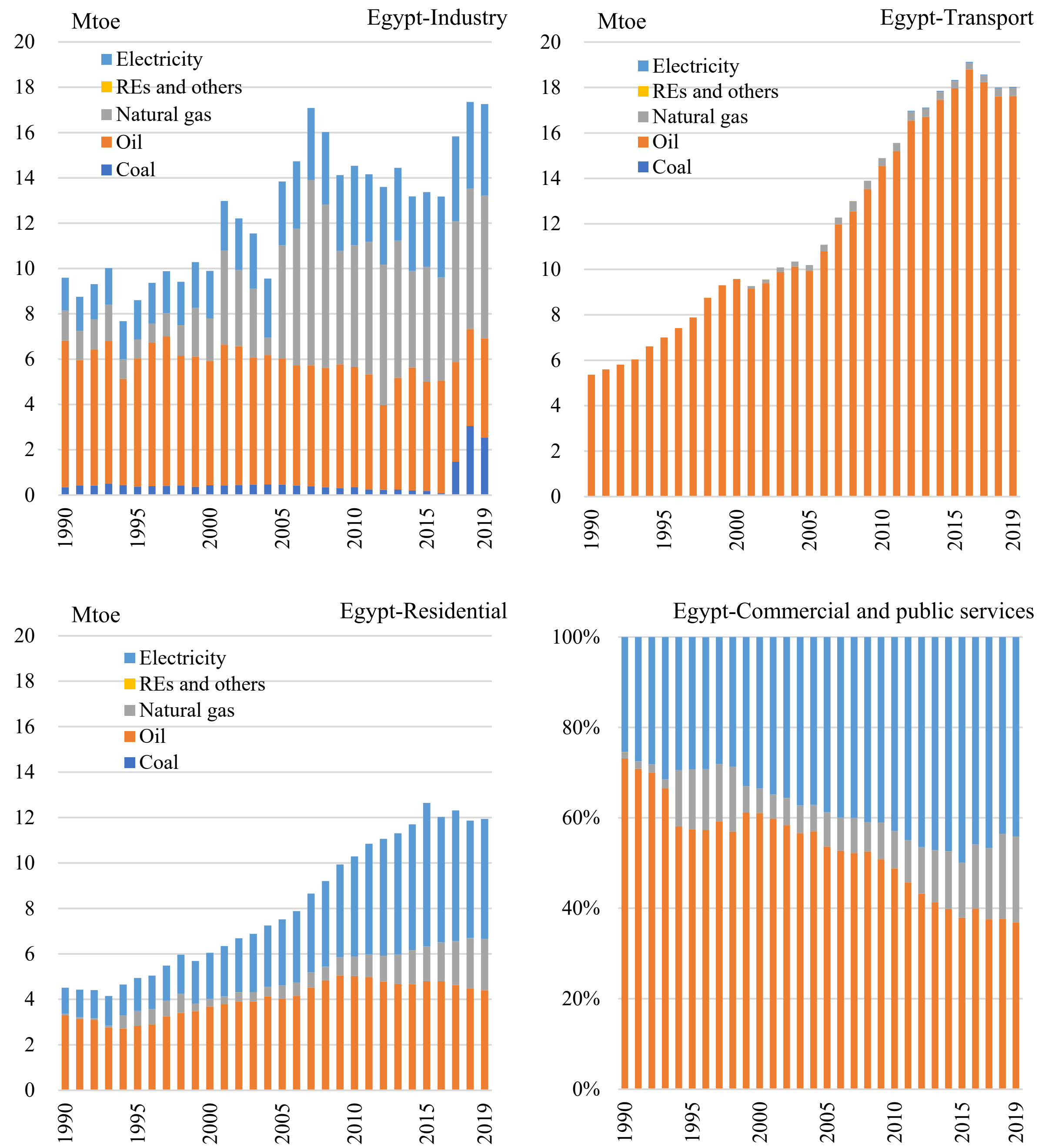


Figure 142　Final energy Consumption of major sectors in Egypt

"Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal" are excluded.
"Others" in TEFC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP has not changed significantly since the 1970s, remaining around 0.25 toe/$1,000 (2015 prices) and was 0.239 in 2019 (0.090 in Japan). This indicates that Egypt is not making progress in decoupling economic growth from energy consumption, i.e., improving energy efficiency.

The average thermal efficiency of gas-fired power is just over 40%. The thermal efficiency of state-of-the-art CCGTs exceeds 60% (LHV), and CO2 emissions can be reduced by replacing aging thermal power. If conditions are right, cogeneration could also be utilized.

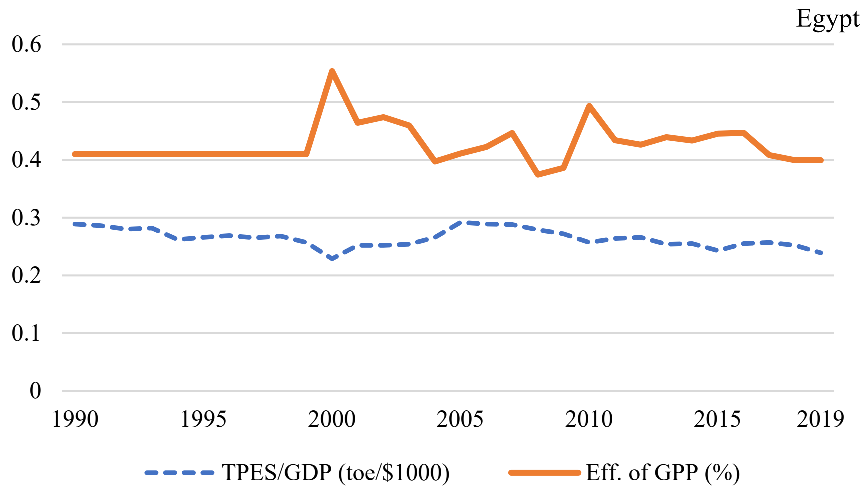


Figure 143 Energy Efficiency in Egypt

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant
GDP in 2015 price
Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options that could be adopted to reduce CO2 emissions in Egypt in the future and their CO2 reduction effects.

Table 101 Examples of Low-carbon/ Decarbonization Potential in Egypt

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		227.6 mton-CO2
【Example of CO2 Emission Reduction Option】		【Reduction Effect】
Generation	Substitue 50% of Oil for Natural Gas	6.08 mton-CO2
Industry	Substitue 100% of Coal and 75% of Oil for Natural Gas	11.71 mton-CO2
Transport	Substitue 20% of Dioesel cars and 20% of Gasoline cars for NGV	5.59 mton-CO2
Residential	Substitue 75% of LPG for Natural Gas	0.96 mton-CO2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICA Study Team

(2) Primary energy mix and electricity mix planning

Egypt's policy is to maximize the use of its domestic resources and is looking to expand the role of natural gas in all sectors. For example, Minister of Energy El Molla has issued a policy that aims to expand the use of CNG vehicles.

In addition, the Sustainable Development Strategy: Egypt Vision 2030, published in 2016, sets the following goals. The "Integrated Sustainable Energy Strategy to 2035," also released in 2016, sets a target of 42% renewable energy, 3% nuclear, and 55% thermal for the 2035 electricity mix.[394]

However, the environment surrounding natural gas supply and demand has changed significantly between the time these targets were established (natural gas supply shortages) and today (abundant production), and the reliability of the power mix targets should be viewed with caution.

[394] New and Renewable Energy Authority, http://nrea.gov.eg/test/en/About/Strategy

Table 102 Key Performance Indicators for Energy to 2030 in Egypt

Indicator	Current/ Base year	2030
Ratio of primary energy supply to the total planned energy consumption	-	100%
Average duration of outages	-	0
Percentage change in energy intensity	0.65 (2010)	-14%
Contribution of energy sector to GDP	13.1% (2013)	25%
Percentage decline in GHG emissions from the energy sector	-	-10%
Crude oil reserves (years)	15 (2014)	15
Natural gas reserves (years)	33 (2014)	33
Efficiency of electricity production	41.3% (2014)	-
Efficiency of electricity transmission and distribution	15% (2014)	8%
Percentage of residential, commercial, and industrial buildings connected to electricity	99% (2014)	100%
Percentage of primary fuel mix	Gas/ Oil/ RE/ Coal/ Hydro 53%/41%/1%/2%/3%	-
Percentage of fuel mix for electricity production	Gas & Oil/ Hydro/ RE 91%/8%/1%	Gas & Oil/ Hydro/ RE/ Coal/ Nuclear 27%/5%/30%/29%/8%
Value of fuel subsidy	LE 126.2 billion in 2013-2014)	0
Efficiency of transportation and distribution of petroleum products	-	-

Source: "Sustainable Development Strategy: Egypt's Vision 2030", Ministry of Planning

(b) Electric utility system

(1) Electricity supply system (major players, status of deregulation of power generation, transmission and distribution, etc.)

Egypt's electricity industry consists of six power generation companies, one transmission company, and nine distribution companies under the umbrella of the Egyptian Electricity Holding Company (EEHC), the state-owned electricity company. IPPs are allowed to participate in power generation, while a monopoly is maintained for transmission and distribution.

(2) Supply system of renewable electricity

There are three types of renewable electricity: those directly invested by the New and Renewable Energy Authority, those procured from the private sector through FIT, and those procured from the private sector through competitive bidding. The renewable electricity procured through the FIT will be purchased by EETC (Egyptian Electricity Transmission Company) or distribution companies.

(c) Policy on renewable energy

(1) Renewable energy potential

All the land receives good sunlight and has great potential for photovoltaic power generation. However, geographic and institutional constraints limit the areas that can be developed. The potential of the Sinai Peninsula is also inferred to have little actual development potential, given the distance to the demand areas.

The northern area with large cities has poor wind conditions, but in the south and along the Red

Sea coast, wind power generation is prevalent. Therefore, the development will also require an increase in transmission lines.

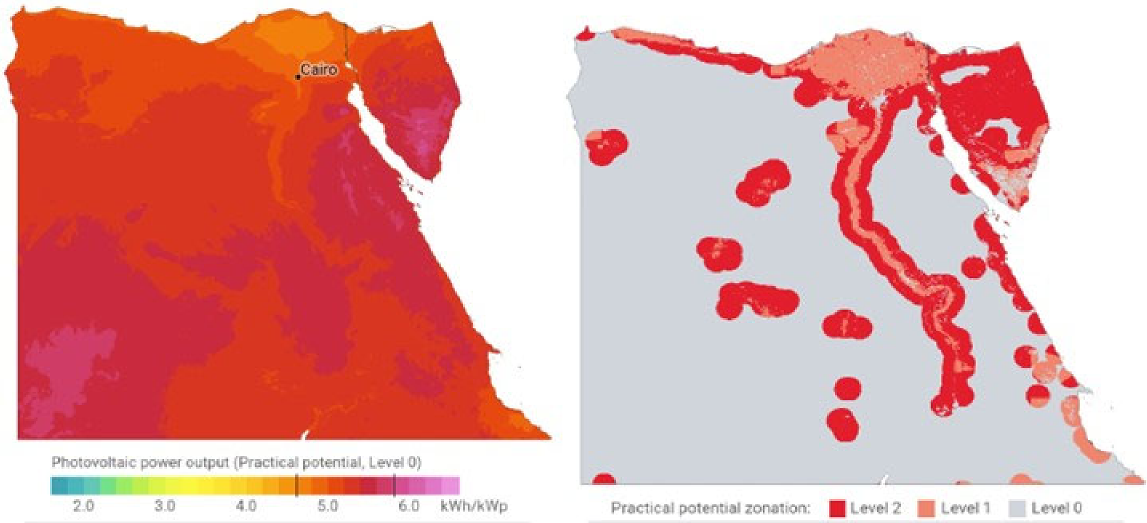


Figure 144　Solar Power Generation Potential in Egypt

Note: Left = Estimated power generation
Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints; Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

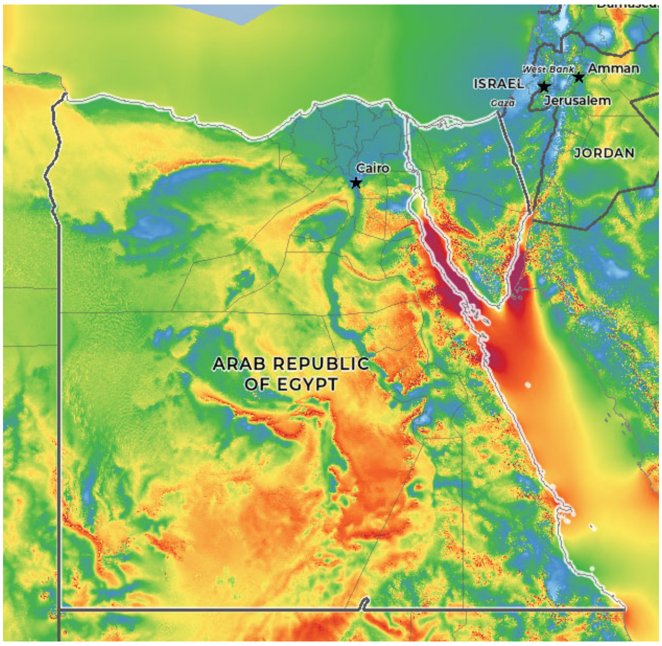


Figure 145　Wind Power Generation Potential in Egypt

Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

Ministry of Electricity and Renewable Energy is in charge.

(3) Development goals

The Integrated Sustainable Energy Strategy to 2035 sets targets for the share of renewable energy in electricity supply to be 20% by 2022 and 42% by 2035. The 2035 target consists of 22% solar PV, 14% wind, 3% solar thermal (CSP), and 2% hydro.

(4) Policies to promote introduction

Several institutional changes have been made to expand the use of renewable energy [395].

June 2012	Permitted third-party access to the power grid for IPP projects using renewable energy.
January 2013	Net metering system is applied to small solar power generation.
September 2013	Mandated the purchase of renewable electricity for energy-intensive industries. (Started 2015. 1% of electricity consumption)

In September 2014, feed-in tariffs (FIT) for solar and wind power began. Larger projects will be purchased in U.S. dollars. [396] The second phase of PV and wind FIT was announced in 2016 [397].

	Maximum purchase amount	Purchase period
Solar/thermal	2,300 MW	25 years
wind power	2,000 MW	20 years

(d) Energy conservation policy

(1) Institutions in charge of policy

Ministry of Electricity and Renewable Energy is in charge. Under the National Energy Efficiency Action Plan II, each ministry and agency is developing its institutional structure to promote energy conservation[398].

(2) Target

The Sustainable Development Strategy: Egypt's Vision 2030 outlines a goal of reducing energy consumption per unit of GDP by 14% from 2010 by 2030.

(3) Promotion policy

The following policies can be identified.

- The Electricity Law No. 87 of 2015 provides for energy conservation and demand management to conserve resources and economically supply electricity.
- Egyptian Electricity Holding Company states that it will reduce its investment in power generation equipment by increasing energy efficiency, especially in the lighting sector (replacement with LED lighting).
- \- In 2017, NEEAP-II was approved by the government, and NEEAP-II complies with the Integrated Sustainable Energy Strategy to 2035 (adopted in 2016). NEEAP-II also sets out to enforce the provisions of Electricity Law No. 87 of 2015 and its Executive Regulations related to energy efficiency improvements.
- NEEAP-II sets out mechanisms for securing funding for energy efficiency projects through EEF and a Credit Risk Guarantee Mechanism. NEEAP-II adopts necessary measures to ensure energy efficiency in both supply and demand side.[399]

[395] New & Renewable Energy Authority, Annual Report 2012/2013

[396] Egyptian Electricity Holding Company, Annual Report 2014/2015

[397] http://auptde.org/Article_Files/Egypt.pdf

[398] JICA is currently providing support on energy conservation capacity building to the Ministry of Electricity and Renewable Energy, the Ministry of Petroleum and Mineral Resources, the Ministry of Industry, and the Central Agency for Public Mobilization and Statistics. (Project title: The Project for Capacity Development on Energy Efficiency and Conservation)

[399] Second: National Energy Efficiency Action Plan (NEEAP), https://sustainableenergyegypt.com/wp-

A labeling system for air conditioners has been introduced, however, there is a double standard of inverters and non-inverters from the perspective of protecting local businesses, resulting in low-efficiency non-inverters being used for 90% of air conditioners.

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

The NDC does not include a numerical target for reduction, but lists the following actions as reduction efforts.

- Improved energy efficiency, particularly in the final consumption sector
- Expansion of use of renewable energy
- Use of more efficient fossil energy technologies
- Energy subsidy reform

(2) Promotion policy

It aims to reform energy subsidies that remove incentives to conserve energy. In petroleum products, subsidies have been phased out and are now linked to international prices, which are adjusted quarterly. Electricity subsidies are scheduled to be completely eliminated by FY2025.

(3) Transportation

The company is focusing on promoting CNG vehicles that use domestically produced natural gas.

(4) Urban development

Egypt is building a new capital city near Cairo. Some reports [400] have described this as Egypt's first smart city, but the actual situation is unclear.

(f) Next generation technology, innovation

Within the INDC, CCS and next-generation reactors are listed as technologies that may be applied in the future. Egypt has oil fields, which could make CCS economically viable when combined with enhanced recovery through CO2 injection.

In addition, studies have begun to look into the future utilization of hydrogen. In May 2021, the Prime Minister directed the Minister of Petroleum and Mineral Resources and the Minister of Electricity and Renewable Energy to develop a green hydrogen strategy. [401]

(g) Points to consider for future cooperation in promoting low carbon and decarbonization

- The energy saving potential is great and measures should be strengthened. Possible countermeasures include the following.
  - Development of energy efficiency benchmarks for the energy conversion and industrial sectors
  - Introduction of energy management in energy-heavy industries
  - Introduction of fuel efficiency standards for automobiles
  - Improvement of public transportation network and suppression of car use
  - Introduction of building insulation standards
  - Introduction of minimum efficiency standards for equipment
  - Expansion of equipment subject to labeling system
- We assume that there is a high level of interest in the highly efficient use of natural gas

content/uploads/2020/07/The-National-Energy-Efficency-Action-Plan-II.pdf

400 ZD Net, January 28, 2020, https://www.zdnet.com/article/egypts-building-a-new-capital-inside-the-smart-city-in-the-desert/

401 Egypt Oil &Gas, May 5, 2021, https://egyptoil-gas.com/news/petroleum-electricity-to-draft-green-hydrogen-strategy/

(CCGT) and the expansion of its use (in power generation, industry, CNG vehicles, stationary FC) not only for low carbon and decarbonization, but also to contribute to energy security and maximize foreign currency earnings through LNG exports. Reductions from fuel conversion in the industrial sector are expected to be particularly large, and conversion from coal and oil to natural gas is promising.

- In renewable energy, solar power generation is advantageous because it can be developed adjacent to demand areas.
- Demonstrations could include zero-emission LNG, blue hydrogen, and blue ammonia using CCS potential, and green hydrogen from PV, which could be of interest.

(15) Morocco

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

With the exception of a small amount of natural gas (less than 10% self-sufficiency), Morocco relies on imports for the majority of its fossil energy supply. Primary energy supply lacks diversity, with a structure based on two main types of energy: oil, which is heavily used in all end-use sectors, and coal for power generation. Traditional biomass, although not abundant, is still being used, and its gradual conversion to commercial energy will be a factor in boosting future energy demand. Renewable energy use is increasing, but together with hydropower it is not large, at 3% of primary energy supply.

The use of inexpensive coal-fired power is increasing in power generation, accounting for 65% of the electricity supply in 2019. Renewable energy (excluding hydro) was the fastest growing, increasing at a high average annual rate of 18.6% for the five years from 2014 to 2019, to account for 18% of electricity supply in 2019. On the other hand, petroleum (heavy oil and diesel), natural gas, and hydropower are on the decline. From a low-carbon perspective, the expansion of natural gas power generation and hydropower is desirable, but this has not been the case for about a decade. It can be inferred that the development of coal-fired power plants is prioritized for the purpose of lowering the cost of power generation.

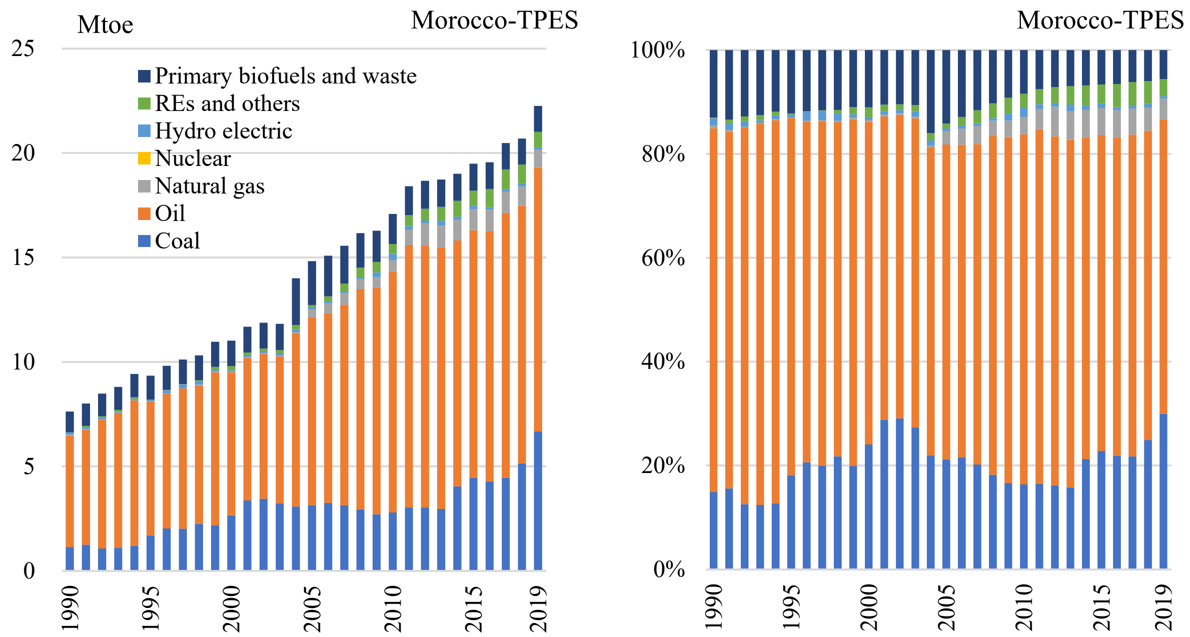


Figure 146 Primary Energy Supply in Morocco

Source: World Energy Balances 2021 extended edition database, IEA

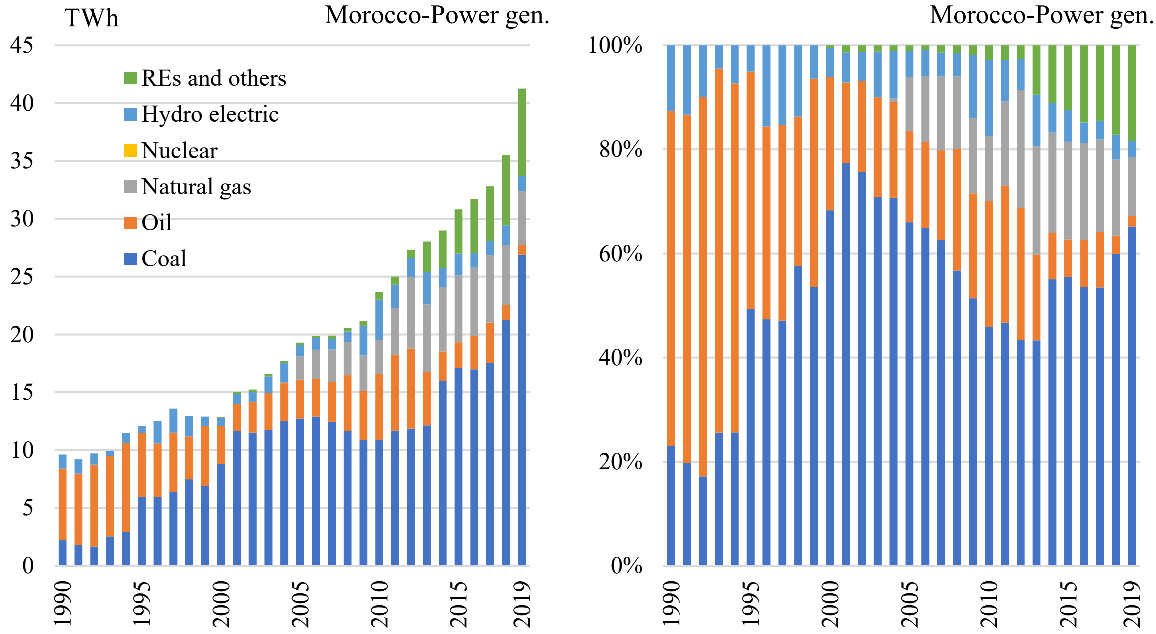


Figure 147 Fuel Mix of Electricity Generation in Morocco

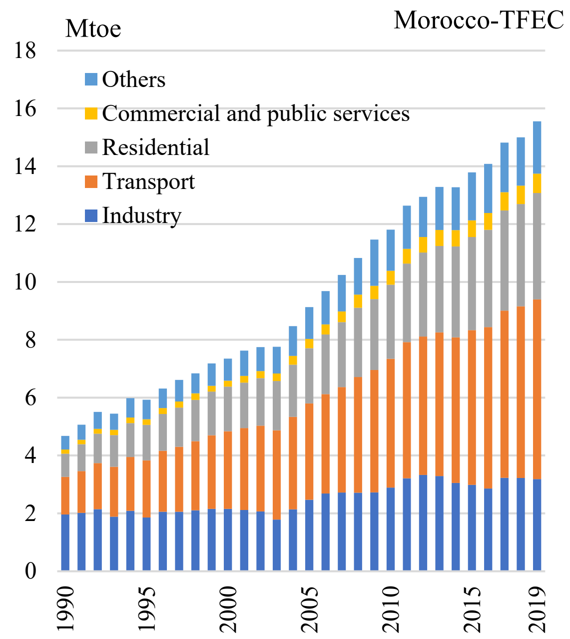
Source: World Energy Balances 2021 database, IEA

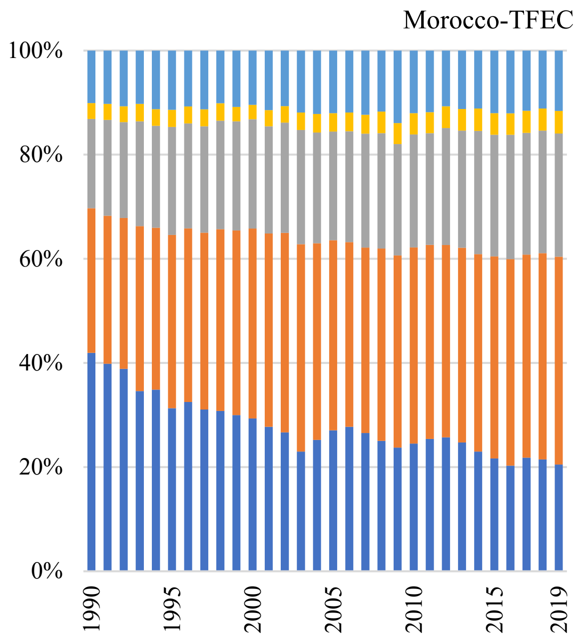
In terms of final energy consumption by sector, transportation is the largest at 40% (2019), residential (24%) and industrial (20%) are about equal, commercial/public services is 4%, and others is 12%. In terms of growth over the past five years (2014-2019), transportation again shows the strongest growth here, averaging 4.3% per year, followed by commercial/public services at 3.4% and residential at 3.2%. Conversely, industry growth was low, averaging 0.9% per year.

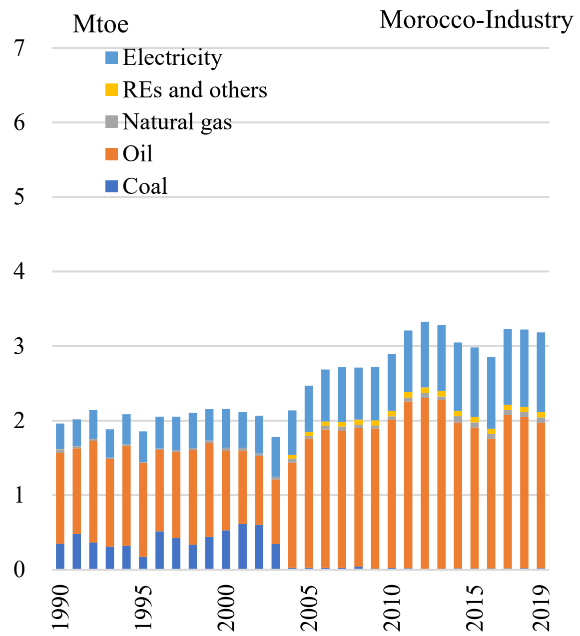
The industrial sector uses the most oil, accounting for 61% (2019). However, demand has been declining, averaging -0.1% per year for the five-year period from 2014 to 2019. Electricity (33%) is the next most used source, with a steady growth rate of 3.1% per year on average over the same period. Demand for electricity is expected to increase further in the future. From a low-carbon perspective, oil should be converted to natural gas. However, expanding the use of natural gas will require strengthening supply infrastructure such as pipelines, which are currently imagined to be in their infancy.

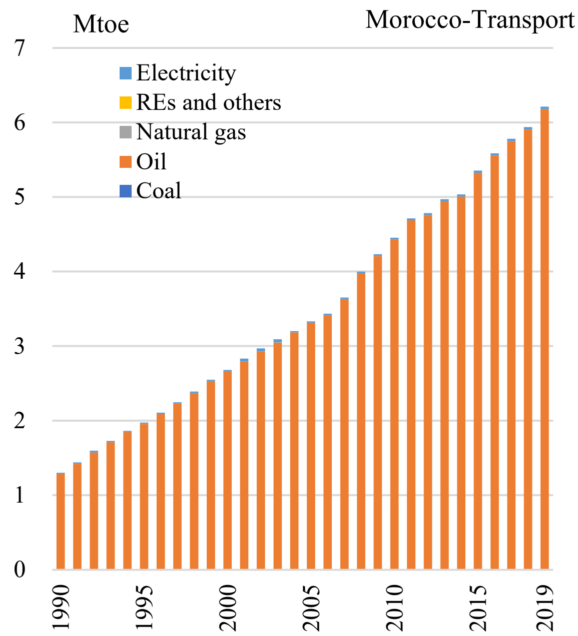
In the transportation sector, oil accounts for 99% and electricity for the remaining 1% (2019). The demand for automobile oil is growing fast and will become a risk factor for Morocco's energy and climate if measures are not taken to improve the fuel efficiency of automobiles as well as the introduction of alternative fuel vehicles and measures to improve public transportation and encourage modal shifts.

Residential energy consumption is 64% oil (LPG) and 23% electricity (2019). Growth over the past five years between 2014 and 2019 has been strong for both, with oil averaging 3.3% per year and electricity averaging 2.9% per year. Although not shown in the figure, there is still 0.5 Mtoe of traditional biomass use as of 2019, albeit on a gradually decreasing trend. Therefore, there is no doubt that commercial energy consumption in this sector will increase in the future. In terms of low-carbon emissions, conversion of LPG to natural gas can provide reduction benefits, but the effects are not large and should be considered in light of infrastructure development costs and natural gas prices. Alternatively, if the development of renewable energy sources in the future leads to a significant decrease in the CO_2 emissions intensity of electric power, then conversion to electric power could be considered.


Mtoe
Morocco-TFEC
Others
Commercial and public services
Residential
Transport
Industry
18
16
14
12
10
8
6
4
2
0
1990
1995
2000
2005
2010
2015
2019


Morocco-TFEC
100%
80%
60%
40%
20%
0%
1990
1995
2000
2005
2010
2015
2019


Mtoe
Morocco-Industry
Electricity
REs and others
Natural gas
Oil
Coal
7
6
5
4
3
2
1
0
1990
1995
2000
2005
2010
2015
2019


Mtoe
Morocco-Transport
Electricity
REs and others
Natural gas
Oil
Coal
7
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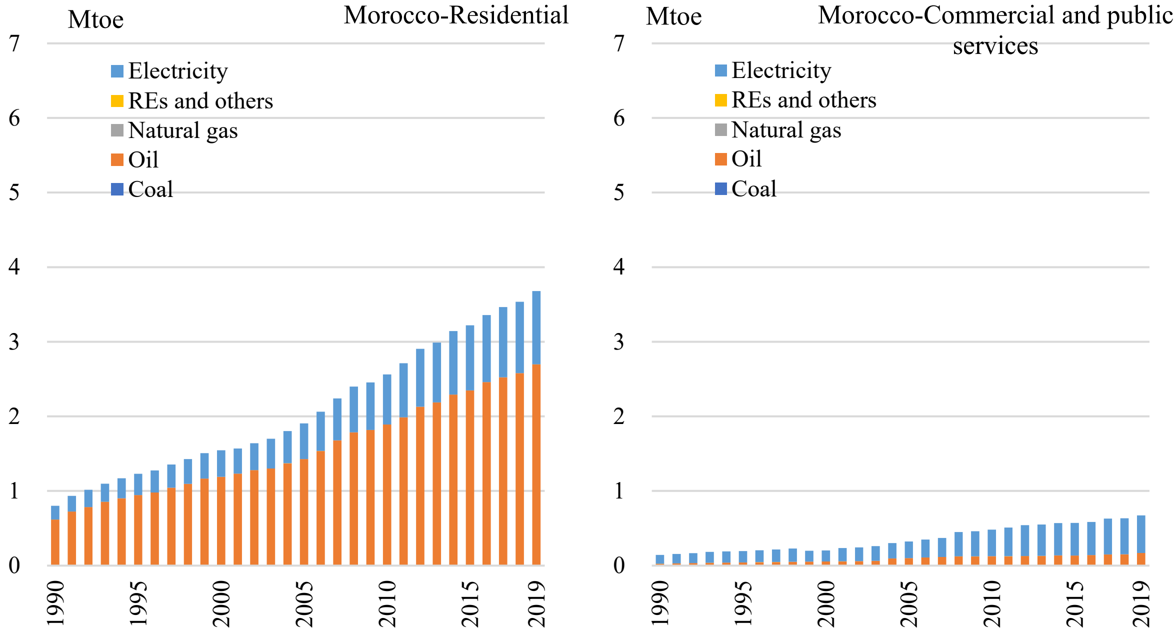

Figure 148 Final Energy Consumption of Major Sectors in Morocco

"Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal" are excluded.
"Others" in TEFC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP has changed little since the 1990s and was 0.198 toe/\$1,000 (2015 prices) in 2019 (0.090 in Japan). This value is the same or higher than the level before Japan experienced the oil crisis, indicating that there is much room for efficiency improvement.

Average power generation efficiency is not bad, with natural gas at over 50% and coal at just under 40%. This may reflect the fact that many of the generating facilities are relatively new. Conversely, there is not much room for improvement in CO_2 intensity by increasing power generation efficiency. Therefore, in order to lower CO_2 emissions from electricity, it is important to replace coal-fired power with lower-carbon sources.

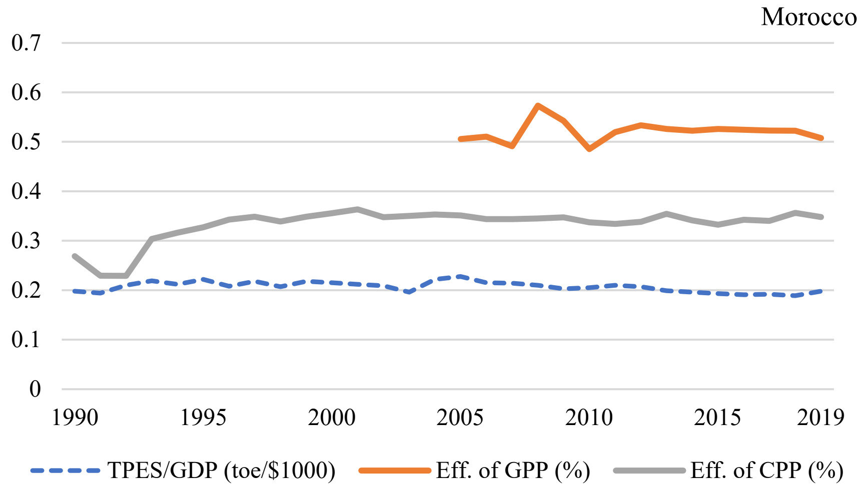

Figure 149 Energy Efficiency in Morocco

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant
GDP in 2015 price
Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options that could be adopted to reduce Morocco's CO_2 emissions in the future and their CO_2 reduction effects.

Table 103 Examples of Low-carbon/ Decarbonization Potential in Morocco

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		66.9 mton-CO2
【Example of CO2 Emission Reduction Option】		【Reduction Effect】
Generation	Substitue 50% of Coal for Natural Gas	7.79 mton-CO2
Industry	Substitue 50% of Oil for Natural Gas	0.87 mton-CO2
Transport	10% Improvement of Fuel Mileage	1.89 mton-CO2
Residential	10% Improvement of Energy Efficiency	0.99 mton-CO2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICA Study Team

(2) Primary energy mix and electricity mix planning

The plan is to promote the introduction of new energy sources in order to reduce dependence on fossil energy. The project is expected to build 10.1 GW of power sources at a cost of approximately $40 billion between 2016-2030, avoiding more than 30% greenhouse gas emissions.

Table 104 Outlook of Fuel Mix of Electricity Generation in Morocco

	2015	2020	2025	2030
Coal	32%	40%	32%	20%
Oil	24%	11%	5%	3%
Gas	11%	5%	16%	25%
Hydro	22%	14%	13%	12%
Solar	2%	14%	16%	20%
Wind	10%	15%	18%	20%

Sourcer: Ministry of Energy, Mines and Environment[402] (Current Ministry of Energy Transition and Sustainable Development)

(b) Electric utility system

(1) Electricity supply system (major players, status of deregulation of power generation, transmission and distribution, etc.)

The power generation business is open to private companies other than the Office National de l'Electricité et de l'Eau potable (ONEE, Moroccan electricity and water corporation). ONEE has a monopoly in the power transmission business. In addition to ONEE's distribution arm, there are seven private distribution companies under contract with local governments and four public distribution companies operated by local governments.

(2) Supply system of renewable electricity

As far as can be confirmed, the renewable energy projects are procured from the private sector on a BOOT (Build Own Operate Transfer) basis through a bidding process conducted by the Moroccan electricity and water corporation ONEE.

402 Speech by the Ministry of Energy, Mines and Environment on January 28-29, 2016, http://www.mem.gov.ma/SiteAssets/Dicsours/Discours2016/London%20speech%20English.pdf#search=%27Morocco%2C+Ministry+of+Energy%2C+Mines+and+Water%2C+Energy+Mix%27

(c) Policy on renewable energy

(1) Renewable energy potential

The entire land receives moderate to high levels of sunlight and has a great potential for solar power generation. However, the northwestern Atlas Mountains, with its high population and industrial concentration, has many location constraints and many points where the potential cannot be exploited. The southwestern Atlas Mountains are dominated by sand, gravel, and desert areas, and construction of power lines are expected to be a challenge for large-scale development.

Wind power generation is limited to areas with good wind conditions, such as the southern border with Western Sahara. The northwestern Atlas Mountains, where cities are located, have generally poor wind conditions and little potential for onshore wind power. At sea, there are areas of good wind conditions near the Strait of Gibraltar and off the coast of Essaouira in the south. Development near the Strait of Gibraltar is expected to be difficult due to heavy vessel traffic, while development offshore of Essaouira in the southern part of the country is expected to face the challenge of increasing power transmission lines.

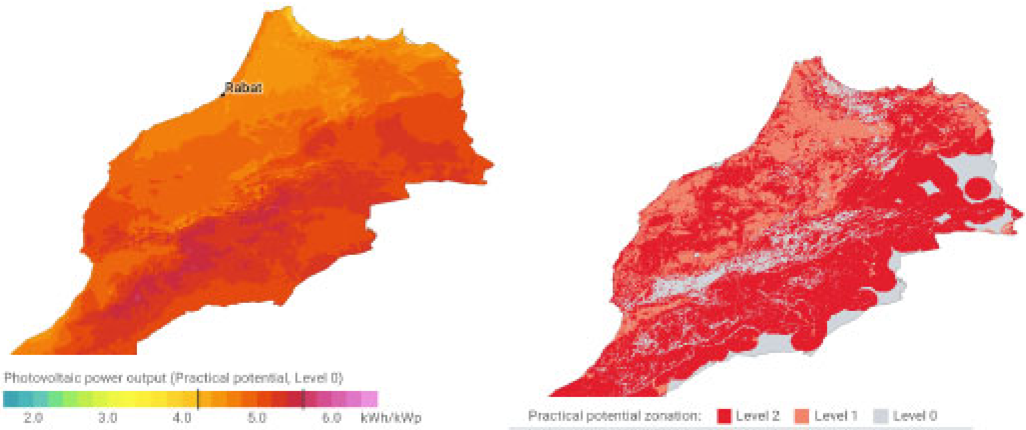

Figure 150 Solar Power Generation Potential in Morocco

Note: Left = Estimated power generation
Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints; Level 2 = excluding topographic and regulatory constraints.

Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

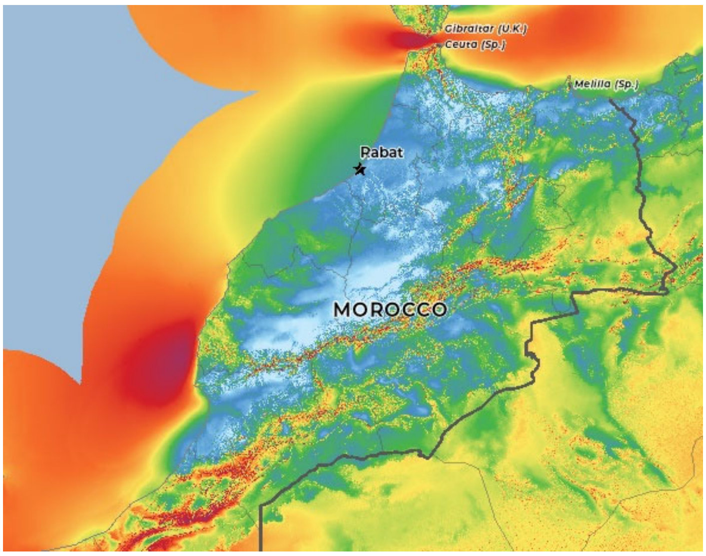

Figure 151 Wind Power Generation Potential in Moocco

Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.

Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The Ministry of Energy Transition and Sustainable Development is responsible for energy policy. There are eight Directorates. The Directorate of Renewable Energies and Energy Efficiency is in charge of renewable energy, and there are four services for renewable energy: wind, solar, hydropower, and new energy technologies. The implementing agency is the Moroccan Agency for Sustainable Energy (MASEN).

(3) Development goals

It sets a target of 52% (20% solar, 20% wind, and 12% hydro) of renewable energy in installed generating capacity by 2030. [403]

(4) Policies to promote introduction

The company provides active support regarding the development of large-scale solar and wind power generation.

On the financial side, the government has established a public investment company (Société d'Ingénierie Énergétique, SIE) to manage an Energy Development Fund (EDF) with $100 million in capital, with the aim of diversifying energy resources, promoting renewable energy, and encouraging greater energy efficiency.

A Public Private Partnership (PPP) approach is used for large-scale solar and wind development. The project will be implemented with the support of SIE, Hassan II Fund (Morocco's infrastructure development fund) and multilateral development banks.

It has established a clean energy park in Oujda and is attracting a wide range of renewable energy-related investments by providing land and introducing tax incentives.

Law 13-09 (enacted in 2010) allows independent power producers to sell renewable energy directly to end users via the grid (except for low voltage transmission). A decree is being prepared to expand the scope to include low-voltage transmission.

Work on development of pumped storage power plants (1,000 MW by 2030) and strengthening of the power grid in order to integrate the expanding renewable energy grid.

The company is actively involved in the development of Nationally Appropriate Mitigation Actions (NAMA).

Low Emission Capacity Building (LECB) program with financial support from the EU, Germany and Australian Aid is implemented. The LECB includes Development Strategies (LEDS), Nationally Appropriate Mitigation Actions (NAMAs), and a data collection system. NAMA has specific projects, policies, and programs that move a country's technology or sector onto a low-carbon development trajectory [404].

(d) Energy conservation policy

(1) Institutions in charge of policy

The Directorate of Renewable Energies and Energy Efficiency of the Ministry of Energy Transition and Sustainable Development formulates the policy and Agence Marocaine pour l'Efficacité Energétique (AMEE) implements it.

(2) Target

Updated NDC, 22 June 2021, has a goal of 20% energy reduction by 2030 compared to BAU. Energy consumption in buildings, industry, and transportation is reduced by 5% by 2020 and 20% by 2030. In 2030, the energy savings by sector will be 17% for industry, 24.5% for transportation,

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403 Updated NDC, 22 June 2021, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Morocco%20First/Moroccan%20updated%20NDC%202021%20_Fr.pdf

404 UNDP, https://www.adaptation-undp.org/projects/bf-morocco-nama

14% for urban, residential, and tertiary industries, and 13.5% for agriculture and marine fisheries.

(3) Promotion policy

Energy conservation programs include the followings[405].

- Building insulation standards and construction manuals, and human resource development
- Promotion of solar water heaters
- Installation of solar-powered driven irrigation pumps
- Introduction of renewable energy to mosques and promotion of energy conservation
- Renewable energy and energy conservation support and education targeting local governments (JIHA TINOU Program)
- Energy saving of street lights
- Establishment and operation of energy conservation standards for public buildings
- Human resource development related to energy conservation in buildings
- Public relations
- Establishment of sector-specific (industry, buildings, applicable, agriculture, transportation) energy conservation technical committees

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

Reduction target of Updated NDC, 22 June 2021, is an unconditional 18.3% reduction relative to BAU by 2030. This will be conditionally raised to 45.5%.

(2) Promotion Policy[406]

Promoting policies include: i) increasing the share of renewable energy in power generation capacity to 52% by 2030; ii) energy efficiency of 15% compared to BAU by 2030; iii) by 2030. 450 MW of additional capacity will be installed with combined cycle technology using imported natural gas; iv) energy will be supplied to major industries through pipelines of imported and regasified natural gas.

(3) Transportation[407]

Updated NDC, 22 June 2021, listed the following initiatives in the transportation sector.

- Rabat and Casablanca extend tramways to for transportation.
- From January 2023, new passenger and commercial vehicles in the Moroccan market will comply with EURO VI.[408]
- Bonus-malus system to promote the selection of vehicles with low CO2 emissions.[409]
- Adoption of eco-driving promotion (to reduce fuel consumption, maintenance costs, and pollutants)
- New CO2 emission performance standards and fuel efficiency standards for new passenger cars and light commercial vehicles, aiming to apply EU regulations in 2030

(4) Urban development

Current status and promotion measures

The goal is to convert major cities such as Casablanca, Rabat, and Marrakech into smart cities and interconnect them with each other. In addition, while the various services will be led by each

405 Ministry of Energy, Mines, and Environment, https://www.mem.gov.ma/en/Pages/secteur.aspx?e=3

406 Updated NDC

407 Updated NDC, 22 June 2021

408 EURO VI is a vehicle emission regulation. EURO VI specifically tightens emission standards for PM and NOx.

409 This is a system in which a subsidy (bonus) is paid for the purchase of vehicles with low CO2 emissions, while vehicles with high CO2 emissions are taxed (malus).

city, the main platforms and interfaces will be unified by the national government to achieve national consistency.

Casablanca aims at further economic development by improving public services and ensuring security through the use of AI. AI applications are expected to be used in areas such as reducing traffic congestion, improving energy consumption efficiency, and making buildings smarter.

(f) Next generation technology, innovation

Green hydrogen is attracting attention as an energy source to reinforce self-sufficiency through renewable energy, or as an export energy source to Europe. A hydrogen roadmap was developed for 2019 and also an inter-ministry Hydrogen Committee was established.[410] Cooperation with Europe is being developed, and examples are the cooperation with Germany and Portugal as followings.

In June 2020, the government signed a cooperation with Germany on the development and use of green hydrogen. For the time being, according to the statement, the Moroccan Sustainable Energy Agency will proceed with its proposed green hydrogen production project and the establishment of a research platform on Power-to-X.[411]

In February 2021, the government signed a cooperation on green hydrogen with Portugal.[412]

As of October 2021, there are following three hydrogen projects.[413]

HEVO Ammonia Morocco Project

Announced by the Minister of Mines and Environment, Aziz Rabbah, in July 2021. This is a project where Fusion Fuel Green PLC of Ireland and Greek construction company Consolidated Contractors Group are collaborating to produce green ammonia and trader Vitol purchases the ammonia produced. Upon completion of the FS, the first phase of the project is expected to begin in 2022. Fusion Fuel installs off-grid, rotating solar power plant to supply 31 thousand tons of green hydrogen per year (HEVO SOLAR).

Morocco-Germany MoU

Hydrogen is used for ammonia. Current status is FID. Operation will start in 2025. Renewable energy source is unknown.

Saipem and Alboran Hydrogen (1 plant)

The project is being planned by Italian companies Saipem and Alboran Hydrogen, but it is still at the concept stage. Hydrogen will be used for ammonia.

(g) Points to consider for future cooperation in promoting low carbon and decarbonization

The energy saving potential is great and measures should be strengthened. Possible countermeasures include the following. Several measures targeting buildings can be identified, while other industries, transportation, and equipment are likely to be focused on.

- Development of energy efficiency benchmarks for the energy conversion and industrial sectors
- Introduction of energy management in energy-heavy industries
- Introduction of fuel efficiency standards for automobiles
- Improvement of public transportation network and suppression of car use
- Introduction of minimum efficiency standards for equipment
- Expansion of equipment subject to labeling system

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410 Morocco World News, January 21, 2021, https://www.moroccoworldnews.com/2021/01/332775/energy-minister-celebrates-moroccos-green-hydrogen-achievements/
Ministry of Energy, Mines and Environment, https://www.observatoirenergie.ma/en/actualites/energies-renouvelables-creation-dune-commission-nationale-de-lhydrogene/

411 FuelCellWorks, 2020.6.16, https://fuelcellsworks.com/news/morocco-germany-sign-green-hydrogen-cooperation-agreement/

412 Morocco World News, 2021.2.2, https://www.moroccoworldnews.com/2021/02/333919/morocco-portugal-sign-agreement-on-green-hydrogen-cooperation/

413 IEA, Hydrogen Projects Database, https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database

A low-carbon economy can be expected from the conversion of coal and oil used in power generation and industry to natural gas, even if only partially. Across the sea, Spain has an LNG import terminal, but its operation has been slowing down due to the increase in renewable energy, and a possible way is to reverse the pipeline between Morocco and Spain (actually a swap agreement).

In renewable energy, suitable sites for wind power are limited, and solar power generation, which can be developed adjacent to demand areas, has an advantage.

-They are keen to increase self-sufficiency and expand VRE and green hydrogen as export goods to Europe. Pilot projects for VRE + BEV and green hydrogen + FCEV are likely to attract policy interest.

Chemical fertilizers are manufactured by blending the three elements of fertilizers (nitrogen, phosphoric acid, and potassium) in a well-balanced manner according to their uses. With regard to phosphorus ore, the raw material for phosphorus, one of the three elements of fertilizer, Morocco is the world's second largest producer (approximately 30% of global demand) after China, and the world's largest exporter. Although the country is rich in phosphate ore resources, it is not rich in fossil fuel resources and can produce only a small amount of ammonia, the source of nitrogen fertilizer (the main ingredient of chemical fertilizers), and is largely dependent on imports. If green hydrogen could be produced with renewable electricity, it would be possible to produce large quantities of ammonia domestically. (Industrially, ammonia (NH_3) is produced by extracting hydrogen from fossil fuels and nitrogen from the atmosphere.)

(16) Mozambique

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

As symbolized by the low access rate to electricity of 35% (2019, IEA), the commercial energy supply is inadequate. Traditional biomass accounts for 68% of primary energy supply and is being converted to this commercial energy. Therefore, energy consumption for electricity and heat supply will increase in the future. The main energy sources other than traditional biomass are hydropower for electricity generation and petroleum for transportation.

For power generation, the country had previously relied on hydropower. However, natural gas production has been in full swing since 2004, and its use in power generation has increased since 2013.

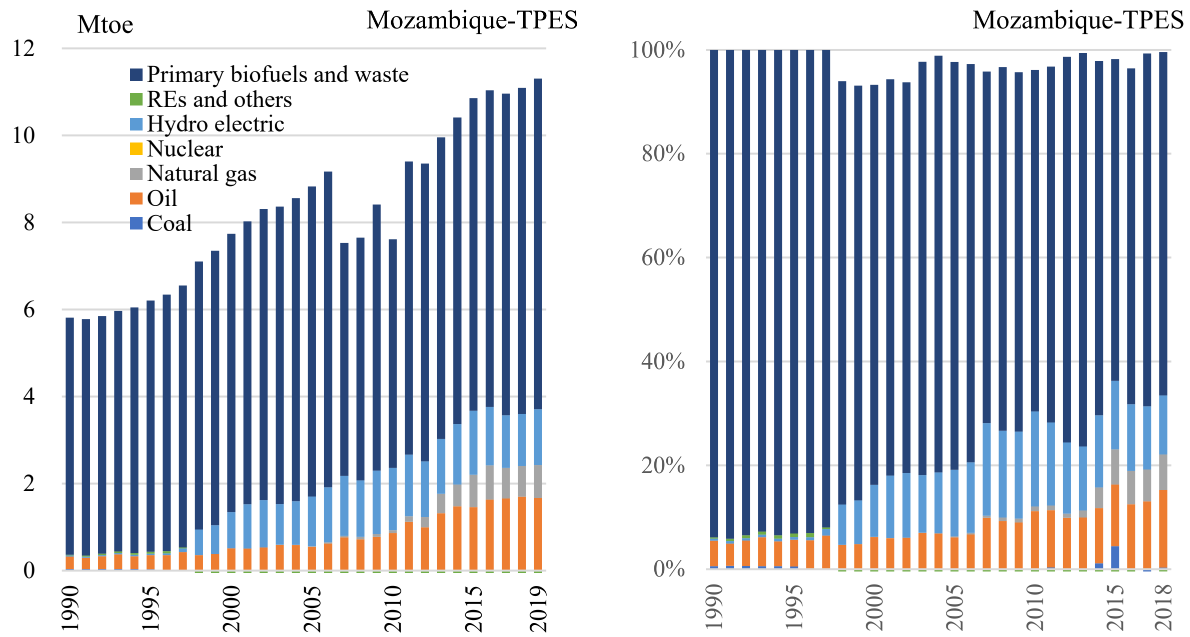


Figure 152 Primary Energy Supply in Mozambique

Share structure doesn't become 100% when there is an electricity export.
Source: World Energy Balances 2021 extended edition database, IEA

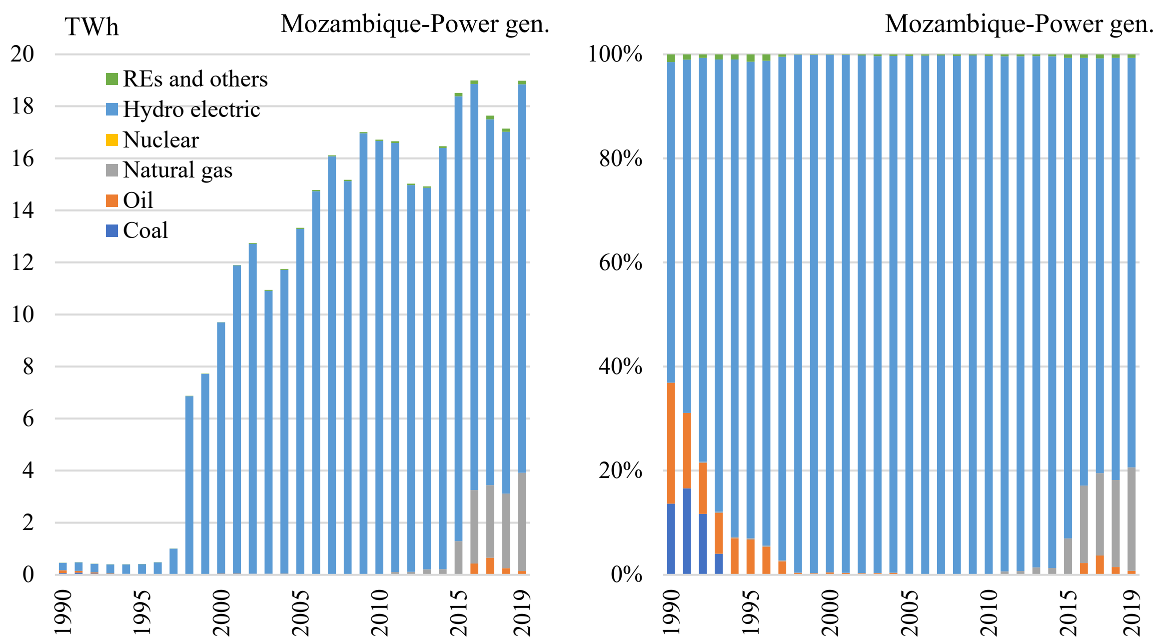


Figure 153 Fuel Mix of Electricity Generation in Mozambique

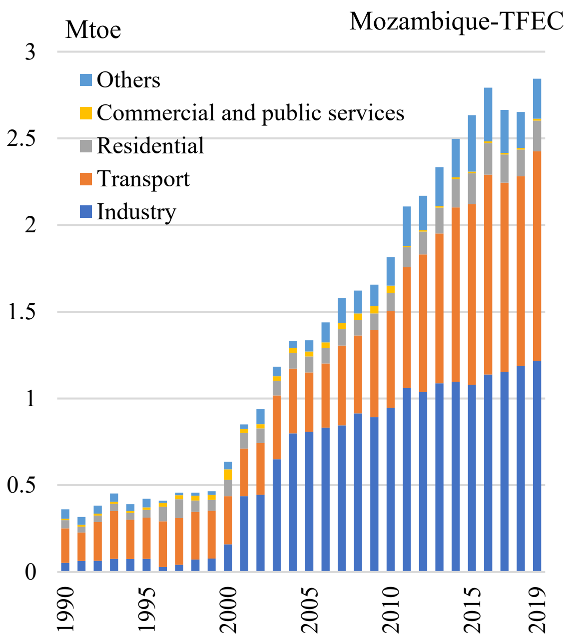
Source: World Energy Balances 2021 database, IEA

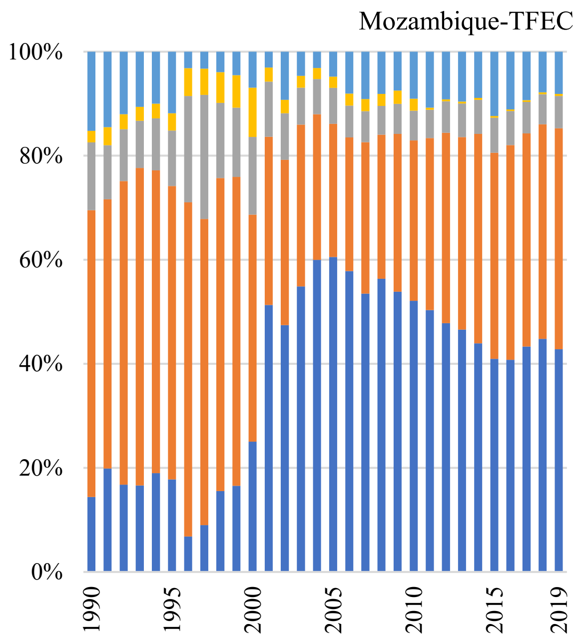
By sector, industry and transportation account for the largest shares of final energy consumption (43% and 41%, respectively, in 2019), while residential (6%), commercial/public services (0%), and other (8%) account for only a small share. In terms of average growth over the five-year period from 2014 to 2019, commercial/public services and transportation are the largest, at 4.1% and 3.7%, respectively, despite lower consumption, followed by industry at 2.1% and housing at 1.5%.

In the industrial sector, electricity accounts for 63% (2019), with oil (17%) and natural gas (5%) making up the rest. From this it can be inferred that there are not many manufacturing operations that require large amounts of heat. The CO2 emissions intensity of electric power is very small due to the power source structure centered on hydropower, and the supply-demand structure centered on electric power contributes to a low-carbon society. However, in recent years, oil consumption has grown at an average annual rate of 5.1% (2014-2019). In addition, depending on future changes in industrial structure and power source composition, electrification may not necessarily be the appropriate low-carbon means.

The transportation sector is almost entirely petroleum. The low carbon intensity of electricity makes the use of electric vehicles an effective decarbonization tool, assuming that the hydroelectricity-based power supply mix will be maintained in the future.

In terms of the percentage of various residential commercial energy costs, electricity is the most commonly used source at 87%, followed by oil at 12%. About 2/3 of oil is LPG and 1/3 is kerosene, but CO2 emissions can be reduced by converting kerosene consumption to natural gas. Traditional biomass use still accounts for 97% of residential use as of 2019. Which energy sources will be supplied to meet this potential commercial energy demand will be an important choice for Mozambique's low-carbon transition in the future.





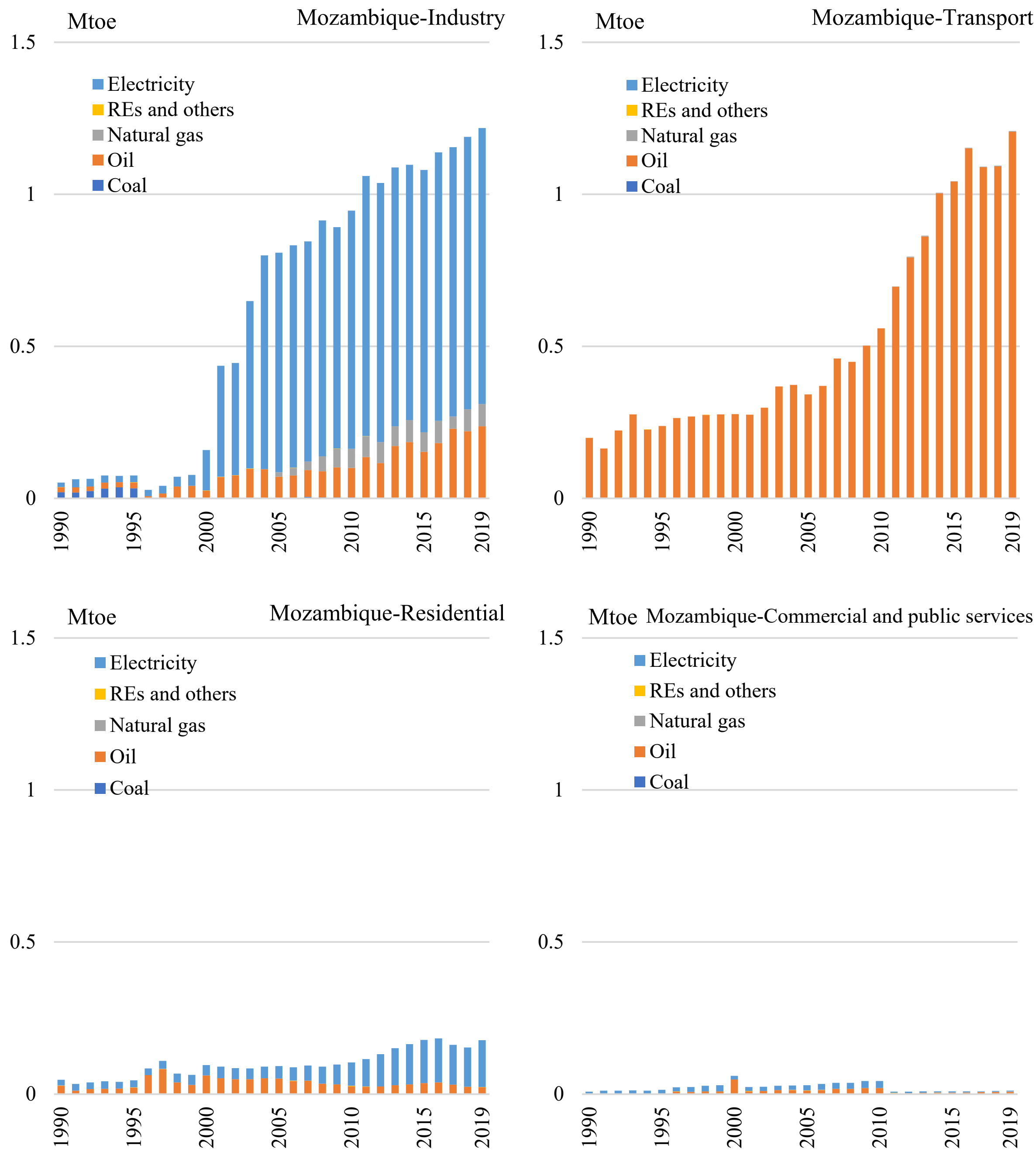


Figure 154 Final Energy Consumption of Major Sectors in Mozambique

"Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal" are excluded.
"Others" in TEFC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP has shown a declining trend since the mid-1980s and was 0.611 toe/$1,000 (2015 prices) in 2019 (0.090 in Japan). It is clear that there is significant room for efficiency improvement.

The average thermal efficiency of gas-fired power plants is about 50%, which is not bad. Conversely, due to the small amount of gas-fired thermal power used, the CO2 emission reduction effect from improving the efficiency of gas-fired thermal power is not that great.

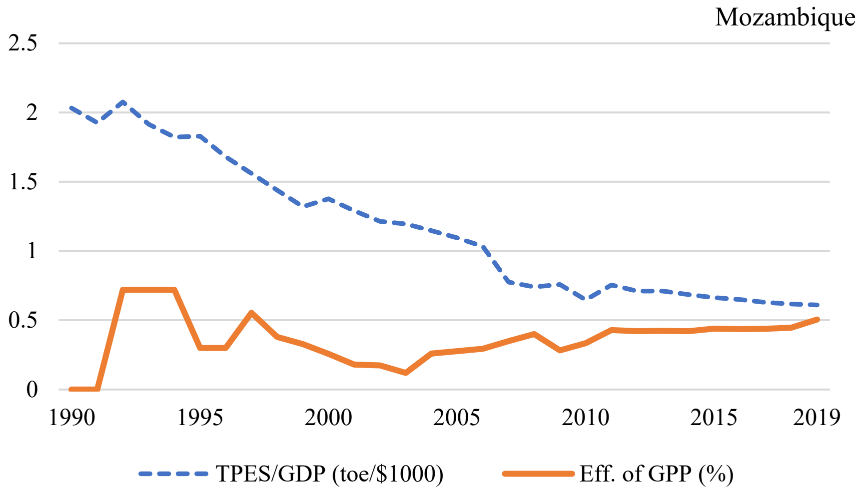


Figure 155 Energy Efficiency in Mozambique

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant
GDP in 2015 price
Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the followings are examples of options that could be adopted to reduce Mozambique's CO2 emissions in the future and their CO2 reduction effects. Mozambique is a natural gas resource-rich country, but the natural gas produced is mainly exported, with little domestic use. As offshore gas fields are developed and become available to the domestic market in the future, they will be able to replace oil.

Table 105 Examples of Low-carbon/ Decarbonization Potential in Mozambique

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		8.4 mton-CO2
【Example of CO2 Emission Reduction Option】		【Reduction Effect】
Generation	Substite 10% of Natural Gas for Renewable Energy (Exclusive of Hydro)	0.16 mton-CO2
Industry	Substite 75% of Oil for Natural Gas	0.40 mton-CO2
Transport	10% Improvement of Fiel Mileage	0.35 mton-CO2
Residential	Substite 75% of Oil (LPG) for Natural Gas	0.01 mton-CO2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICA Study Team

(2) Primary energy mix and electricity mix planning

The bulk of the energy used in Mozambique is biomass, such as firewood and charcoal, which will undoubtedly be converted to commercial energy sources such as electricity in the future.

Natural gas resources have been confirmed to be of a scale that would allow LNG exports, and there is a possibility that natural gas will be used extensively not only for power generation but also for industrial and consumer use. However, there is a tendency for investment decisions to be delayed due to oversupply caused by the new coronavirus in the current period (2020).

The development and export of coal resources has been expected, but the outlook is uncertain due to the accelerating trend toward low carbon and decarbonization throughout the world and a move to pull investments in Mozambique's coal assets.

The primary energy demand outlook for Mozambique from Africa Energy Outlook 2019 (IEA) is as follows.

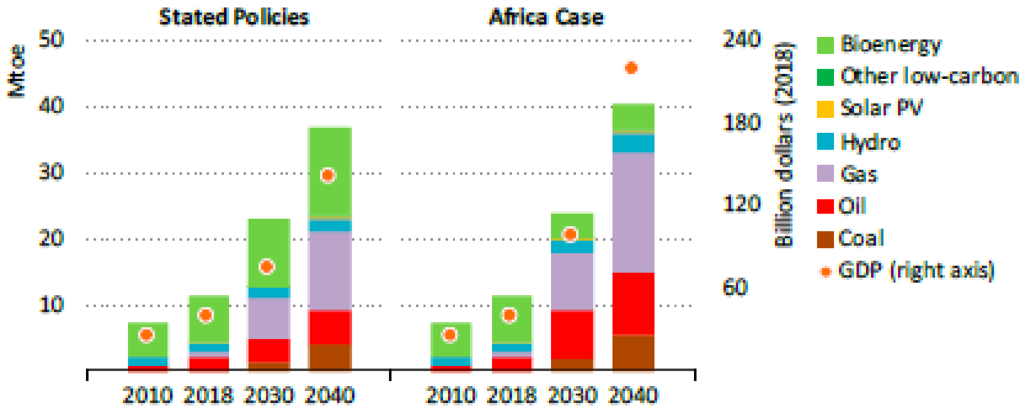


Figure 156 Primary Energy Supply Outlook in Mozambique

Source: Africa Energy Outlook 2019, IEA

Two different plans can be identified in the power development: one by the Ministry of Mineral Resources and Energy (MIREME) and one by the state-owned Electricidade de Moçambique (EdM).

Table 106 Power Development Plan 2017-2042 by MIREME (MW)

	Capacity	Hydro	Natural Gas	Coal	Solar	Wind	Total
2017	2,865	-	40	-	-	-	40
2018	2,936	-	110	-	40	-	150
2019	3,172	-	-	-	40	-	40
2020	3,451	-	-	-	-	-	-
2021	3,572	-	-	-	-	-	-
2022	3,932	-	400	-	-	-	400
2023	4,042	-	210	650	-	30	890
2024	4,381	-	100	-	30	-	130
2025	4,511	50	1,000	-	30	-	1,080
2026	5,592	-	100	300	30	-	430
2027	5,922	-	180	-	-	30	210
2028	6,132	-	100	-	30	-	130
2029	6,132	1500	-	300	30	-	1,830
2030	7,962	100	-	300	30	-	430
2031	8,392	100	-	-	-	30	130
2032	8,522	650	-	-	30	-	680
2033	9,202	100	-	-	30	-	130
2034	9,332	1245	-	-	30	-	1,275
2035	10,607	100	1,500	-	-	30	1,630
2036	12,237	100	-	-	30	-	130
2037	12,367	200	-	-	30	-	230
2038	12,597	100	2,000	-	30	-	2,130
2039	14,727	-	400	-	-	30	430
2040	15,157	-	2,000	-	30	-	2,030
2041	17,187	-	400	-	30	-	430
2042	17,617	50	-	400	30	-	480
Total		4,295	8,540	1,950	530	150	3,500

Source: MIREME, Integrated Master Plan, Mozambique Power System Development, Final Report, November 2018

Table 107 Power Development Plan 2018-2028 by EdM (MW)

	Hydro	Natural Gas	Coal	Solar	Wind	Total
2018	-	106	-	40	-	146
2019	-	-	-	40	-	40
2020	-	-	-	-	-	-
2021	-	-	-	-	-	-

2022	-	400	-	-	-	400
2023	-	206	650	-	30	886
2024	1,500	-	-	30	-	1,530
2025	50	-	-	30	-	80
2026	-	-	300	30	-	330
2027	650	80	-	-	30	760
Total	2,200	792	950	170	60	4,172

Source: EdM, Estrategia da EDM 2018-2028, https://portal.edm.co.mz/en/website/page/reports

(3) Current status and goals of electricity access

According to the IEA's Electricity Access Database, Mozambique's electricity access rate in 2019 is 35% (57% in urban areas and 22% in rural areas). The Five-Year Government Plan (Programa Quinquenal do governo: 2020-2024) sets a goal of raising this to 64%.

(b) Electric utility system

(1) Electricity supply system

The state-owned EdM will handle all of the electricity dispatch and distribution. There are also other systems such as Hidroeléctrica de Cahora Bassa (HCB), established in 1975 by the Portuguese and Mozambican governments to develop, manage, and operate the Cahora Bassa dam, and other IPPs. There is also Mozambican Transmission Company (MOTRACO), established in 1998 with a 1/3 stake each by EdM, South Africa's state-owned ESKOM, and Swaziland's SEC to provide a stable supply of electricity to MOZAL, an aluminum smelter.

(2) Supply system of renewable electricity

Procurement will be done through a bidding system.

(c) Policy on renewable energy

(1) Renewable energy potential

The entire area receives moderate sunlight and has potential for solar power generation. Location constraints are more prevalent in the south, while the north has fewer constraints.

Wind power development potential is limited due to poor wind conditions except for offshore around the capital city of Maputo.

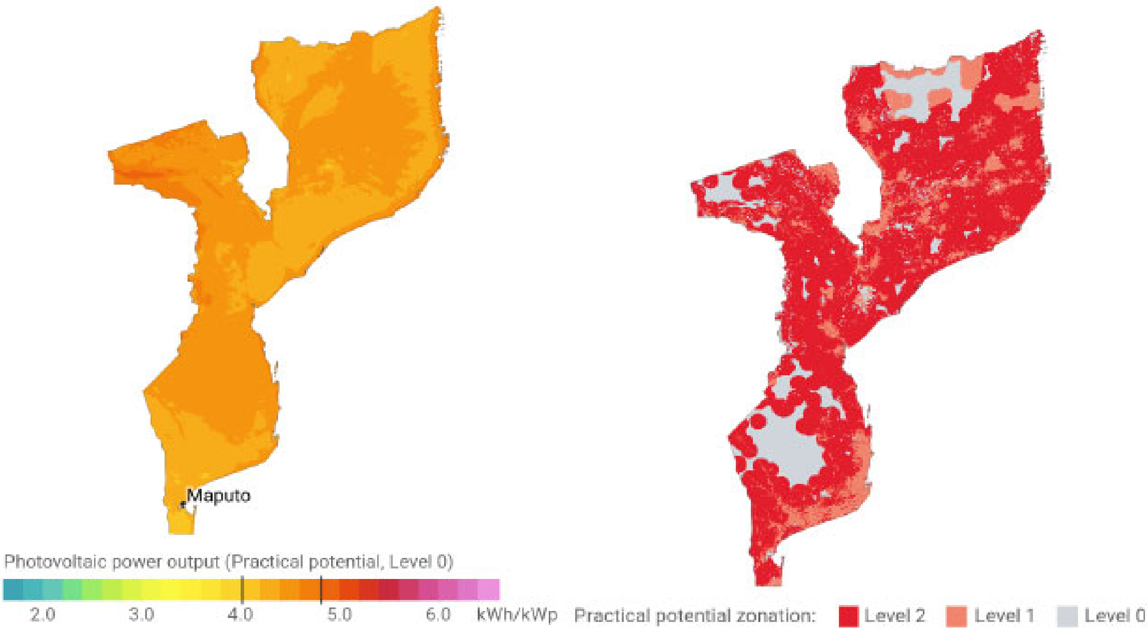


Figure 157 Solar Power Generation Potential in Mozambique

Note: Left = Estimated power generation

Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints; Level 2 = excluding topographic and regulatory constraints.
Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

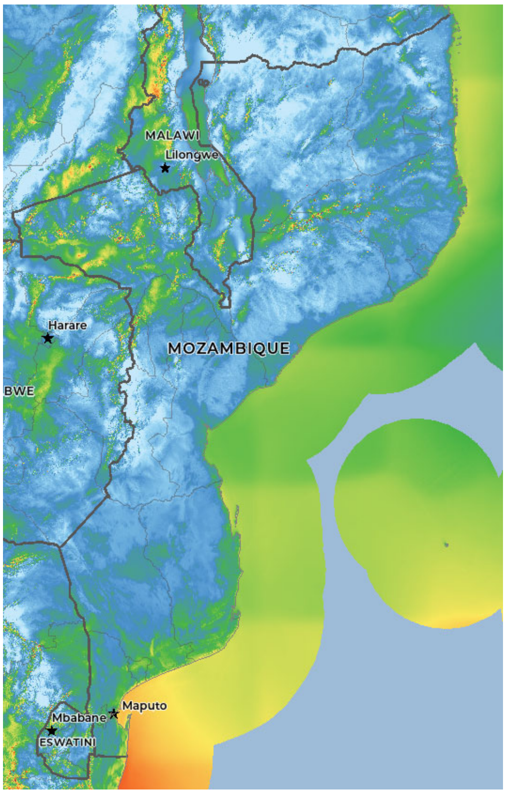


Figure 158　Wind Power Generation Potential in Mozambique
Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

The Ministry of Mineral Resources and Energy (Ministério dos Recursos Minerais e Energia) is responsible for energy policy. The independent regulator of the electricity market, the Autoridade Reguladora de Energia (Energy Regulatory Agency), will be involved in the purchase of renewable energy and other activities.

(3) Development goals

The goal is to achieve access to commercial energy for all citizens by 2030. One means of achieving this is through the use of off-grid renewable energy systems.

(4) Policies to promote introduction

In September 2017, the Department of Mineral Resources and Energy announced that it would attract $500 million in foreign investment in domestic renewable energy generation projects by 2030. Within 15 years, the company plans to supply electricity from hydro and solar power to 332 villages. [414]

Proler program was launched in September 2020[415]. Four sites (3 solar, 1 wind) will be bid through this program.

- Selection of potential location sites

[414] Reuters, September 20, 2017, https://af.reuters.com/article/investingNews/idAFKCN1BV0P5-OZABS
[415] http://proler.gov.mz/about/

- Preparation of procurement specifications
- Bidding

(d) Energy conservation policy

N/A.

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

The INDC submitted in June 2018 does not indicate a numerical target for GHG reduction. In December 2021, Mozambique submitted an updated NDC to the UN covering the years 2020-2025. Between 2020 and 2025, we expect to reduce GHG emissions by about 40 MtCO2 compared to BAU. [416]

(2) Promotion policy

N/A.

(3) Transportation

According to press reports, the electric vehicle strategy was discussed at the Ministry of Mineral Resources and Energy in November 2019. [417]

(4) Urban development

N/A.

(f) Next generation technology, innovation

N/A.

(g) Points to consider for future cooperation in promoting low carbon and decarbonization

- Access rates to commercial energy remain low and there is a need for improved energy access through distributed systems utilizing solar and other energy sources. In addition to VRE + batteries, distributed energy systems could consider the possibility of lorry transportation of LNG, ammonia, etc. and power generation.
- The energy saving potential is great and measures should be strengthened. Possible countermeasures include the following.
  - Development of energy efficiency benchmarks for the conversion and industrial sectors
  - Introduction of energy management in energy-heavy industries
  - Introduction of fuel efficiency standards for automobiles
  - Improvement of public transportation network and suppression of car use
  - Introduction of building insulation standards
  - Introduction of minimum efficiency standards for equipment
  - Introduction of equipment labeling system
- Large-scale natural gas development is underway, and CO2 emissions can be curbed by replacing oil use in industry and buildings with natural gas as the domestic supply infrastructure is developed.
- In terms of renewable energy, the southern part of the country has high potential for offshore wind power development, while the northern part of the country has high potential for solar power development.

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416 UNFCCC, December 27, 2021, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Mozambique%20First/NDC_EN_Final.pdf

417 Global Fuel Economy Initiative, December 6, 2019, https://www.globalfueleconomy.org/blog/2019/mozambique-discusses-electric-mobility-strategy

- The current CO2 emission intensity of electricity is very low, and the use of electric vehicles in the transportation sector is an effective means of reducing carbon emissions. However, it is possible that the electricity mix centered on hydroelectric power may become unsustainable as demand for electricity expands in the future, and the transition needs to be monitored.

(17) South Africa

(a) Long-term energy policy

(1) Current status of primary energy mix and electricity mix

South Africa is a coal exporting country and uses a lot of coal in its own industries and in ordinary households. The oil embargo imposed by the international community between 1979 and 1994 due to criticism of apartheid policies also underlies the supply-demand structure that is heavily weighted toward coal. Sasol has developed a synthetic liquid fuel production process using coal as a substitute for petroleum.

Coal is the most common primary energy supply at 72% (2019), followed by oil at 16%. While many countries have a reasonable share of petroleum demand, primarily for automobiles, South Africa produces synthetic liquid fuels from coal, so the share of petroleum in the primary energy supply is smaller than normally seen. Renewable energy (excluding hydro) has the largest growth rate from 2014 to 2019, but only accounts for 1% of primary energy supply in 2019. It is said that there is a commitment to renewable energy and energy conservation among some wealthy people, but the impact on the overall energy supply and demand in South Africa is small.

Electricity generation is more significantly dependent on coal at 89% (2019). It is clear that it is essential to build low carbon and decarbonized power sources to replace coal-fired power. However, it is easy to imagine that this will not be easy, given that the country is so dependent on coal and that power generation using domestic coal would be low-cost.

South Africa has the only nuclear power plant on the African continent, the Koeberg Nuclear Power Plant (1.91 GW in total). The Koeberg NPP will reach the end of its 40-year life in 2024, and a 20-year extension of its operating life is planned. In addition, a total of 2.5 GW of new construction is under consideration.

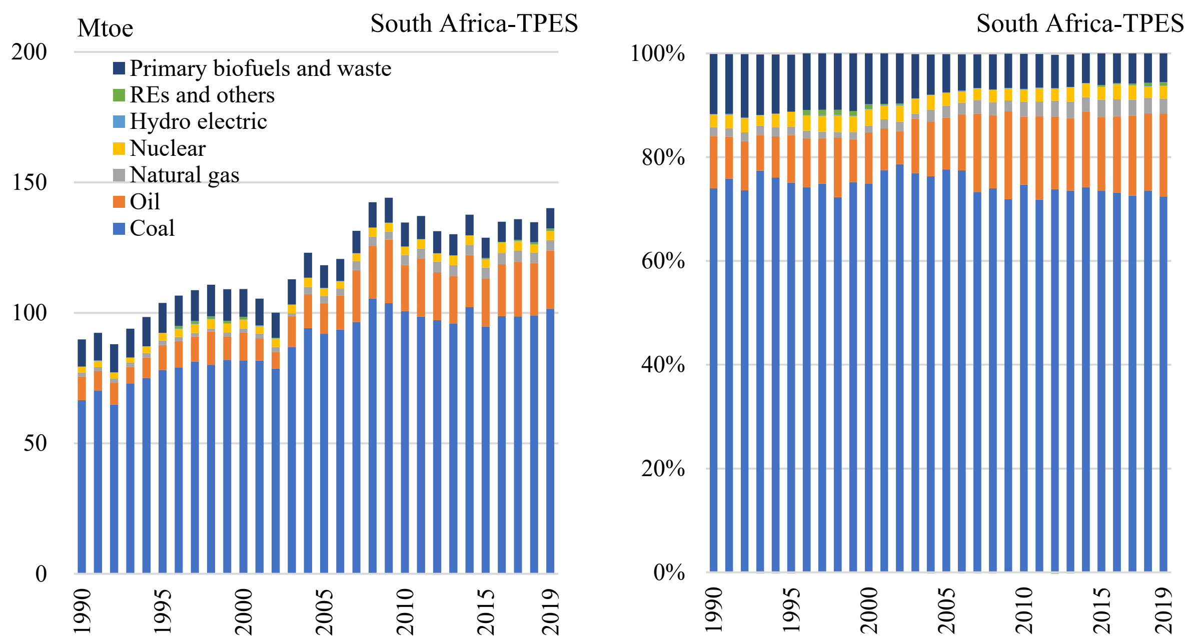


Figure 159 Primary Energy Supply in South Africa

Source: World Energy Balances 2021 extended edition database, IEA

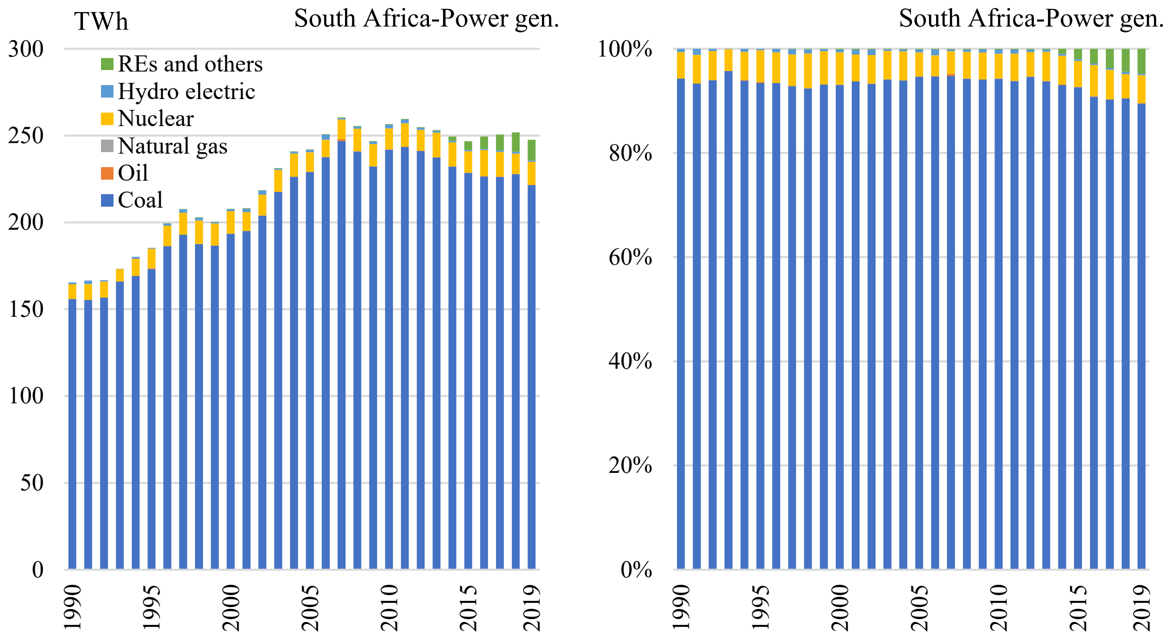


Figure 160 Fuel Mix of Electricity Generation in South Africa

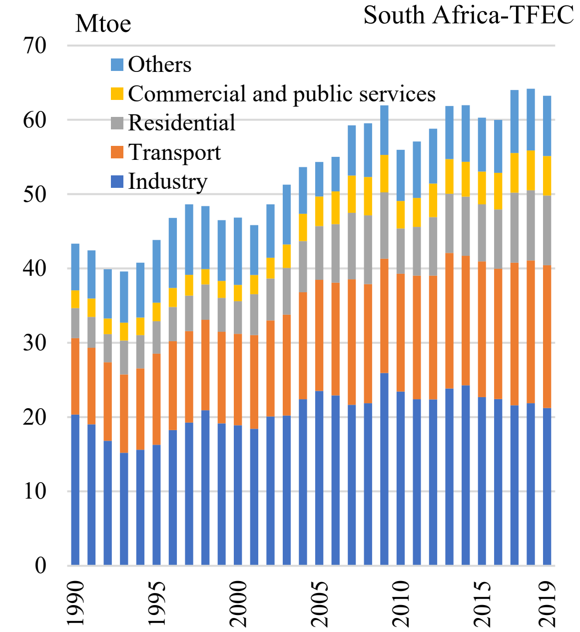
Source: World Energy Balances 2021 database, IEA

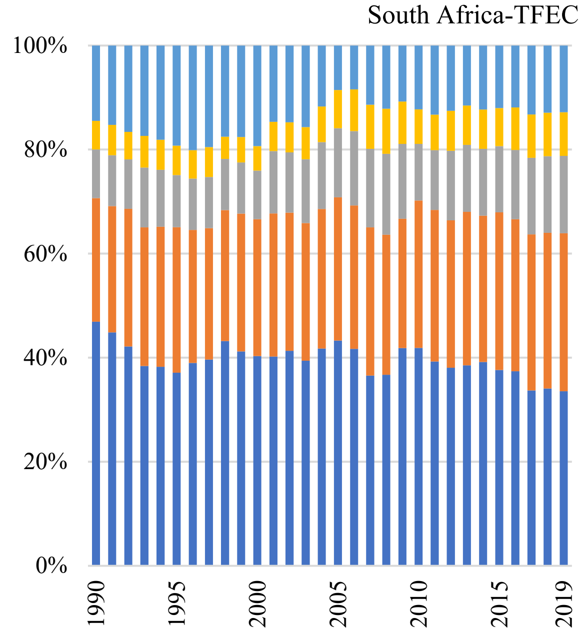
By sector, industry has the largest final energy consumption at 34% (2019), followed by transportation (30%), residential (15%), other (13%), and commercial/public services (8%). Looking at the average annual growth rate from 2014 to 2019, residential and commercial/public services were the largest, at 3.5% and 2.8%, respectively, followed by transportation at 2.0%. On the other hand, industry had negative growth (-2.7%).

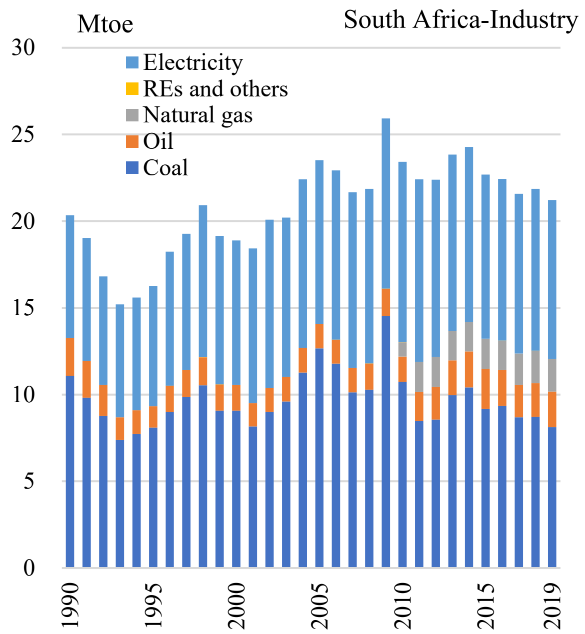
The industrial sector uses more electricity (38%) and coal (34%) and less oil (9%) (2019). Also here, one can see a structure that differs from other countries in its heavy use of coal. This, in turn, indicates the potential for significant reductions in CO2 emissions by converting coal to natural gas, although investment in imports would be required. Natural gas cogeneration is a promising option if the heat demand can be harnessed.

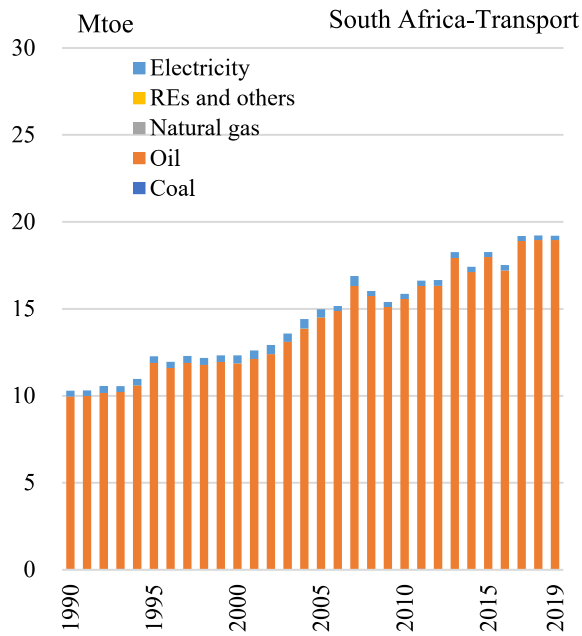
In the transportation sector, petroleum accounts for 99% and electricity for the remaining 1%. The CO2 intensity of electricity is high due to the coal-based power supply structure, and electric vehicles will not be a low-carbon option unless a significant low-carbon shift in the electricity mix is achieved in the future.

Even in housing, coal accounts for 43% (in 2019), a high percentage not seen in any other country. Of the remainder, 28% is electricity and 4% is petroleum. Coal and electricity have increased at an average annual rate of 5.4% and 2.2% (2014-2019), respectively, due in part to a shift from traditional biomass to commercial energy. Commercial/public services have a similar structure. In these sectors as well as in industry, the conversion of coal to natural gas or LPG is a promising low-carbon option.


Mtoe
South Africa-TFEC
70
60
50
40
30
20
10
0
Others
Commercial and public services
Residential
Transport
Industry
1990
1995
2000
2005
2010
2015
2019


South Africa-TFEC
100%
80%
60%
40%
20%
0%
1990
1995
2000
2005
2010
2015
2019


Mtoe
South Africa-Industry
30
25
20
15
10
5
0
Electricity
REs and others
Natural gas
Oil
Coal
1990
1995
2000
2005
2010
2015
2019


Mtoe
South Africa-Transport
30
25
20
15
10
5
0
Electricity
REs and others
Natural gas
Oil
Coal
1990
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2000
2005
2010
2015
2019

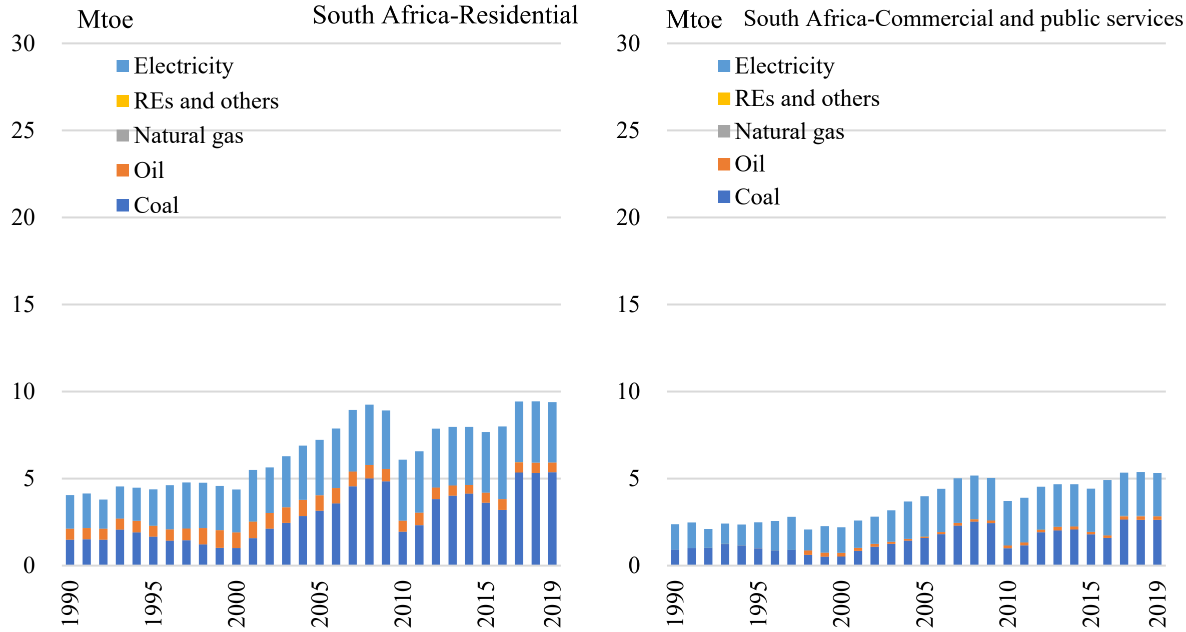

Figure 161 Final Energy Consumption of Major Sectors in South Africa

"Primary solid biofuels", "Non-specified primary biofuels and waste" and "Charcoal" are excluded.
"Others" in TEFC includes agriculture, forestry, fishing, other and non-energy uses.
Source: World Energy Balances 2021 extended edition database, IEA

Primary energy consumption per GDP has been on a gradual downward trend since the late 1990s and was 0.429 toe/$1,000 (2015 prices) in 2019 (0.090 in Japan). Compared to Japan, the energy efficiency of the economy is far below that of Japan, and potential improvements in all sectors need to be explored. However, this may be influenced by the heavy use of coal, which is generally less efficient for energy conversion than oil or natural gas.

The efficiency of coal-fired thermal power generation is about 35%, and there is room for improving efficiency with newer equipment. However, if the goal is to achieve a low-carbon, decarbonized society in the long term, investment in new coal assets will carry the risk of future failure and should be avoided.

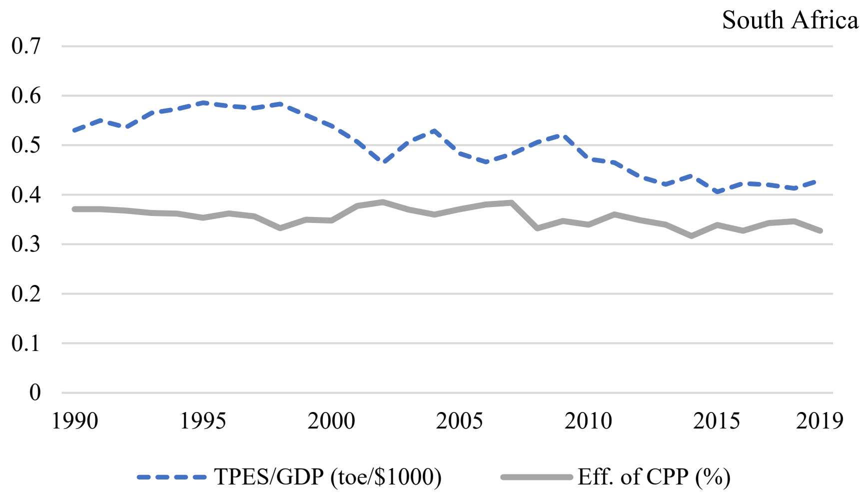

Figure 162 Energy Efficiency in South Africa

TPES = total primary energy supply, Eff. = thermal efficiency, GPP = gas power plant
GDP in 2015 price
Source: World Energy Balances 2021 extended edition database, IEA

Based on the above analysis, the following are examples of options that could be adopted to reduce South Africa's CO2 emissions in the future and their CO2 reduction effects.

Table 108 Examples of Low-carbon/ Decarbonization Potential inSouth Africa

Sector	Option	CO2 Emission Reduction Effect
Total CO2 Emission from Fuel combustion (2019 actual)		440.0 mton-CO2
	【Example of CO2 Emission Reduction Option】	【Reduction Effect】
Generation	Substitue 50% of Coal for Natural Gas	71.79 mton-CO2
Industry	Substitute 50% of Coal and 50% of Oil for Natural Gas	7.31 mton-CO2
Transport	10% Improvement of Fuel Mileage	5.36 mton-CO2
Residential	Substitue 75% of Coal for Natural Gas	6.43 mton-CO2

Note: Record in 2019 = Greenhouse Gas Emissions from Energy, IEA, 2021 - Highlights
Emissions intensity = 2006 IPCC GUIDELINES
Source: JICA Study team

(2) Primary energy mix and electricity mix planning

The IEA projected that South Africa's energy demand would increase to 142 Mtoe in 2040 under the published policy scenario (STEPS), while it would decrease to 107 Mtoe under the sustainable development scenario (SDS), which assumes stronger low-carbon and decarbonization policies and actions, including coal-free. The energy mix in 2040 is expected to decrease the use of coal in both scenarios, while nuclear power and renewables are expected to increase.

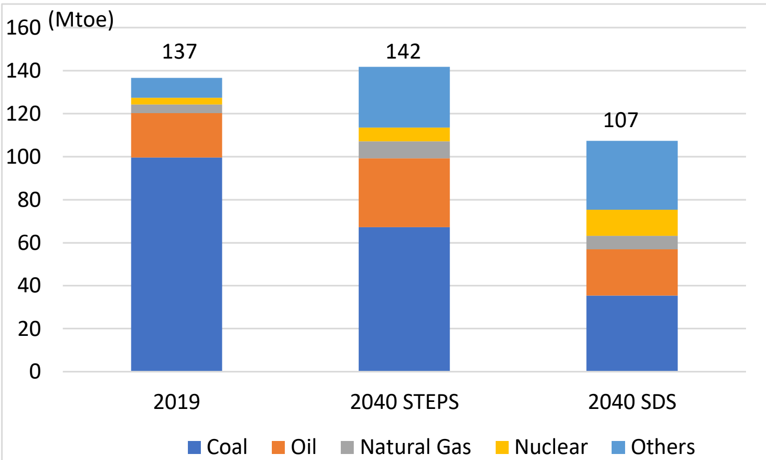

Figure 163 Primary Energy Supply in South Africa

SPEPS = stated policy scenario, SDS = sustainable development scenario
Source: World Energy Outlook 2020, IEA

The government released the Integrated Resource Plan 2019 (IRP2019) in October 2019. [418] The plan is to eliminate aging and inefficient coal-fired thermal power generation while developing new power sources, mainly renewable energy sources, to secure the necessary power supply. In the first half of the plan (2019-24), coal-fired power plants will be replaced while also introducing renewable energy (especially wind and solar), whereas in the second half of the plan, old coal-fired power plants will be phased out while introducing renewable energy on a large scale. This will result in a significant reduction in the coal-fired share (based on generating capacity) from 71.3% in 2018 to 42.6% in 2030, while also significantly raising the share of

[418] Although it is called a Resource Plan, it is a so-called power development plan.

renewable energy (excluding hydro) from 7.2% to 34.0%.

After 2030, coal-fired thermal power plants that will reach the end of their useful lives will be successively shut down, and the capacity of shutdown thermal power plants will increase to 28 GW by 2040 and 35 GW by 2050. As a result, coal's share of energy supply will decline to just under 30% by 2040 and will fall below 20% by 2050. [419]

Table 109 Electricity Generation Capacity Outlook by Fuel (IRP2019)

	2018		Decommissioned	New addition	(of whichi)		2030			
	Capacity (MW)	Share (%)	(MW)	(MW)	Committed (MW)	Uncommotted (MW)	Capacity (MW)	Share (%)	Growth (%)	Share of generation (%)
Coal	37,149	71.3%	11,017	7,232	5,732	1,500	33,364	42.6%	▲10.2%	58.8%
Nuclear	1,860	3.6%					1,860	2.4%	0.0%	4.5%
Hydro	2,100	4.0%		2,500		2,500	4,600	5.9%	119.0%	8.4%
Pomped Storage	2,912	5.6%		2,088		2,088	5,000	6.4%	71.7%	1.2%
Solar	1,474	2.8%		6,814	814	6,000	8,288	10.6%	462.3%	6.3%
Wind	1,980	3.8%		15,762	1,362	14,400	17,742	22.7%	796.1%	17.8%
Solar thermal	300	0.6%		300	300	0	600	0.8%	100.0%	0.6%
Gaso and Oil	3,830	7.4%		3,000		3,000	6,830	8.7%	78.3%	1.3%
Others*	499	1.0%					0	0.0%	▲100.0%	
Hydro total	5,012	9.6%	0	4,588	0	4,588	9,600	12.3%	91.5%	9.6%
RES total (Excld. Hydro)	3,754	7.2%	0	22,876	2,476	20,400	26,630	34.0%	609.4%	27.2%
Total	52,104	100.0%	11,017	37,696	8,208	29,488	78,284	100.0%	50.2%	100.0%

*As other power sources, it is assumed that 500 MW of distributed power sources (including cogeneration) will be put into operation every year from 2023 to 2030.

Source: IRP2019, p. 42

(3) Current status and goals of electricity access

According to the IEA, the electrification rate for 2019 is 94% (urban: 95%, rural: 92%). [420] On the other hand, according to the World Bank, the electrification rate in 2018 was 91% (urban: 92%, rural: 90%). [421]

Rural electrification and the penetration of electricity use throughout the country have been key goals. Eskom embarked on a national electrification program in 1991, and resale companies (such as local governments) also undertook electrification in their respective regions.

(b) Electric utility system

(1) Electricity supply system

In the South African power industry, state-owned power company Eskom has a strong influence. In the power generation sector, Eskom owns 90% of the generation capacity, while IPPs and others own the remainder. IPPs, including renewable energy, will enter into a Power Purchase Agreement (PPA) with Eskom. Local governments and others have owned small-scale coal, gas, and diesel oil-fired thermal power generation facilities, but because they are old and expensive, in recent years they have stopped using them and switched to buying power from Eskom. [422] Low electricity sales rates relative to costs have long pointed to a financial crisis of Eskom. In response to Eskom's deteriorating financial situation, the Electricity Regulations Act was amended in October 2020 to allow municipalities with good financial standing to enter into power purchase agreements directly with IPPs. [423]

419 RSA, Roadmap for Eskom in a Reformed Electricity Supply Industry 2019, October 2019, p.9

420 https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity#abstract

421 https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=ZA

422 IEEJ, May 2016

423 ESI Africa, October 16, 2020, https://www.esi-africa.com/industry-sectors/generation/municipalities-given-the-green-light-to-procure-power-from-ipps/

Power transmission is owned and operated by Eskom. Electricity distribution is finely subdivided, with Eskom (45% of the total number of consumers) as well as a number of municipally owned (188 municipalities have licenses) and a few privately owned distribution companies.[424]

45% of end-users purchase electricity directly from Eskom and 55% from resale companies (e.g. municipalities) [425].

(2) Supply system of renewable electricity

The project will be procured from the private sector through a bidding process. Previously, IPPs could only sell power to Eskom, but a legal amendment in October 2020 allowed them to sell power to local governments.

(c) Policy on renewable energy

(1) Renewable energy potential

Although particularly good sunlight is available in the inland area to the northwest, this area has many location constraints that make it difficult to exploit its potential in practice. While the coastal areas and along the Mozambican border in the northeast have moderate sunshine conditions, there are fewer siting constraints.

While there are few suitable sites for wind power generation on land, offshore sites provide favorable wind conditions throughout the coastal areas.

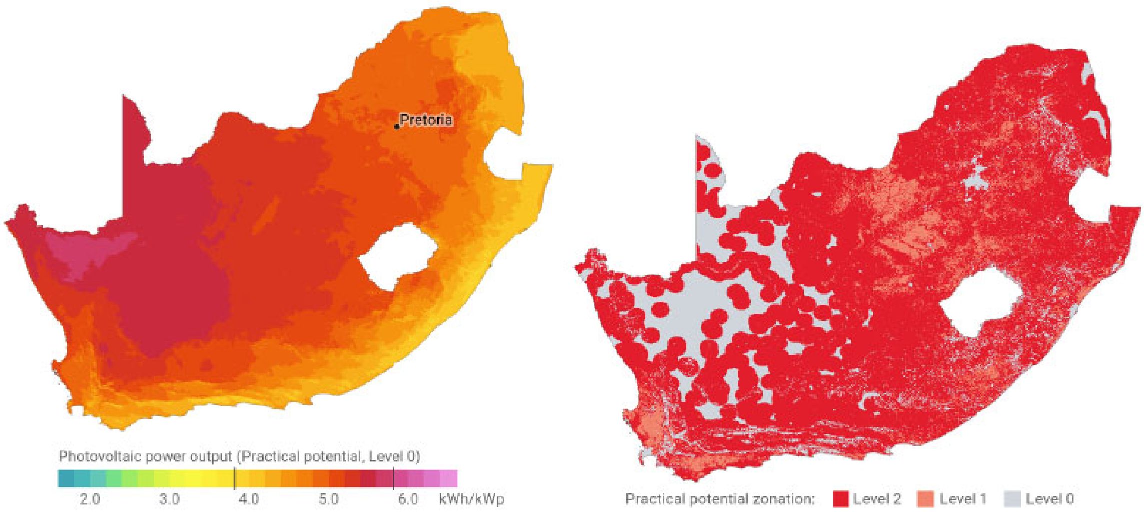

Figure 164 Solar Power Generation Potential in South Africa

Note: Left = Estimated power generation

Right = potential zone; Level 0 = no constraints; Level 1 = excluding topographic constraints; Level 2 = excluding topographic and regulatory constraints.

Source: Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study), access on March 2021

[424] Overseas Electric Power Industry Statistic I 2019-2, JAPAN ELECTRIC POWER INFORMATION CENTER

[425] South African Yearbook, Energy, p.4

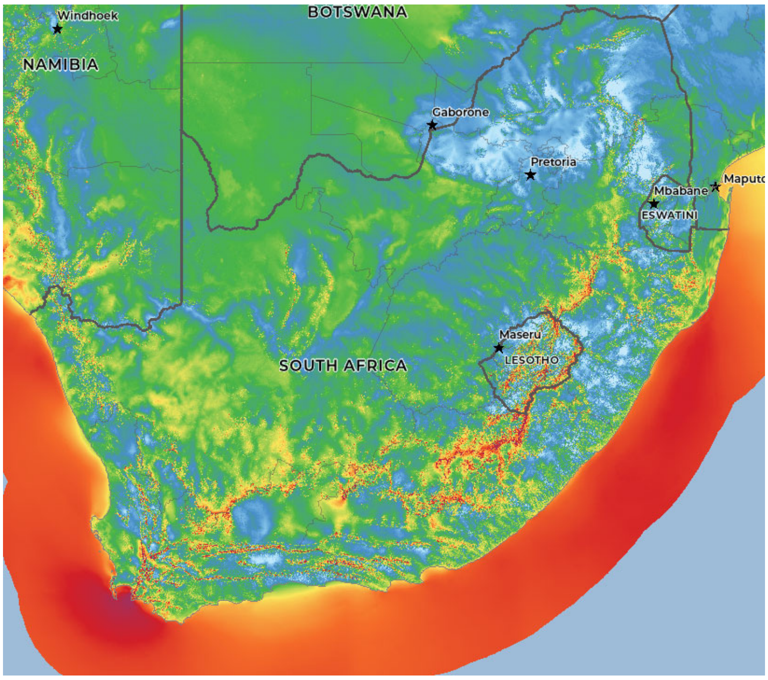

Figure 165 Wind Power Generation Potential in South Africa

Note: Intermediate wind speed values are representative values at 50 m elevation. Red indicates the fastest wind speed.
Source: Global Wind Atlas (https://globalwindatlas.info/), access on March 2021

(2) Institutions in charge of policy

Ministry of Mineral Resources and Energy is in charge.

(3) Development goals

According to the Integrated Resource Plan 2019 (IRP2019), the goals for 2030 are as follows.

- Solar: 8,288 MW capacity (10.6% share), 6.3% share of electricity generated
- Wind: 17,742 MW capacity (22.7% share), 17.8% share of electricity generated

Also, according to the Transmission Development Plan for 2022 to 2031 by Eskom, at least 30 GW of generating capacity will be added mostly by solar and wind over the next 10 years[426].

[Biofuel]

In February 2020, the Ministry of Mineral Resources and Energy announced the South African Biofuel Regulatory Framework, which aims to promote biofuels and foster the industry. It provides for the subsidization of the production of first generation biofuels and their incorporation into products in order to make the more expensive biofuels an economically rational choice and to increase supply capacity. [427]

(4) Policies to promote introduction

The FIT system was introduced in 2009, but was abolished. [428] Currently, the company is promoting renewable energy under the Renewable Energy Independent Power Producer Procurement Program (REIPPPP), which was created at the end of 2010. The program is based on open bidding and autonomous operations with fees derived from the resulting private sector

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426 Eskom, October 26, 2021, https://www.eskom.co.za/eskom-shares-its-transmission-development-plan-for-the-period-2022-to-2031/

427 https://www.gov.za/sites/default/files/gcis_document/202002/43003gon116.pdf

428 IEA, https://www.iea.org/policies/4786-renewable-energy-feed-in-tariff-refit?country=South%20Africa&page=2, https://www.iea.org/policies/5322-renewable-energy-feed-in-tariffs-phase-ii?country=South%20Africa&page=2

investments.

(d) Energy conservation policy

(1) Institutions in charge of policy

Ministry of Mineral Resources and Energy is in charge.

(2) Target

In 2016, the government published the Draft Post-2015 National Energy Efficiency Strategy[429], which sets reduction targets through 2030.

Table 110 Sectoral Targets of Energy Efficiency Improvement Strategy in South Africa

Reduction target Sector	2015 reduction target (Compared to 2000)	Achieved by 2012	2030 reduction target (Compared to 2015)	
The whole economy	12% (*1)	23.7%	29% (*3)	
Industry	15% (*1)	34.3%	15% (*3)	16% (*3、*4)
Mining				40PJ (*3、*5)
Residential	10% (*1)	28.2%	—	
Commercial building	15% (*1)	0.3% (2003-2013) (only elec. consumption)	37% (*3)	37% (*3)
Public building				50% (*3)
Transport	9% (*1)	14.1%	39% (*3)	
Generation	15% (*2)	26% (Estimated by Eskom)	—	
Agriculture	—	—	30% (*3)	

*1：Energy intensity, *2：Electricity own use, *3：Final Energy Consumption
*4：The target is the manufacturing industry, *5：PJ

Source: Draft Post-2015 National Energy Efficiency Strategy, JICA, January 2013

(3) Promotion policy

The following policies can be identified.

- Building insulation standards
- Efficiency standards and labeling systems for equipment such as refrigerators and air conditioners
- Automotive fuel economy labels
- CO2 emission taxation for automobiles

(e) Environmental policy

(1) Greenhouse gas emission reduction targets

In September 2015, the Intended Nationally Determined Contributions (INDCs) were submitted to the UN under the Paris Agreement, followed by the signing of the Paris Agreement in April 2016 and ratification in November 2016. [430]

According to the revised NDC submitted to the UNFCCC in September 2021, greenhouse gas emissions in 2025 should be 398-510 million ton-CO2eq and 350-420 million ton-CO2eq in 2030. Emissions targets have been lowered from the NDC submitted in 2015[431].

In September 2020, the Cabinet also approved the establishment of the Presidential Climate Change Coordinating Committee and the Low Emission Development Strategy, which was submitted to the UNFCCC as a long-term strategy. The Low Emission Development Strategy

[429] Draft Post-2015 National Energy Efficiency Strategy

[430] UNFCC, https://unfccc.int/process/the-paris-agreement/status-of-ratification

[431] UNFCCC, https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx

notes that the goal is to be carbon neutral by 2050. [432]

(2) Promotion policy

The Carbon Tax Act was passed in May 2019. Since the law's parliamentary debate began in 2010, its passage has been postponed at least three times due to fierce opposition from the mining and steel industries, Eskom, and others. The finance minister explained that electricity prices will not increase even after the carbon tax is introduced.

The carbon tax will be introduced in two phases. The tax rate for the first phase is 120 Rand/ton-CO_2e, but the effective tax rate is expected to be 6-48 Rand/ton-CO_2e after applying tax credits. The tax rate, etc. for the second phase will be determined by taking into account the actual GHG emission reductions by the end of 2022, the NDC of the Paris Agreement, and other factors. [433]

Table 111　Outline of Carbon Tax in South Africa

	First phase	Second phase
Implementation period	From June 1 2019 to December 31 2022	From January 1 2023 to December 31 2030
	(3 and a half years)	(8 years)
Taxable	Due to fossil fuel consumption by companies that exceed tax exemption standards (below) GHG emissions (①) minus tax exemption (②, below) (①-②)	
Tax rate	1st year 120 rand /ton-CO2e	—
Tax rate increase (after the second year)	Consumer price index (annual rate%) + 2%	Consumer Price Index (annual %)
Tax exemption standard	Set standards for each industrial sector. In most industries (including electricity, oil refining, mining, and steel), companies with a total power generation capacity of more than 10 MW are taxable.	Separately, it will be decided based on the implementation status of the first phase.
	However, if the conditions are met, up to 90% of GHG emissions will be recognized as tax exemption. The conditions are stipulated for each industry, but the electricity, oil refining, mining, steel industry, etc. are as follows.	
	①Basic tax exemption: 60% of GHG emissions	
	②Tax exemption for companies exposed to international competition: 10%	
	③Tax exemption for emission reduction efforts: 5%	
	④Tax exemption for carbon budget: 5%	
	⑤Tax exemption for offset: 10%	
	Each company is allowed up to 90% of GHG emissions (total of ① to ⑤) as tax exemption.	
	Companies using the CTL, GTL, and Gas to Chemicals processes are allowed a maximum of 95% of GHG emissions by limiting ⑤ above to 5% instead of allowing 10% as a tax exemption for GHG leaks.	

Source: Website of Ministry of Finance, Local Media Reports

In addition, as support from developed countries, in November 2021, the governments of South

[432] UNFCCC, https://unfccc.int/process/the-paris-agreement/long-term-strategies

[433] www.reuters.com/article/us-safrica-carbontax/south-african-carbon-tax-finally-becomes-law-idUSKCN1SW0K6

Africa, France, Germany, the United Kingdom, and the United States, as well as the European Union, announced the Just Energy Transition Partnership to support South Africa's decarbonization efforts. [434]

(3) Transportation

The government introduced a carbon tax on new cars in 2010. The tax is levied on new vehicles manufactured in South Africa. Tax rates are as follows (as of December 2020) [435].

- Passenger cars: 120 rand/g-CO_2 for CO_2 emissions exceeding 95 g per km traveled
- Freight vehicles: 160 rand/g-CO_2 for CO_2 emissions exceeding 175 g per km traveled

In 2015, the government issued a policy under the National Energy Law to achieve commercial biofuel production through full and proper implementation of the bio-strategy. Specific measures include: (1) mandatory blending of biofuels in gasoline and diesel oil after October 2015 (2-10% bioethanol blending in gasoline and at least 5% biodiesel blending in diesel oil), and (2) subsidies for companies that obtain biofuel production licenses (0.045-0.065 rand/ℓ for 20 years starting in October 2015)[436].

In May 2021, the Department of Trade, Industry and Competition (DTIC) released the country's first draft roadmap for electric and other vehicles, the Auto Green Paper. The proposal was released to solicit input from interested parties in the country. The main contents of the proposed policy on electric vehicles and other issues are as follows. (1) Imported parts for domestic production of electric vehicles shall be subject to reduced or no tax. (2) Imported parts for domestic production of electric vehicles are regarded as locally procured parts. [437]

(4) Urban development

N/A.

(f) Next generation technology, innovation

[Hydrogen]

The government is developing the "Platinum Valley" concept, in which hydrogen-related businesses will be concentrated. The development will originate from Platinum Group Metal's platinum mine and science and technology park in Limpopo. The country is promoting the use of hydrogen, including fuel cells, under Hydrogen South Africa (HySA). [438] It is also reported that in July 2020, the Ministry of Science and Innovation took the lead in developing a hydrogen roadmap[439].

In April 2021, Sasol and Toyota South Africa Motors announced the formation of a partnership to begin investigating the development of a green hydrogen mobility system in South Africa. The two companies plan to demonstrate a large hydrogen-fueled vehicle that can travel long distances on the highway between Durban and Johannesburg, for example. [440] Also that month, Sasol and the German LEN consortium announced a collaboration to produce Sustainable Aviation Fuel (SAF). LEN consists of chemical giant Linde and two other companies. FS for SAF production is

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[434] European Commission, November 2, 2021, https://ec.europa.eu/commission/presscorner/detail/en/ip_21_5768

[435] SCHEDULES TO THE CUSTOMS AND EXCISE ACT,1964 Schedule Part 3D https://www.sars.gov.za/Legal/Primary-Legislation/Pages/Schedules-to-the-Customs-and-Excise-Act.aspx

[436] ENSafrica, "bio fuels in South Africa", May 5, 2014

[437] JETRO, May 25, 2021, https://www.jetro.go.jp/biznews/2021/05/e1ccd861d14ff716.html

[438] allAfrica, October 19, 2020, https://allafrica.com/stories/202010200636.html

[439] Siemens, July 7, 2020, https://www.engineeringnews.co.za/article/south-african-govt-initiates-process-of-developing-societal-hydrogen-roadmap-2020-07-07/company:siemens-2019-01-09

[440] Sasol, April 14, 2021, https://www.sasol.com/media-centre/media-releases/sasol-and-toyota-south-africa-motors-form-green-hydrogen-mobility

conducted based on Sasol's synthetic technology[441].

(g) Points to consider for future cooperation in promoting low carbon and decarbonization

- The energy saving potential is great and measures should be strengthened. Possible countermeasures include the following. Certain measures are being taken in buildings, automobiles, and equipment, and measures in the industrial sector are likely to be the main focus. In addition, power conservation is important because the CO2 emission intensity of electricity is very high.
  - ➢ Development of energy efficiency benchmarks for the energy conversion and industrial sectors
  - ➢ Introduction of energy management in energy-heavy industries
  - ➢ Stricter fuel economy standards for automobiles
  - ➢ Strengthening of building insulation standards
  - ➢ Expansion of equipment subject to labeling system
  - ➢ Although it requires the development of import infrastructure, the conversion from coal to natural gas is an effective option to significantly reduce CO2 emissions, and its use could be expanded for all applications in power generation, industry, and buildings.
- In terms of renewable energy, offshore wind power, which provides favorable wind conditions, and sunshine suitable for solar power generation are expected throughout the region.
- Coal-fired ammonia co-firing may attract attention as a low-carbon alternative without stranding coal assets. Producing ammonia from green hydrogen could make this a symbolic project.
- In the transportation sector, the very high CO2 emission intensity of electricity precludes the use of electrification methods, so improving fuel efficiency and limiting automobile use are the available tools.
- JICA-South African government consultations confirmed the potential of (1) using electric boilers and boilers to heat pump hot water and (2) increasing the efficiency of air conditioners (currently mainly non-inverters).

1.2.2 Organizing trends in low and non-carbon energy technologies, services, practical application and commercialization

Low-/de-carbon technologies are organized as shown as below for the fields of electric power and energy, transportation, industry, buildings, and urban transportation. The current status of implementation is categorized into three stages: "research and development," "prototype/demonstration," and "commercialization (practical application)".

Table 112 Low-/de-carbon Technologies Categorizing Table

Sector	Type	Current status	Related Japanese companies	Related foreign companies/ trends oversea
Power and Energy	Wind Power - Onshore - Implantable Offshore - Floating Offshore	- Onshore: commercial Implantatable Offshore: commercial - Floating Offshore: pilot in 2025	Toshiba (parts), Toray subsidiary (blade materials), Komai Haltech (small wind turbines), Eurus Energy (operator)	GE, Vestas*, Siemens Gamesa*, Goldwind, Envision*, Ming Yang, Dongfang *: Foreign companies with advantages in offshore wind
	PV Power (Silicon/compound-based) Perovskite solar	- Silicon/compound-based: commercial - Organic based: pilot	Kyocera Sharp* Choushuu Sangyo	BBOXXLongi (China) Tongwei Solar (China) DaZheng* (China)

[441] Sasol, April 14, 2021, https://www.sasol.com/media-centre/media-releases/sasol-explore-potential-cleaner-aviation-fuels-world-class-partners

Sector	Type		Current status	Related Japanese companies	Related foreign companies/ trends oversea
	cells (Organic based)			Kaneka* *: Japanese companies developing organic-based products	First Solar (US) *: Foreign companies developing organic-based products
	Ocean power generation		Tidal power generation	Kyuden Mirai Energy (Tidal Power: MoE demonstration) Okinawa OTEC Demonstration Facility, Institute of Industrial Science, University of Tokyo (Wave Power)	European Marine Energy Centre（Wave power, Under demonstration, Scotland） Natural Energy Laboratory of Hawaii (OTEC:R&D stage, USA.）
	Nuclear Power - SMR		Commercial (oversea)	Mitsubishi H.I. Toshiba Hitachi GE	NuScale Power (US), TechnicAtome (France), TVEL (Russia)
	Thermal Power	NH_3 co-firing/ mono-firing	Co-firing: pilot, commercial in mid 2020s Mono-firing: commercial in 2040s	JERA Mitsubishi H.I. IHI (Aioi Plant Pilot)	Yara International
		H_2 co-firing/ mono-firing	Co-firing: commercial in 2030 Mono-firing: commercial in 2050	JERA Mitsubishi H.I. (Takasago Hydrogen Park Pilot)	Nuon Magnum PS, The Netherlands Intermountain Power, US
		Oxygen-blown coal gasification CCGT with CO_2 capture	Demonstrating	Osaki CoolGen	Siemens AG ZeroGen Pty Ltd.
	Battery	Li-ion	Commercial	GS Yuasa Toshiba, Lithium Energy Japan	LG Chemical, Samsung SDI
		NAS	Commercial	NGK	NA:Japan-original
		Redox Flow	Commercial	Sumitomo Electric	NA:Japan-original
	Energy carrier (hydrogen)	Liquefied H_2	Demonstrating Commercial in 2030	HySTRA (Iwatani, Kawasaki H.I., Shell, ENEOS, etc.)	AIR PRODUCT (US) Ballard Power System (Canada) Others *Assumed to be working with multiple carriers
		MCH	Demonstrating	Chiyoda Chemical	NA
		NH_3	Demonstrating	IHI, Ube Industries, Sumitomo Chemical, Tokyo Gas, etc. (from Green Ammonia Consortium board members)	AustriaEnergy Yara International (Norway) Others
		Methanation	Demonstrating	Hitachi Zosen Corporation, INPEX Tokyo Gas, IHI	Electrochaea (Germany) Haldor Topsoe (Denmark) Others
	Pumped storage (variable		Commercial	Toshiba, Hitachi	GE

Sector	Type		Current status	Related Japanese companies	Related foreign companies/ trends oversea
	speed)			Mitsubishi Hydro	Sichuan Power Company
	DR/VPP (including smart meters, aggregators, etc.)		- Smart meters, Aggregators: commercial - VPP: demonstrating	- Smart meters: Osaki Electric Works, Mitsubishi Electric, Fuji Electric, Kyuden Techno Systems, etc. - VPP: Yokogawa Electric, Fuji Electric	- Smart meters: Schneider Electric (France), Landis+Gyr (Switzerland), Itron (U.S.), Siemens (Germany), Wasion Group (China) - DR/VPP: Next Kraftwerke (Germany), Energy Pool
	Low-loss, high-capacity conductor		Commercial	Sumitomo Electric	Zhengzhou JINYUAN Wire and Cable（China）
	Superconducting cable		Finish demonstrating	Showa Electric Wire	State Grid Corporation of China（China）
	System utilization capability enhance-ment	HVDC	Commercial	Toshiba, Hitachi, Mitsubishi Electric	TransnetBW, HITACHI ABB
		VSG	Demonstrating	Kawasaki H.I., Meidensha	ABB、Tesla（USA）
		MG set	Commercial	Fuji Electric (Hateruma Island) Meidensha (Factories, Offices etc)	Power Systems & Controls Inc（USA）， Kato Engineering（USA）
		Synchronous phase shifter	Commercial	Toshiba (Shin-Tokorozawa S/S, Shin-Hanno S/S)	Siemens Energy (Germany) HITACHI ABB
	CCUS (Carbon dioxide Capture, Utilization and Storage)		Demonstrating	Kansai Electric Power, Kawasaki Electric Works, Toshiba, Osaki CoolGen Mitsubishi Heavy Industries Engineering (Emi collaboration)	A total of 26 commercial-scale CCS projects in operation (including for EOR purposes) in Australia, Brazil, Canada, China, Norway, Qatar, Saudi Arabia, UAE, and the United States
Transport and traffic	Battery EV		Commercial	Nissan, Mitsubishi, Toyota, Honda, Mazda	JAGUAR, BMW, Tesla, Audi, VW, PEUGEOT, Porsche, Mercedes-Benz
	Plugin hybrid EV		Commercial	Mitsubishi, Toyota, Honda	BMW, Audi, CITROËN, VW, PEUGEOT, Volvo, Porsche, Mercedes-Benz, Land Rover
	Fuel Cell EV		Commercial	Toyota, Nissan, Mitsubishi Fuso	BMW, Daimler, Hyundai
	Rapid Charger		Commercial	(Standard) CHAdeMO	(Standard) GB/T、CCS 1、CCS 2、Tesla
	Fuel Cell Railcar		2024	Toyota, Hitachi	Alstom
	Advanced Biofuels: Cellulosic Ethanol, HVO, HEFA		Commercial	NA	NA
	Advanced Biofuels: BTL Fuels		2030	NA	Enerkem, Fulcrum, KIT, Red Rock Biofuels, TotalEnergies, Woodland Biofuels
	Automated Driving Technology		(Level 3)	Nissan, Toyota, Honda	Audi, VW, Daimler, BMW, Volvo Baidu (platform provider)

Sector	Type	Current status	Related Japanese companies	Related foreign companies/ trends oversea
Industry	Steel Industry (CCUS)			
	Blast furnace off-gas CO_2 removal	2030	Japan Iron and Steel Federation	ArcelorMittal
	Ethanol conversion of blast furnace off-gas	Commercial	NA	ArcelorMittal, China
	Chemical conversion of blast furnace off-gas	2025	NA	Thyssenkrupp (Germany)
	Natural gas based DRI with CCS	Commercial	NA	Abu Dhabi, Mexico Ternium, Venezuela
	Smelting reduction with CCUS	2028	NA	TATA
	Steel Industry (hydrogen)			
	Water electrolysis hydrogen use in blast furnaces	2025	NA	Thyssenkrupp (Germany)
	Natural gas based DRI with high concentration hydrogen blend	2030	NA	Mexico Tenova, Germany Salzgitter
	Water electrolysis hydrogen-only DRI	2030	NA	Sweden, ArcelorMittal
	H2 plasma reduction	NA	NA	Austria SuSteel, University of Utah
	Ancillary processes: H2 for high-temperature heat	2025	NA	Sweden, Norway
	Steel Industry (electrolysis)			
	Low-temperature alkaline	NA	NA	EU Siderwin
	High-temperature molten oxide	NA	NA	EU ULCOS, US MIT
	Steel Industry (biomass)			
	Dry biomass to blast furnace	2025	NA	ArcelorMittal
	Charcoal to blast furnace	Commercial	NA	Brazil
	Steel Industry (trends in Japan)			
	Carbonate fixation of CO_2	NA	JFE, Pacific Cement	NA
	Cement Inducstry (CCUS)			
	Partial absorption by chemicals	Commercial	NA	US Capitol Aggregates
	Complete absorption by chemicals	2024	NA	Norway, Canada, India
	Calcium looping	2025	NA	Taiwan, Germany
	Oxy-fuel	2030	NA	Denmark, Germany
	Absorption by silica, etc.	2035	NA	Canada, US
	Direct separation	2030	NA	Belgium
	Other Capture Technology	NA	NA	EU
	Mineralization of CO2 in concrete	Commercial	NA	China and others
	Cement Industry (raw material substitution)			
	Calsine Clay	Commercial	NA	India, China, etc.
	Calcium Silica Carbonate Chloride	Commercial	NA	US
	Magnesium Silica	NA	NA	UK

Sector	Type	Current status	Related Japanese companies	Related foreign companies/ trends oversea
	Alkali activated binder	Commercial	NA	Switzerland
	Cement Industry (electrification)			
	Direct Electrification	NA	NA	Switzerland
	Solar Concentration	NA	NA	France, US
	Cement Industry (hydrogen)			
	Partial use of hydrogen	NA	NA	UK
	Calcium carbonate calcination	NA	NA	US
	Cement Industry (technology)			
	Advanced Grind	NA	NA	NA
	Cement Industry (trends in Japan)			
	Carbon Recycling	2020 Demonstration	Pacific Cement	NA
	Expanding Applications for CO_2 Effective Concrete	2020 R&D	Kajima, Chugoku Electric Power, Mitsubishi	NA
	CO_2-SUICOM	Commercial	Kajima, Chugoku Electric Power, DENKA, Landes	NA
	Aggregate material utilizing CO_2	2021 Demonstration	Mitsubishi	NA
	CO_2 injection into concrete building materials	Commercial	Mitsubishi	NA
	T-eConcrete/Carbon-Recycle	Commercial	Taisei	NA
	Chemicals and Petrochemicals (CCUS)			
	Chemical absorption - ammonia	Commercial	Mitsubishi Heavy Industries	US
	Chemical absorption - methanol	Commercial	NA	Brazil
	Chemical absorption - high value-added chemical	2025	NA	China
	Physical absorption - ammonia	Commercial	NA	US, China
	Physical absorption, methanol	2023	NA	US
	Physical absorption - high value-added chemical	2025	NA	China
	Physical absorption - methanol	Commercial	NA	China
	Chemicals and Petrochemicals (hydrogen)			
	Green hydrogen - ammonia	2025	NA	Australia, Germany, etc.
	Green hydrogen - methanol	2025	Mitsui Chemicals	Iceland, Germany
	Chemicals and Petrochemicals (eletricfication)			
	Methane → Methanol	2030	NA	Germany
	Steam reforming electrification	NA	NA	Austria
	Chemicals and Petrochemicals (biomass)			
	Biomass gasification -	NA	NA	NA

Sector	Type	Current status	Related Japanese companies	Related foreign companies/ trends oversea
	ammonia			
	Biomass gasification - methanol	Commercial	NA	Canada, Netherlands
	Ethanol dehydration ethylene	Commercial	NA	India
	Lignin-based BTX	2030	NA	Netherlands, Germany
	Chemicals and Petrochemicals (raw material substitution)			
	Methanol → BTX	2030	NA	China
	Naphtha decomposition using catalyst	Commercial	NA	Korea
	Chemicals and Petrochemicals (trends in Japan)			
	CO_2 raw material paraxylene	2020 R&D	University of Toyama, Chiyoda, Nittetsu Engineering, etc.	NA
	Waste plastic recycling	NA	Nippon Steel	NA
	Food Industry (trends in Japan)			
	EMS for local energy production and consumption	Commercial	IHI, TEPCO and many others	NA
	Biogas power generation facility for local energy production and consumption	Commercial	Yanmar etc.	NA
	Utilization of bio-liquid fertilizer	Commercial	Bioseed Technologies, and many others	NA
	Visualization of production process	Commercial	NEC Solution Innovators, etc.	NA
	Energy utilization systems using snow, cold heat, industrial waste heat, etc.	Commercial	Data Dock etc.	NA
	Further utilization of geothermal resources	Commercial	KOBELCO, etc.	NA
	Conversion of food residues into fuel, etc.	Commercial	TAKAFUJI, etc	NA
	Highly functional bio-products from inedible biomass	NA	NA	NA
	Electrification of agricultural and forestry machinery and fishing boats, hydrogenation, etc.	NA	NA	NA
	High-speed humidifying heat pumps	NA	NA	NA
	Development of plants and seaweeds with high CO_2 fixation performance	NA	NA	NA
	CO_2 fixation by seaweed, etc.	NA	NA	NA
	Development of functional packaging materials such as anti-mold	NA	NA	NA
Building	Thermal insulation	Commercial	AGC, Nippon Sheet	In major developed countries,

Sector	Type	Current status	Related Japanese companies	Related foreign companies/ trends oversea
		Japan: developing vacuum insulation materials, Energy-efficient glass （ Japanese companies account for 70% of the total）, multi-ceramic membranes, non-CFC insulation materials, etc.	Glass Company, Ltd 、Pilkington Group Limited, LIXIL, Panasonic, Sekisui Chemical, others. In Japan, insulation performance standards for homes and small buildings are mandatory.	heat insulation performance standards are mandatory; and other standards are being strengthened. Energy-efficient glass ： Saint-Gobain Glass （France）
	Heat pumps (for heating)	Commercial	Daikin, Mitsubishi Electric, Panasonic, Hitachi, Mitsubishi Heavy Industries Thermal Systems, Aisin Seiki, Takasago Thermal Engineering	China, EU
	Heat pumps (air conditioners)			LG, China, etc.
	Cogeneration	Commercial	Gas: IHI Power Systems, JFE Engineering, Hitachi, Kawasaki Heavy Industries, Fuel Cells: Toshiba Energy Systems, Fuji Electric	NA
	EMS	Commercial (implementation focused on HEMS and BEMS)	Hitachi, Fuji Electric, Toshiba, Denso, Panasonic (mainly HEMS), etc.	BEMS: Johnson Controls, Honeywell, Gridpoint, Siemens, Schneider Electric
Urban planning	Smart Cities	Commercial	Participating companies are diverse, depending on the issues to be solved[442]	Digital technology usage is progressing with the entry of giant IT companies: GAFA, IBM, Cisco, IBM.
	Urban Mobility: TOD	Commercial	Nikken Design, Mori Building, Mitsubishi Estate, Mitsui Real Estate, Shimizu, etc.	NA
	Urban Mobility: MaaS	Commercial	Participating companies are diverse depending on the problem to be solved[443]. In particular, Hitachi, Ltd. and NTT have participated in many projects.	Narrowly defined multimodal service providers: RIDESCOUT, moovel, Whim, DiDi, Ola, Go-Jek, etc.
	Local Area Heat Supply	Commercial	TGES, Toho Gas, Daigas Energy, KENES, and others have established consortiums to provide	NA

442 Smart City Public-Private Partnership Platform, https://www.mlit.go.jp/scpf/index.html

443 Smart City Public-Private Partnership Platform, https://www.mlit.go.jp/scpf/index.html

Sector	Type	Current status	Related Japanese companies	Related foreign companies/ trends oversea
			heat supply in various locations[444].	

（1） Power & Energy

(i) Trends in worldwide developments and implementations of technologies and services

The SDS (Sustainable Development Scenario) sets the goal of achieving (net) zero emissions by 2070 as an early CO_2 reduction scenario based on the UN Sustainable Development Agenda.
The "IEA Energy Technology Perspectives 2020" identifies renewable energy, nuclear power, CCUS, hydrogen from low-carbon energy sources, energy efficiency, and non-fossil power generation and storage as low-carbon energy technologies needed to achieve the above SDS. The current status is analyzed as follows.

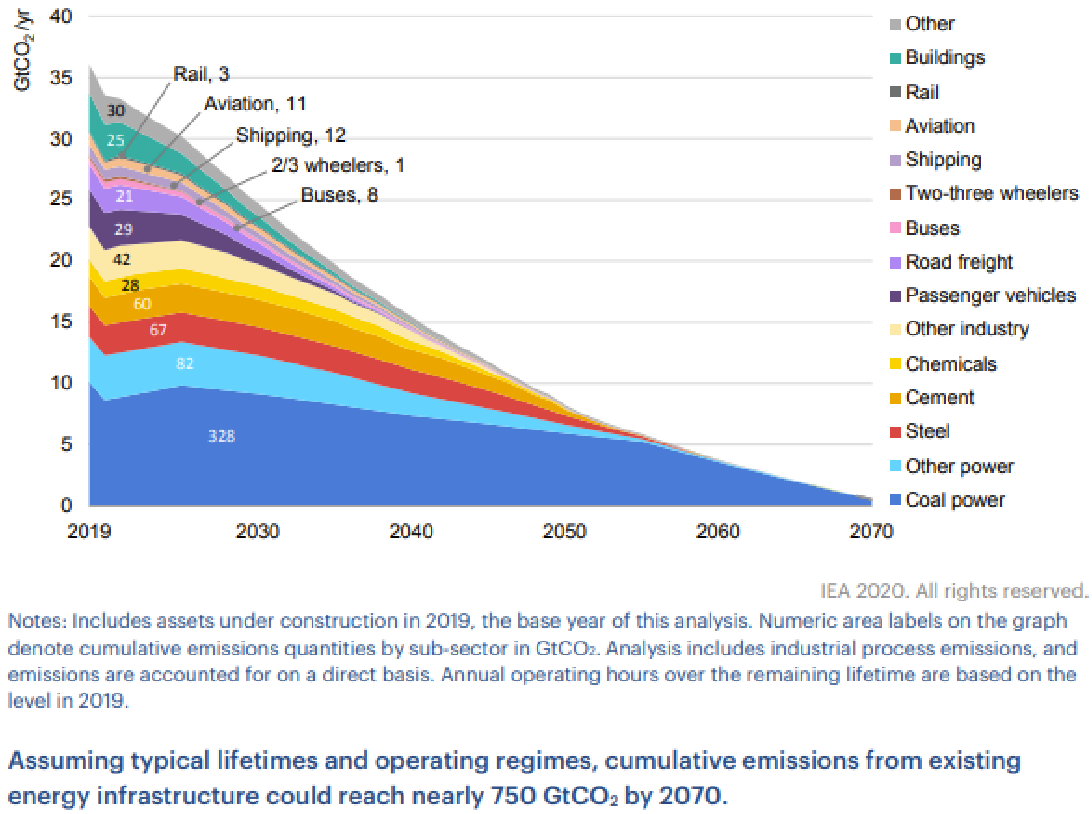

Figure 166 Global CO_2 Emissions from Existing Energy Infrastructure 2019-2070

CO_2 emissions from the energy sector on a global scale have been decreasing due to measures taken by governments around the world, and nuclear power saw an increase in new construction in the 1960s and 1970s, but has since begun to decline. Recently, with policy support from Europe, the U.S., and China, wind and solar power have been expanding rapidly, and currently wind power and solar power account for 5% and 2.5% of the world's electricity supply, respectively.

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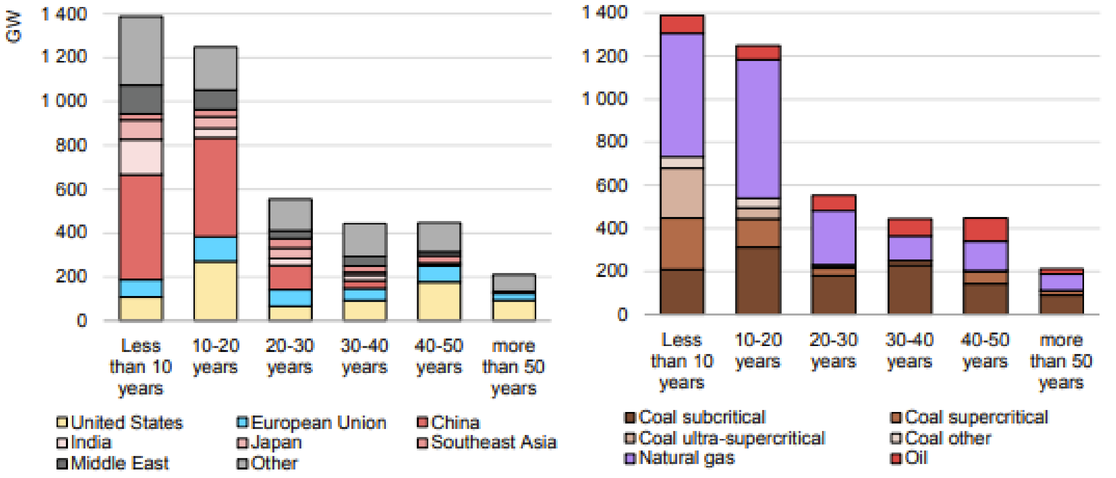
[444] https://www.jdhc.or.jp/category/area/

On the other hand, progress in clean energy technologies in the end-user sector has been slow, with CO_2 emissions from end-user demand mitigated by more efficient energy consumption. More recently, examples such as the development of EVs, and advances in hydrogen and CCUS technologies can be seen. In order to achieve zero emissions by the end of this century, the report states that progress in the end-user sector, which currently accounts for 55% of CO_2 emissions, needs to be hastened.

Increasing global energy demand is outpacing the pace of clean energy technology development. Many fossil fuel power generation facilities are relatively new, especially in Asia, and many steel, cement, and chemical facilities are also new, especially in China. For example, 45% of fossil fuel power generation facilities in Southeast Asia were built within the past 10 years, 70% are less than 20 years old, and where the global average life of a chemical plant is 30 years and steel and cement is 40 years, these facilities are actually only 10-15 years old. At this rate, the existing energy infrastructure will emit 750 gigatons of CO_2 in 2070, making it difficult to achieve the Paris Agreement's goal of "keeping the temperature well below 2°C", let alone the 1.5°C target.



Notes: Based on fossil fuel power plants in operation in 2018.
Source: Informed by Platts (2020a).

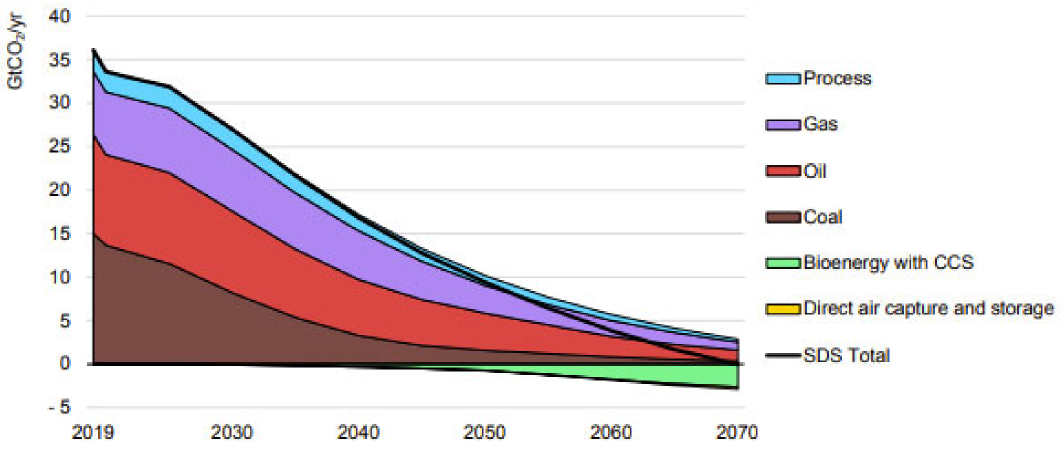
Around a third of existing coal-fired power capacity worldwide was added during the last decade, and almost a third of that new capacity uses inefficient subcritical technology.

Figure 167 Age structure of existing fossil power capacity by region and technology

The core of achieving zero emissions by 2070 will be to increase the efficiency of energy consumption and expand renewable energy, but the following four other technologies will also cut emissions by half.

- Electrification of end-user sectors
- CCUS
- Hydrogen and hydrogen-related fuels
- Bioenergy

In the SDS, electricity, which currently accounts for 20% of final energy demand, will reach 50% by 2070, accounting for 20% of cumulative emission reductions.



Notes: CCS = carbon capture and storage. SDS= Sustainable Development Scenario.

In the Sustainable Development Scenario, CO_2 emissions from fossil fuel combustion and industrial processes drop to 3 Gt in 2070; they are offset by negative emissions technologies, resulting in net-zero emissions.

Figure 168 Global Energy Sector CO_2 Emissions by Fuel and Technology in SDS 2019-70

The power generation sector is the center of the clean energy transition, with renewable energy sources such as PV and wind, nuclear power, and thermal power with CCUS contributing to CO_2 reduction. In addition, an increase in the electrification rate will also lead to a low-carbon transition in end-user demand. Renewable energy (including "BECCS, Bioenergy with Carbon Capture and Storage"; "Biomass power generation with CCS") is expected to reach 86% of total power generation in 2070, with nuclear power at 8%, thermal power with CCUS at 5%, and hydropower at 1%. The share of electricity in primary energy is currently 38%, but is expected to reach 60% by 2070.

Electricity generation is expected to triple in the next 50 years, with 70% of the electricity generated to be used for end-use electrification and the remaining 30% for heat, hydrogen, ammonia, methanol, and hydrogen-based synthetic hydrocarbon fuel production. The production of fuels and feedstocks from such low-carbon electricity is particularly important in the long-distance transportation, shipping, and aviation sectors, where direct electrification is difficult, and by 2070, 19% of electricity generated will be used to produce hydrogen and hydrogen-based fuels, among others.

In addition, as electrification progresses, power systems will need to become more flexible: EV charging, along with the proliferation of EVs, could increase peak demand during the weekday daytime by non-industrial EVs if demand diffusion measures are not taken. In addition, building air conditioning systems using heat pumps may also increase peak demand during lighting hours after sunset, especially in cold regions, and since they will rely more on PV and wind power, they must be flexible enough to cope with daily and inter-seasonal variations.

"Flexible power generation technology"

Synchronous generators such as gas turbines, steam turbines, CCGTs, gas engines, solar thermal plants, stored water hydropower, and nuclear power that can respond to short-notice supply and demand fluctuations immediately to VRE operations can provide the ancillary services to maintain frequency and voltage, and provide inertial power. New wind turbines and PV systems of the type that can provide frequency support are also becoming commercially available, and this new wind power (e.g., Grid Forming Invertor wind power) can also be expected to provide inertial power.

PV and WT VREs, which are essential for low-carbon and decarbonization, are power sources which output fluctuates depending on weather conditions, and there are concerns for frequency fluctuations and reduced inertia in the power system caused by the mass introduction of these VREs. In order to be able to respond to short-notice supply and demand fluctuations and maintain a stable power system supply, stable power sources such as synchronous generators, gas turbines, steam turbines, CCGTs, gas engines, solar thermal plants, and stored water hydropower, etc., need to maintain frequency & voltage, and provide inertia power, as well as ancillary services of the power system. However, most of them, with the exception of solar thermal plants and water storage hydropower, currently use fossil fuels as their energy source, and conversion of that energy source is required. Hydrogen is a typical example of an energy source that is expected to be converted. Nuclear power is mostly operated in base load mode in Japan, but in France and the U.S., it is also operated in frequency control mode or load following mode, and is a synchronous generator that can provide ancillary services and is also a decarbonized power source。

"Promotion of grid interconnection"

Flexible wide-area power system operation technology is one of the useful measures to mitigate sudden changes in VRE output, etc. By accepting electricity from VRE over a wide area, a system-wide dampening effect can be expected, and the system as a whole will mitigate the volatility of VRE. Such wide-area grid operation requires long-distance and high-capacity power transmission technology, and long-distance direct current transmission (HVDC: High Voltage Direct Current) is one of the technologies that can achieve this. A wide-area power system interconnected by HVDC can accommodate time differences in PV output between East and West, and can ensure flexibility in seasonal balance between North and South. Flexible power system operation technologies such as power system control by HVDC (e.g., development of mesh HVDC) are currently in the demonstration stage, but will be necessary for wide-area power system operation involving long-distance power transmission and grid interconnection of large-scale offshore wind farms.

"Demand Response"

To flexibly address needs for reducing peak demand and increasing usage during times of low demand and lower rates. As digitization progresses, EVs and (thermal storage) heat pumps for water and air conditioning can enable demand shifting.

"Energy Storage Technology"

Electricity storage in response to VRE generation is an important technology. While it has been functioning for the past decades and has reached 158GW worldwide in 2019, pump hydro will continue to be important, especially for the capability of 10-15 hours of storage; pump hydro is expected to reach 300 GW by 2070. Storage batteries are also becoming an attractive option due to cost reductions. They are needed for roof-mounted PV on the consumer side and storage for power company storage plants and grid constraint relief. SDS estimates that utility-scale electricity storage capacity will grow from 173 GW in 2019 to 2,100 GW by 2070. The spread of EVs is also seen as an important means of increasing electricity storage. In the SDS, there will be 2 billion EVs in 2070, equivalent to 150 TWh of storage capacity. These will be supported on the grid by V2G inverters. Solar thermal generation can also provide flexibility in regions with good sunlight conditions. Hydrogen-based fuels such as hydrogen, methane, and ammonia are also better options than storage batteries for long-term, large-scale storage. (At present, however, these are more expensive than gas turbines with seasonal balancing capabilities.)

Many technologies to achieve net-zero emissions in the electricity sector are already commercialized; 80% of the SDS reductions are expected to be addressed by technologies that are already mature or in the early adoption stage. Nuclear and hydro are mature technologies, although there are environmental concerns. PV and onshore wind power are now price-competitive in many parts of the world due to the significant price declines in recent years, and offshore wind is expected to become price-competitive in the near future.

The following is to discuss the trends in each of the nuclear energy regions.

In Japan, nuclear power is a major element in promoting decarbonization as a power generation method that does not emit CO_2 during power generation, and is a decarbonization option that is at the practical stage. In the "Green Growth Strategy with Carbon Neutrality in 2050" as of December 2020, it is stated that the aims are for "Japanese companies will participate as key players in the project, contributing to the demonstration of the safety of SMR as a decarbonization technology. Achieve the status of a major supplier. After developing the first SMR overseas at the end of the 2020s, establish a global development and mass production system through overseas collaboration". Recently, in May 2021, IHI announced that it will invest in US-based NuScale Power, which is involved in the development of SMRs.

Table 113 Next Generation Innovative Reactor

	Current status and issues	Future initiatives
Small Modular Reactor (SMR)	**Development of various key technologies is required** ・ Basic design and development in collaboration with overseas demonstration projects. ・ Japanese companies independently develop Small Modular Reactors that meet various needs. **Verify the safety and economics of innovative technologies** ・ For safety, the process for obtaining permits is underway in the United States, the United Kingdom, and Canada. ・ Economic efficiency is pursued by mass production.	**Participation in international collaboration projects** ・ Support the efforts of Japanese companies in collaboration with overseas demonstration projects aiming to start operation at the end of the 2020s, while paying attention to safety, economic efficiency, supply chain construction, and regulatory compliance. ・ Participated in technological development and demonstration based on the formulation of regulations that preceded internationally. ・ Japanese companies participated as the main players in the project and contributed to the demonstration of the safety of SMR, which is a decarbonization technology. After developing the first SMR overseas at the end of the 2020s, establish a global deployment and mass production
High-tempurture Gas Reactor	**The necessity to accumulate development and operation know-how and expand it to a practical scale.** ・ Demonstrated safety while achieving high-temperature engineering test reactor (HTTR) 950 °C (world's highest level) for continuous operation for 50 days (JAEA). ・ Japanese companies are developing a hydrogen production / power generation cogeneration plant and a high-temperature gas reactor for power generation that can store heat. ・ Establishment of connection technology between the high-temperature gas reactor and the hydrogen production facility is necessary.	**Tests and demonstrations using HTTR** ・ In addition to international safety demonstrations using the HTTR, supporting the development of technologies necessary for mass production of low-cost carbon-free hydrogen by 2030. ・ Participate in technological development and demonstration while providing development support with safety, economic efficiency, supply chain construction, and regulatory. Formulate joint overseas projects based on the status of current leading international projects. ・ Promote cooperation with related organizations in other countries to disseminate Japanese standards.
Nuclear fusion	**R&D at domestic facilities, manufacturing and testing for the construction of the fusion experimental reactor (ITER), and development of various key technologies are required.** ・ Testing for the advancement of plasma control technology. ・ Starting assembling and installing the ITER body. ・ Delivered major equipment such as coils from Japan. ・ Design of a fusion prototype reactor that can operate safely and stably.	**Steady promotion of ITER plans** ・ Through efforts for international joint technology development such as the ITER project and future prototype reactor construction plans, verification of major equipment and establishment of long-term output maintenance technology. Reflected in Japan's fusion prototype reactor construction plan. ・ Accelerate collaboration between U.S. and U.K. ventures and Japanese venture companies, aiming for commercialization around 2030. ・ Promote the development of carbon-free hydrogen production technology that utilizes the high-temperature heat of fusion reactors.

Source: Green Growth Strategy Accompanying Carbon Neutrality in 2050 (2020/12)

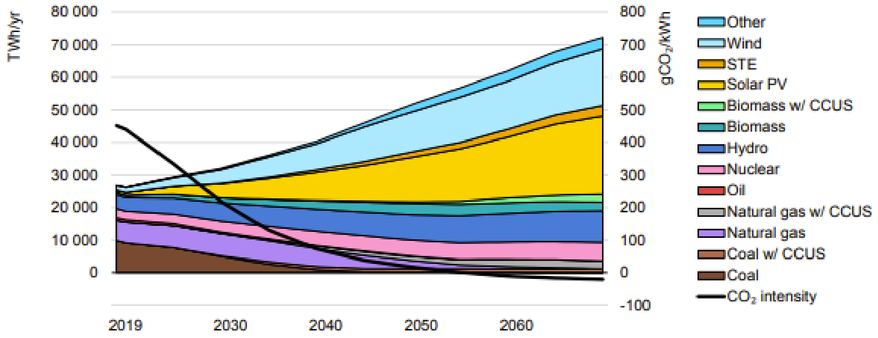
In the U.S., new nuclear power development had been halted since the TMI accident in 1979, but in the 2000s, the Bush administration launched measures to support nuclear power development, and applications for the construction of three units were submitted. Since then, the rise of shale gas and other factors have made economic feasibility difficult, and development has been delayed. On the other hand, development of small module reactors (SMRs), which are safer than the current large commercial reactors, is in progress, and some of them have received type approval from the Nuclear Regulatory Commission. SMRs, which are smaller in power output and have higher safety standards, may be deployed in other countries once the technology is commercially established in the U.S. Japanese manufacturers are also investing in the development of SMRs.

In the EU, while Germany and Italy are moving away from nuclear power, it major power source in France remains, and Poland is planning new nuclear power installations. In March 2020, the European Commission's (EC) Technical Expert Group on Sustainable Finance published its final report on the classification (taxonomy) of green projects that will be the focus for action plan to achieve climate neutrality (virtually zero CO_2 emissions) by 2050. Although there was no recommendation to include nuclear energy in the report, a separate committee (JRC) has been established within the EU to examine the role of nuclear energy and is now deliberating on the issue.

In China, as of the end of September 2018, 40 reactors were in operation, with 18 under construction. The government intends to continue building new reactors in coastal areas. It intends to position domestically produced reactors (Hualong No. 1) and CAP1400 reactor types that incorporate overseas technologies as its main domestic plants, as well as to expand its business overseas.[445]). In addition, it is already developing nuclear power development projects in the United Kingdom, Romania, South Africa, Pakistan, and the Czech Republic[446].

In addition, the decarbonization status of the electricity sector will vary from region to region due to differences in reliance on renewable energy, CO_2 storage sites, and other factors. For example, CCUS applied to gas-fired and bio-power plants in the US could reach 7% of electricity generation in 2070. Wind power predominated in the EU, accounting for 40% of power generation; PV is used with storage batteries in India, reaching 40%. In China, PV and wind will account for the majority of electricity generation. Also, in China, nuclear power and CO_2 capture plants are expected to account for 13% and 12%, respectively. Moreover, many European countries are expected to achieve net zero around 2050.

In Asia, where demand is growing rapidly, nuclear is expected to occupy an important position in the transition to clean energy. Most are current reactor designs, but advanced technologies such as SMRs, which are currently still prototypes, are expected to contribute to increasing VRE market share.



Notes: TWh = terawatt-hours; gCO_2/kWh = grammes of CO_2 per kilowatt-hour; STE = solar thermal electricity; PV = photovoltaic; CCUS = carbon capture, utilisation storage. Other includes geothermal power, ocean energy and hydrogen.

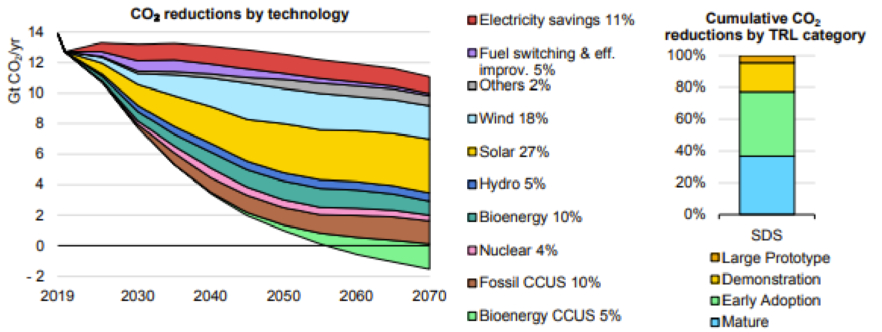
Global power generation sector achieves net-zero CO_2 emissions before 2060, largely from renewables which account for over 85% of the generation mix by 2070.

Figure 169 Global Power Generation by Fuel/Technology in SDS 2019-70

[445] "Electricity Projects in Overseas Countries, Volume 1 (Part 2)," Japan Electric Power Information Center, 2019

[446] The above information is from the "Overseas Electric Power Related Information" on the website of the Alliance of Electric Power Companies of Japan.

Figure 3.3 Global CO_2 emissions in the power sector by scenario and decomposition of the difference by technology type



Notes: TRL = technology readiness level; eff. improv. = efficiency improvements; STE = solar thermal electricity. Others include geothermal and marine energy as well as hydrogen. Electricity savings refer to electricity demand reductions in end-use sectors through more efficient end uses of electricity, leading to emissions reduction in the power sector. The percentages in the labels indicate the contribution of each technology type to cumulative overall emissions savings by 2070. See Box 2.6 in Chapter 2 for the definition of the TRL categories *large prototype, demonstration, early adoption* and *mature*.

A broad portfolio of technologies decarbonises the power sector in the Sustainable Development Scenario: most are available today, though BECCS has not yet been demonstrated at commercial scale.

Figure 170 Global CO_2 reductions by technology and cumulative CO_2 reductions by technology level

One challenge in Asia is the relatively new fossil fuel-fired power, especially coal-fired power in China. 190 GW of coal-fired power in China is expected to be retrofitted with CCS. Many existing coal-fired power plants may change their role to supplying reserve power to the power grid, by life-extension measures such as low carbonization and wider range for flexible operation. Co-firing with biomass at 15-20% requires no equipment changes, and Japan's Chugoku Electric Power Company has demonstrated ammonia co-firing (2018). A full transition from coal to biomass is also possible and more expensive than co-firing, but has been demonstrated in several projects. Early retirement of coal-fired capacity is also important, with SDS assuming that 600 GW of the 2,100 GW of coal-fired capacity will be retired early.

(a) Wind Power

According to the Global Wind Report 2020, as of 2020, there is 743 GW of wind power capacity worldwide. This helps the world avoid more than 1.1 billion tons of CO_2, the equivalent of South America's annual carbon emissions, and in the 10 years since 2010, the amount of installed capacity has nearly quadrupled.

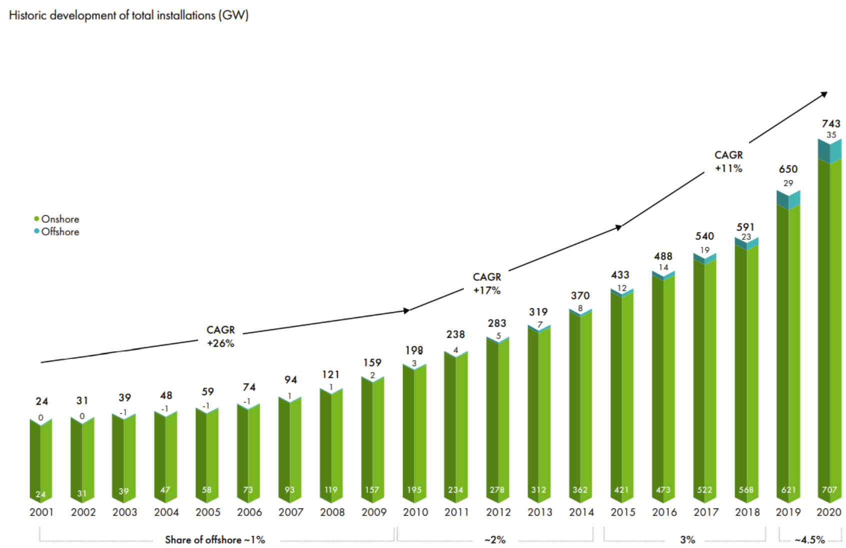


Figure 171 Total installed wind power generation capacity (GW)

Source: GWEC | GLOBAL WIND REPORT 2021

Recently, offshore wind power generation, in which huge wind turbines are built in large numbers on the sea, has been increasing, with total capacity exceeding 35 GW as of 2019, which is equivalent to 4.8% of the world's cumulative wind power generation capacity.

In Europe, in particular, there is a sense that development in suitable onshore locations is approaching its limits, and the scope of development is rapidly expanding to vast, windy offshore areas.

The initial cost of wind power generation is about 1/3 of the cost of transportation and construction on land and 2/3 of the cost of construction at sea. To improve economic efficiency, efforts are underway to reduce the initial cost by reducing the number of units built through increased rated capacity. The world's largest wind turbine in operation as of November 2020 has a rated output of 13 MW and a rotor diameter of 220 m.

Although still in the demonstration stage, floating offshore wind turbines are also being developed in many countries to expand the scope of offshore wind power development (the boundary water depth at which a floating type is economically advantageous over a landing type is considered to be 50 m or more). If future technological innovation and cost reduction progress smoothly, commercialization is expected in a few years. The following types are typical examples.

Table 114　Typical form of floating type

Floating form	Performance		Applicable sea area
	Floating body	Mooring	
Float (barge)	Since the secondary moment of water surface is large, the natural frequency overlaps with the main frequency of the wave, resulting in a large response	Due to the catenary mooring, the mooring force is relatively small.	Suitable for installation in calm waters, as this type is relatively prone to oscillation.
Semi-sub	An improved form of pontoon. Stable because the natural frequency in all degrees of freedom does not overlap with the main frequency of the wave.	Due to the catenary mooring, the mooring force is relatively small.	Most of the floats are submerged and less susceptible to waves, making them suitable for offshore installation.
Super	Stable because the natural frequency in all degrees of freedom does not overlap with the main frequency of the wave.	Due to the catenary mooring, the mooring force is relatively small.	Since the part penetrating the water surface is small, it is suitable for installation offshore where wave conditions are severe.
TLP	Due to the tension mooring, there is almost no sway in the heave or pitch direction.	A large load acts on the mooring anchor due to tension mooring. The mooring force fluctuates greatly.	(Since it is not in the practical stage at this time, no applicable area is mentioned.)

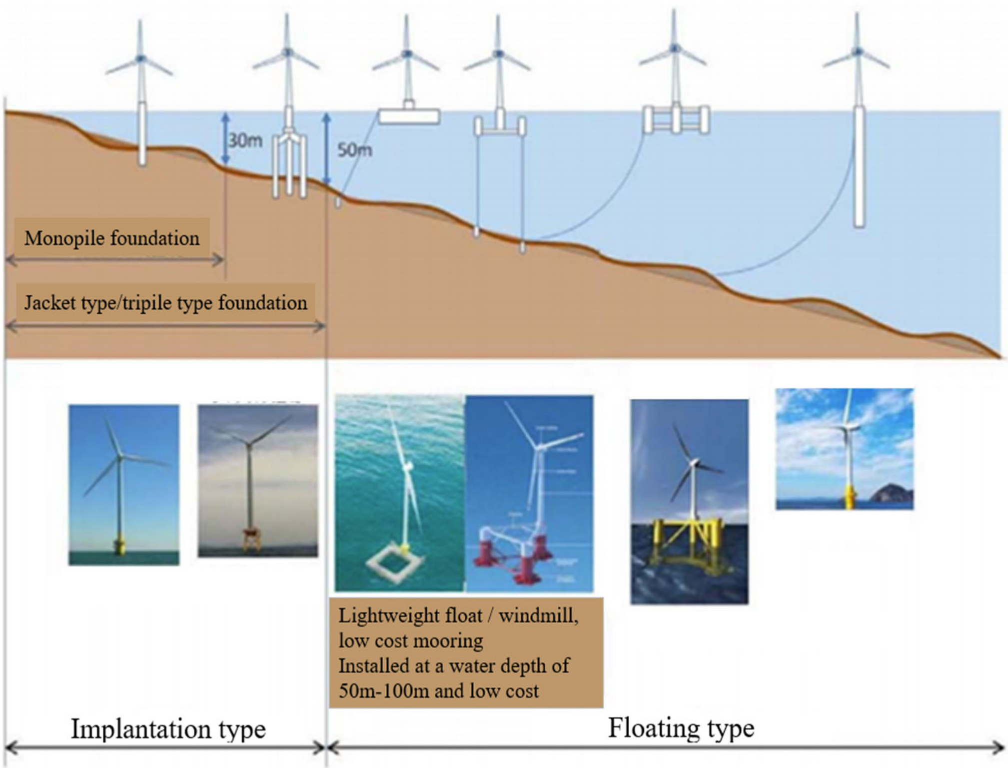


Figure 172　Applicable water depths for offshore wind power facilities
Source: Floating Offshore Wind Power Generation Technology Guidebook (March 2008)

At the present, yaw control (wind direction tracking control), pitch control (blade angle control during strong winds), and variable speed control (speed control according to wind speed) are standard equipment. Recently, storm control has been developed to avoid large output fluctuations in cut-out and cut-in during strong winds, and to continue operation by adjusting output according to increases and decreases in wind speed without stopping the wind turbine.

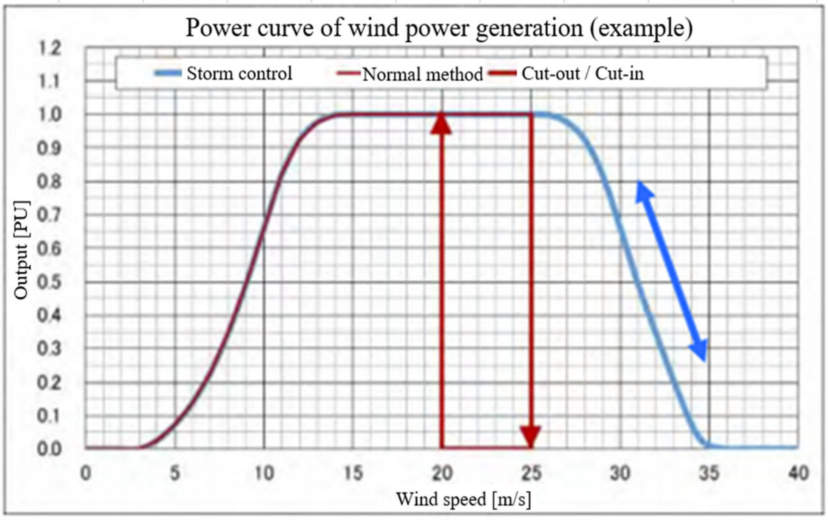


Figure 173 Power curve for wind power (example)

Source: Wind Power Generation Facts 2018/7/9 Japan Wind Power Association

In terms of manufacturer trends, for onshore wind power, Mitsubishi Heavy Industries, Nippon Steel Works, and Hitachi, which were the major wind turbine manufacturers, all withdrew from the market by 2019, partly due to slow growth in the Japanese market. In the global market, price competition is fierce, and although Vestas (Denmark) maintains the top share, Chinese manufacturers hold more than 30% of the market.

While technologically advanced Western manufacturers hold a 60% share of the offshore wind power market, Chinese manufacturers are also increasing their share, with the five Chinese companies in the top 10 accounting for about 39% of the market. Japanese companies have also been expanding their business, with Mitsubishi Heavy Industry establishing a joint venture Offshore Wind Power Generation Equipment Company with Vestas in 2013. However, they dissolved this joint venture and established MHI Vestas Japan as a joint venture with Vestas in February 2021 to engage in the sales business of Vestas wind power generation equipment in Japan.

The Global Wind Energy Council (GWEC) published the following market share rankings (in order of annual installed capacity) in its Annual Analysis Report on Wind Turbine Supply published on May 27, 2020(*)。

New installed wind power capacity in 2019 was 63 GW; 22,893 wind turbines were built. There are 33 manufacturers, of which 6.4 GW are offshore wind.

Table 115 Onshore Wind Turbine Manufacturers Market Share by Newly Installed Capacity (2019)

Rank	Manufacturer	Share (%)
1	Vestas (Denmark)	20.10
2	Goldwind (China)	13.61
3	Siemens Gamesa Renewable Energy (Spain)	12.97
4	GE Renewable Energy (US)	12.45
5	Envision (China)	8.55
6	Mingyang (China)	5.55
7	Nordex Acciona (Germany)	5.47
8	Enercon (Germany)	3.34
9	Widney (China)	2.82
10	Dongfang (China)	2.35

Table 116 Offshore Wind Turbine Manufacturers Market Share by Newly Installed Capacity (2019)

Rank	Manufacturer	Share (%)
1	Siemens Gamesa Renewable Energy (Spain)	39.77
2	MHI Vestas (Denmark)	15.70
3	Sewind (China)	10.04
4	Envision (China)	9.53
5	Goldwind (China)	9.37
6	Mingyang (China)	7.29
7	GE Renewable Energy (US)	4.28
8	CISI Haizhuang (China)	2.33
9	Senvion (Germany)	1.57
10	SEMC (The Netherlands)	0.12

The preliminary report published in March 2021 on the combined capacity of new onshore and offshore wind turbines in 2020, ranked from first to fifth, is available. (In order from first to fifth are Vestas, GE Renewable Energy, Goldwind, Envision, and Siemens Gamesa.)

In addition to the common VRE issues of cost, utilization rate, and grid interconnection problems associated with variable loads, wind power generation also faces issues such as noise, high wind speeds, and lightning strikes.

Noise is an issue comes from wind noise from the blades and mechanical noise from the speed-up gears. Such noise has a specific frequency and is accompanied by harmonic components and low-frequency vibrations, which can cause ear problem even if the sound intensity (sound pressure) is reduced. Countermeasures should include not only improvement of blades and speed-op gears, but also selection of installation sites.

Failures have often been reported in which wind turbine foundations collapse due to stronger-than-expected winds, and blades and nacelle covers break or shatter.

Lightning strikes are also a frequent problem for wind turbines, which are located in open areas at high elevations with high support towers. The impact of a lightning strike can cause structural damage to the blades and damage to electrical control components, often forcing an interruption in operation.

The challenge is to establish guidelines to reduce the damage caused by these strong winds and lightning strikes due to the natural characteristics of Japan, as well as to set up wind conditions and evaluation methods, typhoon and turbulence countermeasures, and lightning protection measures including lightning protection equipment and surface coating.

(b) P Photovoltaics (PV) Power

Global annual PV installed capacity has exceeded 100 GW for three consecutive years as of 2019, and deployment is progressing in many countries; total cumulative installed capacity at the end of 2019 reached 627 GW globally, with China accounting for 204.7 GW of cumulative capacity, followed by the EU (131.3 GW, Germany 49.2 GW), the US (75.9 GW) Japan (63.0 GW), and India (42.8 GW).

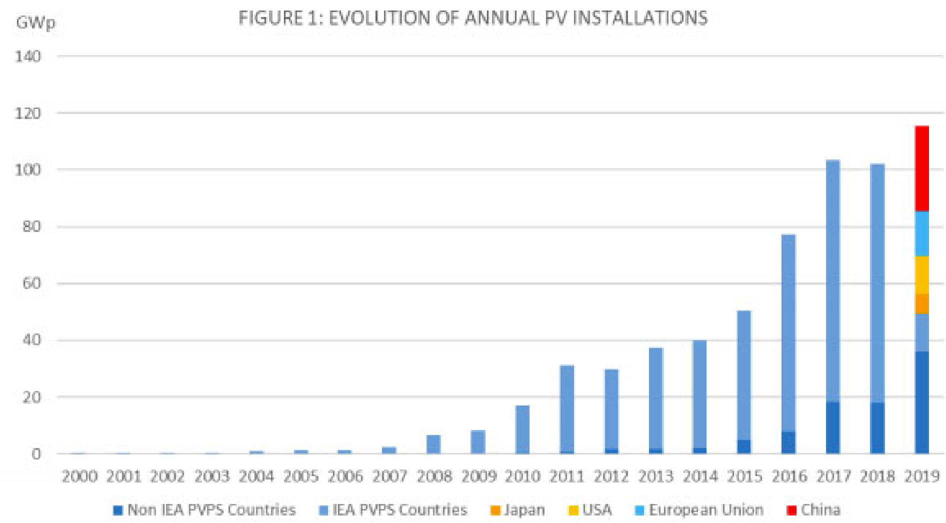


Figure 174 Annual development of photovoltaic facilities

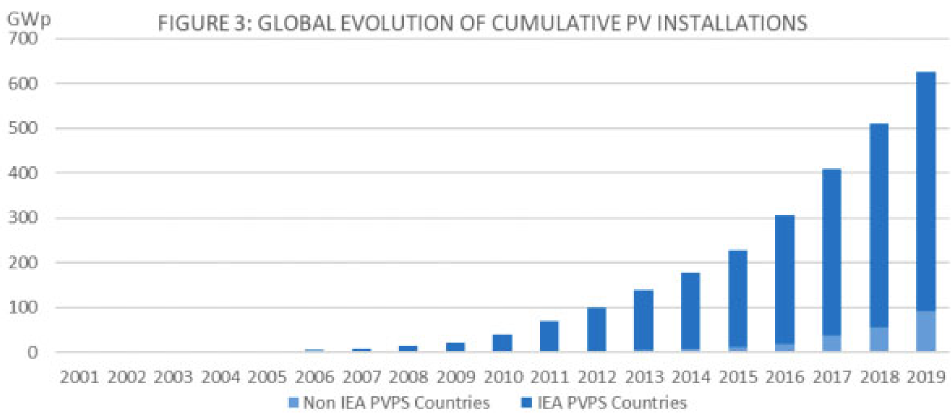


Figure 175 Cumulative development status of photovoltaic facilities

Source: IEA PVPS: Snapshot of Global PV Markets 2020

According to a few information sources including Taiyang News, an information service provider on solar energy, and Bloomberg, PV InfoLink, which provides information on renewable energy market, released the ranking of PV module shipment in January 2022. The top 10 companies are shown below. Except each one company in Canada, Korea and U.S.A., all companies are based in China. PV InfoLink says these top 10 companies occupy about 90% of the market share.

Table 117 PV Module Shipment Rankings 2021

Ranking	Manufacturer
1	Longi (China)
2	Trina Solar（China）
2	JA Solar （China）
4	Jinko Solar（China）
5	Chnadian Solar（Canada）
6	Risen Energy（Chia）
7	Hanwha Q-Cells（Korea）
8	First Solar（U.S.A.）
9	Suntech (Wuxi + Changzhou)（China）
10	Astronergy（China）

(Source: Taiyang News All About Solar Power, January 26, 2022)

Furthermore, according to “Mega Solar Business”, Nikkei-based information site, SVP Market Research published the market share of PV manufacturers (shipment base) in 2022. Ranked No. 1 is Longi, No. 2 is Tongwei Solar, No 3 is JA Solar, No. 4 is Aiko Solar, and No. 5 is Trina Solar, all of which are Chinese manufacturers. They occupy 43% of the total shipment of PV batteries.

According to Deallabo, a data-based platform for market analysis, in terms of sales in 2020, No. 1 is Longi (China), No. 2 is Jinko Solar (China), No.3 is Trina Solar (China), No.4 is JA Solar (China), No. 5 is Canadian Solar (Canada), No.6 is Hanwha (Korea), No.7 is Risen energy (China) and No. 8 is First Solar (U.S.A.). While the ranking differs between shipment base and sales base, Chinese manufactures are predominant.

Table 118 Global Market Share of PV Panel in 2020 (Sales Base)

Ranking	Manufacturer	Share (%)
1	Longi（China）	4.80
2	Jinko Solar（China）	3.17
3	Trina Solar（China）	2.59
4	JA Solar（China）	2.27
5	Canadaian Solar（Canada	2.05
6	Hanwha（Korea）	1.93
7	Risen Energy（China）	1.04
8	First Solar（U.S..）	1.00

(Source: “Analysis of Global Share of PV Panel Industry” (Deallab, May 2, 2022)

In Japan, the introduction of the FIT system has promoted the introduction of PV. However, to be independent from FIT, it is necessary to reduce of initial costs and generation costs for PV by improving generation efficiency/strengthen competitiveness with other power sources; reduce the cost of storage batteries, which are essential for utilizing the generated power without waste, and develop smart grids and electricity markets. The need for smart grid advancement, progress in the electricity market, and the creation of diverse business models are also important. In other words, innovation is required in various fields, including PV, storage batteries, digital/information, AI, and other technological aspects, institutional aspects such as electricity markets, and business models.

In its "PV OUTLOOK 2050," JPEA (Japan Photovoltaic Energy Association) presented the following image of independence from FIT by around 2030, with an eye toward carbon neutrality in 2050.

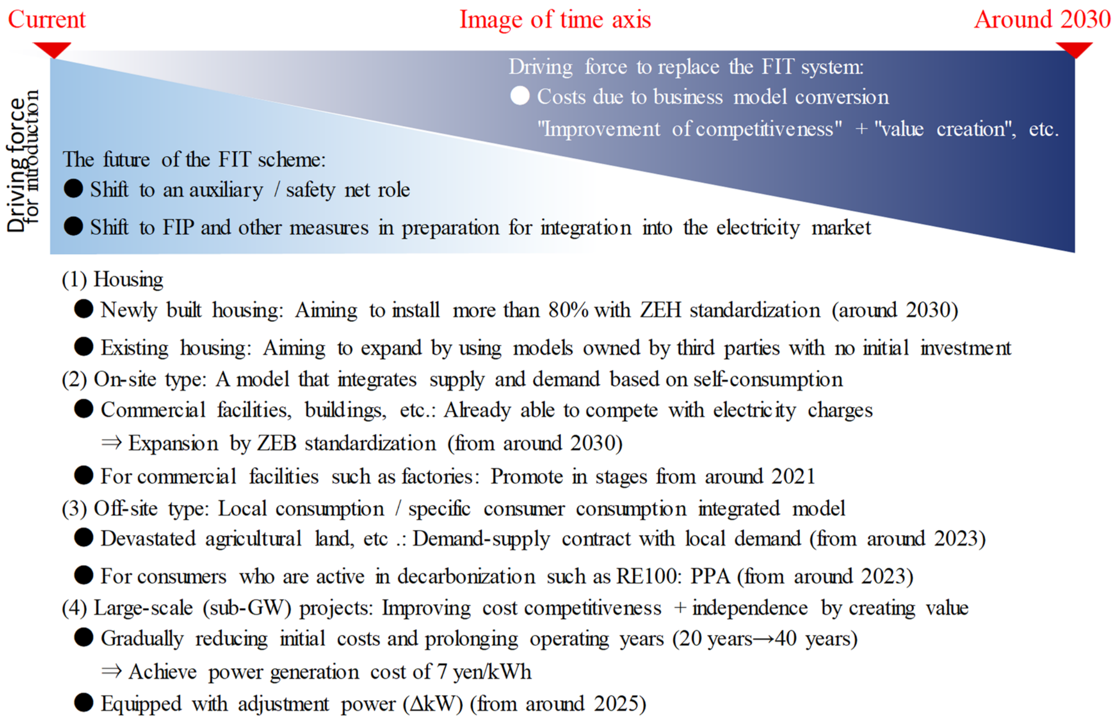


Figure 176 Toward Solar Power as the Primary Source of Electricity

Additionally, to solve the location constraints that are becoming more pronounced and to further promote the introduction of solar power generation, it is important to reduce the cost of existing power sources by promoting the commercialization of lightweight perovskite systems that can attach to curved surfaces, tandem-type and Group III-V cells that use a wider range of wavelengths to increase efficiency.

In the "Strategy for Environmental Innovation" of the Integrated Innovation Strategy Promotion Council, it is stated that innovative devices and materials in the key technology development phase, such as perovskites, next-generation tandem-type devices, and III-V materials, will be researched and developed under industry-academia-government collaboration, aiming to start social implementation around 2030.

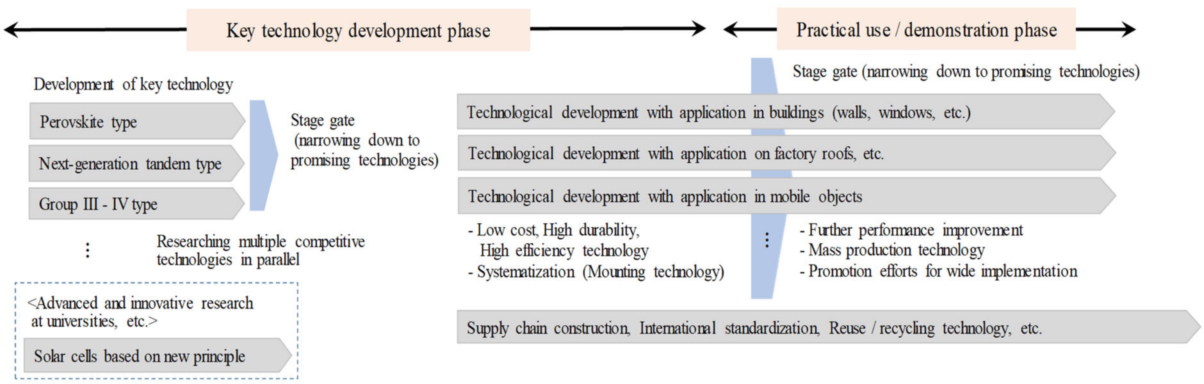


Figure 177 Key development technology and practical application of photovoltaic power generation

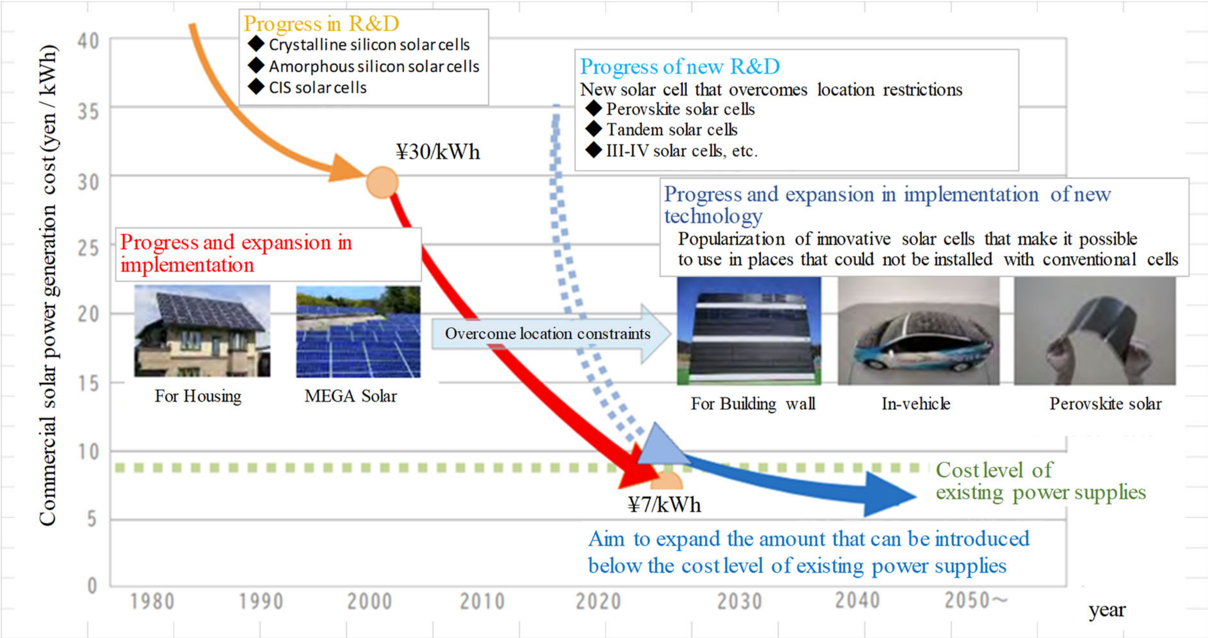


Figure 178 Example of Cost Reduction in Innovation

Source: Environmental Innovation Strategy kankyousenryaku2020.pdf (kantei.go.jp)

(c) Thermal Power

For rotating synchronous generators, thermal power generation, along with hydroelectric power generation, nuclear power generation, etc., has not only been the main source of power supply, but has also played a fundamental role in maintaining stability by establishing and maintaining frequency and voltage in the AC power system due to their rotational energy inertial force.

For a low-carbon or de-carbon society, part of their electricity supply is being ceded to renewable energy sources such as solar power and wind power.

Although progress is being made in the development of technologies such as GFM inverters with pseudo inertia and frequency regulation using storage batteries, thermal power generation is expected to play a fundamental role for the time being in terms of maintaining stability in terms of establishing and maintaining frequency and voltage and of securing load-adjusting function, so a shift to co-firing and dedicated burning of non-fossil fuels such as hydrogen and ammonia, further improvements in efficiency, and the introduction of CCUS are required to achieve low-/de-carbonization.

Especially in Asia, where there are many relatively new thermal power plants, the role of thermal power generation is significant in terms of both low-/de-carbonization and stable supply, and therefore, more low-/de-carbon technologies are required to be introduced.

“Ammonia co-firing/mono-firing”

Currently, demonstration experiments are underway to test the co-firing of ammonia in coal-fired power plants, and it has been confirmed that the concentration of CO_2 in exhaust gas can be reduced by approximately 20% when 20% mixture is co-fired. If all coal-fired power plants owned by major electric power companies in Japan adopt 20% co-firing, the amount of CO_2 emissions reduction will be approximately 40 million tons. It is estimated that if all such coal-fired power plants were replaced with ammonia-only power plants, the reduction in CO_2 emissions would amount to approximately 200 million tons, and the introduction of fuel ammonia would have a significant impact.

Since ammonia is already widely used in fertilizer and other applications around the world, it is possible to develop infrastructure using existing production, transportation, and storage technologies with established safety measures. When ammonia is mixed with coal-fired power generation boilers that use pulverized coal, if the aim is not to achieve a high mixing ratio, it may be possible to modify (replace) the burners for ammonia combustion or install denitration equipment, etc. Therefore, existing facilities can be used, and new maintenance and initial investment can be minimized while CO_2

emissions can be reduced. However, since NO_x emissions increase due to ammonia combustion, it is necessary to have a corresponding denitration facility.

In May 2021, JERA and IHI announced that their demonstration project for ammonia co-firing in large commercial coal-fired power generators had been selected as a NEDO-subsidized project. The purpose of the project is to establish a technology for ammonia co-firing by generating electricity with coal and ammonia and evaluating the heat yield characteristics of the boiler and the environmental impact of exhaust gas, etc. The two companies will conduct co-firing at Unit 4 of JERA's Hekinan Thermal Power Plant (output: 1GW) between June 2021 and March 2025, aiming to achieve 20% ammonia co-firing by 2024. In addition, from October 2021 to March 2022, the two companies will conduct small-scale use of fuel ammonia at Unit 5 of the Hekinan Thermal Power Plant for the purpose of developing a demonstration burner for use in the large-scale co-firing described above, and will convert two of the 48 burners to test burners to investigate the effects of different materials and the conditions required for a demonstration burner. The company plans to investigate the effects of different materials and the conditions required for the burners for demonstration purposes. Based on the satisfactory progress so far, the large-scale co-firing demonstration will start in FY 2023, ahead of the original schedule, for early establishment of technology.[447]

In March 2021, IHI Corporation, under contract with the New Energy and Industrial Technology Development Organization (NEDO), developed a 2MW-class gas turbine that mixes liquid ammonia and natural gas by spraying it directly into the combustor. The project succeeded in achieving the world's first stable combustion of liquid ammonia with a heat rate of 70% and suppressed NOx emissions, and also succeeded in operating a gas turbine with 100% liquid ammonia-only combustion on a limited basis.

Other than IHI Corporation, Mitsubishi Power announced, in March 2021, that it had begun development of a 40 MW-class gas turbine system that uses ammonia as the sole fuel for thermal power generation, aiming for commercialization after 2025.

“The Role of Low-Carbon fuels in the Clean Energy Transitions of the Power Sector" published by the IEA in October 2021 stated that ammonia co-firing requires investment in boiler modifications, ammonia tanks, and vaporization equipment, and that there are other issues such as maintaining combustion conditions and NO_x emission constraints. Currently, only two co-firing projects under development in the world are discussed: the 1% co-firing demonstration project conducted by Chugoku Electric Power (Japan) in 2017 and JERA/IHI's Hekinan coal-fired power plant demonstration project mentioned above.

“Hydrogen co-firing/ mono-firing”

Even though existing gas turbines fueled by natural gas can be used up to a certain level of hydrogen mixed combustion, Mitsubishi Power has developed a combustor for gas turbines that can use 30% hydrogen mixed with LNG. The combustion of hydrogen can reduce NO_x emissions to the level of existing gas-fired power plants, and the technology can handle an output equivalent to 700 MW (turbine inlet temperature of 1,600°C). CO_2 emissions during power generation is reduced by approximately 10% compared to conventional combined cycle gas turbines (GTCC). This technology is one of the most promising ones for hydrogen co-firing due to its non-requirement of large-scale renewal of power generation facilities other than gas pipelines and combustors.

On the other hand, as for hydrogen mono-firing, it is required to efficiently mix hydrogen and air and stably combust them, leading to the necessary of hydrogen combustor, which is currently in development stage.

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[447] JERA press releases May 24, 2021, and October 6, 2021, and May 31, 2022

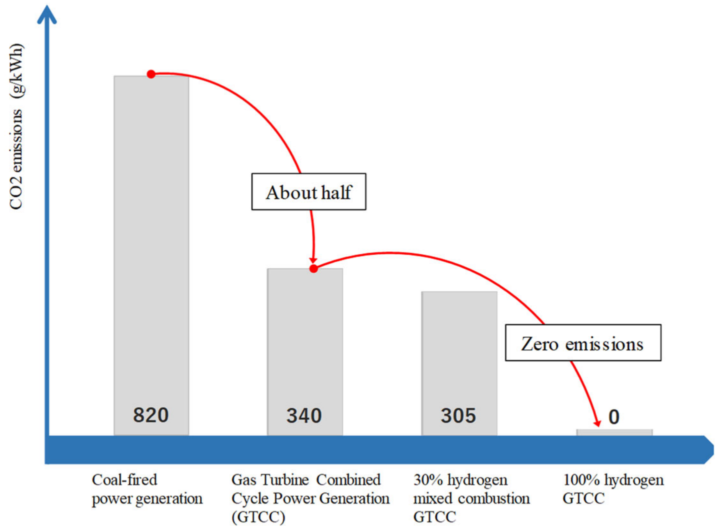

Figure 179 CO_2 emissions intensity by thermal power generation type

Source: Mitsubishi Power's website

Regarding overseas hydrogen co-firing, the Global Hydrogen Review 2021 published by the IEA in October 2021 listed 9 hydrogen projects (including ammonia) in the power sector, including JERA South Thermal Power Plant's ammonia co-firing demonstration project. The following is an overview of projects outside Japan.

Table 119 Overview of Overseas Hydrogen Projects

Project name	Location (Country)	Operation (Planned)	Capacity (MW)	Outline
Daesan Green Energy	Korea	2020	50	A joint project between Daesan FC, Korea East-West Power, and others. Operation of 114 fuel cell units (50 MW in total) powered by hydrogen byproduct from petrochemical plants. Will begin in July 2020.
Long Ridge Energy Terminal	US	2021	485	Hydrogen co-firing CCGT under construction in Ohio, manufactured by GE. Initially 15% to 20% co-firing, aiming for 100% within 10 years.
Magnum	The Netherland	2023	440	Nuon/Vattenfall, Equinol, Gasunie joint project. One of the three gas turbines (440 MW in total) is currently being converted to hydrogen-fired. Aim for hydrogen-fired for all 3 units in 2030.
Keadby Hydrogen	UK	2030	1,800	SSE Thermal to build a 1,800 MW dedicated hydrogen plant at its Keadby power plant, with Equinor also participating. The investment decision has not yet been made, depending on the UK government's hydrogen development plan. Keadby #3,

				which will be developed at the same time, will be equipped with CCS.
Air Products' Net zero Hydrogen Energy Complex	Canada	NA	NA	Air Products, a leading hydrogen producer, announced plans to partner with the national and Alberta governments to create a large-scale hydrogen complex. The project will include a power plant using Baker Hughes' hydrogen-fired gas turbines. (Timing and scale not yet disclosed)
Ulsan	Korea	2027	270	Joint project with Korea East-West Power, Ulsan City and SK Gas. A 270 MW hydrogen gas turbine will be constructed by Daesan Heavy Industries.
Hyflexpower	France	2023	12	Jointly developed by ENGIE Solutions, Siemens, Power Energy and others with funding from the European Commission. The plant will co-fire hydrogen with a cogeneration plant currently in operation with an electrical output of 12 MWe, and will be in 100% hydrogen operation by 2023.
Intermountain Power Project	US	2025	840	Conversion of Utah's largest coal-fired power plant (1,800 MW) to Mitsubishi Power's 840 MW CCGT. 30% hydrogen co-firing with natural gas in 2025. 100% hydrogen mono-firing in 2040.

Source: IEA "Global Hydrogen Review 2021" and Related Companies' websites

"The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector," published also in October 2021 by the IEA, also describes similar projects. According to the report, in addition to Mitsubishi Power's ammonia co-firing efforts at Hekinan Thermal Power Plant, the company aims to achieve 30% hydrogen co-firing at three sites in the U.S. between 2023 and 2025, with the ultimate goal of 100% hydrogen operation. GE has a track record of operating at least 50% hydrogen co-firing in 25 gas turbines. In addition, Energy Australia is aiming to achieve hydrogen co-firing in more than 300 MW of gas turbines by 2024.

"Oxygen-blown coal gasification combined cycle power generation with CO_2 capture"

Japan, with its extremely low energy self-sufficiency rate, depends on coal as an important primary energy resource due to its high supply stability and economic efficiency.

However, compared to other fossil fuels, coal emits more CO_2 per unit calorific of energy value during combustion, and there are many limiting factors in terms of the global environment, so there is a need to further reduce CO_2 emissions from coal-fired power generation.

The CO_2 capture type oxygen-blown coal gasification combined cycle power generation is an innovative low-carbon coal-fired power generation system that combines the ultimate high-efficiency coal-fired power generation technology, Integrated Coal-gasification and Fuel-cell Combined Cycle (IGFC: Combined generation of coal-gasification and three other types: fuel cell, gas turbine, and steam turbine), with CO_2 capture technology, to significantly reduce CO_2 emissions from coal-fired power generation. The performance, operability, reliability, and economic efficiency of the system are being verified at a 170 MW scale demonstration facility constructed on the premises of the Osaki Power Plant of the Chugoku Electric Power.

The plant achieved a transmission end efficiency of 40.8% (HHV), which is the world's highest level of efficiency for a 170 MW scale demonstration plant, and the company claimed that it has reached a prospect of achieving a transmission end efficiency of approximately 46% for a 500 MW class commercial unit. The company aims to achieve a transmission end efficiency of around 47% when applied to a 500 MW class commercial unit, and by combining this with CO_2 utilization and storage technologies, aims to realize coal-fired power generation with almost no CO_2 emissions, with a view of zero emission as future goal.

As mentioned above, coal gasification technology can produce hydrogen along with CO_2 capture, and is expected to be one of the technologies that will play a role in realizing a low-carbon and hydrogen society.

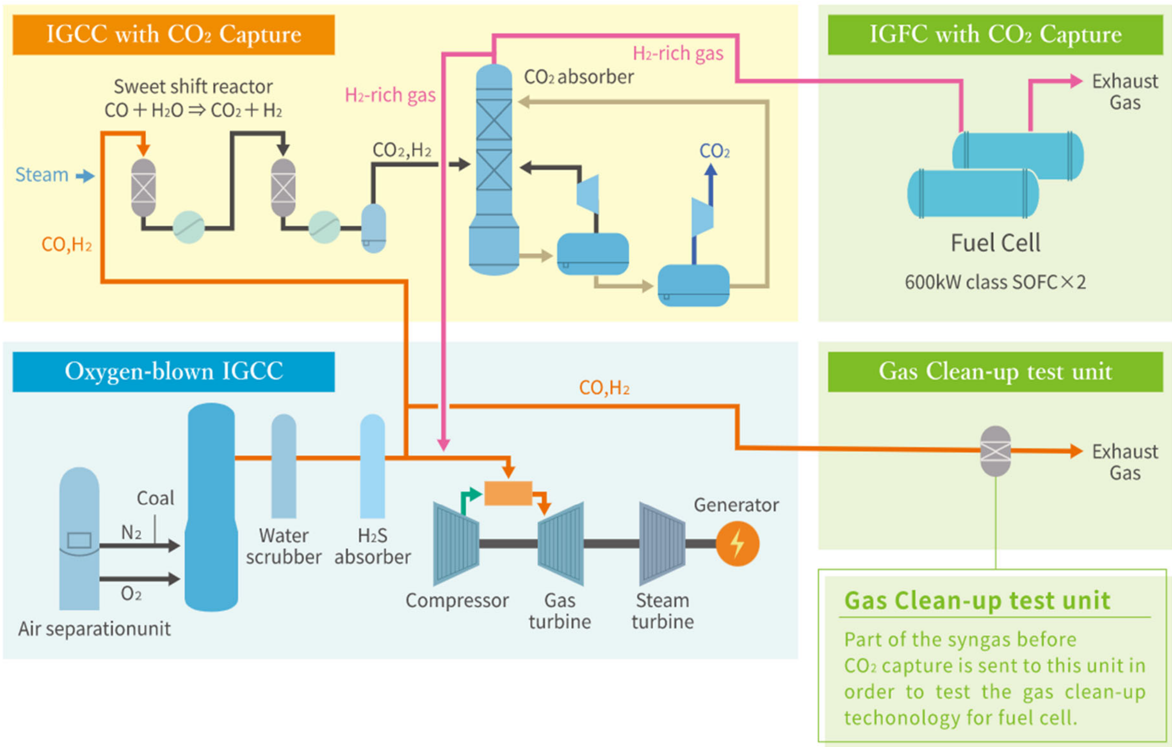

Figure 180 Oxygen-blown coal gasification combined cycle power generation with CO_2 capture
Source: NEDO's website

According to the IEA's "The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector", there are two commercial power plants with CCUS: the Petra Nova Carbon Capture project in Texas, USA and the Boundary dam Carbon Capture project in Canada. However, both are retrofitted CCUS from conventional coal-fired power plants and are not IGCCs.

(d) Battery (Lithium-ion, NAS, Redox Flow)

Storage battery systems are indispensable for the realization of a low-carbon and de-carbon society, including measures to expand the introduction of output-variable renewable energies such as solar and wind power generation, and as a means of managing electricity demand.

"Lithium-ion Battery"

Lithium-ion battery has high energy density, is compact and light weight, and can provide high output. It also has characteristics such as longer life thant nickel battery.

These batteries use metal composite oxides containing lithium ions as the cathode material, carbon materials or other metal composite oxides as the anode material, and organic solvents as the electrolyte. The choice of materials for cathode, anode, and electrolyte is wide, and the characteristics vary greatly depending on the material system selected. Of the grid storage battery technologies installed in the global market in 2018 (excluding pumped storage), 95% were reported to be lithium-ion batteries on a capacity basis.

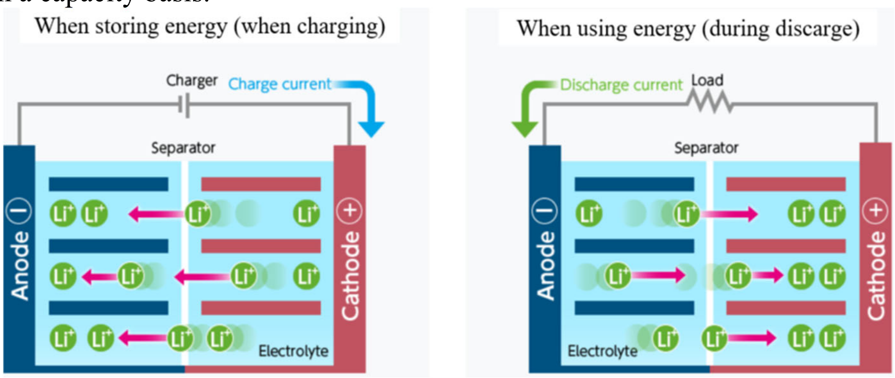

Figure 181 Basic Principles of Lithium Ion Battery

Source: TOSHIBA Japan website

According to METI's "Current Situation and Issues of Battery Industry" (METI, November 18, 2021), the share of production of car-mounted lithium-ion batteries by country is: China 37.4%; Korea 36.1%; and Japan 21.1%. Japan's share has declined from 40.5% of 2015. The share in 2020 by manufacturers is: 26.2% for LGES (Korea), 20.4% for Panasonic (Japan), 20.1% for CATL (China), 6.5% for BYD (China) and 5.9% for Samsung (Korea.)

Table 120 Share of Car-moundbted Lithium-ion Battery Production in 2020

Ranking	Manufacturer	Share (%)
1	LGES (Korea)	26.2
2	Panasonic (Japan)	20.4
3	CATL (China)	20.1
4	BYD (China)	6.5
5	Samsung SDI (Korea)	5.9
6	Envision AESC (China)	2.5

(Source: "Current Situation and Issues of Battery Industry", METI, November 18, 2021)

As for the stationary (fixed) lithium-ion battery, the national share is: Korea 37.7%, China 16.8%, and Japan 4.5%. Japan's share declined very much from 27.4% of 2015.

Table 121 Share of Stationary Lithium-ion Battery Production in 2020

Ranking	Manufacturer	Share (%
1	Samsung SDI (Korea)	22.9
2	LGES (Korea)	13.5
3	CATL (China)	7.1
4	Panasonic (Japan)	3.2

(Source: "Current Situation and Issues of Battery Industry", METI, November 18, 2021)

"Sodium Sulfur (NAS) Battery"

NAS battery is developed for power storage. It has high efficiency of charging and discharging and can store large amount of power. It has a relatively long life compared with lithium-ion battery.

This is a storage battery that uses sulfur as the cathode material, sodium as the anode material, and sodium ion conductive ceramic (beta alumina) as the solid electrolyte that separates the two electrodes. It requires a temperature rise to approximately 300°C or higher during operation. NAS battery has been put to practical use early on as a large-capacity storage battery for stationary applications by NGK Insulators, Ltd.

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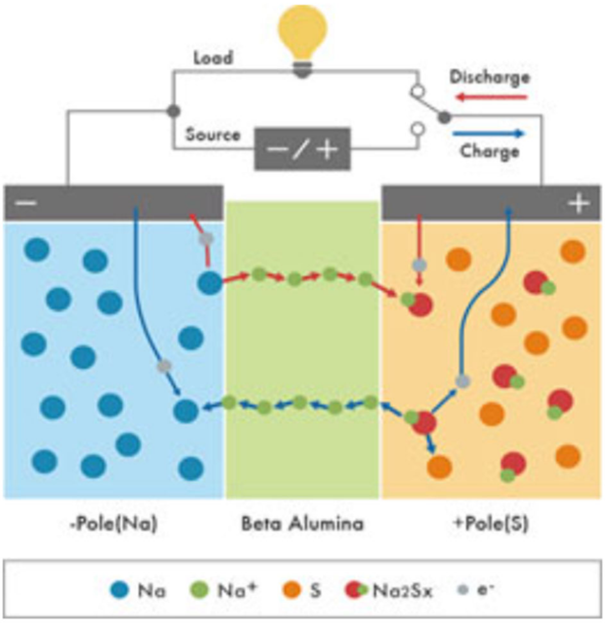

Figure 182 Basic Principles of Sodium Sulfur (NAS) Battery

Source: NGK website

"Redox Flow Battery"

A storage battery that charges and discharges by circulating electrolyte through positive and negative electrodes containing active material and exchanging electric charges through ion-exchange membranes. The electrolyte is stored in positive and negative electrode tanks, and pumps and piping are required for circulating the electrolyte between stations. Since the charge-discharge reaction only changes the valence of vanadium ions in the electrolyte and does not involve dissolution or deposition of electrodes, the electrolyte can be used semi-permanently with long life, little degradation, and unlimited number of charge-discharge cycles. Although the energy density is low, its superiority can be demonstrated in applications that require a long time capacity (>4 hours), mainly for energy shift.

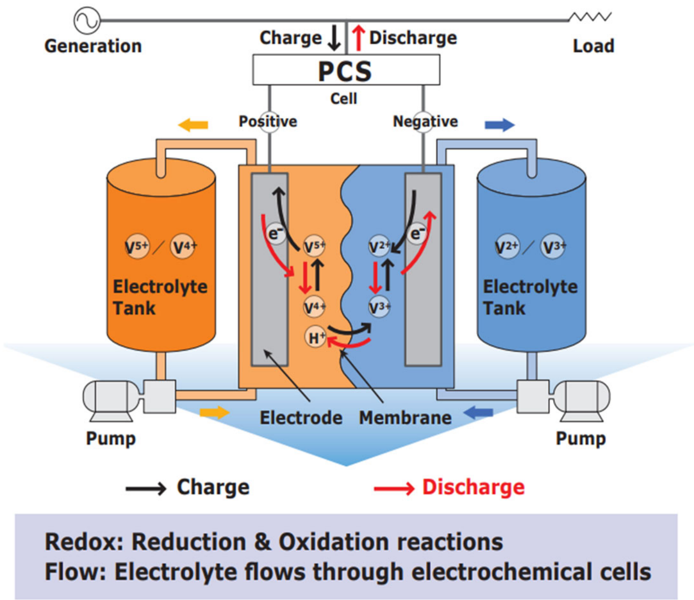

Figure 183 Basic principle of Redox Flow battery

Source: Sumitomo Electric Industries, "Redox Flow Battery Catalog"

Table 122 Comparison of Storage Battery Technologies [448]

		Lithium ion battery	Sodium-sulfur (NAS) battery	Redox flow battery
Charge/Discharge efficiency	Single storage battery	95%	90%	85%
	Whole system	86%	80%	70%
Durability	Calendar life	10 years	15 years	20 years
	Cycle life	15,000 cycles	4,500 cycles	100,000 cycles
Volumetric energy density (theoretical value)		176 Wh/L (～3,350 Wh/L)	83 Wh/L (～1,000 Wh/L)	15 Wh/L (～182 Wh/L)
Characteristics		・High energy density ・Suitable for high output applications ・Many safety considerations due to the use of Fire Service Act dangerous materials. ・Usage records in power system ・Multiple material types for both cathode and anode.	・High energy density ・Many safety considerations due to the use of Fire Service Act dangerous materials. ・Usage records in power system ・Low price per capacity ・High temperature operation type (heater power supply is required during temperature rise and standby, not affected by ambient temperature) ・Can take several tens of hours to raise the temperature from room temperature.	・Long cycle life ・Low energy density ・Possible to keep track of SOC during operation. ・Since the output and capacity can be designed independently, flexible design according to the application is possible. ・The active material is non-combustible and the risk of fire is extremely low. ・Pump maintenance is required because a circulation pump is required for charging and discharging.

Source: IEEJ Technical Report No. 1403, "Storage Battery Utilization and Control Technology in the Power System" 2017/5

There is no detailed information available from Japanese companies on the cost of manufacturing storage batteries, but the National Renewable Energy Laboratory (NREL) predicts that the cost of typical lithium-ion batteries, will drop from about $400/kWh today to $156/kWh in 2050.

As for NAS battery, while the data of cost for manufacturing is not available, the manufacturer

[448] This table compares the performance of large-capacity storage batteries applied to power systems. Researches for higher density lithium-ion batteries for EV and cell phones are being accelerated.

intends to pursue the cost advantage compared to lithium-ion battery with large MWh capacity. Having been developed for the purpose of energy shift, the NAS battery is now produced and sold as standard capacity as 6 hours per MWh. As for Redox Flow battery, it has high safety but low energy density, leading to high cost. However, since it has longer life time, the manufacturer intends to lower the cost similar to that of lithium-ion battery, with further technical development.

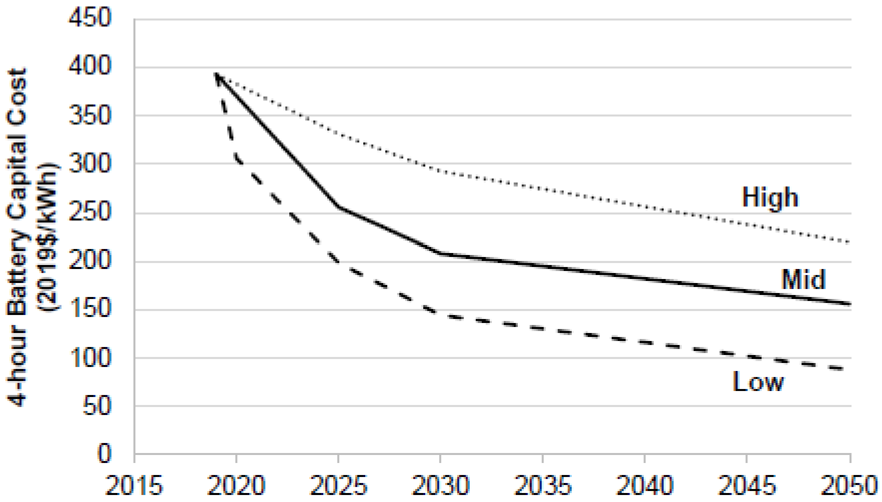

Figure 184 Cost Reduction Outlook for Lithium-Ion Batteries (NREL, U.S.)

Source: "Cost Projections for Utility-Scale Battery Storage: 2020 Update" (Wesley Cole and A. Will Frazier, National renewable Energy Laboratory)

(e) Energy Carrier (for Hydrogen)

The Prime Minister's Office's "Innovative Strategy for Environmental Innovation" also has the goal of establishing a low-cost hydrogen supply chain.

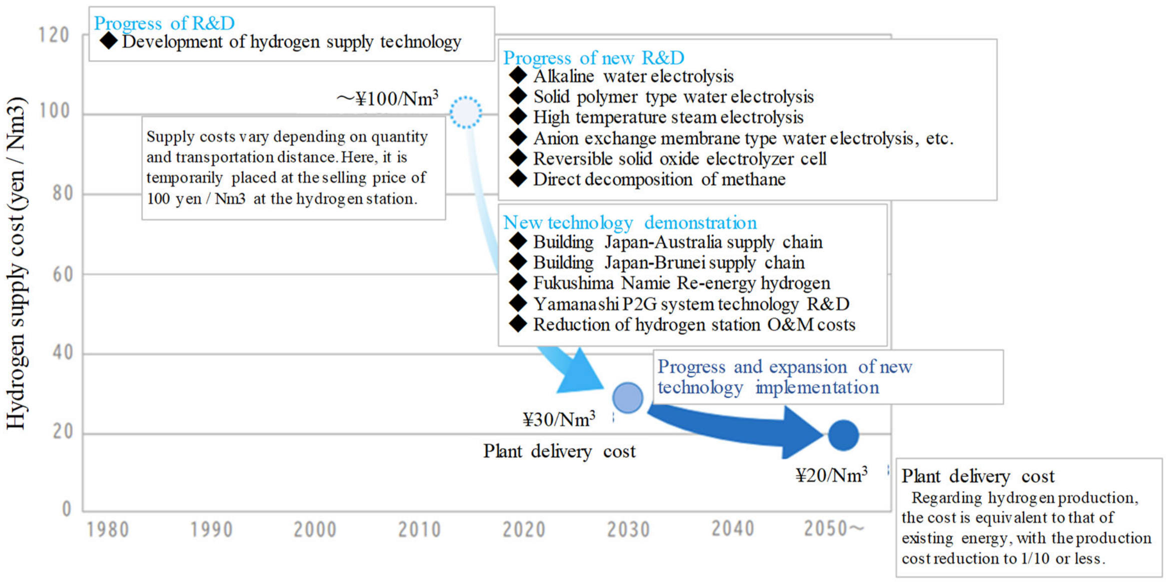

Figure 185 Examples of cost savings from innovations in hydrogen supply

The 2nd Working Group on Hydrogen and Fuel Cell Strategy Roadmap Evaluation (June 8, 2020) stated that the hydrogen cost (plant delivery cost) should be reduced to around 30 yen (JPY)/Nm^3 around 2030 and to 20 yen/Nm^3 in the future. While taking into account the LNG price and environmental value, it aims to reduce the cost to a level comparable to conventional energy sources.

For example, if the LNG price is $10/MMBtu (CIF price), the hydrogen price would be 13.3 yen/Nm^3 when converted to calorific value equivalent without considering environmental value. (Hydrogen costs of 30 yen/Nm^3, 20 yen/Nm^3, and 13.3 yen/Nm^3 can be converted to unit power generation costs of 17 yen/kWh, 12 yen/kWh, and 8.7 yen/kWh, respectively.)

Energy from hydrogen combustion emits only H_2O (water) and can be produced inexhaustibly from surplus electricity and water from renewable energy sources. One of the problems with hydrogen as a fuel is that although the calorific value per unit weight of hydrogen is about three times greater than that of gasoline, hydrogen has a low density (about 82 g/m^3) at room temperature, and about 3,000 liters of hydrogen are needed to obtain the 32.9 MJ of calorific value from burning one liter of gasoline.

Major hydrogen carriers include liquid hydrogen, ammonia, and methane, and basic technologies have been developed for each.

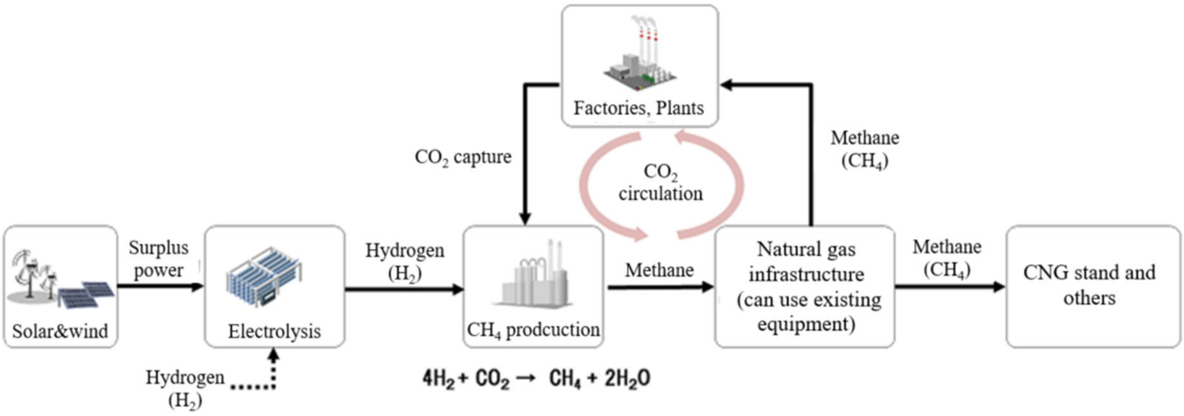

Figure 186 Hydrogen carrier (methane)

Source: Hitachi Research Institute's Website

However, the characteristics of each hydrogen carrier are unique, and there is no single hydrogen carrier that is superior in all respects and overwhelmingly advantageous. The selection of hydrogen carriers is an important point of discussion in the METI's "Hydrogen and Fuel Cell Strategy Council", but each carrier faces different issues, and it is impossible to determine which one will be generally superior in the long term at this point. It is expected that applications will be segregated over the long term, depending on their chemical characteristics and whether or not they can make use of existing infrastructure. Therefore, the committee does not narrow down the list of carriers at this point, but rather encourages competition while at the same time supporting each carrier in overcoming technological issues.

Table 123 Comparison of various hydrogen carriers

Carrier	Liquefied hydrogen	MCH	Ammonia	Methanation
Volume	Apx. 1/800	Apx. 1/500	Apx. 1/1300	Apx. 1/600
Liquid conditions	-253°C, 1atm	Room temp., 1atm	-33°C, 1atm	-162°C, 1atm
Direct use	OK (no change in chemical properties)	Currently can not	OK	OK
Primary use	- Power generation (co-firing, mono-firing) - Transportation (FCV, FC bus, aircraft, ship) - Industry (hydrogen boilers, burners, etc.) - Fuel Cells - Storage (Power-to-Gas)	- Hydrogen transport - Storage	- Power generation (coal-fired co-firing, gas turbine) - Transportation (car, ship engine) - Industry (industrial furnace) - Fuel cell	- Power generation (LNG thermal power) - Transportation (tanker) - Industry (raw materials for chemicals, synthetic gas) - City gas alternative
Add-on for higher purity	Unnecessary	Necessary (for dehydrogenation)	Necessary (for dehydrogenation)	Necessary (for dehydrogenation)
Energy loss due to conversions.	Currently: 25-35% Future: 18%	Currently: 35-40% Future: 25%	Hydrogenation: 7-18% Dehydrogenation:<20%	Currently: -32%
Existing	International transportation	Possible (chemical tanker,	Possible (chemical tanker,	Possible (LNG tanker, city

infrastructure	not possible (new equipment required), domestic delivery possible	etc.)	etc.)	gas pipe, etc.)
Advantages & Disadvantages	Non-toxic, no need for additional equipment for combusting. Issue with large-scale sea transportation.	Can be handled at normal temperature and pressure. Toxicity from toluene and energy loss are the issues.	Can be used with existing infrastructure. Toxic and corrosive; dehydrogenation technology and implementation for direct usage need to be developed	Non-toxic, can be used with existing infrastructure. Competitive supplies of H_2 from renewable energy and CO_2 in the production area are important.

Source: Materials from the "25th Hydrogen and Fuel Cell Strategy Council", "How to proceed with the examination of future hydrogen policy" (November 2020, Agency for Natural Resources and Energy), "Efforts to establish a fuel ammonia value chain" (October 2020, Fuel Ammonia Introduction Public-Private Council)

Ammonia is a compound with the highest hydrogen density per volume of liquefied ammonia among the 4 energy carriers, since it liquefies under mild conditions such as -33°C at normal pressure or 8.5 atm at room temperature. This liquefaction conditions are almost the same as the liquefaction condition of LPG, and ammonia can be transported and stored by the same infrastructure and technology as LPG. In fact, about 180 million tons of ammonia is produced annually, and about 18 million tons are distributed internationally. One of the major technical challenges when using hydrogen as energy is the mass transportation and storage of hydrogen energy, which is non-existing with ammonia. Since MCH is a liquid with properties similar to petroleum, existing petroleum infrastructure can be utilized, and the MCH transported will be used at the site after hydrogen is extracted (dehydrogenation reaction). The greatest advantage of synthetic methane is that it can utilize existing gas infrastructure, and it also has the advantage of achieving net-zero emissions in some industrial applications (welding, glass production, etc.) where electricity and hydrogen are not available and hydrocarbons are required.

There is a major trend to produce green hydrogen by utilizing surplus electricity from renewable energy sources and using an electrolyzer (water electrolysis), but at present, none of this is commercially available and is still in the demonstration stage.

According to the IEA "Energy Technology Perspectives 2020", the cost competitiveness of low-carbon hydrogen produced from natural gas with CCUS or from renewable energy-based electricity depends primarily on the cost of gas and low-carbon electricity. For now, hydrogen from fossil fuels is more competitive, but low-carbon hydrogen could become competitive in the long run if costs are reduced through large-scale deployment. Currently, the cost of hydrogen produced from natural gas varies between 0.7-1.6 USD/kgH_2, and adding CO_2 capture costs increases the cost to about 1.2-2.0 USD/kgH_2. However, producing hydrogen from renewable energy typically costs about 3.2-7.7 USD/kgH_2. The report also stated that the cost savings of renewable technologies and water electrolysis in a sustainable development scenario would make the cost of producing hydrogen from these sources competitive with natural gas with CCUS in some regions of the world. For hydrogen production from fossil fuels combined with CCS, geological conditions and public acceptance of CO_2 storage are prerequisites for combining with CCS.

Table 124 Hydrogen production cost[449]

	Current Cost	Hydrogen cost reduction target *1
Natural gas generated hydrogen	7.2-16.4 JPY/Nm^3	-
Natural gas generation + CO_2 capture cost	12.3-20.5 JPY/Nm^3	-
Renewable energy hydrogen generation	32.9-79.1 JPY/Nm^3	2030: 30 JPY/Nm^3, future: 20 JPY/Nm^3
(Ref) Equivalent calorific value LNG price *2	13.3 JPY/Nm^3	-

Source: Hydrogen cost (plant delivery cost) in the 2nd Hydrogen and Fuel Cell Strategy Roadmap Evaluation Working Group (June 8, 2020)

449 Converted to calorific value equivalent to hydrogen price without considering environmental value as LNG price $10/MMBtu (CIF price)

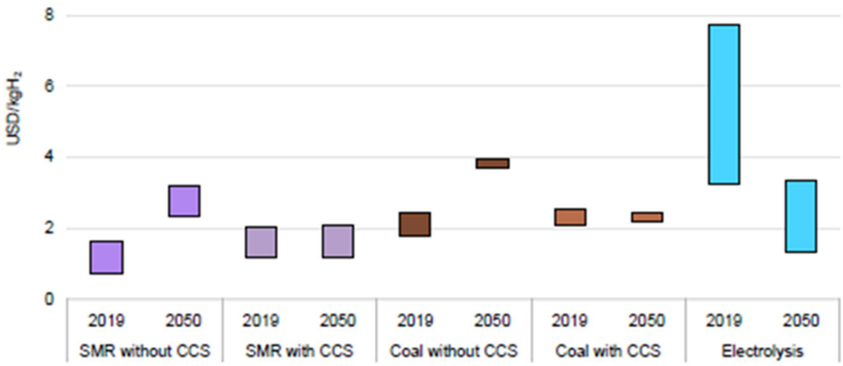

Figure 187 Hydrogen production costs by technology in SDS in 2019 and 2050
Source: IEA "Energy Technology Perspectives 2020",
SMR (steam methane reforming): A method for producing hydrogen from natural gas

Two types are currently in practical use: alkali type and PEM type. The former is characterized by high efficiency and low cost, while the latter has high load-following capability and is expected to be utilized as a regulator. However, Japan's resource endowment, including renewable energy, is small compared to its domestic demand, and it is said that Japan is expected to import hydrogen from overseas even in the long term.

Table 125 Main Hydrogen Production Types

	Alkaline type	PEM type
Major manufacturing companies (example)	Asahi Kasei, Hydrogenics (Canada), Thyssenkrupp (Germany), Nel (Norway)	Hitachi Zosen, Toray (electrolyte membrane only), ITM (UK), Hydrogenics (Canada), Siemens (Germany), Nel (Norway)
Scale of NEDO demonstration (participating companies)	10MW at Fukushima (Toshiba Energy Systems, Tohoku Electric Power, Tohoku Electric Power Network, Iwatani Corp.)	1.5MW at Yamanashi (Yamanashi Prefectural Enterprise Bureau, Toray, TEPCO Holdings, Toko Takaoka)
Electrolysis efficiency (LHV,%)	63-70	56-60
Cost of capital (USD/kW)	500-1400	1100-1800 (high cost due to rare metal usage)
Product life (time)	60,000 - 90,000	30,000 - 90,000
Current density (A/cm$_2$)	-0.6	-2 (Contributes to miniaturization of cell stack)
Pressure (bar)	1-30	30-80 (Additional compression cost can be reduced)
Load followability (utilization as adjustment power)	Narrow load fluctuation range	Wide range of load fluctuation

Source: METI, "How to Proceed with Future Hydrogen Policy Considerations," 2020/11

The hydrogen production method used in a pilot project in Yamanashi Prefecture and in the Kitakyushu Hydrogen Production and Utilization Demonstration Project is the PEM type. The hydrogen production at the Fukushima Hydrogen Energy Research Field (Namie Town) is the alkaline type.

“World's first demonstration test for establishing an international supply chain for liquefied hydrogen”

NEDO has been promoting research and development for the utilization of hydrogen energy for about 30 years, and as part of this effort, in FY2015 it launched the "Demonstration Project for Establishing a Large-Scale Marine Hydrogen Transportation Supply Chain from Unused Lignite Coal". This demonstration project, subsidized by METI, will produce hydrogen from brown coal produced in the Latrobe Valley of Victoria, Australia, liquefy and load it at the Port of Hastings in Victoria, Australia, and transport it to the Kobe Liquefied Hydrogen Cargo Terminal (Hytouch Kobe) in Japan. The project aims to demonstrate a series of technologies required to establish a hydrogen supply chain by constructing a coal lignite gasification and hydrogen refining facility (under the control of J-POWER) and a hydrogen liquefaction and loading terminal (under the control of Kawasaki Heavy Industries and Iwatani) in Victoria, Australia. Kawasaki Heavy Industries, J-POWER, Iwatani, Marubeni, AGL Energy Limited, and Sumitomo are participating in the project.

The consortium of the above 6 companies confirmed the functions and performance of the hydrogen liquefaction and loading terminal constructed at the Port of Hastings in November 2020 and the lignite gasification and hydrogen purification facilities that began hydrogen production in the Latrobe Valley in January 2021, and is currently conducting operational tests of the two facilities in coordination after the completion of function and performance confirmation. In addition, the liquefied hydrogen carrier "SUISO FRONTIER" is scheduled to visit the port of Hastings from Japan during 2021 to conduct a transport test between Japan and Australia.

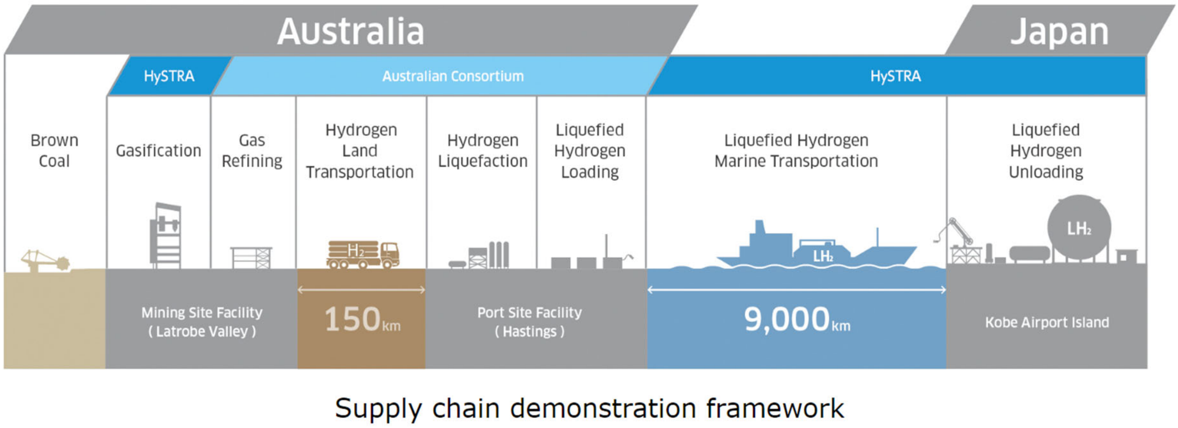

Figure 188 Outline of the Demonstration Project

Source: Iwatani Corporation HP News Release

*"HySTRA": Technical Research Association CO2-free Hydrogen Supply Chain Promotion Organization (http://www.hystra.or.jp/about/)

"Fukushima Hydrogen Energy Research Field (FH2R)"

One of the efforts to transform the hydrogen supply structure is the FH2R, a hydrogen production project using renewable energy (renewable energy) in the "Fukushima New Energy Society Concept" and "Fukushima Innovation Coast Concept" being promoted in Namie Town, Fukushima Prefecture.

Using 20MW of photovoltaic power generation installed on the 180,000m^2 site, a 10MW hydrogen production unit (alkaline water electrolysis method), one of the largest in the world, electrolyzes water to produce 1,200Nm^3 per hour (during nominal operation) of hydrogen, which is stored and supplied to the plant.

Hydrogen production and storage is based on the market demand forecast by the hydrogen demand forecast system. The system adjusts the supply-demand balance of the power system by the amount of hydrogen produced according to needs of the power system. The biggest challenge of this demonstration is to realize the optimal combination of hydrogen production/storage and the hydrogen-powered system supply/demand balance adjustment without the use of storage batteries.

Therefore, FH2R will verify the optimal operation control technology that combines the demand response of the power system and the hydrogen supply & demand condition through the utilization of equipment with different operation cycles.

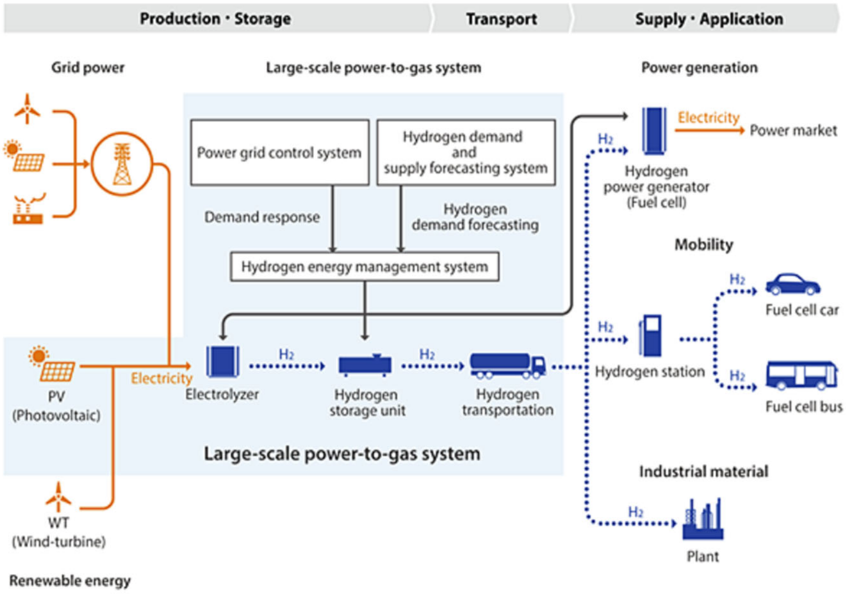

Figure 189 Example of Hydrogen Supply Chain ("Fukushima Hydrogen Energy Research Field" system overview diagram)

Source: Toshiba Energy Systems' website

On July 8, 2020, the European Commission published its Hydrogen Strategy, which aims to decarbonize the European economy based on the use of renewable energy-derived hydrogen. It aims to take a leading position in the field of hydrogen supply & consumption equipment.

In June 2020, the U.S. Department of Energy released a roadmap for renewable energy-derived hydrogen, setting goals such as utilizing 1/4 of renewable electricity for renewable energy-derived hydrogen production by 2050, and utilizing hydrogen in sectors where decarbonization is difficult.

(f) Pump Storage Power Generation (Variable Speed)

Pumped storage hydropower generation is a large-capacity energy storage system that stores electricity in the form of water during periods of low electricity consumption (demand) by pumping water from the lower reservoir to the upper reservoir and dropping water from in the reverse order for power generation during periods of high electricity consumption.

Conventional pumped-storage hydroelectric generators are rotary synchronous generators and have a frequency adjustment function, but are constant speed motors in pumped-storage operation and do not have a frequency adjustment function.

Variable-speed pumped storage power generation has a frequency adjustment function that adjusts the power consumption via increasing or decreasing the pump speed by changing the excitation frequency even during pumping operation.

In other words, variable-speed pumping is a large-capacity energy storage system that has a frequency adjustment function during operation, regardless of whether it is in pumping or generating power. It is expected to play a major role as a measure to expand the introduction of renewable energy with variable output.

On the other hand, although operating costs are lower than storage batteries due to their large capacity and semi-permanent life, initial costs are higher, and unlike storage batteries, location restrictions are greater, requiring a long period of time from planning, site selection, construction, and start of operation.

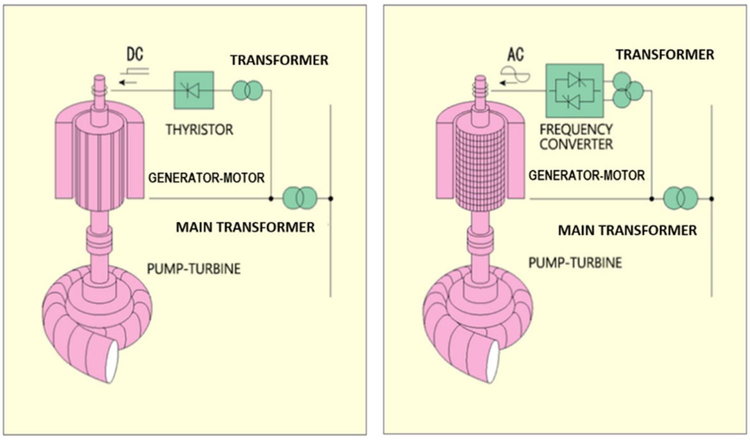

Figure 190 Conventional pumped storage and variable speed pumped storage

Source: Toshiba Energy Systems' website

(g) DR/VPP (including smart meters, aggregators, etc.)

Demand Response (DR) refers to "a change in the pattern of electricity demand energy resources on the customer side by the owner or a third party controlling those energy resources". Demand response can be classified into two types depending on the pattern of demand control: "down DR," which reduces (suppresses) demand, and "up DR," which increases (creates) demand.. In addition, depending on the method of demand control, there are two types: (1) electricity rate-based (electricity demand is controlled by setting electricity rates) and (2) incentive-based (power companies and aggregators enter into contracts with consumers, and consumers suppress electricity demand in response to requests from the power companies and aggregators). (1) Electricity rate type includes pricing menus that set higher daytime rates and lower nighttime rates; and nighttime pricing menus that can only be used at night; different to a uniform rate pricing. The incentive type (2) includes supply-demand adjustment contracts between electric power companies and consumers (mainly large industrial and commercial users), whereby consumers curb their consumption at the request of the power company when supply and demand are tight and receive a discount (or points) on their electricity bills. The pricing menus in (1) and the supply-demand adjustment contract in (2) are considered applicable in all countries. On the other hand, in order to go beyond such tariffs and integrate the reduced consumption (aggregation) into VPPs and utilize them as a new business, electricity markets must be liberalized and competitive transactions must take place. It is difficult to apply the advanced market trading model as it is in many developing countries with vertically-integrated or single-buyer model electricity supply systems. The purpose of the transaction is to help retail electricity providers achieve the same amount of electricity at the same time as the planned value and to help grid operators balance supply and demand.[450]

A virtual power plant (VPP) is a power generation facility or thermal storage facility at the customer side directly connected to the power grid, that is controlled by the owner or a third party (including reverse power flow from the customer's energy resources) to provide the same functionality as a power plant. (From Energy Agency data)

With the spread of energy storage devices such as electric heat pump water heaters (EcoCute), thermal storage tanks, storage batteries, and EVs, and with the development of IoT, the use of networks to connect devices on the customer side to increase convenience is becoming widespread in many fields. VPP is a system that remotely integrates and controls various devices at the customer side via the Internet, so that it functions as if it were a single power plant and is used to regulate the receiving of electricity.[451])

The following participants are in the VPP market:

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[450] "Energy Resource Aggregation Business Handbook", Agency for Natural Resources and Energy, METI (https://www.enecho.meti.go.jp/category/saving_and_new/advanced_systems/vpp_dr/files/erab_handbook.pdf)

[451] "50 Technologies that will Transform the Electric Power and Energy Industries" (Ohmsha)

(1) Distributed power sources (consumers side): Each household (operation and control of household equipment), buildings and factories (recharge and discharge of storage batteries), EVs (recharge and discharge), etc. (Effective use of renewable energy generated by the consumers themselves and reduction of electricity costs through energy conservation can be achieved)
(2) Resource aggregator: A business operator that directly concludes VPP services with consumers of distributed power sources to control resources
(3) Aggregation coordinator: A business operator that bundles the amount of electricity controlled by resource aggregators and trades electricity directly with general transmission and distribution companies and retail electricity companies
(4) General transmission and distribution companies, etc.: Receive virtual power from VPPs and are responsible for providing regulating power and maintaining power quality
(5) Retail electricity providers: Receive supply power from VPPs and avoid imbalance
(6) Renewable energy power producers: By using VPP functions to adjust output, they can avoid output curtailment by general transmission and distribution utilities (grid operators)

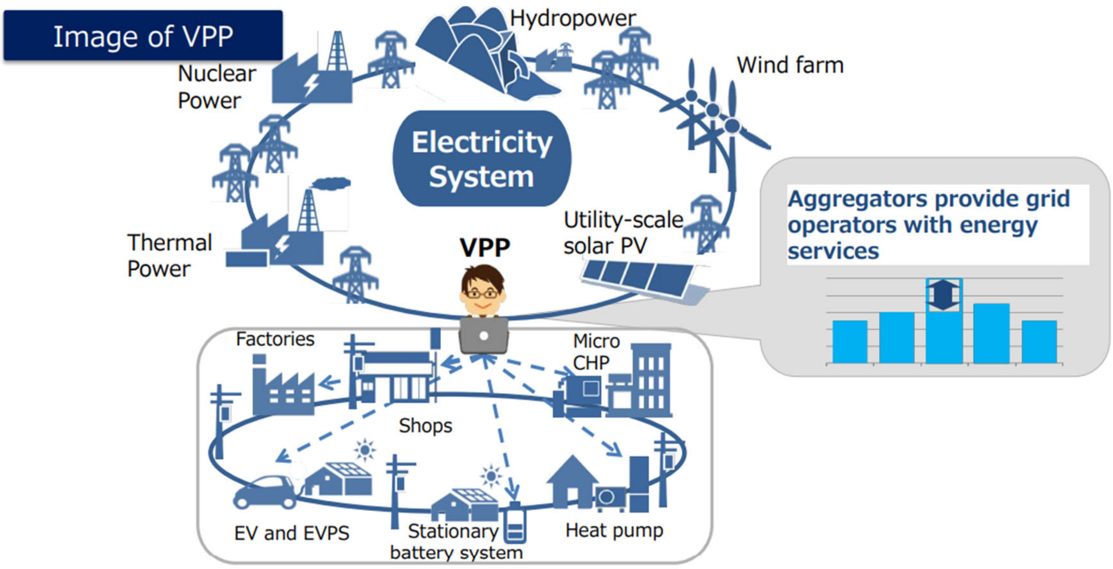

Figure 191 Images of VPP

Source: Agency for Natural Resources and Energy, "Energy Resource Aggregation Business Handbook"

DR and VPP are expected to have the following effects:

i. Establishment of an economical power system (reduction of power generation costs): DR/VPP makes it possible to lower electricity demand during peak hours and to level the load by shifting it to other time periods, thereby reducing the need to burn more power sources with high fuel costs during peak hours

ii. Contribution to the expansion of renewable energy: Output fluctuations of VRE, which are affected by the amount of sunlight and wind conditions, need to be absorbed by adjusting the output of other power sources to match supply and demand. For example, if demand can be created through DR/VPP by controlling energy resources on the consumer side, such as recharging storage batteries on the consumer side, it will be possible to make effective use of renewable energy power

iii. Reduction of grid stabilization costs: Traditionally, peak power sources such as thermal power and pumped storage have been used as grid stabilization measures, but with DR/VPP, customer-side facilities that originally have other purposes (e.g., storage batteries to reduce electricity prices through day/night price differences) can be used to ensure power quality, such as VRE output fluctuations, thus reducing capital costs. This allows for lower capital costs and low-cost grid stabilization.[452]

(From Energy Agency data, and from “50 Technologies that that will Transform the Electric Power and Energy Industries" (Ohmsha))

Participants in VPP projects are expected to benefit from the following:

Table 126 Expected benefits of VPPs

Beneficiary	Benefits		Overview
Transmission and distribution operator	System stabilization	Frequency adjustment	Gathering distributed power generation, storage battery charging / discharging, load control / demand suppression amount, etc. on the consumer side, and provides various services to power transmission and distribution companies through the real-time market (established in 2020).
		Supply-demand balance	
		Others	
	Investment optimization		Avoid renewal/ enhancement of grids/ substations by utilizing storage batteries, etc.
Retailer	Power procurement Avoiding imbalance		Resource aggregators (including retailers) supply the procured electricity / negawatts via the market (spot market, 1 hour ahead market (April 2017 ~)) or by bilateral transaction.
Consumer	Electricity fee reduction		・Contract power reduction (peak cut) ・Optimized timing and amount of power purchases (energy management, usage time shift, energy saving)
	Profit through optimal use of equipment		Selling electric energy / negawatts by utilizing distributed power sources and storage batteries of consumers who have excess supply capacity.
	BCP		Utilize power from distributed power sources and storage batteries even in the event of a disaster
	DR participation incentive		Provide incentives for consumers to participate in DR
RE power generation company	Avoid output suppression		Maximize the use of renewable energy power generation by creating demand with storage batteries, etc. when output suppression is activated.

Source: Energy Resource Aggregation Business Study Group 1st Meeting materials (January 29, 2016)

In order to make better use of DR and VPP functions, it is necessary to expand the competitive electricity trading market. The prerequisite for this is a highly automated power grid, and electricity transactions must be measured by multifunctional and automatic meters. Smart meters are next-generation electricity meters with communication functions to meet these requirements, enabling automation of meter reading and visualization of electricity usage through HEMS. 1 It is technically possible to measure consumption by time of day in 15-minute and 30-minute increments, and to adjust (control) electricity consumption and operate electrical devices within the customer's home. The introduction of this technology has been progressing worldwide since around 2000, and it is currently being used in many countries. (The EU as a whole is expected to reach 70% by 2023. In the U.S., installation varies by state, but installation is completed every other week in California, Texas, Florida, and Illinois. New York State is scheduled to complete installation in 2022). In Japan, full-scale installation has been underway since 2010, with new customers as well as existing customers switching to smart meters when their conventional meters expire. Although there are differences among electric power companies, installation is generally expected to be completed in all customers around 2023. [453]

Osaki Electric Industry, Mitsubishi Electric, Fuji Electric, Kyuden Techno Systems, and many others manufacture and deliver smart meters based on the specifications of electric power companies. Osaki Electric Industry has established factories in Malaysia, China, Singapore, and the U.K. to manufacture smart meters for overseas markets; and Touko Toshiba Meter Systems has acquired Landis+Gyr, a major Swiss meter manufacturer. Overseas, Schneider Electric (France), Landis+Gyr

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452 “Energy Resource Aggregation Business Handbook”, Agency for Natural Resources and Energy, METI, and “50 Technologies that will Transform Electric Power and Energy Industries” (Ohmsha)

453 Foreign data is from the 1st Next Generation Smart Meter System Study Group

(Switzerland), Itron (U.S.), Siemens (Germany), and Wasion Group (China) are the main manufacturers of smart meters.

DR/VPP case studies in Japan

Yokohama City and Kitakyushu City engaged in smart city demonstrations with subsidies from METI.

(1) Yokohama Smart City Project[454]

In 2010, the project was selected by the Ministry of Economy, Trade and Industry (METI) as a "Next Generation Energy and Social System Demonstration Area". In collaboration with domestic energy-related businesses and electrical manufacturers, the project worked on the introduction and verification of systems to optimize the balance of energy supply and demand in existing urban areas. Through the Yokohama Smart City Project, targets were set for the introduction of HEMS, solar panels, and EVs, which were achieved by FY2013. (Achievements: 4,200 HEMS, 37MW of solar panels, and 2,300 EVs)

In order to leverage these results and realize an energy-recycling city that excels in disaster prevention, environmental friendliness, and economic efficiency, the City of Yokohama established a new public-private partnership organization, the Yokohama Smart Business Council, in 2015, and will continue to improve public recognition of YSCP, strengthen disaster prevention (creating a low-carbon, safe, and secure year), and stimulate the economy (supporting independent activation of smart-related businesses) until March 2024.

(2) Kitakyushu Smart Community Creation Project[455]

The project was initiated following a similar selection process as above.

Kitakyushu City has since been working to realize a low-carbon society (decentralized energy) in which local energy (hydrogen, electricity, and heat) is used to the fullest in the Higashida area, where Japan's first modern blast furnace was located, and to create a cutting-edge smart city that includes environment-related industrialization that takes advantage of the potential of the Higashida area. In 2021, Kitakyushu City applied to the national government's Super City Initiative as the "Kitakyushu Higashida Super City for SDGs Initiative".

Examples of VPP initiatives by electric utilities include Kansai Electric Power and Tohoku Electric Power.

(3) Kansai Electric Power's VPP[456]

Kansai Electric Power and Kansai Electric Power Transmission and Distribution applied for the "Subsidy for Demonstration Project for Construction of Virtual Power Plant (VPP) Utilizing Customer-Side Energy Resources (VPP Construction Demonstration Project)" a project subsidized by the Agency for Natural Resources and Energy, METI. The project was adopted by the Environment Co-Creation Initiative, which is the executive body of the subsidy, and the demonstration has been conducted under a theme determined for each fiscal year from FY2016 to FY2020.

FY 2016: Installation of resources and entire system under experimental environment. Communication and control functions from the integrated server to the resources were confirmed.

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[454] Yokohama City HP "Yokohama Smart City Project (YSCP)")
(https://www.city.yokohama.lg.jp/kurashi/machizukuri-kankyo/ondanka/etc/yscp/yscp02.files/0003_20190312.pdf)
"Yokohama Smart Business Council")
(https://www.city.yokohama.lg.jp/kurashi/machizukuri-kankyo/ondanka/etc/yscp/yscp05.html)

[455] Kitakyushu City website
(https://www.city.kitakyushu.lg.jp/kikaku/28500190.html)
(https://www.city.kitakyushu.lg.jp/files/000689061.pdf)

[456] Kansai Electric Power's website, "Participation in the FY2020 Virtual Power Plant Construction Demonstration Project" (June 1, 2020) and "50 Technologies that will Transform the Electric Power and Energy Industries" (Ohmsha)

FY2017: On the system side, expanded the functions of the integrated server, and on the resource side, installed and deployed resources in the field that could be utilized in the demonstration, with a focus on storage batteries.
FY 2018: On the system side, added real-time reporting and command value change functions for one-minute locations as a common demonstration menu, improved control accuracy, and confirmed linkage with the upper server (grid operator) and all resource servers.
FY 2019: Review feedback control specifications and study optimal tuning for the portfolio.
FY 2020: Working on establishing frequency control technology by linking with resource aggregators and utilizing Internet lines. (Introduced EneFarm household fuel cells for the first time, and started a demonstration of remote control of EV recharge/discharge by an aggregator)

(4) Tohoku Electric Power's VPP[457]
The VPP Construction Demonstration Project, a project subsidized by the Agency for Natural Resources and Energy, has been underway since 2018. In this three-year demonstration project, Nissan Motor, Mitsui, Mitsubishi Estate, Ricoh Japan, and Efficient will work together to verify V2G (Vehicle to Grid), and initiatives targeting local communities and consumers such as corporations and households. Target deployment at all elementary and junior high schools and designated evacuation centers in Sendai City, Miyagi Prefecture, that are equipped with solar power generation equipment and storage batteries based on the experience of the Great East Japan Earthquake of 2011.
FY 2018: PV equipment and storage batteries owned by the City of Sendai at five designated evacuation centers were consolidated as energy resources, and remote monitoring and control of equipment operation status was implemented.
FY 2019: Recharge/discharge stands and EVs were installed at the Sendai Royal Park Hotel, the aquarium, park parking lots, and two Ricoh Japan offices in Sendai, and these were simultaneously controlled remotely to verify the accuracy of the operation required as a function to adjust the balance of electricity supply and demand.
FY 2020: Collaborated with Efficient as a VPP resource aggregator, increased the number of resources to be controlled, and verified the use of multiple resources (stationary storage batteries and EV storage batteries) for VPP supply and demand adjustment through remote and integrated control.

DR/VPP case studies outside of Japan

DR and VPP are not merely power-saving programs, but programs in which those who comply with the competitive market receive a certain amount of reward (merit). For this reason, DR is becoming increasingly popular in the United States and Europe, where competitive electricity markets have developed.

(The U.S.A.)[458]

In the US, where competitive electricity markets are well developed, a variety of DR initiatives are being developed (In some states, utility regulatory commissions have mandated DR for retail electric utilities). According to Japan Electric Power Information Center as a result of a survey of major electric utilities across the U.S., DR registered capacity in 2016 was 13.63 GW, of which 10.7 GW, or 78%, was activated. The top three categories of DR registered capacity were: 5.53 GW (85%

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[457] Tohoku Electric Power' website, "Implementation of the VPP Demonstration Project", a project subsidized by the Agency for Natural Resources and Energy, METI, for the construction of a virtual power plant using distributed energy resources) (November 16, 2020, https://www.tohoku-epco.co.jp/news/normal/1216834_2558.html)
"Tohoku Electric Power's approach to the VPP business including collaboration with local governments" (from Tohoku Electric Power's presentation material at the Distributed Energy Promotion and Awareness Seminar, February 17, 2020)
[458] "Electric Utilities in Overseas Countries, Volume 1," 2019, Japan Electric Power Information Center

activation rate) for customer response (utility company notifies customers and they reduce their electricity consumption) targeting large and medium-sized customers; 3.00 GW (61% activation rate) for air conditioning control targeting residential and small-scale customers; and thermostat control 2.38 GW (96% activation rate). These three categories accounted for 80% of the registered capacity.

The examples below are from NRG Energy, a major electric utility, and TriEagle Energy, an electric utility with a retail electricity business in Texas.

(1) NRG Energy's Automated DR Program[459]
NRG Energy, a major electric power retailer in several states in the U.S., is developing an Automated DR program for business customers besides a DR program for general households that controls air conditioning and other equipment at home when supply and demand are tight. This Automated DR program for business customers called the NRG Demand Response Program. This program allows consumers to set up control settings in advance for air conditioning, lighting, and other electrical equipment that can be controlled, and when supply and demand are tight, the program automatically controls such equipment upon receiving instructions (signals) from the power company. NRG also provides a service that diagnoses the electricity usage status of customers so that they can keep track of the amount of electricity that can be curbed. Customers participating in the DR program receive a rebate for the amount of curtailed energy when DR is activated.
(2) Texas retailer TriEagle Energy's "Prime Time" DR program for residential demand[460]
Texas is in the process of liberalization, and competition among the many retail electricity providers is intense. One of the leading companies, TriEagle Energy, is also developing a DR program. When customers receive load curtailment requests via e-mail, they voluntarily curb their air conditioning and lighting consumption for 1 to 3 hours to comply with the DR request. Customers are compensated according to the kWh saved from their base usage charges. There is no obligation to respond to DR requests, and no penalty is incurred. For TriEagle, this means that it will be able to avoid purchasing the load reductions that consumers cooperate with in the spot market at high peak rates.

(Europe)
In the EU, where the electricity market has been liberalized, many power companies are also developing DR and VPP projects. Typical examples from Germany and France are given below.
(1) Next Kraftwerke's VPP (Germany)[461]
The company is a VPP operator established in 2009, with 10,531 VPP resources (aggregate projects) and over 8,526 MW of power capacity. It operates large-scale VPPs and trades power (15 TWh/year) on the spot market, In 2020, the company is partnering with Toshiba Energy Systems to develop an energy resource operation support service business in anticipation of the introduction of the Feed-in-Premium (FIP) system (a new commercial renewable energy support system that will replace the Feed-in-Tariff (FIT) system in Japan). Energy Pool's DR business (France)[462]
Founded in 2009, the company formed a capital alliance with the Schneider Electric Group, a major electronics manufacturer, in 2010. The company provides a control system for RTE, the French national grid operator, when it procures ancillary services not only from generation

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[459] https://www.nrg.com/insights/energy-education/plan-to-reduce.html
[460] https://www.trieagleenergy.com/Docs/PT-AboutPrimeTime.pdf
[461] Next Kraftwerke's website, https://www.next-kraftwerke.com/vpp;
Toshiba Energy Systems website, October 28, 2019, https://www.toshiba-energy.com/info/info 2019_1028.htm,
"50 Technologies that will Transform the Electric Power and Energy Industries" (Ohmsha)
[462] Energy Pool's website https://www.energy-pool.eu/jp,
"50 Technologies that will Transform the Electric Power and Energy Industries" (Ohmsha)"

facilities but also through DR, and a system for the grid command center of Stattnet, the Norwegian transmission operator, to monitor, forecast, and optimize the supply-demand situation of the entire grid. The company also provides EMS services to electric power companies in various European countries.
In Japan, the company launched its business in 2014 in partnership with Tokyo Electric Power to establish a DR program for industrial customers' production lines.

(h) Low-loss High Capacity Conductors

The cutting edge low-loss high-capacity conductors have a steel core, a higher strength material, make it smaller in diameter than conventional conductors, and trapezoidal aluminum shapes arranged without gaps on the outside of the core to increase the aluminum filling ratio, resulting in lower electrical resistance while maintaining the outer diameter and tensile strength of the conductor at the same level and reducing transmission loss by 20-25% compared to conventional ones.

The improved efficiency of power transmission enables the delivery of power to the demand side with less transmission loss, reducing the necessary amount of electricity generated and contributes to the reduction of CO_2 emissions generated during power generation.

In addition, by applying heat-resistant aluminum, approximately twice the current capacity comparing to conventional conductors can be achieved. This extra capacity can also serves as emergency backup and can contribute to improving the reliability of the power grid.

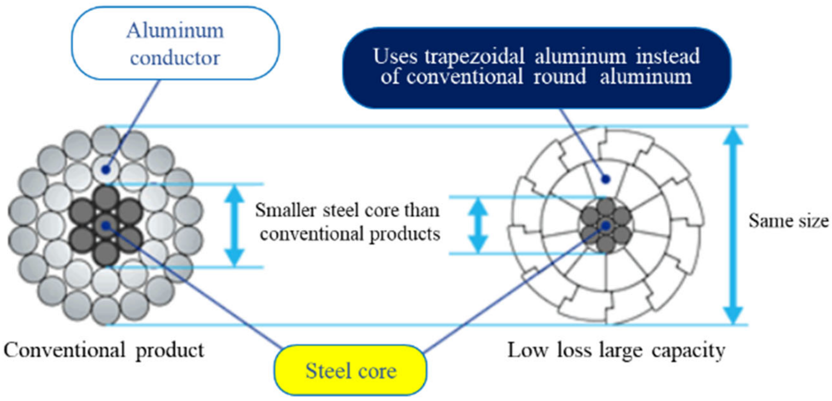

Figure 192 Conventional High-capacity conductors and Low-loss High-capacity conductors
Source: Sumitomo Electric Industries website

In Bangladesh, the required strength of steel towers was higher than in other regions because the wind speed assumed in the design was higher. However, by adopting low-loss high-capacity conductors, it was possible to reduce wind pressure by making the conductors thinner while maintaining transmission losses at the same level as conventional conductors, thereby reducing the load on the towers and the required strength of the towers, contributing to lower construction costs.

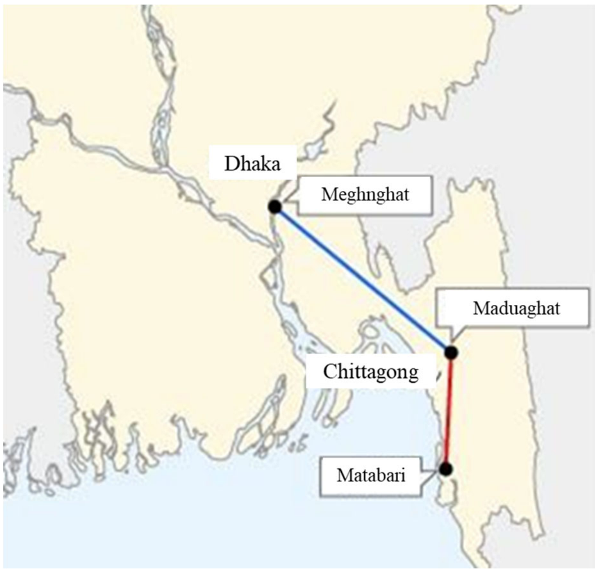

Figure 193 Example of Low-loss High-capacity Conductors (Bangladesh)
Source: Sumitomo Electric Industries website

(i) Enhanced grid operation capability (HVDC, VSG, MG sets, synchronous regulators)

<u>HVDC</u>

Since the 1950s, High Voltage Direct Current (HVDC) has been put to practical use around the world as an effective means of transmitting large amounts of power over long periods of time. Today, HVDC technology has advanced significantly, enabling cost-effective, high-capacity power transmission and is expected to become the backbone of future power networks.

Not only is HVDC capable of instantaneous and precise control of power flow, but the HVDC link allows for secure and stable asynchronous interconnection of power networks operating at different or incompatible frequencies, plus it can provide fast response to changes in voltage and frequency at both ends. Moreover, HVDC transmission does not contribute to short-circuit currents in interconnected AC systems, and thus does not affect the existing transmission infrastructure.

In addition, while AC transmission lines require three overhead lines, DC transmission lines require only two overhead lines, so existing AC transmission lines can be used as DC transmission lines without modification, and the transmission capacity can be increased approximately twofold.

Therefore, flexible wide-area power system operation technology is one of the useful measures to mitigate the rapid increase in demand. Long-distance DC power transmission that takes advantage of this feature can respond to PV fluctuations between east and west, and can ensure flexibility in seasonal balance between north and south. Flexible power system operation technologies such as system including HVDC (e.g., development of meshed HVDC) are currently in the demonstration stage, but these technologies are necessary for wide-area power system operation with long-distance power transmission and for grid connection of large-scale offshore wind power.

In Europe, DC power transmission projects are being promoted against the backdrop of the growing introduction of offshore wind farms, the integration of international power markets, and the elimination of the problem of uneven distribution of power demand and supply areas.

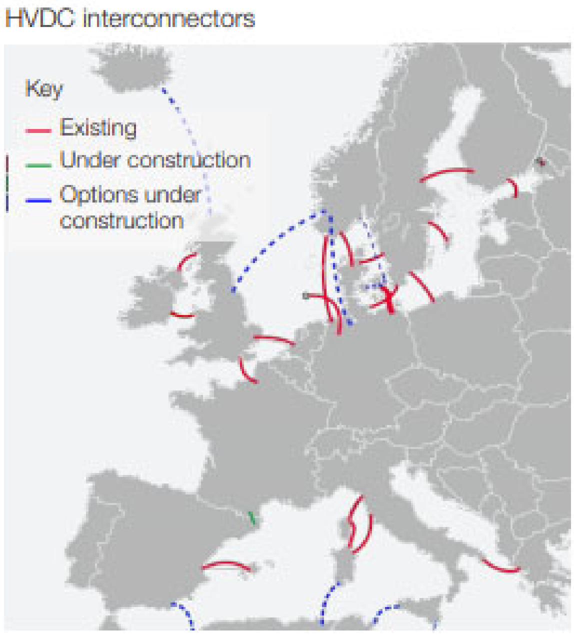

Figure 194 International interconnection by HVDC
Source: ARUP "Five minute guide to DC Power"

In Germany, an AC/DC hybrid overhead transmission line is planned to be in operation in 2025 to increase transmission capacity by utilizing one of the two AC transmission circuits as a DC transmission line in order to transmit the abundant wind power in the north to demand areas in the south. (Osterath - Philippsburg: 340 km)

Figure 195 AC/DC hybrid overhead transmission line installation plan
Source: ULTRANET | TransnetBW GmbH

In China, a multi-terminal DC transmission project is underway in Zhangbei, Hebei province, with the world's first 4-station mesh HVDC grid capable of delivering 500 kV, up to 4,500 MW of wind-generated electricity, which has been operational since 2019.

Figure 196　Example of mesh HVDC grid installation

Source: HITACHI ABB's website　Zhangbei (hitachiabb-powergrids.com)

In the "Next Generation Offshore DC Power Transmission Technology Development Project" of NEDO, the development of a multi-terminal DC power transmission system with world-class transmission capacity (voltage ±500kV, capacity 1GW) with high reliability and low cost, which is also compatible with multi-vendor systems, and the necessary element technologies is being promoted for the purpose of establishing fundamental technologies to expand and accelerate the introduction of large-scale offshore wind power generation systems in the future.

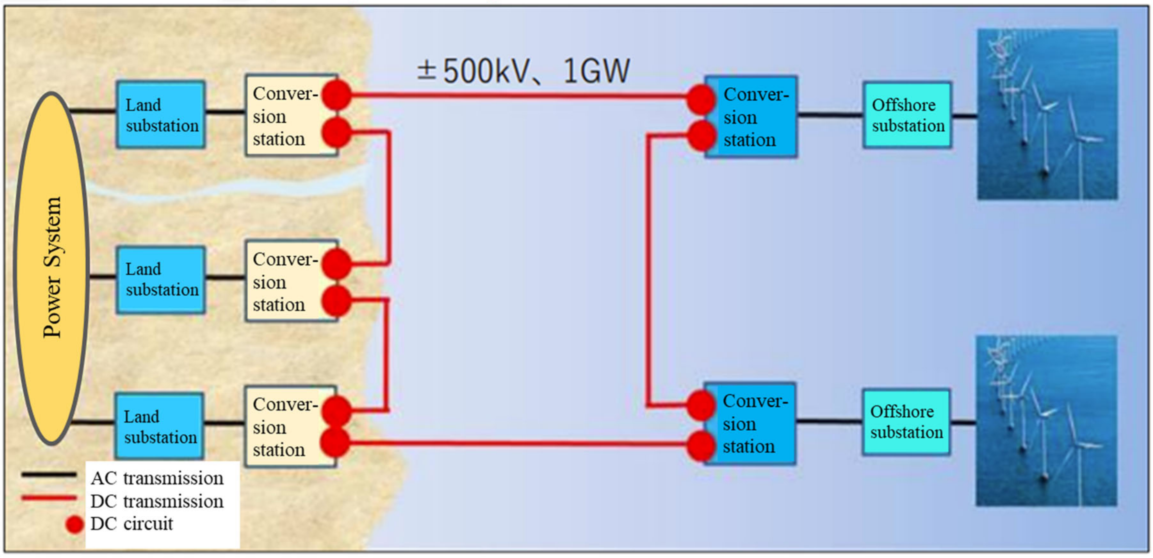

Figure 197　Next Generation Offshore DC Power Transmission Technology Development Project

Source: NEDO, "NEDO Initiatives in DC Power Transmission Technology," 6/4/2019.

VSG (Virtual Synchronous Generator)

With the current massive introduction of renewable energy, the ratio of conventional synchronous generators is decreasing, and problems due to the reduction of inertial power in the power system are prominent. Under these circumstances, grid-forming (GFM) inverters and new grid-following (GFL) inverters, which are VSGs that aim to equip inverter power supplies such as wind turbines with virtual inertial force, have been proposed.

The GFM inverter is a new type of AC converter that can provide the inverter power supply with characteristics similar to a rotating synchronous generator, can be synchronously interconnected to the power system as a voltage source, and can supply transient current at high speed, thus contributing to the improvement of the pseudo-inertia, improving frequency fluctuation characteristics. Therefore, it is expected to play a major role in making renewable energy the main source of power in the future, including the grid stabilization effect that rotating generators play, also, it also strengthens the power system, and can function as a micro-grid independent power source as part of such a system.[463]

In addition, various methods of implementing frequency response characteristics have been proposed for new GFL inverters. However, because of the limitation of frequency response speed in general, they can contribute to the improvement of the lowest point of frequency (Nadir) when the power supply drops out, but unlike GFM, they are not expected to contribute to the improvement of the rate of change of frequency (RoCoF: Rate of Change of Frequency).

In Japan, Tokyo Power Grid, Ogasawara Town, and Meidensha have been jointly implementing the "100% Renewable Energy Power Supply Demonstration Project on Hahajima" since 2018, which aims to back up the intermittent nature of solar power output by applying VSG control to storage batteries.

In Australia, ABB has been operating large storage batteries in parallel to the grid with VSG control since December 2018, with ABB earning revenue by providing ancillary services.

Tesla has started operation in 2019, funded by the Australian Renewable Energy Agency, adding GFM-type control to its existing GFL-type controlled storage batteries, and equipping them with the ability to handle low inertia issue.

<u>Motor Generator (MG) set</u>

An MG set is a power generation facility driven by an electric motor, and is a power, voltage, phase, and frequency converter that can meet various needs, such as power sources for various tests, frequency converters, and simulation test equipment, etc. By connecting a VRE with storage batteries to the power system via an MG set (both MGs are synchronous machines) as a power source, the power system simply becomes a "synchronous generator with a fast controllable effective power output", which in theory can basically solve various problems caused by renewable energy. In addition, they are generally robust and reliable, have a long life-cycle, and price advantages over inverter-type converters for large machines at present.

MG sets and VSG with VRE and storage batteries are also still in the demonstration stage in large-scale power systems, etc., and future progress is expected.

<u>Synchronous Condenser</u>

Synchronous condenser are used to adjust the voltage and power factor by connecting a synchronous motor to the power system with no load and adjusting the field current. In Japan, it has been mainly used as a voltage reactive power regulator. On the other hand, as a synchronous rotor, when implemented, it is expected to contribute to the stabilization of the power system due to its ability to maintain frequency by its rotational energy.

(j) CCUS (Carbon dioxide Capture, Utilization and Storage)[464]

CCUS is a technology for separating and recovering CO_2 contained in exhaust gases from thermal power plants, factories, etc., and storing it in a stable subterranean formation, and is one of the measures against global warming. In addition to separation, capture, and storage, CCUS also includes effective utilization of the recovered CO_2.

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463 "50 Technologies that will Transform the Electric Power and Energy Industries", (Ohmsha)

464 "Efforts to Achieve a Carbon-Neutral Society Using CCUS," Ministry of the Environment of Japan
"What is 'CCUS' that Converts Carbon Dioxide into Resources," Business+IT
"50 Technologies that will Transform the Electric Power and Energy Industries" (Ohmsha)

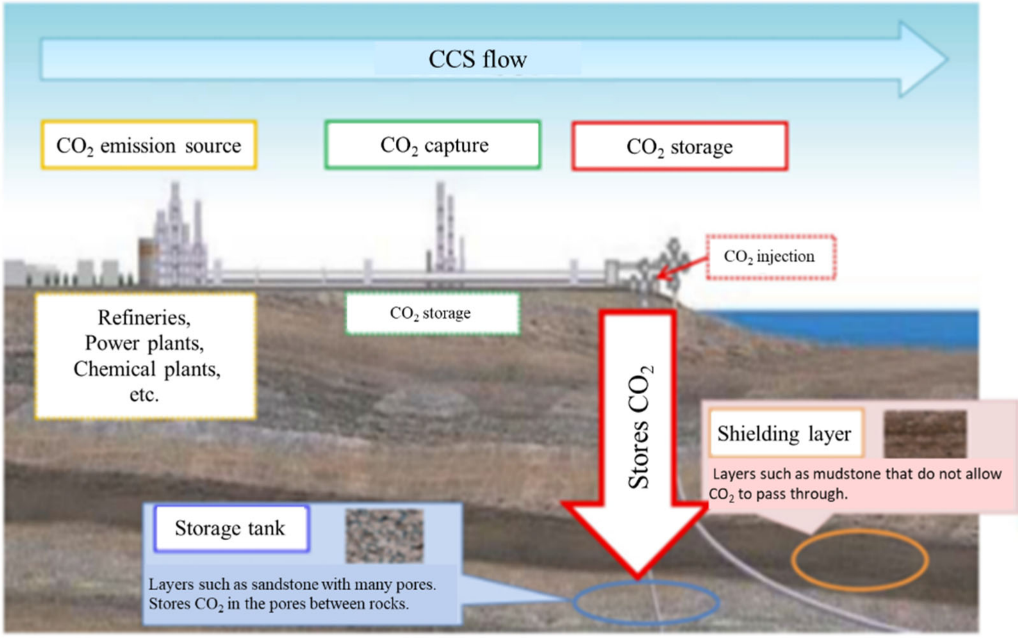

Figure 198　Flow of CCS

Source: Agency for Natural Resources and Energy, "Basic Energy Knowledge You Need to Know"

(1) Capture

There are several methods to recover high purity and large amounts of CO_2 from exhaust gases. The chemisorption method using pricey amines type substance such as monoethanolamine (MEA) is the most common and industrially established technique. In this method, when exhaust gas is brought into contact with an amine solution, the amine solution absorbs CO_2, and by heating the solution to 120°C, the CO_2 is separated and can be captured. In addition, there is also a physical adsorption method in which CO_2 is adsorbed onto a porous solid absorbent. Transportation

There are several methods for transporting recovered high-purity CO_2 to underground injection facilities, including CO_2-only pipelines, CO_2 transport ships, tanker trucks for small-volume transport, and railroad container transport.

Pipelines are already being utilized mainly in the U.S. due to their large transport volumes. They are inflexible because once burial is finished, it is almost impossible to change to another location. Tankers, ships, and railroads are used for small-scale transportation. Ships, in particular, are capable of transporting goods across national borders and are likely to be used more widely in the future.

The Ministry of the Environment is conducting studies aimed at the early establishment of a marine transport technology for CO_2 that offers a high degree of freedom in the combination of emission sources and storage sites and can be widely adapted to the promotion of transport distances and storage sites. (From Ministry of the Environment pamphlet, Business+IT)

(2) Storage

High-purity CO_2 is stored in a "reservoir" formation, located 1,000 to 3,000 meters underground and is composed of sandstone and other materials with many pores. The CO_2 must be transported through the upper part of the reservoir, the “shielding layer”, which is a dense formation of mudstone and other materials that do not allow CO_2 to pass through. The reservoirs include a deep saltwater layer (a layer in which the pore spaces are filled with saline formation water) and an oil reservoir. The method of injecting CO_2 into an oil reservoir has been used for more than 40 years in the United States and other countries as Enhanced Oil Recovery (EOR). Some of the stored CO_2 is returned to the surface with the crude oil, but most of it is stored underground by repeated capture and injection. The CO_2 is stored in a "reservoir" at depths deeper than 800 meters below ground. In Japan, since there are many places where CO_2 can be stored in undersea and many large-scale CO_2 emission sources such as thermal power plants are located in coastal areas, this technology is considered to be suitable.

(3) Utilization

To effectively use CO_2 as a resource, there are two methods: one is to convert CO_2 into fuels, plastics, etc., and the other is to use CO_2 directly as it is. Direct utilization includes enhanced oil recovery (EOR) and use in dry ice.

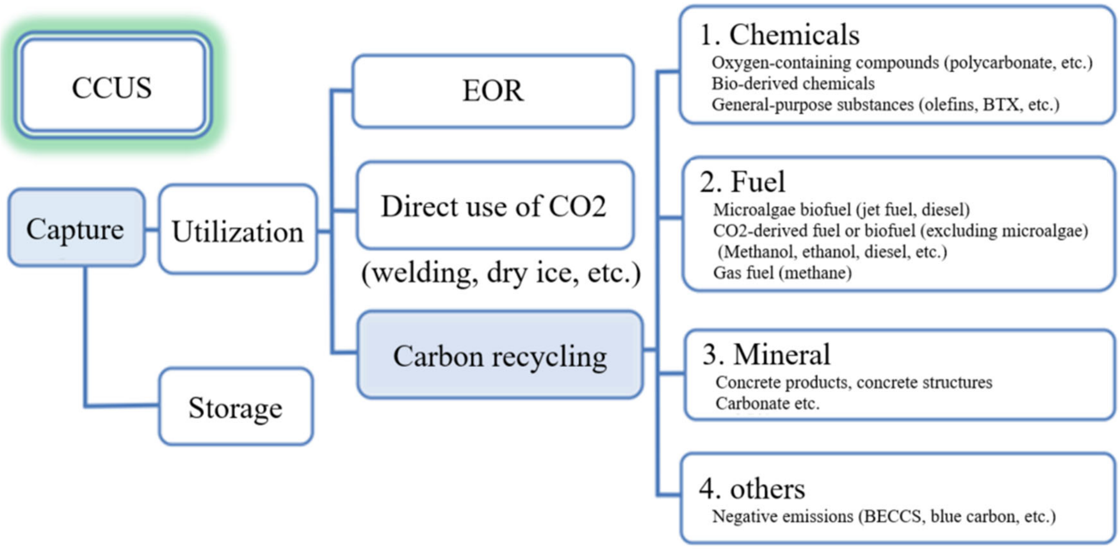

Figure 199 Example for CCUS

Source: Ministry of Economy, Trade and Industry, "Carbon Recycling Technology Roadmap," 2019/6

As for direct usage, CO_2 gas supplied for industrial use (welding, carbonated beverages, etc.) is total about 1,000,000 tons annually, including about 800,000 tons of carbon dioxide gas and 200,000 tons of dry ice. (Information from the Japan Industrial and Medical Gas Association)

In addition, as described in the section on storage (see above), EOR has been conducted in the U.S. and other countries by injecting CO_2 into depleted oil fields to achieve oil recovery statues.

The Ministry of the Environment has drawn the following roadmap for future CCUS efforts[465]:

- 2016 - 2020 “Establishment Technologies”: The operational and environmental performance of the CO_2 capture system was confirmed. Transport and storage technologies were studied; demonstration of CCU technology was initiated. Studied the feasibility of storage in collaboration with METI.
- 2021 - 2025 “Practical Development”: Establish the first commercial-scale CCU technology by 2023. Establish supply chain (comprehensive verification) and conduct FS (including overseas and international cooperation) for transportation and storage.
- 2026 - 2030 “Implementation”: Based on the operational results to date, proceed with full-scale social implementation.

Examples of CCUS initiatives in Japan:

(1) Capture[466]

Sigma Power Ariake's biomass power plant (Mikawa Power Plant, Omuta City, Fukuoka Prefecture, 50 MW output), which has been certified by METI as a facility of the "Omuta City Next-Generation Energy Park," is conducting a demonstration test using Toshiba's CO_2 capture and separation

[465] "CCUS and Hydrogen in Japan," Ministry of the Environment presentation, from March 11, 2021

[466] Sigma Power Ariake website, Kansai Electric Power press release, September 24, 2020;
"Basic Energy Terms You Need to Know - "CCUS" to Collect, Bury,
Utilize CO_2," November 14, 2017, Agency for Natural Resources and Energy, METI

technology to capture more than 500 tons, or 50% of the CO_2 emitted per day. (Such biomass CCS falls under BECCS (Biomass Energy with CCS)).
Since 2016, Kansai Electric Power, Kawasaki Heavy Industries, and the Research Institute of Innovative Technology for the Earth (RITE) have also been conducting durability and economic evaluation of CO_2 capture technology using solid absorbers at KEPCO's Maizuru power plant as a project commissioned by METI. From 2020, the project will move to pilot-scale testing as a NEDO project. METI is aiming for capturing process at less than half the cost of conventional technologies using solid absorbent materials. Storage[467]
A large-scale demonstration experiment of CCS has been conducted in Tomakomai, Hokkaido since 2012. In this demonstration, a portion of the off-gas containing CO_2 generated from the hydrogen production equipment at Idemitsu Kosan's Hokkaido Refinery is transported by a 1.4 km pipeline to an adjacent CO_2 capture, and injection facility, where it is stored in two reservoir at different depths using two independent injection wells. It started in 2012, and the design and construction of the capture equipment and injection facilities were carried out for four years until FY2015. In 2016, it began injection into a 1,000-meter underground reservoir with the goal storing 100,000 tons per year, and also conducted a trial injection into a 2,400-meter reservoir. In November 2019, the injection was stopped as the CO_2 injection volume reached the target of 300,000 tons. Since then, the behavior of CO_2 post-injection and other factors have been monitored to ensure that there are no leaks. Utilization
Examples of efforts related to CCU (effective utilization) supported by the Ministry of the Environment include the following:

- Saga City's waste power generation study project with CO_2 capture function:
  Japan's first CO_2 capture facility was installed in a waste-to-energy facility at a waste incineration plant. The captured CO_2 is sold to an algae cultivation company and commercialized as cosmetics and supplements.
- Demonstration of the establishment of a carbon cycle model through the recycling of CO_2 collected from Hitachi Zosen's waste incineration plant:
  CO_2 emitted from waste incineration plants is reacted with hydrogen derived from renewable energy to produce methane.
- Technology development and demonstration of Sekisui Chemical's chemical products using CO_2:
  Syngas ($CO + H_2$) is synthesized from CO_2 emitted from waste treatment facilities and hydrogen derived from renewable energy. Ethanol is produced from syngas using microbial catalysts.
- Kawasaki Heavy Industries' Carbon Cycle Model Building Demonstration:
  Energy-saving recovery of CO_2 in low CO_2 concentration gas, which has been difficult to use effectively, using special solid absorbent. Direct Air Capture (DAC) is implemented.
- Construction and demonstration of a carbon cycle model for highly efficient synthesis of syngas at room temperature and 1atm at Toyota Central R&D Labs:
  Highly efficient synthesis of syngas (CO + H2) from CO_2, water, and sunlight.
- Demonstration of a community-compatible CO_2 resource recovery model using artificial photosynthesis technology at Toshiba's high-volume CO_2 emitting facilities:
  CO_2, and high throughput production of carbon monoxide (CO), a raw material for chemical products and fuels, from sunlight.
- Ready-mixed concrete production with CO_2 injection：
  In January 2021, Mitsubishi Corporation took a stake in Carbon Cure, a Canadian company with carbon recycling technology that injects CO_2 into concrete building materials, and agreed to an alliance to expand the business. This involves the installation of related equipment developed by the company without major changes to the manufacturing process at ready-mixed concrete plants. The company claims that the CO_2 injection will reduce the amount of cement used, which will also lead to a reduction in CO_2 emissions from building materials.[468]

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467 Japan CCS Study (JCCS) press release, May 15, 2020;
"Overview of the Report of 300,000 Ton Injection of CCS Large-Scale Demonstration Test at Tomakomai," May 2020, from METI, NEDO, JCCS
468 Mitsubishi Corporation press release from January 29, 2021

Large-scale CCS projects worldwide:

According to the Global CCS Institute Database, as of April 2021, a total of 26 commercial-scale CCS projects were in operation worldwide in Australia, Brazil, Canada, China, Norway, Qatar, Saudi Arabia, UAE, and the United States. Most of them are aimed at EOR, and there are five projects that store CO_2 in dedicated deep saltwater reservoirs: two in Norway and one each in Australia, the United States, and Canada. Among them, the Sleipner storage facility in Norway is the world's first project to store CO_2 in a dedicated underground reservoir rather than EOR, and began storage in 1996 as part of offshore natural gas development. Currently, approximately 850,000 tons of CO_2 injection per year continues. The cumulative storage volume is estimated over 17 million tons.[469]

Figure 200 Commercial-scale CCS projects

Source: Global CCS Institute Database

Trends and results for targeted countries

(ii) Trends in the development and social implementation of technologies and services in the countries covered by the field survey

(a) India

Renewable Energy Introduction

In 2014, thermal fuels accounted for approximately 80% of total electricity generation in India. Most of the oil and gas are imported.

Prime Minister Modi has set a goal of becoming energy independent by 2047, the 100th anniversary of India independence. In order to achieve energy self-sufficiency by 2050, an appropriate energy mix and effective technologies must be in place, and to this end, the Indian government and its think tank, NITI Aayong (National Institution for Transforming India), prepares a roadmap and action plan for up to 2050. NITI Aayong conducted a basic trend analysis and submitted a report in 2020.

India is aiming for zero emissions by 2070 and plans to have a total generation capacity of 810GW by 2030, 500GW of which will be non-fossil power. According to the NTPC (National Thermal Power Corporation) the planned non-fossil power generation includes 290GW of solar power, 140GW of wind power, 15GW of biomass, 57GW of hydropower, 14GW of pumped storage (used as regulating power), 5GW of small hydropower, and 21GW of nuclear power.

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[469] Facilities Database, GCCSI Database: https://co2re.co/FacilityData

India aims to achieve a 50% renewable energy ratio by 2050, and the decarbonization of the power generation sector is primarily based on the large-scale introduction of solar power and wind power. According to TERI (The Energy and Resource Institute), coal resources are abundant in the country, and coal-fired power plants are expected to remain in operation until 2040-2050 due to their relatively young lifetime.

Regarding solar power generation, India has tremendous potential due to the abundant sunlight conditions throughout the country. Large-scale solar parks are already being built and planned in various locations, and the cost of power generation is one of the lowest in the world.

The first item of the eight action plans in the NAPCC (National Action Plan on Climate Change) is to promote solar power. In 2010, RPO (Renewable Purchase Obligations) were initiated, which require electric distribution companies and other entities in each state to procure a certain percentage of renewable energy. Although the RPO system has been introduced in many states, some have failed to meet their targets due to the weak binding effect of the implementation rules.

In 2010, the government announced the JNNSM (Jawaharlal Nehru National Solar Mission). This mission is to expand mega solar power through a bidding system in three phases over the period 2010 - 2022. In 2014, the DSPP (Development of Solar Parks and Ultra Mega Solar Power Projects) was launched as one of the means to promote the achievement of the JNNSM. While there are some exceptions, the plan is basically to install more than 50 solar parks of 500MW or more (total capacity of 40GW).

As for wind power, there is high potential in the southern and western coastal areas, especially in the southern province of Tarminad, where wind power is being actively developed.

Thermal Power Generation

In India, in addition to the renovation and modernization of existing coal-fired power plants, efforts are being made to introduce the latest technology in newly developed coal-fired power technologies (USC and A-USC). Existing coal-fired power plants are still new, with an average operating life of 15 years, therefore, few prospects are available for new development in the future, and with average efficiency as low as 35%, efforts for existing power plants are particularly important. In recent years, studies have begun to examine ways to further reduce the carbon footprint of existing power plants, including a feasibility study on the CCUS project and a national mission to increase the ratio of biomass co-firing power plants.

Construction and Operation of Coal-fired Power Plants

Fossil fuel generation accounted for about 80% of total electricity generation in 2014, in which, as of 2018, coal-fired generation accounted for 73% of electricity generated. The share of coal-fired power in the power generation sector remains high, but 6.5GW of coal-fired power is also planned to be phased out by 2030.

Regarding the development of coal-fired power, the power plants currently under construction will be completed in the next few years, and there are no plans for new construction after that.

According to MoP (Ministry of Power), with the estimation of the useful life of coal-fired power plants to be 50 years, there are 35GW that are more than 25 years old as of 2022, and these are expected to be automatically decommissioned by 2047.

Although the government has created a policy to reduce coal-fired power and expand gas-fired power and renewable energy, the use of coal-fired power is expected to continue to a certain extent. Therefore, the introduction of clean coal technology and high-efficiency gas-fired power is necessary to achieve a low-carbon electricity.

NTPC is eliminating and replacing about 200MW units with low efficiency. A 660MW class improved ultra-supercritical pressure unit has achieved a generation efficiency of 41.5%, and an 800MW unit is being studied and planned to construct. In addition, as a medium to long-term role, coal-fired power will be the main source of power generation until 2030, and although there is potential for gas turbines and hydro power, a total withdrawal of coal-fired power is not realistic.

Currently, peak demand is about 200GW compared to installed generation capacity of about 360GW. There is a certain amount of installed capacity surplus, and the utilization rate of coal-fired power has declined from over 80% in the past to 50 - 60%. According to TERI, the reduction in coal-fired power has been achieved by lowering the utilization rate, and some believe that continuing to do so will contribute to reducing CO_2 emissions.

WB (World Bank) believes that coal-fired power plants will remain even with the 2030 reduction target, but as the introduction of renewable energy advances and prices fall, high-cost power plants will have to be phased out. It has begun dialogs with several states on how to utilize aged thermal power assets, with particular attention being paid to state-owned plants.

ADB (Asian Development Bank) also considers coal-fired power plants older than 20 years old to have low efficiency and environmental pollution problems. Indian government aims to improve efficiency and does not recommend extending the life of coal-fired power plants, but rather advocates their early termination. The relatively new coal-fired power plants owned by the private sectors have no intention of selling them off. On the other hand, older thermal power plants are less efficient, but the fact that they use domestic coal makes them less costly.

According to NTPC, AGCs are planned to be connected to all units in thermal power plants and are currently installed in 70% of them. 5% fluctuation is expected to be handled by AGCs.

Specific recent initiatives are listed below:

・In 2015, new emission standards for thermal power plants
 (Amendments to the Environment (Protection) Act of 1986)
 →Was mandated for response by 2017, but response date was postponed until 2022 - 2025 (information dated March 2021)
・In 2017, announcement of a national mission on A-USC technology (total: $238 million)
 →Planned to operate A-USC demonstration site (800MW) at the NTPC and Bharat Heavy Electrical Ltd.
・In 2019, the NTPC announces commencement of operation of the first Ultra-Supercritical Pressure (USC) coal-fired power plant in India
 →Unit 2 (660 MW) of Khargone Power Plant, State of Madhya Pradesh
・In 2019, IOC signed MoU with OIL and ONGC on CCUS and Enhanced Oil Recovery (EOR)
 →In January 2021, IOC injected CO_2 recovered from IOC's Koyali refinery into ONGC's Gandhar oil field
・EOR project feasibility study commissioned to a consortium led by the Indian company Dastur. In addition to EOR, economically feasible utilization of CO
・In 2021, the "National Mission on the use of Biomass in coal based thermal power plants" (5-year period) was launched to research and development and introduction of regulations to increase the ratio of biomass co-firing power plants (5% in 2021)
・WB initiates dialogue with West Bengal and two other states on how to utilize aging thermal assets

Flexible Operation of Coal-fired Power Plants

Recognizing the need for flexible operation of coal-fired power plants according to load, thermal power plants are currently implementing sliding pressure operations (transformer operations). According to MoP, a minimum load factor of 55% is the target.

According to NTPC, in order to increase operational flexibility, new technology is being employed in the new plants to allow for low utilization. In addition, existing plants are being equipped with equipment to monitor lifetime consumption. Older thermal units with extended lives are being decommissioned, while efficiency improvement measures are being implemented for existing units where efficiency gains can be expected.

In addition, through a multi-year pilot project with USAID (United States Agency for International Development), India has gained various insights into the flexible operation of coal-fired power plants. It has also confirmed that frequent startups and shutdowns, load shedding (ramping), and minimum power operations can affect equipment fatigue and service life. India is also currently operating at a minimum output of 55% of rated capacity. To lower this capacity percentage to 30 - 40%, many adjustments will have to be made, which can be difficult. Therefore, the operation will be kept within a limited range.

Biomass Co-firing

In the power generation sector, biomass cogeneration (bagasse feedstock), biomass generation and small-scale biogas generation in rural areas are being promoted. However, the supply chain for biofuels is not sufficient. Currently, 8 tons of biomass is consumed annually. If sufficient quantities are procured in the future, all 16 units of NTPC can be co-fired. Although there is a problem that co-firing biomass raises boiler temperatures and reduces boiler efficiency, NTPC is aiming for a minimum of 5% co-firing at first, and has mandated that the co-firing rate be gradually increased to 20%.

There is no support from other donors for biomass co-firing. Since the recovery of rice straw as biomass fuel would lead to increased income for farmers, MoP, through the National Biomass Mission, is working to convert agricultural waste (rice straw, etc.) into pellets. In addition, MoP expects to receive support for more cost-effective methods of bioenergy.

The WB reports that it is in discussions with the Indian government for a $250 million financing project for biogas.

According to the ADB, they has been working on a technical cooperation program for biofuels since a few months ago (interviewed on December 21th, 2021), which involves adding biogas to compressed natural gas (CNG) systems, using Japanese high level technical funds, and the program is not intended for any particular state. The Indian government states that improving air condition is its primary concern and that it intends to co-fire 10% biofuels.

Hydrogen/Ammonia Co-firing, Mono-firing

The introduction of hydrogen and ammonia co-firing in existing thermal power plants is being considered. Plan for ammonia co-firing in coal-fired power plants in the next two to three years have been set with several international organizations partnership for its study.

MNRE (Ministry of New and Renewable Energy) plans a pilot project for hydrogen/ammonia co-firing using ammonia as fuel.

NTPC, in cooperation with Mitsubishi Heavy Industries, is considering hydrogen co-firing, and the state-of-the-art gas turbine currently under development is capable of co-firing up to 20%.

*NTPC's Hydrogen Generation Project:

1,000 ton/day, 4.7GW (Solar: Wind = 9 : 1),

Preparing RFP for DPR creation

According to ADB, ammonia production uses a large amount of electricity, which causes efficiency problems and losses, but is effective in reducing CO_2.

Hydrogen Related Developments and Supply Chain

Hydrogen is attracting attention as a new energy source to improve energy self-sufficiency and reduce CO_2 emissions. A roadmap for the utilization of green hydrogen is being discussed within the Indian government.

The demand for hydrogen in the industrial sector will increase in the future. Hydrogen is being used in fertilizers and in refineries. Pilot projects for hydrogen use in the steel industry are planned. In addition, the use of hydrogen ammonia fuel for ships is being considered. MNRE is conducting research and development while eyeing domestic and international developments.

ADB states that although hydrogen has high efficiency losses when used for power generation, it is useful for electrification of industries such as steelmaking and transportation, and some believe that it is more efficient to use it for industrial purposes.

The Indian government is considering regulations regarding mandatory green hydrogen use, which would require that 5 - 10% of hydrogen use in the industrial sector must be green hydrogen. This move will ensure a market for green hydrogen and kick-start hydrogen use in the industrial sector.

According to the MNRE, blue hydrogen is also on the agenda, as a shift from coal-fired to gas-fired power generation are being promoted, the amount of natural gas for hydrogen production is inadequate, hydrogen can be produced from lignite coal.

Specific recent developments are listed below:

・In September 2020, a committee was established to develop goals for hydrogen energy development

・In August 2021, Prime Minister Modi announced the launch of the "National Hydrogen Mission" and mentioned the following:
  - Aims to make India a green manufacturing and exporting hub
  - Consider proposal to mandate purchase of green hydrogen at fertilizer plants and oil refineries
  - Extend production-linked incentive (PLI) scheme to green hydrogen production facilities (electrolyzers)

Electrolyzers and Fuel cells

According to TERI, fuel cell production and electrolyzer development are areas of further research and development. The Ministry of Science and Technology (coordinates national-level research institutions) has announced an advanced hydrogen research program involving educational institutions and other research organizations. In addition to basic research on fuel cell and electrolyzer development, the program focuses on product development and other technological applications. Research on materials for storage tanks is also considered an area of future need.

NTPC is considering a fuel cell system to supply electricity to villages in a poor and isolated area (Ladakh) as a small-scale project. The region has one of the highest solar potentials in the country. Therefore, the fuel cell system is being considered to provide nighttime electricity for the villages.

TERI analyzed that the use of hydrogen in the power generation sector will become less cost-effective as the share of renewable energy increases significantly. In their opinion, hydrogen will be used in the power generation sector after 2040.

CCS and CCUS

According to TERI, 99% of hydrogen is currently produced from the natural gas reforming process, however, for green hydrogen production, CCUS technology will be required to be added to existing infrastructure. CCUS projects are being implemented in India by a private companies, but only in the demonstration phase. The challenge for CCUS projects lies with CO_2 storage, since oil and gas wells is very limited in India, and costs are expected to be high due to geological distribution.

MoP aims to reduce emissions to the same level as gas turbines rather than aiming for zero emissions of coal-fired power plants.

According to MNRE, the Ministry of Coal is considering implementing CCUS and is conducting a study.

Domestic Power System

According to MNRE, power plants are concentrated in the southern and western parts of the country, which means that transmission capacity needs to be maximized to deliver power to all parts of the country.

In 2012, the "Green Corridor Plan" was launched in collaboration with Germany to develop the power grid throughout India with a view to expanding the introduction of renewable energy in the future. The plan includes the reinforcement of intrastate transmission lines in states with high renewable energy potential, the reinforcement of interstate interconnection lines for exporting electricity to other states, and the establishment of a renewable energy management center.

In addition to this, bids for renewable energy and storage facilities (1.2GW) are now being sought to utilize storage batteries and upgrade the operation of the power distribution network in order to integrate renewable energy into the grid. Moreover, since the aim is to expand the use of EVs, the integration of EVs into the power system (and their impact on the grid), along with renewable energy, is also an area of high interest. (Ref.) NITI Aayog, IEA "Renewables Integration in India".

The Interstate Transmission System (ISTS), consisting of 3,200km of transmission lines and 17,000MVA substations, was completed in March 2020 under the Green Corridor Plan. The Intrastate Transmission System (InSTS) has been approved in renewable energy rich areas of Tamil Nadu, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh, and Madhya Pradesh. Of the InSTS component's target of approximately 9,700km of transmission lines and substations with a capacity of approximately 22,600MVA, approximately 7,362km of transmission lines and 9,656MVA of substations have been installed. The InSTS component is scheduled for completion in 2021.

One of the challenges for the Indian power sector is to improve the efficiency and financial health of the power distribution sector. India has an AT&C loss (Aggregate Technical and Commercial Loss) of about 20%, which is high considering that the OECD average is about 6%. The Indian government is working on a plan to strengthen the national electricity distribution system and reduce the debt of electricity distribution companies (UDAY: Ujjwal DISCOM Assurance Yojana) to help improve its finance, install smart meters, and reduce AT&C losses.

Regarding the issues above, the government has launched the RDSS (Revamped Distribution Sector Scheme) for the period from FY2021/22 to FY2025/26 to support the installation of smart meters to reduce non-technical losses, expansion of the power distribution system, and human resource development, and ADB is considering providing grants for the distribution companies to pay their own share.

International Interconnection

Since India's power system is also interconnected with neighboring Bhutan and Bangladesh, etc., it is necessary to consider the impact of these interconnections. Countries other than Bhutan import electricity from India. When a large amount of VRE is introduced, increased frequency/voltage fluctuations, and grid overloads may occur grids that are interconnected with other countries.

Electricity exports are counted with 400MW to Nepal, 500MW to Bangladesh, and, on a very small scale, a linkage with Myanmar. A submarine cable linkage with Sri Lanka is under consideration.

Imports are supplied from three hydro power plants built in Bhutan (1.5GW in total). Three more hydro power plants (2.91GW in total) and a 400kV DC interconnection line are under construction.

Ancillary Services

NTPC, a provider of ancillary services, is concerned about the cost of ancillary services and battery storage by AGC and others. In particular, it believes that battery storage is extremely expensive and must be economically acceptable to residents.

NTPC expects that secondary ancillary service using battery storage will be necessary to cope with the large amount of unstable VRE installations, and in the future, NTPC would like to store excess VRE generation in batteries and discharge it when needed, but at the present, no such a battery storage system (BESS) is used.

The MNRE believes that power storage and flexibility systems need to be implemented because supply will exceed needs during the monsoon season. Demand for power storage systems is high, and MNRE expects that battery prices will come down in the future, so that these systems will eventually become available in India.

According to POSOCO (Power System Operation Corporation Limited), current BESS is mainly at the distribution level, and there is only very limited experience with grid-scale BESS, which is a challenge for the future. The Indian government is also conducting a grid-scale pilot program, but it needs further studies. During the interview, POSOCO also expressed interest in pumped storage in Japan.

The WB supports the BESS project as an incentive to BESS manufacturers. It also believes that lots of technical assistance training is needed.

To this date, USAID has supported BESS as well as studies and demonstrations that contribute to grid stabilization.

・Technical assistance for system operators and pilot activities underway in 6 states: Tamil Nadu, Karnataka, Andhra Pradesh, Rajasthan, Gujarat, Maharashtra.
・Pilot project to introduce BESS into the power transmission and distribution system (Puducherry)
・Pilot projects using AGC (hydro power plant in Karnataka and Solar PV of NTPC in Andhra Pradesh)
・Dynamic Voltage Control pilot (at the same location as AGC)

ADB pointed out that DR is valuable and can lead to ancillary services. It was also noted that the purpose of smart meters is first and foremost for bill collection, but in the future they will lead to DAS, which is necessary for DR.

POSOCO reported that for voltage control, they have implemented a pilot program to control BESS for reactive power at night. They also expressed interest in the Japanese system, with how voltage and reactive power are controlled, and whether the standard needs to be changed, as voltage control is also an important initiative in the policy of decarbonization,

Demand Forecast

For stable grid operation, it is effective to forecast the amount of solar and wind power generation and maintain a balance between supply and demand. POSOCO recognized that although the current installation of rooftop solar is only 7GW, it is expected to grow rapidly in the future, and that the demand forecast for rooftop solar is also important in terms of power supply management.

In addition, POSOCO is preparing a technical standard (Code) for grid interconnection of renewable energy (VRE) to address the grid issues and measures to be taken when large amounts of renewable energy are introduced. POSOCO also recognizes that the issue of grid interconnection of large amounts of VRE, including the issue of maintaining inertia, is an issue that should continue to be considered, since incorrect settings for grid interconnection can lead to large-scale power outages.

(b) Indonesia

Renewable Energy Introduction

Indonesia's NDC calls for at least 23% new renewable energy in 2025 and at least 31% in 2050.

The potential for geothermal, hydro power, and other natural energy is abundant, and although efforts have been made to develop these, there are also significant untapped sources. Currently, biomass, geothermal, and hydro power are the main sources of energy, but the NDC aims to expand the introduction of photovoltaic power generation in the future.

Goals:

Renewable energy development in 2021 - 2030: 20.9GW (approx. 52% of total new power source development)

- Hydro 10.4GW, solar 4.7GW, geothermal 3.4GW, etc.

Source: Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik: RUPTL) 2021 -2030

*Indonesia's power generation capacity forecast to 2030
RUPTL2021 - 2030 (Published October 2021)

In terms of power source composition, the plan is to increase the share of renewable energy sources, mainly hydroelectric and geothermal.

Coal-fired power plants, with the exception of those under construction or contracted for construction, will not be built anew, but will still account for the largest share of power source development (13.8GW) through 2030, and will continue to account for a large share of the total. MEMR (Meanwhile, the Ministry of Energy and Mineral Resources) outlines a roadmap for achieving carbon neutrality: "In 2030, the share of NRE in the energy mix will increase to 42% with solar power still taking up the largest portion".

Regarding solar power, Indonesia has great potential due to its sunny conditions throughout the country, especially on the island of Java. The potential is estimated at 207GW (4.8 kwh/m^2/day). (RUPTL 2021 - 2030)

As for wind power, some parts of Java have potential, but overall it is not very large.

The potential for hydropower is very large, with approximately 96GW of large hydropower and 19GW of small hydropower. Over 40% of the potential is concentrated in Kalimantan, with relatively little potential in the Java-Bali region, which has a large electricity demand (RUKN 2019 – 2038： Rencana Umum Ketenagalistrikan Nasional).

Although Indonesia has abundant hydropower resources, development has not progressed due to the different distribution of resources and areas of high demand, as well as environmental and social impacts of development (adverse effects on forests and ecosystems, resettlement due to development, etc.). The development rate is about 7% of the resource volume.

The development target is set at 10.4GW for 2021 - 2030. (RUPTL 2021 - 2030)

The potential for geothermal power is about 29GW, with a relatively high potential for development of about 17.5GW (RUKN 2019 - 2038).

In 2003, the Geothermal Law was enacted, establishing a system that primarily focuses on development by private developers. In 2014, the Geothermal Law was amended to remove the cap on the field area for which the government grants project rights to developers, which is expected to lead to progress in geothermal development and an increase in large-scale projects in areas with strict environmental regulations.

The development target is 3.4GW for 2021-2030. (RUPTL 2021 - 2030)

MEF (Minister for Environment and Forestry) has released its "Long-Term Strategy for Low Carbon and Climate Resilience 2050".

The following is an excerpt of the description pertaining to power and energy:

・The energy sector is second in emissions after AFOLU (agriculture, forestry, and other land use).

・Highest share of coal-fired power generation in the power sector, so climate change mitigation measures need to be focused on coal-fired power.

・Development projections for the energy sector, includes:

(i) Large-scale use of natural energy (hydropower, geothermal, solar, wind, biomass)
(ii) Introduction of CCS/CCUS to coal power plants
(iii) Biomass and coal co-firing power plant + CCS
(BECCS: Biomass Energy with Carbon Capture and Storage)

・Development of distributed power systems rather than large centralized systems

・Reliable technology and dispatch management to ensure the stability of the power grid

・Integrated land use planning is important to supply large amounts of solid biomass to BECCS and to ensure a sustainable supply of biofuels and woody biomass

The roadmap by MEMR lists five key points: expansion of renewable energy, reduction of fossil fuels, promotion of EVs, promotion of electrification of industrial and residential sectors, and promotion of CCS.

Milestones related to power and energy are listed below:

2021: NRE issues Presidential Rule on coal-fired retirements. No new coal-fired power plants are built, except those under contract or under construction

2022: NRE legislation enacted

2024: Grid interconnection, smart grids, and smart meters are actively introduced

2025: NRE share 23%, with solar accounting for half of that

2027: Suspension of gas imports

2030: NRE share increases to 42%; electricity consumption reaches 1,548kWh per capita

2031: Early phase-out of the first phase of subcritical coal-fired power plants

2035: Inter-island interconnection shifts to COD; electricity consumption reaches 2,085kWh per capita; renewables account for 57%; solar, hydro, and geothermal are the three major energy sources

2040: NRE accounts for 71% of the energy mix; diesel power plants are phased out. Electricity consumption increases to 2,847kWh per capita

2050: NRE share 87%, electricity consumption 4,299kWh per capita.

2060: NRE share in the energy mix reaches 100%, with solar and hydro becoming dominant. Electricity consumption will be 5,308kWh per capita. As for nuclear power, the introduction of 35GW between 2045 and 2060 will be considered

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Thermal Power Generation

Indonesia has abundant coal resources and is one of the world's leading coal exporters.

Coal-fired power accounted for the largest share of electricity generated in 2019, at 59%, but Indonesia aims to break away from dependence on coal-fired power and has set targets to reduce the share of coal in primary energy supply to 30% in 2025 and 25% in 2050. It is also working to introduce clean coal technology.

The goal is to "limit the share of coal-fired power generation to 59% of total power generation in 2030 (Low Carbon scenario) and promote the introduction of clean coal technologies (high efficiency, biomass co-firing, and CCUS)." (RUPTL 2019 - 2028 and others)

While oil production is decreasing due to aging oil fields, oil demand is increasing, and ensuring energy security is an urgent issue. Measures are being taken to expand exploration and development investment, including foreign investment, and to increase oil refining, etc.

・Like petroleum, domestic production of natural gas has been declining, and Indonesia is working to increase exploration and development investment, including foreign investment.

・While currently an LNG exporter, if domestic gas demand continues to increase at the current trend, Indonesia is expected to become a net importer in the medium to long term. It is also working to shift away from coal in the power generation sector.

Diesel generator is used in remote islands and rural areas. Electricity supply except for Java, such as in Maluku, Kalimantan, and Papua, is fragile, and the cost of generating diesel power in remote islands is high. Installation of low-carbon power sources and strengthening of power distribution are required.

Construction and Operation of Coal-fired Power Plants

With the exception of coal-fired power under contract or under construction, Indonesia has a policy of not implementing new coal-fired power development and plans to implement the first phase of the early phase-out of subcritical coal-fired power (SC) in 2031.

Regarding the early retirement of coal-fired power, the Energy Transition Mechanism (ETM) has been established by ADB, and a full-scale FS is currently underway to achieve early retirement of coal-fired power.

*The Climate Investment Funds (CIF), the world's largest multilateral fund, announces the launch of its $2.5 billion Accelerating Coal Transition (ACT) investment program, the first effort to advance the transition from coal-fired power to clean energy in emerging economies. South Africa, India, Indonesia, and the Philippines, which account for more than 15% of the world's coal-related CO_2 emissions, have been selected as the initiative's first target countries. Through six multilateral development bank partners, ACT will combine financing and technical assistance, including the conversion or decommissioning of coal-fired power plants and the creation of sustainable economic opportunities and social protection programs for coal-dependent communities.

Biomass Co-firing

PLN (Perusahaan Listrik Negara: Indonesia's state-owned power company) has stated that 114 existing coal-fired power plants will be biomass co-firing by 2024. In October 2020, Mitsubishi Power, PLN, and the National Institute of Technology Bandung announced their cooperation in developing a "Roadmap for the Spread of Biomass Co-firing".

PLN has conducted co-firing trials at several coal-fired plants and is considering mandatory biomass co-firing for coal-fired plants.

The goal is to "reduce dependences on fossil fuels and switch to biofuels made from domestic palm oil."

In order to reduce fossil fuel consumption and increase energy self-sufficiency, as well as to combat poverty and unemployment, Indonesia is working to promote the use of biofuels made from palm oil produced domestically.

The main use of palm oil biofuel is biodiesel for transportation, while bioethanol has not been addressed due to lack of financial support, expensive feedstock, and limited domestic production capacity. The biofuel blending obligation was enacted in 2008 (MEMR Regulation 32/2008) and most recently revised in March 2015 (MEMR Regulation 12/2015).

Biofuel targets have been established for each sector, and a 30% biofuel blend is mandatory for fuels used in power generation.

CCS and CCUS

Several CCUS studies have been conducted and demonstration projects are beginning to emerge. Examples are listed below:

- Gundih CCUS Project (FS implemented, demonstration project from 2021 to 2025): METI, J-Power, JGC, etc. Commercial operation is scheduled around 2025.
- Sukowati: Commercial operation is scheduled around 2030.
- Tangguh CCUS Project (FS implemented): bp, LEMIGAS, ITB, Japan Business Alliance, etc.
- Central Sulawesi Clean Fuel Ammonia Production with CCUS: PAU, ITB, JOGMEC, Mitsubishi Corporation etc.

・The challenges for commercialization include economic feasibility and the development of related laws and ordinances

・Government and ministerial ordinances on CCS and CCUS are being drafted

・Blue hydrogen production using CCS technology is also being studied. Pertamina, Indonesia's state-owned oil company, has said that there is a possibility of marketing blue hydrogen in the future.

Power System

There are issues related to the vulnerability of the power system due to the fact that the power system is separated by islands, such as Sumatra, Java, Kalimantan, and Sulawesi, and that demand is unevenly distributed.

"Status of ETS (Emissions Trading System) and carbon tax"

President Joko Widodo signed a presidential decree called "The Economic Value of Carbon" prior to COP26 (not disclosed). The presidential decree stipulates a payment-for-performance system based on CO_2 reductions, the implementation of a "cap-and-trade" (emissions trading) system domestically and abroad, in which emissions limits (caps) are set and surpluses or shortfalls are traded, and the establishment of a carbon trading market. The full-scale carbon market is expected to be operational around 2025. The government has also provided for the introduction of a carbon tax in October 2021, with coal-fired power plants to be taxed at 30 rupiah (about $2) per kilogram of CO_2-equivalent emissions for pollution levels above the cap, starting in April 2022.

“Status of ETS studies” (ICAP: International Carbon Action Partnership)
In 2017, Indonesia passed the Government Regulation on Environmental and Economic Instruments, which serves as the basis for ETS implementation. The regulation mandates the implementation of an emissions and/or waste permit trading system by 2024 (within 7 years since issuance).
In 2018, in addition to completing the design and governance framework for the MRV system (Measurement, Reporting and Verification: GHG emissions measurement, reporting and verification), Indonesia also completed the emission profiles and marginal abatement cost curves for the power and industrial sectors. The study outlining the emission profiles and marginal abatement cost curves for the power and industrial sectors has also been completed. The MRV guidelines for the power sector were published in mid-2018. This was followed in late 2018 by the launch of an online GHG reporting platform for power generators and a pilot MRV program for power generators in the Java – Madura - Bali grid (covering ~70% of Indonesia's electricity demand). The Ministry of Industry also developed an online GHG emissions reporting system for Indonesian industry. Pilot MRV programs are being implemented in the cement and fertilizer sectors.
Four market-based instrument options were considered in the study completed at the end of 2018: an ETS for the electricity and industrial sectors, energy efficiency certificates for the industrial sector, a cap-and-tax system, and a carbon offset mechanism. Based on this study and stakeholder consultations, an ETS scenario was selected for further development. A Presidential Regulation providing a national framework for carbon pricing instruments, including an ETS, is in the advanced stages, with a decision expected in early 2021.
In March 2021, Indonesia's Minister of Energy and Mineral Resources announced the start of a voluntary emissions trading pilot for the power sector. 80 coal-fired power plants participated, 59 of which are owned by the state-owned power company, PLN. The voluntary program is considered a pilot and focuses on informing stakeholders about the development of a national ETS, ETS compliance procedures, and offsetting mechanisms. The cap for this pilot program is based on carbon emission intensity, with different intensity benchmarks set for three subgroups: generators with a capacity of 100 - 400MW, generators with a capacity of 400MW or more, and generators adjacent to coal mines (with a capacity of 100 - 400MW). The benchmarks are based on the weighted average carbon emission intensity of generators in each participant subgroup in 2019. In addition to their respective emission quotas in the ETS, participants may trade offset credits from renewable energy generation. This voluntary program is to continue until a national ETS is in place, with an annual trading period and review.

“Purchasing Scheme”
In 2006, PLNs were mandated to purchase all renewable energy with a capacity of 1 - 10MW. The purchase price was then set and reviewed, and in 2017, new regulations for renewable energy purchase were published (e.g., MEMR Regulation No. 50/2017).
A benchmark price (Basic Cost of Electricity Supply: Biaya Pokok Penjualan: BPP) is set based on the average cost of electricity generation in each region, and a purchase price below this price is set.
→ Low BPP due to the influence of inexpensive thermal power installed in central regions such as Java, Bali, and Sumatra, which suppresses the purchase price ceiling and reduces the business potential of renewable energy. The purchase price system has not contributed to the promotion of renewable energy.
In March 2020, a partial revision of the purchase regulation was published (MEMR Regulation No. 4/2020).
For renewable energy projects with a capacity of 10MW or less, it was decided to abolish the existing BOOT system and shift to a BOO system.

(No transfer of equipment to PLN is required after the PPA contract term ends)
The procurement method by PLN was changed from the public bidding method to “direct selection” and “direct appointment” allowing PLN to appoint a specific power supplier without going through a bidding process.

“Others”
In November 2018, roof-mounted solar installations can now sell excess electricity to PLN upon application to and approval by PLN (MEMR Regulation No. 49/2018).
While the country's overall electrification rate is 99.5% (2019), some remote islands and rural areas far from towns are forced to use diesel and gasoline generators to generate electricity, and biomass is also widely used. Microgrid projects using renewable energy in these regions would also contribute to the promotion of low-carbonization and decarbonization.

(c) Thailand

Renewable Energy Introduction
DEDE (Department of Alternative Energy Development and Energy) is responsible for implementing energy efficiency improvements in Thailand, formulated the Energy Efficiency Plan (EEP) for 2018 - 2037. The goal is to reduce 30% of energy intensity in 2037 compared to 2010 levels. With the goal of achieving carbon neutral in 2050, DEDE says it is conducting a review of the EEP 2018 - 2037 and may raise the target to as high as 40% or 50%, as energy efficiency issues are becoming more important.

In an interview with the WB (World Bank), the composition of power sources is described: In Thailand, natural gas accounts for a high percentage of power generation, and renewable energy sources are limited. The main power sources are wind power and biofuels. Thailand has a long coastline, so wave power may be an alternative energy source.

According to ADB (Asian Development Bank), Thailand has a lot of land for solar power generation, but wind power resources are unevenly distributed in the north of the country, and it is better to consider the possibility of offshore wind for hydrogen production. ADB is conducting a pre-FS for the introduction of offshore wind power and has obtained the following information:
・With the increasing size and technology of turbines, it is feasible to build large offshore wind power projects in the Thailand Gulf.
・Hydrogen is produced by electrolysis and used in coastal transportation, it can eventually be used for power generation and ships, and can be treated as power source for green hydrogen.
・The Pre-FS was completed and submitted to the Thai government. A proposal was also submitted to EGAT (Electricity Generating Authority of Thailand) for a potential large-scale project. It will take the form of PPP (Public Private Partnership), including wind power construction and the laying of submarine DC cables.

Thermal Power Generation
According to ADB, Thailand has set even more ambitious goals since COP26. The ADB's view was that Thailand should move away from coal and focus on gas-fired power, but should also move away from gas as well.

Hydrogen and Ammonia
The DEDE interview showed that the study of hydrogen utilization has only just begun, with both the industrial sector and cross-sectoral possibilities in mind. Expectations for opinions and proposals from Japan were expressed in the DEDE interview.
The consortium for hydrogen in Thailand was established by PTT (Petroleum Authority of

Thailand), BIG (Bangkok Industrial Gas Company Limited), and PTT Global Center from the Thai side, and Toyota, Osaka Gas, Kansai Electric Power, and others from the Japanese side. According to information from the Embassy of Japan in Thailand, the consortium will implement projects related to the establishment of Carbon Neutral Smart Parks (introduction of renewable energy and offsetting within industrial parks) and the introduction of hydrogen.

According to the WB's view, hydrogen energy is under-recognized in Thailand and with little interest. The development plan is only being managed by PTT, the petroleum corporation.

The following information was obtained from the ADB interview regarding green hydrogen production: Biomass-derived hydrogen is not an ideal option because green hydrogen production requires a large renewable energy supply. Thailand is currently considering exporting electricity to Vietnam due to oversupply of electricity, but the use of transmission in southern China is a challenge, and exporting electricity may be difficult. Therefore, Thailand is considering blue and green hydrogen production in its own country.

Banpu (Banpu Public Company Limited) has formed a partnership with a government agency and is formulating a policy for energy transformation in line with Thai national policy. In order to achieve low carbon emissions in the future, it is necessary to shift from coal to gas and to incorporate co-firing, etc. For this purpose, they are conducting research on hydrogen, ammonia, and CCUS.

CCS and CCUS

CCUS's efforts are described in the Thai government's low-carbon roadmap, and the following information was obtained from Banpu and others:

・Since gas accounts for a large portion of Thailand's energy consumption, transitions are not being pursued as aggressively as in other countries. Currently, the feasibility of introducing CCUS is being studied

・The feasibility of CCUS in Thailand is still under consideration, and the price of electricity will determine the feasibility

・In order to introduce CCUS, it is necessary to establish certification for CO_2 emission reduction, etc. (In Thailand, the introduction of IREC (International Renewable Energy Certificates) is under progress)

・Banpu is promoting research on CCUS for the future

EGAT currently has two pilot projects planned, and PTT is currently studying CCUS in the Thailand Gulf region, according to the report.

Two projects: Thailand's first EOR (Enhanced Oil Recovery) project, and EGR (Enhanced Gas Recovery) project at a power plant with gas resources in the vicinity. Currently, these are being discussed within EGAT, and in the future, evaluation of partner companies and project process are planned to be carried out.

EGAT aims for CCS commercialization by 2045 in order to realize Carbon Neutral by 2050.

Power System

In an interview with the ERC (Energy Regulatory Commission), grid optimization was suggested as one of the areas for future cooperation and the challenges are more in the transmission sector than in the generation sector.

There are regulations that limit the capacity of the RE grid connection to, for example, 8 or 10MW. RE power producers must have spare capacity. In terms of operation, the capacity must be increased or limited in the future. Currently, RE is allowed to connect to the grid without restrictions.

EGAT remarked that one of the necessary item for grid modernization is RE forecasting. Although forecasting models have already been introduced in some regions, more accurate and appropriate models are needed, and EGAT would like to learn from Japan.

ADB remarked that IEA has done a lot of research on grid stabilization and has an IEA/EGAT study report on grid stability (2020 - 2021). Regarding business models for distributed generation, according to the ADB, study is under progress.

Power Market

As a policy maker, ERC places the highest priority on regulatory relations, and the following is a list of information obtained from interviews regarding the ERC's interests and possible cooperation from Japan:

- The outlook for Japan's renewable energy market, its power source mix, requirements for development, and green fees
- How DR works in Japan, how payment methods and incentives are implemented, and how to make DR work
- Regulations for promoting solar, new regulations for EVs, and open access to the grid
  Also, interest of cooperation with the Japanese METI, especially in the area of electric power, is expressed
- Request the dispatch of a regulatory official
  Regulations for open access are currently unsatisfactory and need to be adjusted. The dispatched experts are with high expectations.
- Japanese experience with grid liberalization and open access
  Regulations regarding open access so that VRE generation can access the grid
  Some countries allow consumers to choose their power sources, but Thailand does not have such a system.

During the EGAT interview, Japan's DR and VPP initiatives were also of the interest:

- EGAT management has requested a draft model and would like to learn about the Japanese experience in preparation for implementation. In addition to technical issues, they also shows interest in information on regulations and market models, plus customer profitability and financial support models.
- Successful models do not yet exist to promote investment and consumer participation in VPP platforms due to regulatory and profitability challenges.

During the meeting and exchange of opinions with the ERC, the following information was obtained regarding future initiatives for the electricity market:

- In FY2021, the focus was on the TPA (Third Party Access) framework, which was completed to public comment stage. Since operators require TPA rules and grid rules, these were the main topics. The next five-year plan will address improvements to the TPA and grid rules. Further disruptive technologies are, for example, DR, solar systems, EVs, and RE. Ultimately, the plan is to build a microgrid system.
- Another initiative is the 10-year "Market Plan," which has already been announced. In addition, the "EC Electricity Market" has been launched as a demonstration project.

The following is a summary of the efforts and future directions obtained from the WB interviews regarding the Thai electricity market:

- Thailand's domestic market has a voluntary emission reduction scheme, but it remains to be seen whether this will evolve into an international ETS trading framework. WB would like to see a climate change law enacted in Thailand. The Ministry of Finance is then expected to budget for financial resources from carbon pricing.

- Thailand is working on ETS using PMR (Partnership for Market Readiness) provided by WB, and the Ministry of Energy is even trying to certify energy performance. Other sectors besides energy, such as low-carbon cities, are also being promoted.
- The Thai government is self-financing the East Energy Corridor ETS pilot project, and the Partnership for PMI (Market Implementation), the next phase of the support program, could also be utilized.

(d) Morocco

Renewable Energy Introduction

In its NDC submitted in June 2021, Morocco indicated its goal of having at least 52% of its electricity production capacity from renewable energy sources by 2030, with 2010 as the base year. This includes 20% from solar energy, 20% from wind energy, and 12% from hydropower energy.

Renewable energy, excluding hydropower, increased at an average annual rate of 18% over the five-year period from 2013 to 2018, accounting for 17% of the electricity supply in 2018. At the time of the interview with ONEE (Office National de l'Electricité et de l'Eau Potable: Moroccan National Electricity and Water Authority) in April 2022, the energy mix of solar, wind, and hydroelectricity has achieved approximately 40%.

Morocco is moving forward with plans to build 10.1GW of power sources with an investment of approximately $40 billion between 2016 and 2030, aiming for 3.16GW from solar and 3.16GW from wind. It also has a policy to achieve green hydrogen generation through VRE with a long-term goal of 20 years.

The government has introduced a system to provide financial support for the development of renewable power sources by establishing an energy development fund with a contribution of $1 billion from government source. It also plans to introduce preferential measures for access to the power grid and export licenses for the export of electricity from renewable sources.

A clean energy park has been established in Oujda to attract a wide range of renewable energy-related investments by providing land and introducing tax incentives.

According to MASEN (Moroccan Agency for Sustainable Energy), energy production is being promoted to add value to the country's overall economy with the aim of creating jobs and increasing the domestic production rate. In the case of wind power generation, 60% of wind turbine components are produced domestically, and efforts are being made to produce wind turbine shafts domestically as much as possible. The blade manufacturing plant is also located domestically. In the case of solar power generation, on the other hand, Chinese-made panels are so competitive that only 30% of the components are produced domestically. The private and public sectors are working together to increase added value.

MASEN also believes that unstable energy supply (intermittency) is a challenge in promoting renewable energy. Since the current infrastructure is based on a stable electricity supply, a nationwide network must be developed for unstable and uncontrollable energy. As one method, they believe that energy production can be stabilized by converting it into heat energy with CSP (Concentrate Solar Power).

Solar photovoltaic and solar thermal power generation has high potential throughout the country due to the availability of moderate to high levels of sunlight, but there are many locations in the northwestern Atlas Mountains, where population and industry are concentrated, which prevent from taking advantage of this potential. The southwestern Atlas Mountains are dominated by sand, gravel and desert areas, making it difficult to install power transmission lines and thus preventing large-scale development.

Wind power generation is limited to areas with good wind conditions, such as the southern part of the country, near the border with Western Sahara. The northwestern Atlas Mountains, where the cities are located, have generally poor wind conditions and little potential for onshore wind power.

For offshore wind power, there are areas with good wind conditions near the Strait of Gibraltar and off southern Essaouira, but development near the Strait of Gibraltar is seen as difficult due to heavy shipping traffic, and development off southern Essaouira will require the reinforcement of power transmission lines.

As for hydropower, its relative share of electricity supply is declining. The amount of precipitation is on a downward trend, and the water resource endowment is decreasing. Furthermore, the water supply capacity is also decreasing due to sedimentation in dam, one of the main water resources. Therefore, increasing and restoring the water resource endowment and the water supply capacity of dams are important issues. On the other hand, there is a significant need for pumped storage power generation.

The following information on other donors' efforts to develop renewable energy in Morocco was obtained through interviews:

・GIZ (Deutshe Geselleschaft fuur Internationale Zusammenarbeit: German International Cooperation) worked with MASEN to conduct an analysis for energy planning. The German Aerospace Center also conducted a study on the economically feasible energy mix in Morocco and developed 18 feasible scenarios. The need for energy backup was also addressed.

・One of the projects funded by the WB (World Bank) is the "Noor Solar Power Project" led by MASEN. The project covers two solar power plants with a total capacity of 500MW. Currently, one of the two sites is not in operation due to undisclosed problems, but the other site is in normal operation and supplying power. This project is being implemented jointly with the AfDB (African Development Bank) and the EIB (European Investment Bank).

・Another is the “Noor - Midelt Solar Power Project”, which uses both PV and CSP to reduce costs, and is supplying power without problems.

・A 120MW PV generation improvement project that ONEE is leading is also funded by WB . The project will install systems and smart meters that can distribute electricity to larger customers.

Thermal Power Generation

Coal-fired power accounts for 60% of the major power sources, and the introduction of ammonia co-firing and combined gas cycle is necessary to decarbonize coal-fired power. The NDC calls for the addition of 450MW of combined cycle power generation capacity from imported natural gas by 2030.

Although natural gas has been declining as a percentage of overall electricity supply, the policy is to switch from coal-fired to gas-fired power. The challenge is to develop pipelines and other supply infrastructure.

As for power generation efficiency, the average for natural gas is over 50%, and the average for coal is just under 40%. Since many of the power generation facilities are relatively new, there is not much room for improvement in CO_2 intensity through further improvement of power generation efficiency. Therefore, in order to lower CO_2 emissions from electricity, coal-fired power generation needs to be replaced with lower-carbon power sources. The policy is to replace coal-fired thermal power with gas-fired thermal power as a medium-term goal for the next 10 years.

A large portion of the fossil fuel supply is dependent on imports, especially for petroleum, which accounts for about 60% of the primary energy supply. The use of natural gas is on the decline, with a self-sufficiency rate of less than 10%.

From a low-carbon perspective, the policy is to strengthen natural gas supply capacity in the 5-year short-term target, and to gradually replace natural gas use with hydrogen in the 20-year long-term target.

WB believes that gas-fired power is necessary in Morocco to provide a stable electricity supply over a wide area. Although there are some price issues, the transition to gas-fired power generation will continue, and the use of hydrogen or ammonia needs to be realized as quickly as possible.

Construction and Operation of Coal-fired Power Plants

Even at the time of mass RE introduction, low-cost coal-fired power plants are important for stable electricity supply, as they are responsible for about 70% of energy consumption as base load. However, last year, ONEE reported that Morocco made an important decision not to build new coal-fired power plants.

The following information on other donors' policies and initiatives for coal-fired power was obtained through interviews:

・GIZ does not provide assistance related to the low-carbonization or decommissioning of existing coal-fired power plants, but believes that this will be necessary in the near future. Currently, the Moroccan government is discussing the establishment of guidelines for the low-/decarbonization of coal-fired power plants. GIZ will provide assistance related to coal-fired power plants in line with the Moroccan government's energy mix plan, and believes that the best balance between coal-fired power, natural gas, and renewable energy must be found.

・AfDB has not provided assistance related to coal-fired power plants since 2011. It states that it can provide support for low-/decarbonization in these areas if requested by the government, but this is not currently being carried out.

Hydrogen and Ammonia

Green hydrogen is attracting attention as an energy source to reinforce self-sufficiency from renewable energy sources or as an export energy for Europe. A hydrogen roadmap has been established for 2019, and an interagency Hydrogen Committee has been set up. Cooperation with Europe is also underway.

- Signed cooperation with Germany on the development and use of green hydrogen in June 2020
  According to the statement, at the moment, MASEN will promote the establishment of a research platform on green hydrogen production projects and Power-to-X proposed by MASEN
- Signed cooperation on green hydrogen with Portugal in February 2021

The long-term policy for 10 - 20 years is green hydrogen production by VRE and gradual replacement of natural gas by hydrogen.

The long-term power purchase agreement with IPP does not include requirements for low-/decarbonization, such as ammonia co-firing and output limits, and it is difficult to make new requirements now. ONEE's view was that it would be necessary to renegotiate in order to have them make low carbon commitments.

In the interview with ONEE, there was a suggestion to hold workshops on the use of hydrogen and ammonia in thermal power plants, such as ammonia co-firing, to share the experiences of Japan and other countries, so that both the private sector and ONEE can come up with satisfying answers.

Hydrogen Production

During the MASEN interview, the following information was obtained regarding challenges in green hydrogen production in Morocco, export policy, and future price competitiveness:

"Technical and financial challenges in green hydrogen production"

① The challenge is that historical data does not exist on the amount of hydrogen produced. For example, no data exists on how much hydrogen a water electrolyzer facility has produced in the past 10 years and over. With several hundred MW of water electrolyzers scheduled to produce hydrogen in the future, the absence of such data is an issue when considering the risks of the project. In addition, it has not been assumed that hydrogen will be produced using highly intermittent renewable electricity. For equipment manufacturers, it is assumed that stable electricity will be used to produce hydrogen, and to date, they have not manufactured machines that are designed to use unstable electricity.

② From an economic perspective, the challenge is to secure a long-term market. To make the business profitable over the 20-year operating period of production facilities, long-term hydrogen sales contracts will need to be concluded (including consideration of competition between green and gray hydrogen and taxation systems such as carbon taxes). The energy supply to produce hydrogen also needs to be procured on a long-term basis.

③ From an investment perspective, the attractiveness of green energy production (green hydrogen) to investors may still be lacking. There is no active movement by the private sector to produce and export green hydrogen in Morocco. Since there are limits to investment by public institutions, it is necessary to attract investment by the private sector.

④ There are also challenges in terms of energy storage and transportation. A candidate application for green hydrogen in Morocco is the production of green fertilizer with green ammonia, which is produced and consumed domestically, so there are no transportation or storage issues. However, looking at the global market, there is no desire to incur costs for green fertilizers. Exporting green hydrogen itself requires transportation infrastructure, but existing gas pipelines cannot be used, and transporting hydrogen carriers such as ammonia and methanol by ship are also costly. Another issue is how to store the hydrogen produced, as Morocco has limited underground storage capacity. Southern Morocco will be the source of green hydrogen, but the infrastructure to utilize the southern part of the country is not yet in place.

"Securing water resources for green hydrogen production"

In general, water resources are to be secured by desalinating seawater. Water itself is quite scarce in Morocco (both for daily life and for agriculture). In Agadir, the largest desalination plant in Africa is under construction.

Since desalination consumes a large amount of electricity, increasing desalination facilities will increase renewable energy (solar and wind). Desalination facilities to produce green energy will be new facilities, not existing ones.

"Green Hydrogen and Green Ammonia Export Policy"

First, it is believed that Europe will be an important customer (due to its economic exchange and proximity). Europe is the most advanced in decarbonization based on particular specific figures (EU Hydrogen Strategy, targeting 40GW of renewable hydrogen water electrolyzers by 2030). Germany in particular is moving toward green energy, and the Russian invasion of Ukraine may has, in some respects, accelerated the move toward green energy. German Reconstruction Finance Corporation KfW is funding a study on the technical and economic aspects of importing green hydrogen from Morocco. （This is part of a move to produce hydrogen in Morocco using a water electrolysis plant equivalent to 100 MW, which Germany will then import）

Since free trade is possible with the U.S., green hydrogen exports are being of the interest. Morocco is currently constructing a port called Darrah Atlantica for exports to the U.S. and Asia (Korea and Japan).

Japan has announced its hydrogen and green energy promoting, and Morocco is interested in cooperation and believed that JICA share the same mindset. The port construction project has been approved and the construction has begun.

"Green Hydrogen Price Competitiveness Outlook"

It is believed that 80% of the cost for hydrogen production will be the green electricity. Some places in Morocco have solar and wind power meshed together to achieve an operating rate of 70% or more, Morocco can produce green hydrogen at a good price, along with Chile and Australia. In the future, Morocco's green hydrogen may be competitive in the countries that imports carbon tax. The effect of infrastructure investment capital to the price of hydrogen is being studies.

IRESEN (Institut de Recherche en Énergie Solaire et Énergies Nouvelles: Institute for Research on

Solar Energy and New Energies) provided the following information on its green hydrogen strategy, production challenges, and efforts with the German Ministry of Economy, Trade and Industry:
“Integrated national green hydrogen strategy in 8 actions”
① Cost reduction along the entire value chain
② Creation of a Moroccan and regional research and innovation pole
③ Implementation of measures to ensure local content
④ Establishment of an industrial cluster and development of a master plan for the corresponding infrastructure
⑤ Financing the development of the hydrogen industry
⑥ Creation of favorable conditions for the export of green molecules
⑦ Development of a storage plan
⑧ Development of the domestic markets

“Development Plan for Green Hydrogen Production”
Green Hydrogen Cluster: promote development through domestical and international support and competition for related projects
Green Hydrogen Plan: Expand water electrolyzers to 8GW by 2030, 40GW from 2030 to 2040, and 80GW from 2040 to 2050

“Green Hydrogen Production Challenges”
First, the challenge is to improve efficiency by combining various REs. In other words, by combining electrolysis, ammonia, and other hydrogen energies, the water electrolysis system need to first achieve MW-scale and then gradually to GW-scale. The stable efficiency on a small scale must be prioritized, and then expand to GW-scale.
Second is the water supply, which, in general, is to use desalinated seawater. Research has shown that the cost of desalination is as small as 0.1 - 0.2% of the cost of hydrogen production, and it is believed that the production capacity can be doubled or tripled. Increasing the production capacity will also enable the supply of drinking water and agricultural water to the region, thus achieve multiple targets.
The third point is to develop hydrogen production facilities, which is both a challenge and an opportunity.
There are opportunities to revitalize the local economy, for example, by building desalination facilities.
Since the production of hydrogen energy requires various facilities and component manufacturing (e.g. desalination and electrolysis facilities), successfully industrializing these facilities can contribute to the region.
There were concerns that the use of unstable RE to power the hydrogen electrolysis plant would disrupt production, but the green hydrogen production model is an independent model that does not require an existing power network, since wind and solar power can be installed in the vicinity of the plant to promote industrialization.

“Green Hydrogen Development Investment Project with German Ministry of Economy, Trade and Industry”
There are three projects underway in parallel, contracted with Germany in 2020:
- A pilot project for green hydrogen and other projects. These include green ammonia, methane, and synthetic kerosene projects, and are installations of several MW of water electrolyzers
- A study in collaboration with MASEN, with 40 - 50GW of water electrolyzers
- Legal support

Apart from these, there is also a green ammonia project with a 50 - 100MW water electrolysis system, and studies are underway to expand the scale of the project.

As for other donors' efforts in the hydrogen sector, the following information was obtained through interviews with GIZ and WB:

GIZ plans to conduct R&D projects in the near future for the production, export, regional development, and industrial use of green hydrogen, but the feasibility of such projects in terms of Morocco's economic development is challenging

- As for Japanese technology, investment, and JICA support for hydrogen sector, since hydrogen development is still in early stage all over the world, so there are high expectations from both Europe and Morocco. At this stage, we need to focus on technology development and market development. The presence of strategic investors is important, but it is also important to develop the market quickly and to find the catalyst factor.
- The Moroccan government has been unable to invest large sums of money from state funds in the hydrogen sector due in part to the impact of the new coronavirus. Currently, regulations and rules are about to be initiated to attract investment from the private sector.
- GIZ provides technical assistance to government agencies and stakeholders in the hydrogen sector. There is still room for assistance in terms of technical support and market promotion support by strategic investors and off-takers.
- Regarding the support to the Moroccan government for the development of a hydrogen strategy and roadmap, GIZ had provided support for the development of a hydrogen strategy before diplomatic relations deteriorated. After that, the stakeholders formulated their own hydrogen strategy. Therefore, it can be said that GIZ provided support only in the initial stage.

CCS and CCUS

IRESEN's view is that CCS/CCUS and green hydrogen transportation methods are important in Morocco, although they have not yet received attention.

International Interconnection

Morocco and Spain are connected by two systems with a transmission capacity of 700 MW, and a third system is under consideration for direct connection with Spain and Portugal.

ONEE believes that the grid interconnection has helped maintain grid stability on the Moroccan side, rather than being affected by the increasing adoption of RE in Europe.

The following information on the interconnection with the European power grid and its challenges was obtained from an interview with the GIZ:

Morocco and Germany have an energy partnership, but the interconnection of power grids involves political decisions. A roadmap for energy transport is also needed. Efforts with Spain are the most advanced stage in this matter. Morocco used to import electricity from Spain, but has been exporting since Morocco began using a new coal-fired power plant last year. However, now that Algeria has stopped exporting natural gas to Morocco, Morocco may resume energy imports from Spain.
Xlinks (UK) has initiated a project to install PV and wind power in southern Morocco and transmit 10GW of PV and WT power to the UK via submarine cable, and is currently in the process of signing MoUs and collecting investments. The project envisages only the export of electricity and does not envisage consumption within Morocco.
(Reference: Xlinks, “Morocco- UK Power Project” https://xlinks.co/morocco-uk-power-project/)

Grid Stability

The following ONEE opinions were confirmed through interviews regarding the impact and measures to be taken if RE generation exceeds electricity demand:

In general, green hydrogen production and concentrated solar thermal power plants can store electricity; wind power can be shut down, and hydro power plants can be operated only during peak hours. MASEN's concentrated solar thermal generation has a 7-hour storage capacity. To date, RE generation has not exceeded electricity demand.

*Thermal energy storage with MASEN's CSP

Peak power use from 5:00PM to 10:00PM, during which, solar energy is used to supply power.
3 CSP sites were constructed:

- Noor 1 (parabolic trough, 160 MW, 3-hour storage capacity, operational since 2016)
- Noor 2 (200 MW, 7-hour storage capacity, operational since 2018)
- Noor 3 (solar tower, 150 MW, 7-hour storage capacity, operational since 2018)

The ultra-high voltage system (400 kV and 225 kV) allows power generators to sell power to ONEE. A regulation has been passed to further expand the system to medium-voltage systems, it is being addressed so that there is no reverse flow to the high-voltage side through substation facilities.

Regarding the issue of future grid inertia shortage and countermeasures, the percentage of RE will increase, but it is assumed that there will be no problem because thermal power IPP contracts will continue and thermal generation will continue to operate, including a new thermal power plant in 2018, which will remain in operation until 2045.

Meanwhile, according to GIZ, it is in the process of discussing with ONEE the grid stabilization associated with the mass introduction of renewable energy, which is scheduled to be completed in December 2023. In addition, GIZ is conducting a grid stabilization demonstration project for V2G in Casablanca. WB is also providing support for integration with renewable energy, grid codes, and technical evaluation of wind power plants.

With regard to energy storage, pumped storage can be considered. According to WB, one pumped storage plant was built in Morocco in 2005, and another is currently under construction. Much interests are shown for this discussion, and plans including the use of hydrogen are beginning to be considered.

The scenario forecast conducted by the WB clearly shows that the demand for energy storage will increase rapidly, especially after 2040.

(iii) Advantages and Strengths of Japanese Companies

Table 127 Advantages, strengths and issues of Japanese companies

Advantages and Strengths of Japanese Companies	Current Issues	Others (Future Measures, Business Model etc.)
【Thermal Power Generation】 ・Japan has the top-notched technology on ammonia co-firing such as stable combustion of 70% liquid ammonia in 2 MW-class gas turbine. ・Japan has achieved the world highest efficiency as 170 MW demonstration plant of CO_2 capture type oxygen-blown coal gasification combined cycle power generation.	・Various pilot plants are operated all over the world regarding ammonia and hydrogen co-firing and mono-firing, and the technical R&D is under severe competition. Japan is not in absolutely advantageous situation. ・It is substantially impossible for Japan to provide international cooperation for development of new coal-fired thermal plants.	・It is anticipated that comprehensive plant operation technology will be required, including value chain of ammonia and hydrogen, rather than independent technologies of co-firing.
【Battery Storage】 ・Japan's advantage is the high quality (safety and energy intensity). ・Redox flow battery is a large facility and thus is suitable for wide space. Its advantages include long life and non-combustibility. ・NAS battery is suitable for large-scale operations in MWh level. It is well applicable for energy shift and is also expected for multiple use utilizing its large capacity.	・High cost and small production capacity are Japan's weakness. Lack of the market in Japan is another weakness. ・Regarding the price of battery itself, Japan cannot compete with China and Korea. ・It is hard for manufacturers to set up the facility and connect with power system in foreign country. ・NAS battery assume 6 hours operation for MW capacity; therefore, its usage is limited.	・Japanese battery for grid use lacks price competitiveness. Therefore, it is necessary to propose control system with battery storage that fits with the needs of each country's power grid system. Comprehensive technology will be a key.

Advantages and Strengths of Japanese Companies	Current Issues	Others (Future Measures, Business Model etc.)
【Pumped Storage (Hydro) Power Plant (PSPP)】 ・Japan, having many actual plants of conventional and variable speed pumped storage power plants, has abundant knowledge and experience of planning, site selection, construction and operation. ・Japan has abundant operation redord and have high reliability. ・With abundant operation record, Japan is skilled with efficient operation technology.	・Japan is week at cost competition. ・PSPP requires huge initial cost and has limited site, different from battery storage. PSPP requires long time period from planning, site selection, and construction through commencement of operation. ・Because of large capacity, advanced operation technology is required to fully utilize the merit of PSPP. ・Planning of PSPP requires consideration and examination of grid scale, meteorology, geography, combination of power sources, demand, load, load factor and so on.	・Not as construction of PSPP, it would be necessary to propose a comprehensive project including planning, site selection, and efficient operation technology.
【Low Loss High Capacity Conductors 】 ・Compared with conventional T/L, Low Loss T/L can reduce loss reduction by 20-25%. ・Since it is Japan's original technology, Japan has advantage of production and supply performance	・Since the low loss T/L is more expensive than conventional T/L, it needs to be used for long distant and huge power flow to satisfy economy. The usage will be limited.	・It seems realistic to propose the use of low loss T/L combining power development plan based on power system master plan and power development play.

The advantages of Japanese companies are safety and high quality of the products and efficient operation technology backed with abundant experience. On the other hand, equipment itself tends to be over specification against the needs of the country. Japanese products may suffer from price competition against Chinese and Korean companies. Therefore, not only installation of equipment and construction of the plant, but also proposal of minute control system and supply of operational technology, as well as long-term competitiveness considering life-cycle assessment, needs to be provided, which will be Japan's strengths.

（２） Transport

(i) Trends in the development and social implementation of technologies and services worldwide

In 2019, energy-derived CO_2 emissions from the global transport sector were 8,222 million ton-CO_2, with road transport accounting for 74% (6,049 million ton-CO_2) of the whole, as shown in the figure below.

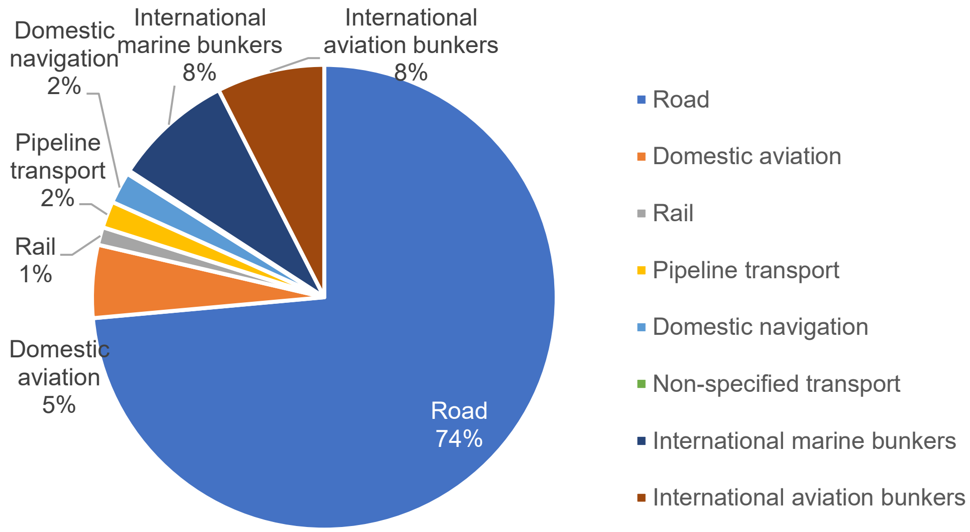

Figure 201 Share of CO2 Emissions by Mode in Transport Sector (2019)

Source: IEA, CO2 emission from fuel combustion 2021

The figure below shows the shares of consumption by energy in the global transport sector in 2019. More than 90% of final energy consumption in the transport sector is accounted for by fossil fuels, with gasoline and diesel being the main sources. Air, road, rail, and marine transportation, which are the four main modes of transportation accounting for 12%, 74%, 2%, and 9.4%, respectively, indicating that road transportation (automobiles) represents by far the largest share. Of transportation, all final energy consumption in aviation and shipping is provided by petroleum (jet fuel, diesel, and fuel oil), and more than 90% of the final energy consumption in automobiles also comes from petroleum (gasoline, diesel, and LPG). In rail transportation, electricity accounts for 42% of the total, but diesel for the remaining 57%. Similarly, in pipeline transportation, natural gas accounts for 95% of the total. Therefore, the share of fossil fuels is high across all modes of transportation. Therefore, in order to achieve low or zero carbon in the transport sector, it is important to reduce the consumption of fossil fuels, especially oil. Note that use of renewable energy accounts for 4% in road transportation, such energy refers to biofuels such as bio-gasoline and bio-diesel.

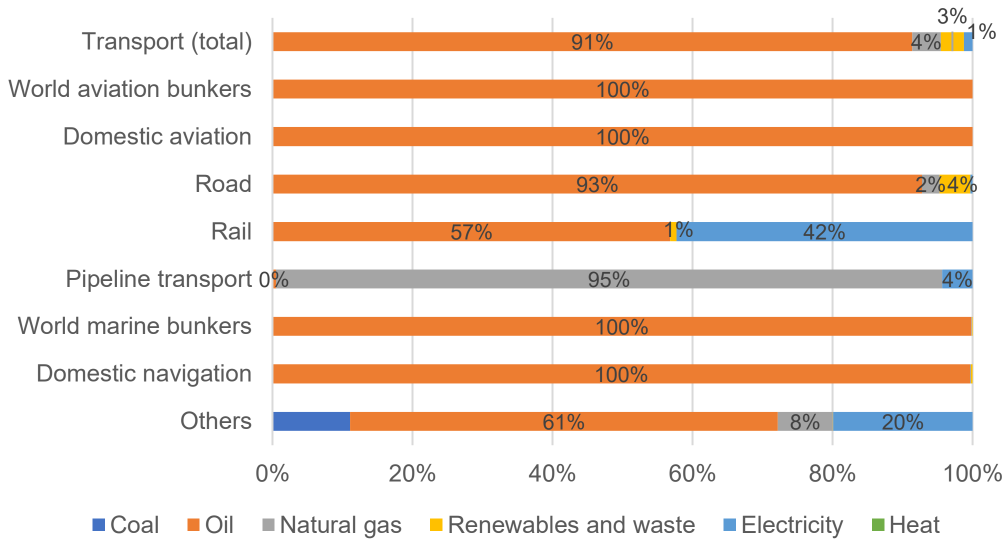

Figure 202 Final Energy Consumption by Transport Mode in Transport Sector (2019)
Source: IEA, World Energy Balances 2021

In the transport sector, fluid energy, as represented by oil, has been considered particularly suitable for transportation because of its high energy density and ease of control. As the global demand for transportation continues to grow, the first energy-saving measure for means of transportation has been to improve the energy consumption efficiency of the means of transportation themselves. Efforts are also underway to incorporate rail and marine transportation into the current automobile-dominated transportation system to save energy in the transportation system as a whole. In addition to these efforts, the development of alternatives to transportation fuels themselves, i.e., battery-powered electric vehicles and sustainable biofuels, is gaining momentum in order to further reduce the demand for oil in the transport sectors. While new technologies are being commercialized and spread mainly in private cars and some public transit systems, progress is also being made in developing low-carbon technologies for long-distance transportation systems such as aviation and marine transportation, where fuel substitution has traditionally been considered difficult due to many technical and economic challenges.

(a) Electric vehicles

Electric vehicles include battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and fuel cell electric vehicles (FCEV).

According to the IEA, the global electric vehicle fleet reached 10 million units in 2020. This is a 43% increase over 2019 and represents about 1% of the total number of vehicles owned[470]. As shown in the figure below, the increase is particularly significant in China, where the number of electric vehicles owned reached 4.5 million in 2020, while the largest annual increase was in Europe, where the number of vehicles owned reached 3.2 million.

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[470] IEA (2021) "Global EV Outlook 2021", p.19.

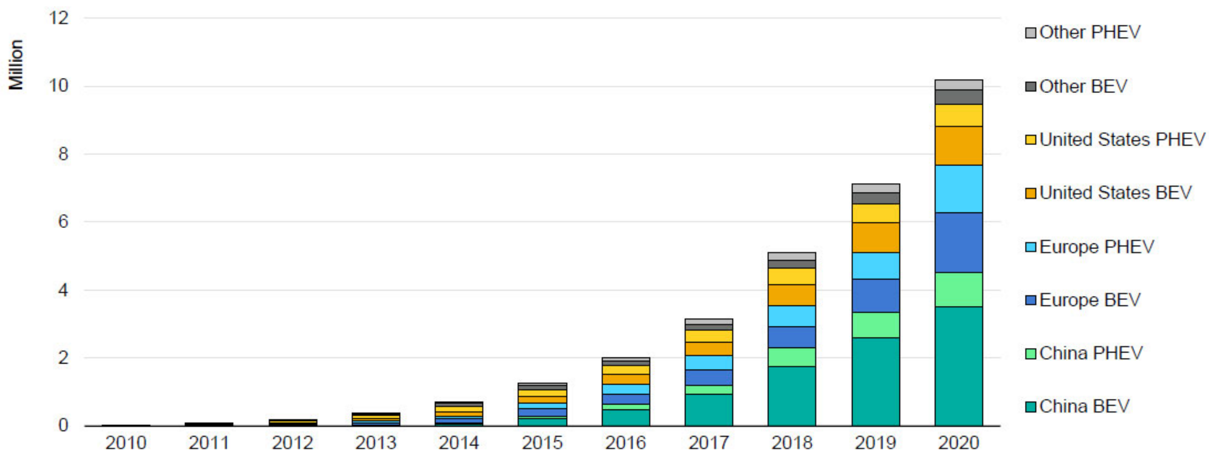

Figure 203 Trend in the Number of Electric Vehicle Stock in the world (2010-2020)
Source: IEA, Global EV Outlook 2021

Although electric vehicles account for only a small percentage of the number of vehicles sold and owned as of 2020, the IEA's sustainable development scenario anticipates that all electric vehicle-related targets will be met. The scenario assumes that the EV30@30 initiative, which sets a goal to reach 30% sales share among new passenger cars, buses, and trucks for electric vehicles by 2030, will be exceeded (reaching about 35% worldwide). In addition, the published policy scenario assumes that the global electric vehicle fleet will expand to 145 million vehicles in 2030. As the market is expected to expand further in the future, on-board storage batteries and fuel cells are key technologies for the popularization of electric vehicles.

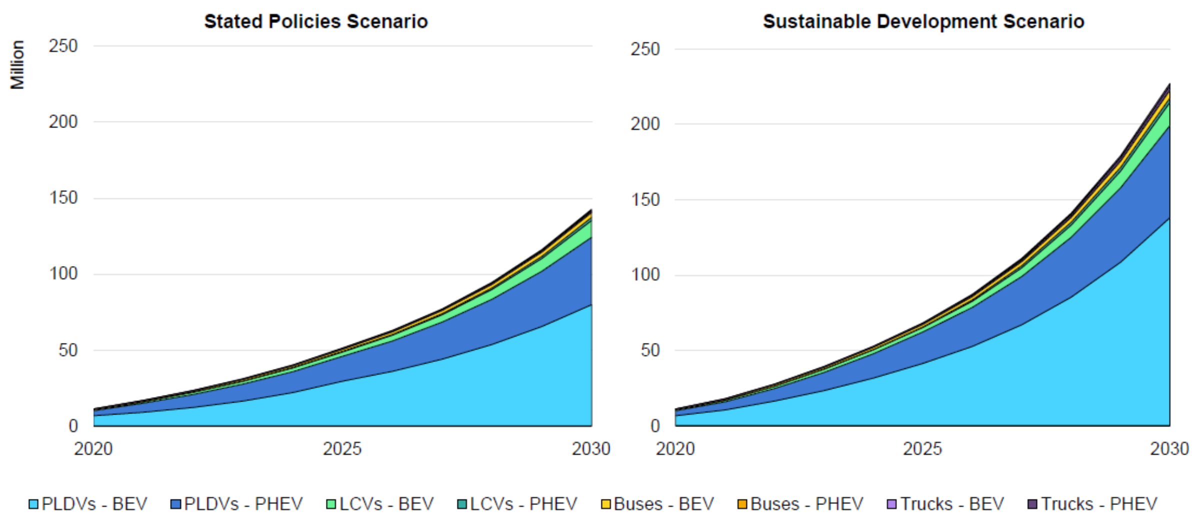

Figure 204 Outlook for Global Electric Vehicle Stock (2020-2030)
Source: IEA, Global EV Outlook 2021

[On-board Storage Batteries]

First, the technical requirements for automotive storage batteries include high energy density, short charging time, small effect of temperature change on charge-discharge characteristics, long life, low cost, and high safety assurance[471].

Currently, on-board storage batteries in widespread use worldwide are lithium-ion batteries (liquid LiBs) using organic liquid electrolytes, and the weight energy density of a battery pack is estimated to

[471] Mizuho Information & Research Institute, “Mizuho Jyoho Soken Report” vol.18(2019) 、pp.2-4.

be around 200 Wh/kg. Liquid LiBs are said to be a technological area that will be centered on private companies' (automobile, electrical equipment, storage battery, material manufacturers, etc.) R&D intended to customize their own products based on their business strategies, while research and development of lithium-ion batteries using inorganic solid electrolytes (all-solid-state LiBs) is said to be a technological area that requires cooperation and collaboration between industry, academia, and government[472]. In Japan, the commercialization of the first-generation all-solid-state LiB (sulfide-based) with improved specific energy of 300 Wh/kg is targeted for around 2025 (target specifications for a BEV with 40 kWh battery capacity: 600,000 yen for battery pack cost, 400 km cruising range, and 10-year battery pack calendar life), and that of a next-generation all-solid-state LiB (sulfide or oxide-based with high ionic conductivity) with further improved specific energy of 400 Wh/kg is targeted for around 2030 (target specifications for a BEV with 40 kWh battery capacity: 400,000 yen for battery pack cost, 500 km cruising range, and 15-year battery pack calendar life).

The period from 2010 to 2020 was a time of improved energy density and lifetime of LiBs and greatly reduced cost, and it is expected that LiBs will continue to be the technology of choice from 2020 to 2030, and that the three key elements of LiBs - cathode, anode, and electrolyte - will continue to be improved to enhance LiB energy storage performance. In its Global EV Outlook 2018, the IEA organized the timeline for the commercialization of energy storage technologies as shown in the figure below. Next-generation LiBs coming to market within the next 5-10 years will likely use either a nickel cobalt aluminum oxide (NCA) cathode or a nickel manganese cobalt (NMC) 811 cathode, with improved binders and electrolytes that will also allow for increased silicon content in the anodes. These improvements will increase energy density.

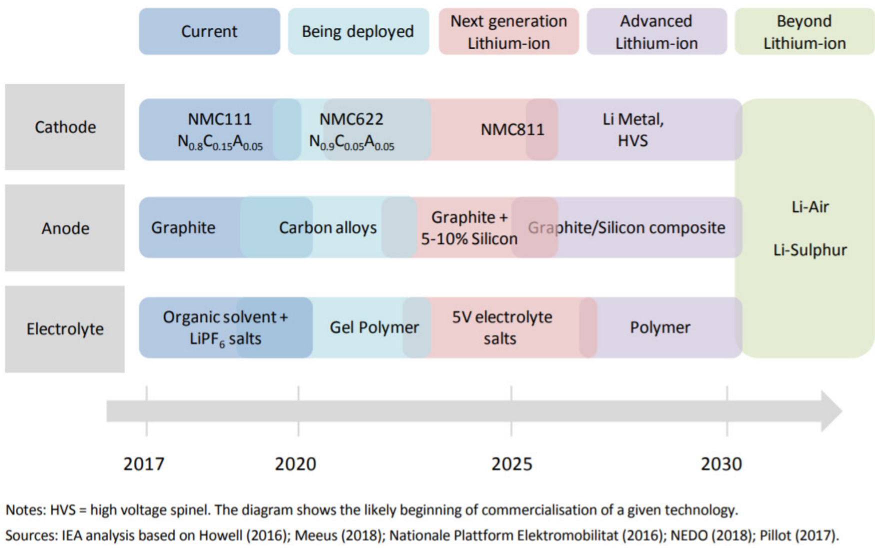

Figure 205 Timeline for Commercialization of Battery Technologies

Source：IEA, Global EV Outlook 2018

One of the most promising advanced concepts for technology beyond 2030 is the lithium metal solid state battery[473]. This technology is said to achieve specific energy of 400-500 Wh/kg. Prototypes have already been tested, and Toyota plans to incorporate the technology into actual products in the early 2020s. Toyota also announced the application of all-solid-state batteries to HEVs[474]. Nissan has also announced that it aims to bring to market electric vehicles powered by all-solid-state batteries

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472 NEDO, https://www.nedo.go.jp/content/100881230.pdf.

473 IEA (2020) "Global EV Outlook 2020", p.188.

474 Toyota Mortor Corporation, 7 September 2021, https://global.toyota/jp/newsroom/corporate/35971587.html.

developed in-house by fiscal 2028[475]. Commercialization of lithium metal solid-state batteries is expected around 2025-2035.

Note that technologies such as lithium-sulfur batteries, multivalent ion batteries, and metal-air batteries are considered to be in the early prototype stage or even earlier[476].

[Fuel Cells]

In fuel cell vehicles, the device generates electricity through a chemical reaction between hydrogen and oxygen. The element of a fuel cell is called a cell, which structurally consists of a positive electrode plate (air electrode) and a negative electrode plate (fuel electrode) that sandwich a solid polymer membrane (electrolyte membrane) in between[477]. A connected group of cells is called a fuel cell stack. The electricity generated by a fuel cell stack can also be used as an external power supply during power outages, etc.[478], and there is also an example of a demonstration project for supplying electricity from FCEVs to detached houses (Kitakyushu City)[479].

Global numbers of fuel cell vehicles sold and owned, including passenger cars, buses, and trucks, in 2019 totaled 12,350 and 25,210 units, respectively, nearly doubling the previous year (global numbers of vehicles sold and owned in 2018 totaled 5,800 and 12,950 units, respectively). However, they are very small in scale compared to battery electric vehicles and plug-in hybrids. Passenger cars account for the majority of fuel cell vehicles sold and owned, with Toyota MIRAI, Hyundai Nexo, and Honda Clarity FUEL CELL accounting for the majority of market share. FCEVs in Japan, the U.S., and South Korea are almost exclusively passenger cars, and in Europe, approximately 95% of the entire FCEV fleet is passenger cars, while buses and trucks (light and heavy) are also used, though to a small extent. While the U.S. accounts for the largest share of the world's FCEV fleet, China's rapid expansion of fuel cell buses and commercial vehicles has led to an increase in the number of FCEVs owned in the country. China is characterized by the fact that fuel cell buses account for about 70% of the FCEV fleet, cargo vehicles for most of the remainder, and passenger cars account for only about 1% of the fleet. [480]

Japan is actively engaged in research and development of stationary and on-board fuel cells, and a revised Strategic Roadmap for Hydrogen and Fuel Cells was formulated in March 2019. This revision is based on the December 2017 Basic Hydrogen Strategy, the July 2018 Fifth Basic Energy Plan, and the October 2018 Tokyo Declaration, and is the second since the first roadmap was formulated in 2014. The roadmap calls for the popularization of fuel cell vehicles at around 400,000 units by 2020, around 200,000 units by 2025, and around 800,000 units by 2030, and aims to reduce the cost of a fuel cell system (currently about 20,000 yen/kW) to 8,000 yen/kW by 2020, 5,000 yen/kW by 2025, and 4,000 yen/kW by 2030. According to the IEA, the number of fuel cell vehicles owned in Japan was 4,100 (in 2020)[481].

In addition, the "Green Growth Strategy Through Achieving Carbon Neutrality in 2050," formulated in December 2020, referred, in relation to automobiles, to the study of demonstration and introduction support measures to accelerate the spread of fuel cells for commercial vehicles, especially the commercialization of fuel cell trucks[482]. In June 2021, a revised Green Growth Strategy with more concrete content was formulated, and it is also pointed out in the strategy that regulatory reforms, including the unification of related regulations under the Road Trucking Vehicle Act and the High

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475 Nissan Mortor Corporation, 29 November 2021, https://global.nissannews.com/ja-JP/releases/211129-00-j.

476 IEA (2020) “Energy Technology Perspectives 2020”, p.158.

477 Fuel Cell Commercialization Conference of Japan, http://fccj.jp/jp/aboutfuelcell.html.

478 METI, 17 May 2018, https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo_denchi_fukyu/pdf/006_05_00.pdf.

479 City of Kitakyushu, https://www.city.kitakyushu.lg.jp/kankyou/28900005.html.

480 IEA (2020) “Global EV Outlook 2020”, pp.49-50.

481 IEA (2021), “Global EV Data Explorer”, https://www.iea.org/articles/global-ev-data-explorer.

482 METI (2020) “Green Growth Strategy Through Achieving Carbon Neutrality in 2050”, 25 December 2020.

Pressure Gas Safety Act, should be considered in order to expand the use of fuel cell vehicles[483].

Most recently, Toyota announced that it developed a FC module that packages a fuel cell system and would begin selling it[484]. Toyota says the modularization of the system will enable developers and manufacturers of fuel cell products to utilize the system for various applications, such as mobility of trucks, buses, trains, ships, etc. stationary generators. At the same time, Toyota Industries Corporation announced a plan to develop and market a general-purpose, compact FC module[485]. Toyota Motor Corporation has announced that it will begin production of its second-generation fuel cell module in Europe (assembly to begin in January 2022)[486] and that it will begin assembling dual fuel cell modules for heavy-duty commercial trucks at its plant in Georgetown, Kentucky, USA in 2023[487]. Toyota also announced the establishment of a joint venture with Beijing SinoHytec to locally produce core systems for fuel cell vehicles in China. It is reported that the joint venture will begin mass production of fuel cell vehicle systems, mainly fuel cell stacks, in Beijing in 2023[488].

In the U.S., the Department of Energy is taking the lead in research and development of stationary and on-board fuel cells, with 2025 goals of $40/kW production cost ($30/kW as the ultimate goal after 2030), 5,000 hours durability (8,000 hours as the ultimate goal after 2030), and 65% efficiency[489]. In addition, the Department of Energy has established two new consortia, Million Mile Fuel Cell Truck (M^2FCT) and H2NEW, to advance R&D for fuel cell trucks and hydrogen production. Each consortium will receive up to $10 million per year over the next five years, with DOE's national laboratories leading the research and development[490]. In Europe, the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) is responsible for fuel cell R&D and demonstration projects, focusing on the development and production of common stacks for use in passenger and commercial vehicles[491]. The FCH JU has set the following goals for fuel cell vehicles (passenger cars): increasing the fuel cell system durability to 5,000 hours in 2020, 6,000 hours in 2024, and 7,000 hours in 2030, and reducing the fuel cell system cost to €60/kW in 2020, €50/kW in 2024, and €40/kW in 2030[492]. In the period 2008-2020, 80 projects in the transport sector (demonstration of fuel cell use, development of advanced fuel cells) have received financial support a total of approximately €486 million from the FCH JU[493]. The FCH JU ceased its activities in November 2021, and its activities were taken over by the Clean Hydrogen Joint Undertaking[494].

(b) Charging facilities

Charging facilities for BEVs and PHEVs are categorized into regular charging facilities and quick charging facilities. Regular charging facilities use single-phase 200 V AC or 100 V AC, which are

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483 METI (2021) "Green Growth Strategy Through Achieving Carbon Neutrality in 2050", 18 July 2021.

484 Toyota Motor Corporation, 26 February 2021, https://global.toyota/jp/newsroom/corporate/34799387.html.

485 Toyota Industries Corporation, 26 February 2021, https://www.toyota-shokki.co.jp/news/release/2021/02/26/002816/.

486 TOYOTA UK, "Toyota to Start European Production of Second Generation Fuel Cell Modules", 2 December 2021, https://media.toyota.co.uk/toyota-to-start-european-production-of-second-generation-fuel-cell-modules/.

487 TOYOTA, "Toyota to Assemble Fuel Cell Modules at Kentucky Plant in 2023", 25 August 2021, https://pressroom.toyota.com/toyota-to-assemble-fuel-cell-modules-at-kentucky-plant-in-2023/.

488 Nihon Keizai Shimbun, 29 March 2021, https://www.nikkei.com/article/DGXZQOFD299QN0Z20C21A3000000/.

489 U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, "Fuel Cell R&D Overview", 2019 Annual Merit Review and Peer Evaluation Meeting, April 29, 2019, https://www.hydrogen.energy.gov/pdfs/review19/plenary_fuel_cell_papageorgopoulos_2019.pdf.

490 U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (Press Released on October 8, 2020), "DOE Launches Two Consortia to Advance Fuel Cell Truck and Electrolyzer R&D", https://www.energy.gov/eere/articles/doe-launches-two-consortia-advance-fuel-cell-truck-and-electrolyzer-rd.

491 NEDO, 21 August 2020, https://www.meti.go.jp/shingikai/energy_environment/green_innovation/pdf/002_04_01.pdf.

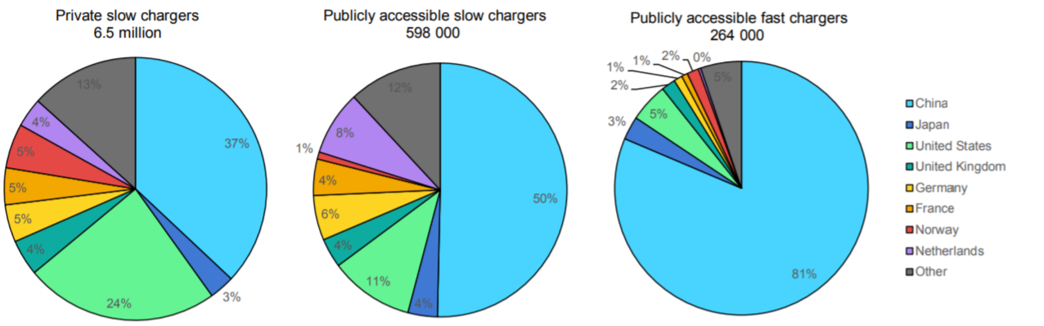
492 Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU), "Addendum to the Multi-Annual Work Plan 2014-2020", 15 June 2018, https://www.fch.europa.eu/page/multi-annual-work-plan.

493 Clean Hydrogen Partnership, "Programme Review Report 2020-2021", 2 December 2021, https://www.clean-hydrogen.europa.eu/media/publications/programme-review-report-2020-2021_en.

494 Clean Hydrogen Partnership, "Who we are", https://www.clean-hydrogen.europa.eu/about-us/who-we-are_en.

commonly used, and are expected to be used in detached houses, condominiums, buildings, outdoor parking lots, etc. Charging time is approximately 14 hours at 100 V or 7 hours at 200 V for a cruising range of 160 km. Quick recharging facilities use three-phase 200 VAC as the power source, and are expected to be used at locations where vehicles need to be charged in a short period of time, such as gas stations and expressway service areas. Since the maximum output voltage is 500 VDC, the charging time for a cruising range of 160 km is approximately 30 minutes, which is significantly shorter than that of regular charging facilities. [495]

At the end of 2019, there were 7.3 million electric vehicle charging facilities installed worldwide, of which approximately 90%, or 6.5 million units, were low-speed or regular charging facilities for passenger cars (privately owned). Many of privately owned charging facilities are installed in residences and workplaces from the viewpoints of convenience, cost-effectiveness, and installation support measures. On the other hand, publicly available charging facilities number 862,000 units, accounting for only 12% of all charging facilities for passenger cars (2019). As shown in the figure below, among these, quick charging facilities number only 263,000 units, but more than 80% of them have been installed in China. Note that as of 2020, the number of publicly available charging facilities expanded to 1.3 million, 30% of which were fast charging facilities[496].



Sources: IEA analysis based on country submissions, complemented by Chinabaogao (2019) and (EAFO, 2020a).

Figure 206　Private and Publicly Available Chargers by Country (2019)

Source：IEA, Global EV Outlook 2020

Quick charging facilities are large-capacity power supplies that convert an alternating current to a direct current and have an output voltage of as high as 500 VDC, and therefore, they need to be connected to car terminals with a special connector. In addition, the quick charging facility communicates a the battery management system while charging, constantly monitoring the status of the lithium-ion battery to ensure safety and reliability[497]. One of the fast charging standards that define matters such as connector standards, charging, and communication protocols is the CHAdeMO standard, which is led by Japanese companies. Other major standards include CCS1 (U.S. standard) and CCS2 (European standard), which are being developed mainly by European and U.S. automakers, GB/T (China's national recommended standard), and Tesla's Supercharger. When comparing the number of units installed, GB/T represents by far the largest due to the size of the market.

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[495] METI, https://www.meti.go.jp/policy/automobile/evphv/what/charge/index.html.

[496] IEA (2021) "Global EV Outlook 2021", pp.39.

[497] Nichicon, 7 October 2010, https://www.nichicon.co.jp/library/%E9%9B%BB%E6%B0%97%E8%87%AA%E5%8B%95%E8%BB%8A%E7%94%A8%E5%85%85%E9%9B%BB%E8%A8%AD%E5%82%99%E3%81%AE%E6%9C%80%E6%96%B0%E6%8A%80%E8%A1%93%E5%8B%95%E5%90%91/.

Table 128 Major Fast Charging Standards

		CHAdeMO	GB/T	CCS 1 (U.S.)	CCS 2 (Europe)	Tesla	ChaoJi
Standardization	IEC (International Standard)	✓	✓	✓	✓		Applying
	U.S.	IEEE		SAE			
	EN (Europe)	✓		✓			
	JIS (Japan)	✓	✓	✓	✓		✓
	GB (China)		✓				✓
Commnucation Protocol		CAN	CAN	PLC		CAN	CAN
Maximum Output		400kW 1000V x 400A	185kW 750V x 250A	200kW 600V x 400A	350kW 900V x 400A	250kW?	900kW 1500V x 600A
Market Output		150kW	125kW	150kW	350kW	85-250kW	-

Note: IEC = International Electrotechnical Commission, IEEE = Institute of Electrical and Electronics Engineers, SAE = Society of Automotive Engineers, EN = European Norm, JIS = Japanese Industrial Standards, GB = China National Standard.

Source: CHAdeMO Association, "Annual Report 2020" (4 June 2021)

In April 2020, the CHAdeMO Association and the China Electricity Council jointly issued a next-generation ultra-fast output charging standard (ChaoJi) as CHAdeMO 3.0[498]. This is a CHAdeMO version of quick charging using a ChaoJi connector jointly developed by Japan and China, and a work is underway on the Chinese side to develop a new standard that uses the same connector and the Chinese standard (GB/T) communication protocol. With the birth of ChaoJi, it is expected that the cost will be reduced through volume efficiency and the technology will become a de facto standard. At this point, a cooperative framework between CHAdeMO and CCS1/CCS2 has not been established yet.

As the cruising range of electric vehicles is extended, the capacity of storage batteries increases, which in turn requires higher output of recharging facilities. For each of the aforementioned major fast-charging standards in the world, efforts for higher output have been made, with CCS having a maximum output of 400 kW, Tesla 250 kW, and ChaoJi 900 kW.

Note that the V2X (Vehicle to X)[499] functionality has been put to practical use only in CHAdeMO among the major standards mentioned above. Since 2012, demonstration projects using the CHAdeMO standard V2X have been conducted around the world, with particular focus on Europe and the United States[500]. As for CCS, there has been no major movement in V2X commercialization since the start of standards development in 2012, but CharIN, a CCS formulation organization, expressed its support for V2X by publishing its views on the integration of electric vehicles and power networks in December 2018[501], and although CharIN has not set any specific deadline as a development outlook, it organizes the development process until V2H/V2G realization into five stages[502].

(c) Fuel cell railcars

Traditionally, diesel trains have played an important role in non-electrified sections of the rail network. Electrification of non-electrified sections is often not cost-effective, and fuel cell railcars and

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[498] CHAdeMO Association, 24 April 2020, https://www.chademo.com/ja/chademo3-0/.

[499] General term for electric power supply from electric vehicles to electric power networks and consumers. V2X includes V2V (Vehicle to Vehicle), Vehicle to Load, V2H (Vehicle to Home), V2B (Vehicle to Building), V2G (Vehicle to Grid: V2G).

[500] CHAdeMO Association, https://www.chademo.com/ja/technology/v2x/.

[501] Takashi Otsuki and Toru Ogura, September 2019, http://eneken.ieej.or.jp/data/8659.pdf.

[502] CharIN, "Grid Integration Levels 2020-06-26 V5.2", https://www.charin.global/media/pages/technology/knowledge-base/60d37b89e2-1615552583/charin_levels__grid_integration_v5.2.pdf

hybrid railcars with fuel cells and storage batteries are being developed, demonstrated, and commercialized to reduce environmental impact without electrifying the line.

In Europe, France's Alstom unveiled its Coradia iLint fuel cell railcar in 2016, and it began commercial operation in Germany in 2018 for the first time in the world[503]. The railcars run at 140 km/h over a 100 km section in place of a diesel train and, 14 more cars will be delivered in the future. Alstom is moving forward with demonstrations in the Netherlands and Austria, and plans to expand into the UK. In 2020, Siemens Mobility of Germany announced that it would work with Deutsche Bahn to develop fuel cell railcars and infrastructure including hydrogen refueling facilities (H2goesRail). The railcar will run a distance of 600 km at a maximum speed of 160 km/h. Its trial run will be started in 2024[504].

In Europe, the EU's FCH2RAIL project to develop fuel cell hybrid power sources for railroads in a four-year period from January 2021, with a budget of 1.334 billion euros[505], is being implemented[506]. In the project, Toyota Motor Europe will provide FC modules packaged with a hydrogen fuel cell system, and a prototype hybrid power system with the FC modules and a lithium titanate storage battery module from CAF of Spain will be developed, tested and demonstrated[507].

In Japan, the Railway Technical Research Institute began development of a fuel cell railcar (in three phases) in 2001, and a running test of a two-car train equipped with 100 kW-class fuel cells, and 360 kW lithium-ion batteries as storage batteries for hybrid use, was conducted as a demonstration of a practical fuel cell railcar system in 2007-2008[508]. In 2020, East Japan Railway Company, Hitachi, Ltd. and Toyota Motor Corporation announced that they had agreed to work together to develop a test vehicle equipped with a hybrid system powered by fuel cells and storage batteries. Toyota Motor Corporation is in charge of the development of the fuel cell system, and Hitachi, Ltd. is in charge of the development of the hybrid drive system. The two-car train will have a maximum cruising distance of approximately 140 km and a maximum speed of 100 km/h. Demonstration tests are scheduled to begin around March 2022[509].

(d) Advanced biofuels

Biofuels account for 3% (2019) of the transportation fuel demand in the transport sector, the majority of which is conventional biofuels. There are three major categories of biofuels that replace transportation fuels: bioethanol, which replaces gasoline; biodiesel, which replaces diesel fuel; and biojet fuel, which replaces jet fuel. As of 2019, bio-gasoline and biodiesel accounted for 52% and 36% of biofuels, respectively, while bio-jet fuel was not yet available.

The first generation of biofuels refers to bioethanol and biodiesel (fatty acid methyl esters: FAME), which are produced from the edible parts of biomass such as sugar, starch, and vegetable oils. Biofuels derived from edible parts have already been commercialized and are in widespread use, but growing criticism of fuel production in competition with food production has prompted the development of biofuels made from non-edible parts (such as residues from food production). Cellulosic bioethanol, which is made from cellulose and other non-edible parts of biomass, which will be the next generation

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503 Alstom, "Coradia iLint – the world's 1st hydrogen powered train", https://www.alstom.com/solutions/rolling-stock/coradia-ilint-worlds-1st-hydrogen-powered-train.

504 Siemens, 23 November 2020, "Deutsche Bahn and Siemens enter the Hydrogen Age", https://assets.new.siemens.com/siemens/assets/api/uuid:6bdd169b-eff6-45d4-befa-715d36b160d7/Wasserstoff-DB-Siemens-EN.pdf.

505 The FCH 2 RAIL has been adopted by Horizon 2020, which is the EU's research and development support program, and 75% of its budget is funded by EU. In addition to Toyota Motor Europe, DLR, CAF, Renfe, ADIF, CNH2, Infraestruturas de Portugal and Stemmann-technik have joined the project.

506 European Commission, "Fuel Cell Hybrid PowerPack for Rail Applications", https://cordis.europa.eu/project/id/101006633.

507 JETRO, 27 April 2021, https://www.jetro.go.jp/biznews/2021/04/4e07d68a5b01fd40.html.

508 Railway Technical Research Institute, 20 September 2018, https://www.hkd.mlit.go.jp/ky/ki/renkei/splaat000001eosf-att/splaat000001eowi.pdf.

509 Toyota Mortor Corporation, 6 October 2020, https://global.toyota/jp/newsroom/corporate/33954803.html.

of biomass, is already in the commercialization stage and is used as an alternative fuel to gasoline and diesel oil. Note that biofuels derived from edible and non-edible parts are subject to limitation in the ratio of blending with fuels derived from fossil fuels when using existing infrastructure facilities[510].

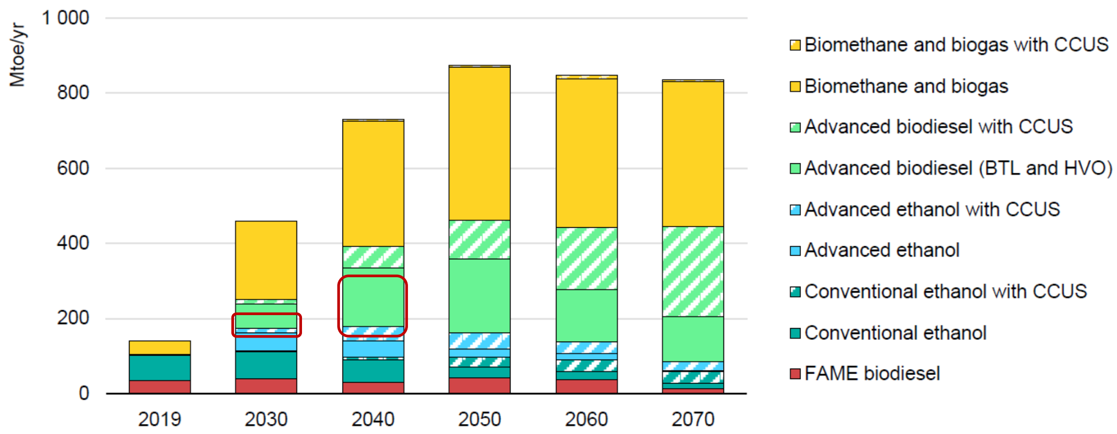
The IEA has identified the following advanced biofuel[511] technologies: cellulosic ethanol, BTL fuels (Biomass To Liquids, a technology for gasifying biomass and synthesizing and liquefying it, and fuels using this technology), hydrotreated vegetable oil (HVO) biodiesel derived from vegetable oil and waste cooking oil, and hydroprocessed ester and fatty acids (HEFA) biojet fuels made from fats and oils such as waste cooking oil, vegetable oil, and oil derived from algae. BTL and HVO/HEFA are drop-in fuels, which can be used directly in existing equipment and facilities. Cellulosic ethanol and HVO/HEFA are currently commercialized, while BTL is in the demonstration stage. BTL is expected to be a technology that makes it possible to use various resources such as municipal solid waste, forest residues and agricultural residues as raw material.

Table 129 Examples of Advanced Biofuel Technologies

Technology	Technology Readiness Level
Cellulosic ethanol	Commercialized
BTL fuels	Demonstration stage
Hydrotreated vegetable oil (HVO) biodiesel	Commercialized
Hydroprocessed ester and fatty acids (HEFA) biojet fuels	Commercialized

Source：IEA, Energy Technology Perspectives 2020

As shown in the figure below, the IEA's Sustainable Development Scenario projects a rapid expansion of liquid biofuels by 2040 (about 390 Mtoe), driven primarily by the BTL technology, which is expected to begin large scale commercial deployment by 2030. [512]



Notes: Advanced biodiesel here includes biojet fuel production. Biomethane and biogas numbers shown here include power generation, gas grid injection and transport use. The vast majority of liquid biofuels are consumed in transport, while a small portion is consumed in industry.

Figure 207 Global biofuels production by technology in the Sustainable Development Scenario (2019-2070)

Source: IEA, Energy Technology Perspectives 2020

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510 NEDO, "TSC Foresight" Vol.21 (November 2017), https://www.nedo.go.jp/content/100870191.pdf; "TSC Foresight" Vol.37 (July 2020), https://www.nedo.go.jp/content/100920836.pdf.

511 The IEA defines advanced biofuels as sustainable fuels produced from non-food crop feedstocks, capable of delivering significant lifecycle GHG emissions reductions compared with fossil fuel alternatives, and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts. (IEA (2020), Tracking Transport Biofuels 2020, https://www.iea.org/reports/tracking-transport-biofuels-2020-2)

512 IEA (2020) "Energy Technology Perspectives 2020", pp.137-138.

Demonstration plants and early commercial-scale projects for BTL are underway in Europe and North America. Examples of projects for plants and facilities that are being constructed or in operation as of July 2021 include the following.

Company Name	Country	Raw material	Summary
Enerkem	Canada	Refuse-derived fuel	Enerkem Alberta Biofuels is a first-of-a-kind commercial scale facility (in operation). Methanol and ethanol (30,000 t/y) are produced from refuse-derived fuels.
Fulcrum	U.S.	municipal solid waste	Construction of Sierra BioFuels Plant (first-of-a-kind commercial plant, construction to be completed in July 2021). Synthetic crude oil (30,000 t/y) and jet fuel components are produced from municipal solid waste (175,000 t/y). Fuel production is scheduled to begin in the fourth quarter of 2021.
Karlsruhe Institute of Technology	Germany	lignocellulose	The bioliq® pilot project is in demonstration phase (in operation). Produces DME (608 t/y) and gasoline-type fuel (360 t/y) from straw and other materials.
Red Rock Biofuels	U.S.	Woody biomass	A plant under construction in Lakeview, Oregon (first-of-a-kind commercial). Synthetic fuels (44,000 t/y) and jet fuel components will be produced from forest residues (127,000 t/y).
TotalEnergies	France	lignocellulose	Bio Tfuel project is in demonstration phase (in operation). Synthetic fuels (8,000 t/y) are produced from straw and forest residues.
Woodland Biofuels	Canada	Waste materials, crop residues	The demonstration plant in operation produces ethanol (601 t/y) from waste wood and crop residues.

Source: IEA Bioenergy Task 39, Database on facilities for the production of advanced liquid and gaseous biofuels for transport; IEA Bioenergy Task 41, “The Role of Renewable Transport Fuels in Decarbonizing Road Transport Production Technologies and Costs” (November 2020); Each company’s website.

(e) Automated driving technology

Six levels of driving automation are defined, ranging from 0 to 5. The most mainstream definitions of automated driving levels are based on criteria by the Society of Automotive Engineers (SAE), and a Japanese translation of the criteria is published in Japan by the Society of Automotive Engineers of Japan. There is a major distinction between Levels 2 and 3 in whether the dynamic driving task is performed by a human or a system.

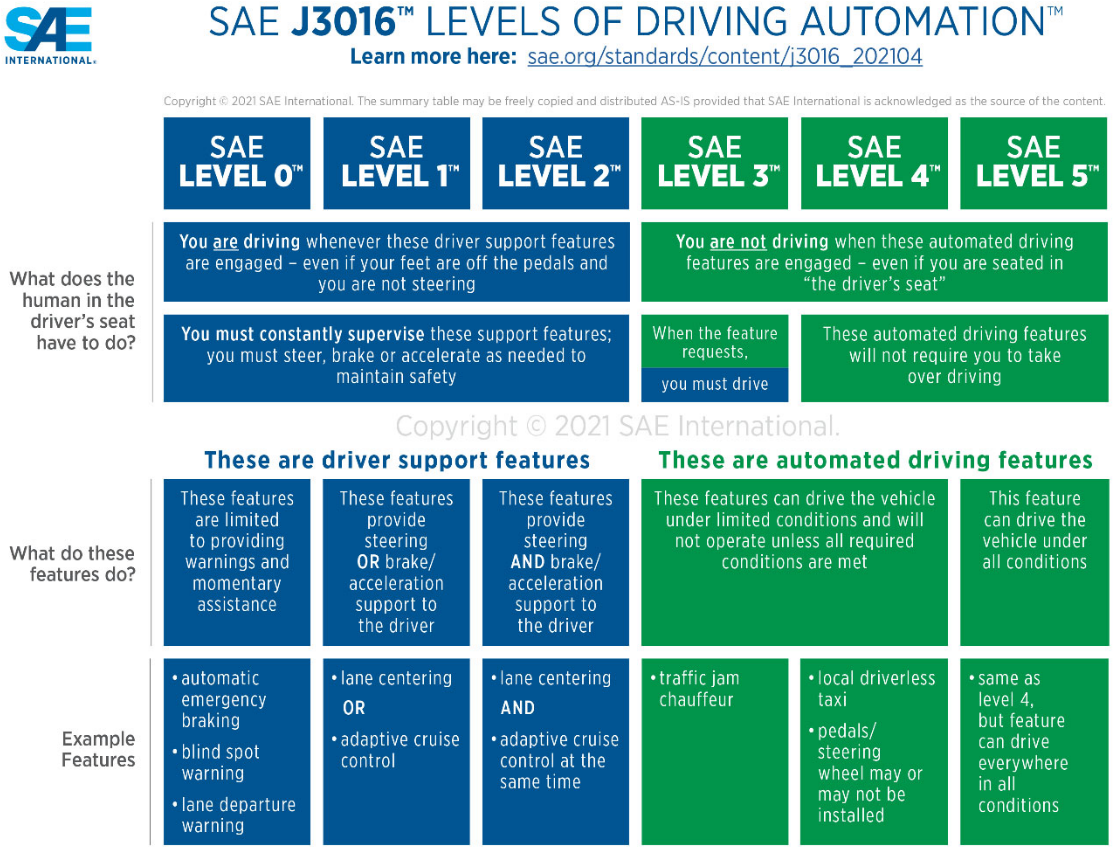

Figure 208　Level of Automated Driving

Source: SAE International, "SAE J3016 Levels of Driving Automation"

In Japan, the "Revised Road Traffic Act" and the "Revised Road Trucking Vehicle Act" came into effect in April 2020, officially defining "Automatic Operation Device" from a legal perspective and allowing Level 3 driving. In March 2021, Honda began selling the new "Legend" equipped with Honda SENSING Elite, which puts a Level 3 into practical use[513]. This is the world's first approved vehicle equipped with Level 3 autonomy.

Other than Honda, foreign manufacturers are also planning to start mass production of Level 3 vehicles and to add Level 3 functions to their driving systems by the end of 2021. However, since they are expected to be installed in flagship models, Level 2 vehicles are expected to lead the market for the time being. According to an analysis by Fuji Chimera Research Institute, 47.66 million vehicles are expected to be equipped with Level 2 autonomy by 2025, and the ratio of those at advanced Level 2 provided with lane change support and hands-free function under limited conditions will exceed 10% of all Level 2 vehicles. By 2035, in addition to the steady growth of Level 2 vehicles, including high-functionality vehicles, the demand for Level 3 vehicles is expected to increase, albeit on a limited basis on expressways. It is also expected that Level 4/5 vehicles will be deployed in some production vehicles as well as cabs and MaaS. In 2045, 42.8 million Level 3 vehicles and 21.39 million Level 4/5 vehicles are expected to be produced[514].

513 Honda Mortor Corporation, 4 March 2021, https://www.honda.co.jp/news/2021/4210304-legend.html.

514 Fuji Chimera Research Institute, 8 September 2020, https://www.fcr.co.jp/pr/20092.htm.

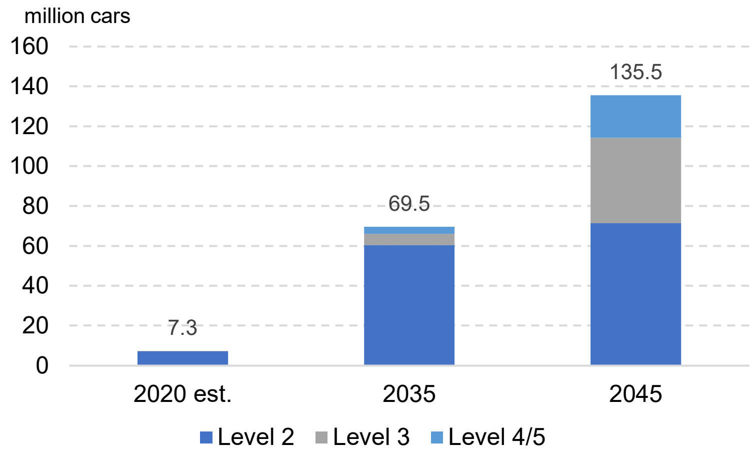

Figure 209 Outlook for Global Production of Automated Driving Vehichles (above Level 2)
Source: Fuji Chimera Research Institute, https://www.fcr.co.jp/pr/20092.htm

The development and promotion of vehicles equipped with Level 3 autonomy or higher is expected to progress mainly in Europe. In the 2020s, in addition to Europe, the use of Level 3 or higher vehicles will gradually increase in China and North America, and the size of the market for vehicles equipped with Level 3 or higher is expected to exceed 10 million units in the early 2030s.

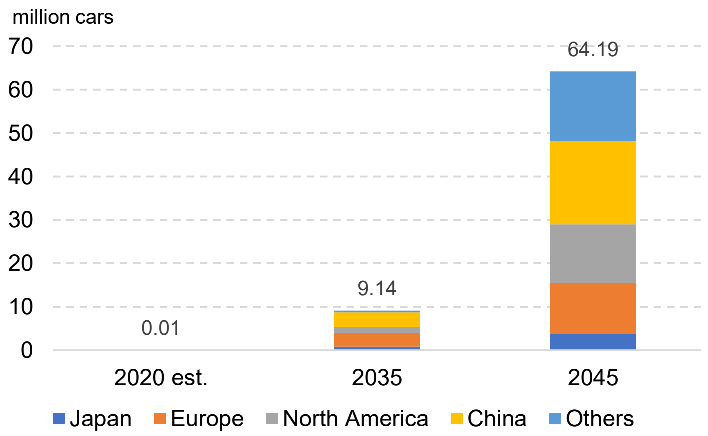

Figure 210 Outlook for Regional Production of Automated Driving Vehicles (above Level 3)
Source: Fuji Chimera Research Institute, https://www.fcr.co.jp/pr/20092.htm

Note that there are many uncertainties as to whether or not the widespread use of automated driving technology will advance the decarbonization of the transportation sector. The energy consumption may be reduced through better route selection by self-driving vehicles based on real-time traffic conditions, and traffic congestion reduction through the linkage of automated driving technology and ridesharing. In addition, the decarbonization of the transportation sector may advance as a result of the advancement of the electrification of self-driving vehicles, on the assumption of the decarbonization of the power supply. On the other hand, the generation of new demand for travel (e.g., long-distance travel by individuals) due to the widespread use of automated driving technology, and the running of shared self-driving cars without passengers, may result in increased energy consumption. The impact of automated driving technology on the mobility demand and changes in human behaviors needs to be closely monitored.

(f) Alternative fuel technologies for ships and aviation

[Shipping]

The International Maritime Organization (IMO) adopted a Greenhouse Gas Reduction Strategy in April 2018 as a measure to reduce greenhouse gas emissions from international shipping. Its long-term goal is to achieve zero greenhouse gas emissions from international shipping as early as possible in this century, with a target of a 40% improvement in average fuel consumption by 2030, and a 50% reduction in total emissions by 2050 (equivalent to an 85% improvement in average fuel consumption), from 2008 as the base year[515]. The strategy adopted in 2018 has been agreed to be revised in 2023, and at the 77th meeting of the Marine Environment Protection Committee in November 2021, it was agreed to set even more ambitious targets than the current ones[516]. The CO2 emissions in the IEA's sustainable development scenario shown in the figure below are largely in line with the IMO's targets for 2050, but to achieve the CO2 emissions assumed in the sustainable development scenario, energy efficiency improvements such as technological streamlining and the use of biofuels in the short term, and the use of hydrogen and ammonia in the long term, are expected to contribute to CO2 emissions reduction. Note that, as the figure below shows, future technological development and maturity are needed to reduce CO2.

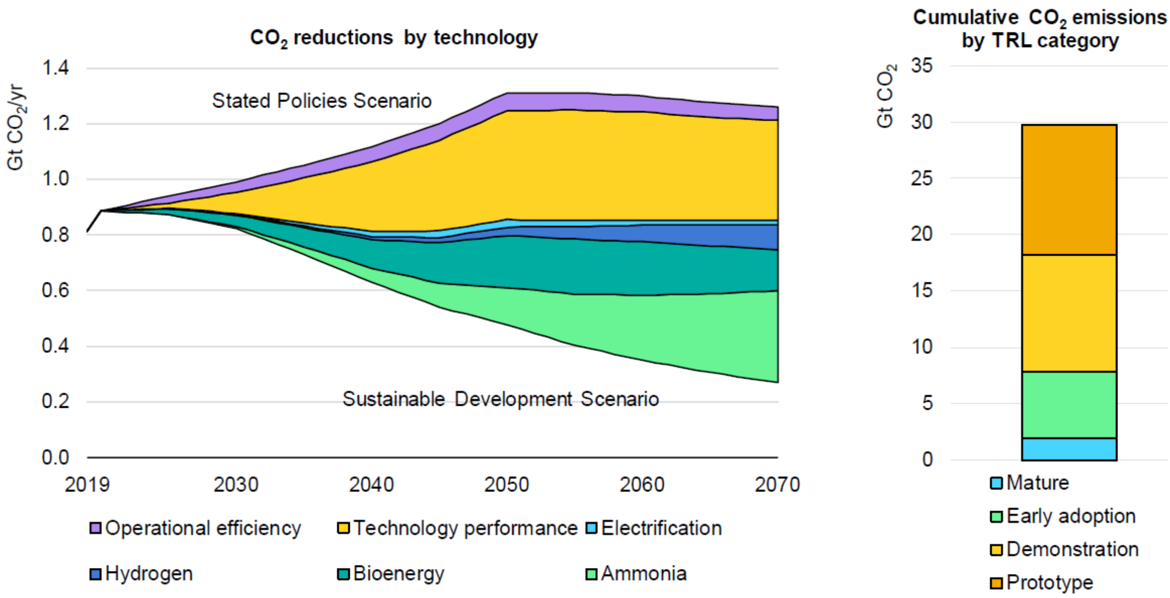

Figure 211 Global CO2 emissions reductions in shipping by mitigation category and technology readiness level (2019-2070)

Source: IEA, Energy Technology Perspectives 2020

In the short term, fuel conversion to very low sulfur fuel oil (VLSFO) and LNG will take place in response to the IMO's tightening of sulfur control for marine fuel oil (reducing sulfur concentration to 0.5% or less), which began in January 2020. The introduction of LNG ships is expected to reduce CO2 emissions by replacing petroleum, but further efforts are needed to reduce the use of fossil fuels. In the medium term (after about 2025), the blending of biofuels with marine fuels is expected to increase, and the progress of BTL technology will enable the mass introduction of biofuels also in marine fuels after 2050.

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[515] Ministry of Land, Infrastructure, Transport and Tourism, August 2019, https://www.mlit.go.jp/common/001302145.pdf; IMO, "Initial IMO GHG Strategy", https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx.

[516] Ministry of Land, Infrastructure, Transport and Tourism, 29 November 2021, https://www.mlit.go.jp/report/press/kaiji07_hh_000221.html.

Hydrogen- and ammonia-fueled vessels are expected to be introduced gradually, but ammonia use is expected to expand more than hydrogen in shipping. This is because fuel cells cannot provide the power needed to navigate a transoceanic route, so the use of hydrogen is limited on ships equipped with internal combustion engines that can burn hydrogen, and furthermore, hydrogen may not be suitable as fuel for ocean-going vessels in view of its high storage cost and low energy density. For ocean-going vessels, MAN-Energy of Germany and Wartsila of Finland have announced the development of ammonia-fueled engines, which are expected to be put into operation in 2023. As for hydrogen-burning internal combustion engines, Hyundai Heavy Industries has announced a plan to develop a large-scale hydrogen-burning internal combustion engine by 2022. In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) published a "Roadmap to Zero Emission from International Shipping" in March 2020, which aims to start demonstration around 2022 to 2025, and deploy actual ships around 2028 to 2030, for research and development of hydrogen- and ammonia-fueled engines, turbines, and fuel cells[517]. Most recently, in September 2020, NYK Line, IHI Power Systems, and Nippon Kaiji Kyokai announced a joint R&D project to achieve the practical use of the world's first ammonia-fueled tugboat[518]. In relation to the use of fuel cells on ships, Yanmar Holdings and Yanmar Power Technology have developed a demonstration boat that is based on a boat they have manufactured and is installed with a marine fuel cell system developed by combining Toyota's automotive fuel cell with other equipment, and have started a demonstration test of a hydrogen fuel cell system for ships[519].

Note that uses of electricity in the form of marine fuels are limited, and their use primarily in hybrid vessels is assumed. Fully battery-powered ships are expected to be used only for short-distance navigations from an economic standpoint. For short- and medium-range vessels, European companies (Scandinavian companies, etc.) in particular are working to develop ammonia fuel cells, hydrogen fuel cells, hydrogen combustion internal combustion engines, and battery-powered ships for short- and medium-range navigations. [520]

[Aviation]

In the aviation sector, the International Civil Aviation Organization (ICAO) and the International Aviation Transport Association (IATA) have announced targets and measures to reduce CO2 emissions. In the aviation sector, the International Civil Aviation Organization (ICAO) and the International Aviation Transport Association (IATA) have announced targets and measures to reduce CO2 emissions. IATA has set three goals: to improve fuel efficiency by an average of 1.5% per year between 2009 and 2020; to set a cap on aircraft CO2 emissions starting in 2020; and to reduce CO2 emissions by 50% from the 2005 level by 2050. To achieve these goals, IATA has a four-pronged strategy consisting of: technology improvements, including the widespread use of sustainable aviation fuels; more efficient aircraft operations; infrastructure improvements, including modernization of air traffic control systems; and closing the emissions gap through a global market-based initiative[521]. The global market-based initiative is the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), established in 2016. CORSIA has three stages: a pilot phase (2021-2023), a first phase (2024-2026) with voluntary participation by countries, and a second phase (2027-2035) with mandatory participation by all countries with some exceptions[522]. Developed Western countries and Japan are scheduled to join this scheme in 2021. CO2 emission reduction measures in the aviation sector include technological innovations such as lighter aircraft and more efficient operation methods

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517 Ministry of Land, Infrastructure, Transport and Tourism, March 2020, "Roadmap to Zero Emission from International Shiping", https://www.mlit.go.jp/common/001377661.pdf.

518 NYK Line, 30 September 2020, https://www.nyk.com/news/2020/20200903_01.html.

519 YANMAR, 24 March 2021, https://www.yanmar.com/jp/news/2021/03/24/89083.html.

520 IEA (2020), "Energy Technology Perspectives 2020", pp.278-280.

521 IATA, "Working Towards Ambitious Targets", https://www.iata.org/en/programs/environment/climate-change/.

522 ICAO, "2. What is CORSIA and how does it work?", https://www.icao.int/environmental-protection/pages/a39_corsia_faq2.aspx.

and management. In particular, the use of alternative fuels is essential to achieve the long-term CO2 emission reduction goal.

According to the policy scenarios published by the IEA, fossil fuel-derived jet fuels are predicted to account for a quarter of the aviation fuel demand even in 2070. But as shown in the figure below, in order to achieve the CO2 emissions assumed in the sustainable development scenario, significant expansion in the use of alternative fuels such as biofuels and synthetic fuels will be necessary after 2030.

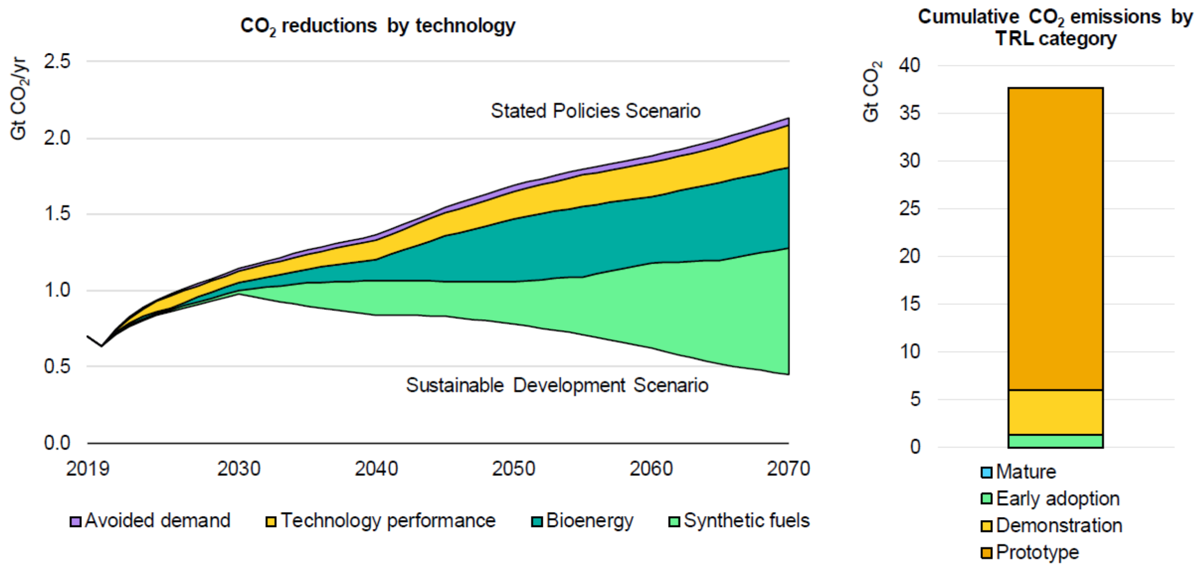

Figure 212 Global CO2 emissions in aviation by abatement measure and technology readiness level (2019-2070)

Source: IEA, Energy Technology Perspectives 2020

Of the biojet fuel production methods that meet ASTM D7566 standards[523], HEFA jet fuel is considered the most likely to be commercially viable at this time. However, HEFA may compete with HVO for automobiles in terms of securing raw materials. BTL is also primarily in a demonstration phase, with two commercial-scale plants to produce biojet fuel for aircraft under construction in the United States. In June 2020, biojet fuel made from microalgae, for which the New Energy and Industrial Technology Development Organization (NEDO) and IHI have jointly worked on its technological development, newly received ASTM certification[524].

As for hydrogen-fueled aircraft, Airbus has announced three types of ZEROe concept aircraft that will be introduced for commercial aviation (practical use) by 2035[525]. The ZEROe aircraft will be equipped with a gas turbine engine that burns hydrogen.

Hybrid electric aircraft, fully electric aircraft, and fuel cell aircraft are in the R&D and prototype development stages. For hybrid electric aircraft, Airbus has developed a prototype under the E-Fan X program in cooperation with Rolls Royce. As for fully electric aircraft, in June 2020, the European Union Aviation Safety Agency approved the Pipistrel Velis Electro, the world's first fully electric aircraft. Velis Electro is two-seat aircraft whose primary purpose is pilot training[526]. As for fuel cell

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523 FT-SPK, Bio-SPK or HEFA, SIP, SPK/A, ATJ-SPK) (ASTM International, https://www.astm.org/d7566-21.html).

524 NEDO, 8 July 2020, https://www.nedo.go.jp/news/press/AA5_101314.html.

525 Airbus (2020-9-21), “Airbus reveals new zero-emission concept aircraft”, https://www.airbus.com/newsroom/press-releases/en/2020/09/airbus-reveals-new-zeroemission-concept-aircraft.html.

526 EASA, 10 June 2020, “EASA certifies electric aircraft, first type certification for fully electric plane world-wide”, https://www.easa.europa.eu/newsroom-and-events/news/easa-certifies-electric-aircraft-first-type-certification-fully-electric.

aircraft, Boeing successfully tested a fuel cell-powered demonstration aircraft in 2008, and DLR tested a four-seat fuel cell motor glider in 2016, but no programs for larger aircraft have been announced. According to NEDO, the cruising range with storage batteries around 2030 will be 2,000 km for large jetliners, 160 km for small aircraft, and 80 km for helicopters, which means that electrification of short domestic flights of small aircraft and helicopter flights is possible, but electrification of long flights of large jetliners is considered difficult[527].

(ii) Trends in the development and social implementation of technologies and services in the countries covered by the field survey

(a) India

In recent years, the demand growth in the transport sector has been the largest compared to the other sectors. While more than three-quarters of the stock vehicles are two- and three-wheelers, the largest CO2 emitters are four-wheelers such as passenger cars and trucks. A modal shift to public transportation (electrification of railroads, buses, etc.) along with the use of alternative fuels and promotion of EVs as pushed forward by the government will be necessary to achieve decarbonization.

[Electric Vehicles]

According to the Society of Manufacturers of Electric Vehicles (SMEV), electric vehicle sales for the 2019-2020 fiscal year were 155,400 units (of which 152,000 were motorcycles and 3,400 were four-wheeled vehicles)[528]. In 2013, India released its National Electric Mobility Mission Plan 2020 (NEMMP2020), which aims to gradually increase xEV sales in India to 6-7 million units by 2020 (most of which are assumed to be electric two-wheelers, followed by HEVs and BEVs)[529]. In 2015, the Faster Adoption and Manufacturing of Hybrid & Electric Vehicles in India (FAME) I was introduced to provide a purchase subsidy for BEVs, HEVs and PHEVs and make capital investment in infrastructure and other facilities[530]. The second phase (FAME II) will begin in April 2019, with a budget of R100 billion allocated for demand incentives, installation of a charging station network, and administrative activities including information, education and communication (IEC), as shown in the table below. The demand incentives, which will be the main support component of FAME II, will cover buses (for electric vehicles only), four-wheeled vehicles (BEVs, PHEVs and SHEVs[531]), three-wheeled vehicles (electric, including registered e-rickshaws) and two-wheeled vehicles (electric), and in the case of buses, four-wheeled and three-wheeled vehicles, the incentives will be applied primarily to those for public transportation or commercial use. Each is provided with an incentive based on its installed battery capacity (on a kWh basis). All vehicles except buses are presented with Rs. 10,000/kWh, and buses with Rs. 20,000/kWh. The amounts of incentives will be reviewed annually or earlier[532]. In June 2021, the incentive for motorcycles was increased to Rs. 15,000. In addition, the Ministry of Heavy Industry has announced that FAME II will be extended for two years from the original plan, to March 31, 2024[533].

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527 NEDO, "TSC Foresight" Vol.37 (July 2020), https://www.nedo.go.jp/content/100920836.pdf, p.10.

528 Society of Manufacturers of Electric Vehicles, EV Sales, https://www.smev.in/ev-sales.

529 Ministry of Heavy Industries & Public Enterprises, Department of Heavy Industry (2012) "National Electric Mobility Mission Plan 2020", https://heavyindustries.gov.in/writereaddata/Content/NEMMP2020.pdf.

530 Ministry of Heavy Industries, About FAME II, https://fame2.heavyindustries.gov.in/content/english/13_1_brief.aspx.

531 Strong hybrid: Hybrid system that can run only on an electric motor even when the engine is stopped.

532 Ministry of Heavy Industries, Publication of notification in Gazzette of India (Extraordinary) regarding Phase-II of FAME India scheme, 8 March 2019, https://dhi.nic.in/writereaddata/fame/famedepository/2-notification.pdf

533 mint, 27 June 2021, "Extension of FAME scheme will help push sales of electric vehicles, say experts", https://www.livemint.com/news/india/extension-of-fame-scheme-will-help-push-sales-of-electric-vehicles-say-experts-11624783763494.html.

Table 130 Budget Allocation of FAME II

	2019-2020	2020-2021	2021-2022	Total Fund requirement in crores
Demand Incentives	822	4587	3187	8596
Charging Infrastructure	300	400	300	1000
Administrative Expenditure	12	13	13	38
Total for FAME II	1134	5000	3500	9634
Committed expenditure of Phase I	366	0	0	366
Total	1500	5000	3500	10000

Source: Ministry of Heavy Industries, Publication of notification in Gazzette of India (Extraordinary) regarding Phase-II of FAME India scheme, 8 March 2019

Incidentally, government think tank NITI Aayog has noted that if policies such as FAME II are successful, EV sales could reach 30% of passenger cars, 70% of commercial vehicles, 40% of buses, and 80% of two and three wheelers by 2030[534].

In addition to the central government's FAME scheme, the central government has also establishes a preferential tax system. The rate of the excise tax collected from all goods in India is 12.5% for HEVs, almost half a rate imposed on internal combustion engine vehicles. In addition, the excise tax on EVs (passenger cars, buses, motorcycles, and tricycles) is 6%, indicating that the preferential rate is high.

In India, there is a tax collection system called CESS for automobile production, and this is used as a resource to finance infrastructure projects. CESS' tax collection rate is 1% for small internal combustion engine vehicles and 2.5% for diesel vehicles. The CESS rate for vehicles with larger displacements is as high as 4%. The CESS on electric vehicles is provided as exempt.

In February 2021, the Go Electric campaign was launched, and has been led by BEE[535]. The initiative aims to raise awareness at the national level about the benefits of e-mobility, charging, and electric cookers.

There are other measures to promote the use of electric vehicles. For example, the Ministry of Road Transport and Highways (MoRTH) will implement green license plates for electric vehicles and their priority treatment on highways and regular roads and parking lots. The promotion of charging stations in the country will be under the jurisdiction of the Ministry of Power and the Ministry of Heavy Industry, and MoRTH plans to install charging stations along the Green Highway[536], which is under construction in the country.

India is also focusing on domestic production of EVs and lithium-ion batteries as part of its "Make in India" manufacturing promotion policy. Currently, almost all Li-ion batteries for automobiles are imported from China and other countries, but in recent years, major local rechargeable battery manufacturers have begun developing Li-ion batteries for EVs in partnership with foreign companies. Japanese companies are also seen moving into the area. In India, organizations such as the Automotive Research Association of India (ARAI), the International Centre for Automotive Technology (ICAT), and the Global Automotive Research Centre (GARC) serve as the core for the conduct of battery performance tests under various conditions. Recently, standards for battery testing at the aggregate level have been published, bringing India into compliance with international standards such as UN-R100 and UN/ECE for battery performance measurement. In May 2021, the government approved a Production Linked Incentive (PLI) scheme for "National Programme on Advanced Chemistry Cell (ACC) Battery Storage." A budget of 18,100 krona has been allocated for a five-year period. With the goal of achieving 50 GWh of domestic ACC manufacturing capacity, under this scheme, the government is focusing on increasing domestic added value and at the same time making the battery

534 NITI Aayog and Rocky Mountain Institute (2019), "India's Electric Mobility Transformation".

535 Ministry of Power, 19 February 2021, Transport Minister Shri Nitin Gadkari launches 'Go Electric' Campaign in the august presence of Power Minister Shri RK Singh, https://pib.gov.in/PressReleasePage.aspx?PRID=1699386.

536 For example, new 1,300km highway between Delhi and Mumbai.

manufacturing cost in India internationally competitive[537]. In January 2022, the Ministry of Heavy Industry announced that it had received applications from 10 companies for the ACC PLI scheme[538].

[Fuel Cell Vehicles]

The Ministry of Science and Technology announced that the Council of Scientific and Industrial Research (CSIR) and KPIT conducted driving tests of India's first fuel cell vehicle prototype, and successfully developed a low-temperature proton exchange membrane (PEM) fuel cell for automotive use. This fuel cell was developed independently by the CSIR-National Chemical Laboratory (CSIR-NCL). [539]

[Railroad]

Indian Railways aims to complete electrification of its all lines by December 2023[540]. In August 2021, the Indian Railways Organisation for Alternative Fuels (IROAF), an affiliate of Indian Railways, announced a competitive tender for a fuel cell railroad. This would involve retrofitting two DEMUs (diesel–electric multiple units) to run on hydrogen in a first phase, followed by installing fuel cells on two hybrid locomotives[541]. The Ministry of Railways announced the closure of IROAF as of September 2021, but the operations under the jurisdiction of IROAF were transferred to Northern Railway[542].

[Others]

In addition, under the National Urban Transport Policy (developed in 2006 and revised in 2014), the government encourages the use of public transit, bicycling, walking, and energy-efficient and clean fuels to mitigate GHG emissions from the transport sector. The policy's goals include incorporating transportation as a key parameter in the urban planning stage, making the public transportation urban, safe, and seamless, making walking and biking a safe means of urban transportation, and introducing ITS. Promotion of investment in MRT as public transportation is also mentioned. [543] In addition, under the Smart Cities Mission, the government is calling for an increase in public transportation utilization from the current 40-45% to 60-70%.

As an alternative fuel, CNG is used primarily in public transportation and tricycles. In Delhi, experiments have begun with more than 50 public buses using a mixture of hydrogen and CNG (18% hydrogen). India also has an initiative called Sustainable Alternative Towards Transportation (SATAT), which is intended to produce compressed biogas from biomass waste, in addition to natural gas. Compressed biogas plants are primarily built by private companies, and the produced compressed biogas is sold as a green alternative fuel at CNG stations and the like[544]. The National Policy on

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[537] Ministry of Heavy Industries, PLI Scheme for National Programme on Advanced Chemistry Cell (ACC) Battery Storage, https://heavyindustries.gov.in/UserView/index?mid=2487.

[538] Ministry of Heavy Industries, 15 January 2022, https://pib.gov.in/PressReleasePage.aspx?PRID=1790139.

[539] Ministry of Science and Technology, 10 October 2020, https://pib.gov.in/PressReleasePage.aspx?PRID=1663396.

[540] Business Standard, 31 January 2022, "Economic Survey: Railways target 100% electrification by Dec 2023", https://www.businessinsider.in/india/news/indian-railways-target-100-electrification-by-december-2023/articleshow/89245160.cms.

[541] Financial Express, 9 August 2021, "Indian Railways' another eco-friendly step! Bids invited for Hydrogen Fuel Cell-based Train; details", https://www.financialexpress.com/infrastructure/railways/indian-railways-another-eco-friendly-step-bids-invited-for-hydrogen-fuel-cell-based-train-details/2306977/; mint, 7 August 2021, "Indian Railways invites bids for hydrogen fuel-based tech for trains", https://www.livemint.com/news/india/indian-railways-invites-bids-for-hydrogen-fuel-based-tech-for-trains-11628326164181.html.

[542] Hydrogen Fuel News, 14 September 2021, "Indian Ministry of Railways shuts down hydrogen fuel cell trains bidding", https://www.hydrogenfuelnews.com/hydrogen-fuel-cell-trains-india/8548330/.

[543] Ministry of Urban Development (2014), "National Urban Transport Policy".

[544] Ministry of Petroleum and Natural Gas, "Sustainable Alternative Towards Affordable Transportation", https://mopng.gov.in/en/pdc/investible-projects/alternate-fuels/sustainable-alternative-towards-affordable-transportation.

Biofuels 2018 emphasizes the active promotion of advanced biofuels, including compressed biogas[545].

(b) Indonesia[546]

The transport sector accounts for a large share of primary energy consumption and the share is expected to increase further in the future.

The National Energy Plan (RUEN), published in 2017, presents an action plan for the transport sector with target years of 2019, 2025, and 2050. However, RUEN has not provided a clear roadmap of what low-carbon transportation technologies will be adopted in the future, and the government has not fully implemented the formulation of the necessary roadmap and regulations. The main contents of the action plan include: development of a roadmap for fuel efficiency standards and public and private transportation modes; development of a roadmap for biofuel use and blending implementation; taxation studies and policies to reduce the use of petroleum fuels; development of a roadmap to expand natural gas use; provision of incentives for NGV production; development of a roadmap for the use of liquefied coal as a fuel; development of regulations for hydrogen use in public and private transportation; development of regulations for synthetic fuel use in public and private transportation; and use of solar light at stations, airports, and ports[547].

In September 2020, the Ministry of Industry published Regulation No. 27/2020, which lays out a roadmap for electric vehicles. In the roadmap, the country aims to become a major player in the global electric vehicle market, with a plan to annually produce more than 600,000 four-wheel electric vehicles and more than 2.45 million motorcycles, by 2030[548]. According to press reports, the Ministry of Industry has indicated that it will favor CKD (Completely Knocked Down) production until 2024, after which it will move to IKD (Incompletely Knocked Down, incomplete local assembly) by pursuing local procurement[549].

In addition, in June 2021, the Minister of Energy and Mineral Resources announced a policy to electrify all new four- and two-wheeled vehicles sold by 2050[550].

[Electric Vehicles]

According to the Indonesian Automotive Association, the electric vehicles sold in 2019 consisted of 0 BEVs, 20 PHEVs, and 685 HEVs[551]. The RUEN sets a goal of introducing 2,200 electric vehicles and HEVs and 2.1 million electric two-wheelers by 2025[552]. It also plans to install 1,000 public charging stations by 2025, with the goal of increasing the share of electric vehicles in the urban transportation fleet to 10% by 2025.

In August 2019, Presidential Regulation No. 55/2019, intended to spread BEVs and to promote their industry, was issued. It provides for the promotion of the domestic BEV industry, the granting of

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545 Indian Oil, "Petroleum Minister launches SATAT initiative to promote Compressed Bio-Gas as an alternative, green transport fuel", https://iocl.com/pages/satat-overview.

546 ICCT (2021) "Overview of vehicle fuel efficiency and electrification policies in Indonesia", https://euagenda.eu/upload/publications/overview-indonesia-fuel-electrification-policies-jul2021-01.pdf; IESR (2020) "A Transition Towards Low Carbon Transport in Indonesia: A Technological Perspective", https://iesr.or.id/wp-content/uploads/2020/10/Towards-a-Low-Carbon-Transport_Oct_2020.pdf.

547 IESR (2020) "A Transition Towards Low Carbon Transport In Indonesia: A Technological Perspective", pp.30-33.

548 German-Indonesian Chamber of Commerce and Industry (AHK Indonesien/EKONID), 1 December 2021, "Indonesian Electric Vehicles Industry Development Gains Momentum", https://indonesien.ahk.de/infothek/news/news-details/indonesian-electric-vehicles-industry-development-gains-momentum.

549 Paul Tan, 27 October 2021, "Hyundai to start building EVs in Indonesia in March, showcase local production capabilities – minister", https://paultan.org/2021/10/27/hyundai-to-start-building-evs-in-indonesia-in-march-showcase-local-production-capabilities-minister/.

550 Bangkok Post, 14 June 2021, "Indonesia aims to sell only electric cars, motorbikes by 2050", https://www.bangkokpost.com/business/2132179/indonesia-aims-to-sell-only-electric-cars-motorbikes-by-2050.

551 German-Indonesian Chamber of Commerce and Industry (AHK Indonesien/EKONID), 1 December 2021, "Indonesian Electric Vehicles Industry Development Gains Momentum", https://indonesien.ahk.de/infothek/news/news-details/indonesian-electric-vehicles-industry-development-gains-momentum.

552 ICCT (2021), "Overview of vehicle fuel efficiency and electrification policies in Indonesia".

incentives, the development of charging infrastructure and electricity rates for BEVs, the compliance with technology-related regulations for BEVs, and the environmental protection. In particular, it provides for a requirement to gradually increase the local procurement rate of raw materials in EV manufacturing for the promotion of electric vehicle-related industries[553]. In October 2019, Government Regulation No. 73/2019 was promulgated, determining the luxury tax rate for electric vehicles. The tax rate for PHEVs, BEVs, and FCEVs is essentially 0%. [554]

Indonesia potentially has an abundance of nickel, an important material for lithium-ion batteries, in the country. To develop the domestic electric vehicle storage battery industry, Indonesia has established a state-owned company called Indonesia Battery Corporation (IBC) in March 2021. IBC's shares are held by four state-owned companies (Pertamina, PLN, Mind ID, and Antam) at 25% each. IBC plans to establish several joint ventures with China's CATL and South Korea's LG Energy Solution to build an electric vehicle battery supply chain in the country, and plans to start producing storage batteries by 2023[555].

In April 2021, the establishment of an Indonesian Electric Vehicle Industry Association (Periklindo) was announced.

[Charging facilities]

In September 2020, the Ministry of Energy and Mineral Resources (MEMR) issued Regulation No. 13/2020 on charging infrastructure for BEVs. The regulation prescribes charging stations, battery swap solutions, and charging fees, and provides for permits, registration and charging station safety[556]. The regulation stipulates that BEV charging will be available at private electric facilities or public electric vehicle charging stations (SPKLUs), while storage battery replacement will take place at public electric vehicle battery replacement stations (SPBKLUs). To promote BEVs, the regulation also recommends that SPKLUs and SPBKLUs be installed in existing facilities (gas stations, shopping malls, government facilities, and public parking lots). In the same regulation, PLN was appointed as the implementing agency for the development of charging infrastructure and was to compile a roadmap for the development of SPKLUs and SPBKLUs. Based on the regulation, PLN plans to install up to 24,720 SPKLUs from 2020 to 2030. PLN also announced the introduction of an app called "Charge.IN" in January 2021, which provides information on SPKLU locations and charging rates[557]. The app can be used to manage and monitor charging at charging stations.

(c) Thailand

In the transport sector, the primary fuel used is petroleum, and most of the primary energy supply of petroleum is consumed in the transportation sector. To reduce dependence on petroleum, the transport sector is working on measures such as fuel efficiency improvement, fuel conversion, and electric vehicle promotion.

[Electric Vehicles]

New services for automobiles, such as MaaS and connected services, are beginning to spread, involving Japanese companies and others. The Thai government is pursuing a plan to make Thailand a

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553 JETRO, 23 August 2019, https://www.jetro.go.jp/biznews/2019/08/6515391d69c6b5c1.html.

554 NNA ASIA, 25 October 2019, https://www.nna.jp/news/show/1965762.

555 Paul Tan, 29 March 2021, "Indonesia closes in on EV battery production goal as state companies unite to form national producer IBC", https://paultan.org/2021/03/29/indonesia-closes-in-on-ev-battery-production-goal-as-state-companies-unite-to-form-national-producer-ibc/.

556 AKSET Law, 8 September 2020, "Minister of Energy and Mineral Resources Sets Ground Rules on Battery Electric Vehicle Charging Infrastructure", https://www.lexology.com/library/detail.aspx?g=aece4a94-399d-4253-bfa0-2d2441707446.

557 PLN, 28 January 2021, "Provide Ease of Electric Vehicle Users, PLN Launches the Charge.IN Application", https://web.pln.co.id/eng/news/press-release/2021/01/beri-kemudahan-pengguna-kendaraan-listrik-pln-luncurkan-aplikasi-chargein; Ministry of Energy and Mineral Resources, 1 February 2021, "Indonesian Govt Supports EV Charging Application", https://www.esdm.go.id/en/media-center/news-archives/indonesian-govt-supports-ev-charging-application.

production base for electric vehicles with the aim of popularizing electric vehicles in the country and expanding exports. In 2021, the number of new electric vehicles registered was 5,781 BEVs, 7,060 PHEVs, and 35,740 HEVs[558].

The National Electric Vehicle Policy Committee (NEVPC) met in March 2021 to discuss policies to promote the production and use of electric vehicles, with the goal of producing a cumulative total of 1,051,000 electric vehicles by 2025, and a cumulative total of 18,413,000 electric vehicles (cars, pickup trucks, motorcycles, buses and trucks), by 2035. NEVPC's early measures to be pursued include promoting the use of electric vehicles, encouraging the establishment of charging stations and battery test centers, and developing an environmentally friendly battery waste management plan[559]. In addition, at a meeting of the National New Generation Vehicle Committee, the government determined the deadline for achieving the target of making Thailand a hub for electric vehicles by 2035, and made a setting to increase the percentage of electric vehicles in the domestic vehicle production to 50% by 2030[560]. The Ministry of Energy will work with EGAT, MEA, and PEA to establish smart grids and infrastructure for electric vehicles by 2025[561].

Table 131 Targets for ZEV deployment in Thailand

	Type of Vehicles	Estimated number of ZEV per Year		
		2025	2030	2035
Usage	Passenger cars / Pick up trucks	225,000 (30%)	440,000 (50%)	1,154,000 (100%)
	Motorcycles	360,000 (20%)	650,000 (40%)	1,800,000 (100%)
	Buses	18,000 (20%)	33,000 (35%)	83,000 (100%)
	Tuk Tuks	500 (85%)	2,200 (100%)	2,800 (100%)
	Ships	130 (12%)	480 (35%)	1,800 (100%)
	Rail System	620 (70%)	850 (85%)	1,170 (100%)
Production	Passenger cars / Pick up trucks	225,000 (10%)	725,000 (30%)	1,350,000 (50%)
	Motorcycles	360,000 (20%)	675,000 (30%)	1,850,000 (70%)
	Buses	18,000 (35%)	34,000 (50%)	84,000 (85%)
	Tuk Tuks	500 (85%)	2,200 (100%)	2,800 (100%)
	Ships	130 (12%)	480 (35%)	1,800 (100%)
	Rail System	620 (100%)	850 (100%)	1,170 (100%)

Source: EVAT

Energy Absolute, which is involved in renewable energy projects as well as electric vehicle-related projects, opened a battery and energy storage system production facility in December 2021. The facility will be located in Chachoengsao Province in the Eastern Economic Corridor and will be able to expand the production capacity for lithium-ion batteries to 50 GWh per year. In addition to producing lithium-ion batteries, the facility also has its own recycling facility. [562] SAIC Motor-CP, a joint venture between SAIC Motor (China) and CP Group (Thailand), has announced a plan to build a storage battery plant for BEVs in Thailand, and will also conduct a feasibility study for a storage battery recycling plant[563].

In February 2022, at a cabinet meeting, the government approved an incentive package to promote

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558 EVAT, "Thailand Electric Vehicle Current Status As of December 2021".

559 JETRO, 30 March 2021, https://www.jetro.go.jp/biznews/2021/03/e9f8ef14f352bbd9.html.

560 Bangkok Post, "Govt ups E-car drive", 25 March 2021, https://www.bangkokpost.com/business/2089087/govt-ups-e-car-drive, Royal Thai Government, https://www.thaigov.go.th/news/contents/details/40325.

561 Nation Thailand, "Energy Ministry has sights on manufacturing 225,000 EVs per year by 2025", 30 June 2021, https://www.nationthailand.com/in-focus/40002624.

562 Bangkok Post, "New battery plant 'crucial' for EV work", 13 December 2021, https://www.bangkokpost.com/thailand/general/2230711/new-battery-plant-crucial-for-ev-work.

563 NNA ASIA, 20 January 2022, https://www.nna.jp/news/show/2288678.

consumption and production of electric vehicles in 2022-2023. The government approved a THB 3 billion contribution from the national budget for FY2022 to provide subsidies, and agreed in principle to contribute THB 40 billion from FY2023 to FY2025 to promote the spread of electric vehicles. The package includes the following. [564]

- The subsidy for the purchase of electric vehicles will range from 70,000 baht to 150,000 baht, depending on the type of vehicle.
- The excise tax rate for electric vehicles will be reduced from 8% to 2%, and 0% for electric pickup trucks.
- Import tariffs on electric vehicles (complete vehicles) will be reduced by up to 40% until 2023. To qualify for the reduced import duties, automakers must produce three electric vehicles domestically for every two imported vehicles until 2024 (deadline may be extended to 2025). If the retail price of the imported electric vehicle is less than 2 million baht, any model of electric vehicle that the automaker produces in the country is acceptable. However, if an expensive model is imported, the automaker must produce the same model domestically.

[Charging facilities]

According to EVAT, as of December 2021, there were approximately 693 electric vehicle charging stations in the country, with 1,511 regular charging facilities and 774 quick charging facilities installed[565]. The Energy Policy and Planning Office (EPPO) aims to install 12,000 charging stations for passenger cars and pickup trucks, and 1,450 battery swap stations for electric motorcycles used by cab and delivery businesses, by 2030.

In order to spread charging facilities, the Metropolitan Electricity Authority (MEA) of Thailand has reportedly temporarily reduced electricity rates for electric vehicle charging service providers. The special rate will apply to building and land owners from the beginning of 2022, with a wholesale electricity price of 2.6 baht/kWh for two years, reverting to the regular rate in the third year. MEA has budgeted 30 million baht for this scheme and expects 100 chargers to be installed by the end of 2022. [566]

As a corporate move, PTT Oil and Retail (OR), an affiliate of oil giant PTT, announced that it would strengthen its partnership with EVLOMO (USA) to install a charging station equipped with 150 kW super-fast chargers at OR's 100 gas stations in the Eastern Economic Corridor region[567]. In addition, Banpu NEXT and EVolt Technology have partnered with each other in expanding the charging network, and will install 5,000 charging stations across the country by 2025 as part of Banpu NEXT's MaaS concept[568].

[Public Transit Improvement Policy]

The Ministry of Transportation has implemented policies for the electrification of buses, ships, and railroads.

The Department of Land Transport promotes EV Buses, approving EV Bus routes and revising or developing related regulations. The main implementers include the Bangkok Mass Transit Authority

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[564] Bangkok Post, "State pumps billions into green cars", 16 February 2022, https://www.bangkokpost.com/business/2264751/state-pumps-billions-into-green-cars; Nation Thailand, "Cabinet gives green light to EV promotion package", 15 February 2022, https://www.nationthailand.com/business/40012375; Royal Thai Government, 15 February 2022, https://www.thaigov.go.th/news/contents/details/51583.

[565] EVAT, "Number of Electric Vehicle Charging Stations in Thailand (Data as of 22 September 2021)".

[566] Bangkok Post, "Initiative to develop EV ecosystem", 8 December 2021, https://www.bangkokpost.com/auto/news/2228319/initiative-to-develop-ev-ecosystem.

[567] EVLOMO, "OR and EVLOMO to collaborate further for rolling out 150kW DC Super-Fast Charging stations at about 100 PTT Stations in Thailand.", 31 January 2022, https://www.evlomo.com/blog/or-and-evlomo-to-collaborate-further-for-rolling-out-150kw-dc-super-fast-charging-stations-at-about-100-ptt-stations-in-thailand.

[568] Banpu NEXT, "EVolt Technology joins hands with Banpu NEXT to close investment deal to expand its EV charger management platform", 5 November 2021, https://www.banpunext.co.th/en/news-updates/evolt-technology-joins-hands-with-banpu-next-to-close-investment-deal-to-expand-its-ev-charger-management-platform.

(BMTA) and The Transport co., ltd, both of which have plans to replace conventional buses with EV Buses. BMTA plans replacement of 2,511 vehicles, and 1,500 vehicles under an operation contract between BMTA and a private company, and The Transport co., ltd. plans replacement of 401 vehicles.

The Marine Department is promoting EV Boats, and in addition to research and development of EV Boats, it is revising or formulating related regulations. In 2021, a total of 23 EV Boats became available on four rivers and one on the ocean. In 2022, additional 28 EV Boats are scheduled to be introduced on rivers.

The Department of Rail Transport and the State Railway of Thailand (SRT) will play a central role in promoting train electrification. In 2021, the Rail Transport Authority and SRT developed a timeline for electrification of long-distance trains, examined a feasibility study on the use of storage batteries for long-distance trains, established a Research and Development Institute for Railway System Technology, and signed a memorandum with research institutions for the development of electrification technology. Going forward, SRT plans to conduct a feasibility study in 2022, and a prototype project for electrification of trains with storage batteries in 2023.

The Ministry of Transportation is in the process of developing an MOT EV Development Plan (2022-2037). This is a roadmap for electrification of public transit (land, water, and rail), with the goals of replacing internal combustion engine buses with EV Buses (4,412 units) by 2027 and replacing 50 conventional trains with electric trains by 2027.

(d) Morocco

As of 2019, 99% of final energy consumption was accounted for by petroleum and the remaining 1% by electricity. The demand for automobile petroleum is growing fast, and that will become a risk factor for Morocco's energy supply and climate change if measures, such as the introduction of alternative fuel vehicles, improvement of public transit, and encouragement of modal shift, as well as the improvement of fuel efficiency of automobiles, are not taken.

A National Strategy for Developing the Competitiveness of Logistics of Morocco has set goals to reduce energy consumption, promote multimodal transportation, and switch to less air polluting modes by 2030[569].

With the support of GIZ, the Ministry of Equipment, Transport, Logistics and Water (METLW) (now split into the Ministry of Equipment and Water and the Ministry of Transport and Logistics) has developed a national roadmap for sustainable mobility. In November 2018, METLW (at that time) published a draft roadmap, noting nine roadmap elements[570][571]. METLW also partnered with UNDP and received financial support from the Global Environment Facility to implement a four-year technical assistance project starting in March 2016. Key activities include organizational strengthening and capacity building for low-carbon development in the transport sector, training of eco-driving trainers, studies on GHG emissions from rail and road logistics vehicles, and design and implementation of inventories.

The Institute for Research into Solar and Renewable Energies (IRESEN) is investigating matters such as the integration of renewable energy into charging networks and the impact of local conditions on the charging process. An example of IRESEN's projects is a Green MILES Program, which aims to develop business models for electric vehicles, charging networks, recharging services and MaaS. IRESEN has also formed a team of experts with Mohammed VI Polytechnic University and others, and the team pursuing a study on the recycling of on-board storage batteries. A research facility is under construction in the Green Park and will conduct activities such as research on issues in the future.

Regarding public transit and railroads, the government is investing in trams in major cities

569 IEA (2019) “Energy Policies beyond IEA Countries: Morocco 2019”, pp.64-68.

570 Integrated urban transformation, Low carbon energy, Optimization the efficiency of modes and systems, Join up and shorten supply chains, Reduce unnecessary travel, Solutions adapted to the rural world, Construction and adaptation of infrastructure, Regulatory and financial tools, Road safety.

571 Ministry of Equipment, Transport, Logistics and Water (2018), “Project: Roadmap for Sustainable Mobility in Morocco”.

(planning to extend trams in Casablanca and Rabat; also mentioned in a Programme for the Improvement of Urban Public Transport). It also plans to construct a high-speed rail network between cities. In Marrakish, the government is conducting a demonstration project for electric buses.

Morocco prohibits the importation of vehicles five years or older in order to reduce emissions and improve vehicle efficiency. A grant program also exist to assist in updating cab fleets. The government assists with energy efficiency audits conducted by cab companies and others, and is conducting an education and training program (eco-driving) for professional drivers. Tire labeling is being pursued as an energy conservation measure.

Challenges for e-mobility in Morocco include the development of power grid infrastructure to enable quick charging in towns and at gas stations, legislation for the operation of charging stations, and domestic production and recycling of storage batteries. In the "EV Roadmap I," published by CGEM (Confédération Générale des Entreprises du Maroc) in December 2021, the period from 2022 to 2035 is divided into three phases, and matters that should be addressed in areas: "Value chain," "Governance," "Regulatory framework," "Incentives," and "Next steps EV and Charging," are outlined. The roadmap projects that in terms of the market share of EVs in new vehicle sales, that of two- and three-wheelers will reach 50% by 2025 and 100% by 2030, and that of urban buses and cabs will reach 50% around 2025 and 100% in Phase III. The main initiatives at each phase are as follows

Phase I (2022-2025): EV and charger manufacturing; formalization of charging services, norms, standards; setting mandatory targets for bus and public procurement; introduction of tax breaks, green loans, and subsidies; introduction of initial fast charging networks, etc.

Phase II (2025-2030): Battery production, review of incentives, installation of public charging facilities in major cities, etc.

Phase III (2030-): Reuse and recycling of batteries; installing public charging facilities in all cities, etc.

(iii) Advantages and strengths of Japanese companies

Table 132 Advantages, strengths and issues of Japanese companies

Advantages and strengths of Japanese companies	Current Issues	Others (future measures, business models, etc.)
[Storage battery] - Japan's advantage is in quality (safety and energy density)	- Japan is weak in cost and production capacity. - Another weakness is the lack of a market in Japan. - When it comes to storage batteries alone, Japan cannot win a price competition with China and South Korea. - It is difficult for manufacturers to perform installation and grid connection works in foreign countries.	- As bringing Japanese-style quality control to emerging countries will be excessive performance, Japanese companies should aim to secure long-term competitiveness by anticipating secondary (and even tertiary) use of their products. - In order to create a market for storage batteries, it is necessary to create indicators that enable the evaluation of deterioration (of storage batteries) and to build a distribution channel. - When aiming for VPP or V2X, it is necessary to conduct a social

		demonstration to see if a large number of small-scale storage batteries can be collected and used as a power supply.
[Charging facilities] - The CHAdeMO standard led by Japanese companies does not include merchantability, but only guarantees interchangeability. Can assist in localization.	- The challenge is that (in India, as an example), although control of the entire grid is necessary, the necessary regulations are not currently in place.	- China and Japan will cooperate to seize the Asian market. - Regarding quick chargers, considering the current situation and needs of emerging countries, it would be desirable to maintain safety and install a large number of quick chargers, even in exchange for a reduced output.
[Fuel Cell Vehicles] - The advantage of Mirai is that the filling pressure is 70 megapascals. This is twice the consumer use, and doubles the cruising range.	- If we do not promote standardization in the world, we will not have an advantage. - Hydrogen-related infrastructure is not yet in place.	- As efforts toward carbon neutrality intensify, the use of fuel cells in heavy-duty vehicles is a possibility, based on the premise that clean hydrogen can be produced.

The advantage of Japanese companies lies in the safety and quality of their products. However, their performance may be excessive as compared to local needs, and they may be inferior to those of Chinese and Korean firms in terms of price competition. Therefore, long-term competitiveness of storage batteries and fuel cells must be secured. In the countries surveyed, initial-stage efforts are underway to expand the use of electric vehicles first, but in the future, they will be required to aggregate storage batteries, and utilize and control them, as with VPP projects. This is an area in which demonstration projects are underway also in Japan and other developed countries. Although the competition with Europe and U.S. is tough, the technical elements required for VPP projects and future V2X utilization, as well as knowledge on the development of existing and new regulations and legal systems, will be a strength for Japan.

（３） Industry

(i) Trends in the development and social implementation of technologies and services worldwide

According to the IEA, global energy-derived CO2 emissions from the industrial sector in 2019 were 6,254 million ton-CO2, of which 4,883 million ton-CO2 emissions were from the manufacturing sector, which accounted for 78% of the total CO2 emissions from the industrial sector. The figure below shows the shares of CO2 emissions by category of business in the manufacturing sector in 2019. Steel accounted for the largest share at 2,172 Mt-CO2 (36% share), followed by ceramics, stone and clay (mainly cement) at 1,148 Mt-CO2 (19% share), and chemical and petrochemical at 819 Mt-CO2 (14% share). These three categories of business accounted for 69% of the total CO2 emissions of the entire manufacturing industry. Therefore, concerning the industrial sector, this paper looks at the trends of technologies for low-carbon and decarbonization in these three categories.

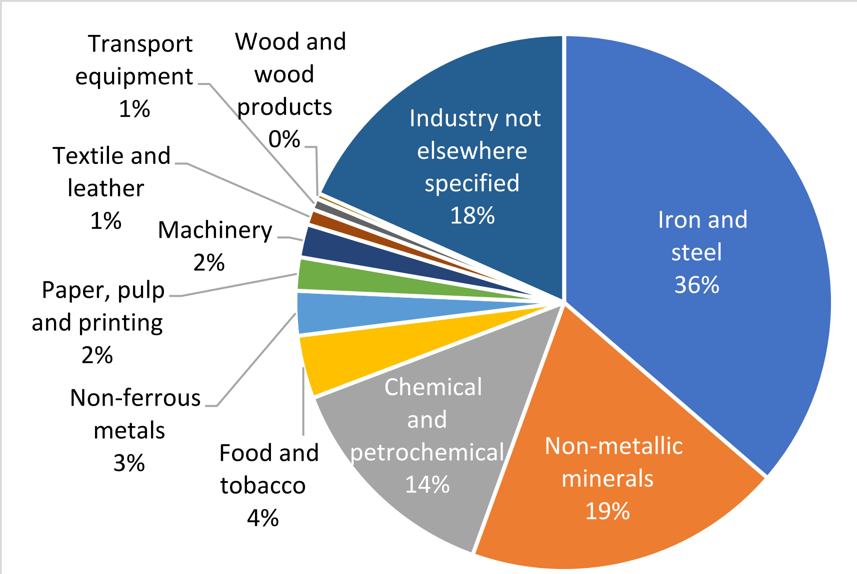

Figure 213　Share of CO2 Emissions by Sub-sector in Indutry Sector (2019)
Source: IEA, CO2 emission from fuel combustion 2021

The figure below shows the shares of global industrial sectors in consumptions by energies in 2019. Fossil fuels, which produce CO2 during combustion, account for 58% of the final energy consumption in the industrial sector, 75% in the steel industry, 82% in the ceramics, stone and clay industry, and 61% in the chemical and petrochemical industry. The share of coal, which represents the highest CO2 emissions among the fossil fuels, is particularly high, at 62% in the steel industry and 54% in the ceramics, stone and clay industry. In the chemical and petrochemical industry, coal has a 15% share, while oil and natural gas have a 13% and 33% share, respectively. This is because naphtha and natural gas are used as raw materials for petrochemical products in the petrochemical industry.

Therefore, to achieve low or zero carbon in the industrial sector, it is important to reduce the consumptions of fossil fuels, especially coal.

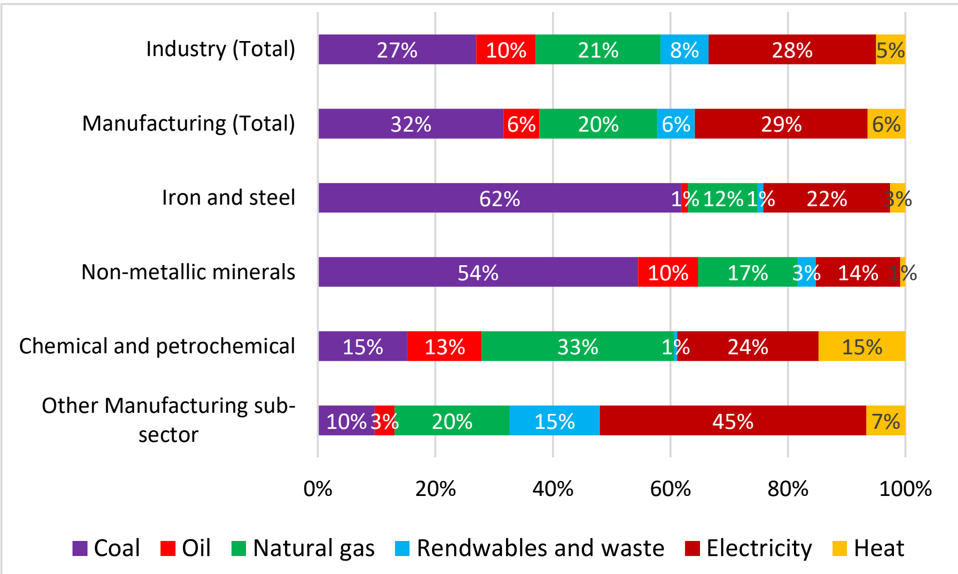

Figure 214　Share of Energy Consumption by Sub-sector by Energy in Industry Sector (2019)
Source: IEA, World Energy Balances 2021

In the meantime, heavy industries such as manufacturing of steel, cement, and chemical and petrochemical products have their own difficulties in reducing CO_2 emissions. Specifically,

- ✓ Requiring high-temperature heat: Many of the processes for manufacturing steel, cement, and chemical/petrochemical products require high-temperature heat. Currently, fossil fuels are the dominant source of high-temperature heat in heavy industry. Currently, the power generation sector is undergoing a low-carbon transition through the promotion of renewable energy, but producing high-temperature, high-volume heat with electricity is impractical and costly with the current technology. There is also a quantitative limitation because it is not sustainable to use large amounts of carbon-free biomass as a heat source. In addition, carbon capture, utilization, and storage (CCUS) and hydrogen technologies can reduce CO_2 emissions while using fossil fuels, but industrial applications of these technologies are often still in the early stages of development.
- ✓ Emissions from manufacturing processes: In the production process for some products, chemical reactions produce CO_2. A major example is CO_2 resulting from the calcination reaction required to produce clinker, the raw material for cement. Reducing CO_2 emissions from the production process for a product requires a structural transition to CCUS, or to a method involving a variety of raw materials, from conventional manufacturing processes.
- ✓ Long-term capital assets: A typical industrial plant has a life of 30-40 years, which is quite long. Prematurely decommissioning a plant in order to switch to a new technology incurs very large costs. Therefore, emissions from recently constructed plants can be considered "locked-in" unless options are available to retrofit or adapt them to reduce emissions intensity.
- ✓ International competition: Many industrial products, such as steel, are traded in highly competitive global markets. Thus, the adoption of more expensive production processes by individual producers to reduce emissions will result in higher costs. Thus, internationally traded industrial products have low profit margins, making it difficult to invest heavily in low-carbon technologies.

Steel industry

The steel industry is a typical energy-intensive industry: in 2019, the global steel industry consumed 524 million metric tons of oil equivalent (Mtoe) of energy, accounting for 18% of the industrial sector's energy consumption and 5% of its final energy consumption. In 2019, coal, natural gas, and electricity accounted for 62%, 12%, and 22% of the global steel industry's energy sources, respectively (see figure above). Energy is said to account for 10-25% of the total steel production cost.

The figure below shows a typical steel production flow diagram containing a blast furnace.

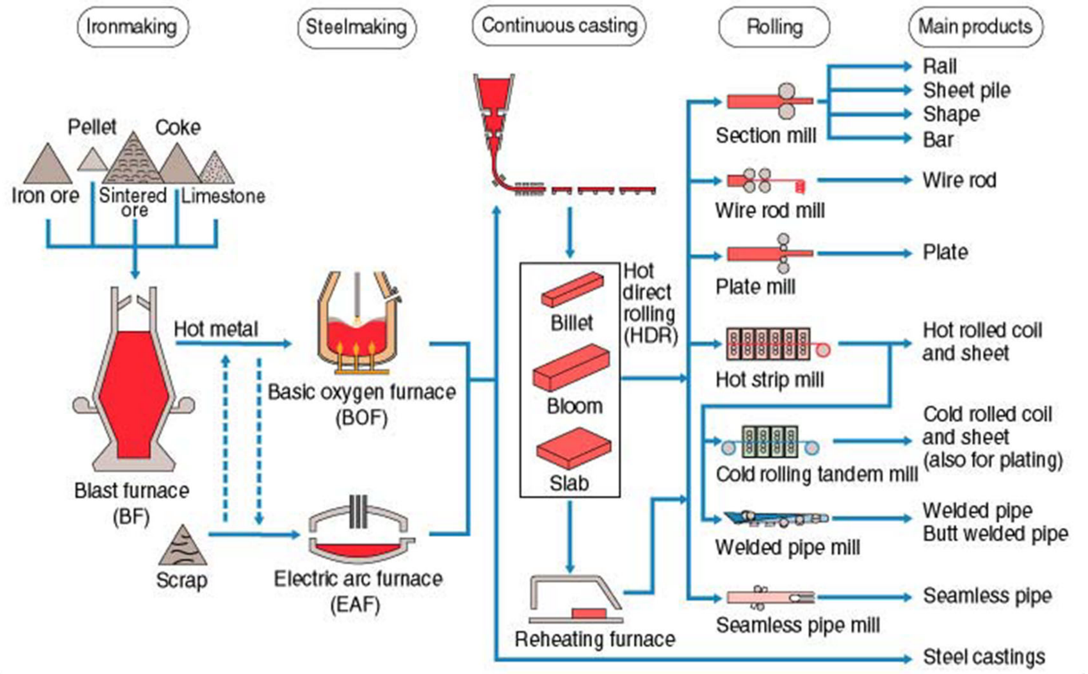

Figure 215 Steel Production Flow

Source: JFE[572]

The CO2 intensity of steel production is high, with an average of about 1.4 tons of CO2 emitted directly from one ton of crude steel, and 2.0 tons of CO2 emitted when emissions from purchased electricity and heat production are included. According to the IEA, lime and graphite (graphite for anodes of electric furnaces) required for steel production, along with ferroalloy production, account for 11% of the steel industry's CO2 emissions in the form of process emissions. In 2019, the global steel industry's direct CO2 emissions reached 2.6 gigatons. This accounted for 7% of energy-derived CO2 emissions and 28% of the industrial sector's CO2 emissions. In addition, if indirect emissions from purchased electricity and heat production (including electricity and heat produced at plants using off-gas, and purchased electricity and fuels) are included, total emissions would be approximately 3.6 gigatons.

Steel use is expected to increase in the coming decades, especially for the construction of buildings and infrastructure. Many of the technologies required for net-zero emission energy systems, such as rail infrastructure, wind turbines, CCUS equipment, and nuclear power plants, utilize large amounts of steel. In other words, steel needs energy, and energy systems need steel. The figure below shows the IEA's outlook for world steel production and use by application. In 2019, an average of about 240 kg of steel per capita was produced globally. Under the Stated Policy Scenario (standard scenario), this figure is projected to rise to 260 kg by 2050 and 270 kg by 2070.

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572 JFE、http://www.jfe-21st-cf.or.jp/chapter_2/2a_1.html

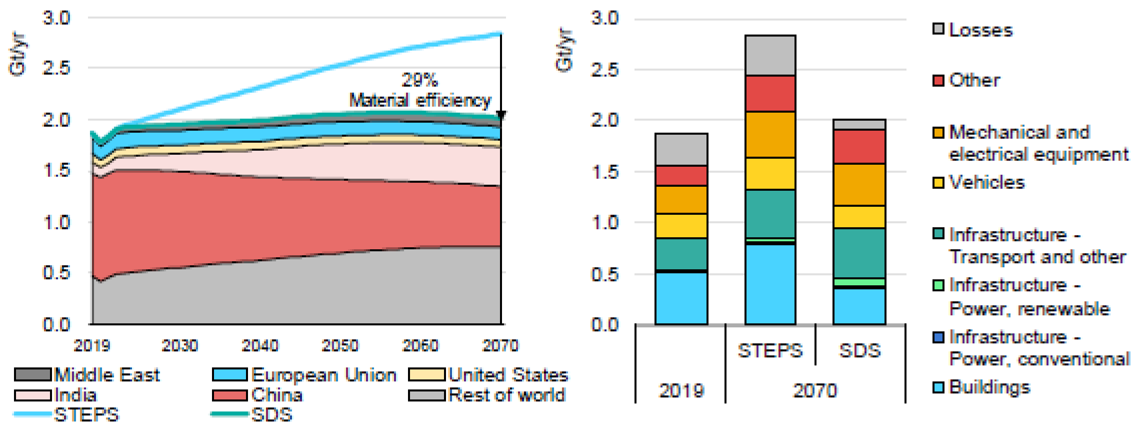

Figure 216 Outlook for Steel Production and Usage by sector in the World

Note: STEPS = Stated Policies Scenario, SDS = Sustainable Development Scenario

Source: IEA, Energy Technology Perspective 2020

The challenges for the steel industry in its low-carbon efforts are as follows.

- ✓ A high share of coal in energy input: Primary production relies heavily on coal (and in some cases natural gas) and coke made from coking coal, and their key role is to serve as a reducing agent in the production of molten iron. While supplying process heat. Innovations are underway in hydrogen-based and electricity-based production, and in production using biomass as part of the fuel, but a complete switch from fossil fuels is technically and economically challenging.
- ✓ Long-term capital assets: The steel industry has a long economic life span and utilizes complex, capital-intensive process equipment. Blast furnaces are typically built to last at least 25 years, and many operate for 40 years or more. Currently, of the 2,300 Mt annual steelmaking capacity, 1,500 Mt is for steel production through the BF-BOF route. More than 90% of the existing BF-BOF steelmaking capacity is still expected to be in operation in 2030, and about 35% could be in operation by 2050. In some cases, carbon capture equipment can be retrofitted to an existing plant, and this is a more economical option than replacing it with a completely new process. However, the current CCUS is not technologically mature.
- ✓ International competition and low margins: Steel products are commodities, traded internationally, and highly competitive, so the economy of steel production is highly dependent on energy costs. Therefore, the steel industry has already invested heavily in reducing the energy intensity of steel production in recent decades, and there is relatively limited room for further energy efficiency improvements in specific processes. In addition, the highly competitive marketplace tends to discourage producers, especially early technology adopters, from adopting breakthrough technologies, as they can significantly increase production costs and undermine competitiveness.

The table below shows trends in low-carbon technologies in the steel industry. The levels of TRL (Technology Readiness Level) shown in the table below are as follows.

TRL 1: Starting point (Concept and area of application have been defined.)
TRL 2: Developing concept and area of application.
TRL 3: An experiment has been carried out that proves the concept.
TRL 4: The technology enters the phase where the concept itself needs to be validated, starting from a prototype developed in a laboratory environment.
TRL 5-6: Testing in the conditions it which it will be deployed.
TRL 7: The technology next moves to the demonstration phase, where it is tested in real-world environments.
TRL 8: The technology has reached a first-of-a-kind commercial demonstration.
TRL 9: Full commercial operation in the relevant environment.
TRL 10: Large scale.

TRL 11: The technology has achieved predictable growth.

Table 133　Trend of New Low-carbon Technologies in the Steel Industry

CCUS

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Blast furnace: offgas hydrogen enrichment and/or CO2 removal for use or storage	5	2030 (Very high)	・Japan's COURSE 50 project has completed the first experimental testing phase; the second phase aims to reach full commercial scale by 2030; it can be deployed with CCUS (JISF, 2011). • Top gas recycling using vacuum pressure swing absorption proven in an experimental blast furnace under ULCOS (EC, 2014). Concepts being further developed at the ArcelorMittal site in Dunkirk, France. IGAR project testing reforming with plasma torches, with a lab-scale pilot successfully completed in 2017 and an industrial-scale demonstration likely to be completed by 2025-27. The "3D" project launched in mid-2019 by a consortium of 11 stakeholders will test amine-based carbon capture for blast furnace process gases, aiming for pilot scale (4 kt/yr CO2) by 2021 and industrial scale (1 Mt/yr CO2) by 2025. Final arrangement would feed plasma torches with recovered CO2 from process gases. (ArcelorMittal, 2019a; 2019b; 2017). • The ROGESA pilot is testing H2-rich coke oven gas in a blast furnace in Germany, with implementation in two blast furnaces expected as early as 2020 (Saarstahl, 2019). • The STEPWISE project is piloting a technology in Sweden to decarbonise blast furnace gas for use in power production (14 t/day CO2 removal) (STEPWISE, 2020).
Blast furnace: Converting off-gases to fuels	8	Today (Medium)	・The first commercial plant began in 2018 in China by Lanza Tech, Shougang Group and TangMing; it produced 30 million litres of ethanol for sale in its first year of operation (Lanzatech, 2018; 2019). A second large-scale plant is under construction in Ghent, Belgium under the Steelanol/Carbalyst project by ArcelorMittal and Lanzatech, to be completed by early 2021 and with a capacity of 80 million litres of ethanol (ArcelorMittal, 2019a). • The FReSMe project, by a consortium of European partners, is piloting steel off-gas conversion to methanol (1 t/day); it builds on research from the STEPWISE project on CO2 capture and the MefCO2 project on producing methanol from CO2 (FReSMe, 2020; EC, 2019).
Blast furnace: Converting off-gases to chemicals	7	2025 (Medium)	• The Carbon2Chem pilot plant in Germany initiated by thyssenkrupp in 2018 has produced ammonia and methanol from steel off-gases; it is aiming for an industrial-scale plant by 2025 (thyssenkrupp, 2020a; 2020b). • Carbon4PUR, a project by a consortium of 11 partners across Europe, is piloting converting steel off-gases to polyurethane foams and coatings (20 t/yr) (Carbon4Pur, 2020).
DRI: Natural gas-based with CO2 capture	9	Today (Very high)	・Operating plant since 2016 in Abu Dhabi with 0.8 Mt/yr of CO2 capture capacity, with CO2 used for enhanced oil recovery at nearby oilfield (ADNOC, 2017). • Two plants of Ternium in Mexico operating since 2008 capturing 5% of emissions (0.15-0.20 Mt/yr combined) for use in the beverage industry, with planning underway to upscale capture capacity (Ternium, 2018). • Commercial Finmet plant since 1998 at Orinoco Iron, Venezuela with aminebased CO2 separation achieving close to 100% CO2 concentrations as an integral part of the process, but captured CO2 is not currently used or stored.
Smelting reduction: with CCUS	7	2028 (Very high)	・Developed by the ULCOS consortium, the HIsarna pilot plant is currently operating at a Tata Steel plant in Ijmuiden, Netherlands (60 kt steel produced, CCS not yet implemented) (Tata Steel, 2017); a demonstration scale (0.5

			Mt/yr) plant (TRL8) is expected in 2023-27 in India and an industrial scale (1.5 Mt/yr) plant with CCS (TRL 9) is targeted in the Netherlands in 2027-33. • Initial testing of amine-based CO2 scrubbing in FINEX plant (Primetals, 2020).

Hydrogen

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Blast furnace: Electrolytic H2 blending	7	2025 (Medium)	Since 2019, thyssenkrupp has been testing the use of hydrogen in a blast furnace in Germany, replacing a portion of injected coal (thyssenkrupp, 2019).
DRI: Natural gas-based with high levels of electrolytic H2 blending	7	2030 (High)	• In the 1990s, Tenova tested 90% hydrogen use in Mexico (scale of 9kt/yr DRI production) (Tenova, 2018). • Salzgitter steelworks is undertaking MW-scale electrolyser demonstration in Germany and conducting a feasibility study for integrating a hydrogen DRI plant into the existing site, as part of the SALCOS project (SALCOS, 2019). • thyssenkrupp is planning to build commercial DRI plants incorporating hydrogen by the mid-2020s (thyssenkrupp, 2020b).
DRI: Based solely on electrolytic H2	5	2030 (Very high)	• Pilot plant began operation in August 2020 in Sweden as part of the HYBRIT project; targeting a 1 Mt/yr demo plant by 2025 (HYBRIT, 2020). • Pilot plant under design also in Hamburg lead by ArcelorMittal, to be built by 2030 (ArcelorMittal, 2019c). • Thyssenkrupp is also planning to transition towards eventually full hydrogen reduction (thyssenkrupp, 2020b).
Smelting reduction: H2 plasma reduction	4	- (Medium)	・SuSteel research project at voestalpine plant in Austria; currently in the process of upscaling a 100 g reactor to 50 kg batch operation, aiming for commissioning in 2020 (K1MET, 2018; Primetals, 2019). • Flash Ironmaking Technology under development at the University of Utah, with a mini pilot reactor commissioned (Sohn et al., 2017).
Ancillary processes: H2 for high-temperature heat	5	2025 (High)	• In early 2020, Ovako and Linde completed a successful trial of using hydrogen to heat steel before rolling in Sweden (Ovako, 2020). • CELSA (a recycled steel producer), Statkraft and Mo industrial park in Norway signed an agreement in mid-2020 to produce hydrogen to replace fossil fuels used in steel production (Statkraft, 2020).

Direct electrification

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Electrolysis: Lowtemperature alkaline	4	- (Mwdium)	Siderwin project building on the ULCOWIN process (electrowinning), previously developed by the ULCOS programme; working towards developing a pilot-scale plant by the end of 2020 (Siderwin, 2019).
Electrolysis: High-temperature molten oxide	4	- (Mwdium)	• ULCOS proposed a concept called MIDEIO during its 2004-12 work programme (Wiencke et al., 2018). • Research at Massachusetts Institute of Technology led to the founding of Boston Metal, which commissioned the first prototype cell in 2014 (more than 1 t of metal produced); now aiming for pilot-scale size plant (Boston Metal, 2019).

Bioenergy

Technology	TRL	Year available (importance	Deployment status

		for net-zero emissions)	
Blast furnace: Torrefied biomass	7	2025 (Medium)	The Torero partnership project is testing the use of bio-coal (torrefied waste wood) to partially substitute coal in ArcelorMittal's plant in Ghent, Belgium; the large-scale demonstration is expected to be operational by the end of 2020 (ArcelorMittal, 2019a).
Blast furnace: Charcoal	10	Today (Medium)	Charcoal is currently being used commercially to substitute for a portion of the coal used in blast furnaces, primarily in Brazil. Some development continues to further optimise charcoal production to improve its product specifications for steel production.

Note: TRL = Technology Readiness Level
Source: Energy Technology Perspectives 2020, IEA

[Low Carbon Technology Trends in the Steel Industry in Japan]

The most recent low-carbon technology trends in the steel industry in Japan include the following.

✓ Technology for fixation of carbon dioxide into carbonate

Carbonate is a general term for ionic crystalline substances containing carbonate ion (CO_3^{2-}). Calcium carbonate, a compound of calcium, is a typical carbonate and is the main component of limestone used as a raw and secondary material in the steel and cement manufacturing processes.

In April 2020, JFE Steel, Taiheiyo Cement, and the Research Institute of Innovative Technology for the Earth (RITE) announced the establishment of a study group to collaborate mainly in 1) developing a technology to capture CO2 emitted from factories, etc. into carbonates, which are a stable compound, through a reaction with it by utilizing alkaline earth metals that are extracted from materials such as steel slag and waste concrete in a wet process, and 2) develop a technology to effectively utilize the carbonates produced. Centering on a highly efficient CO2 carbonate fixation technology that utilizes steel slag generated in the steel industry, and waste concrete, ready-mixed concrete sludge and coal ash generated in the cement concrete industry, this initiative aims to realize practical application of the technology and optimal utilization of the generated carbonates.

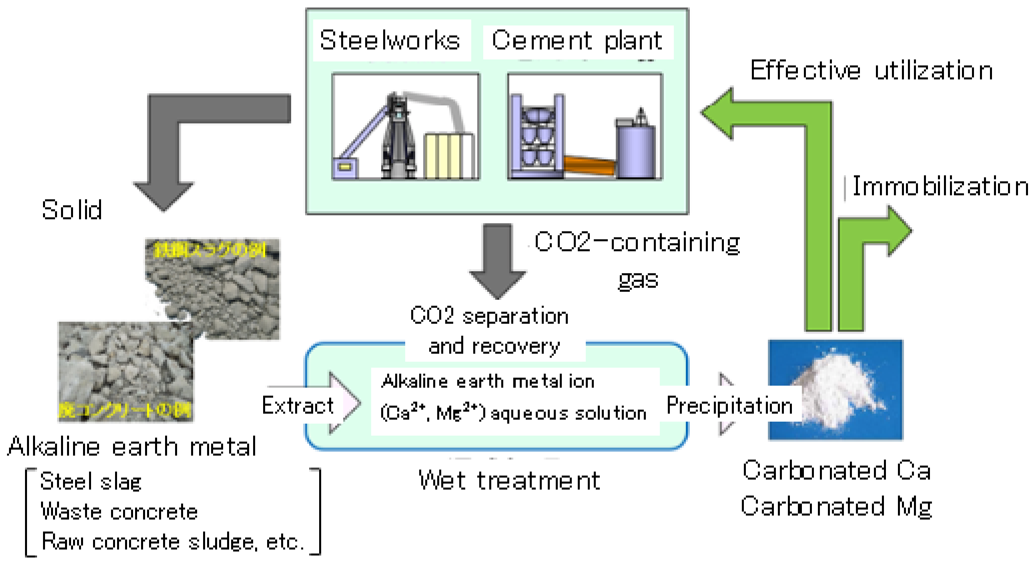

Figure 217 CO2 Carbonate Fixing Technology and Carbonate Effective Utilization Technology
Source: JFE Steel

Cement industry

The global ceramics, stone and clay industry, including the cement industry, consumed 378 Mtoe of energy in 2019, accounting for 13% of the industrial sector's energy consumption and 4% of its final energy consumption. In 2019, coal accounted for 54% of the global steel industry's energy sources, oil for 10%, natural gas for 17%, and electricity for 14% (see Figure 214).

The figure below shows a flow diagram of a typical cement production process.

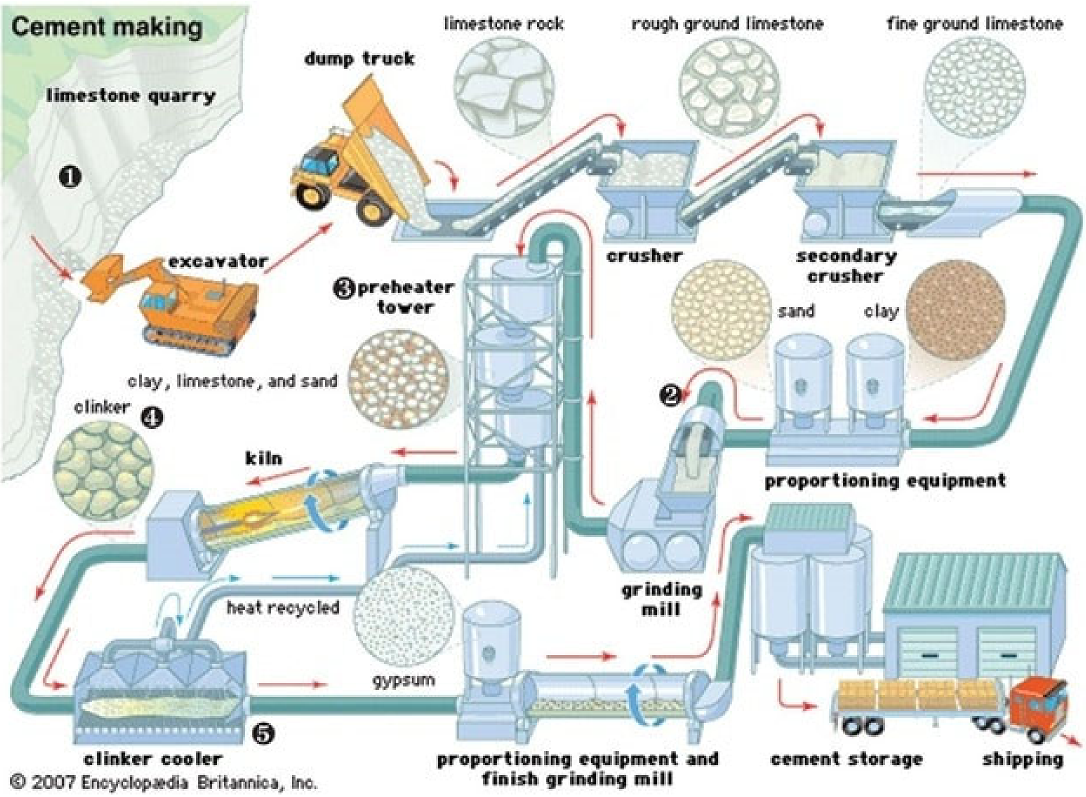

Figure 218 Typical Cement Production Process

Source: The Constructor[573]

To produce cement, a large amount of energy is required for a process that produces a lumpy substance called clinker from a mixture of limestone and clay in the kiln. Clinker is mixed with gypsum, slag, fly ash, limestone, etc., and then ground to fine powder. On average, about 2.8 GJ of energy is required to produce one ton of cement, and the energy cost typically accounts for about 15-40% of the total cement production cost. The production of one ton of cement emits 0.5-0.6 tons of CO_2 on average. According to the IEA, in 2019, the cement industry consumed 280 Mtoe of energy and emitted 2.4 Gt of CO_2. About two-thirds of these emissions are process emissions.

Since cement is essential for the construction of all types of buildings and infrastructure, including facilities in the energy sector, the demand for cement depends on economic activity and local economic development conditions. The figure below shows the IEA's outlook for the global cement production and use by application. Although the spread of the new coronavirus is expected to reduce the demand by about 4% in 2020, the cement demand is projected to continue to increase over the long term, especially in emerging economies where population growth is driving the infrastructure demand. In more advanced developing countries that are already highly industrialized, such as China, the demand for cement has already stabilized and is beginning to decline as the huge wave of construction in recent years recedes. In developed countries, the demand is much lower because cement is used

[573] https://theconstructor.org/building/manufacture-of-cement/13709/

primarily to maintain existing infrastructure facilities and replace them when they become irreparable.

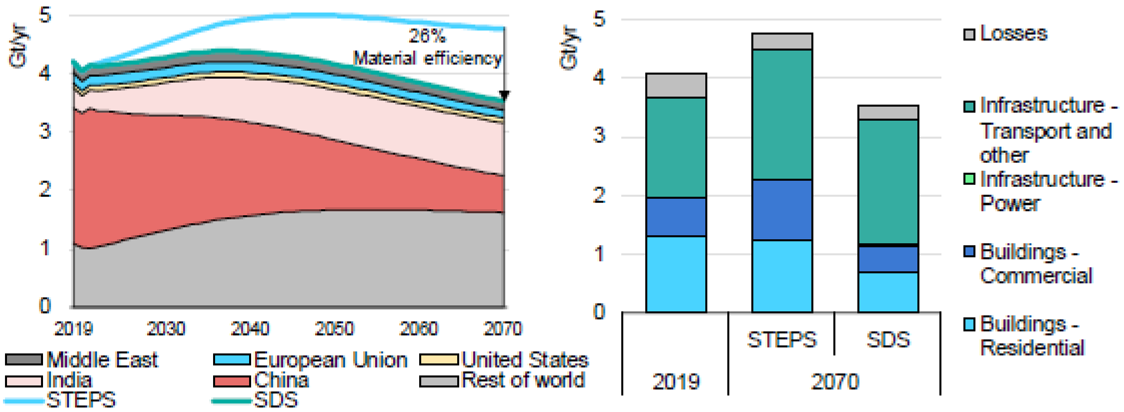

Figure 219 Outlook for Global Cement Production and Usage by Sector

Note: STEPS = Stated Policies Scenario, SDS = Sustainable Development Scenario
Source: IEA, Energy Technology Perspective 2020

The challenges for the cement industry in addressing low-carbon transition are as follows.

- ✓ Process emissions: Direct emissions from cement production occur in a chemical process called calcination, which occurs when limestone, which is made of calcium carbonate ($CaCO_3$), is heated and decomposed into calcium oxide (CaO) and CO2. Therefore, reductions can only be achieved by a) capturing and ultimately storing CO_2, b) blending it with other cementitious materials (such as fly ash or blast furnace slag) to reduce the clinker requirement, and c) using limestone substitutes to produce binding agents. These technologies are still in the pre-commercialization stage or, in the case of the latter two options, the technologies are restricted by building regulations in many countries.
- ✓ Fossil fuel-based processes: Clinker production processes are very energy intensive and tend to rely heavily on coal, which is generally the cheapest energy source. Alternative fuels such as bioenergy and waste are options, but the availability of sustainable biomasses is limited and it competes with other end uses. By contrast, the CO2 footprint of non-renewable energy waste is very fluctuating. In some cases, emissions from non-renewable energy waste are higher than those from coal. Given the high temperatures, large amounts of energy, and technical requirements of the kilns, switching to direct heating from direct electrification, hydrogen, or concentrated solar would be technically difficult and very costly. Some works in the switching options are underway, but are in the early stages of development.
- ✓ Regional constraints: Cement plants are geographically very dispersed, often near the source of raw material supply or the center of the cement demand. Cement plants typically use locally available energy resources. This may mean limited access to cost-effective low-carbon fuels (e.g., biomass). Furthermore, in areas where cement substitutes are difficult to obtain, reducing the clinker/cement ratio would lessen the potential for emissions reduction. While cement is less internationally traded than chemicals or steel, clinker can be traded to some extent, which means that significant cost increases could undermine competitiveness.
- ✓ Long-term capital assets: The long lifespan of cement plants hinders the pace at which they can be rebuilt into low-carbon plants through scrap-and-build.

The table below shows trends in low-carbon technologies in the cement industry.

Table 134 Trend of New Low-carbon Technologies in the Cement Industry

CCUS

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Chemical absorption (partial capture rates, <20%)	8	Today (Medium)	• Commercial facility opened in 2014 at Capitol Aggregates plant in Texas, capturing 15% of emissions (75 ktCO2/yr) for use in materials like baking soda, bleach and hydrochloric acid (Capitol Aggregates, 2020; Global Cement, 2014).
Chemical absorption (full capture rates)	7	2024 (Very high)	• Successful industrial-scale feasibility study in 2016 at the Norcem plant in Norway; operations of full-scale plant (0.4 MtCO2/yr) expected in 2023/24 (Norcem, 2020). • Industrial-scale feasibility study being conducted at the Lehigh Cement plant in Canada (0.6 MtCO2/yr) (Lehigh Hanson, 2019; Voorhis, 2019). • Dalmia Cement will undertake large-scale demonstration (0.5 MtCO2/yr) at plant in India (Perilli, 2019). • Anhui Conch pilot plant (50 ktCO2/yr) began operation in 2018 in China (Global CCS Institute, 2018b).
Calcium looping	7	2025 (Very high)	• Testing at Heping Plant by Taiwan Cement since 2017, pilot-scale trials successfully completed; aiming for commercial scale (0.45 MtCO2/yr) by 2025 (Taiwan Cement, 2020; Cemnet, 2019). • Pilot-scale demonstration completed by CEMCAP in Germany; precommercial retrofit demonstration (1.3 Mt cement/yr) in Italy by CLEANKER project expected to begin in 2020 (Buzzi Unicem, 2019; Hornberger, Sporal and Scheffknecht, 2017; Jordal, 2018).
Oxy-fuel	6	2030 (High)	• Successful pilot in kiln precalciner in Denmark (Davison, 2014). • The European Cement Research Association aims to develop oxy-fueling; however, its two proposed pilot plants appear to be on hold due to funding challenges (ECRA, 2020a). • A joint research initiative by four European cement producers, formed in late 2019, is planning to build a semi-industrial oxy-fuel test facility in Germany (Beumelburg, 2019).
Novel physical adsorption (using silica or organic-based adsorption)	6	2035 (High)	• The CO2MENT project in Canada launched trials in 2019 of Svante's CO2 capture technology at a LafargeHolcim cement plant; it will trial using the CO2 for low-carbon fuels and concrete (LafargeHolcim, 2019; Financial Post, 2019). • In early 2020, several companies announced a joint study to assess the design and cost of a commercial facility (0.725 MtCO2/yr) at the Holcim Portland cement plant in Colorado, United States (Total, 2020).
Direct separation	6	2030 (High)	• Successful pilot-scale demonstration at the Heidelberg Cement plant in Belgium by the LEILAC project in 2019, targeting large-scale demonstration in 2025 (0.1 MtCO2/yr) (LEILAC, 2019; Perilli, 2020).
Other capture technologies	4-5	- (Medium)	• Various other capture technologies could be applied to cement, including membrane separation, chilled ammonia process and cryogenics. Some laboratory and small-scale trials have taken place, but these technologies remain in relatively early development stages (ECRA, 2017; Sayre et al., 2017; Pérez-Calvo, 2018).
Sequester/ mineralise CO2 in concrete and other inert carbonate materials	9	Today (Mdium)	• Multiple commercial-scale plants using CO2 for producing aggregates or in concrete curing (Carbon8, 2020; CarbonCure, 2020; Blue Planet, 2020). • Sinoma International and CNBM completed a project in 2016 in China that uses CO2 to produce precipated barium carbonate (50 kt/yr). • CO2Min, led by HeidelbergyCement and RWTH Aachen University, has proven the ability of olivine and basalt to absorb CO2 (Beumelburg, 2017; Stopic et al., 2019).

			• The FastCarb project in France is investigating accelerated carbonation in recycled concrete aggregates; research is currently at the lab scale (FastCarb, 2020).

Raw material substitution

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Calcined clay	9	Today (High)	• Currently used in a limited number of countries in low proportions; developed by collaboration between researchers in Cuba, India and Switzerland (Scrivener et al., 2018; UNEP, 2016). • A large-scale flash calciner that would considerably improve the energy efficiency of calcinating clay is under development in China, with two 300 t/day lines already built (Sui, 2020).
Carbonation of calcium silicates	8	Today (Medium)	• First produced in 2014 by Solidia Technologies at a Lafarge plant in the United States, with production now at an additional plant in Hungary; in 2019, a first commercial venture was announced to supply a paver plant (Aggregates Business, 2019).
Magnesium silicates (MOMs)	3	- (Medium)	• R&D largely remains in university labs; at present, largely on hold after a venture (Novacem in the United Kingdom) ended in 2012 due to lack of funding (Majcher, 2015).
Alkali-activated binders (geopolymers)	9	Today (Medium)	• Some cements already commercially available, but primarily used in nonstructural applications. An example is Vertua Ultra Zero developed by CEMEX in Switzerland (CEMEX, 2020). Others are at earlier stages of development.

Direct electrification or heating

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Direct electrification	4	- (Medium)	• A Feasibility study, beginning in 2017 by the CemZero project in Sweden, has shown that electrification of cement kilns is technically possible; currently exploring the possibility to build a pilot plant (Cementa, 2019; Vattenfall, 2020). • The ELSE project initiated in Norway in 2018 found in a technical feasibility study that electrification of precalciners is probably possible (Norcem, 2018; Tokheim et al., 2019).
Concentrated solar power direct heating	6	- (Medium)	• The SOLPART project in France successfully commissioned a pilot-scale calcination solar reactor in mid-2019; it aims to open a partially solarpowered cement plant by 2025 (SOLPART, 2019). • US-based start-up Heliogen proved in 2019 at its test facility in the Mojave desert the possibility of generating heat above 1 000°C using concentrated solar power (Heliogen, 2019). • The Paul Scherrer Institute, ETH Zurich and LafargeHolcim are performing a study using concentrated solar power in kilns (LafargeHolcim, 2015).

Hydrogen

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Partial use of hydrogen	4	- (Medium)	• The Mineral Products Association has received funding to conduct physical trials in the United Kingdom using hydrogen and biomass in combination in a

			kiln (another trial will test electrical plasma and biomass in combination), aiming for completion by mid-2021 (MPA, 2020).
Decarbonating calcium carbonate	3	- (Medium)	• Electrolyser-based concept proven through laboratory-scale testing at Massachusetts Institute of Technology, with results published in late 2019 (Ellis et al., 2019).

Technology performance

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Advanced grinding	6-9	Today (Medium)	• Various technologies are at different stages of development, some nearing commercialisation (ECRA, 2017; 2020b).

Note: TRL = Technology Readiness Level
Source: IEA, Energy Technology Perspectives 2020

[Low Carbon Technology Trends in Cement in Japan]

The most recent low-carbon technology trends in the cement industry in Japan include the following.

- ✓ Development of technology to recycle CO2 from cement plants (carbon recycling)
  About 60% of the CO2 emitted by the cement industry is inevitably generated by chemical reactions from the raw material (limestone) in the process of producing clinker, an intermediate product of cement. Since the cement manufacturing process emits CO2, there is a need for innovation in low-carbon technology in the cement industry.
  In June 2020, the New Energy and Industrial Technology Development Organization (NEDO) launched a demonstration test for the development of a technology to recycle CO2 emitted in the cement manufacturing process and reuse it as a raw material for cement and civil engineering material, and selected Taiheiyo Cement as the grant recipient.[574] This is Japan's first demonstration test intended to separate and capture ten tons of CO2 per day at a cement plant, and this project aims to establish an optimal CO2 separation and capture system and a technology for a manufacturing process using CO2 as the raw material (carbon recycling), and put the technology into practical use, and introduce it to cement plants in Japan, by FY 2030. Specifically, a CO2 separation and recovery demonstration facility will be installed in a cement plant to conduct a demonstrate test for separation and capture of 10 tons of CO2 per day from cement kiln exhaust gas. In addition, element technologies for fixing the separated and captured CO2 into as carbonate using waste concrete and fresh concrete sludge, and recycling it as raw material for cement (limestone substitute), roadbed material for road pavement, and other civil engineering materials, will be developed.

[574] https://www.nedo.go.jp/news/press/AA5_101319.html

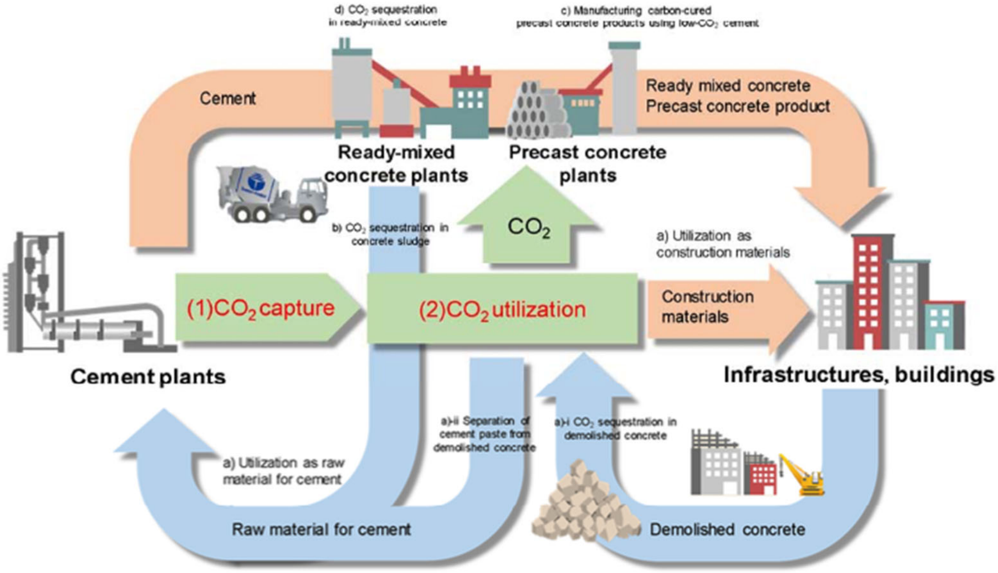

Figure 220 Conceptual Diagram of Carbon Cycle Cement Manufacturing Process
Source: Taiheiyo Cement

✓ Research and development of concrete that effectively utilizes CO2

In August 2020, the New Energy and Industrial Technology Development Organization (NEDO) selected Kajima Corporation, Chugoku Electric Power Co. and Mitsubishi Corporation for its publicly commissioned project of conducting research and development of concrete that effectively utilizes CO2[575].

Carbon recycling technology that captures CO2 emitted from steel mills, power plants, cement plants, and other facilities and effectively utilizes the CO2 in value-added products is one of the climate change countermeasures that need to be developed. However, the applications of the current carbon recycling technology for unreinforced concrete products are limited to those such as concrete blocks, so the development of a technology that can fix CO2 in a wider range of applications is urgent.

Through joint research and development by the above three companies, they aim to expand the application of the concrete that effectively utilizes CO2 by developing technologies to expand the scope of CO2 fixation to reinforced concrete products used for building structures and cast-in-place concrete structures.

✓ Environmentally friendly concrete “CO2-SUICOM”

CO2-SUICOM is concrete that effectively utilizes CO2 for unreinforced concrete products and is developed by Kajima Corporation, Chugoku Electric Power Company, DENKA, and Landes. As a substitute for cement, which is the main component of concrete, a special admixture made from by-product slaked lime generated from chemical plants, as well as coal ash and other industrial by-products are used to significantly reduce the amount of cement used.

The special admixture used as the raw material absorbs CO2 (carbonation reaction) and hardens when it comes into contact with CO2, curing and densifying the concrete. Utilizing this property, exhaust gases containing CO2 are brought into contact with concrete with the special admixture, and the concrete is cured through forced absorption and reaction (carbonation curing). This allows a large amount of CO2 to be absorbed into the concrete.

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575 https://www.mitsubishicorp.com/jp/ja/pr/archive/2020/files/0000045766_file1.pdf

✓ Aggregate utilizing CO2

In September 2020, Mitsubishi Corporation provided funding to Blue Planet Systems Corporation, a U.S. company with technology for manufacturing an aggregate, a raw material for concrete, using CO2 (aggregate utilizing CO2), and signed a collaboration agreement to commercialize the company's technology for effectively utilizing CO2[576]. Normally, concrete is made by solidifying aggregates (sand or gravel, which accounts for about 80% of concrete materials) with a binder (cement, etc.), but Blue Planet has a technology that contributes to CO2 reduction by fixing CO2 in the aggregates.

Since its establishment in 2012, Blue Planet has been working on the development and commercialization of its technology for effectively utilizing CO2 with the goal of reducing environmental impact, specifically pursuing the development of the following advanced technologies.

(1) Technology to fix CO2 contained in exhaust gases from power plants and other sources into concrete

(2) Technology to effectively utilize industrial waste such as unused concrete or waste concrete

The company's aggregate utilizing CO2 has already been used in the renovation of the San Francisco International Airport in the United States. Blue Planet and Mitsubishi Corporation plan to conduct a demonstration project for the technology for effectively utilizing CO2 in the Silicon Valley area of California, U.S.A., through fiscal 2021, followed by full-scale commercial deployment.

Given the size of the global concrete market, utilization of CO2 as a raw material for concrete can be expected to reduce CO2 emissions by several hundred million tons.

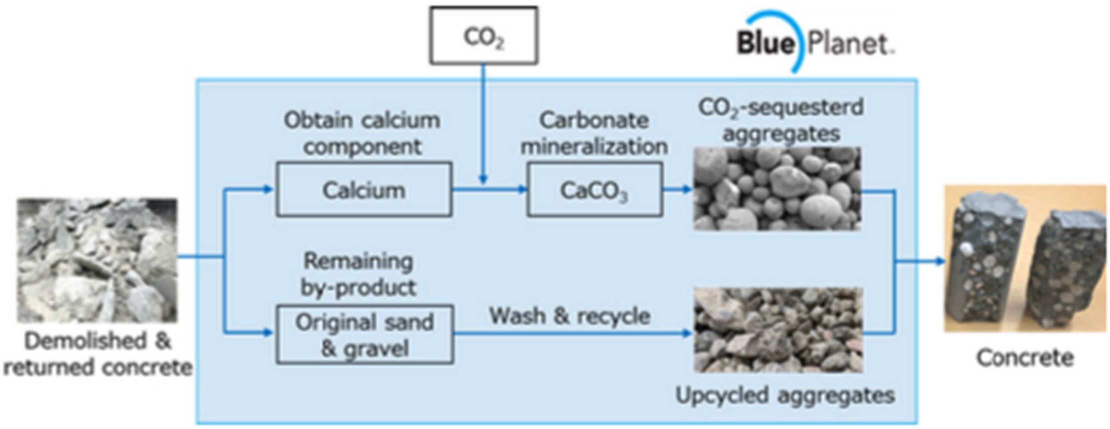

Figure 221 Technical Process Flow of Blue Planet

Source: Mitsubishi Corporation

✓ Carbon recycling technology to inject CO2 into concrete building materials

In January 2021, Mitsubishi Corporation took a stake in CarbonCure Technologies Inc. (CarbonCure) of Canada, which has carbon recycling technology that injects CO2 into concrete building materials, and agreed to a business alliance to expand the business for this technology[577].

CarbonCure's carbon recycling technology reduces the use of cement, a source of CO2 emissions, by fixing and effectively utilizing CO2 during the production of ready-mixed concrete. In addition, it has the same strength and reliability as the conventional concrete and is already widely used commercially, especially in North America.

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576 https://www.mitsubishicorp.com/jp/ja/pr/archive/2020/html/0000046041.html

577 https://www.mitsubishicorp.com/jp/ja/pr/archive/2021/files/0000046577_file1.pdf

Features of CarbonCure-related equipment and technology include the following items.
1. The technology can be introduced by installing relevant equipment developed by CarbonCure without major changes to existing manufacturing processes in ready-mixed concrete plants. In addition, related equipment is provided on a lease basis, allowing for low-cost introduction.
2. CO_2 injection reduces the amount of cement used, which leads to lower CO_2 emissions.
3. In addition, the use of digital technology to visualize CO_2 reductions is also possible.

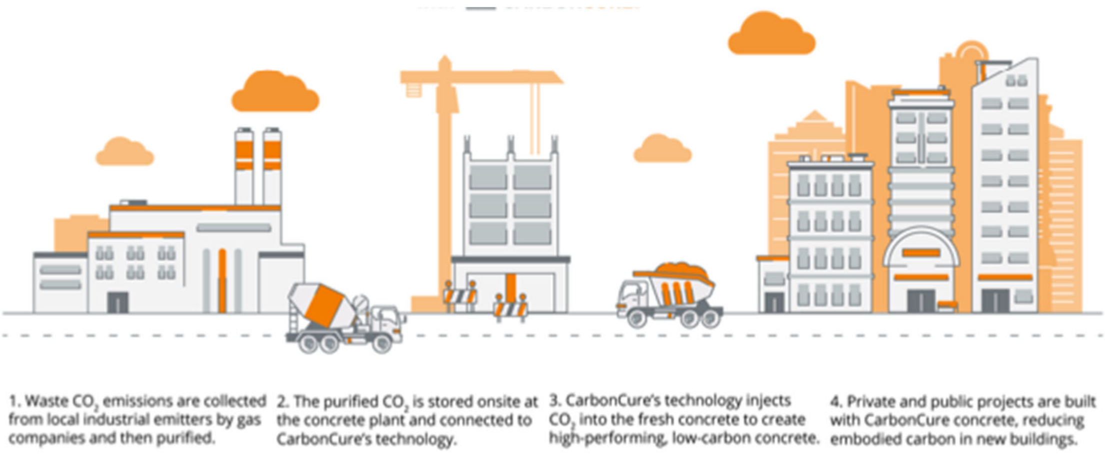

Figure 222 Outline of the Process from CO_2 Recovery to Utilization as a Building Material
Source: Mitsubishi Corporation

✓ Development of carbon recycled concrete

In February 2021, TAISEI CORPORATION developed "T-eConcrete/Carbon-Recycle," carbon-recycled concrete that enables a negative CO_2 balance to be achieved by fixing CO_2 inside the concrete using calcium carbonate produced from CO_2 captured from factory exhaust gases, etc., in order to cope with the amount of CO_2 emitted in the manufacturing process of environmentally friendly concrete "T-eConcrete.
In order to address carbon recycling, the following issues had to be addressed.
- The captured CO_2, if absorbed directly into concrete, will neutralize the concrete and cause the rebar to lose its anti-corrosion function.
- If the structure is designed to contain a larger number of micro voids in the concrete to facilitate CO_2 absorption, the strength of the concrete will decrease.
- Adding large amounts of calcium carbonate produced with captured CO_2 to concrete significantly reduces workability due to increased stickiness and delayed curing, and reduces strength after curing.
TAISEI has developed "T-e Concrete/Carbon-Recycle," carbon-recycled concrete that fixes CO_2 inside the concrete by solidifying calcium carbonate, a carbon recycled material produced from captured CO_2, with a binder consisting mainly of blast furnace slag, a byproduct of steelmaking, while making full use of its concrete technology and know-how to reduce CO_2 emissions accumulated through the development of "T-eConcrete."
The features of this technology are as follows.
- CO_2 can be fixed inside concrete.
- A negative CO_2 balance in the manufacturing process is achieved.
- Prevents corrosion of reinforcing steel inside concrete and maintains the durability of the structure.
- Can be manufactured using standard equipment, and exhibits strength and workability equivalent to ordinary concrete.

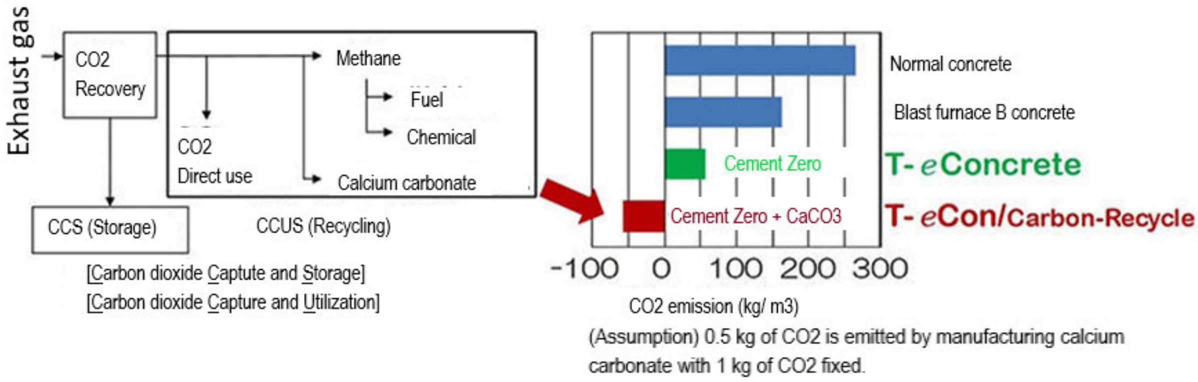

Figure 223 Outline of Carbon Recycling Concrete

Source: Taisei Corporation

Chemical and petrochemical industry

According to the IEA, the chemical sector directly contributes more than 1% of global GDP and is the world's largest industrial energy consumer. Since about half of the energy input is used for feedstocks (raw materials), most of the carbon in the energy input is transformed into the final product rather than being burned or otherwise emitted during the production process. Petroleum and natural gas are the primary feedstocks for the production of chemicals, and the coal consumption is small. Production of chemical products accounts for about 14% of the world oil demand (14 million barrels per day) and about 9% of the world gas demand (315 Bcm).

The chemical sector produces hundreds of thousands of different products, from plastics and fertilizers to pharmaceuticals and explosives. The energy intensity of production varies considerably from product to product. The production of primary chemicals such as ammonia, methanol, ethylene, propylene, benzene, toluene, and mixed xylene is particularly energy intensive (the latter five chemicals are grouped as "high-value chemicals"; the latter three are known as BTX and aromatics). Primary chemicals account for about two-thirds of the chemical sector's total energy consumption, and for a large portion of its raw material demand. In some cases, energy and raw materials can account for 90% of the total production cost for a primary chemical product, including capital investment.

Primary chemicals are then converted into final chemical products, including plastics, synthetic fibers, fertilizers, paints, additives and solvents, through a variety of processes. The energy consumption of these processes is relatively low. The other major chemical categories (specialty and fine chemicals, pharmaceuticals, and consumer chemicals) require much less energy for production, but use energy-intensive upstream materials as feedstock.

The figure below shows the IEA's outlook for global chemical production and the current applications of plastics. Plastic resins are expected to grow at 3-4% per year, while ammonia is expected to grow at about 1% per year.

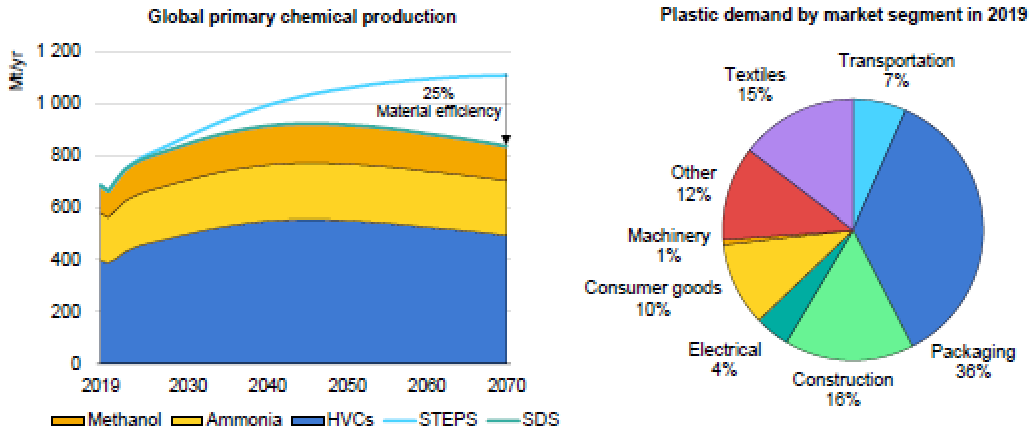

Figure 224 Outlook for Global Primary Chemical Production and Current Plastic Usage

Note: STEPS = Stated Policies Scenario, SDS = Sustainable Development Scenario
Source: IEA, Energy Technology Perspective 2020

Production facilities for chemical are characterized by less geographic concentration than those in the cement and steel sectors. For example, China accounts for about half of the world's cement and steel production capacity, while its high-value chemical production capacity is lower at about 20%. In recent years, primary chemical capacity expansion has been concentrated in the United States, the Middle East, and China, and this is expected to continue. The shale revolution has fueled the expansion of previously stagnant production in the U.S. and has led to a surge in production of ethane, which is the main component of natural gas liquids and whose production is the world's second-largest among the chemical industrial feedstocks after naphtha. Low raw material costs are also behind the expansion of production capacity in the Middle East, particularly in Iran and Saudi Arabia. However, the pace of capacity expansion may be slower over the next few years, as Covid-19 will reduce demand growth for chemicals and may result in overcapacity in some areas.

The challenges for the chemical and petrochemical industries in their low-carbon efforts are as follows.

- ✓ Non-conductive materials require high temperature: Steam crackers (basic unit for producing ethylene, propylene, BTX aromatic compounds, etc.) and other large units operate at temperature approaching 1000°C. Generating this amount of heat from electricity using the current technology would be impractical and costly. There is research and development aimed at reducing the cost of electrification. Consuming large amounts of biomass is not sustainable. Other technologies, such as CO2 emission reductions with CCUS and hydrogen-based production, are still in the pre-commercialization stage.
- ✓ Long-standing capital assets: Upstream units such as steam crackers are very large, expensive to build, and typically operate for about 30 years. The construction cost of a large cracker is estimated to be about US$4 billion, and substantial incentives would be needed to replace it with a low-carbon facility through scrap-and-build before the end of its operational period is reached.
- ✓ International competition: Many chemical products are traded in highly competitive international markets. Investments in low-carbon transition made by certain plants will increase the cost of their products and make them less internationally competitive. While it is possible to invest in low-carbon transition across the region and protect plants within the region, such as through a border adjustment tax on carbon, this would create political problems. In addition, the supply chain for chemical products is very complex, often spanning multiple countries. Therefore, working on the issue in only one region could cause significant disruption to the raw material and product markets.
- ✓ Chemical products are composed of carbon and hydrogen: Chemical products are composed of carbon and hydrogen, and emit CO2 in the disposal stage (combustion) after use. Therefore, it is very difficult to achieve completely zero CO2 emissions in the chemical supply

chain, including the use and disposal phases, and carbon and hydrogen as raw materials for chemical products will require a technology that combines CO2 recovered from the atmosphere, electrolytic hydrogen, recycled chemical products, and bioenergy. This is a very long-term challenge.

The table below shows trends in low-carbon technologies in the chemical and petrochemical industries.

Table 135 Trend of New Low-carbon Technologies in the Chemical Industry

CCUS

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Chemical absorption	11	Today (Very high)	**Ammonia:** Multiple commercial plants in operation capturing CO2 for use (TRL 11 for CCU), e.g. Petronas Fertilizer plant in Malaysia since 1999 and Indian Farmers Fertilizer Co-op since 2006 (MHI, 2020). Koch's Enid Fertilizer plant (0.7 MtCO2/yr) in operation since 2003 using CO2 for EOR (TRL 9 for CCS) (MIT, 2016a).
	9	Today (Very high)	**Methanol**: Commercial coal-based plants use capture as part of the production process (TRL 11 for the capture technology). Projects subsequently using the CO2 at a plant in Brazil operating since 1997 and one in Bahrain operating since 2007 (TRL 9 for CCU) (ZeroCO2, 2016; GPIC, 2020). No projects currently storing the CO2 (TRL 5 for CCS).
	7	2025 (Very high)	**High-value chemicals**: The Sinopec Zhongyuan Carbon Capture Utilization and Storage Pilot Project at a petrochemical plant in Henan, China has been capturing 0.12 MtCO2/yr for EOR since 2015, with plans to expand to 0.5 MtCO2/yr (Global CCS Institute, 2018a).
Physical absorption	9	Today (Very high)	**Ammonia**: Capture technology widely used commercially as part of the production process (TRL 10-11 for capture); Coffeyville Resources plant commissioned in 2013 at commercial scale (0.7-0.8 MtCO2/yr) in the United States, with CO2 used for EOR (TRL 9 for full CCS chain) (MIT, 2016b). Several further plants with CCS are scheduled to come online in the near term at the Nutrien Redwater plant in Canada, Wabash Valley Resources plant in the United States, and the Sinopec Qilu Petchem facility in China (OGCI, 2019; Enhance Energy Inc., Wolf Carbon Solutions and North West Redwater Partnership, 2019; Sharman, 2019).
	7	2023 (Very high)	**Methanol**: Lake Charles Methanol is developing an industrial scale plant in the United States, with CO2 stored via EOR; construction aiming to start in 2020 (Lake Charles Methanol, 2020).
	7	2025 (Very high)	**High-value chemicals**: Yangchang Petroleum built a capture plant at the Yulin coal-to-chemical plant (50 kilotonnes [kt] CO2/yr) and is currently building a large-scale unit (0.36 MtCO2/yr) at a second plant in Jingbian; CO2 is stored via use for EOR (Global CCS Institute, 2016).
Physical adsorption	8	Today (Very high)	**Methanol**: The Xinjiang Dunhua (0.1 MtCO2/yr) plant in China was commissioned in 2016, with CO2 stored via EOR (Asiachem, 2018).

Hydrogen

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Electrolytic hydrogen supplied	8	2025 (Very high)	**Ammonia**: Two medium-sized demonstration projects are planned in Australia with 60-160 MW electrolysers (Arena, 2019; Yara, 2020). Various

by variable renewables			other pilot projects are in development, along with longer-term plans for larger scale projects, in other countries including Chile, Germany, Morocco, the United Kingdom and the United States (IEA, 2019).
	7	2025 (High)	**Methanol**: Several pilot plants – George Olah pilot (4 kt/yr) in Iceland commissioned in 2011, with plans to scale up to small demonstration scale (CRI, 2020); Mitsui Chemicals (0.1 kt/yr) in Japan since 2009 (Green Car Congress, 2009); the Carbon2Chem project in Germany since 2018, using hydrogen from electrolyser and CO2 from steel plant (Thyssenkrupp, 2020a). Two planned demonstration projects received funding from the German government in 2019 (BMWi, 2020).

Direct electrification

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Methanol production from methane pyrolysis	6	2030 (Medium)	• This process to produce hydrogen and solid carbon by heating methane using electricity is being tested by BASF in a pilot plant in Germany, aiming for an industrial-scale plant by 2030 (BASF, 2019). While tests for methanol production are fairly small scale, testing of methane pyrolysis outside of the chemical sector for hydrogen production puts the technology at TRL 6.
Steam cracker electrification (**high-value chemicals**)	3	- (Medium)	• Six petrochemical companies together launched the Cracker of the Future Consortium in 2019 to explore using renewable electricity to run naphtha or gas steam crackers; the first steps involve screening technical options (Borealis, 2019). • VoltaChem is also exploring options (VoltaChem, 2020).

Bioenergy

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
Biomass gasification	5	- (Low)	**Ammonia**: Techno-economic evaluation of producing ammonia via biomass gasification completed, but suggest it is not yet economically viable (Brown, 2017; Andersson and Lundgren, 2014). Higher TRLs for other applications (for example biomethane, ethanol and methanol production), but not yet applied to ammonia.
	8	Today (Low)	**Methanol**: A first commercial plant began in Canada in 2016, deriving methanol from waste (Enerkem, 2016). Production is also taking place at the BioMCN facility in the Netherlands (OCI, 2020). A pre-commercial biomethanol project is also being considered in Sweden (VärmlandsMetanol, 2017).
Ethanol dehydration for **ethylene**	5-9	Today (Medium)	• Several commercial plants using ethanol produced via fermentation are currently in operation in multiple countries, two of the largest being the Braskem plant (0.2 Mt/yr) in Brazil and the India Glycols plant (0.175 Mt/yr) in India (ETSAP and IRENA, 2013; Mohsenzadeh, Zamani and Taherzadeh, 2017). • The spread of TRL corresponds to the ethanol feedstock: 9 for fermentation routes (first generation) and 5 for lignocellulosic biomass gasification (second generation). Ethylene production process is technically similar, but has not yet been linked to lignocellulosic feedstocks, which are less advanced and costlier.
Lignin-based **BTX** production	6	2030 (Medium)	• Successful pilot-scale test of BioBTX technology in the Netherlands (BioBTX, 2020). • ALIGN project launched by eight partners from Belgium and Germany in 2018 to upscale three lignin extraction processes, including through the

			LignoValue pilot in Flanders (200 kg/day) (Biorizon, 2018; Vito, 2018).

Feedstock substitution

Technology	TRL	Year available (importance for net-zero emissions)	Deployment status
BTX production from methanol	7	2030 (Low)	• Three pilot plants were commissioned in 2013 and several commercialscale demonstration projects are under development, mainly in China (Nextant, 2015).
Naphtha catalytic cracking (**high-value chemicals**)	9	Today (Low)	• A first commercial plant (40 kt/yr) is in operation at the KBR plant in Korea (Arne, 2017).

Note: TRL = Technology Readiness Level
Source: IEA, Energy Technology Perspectives 2020

[Low Carbon Technology Trends in the Chemical and Petrochemical Industries in Japan]

Recent low-carbon technology trends in the chemical and petrochemical industries in Japan include the following.

- ✓ Paraxylene production using CO2 as the raw material

The New Energy and Industrial Technology Development Organization (NEDO) has launched its approach to a project on the world's most advanced technological development for the production of paraxylene from CO2, as development of a technology for using CO2 in chemicals with the aim of serving as a substitute for existing fossil fuel-derived chemicals, and in July 2020, the University of Toyama, the Chiyoda Corporation, Nittetsu Engineering, Nippon Steel Corporation, Hichem and Mitsubishi Corporation were selected as collaborators[578].

Paraxylene is a compound that is processed via purified terephthalic acid (PTA) into polyester fiber and resins for PET bottles, and is an extremely important basic chemical for industry. Because of its composition, paraxylene has the advantage of fixing CO2 while reducing the amount of hydrogen feedstock used over other carbon recycling technologies for producing chemicals, making this technology a subject with great potential from both economic and environmental perspectives. The global demand for paraxylene is about 49 million tons/year, and if all the current global demand for paraxylene were switched to CO2 feedstock, the amount of CO2 fixed would amount to 160 million tons/year.

In this project, innovative catalyst improvement for the production of paraxylene from CO2, and development of a mass production technology and process, will be implement, and its aim is to create a path to a demonstration stage by conducting a feasibility study including the overall economic efficiency and the CO2 reduction effect.

- ✓ Toward Efficient Recycling of Waste Plastics

In December 2019, Nippon Steel Corporation released a proposal toward the achievement of the Sustainable Development Goals (SDGs) for the efficient recycling of waste plastics[579].

Since 2000, the company has been conducting chemical recycling using the coke oven chemical feedstock conversion method by installing pre-processing facilities consisting of a foreign material remover, crushers, volume reduction molding machines, etc., and coke oven charging facilities, in its steel mills.

Of the approximately 9 million tons of waste plastic generated annually in Japan, 57% is thermally recovered (thermal recycling) for power generation, etc., and 16% is simply

578 https://www.mitsubishicorp.com/jp/ja/pr/archive/2020/files/0000045680_file1.pdf
579 https://www.nipponsteel.com/news/20191218_100.html

incinerated or disposed of as waste due to difficulty to recycle. Only 23% is recycled by material recycling and 4% by chemical recycling.

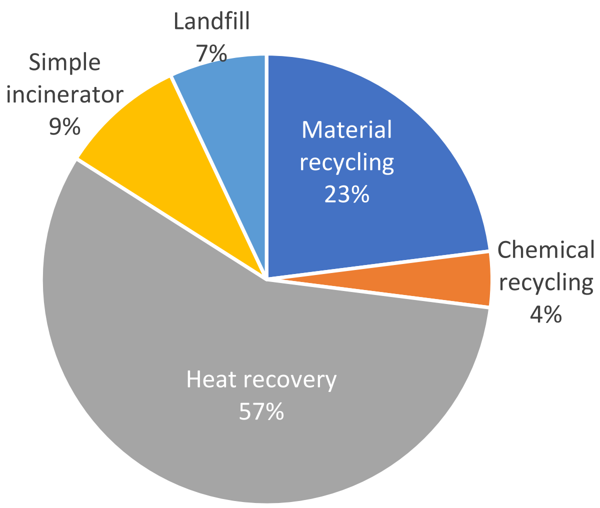

Figure 225 Breakdown of Waste plastic Recycling

Source: Nippon Steel

The figure below shows the CO_2 reduction effect of each recycling method. The chemical recycling method using a coke oven is very effective in reducing CO_2 emissions through recycling. This means that by transferring waste plastics to chemical recycling such as the coke oven method, more CO_2 emissions can be reduced than with the same amount of waste plastics.

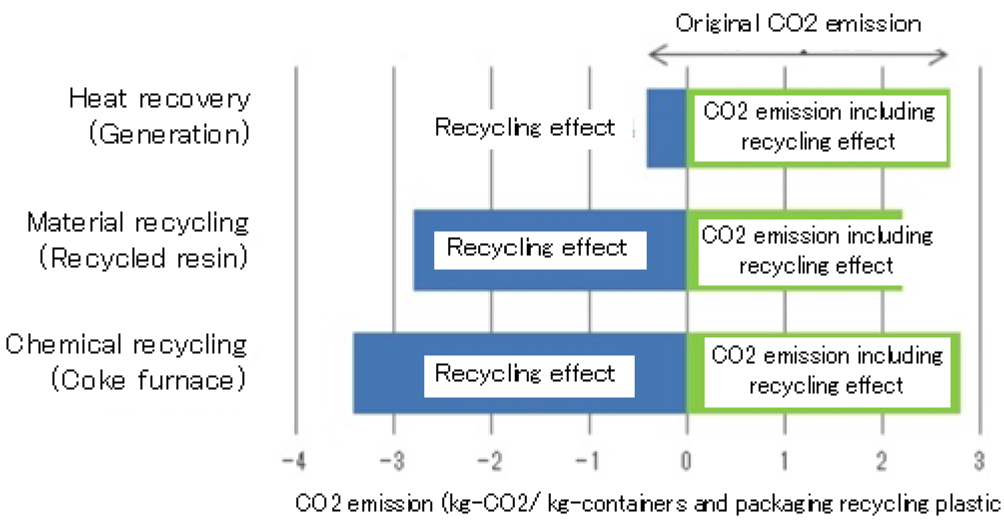

Figure 226 Environmental Load for Each Heat Recovery/ Recycling Method

Source: Nippon Steel

Food industry

In addition to the above three categories of industry, Japan's Ministry of Agriculture, Forestry and Fisheries (MAFF) formulated a "Green Food System Strategy" in May 2021, which aims to achieve both productivity improvement and sustainability in the food, agriculture, forestry and fisheries industries through innovation. The following are some of the low-carbon-related aspects of MAFF's vision for 2050.

- ✓ Achievement of zero CO_2 emissions in agriculture, forestry, and fisheries
- ✓ 50% reduction in the use of agrichemicals

- ✓ 30% reduction in the use of chemical fertilizers made from imported raw materials and fossil fuels

Thus, the Green Food System Strategy can be described as an initiative to reduce the consumption of chemical pesticides, thereby contributing to the low-carbonization of the chemical industry.

In the background, Japan's food, agriculture, forestry, and fisheries industries face policy challenges such as large-scale natural disasters, global warming, weakening of the production base and decline of local communities such as decrease of producers, and changes in production and consumption triggered by COVID-19, and in order to ensure stable food supply in the future, it is necessary to promote administration of agriculture, forestry, and fisheries resistant to disasters and global warming, and that also takes into account the decrease in producers and post-corona society. In this context, in addition to the growing momentum of healthy eating, sustainable production and consumption, and the expansion of the ESG investment market, other countries are also developing strategies related to the environment and health. As these domestic and international movements attaching importance to SDGs and the environment are expected to accelerate in the future, there is an urgent need for Japan's food, agriculture, forestry, and fisheries industries to respond appropriately to these trends and build a sustainable food system.

Among the initiatives of the Green Food System Strategy, the following items are directly related to low carbon.

- ✓ Promotion of departure from importation, decarbonization, and reduction of environmental impact in materials and energy procurement
  - ■ Procurement of sustainable materials and energy
    - ✧Establishment of an energy management system based on local production for local consumption through farm-based solar power generation, biomass, and small-scale hydroelectric power generation, etc.
    - ✧Introduction of small-scale hydroelectric power generation, biogas power generation facilities for local production for local consumption, etc.
    - ✧Promotion of local resource recycling efforts through the use of bio-liquid fertilizer (digestive liquid, a byproduct of biogas power generation)
    - ✧Review of regulations necessary to establish a locally produced and consumed energy system
    - ✧Visualization of production processes that consider environmental conservation and other sustainability issues, promotion of procurement by companies that focus on such processes, etc.
  - ■ Initiatives for further utilization of local and unused resources
    - ✧Construction of an energy utilization system using rice husks, snow cold energy, industrial waste heat, CO2, etc.
    - ✧Study to expand the use of renewable energy (further utilization of geothermal resources)
    - ✧Increase in quality of woody biomass, pelleting, etc.
  - ■ System building and technological development for reuse and recycling of resources
    - ✧Development of recycling technology to convert food residues, waste, sludge, and offcuts into fertilizer, feed, and fuel
    - ✧Development of highly functional bioproducts from inedible biomass feedstock, etc.
- ✓ Establishment of a sustainable production system through innovation, etc.
  - ■ Greening of materials, including machinery electrification and use of hydrogen-powered machinery
    - ✧Conversion of agricultural and forestry machinery and fishing vessels to

energy-efficient fishing vessels, including electrification (small, strong, low-cost storage batteries, etc.) and conversion to hydrogen.

✧Introduction of hybrid-type facilities and horticultural equipment and zero-emission horticultural facilities (development of high-speed humidification-type heat pumps and high-efficiency heat storage and transfer technology and heat radiation control technology)

✧Development and spread of durable biodegradable production materials (e.g., horticulture facilities, coated fertilizers, film for silage, fishing gear; introduction of next-generation technologies such as energy-saving and low-power consumption power semiconductors)

■ Development and spread of earth-friendly super varieties, etc. (reduction of greenhouse gas emissions)

✧Development of plants and seaweeds with high CO_2 fixation performance, etc.

■ Long-term, mass storage of carbon in agricultural lands, forests, and oceans

✧Promotion of CO_2 fixation by seaweeds, etc. (blue carbon), etc.

✓ Establishment of a sustainable processing and distribution system that is free from waste and unreasonableness

■ Switch to sustainable imported food and raw materials and promotion of environmental activities

✧Attracting ESG investments, etc. by promoting environmentally conscious management in light of international trends

✧Promotion of ESG investments and other investments related to improving sustainability and environmental conservation, etc.

■ Development of packaging materials suitable for long-term storage and transportation

✧Development of new functional packaging materials, such as those with anti-mold effects, etc.

■ Strengthening the competitiveness of the decarbonized, health and environmentally conscious food industry

✧Promotion of corporate actions that enhance sustainability, such as calculating and reducing greenhouse gas emissions in the supply chain

✧Reduction of the amount of plastic products used by promoting environmentally friendly design, improvement of recycling rates, promotion of other plastic resource recycling initiatives, etc.

(ii) Trends in the development and social implementation of technologies and services in the countries covered by the field survey

(a) India

The figure below shows the share of CO_2 emissions in the Indian industrial sector in 2019 by major industry categories. The steel industry accounts for the majority, followed by the cement and other non-metallic mineral industries, and the chemical and petrochemical industries, with these three industry categories accounting for 69% of CO_2 emissions from India's industrial sector.

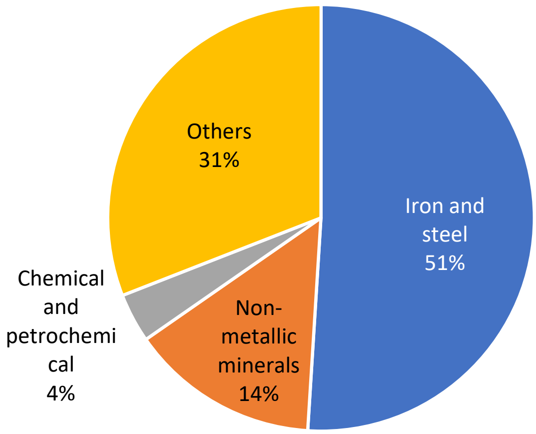

Figure 227 Share of CO2 Emission by Sub-sector in India Industry Sector (2019)
Source: CO2 Emission From Fuel Combustion 2021, IEA

Steel industry

The Indian steel industry became license-free in 1991 and was excluded from government control in 1992. According to data from the World Steel Association, India will be the world's second largest producer of crude steel after China in 2020, and India has also been the world's largest producer of DRI (sponge iron) since 2003.

According to the NATIONAL STEEL POLICY, formulated in 2017, the Ministry of Steel submitted INDC that projected the reduction of CO2 emissions per ton of crude steel in the steel sector to 2.2-2.4 tons-CO2 on the BF-BOF route, and to 2.6-2.7 tons-CO2 on the DRI-EAF route under the DRI-EAF route, by 2030.

Cement industry

India consumed 337 million tons of cement in 2018-19. With various projects such as Smart City Mission, Housing for All, and Urban Transport Metro Rail Projects of the Indian government, cement consumption in India is expected to reach 550 million tons in 2025.

India's CO2 emissions per ton of cement produced in 2018 were 576 kg-CO2, lower than the global average of 634 kg-CO2[580].

Chemical industry

India's population reached nearly 1.4 billion in 2021, making India one of the world's leading consumers of chemical fertilizers to produce food. The Indian government subsidizes more than 70% of urea production costs[581].

The energy consumption per ton of ammonia produced in India is 8 Gal/ton-NH3, and the energy efficiency for ammonia production in India is higher than 8.97 in the US and 9.57 in South America, China and Asia[582].

(b) Indonesia

The figure below shows the share of CO2 emissions in the Indonesian industrial sector in 2019 by major industry categories. The cement and other non-metallic mineral industries account for 29% and

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Alliance for on Energy Efficient Economy, https://aeee.in/emission-reduction-approaches-for-the-cement-industry/#:~:text=The%20CO2%20emission%20intensity%20of,kgCO2%2Fton%20of%20cement%20produced.

The Fertiliser Association of India, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.faidelhi.org%2Fgeneral%2FAbout%2520Fertiliser.pptx&wdOrigin=BROWSELINK

Center for Science and Environment, https://cdn.cseindia.org/attachments/0.88942600_1564389532_The-key-findings-and-Way-ahead.pdf the steel industry 21%, followed by the non-ferrous metals industry and the chemical and petrochemical industry.

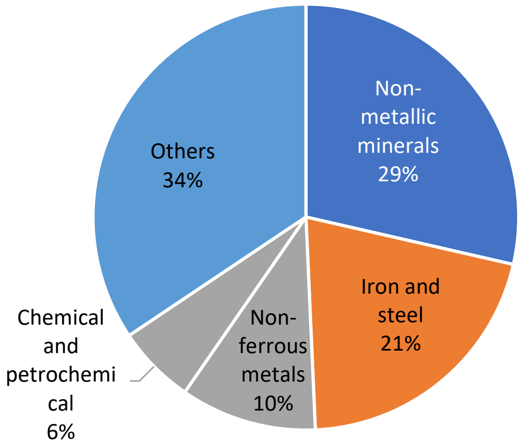

Figure 228 Share of CO2 Emission by Sub-sector in Indonesia Industry Sector (2019)
Source: CO2 Emission From Fuel Combustion 2021, IEA

Steel industry

In Indonesia, energy rates are held down as a policy to strengthen the competitiveness of the domestic steel industry. The Japan Iron and Steel Federation (JISF) is preparing a Technologies Customized List as an initiative to contribute to energy conservation in the ASEAN steel industry.

The Indonesian Ministry of Industry has indicated that five blast furnaces with an annual production capacity of 1.2 million tons are needed in the country to curb steel imports[583].

Cement industry

JFE Engineering's project to install a waste heat recovery facility on the cement production line at PT Surveyor Indonesia's (PTSI) Tuban plant to generate steam using the recovered waste heat in order to generate electricity through a steam turbine generator was adopted by JCM in 2013[584].

Chemical industry

In March 2021, JOGMEC and Mitsubishi Corporation agreed with the Bandung Institute of Technology and PT Panca Amara Utama to conduct a joint study on CCUS for clean fuel ammonia production in Sulawesi province[585].

(c) Thailand

The figure below shows the share of CO2 emissions by major industry categories in the Thai industrial sector in 2019. Non-metallic mineral industries such as cement account for the majority, while the share of steel is low, unlike in India and other countries.

NNA ASIA, https://www.nna.jp/news/show/2299266
JCM, https://gec.jp/jcm/jp/projects/p_archive/13ps_ina_02/
JOGMEC, https://www.jogmec.go.jp/news/release/news_15_000001_00062.html

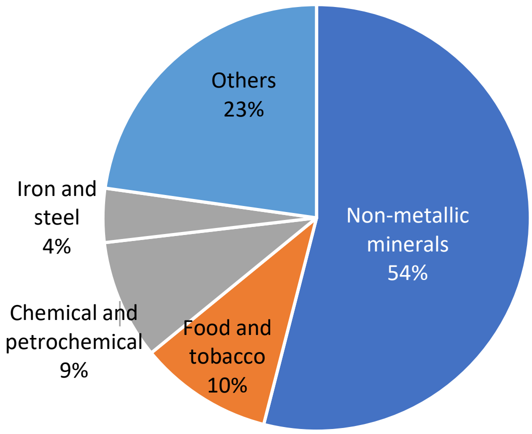

Figure 229 Share of CO2 Emission by Sub-sector in Thailand Industry Sector (2019)
Source: CO2 Emission From Fuel Combustion 2021, IEA

Steel industry

The global steel industry is converting to electric furnaces, which melt and recycle steel scrap to reduce CO2 emissions during manufacturing. In January 2022, Nippon Steel Corporation announced that it would acquire two major electric furnace companies in Thailand.

Cement industry

Japan's Ministry of the Environment conducted a study on the establishment of a 3R system for general and industrial waste in the northern region of Thailand, with a cement plant at its core. In addition, the ministry conducted an investigation on a project to establish a system to produce recycled aggregates for concrete by recycling construction by-products in the Bangkok area.

Chemical industry

Looking at Thailand's imports and exports of chemical fertilizers in 2020, the value exports was US$184 million while that of imports was US$1.51 billion, meaning a significant import surplus.

(d) Morocco

The figure below shows the share of CO2 emissions in the Moroccan industrial sector in 2019 by major industry categories. Non-metallic mineral industries such as cement account for about 2/3 of the total. The share of steel is zero.

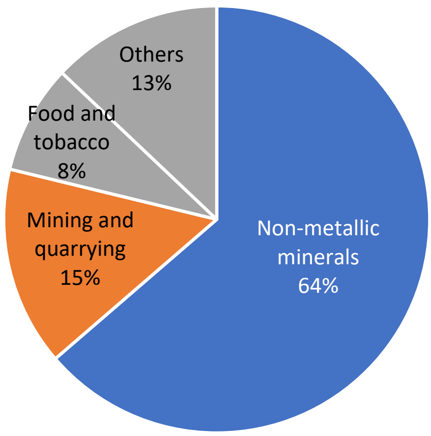

Figure 230 Share of CO2 Emission by Sub-sector in Morocco Industry Sector (2019)
Source: CO2 Emission From Fuel Combustion 2021, IEA

Cement industry

Morocco's cement industry has embraced renewable electricity from wind, with three sites having their own wind farms and the usage of wind-generated power reaching up to 85% of electricity consumption[586]. It also focuses on energy conservation, for example, LafargeHolcim has increased cement production by 79% since 1990, while energy consumption has decreased by 18%[587].

Chemical industry

Morocco is poor in fossil fuel resources and relies on imports for ammonia.

(iii) Advantages and strengths of Japanese companies

(a) Steel industry

The Japan Iron and Steel Federation, a business association for the Japanese steel industry, has developed a long-term vision for global warming countermeasures looking beyond 2030. The long-term vision envisions a path for Japan's steel industry toward the ultimate goal of zero CO2 emissions steelmaking, and in intended to lead to Super COURSE 50, which aims for extremely low CO2 emissions in blast furnaces, and further to hydrogen steelmaking, which is an ultimate zero CO2 emissions steelmaking technology. The figure below shows the status of technological development efforts that the Japan Iron and Steel Federation (JSF) should pursue to realize zero-carbon steel.

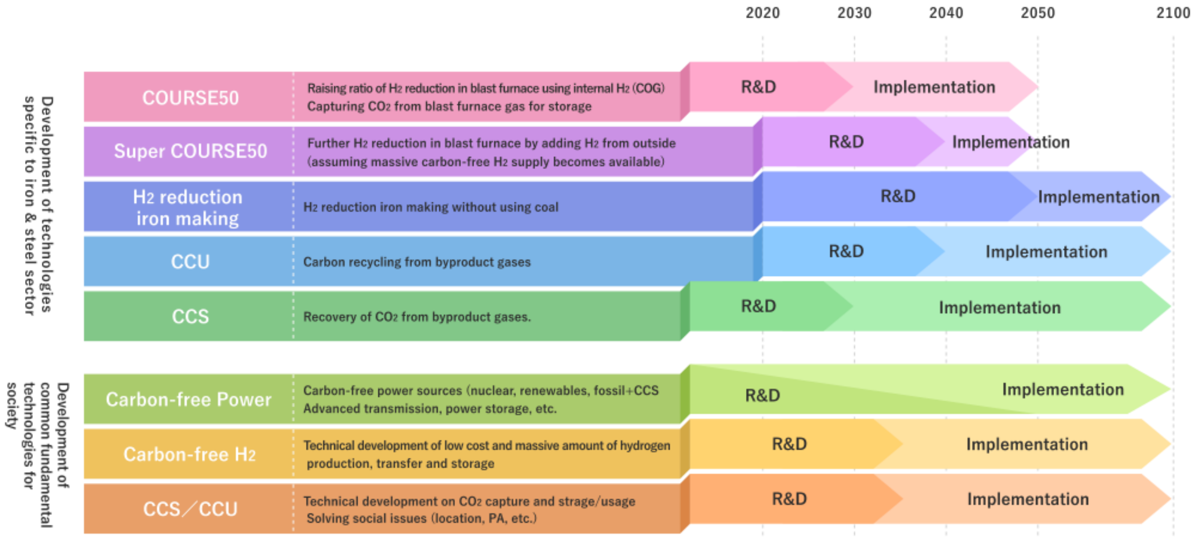

Figure 231 Technological Developments that JISF Promote Towards Carbon Neutrality

Source: The Japan Iron and Steel Federation[588]

Technologies for zero-carbon steel include the use of hydrogen and CCUS, but at present, technological development is still in the R&D stage and none of them have been put into practical use. Therefore, cooperation in low-carbon technology utilizing hydrogen will not be possible until after 2030, and low-carbon cooperation for the current steel industries in developing countries will be conventional cooperation in energy conservation, environmental protection, recycling, etc.

The Japan Iron and Steel Federation (JSF) has published a Technology Customized List (TCL) that lists blast furnace and electric furnace technologies appropriate for steel mills in the covered countries and regions, and that will be a strength. The TCL was developed after i) appropriate technologies were listed by Japanese steel experts, ii) a steel mill diagnosis was conducted, iii) a survey of technologies in the steel industry in each country was conducted through questionnaires, and iv) discussions were held among experts from both the covered countries or regions and Japan. Currently lists of such

https://renewablesnow.com/news/moroccos-cement-industry-embraces-renewable-energy-561525/

https://www.holcim.com/who-we-are/our-stories/wind-energy-tetouan-morocco

588 https://www.zero-carbon-steel.com/en/

technologies in India and ASEAN are being prepared[589].

(b) Chemical industry

In some developing countries, self-sufficiency of food and increase of food production are a challenge, while in others, agricultural products and food are important export commodities. What is important for food production is chemical fertilizers. Fertilizers classified into three types based on elements (nitrogen, phosphate, and potassium), and nitrogen fertilizer is the mainstay among the three types. For nitrogen fertilizer as a chemical fertilizer, generally ammonia is produced, and urea is produced from ammonia. Industrially, ammonia is produced in large quantities by extracting hydrogen from fossil fuels and reacting it with nitrogen extracted from air.

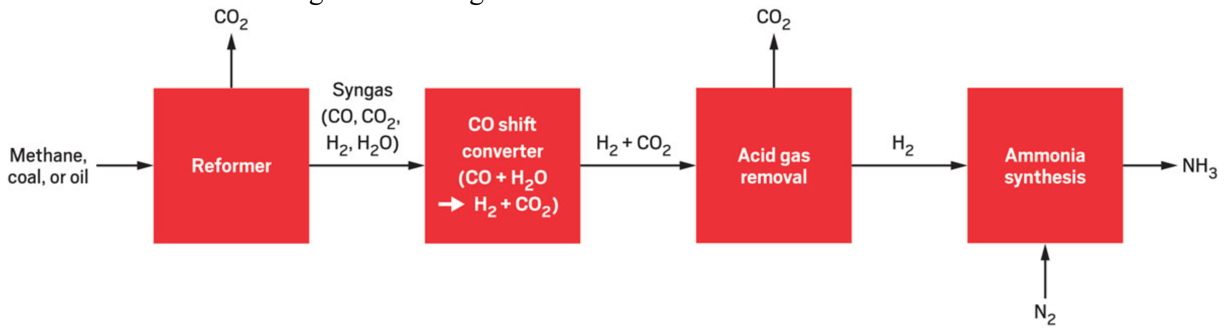

Figure 232 Current Typical Ammonia Production Process

Source: C&EN[590]

Countries without domestic fossil fuel resources have no choice but to import fossil fuels to produce ammonia, or import ammonia. However, if green hydrogen can be produced inexpensively in the future, even countries that are not blessed with fossil fuel resources will be able to supply hydrogen domestically, and domestic ammonia production will also be possible. Therefore, it is necessary to domestically build hydrogen production, storage, and transportation infrastructure.

In Japan, hydrogen is already produced, stored, transported and sold for industrial applications, and a demonstration project is underway to produce hydrogen from renewable energy power sources, and these technologies will be a strength.

（4） Buildings

(i) Trends in the development and social implementation of technologies and services in the world

According to the IEA, buildings account for 30% (3,100 Mtoe) of the global final energy consumption, including direct and indirect consumption. This includes 55% of the world's electricity consumption. In addition, when both the construction and use phases of buildings are included, buildings account for about 37% of the global CO2 emissions. In 2019, the combustion of fossil fuels used for applications such as air conditioning, water heating, and cooking emitted about 3 Gt of CO2 worldwide. Furthermore, when indirect emissions from the consumption of electricity and heat from a vast number of electrical and electronic devices used in buildings (air conditioners, heat pumps, appliances, lightings, etc.) are added, the total CO2 emissions reach 9.8 Gt. In addition, an additional 3.5 Gt of CO2 is emitted by the industrial sector in energy consumption and processes when cement and steel, the main building materials of buildings, are produced[591].

This chapter summarizes trends related to "ZEB/ZEH," which aims for zero emissions from

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589 https://www.jisf.or.jp/en/activity/climate/Technologies/index.html

590 https://cen.acs.org/environment/green-chemistry/Industrial-ammonia-production-emits-CO2/97/i24

591 IEA, Energy Technology Perspectives 2020, https://iea.blob.core.windows.net/assets/7f8aed40-89af-4348-be19-c8a67df0b9ea/Energy_Technology_Perspectives_2020_PDF.pdf

buildings; "heat pumps" and "air conditioning equipment," which are key technologies for low-carbon buildings and in which Japan has a strength; and emissions reduction throughout the "building life cycle."

(a) ZEB・ZEH

"Net Zero by 2050"[592], published by the IEA in May 2021, states that in the 2050 net zero scenario, all countries must establish zero-carbon compatible building energy standards by 2030 at the latest, and all new buildings must meet these standards starting in 2030. It also noted that 20% of existing buildings would need to be renovated to a similar level. This would require raising the average renovation rate from about 1% per year as of 2020 to at least 2.5% by 2030.

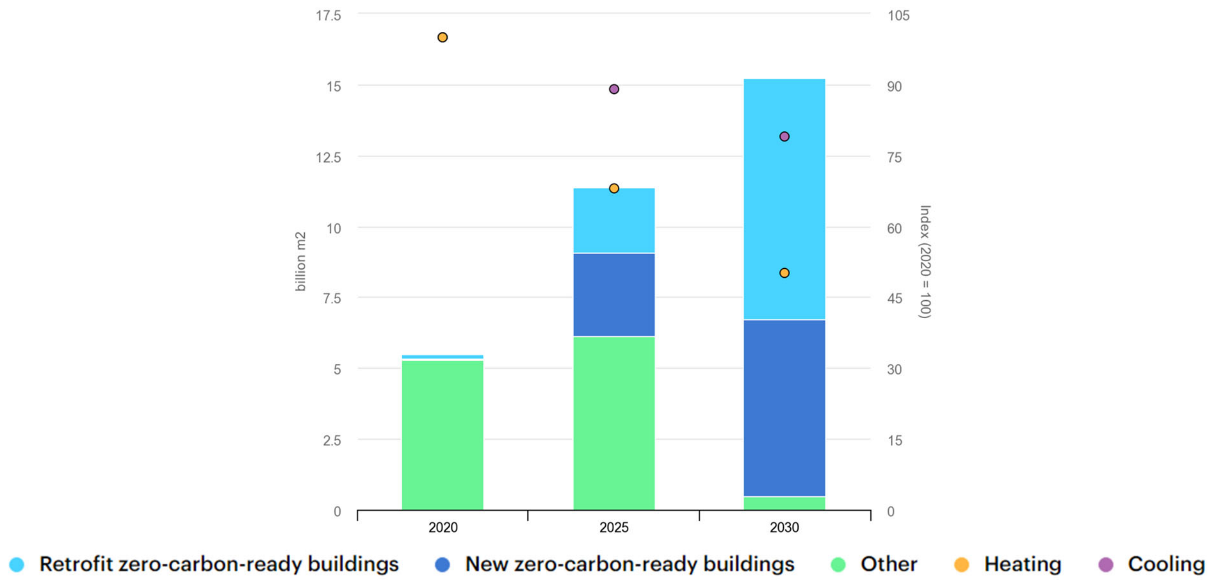

Figure 233 Newly built floor area globally and energy retrofits in the Net Zero Scenario, 2020-2030

Sourse：IEA[593]

As shown in Figure 234, as of 2020, in terms of the final energy consumption in buildings, the heating demand is the largest, followed by the demand for water heating and cooking. In terms of fuels, fossil fuels account for just under half of the total. However, in the IEA's 2050 net-zero scenario, the heating demand in particular will decrease by 2050 due to efficiency improvements and changes in people's behavior (e.g., appropriate temperature settings), and in terms of fuels, fossil fuels will account for only a few percent, and must be replaced by electricity or renewable energy.

592 IEA report outlining a comprehensive energy sector pathway and measures to be taken to achieve zero emissions globally by 2050 (released May 18, 2021).

593 IEA, Building Envelopes, https://www.iea.org/reports/building-envelopes

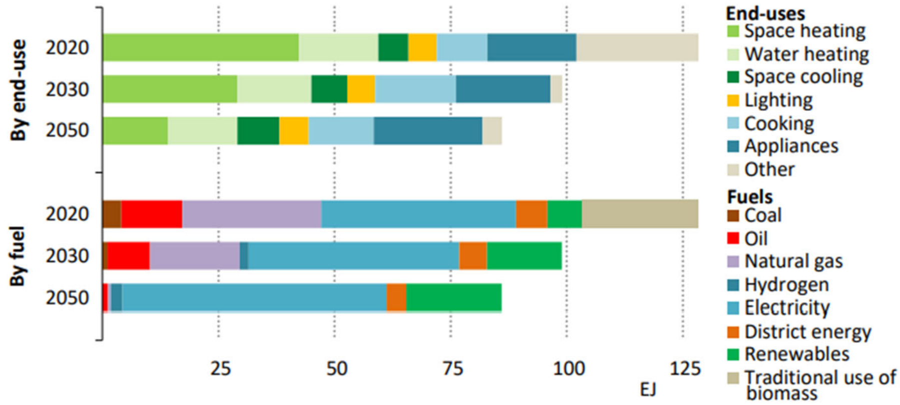

Figure 234 Global final energy consumption by fuel and end-use application in buildings in the NZE

Sourse : IEA, Net Zero by 2050(P143)

In addition, by 2050, more than 85% of buildings will need to comply with the Zero Carbon Ready Building Energy Codes, according to the scenario. To achieve this, it is essential to reduce the heating demand, which currently accounts for the largest share of the final demand in buildings, and the cooling demand, which is expected to increase rapidly in emerging and developing countries in the future.

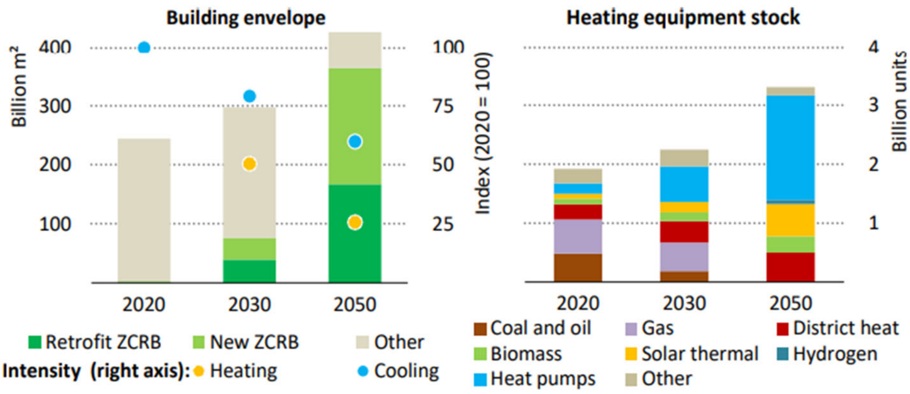

Figure 235 Global building and heating equipment stock by type and useful space heating and cooling demand intensity changes in the NZE

Note 1: A Zero Carbon Ready Building (ZCRB) is a building that is energy efficient and uses renewable energy directly or indirectly from energy sources (electricity, district heating, etc.) that will be decarbonized by 2050 (buildings that will be Zero Carbon Buildings by 2050 without building or equipment upgrades).

Note 2: "Other" in Heating equipment includes resistance heaters, hybrids and gas heat pumps.

Sourse : IEA, Net Zero by 2050(P145)

[Technologies to realize ZEB/ZEH]

So-called ZEB and ZEH are, roughly speaking, "houses and buildings that aim to reduce the balance of annual primary energy consumption to zero by promoting energy conservation and introducing renewable energy."

Technologies to realize ZEB and ZEH can be largely divided into "technologies to reduce energy (energy-saving technologies)" and "technologies to create energy (energy-creating technologies). Further, energy-saving technologies can be divided into two categories: technologies for reducing the amount of energy required to properly maintain the environment in a building (passive technologies), and technologies for using energy efficiently (active technologies). In the operational phase of the building, energy management technologies are also important to address issues, such as where waste of energy waste occurs, and how to efficiently operate facilities.

[Definitions of ZEB and ZEH]

Detailed definitions of ZEB and ZEH vary from country to country. In Japan, ZEB is defined as “a building that achieves significant energy savings while maintaining the quality of the indoor environment by reducing the energy load through advanced building design, actively utilizing natural energy through the adoption of passive technologies, and introducing highly efficient equipment systems, and aims to achieve a zero annual primary energy consumption balance by introducing renewable energy to increase energy independence as much as possible,” and four levels of ZEB are qualitatively and quantitatively defined.

Table 136　Definition and Evaluation Criteria of ZEB in Japan

			Non-residential*1 buildings					
			❶Evaluation of the entire building			❷Partial Evaluation of the building (Evaluation of some uses of multi-purpose*2 buildings)*3		
			Reduction rate of primary energy consumption*4 in the evaluation target compared to the reference value		Other requirements	Reduction rate of primary energy consumption*4 in the evaluation target compared to the reference value		Other requirements
			Energy saving only	Including energy creation*5	4～7	Energy saving only	Including renewable energy, etc.	
『ZEB』			50% or higher	100% or higher	-	50% or higher	100% or higher	Achieve primary energy consumption reduction of 20% or higher compared with the standard value for the entire building, not including energy creation.
Nearly ZEB			50% or higher	75% or higher	-	50% or higher	75% or higher	
ZEB Ready			50% or higher	Less than 75%	-	50% or higher	Less than 75%	
ZEB Oriented	Building use	Offices, schools, factories, etc. 40	40% or higher	-	・The total floor area*1 of the entire building must be 10,000 m² or larger. ・Introduce technologies yet to be evaluated*6. ・Multi-purpose buildings shall achieve the primary energy consumption reduction rate shown on the left for each purpose.	40% or higher	-	The total area*1 of the use to be evaluated must be 10,000 m² or larger. ・The introduction of unevaluated technology*6 into the application to be evaluated. ・The primary energy consumption of the entire building shall be reduced by 20% or higher from the reference value, not including energy creation.
		Hotels, hospitals, etc. Department stores, restaurants, etc. Meeting place, etc.	30% or higher	-		30% or higher	-	

*1 Based on the definition under the Act on the Improvement of Energy Consumption Performance of Buildings (non-residential portions: portions other than residential parts specified in Article 3 of the Cabinet Order).

*2 Based on the usage types (offices, hotels, hospitals, department stores, schools, restaurants, assembly halls, factories, etc.) in the same Act.

*3 The total floor area of the entire building must be 10,000 m² or larger.

*4 Primary energy consumption shall cover air conditioning equipment, mechanical ventilation equipment other than air conditioning equipment, lighting equipment, hot water supply equipment, and elevators and escalators as specified in the 2016 Energy Conservation Standard

(excluding other primary energy consumption). The calculation method shall be in accordance with the methods based on latest energy conservation standards or their equivalent.

*5 The scope of renewable energy is limited to onsite energy. The amount of electricity sold will be included in addition to on-site consumption. (Limited to the amount of surplus electricity sold.)

*6 Unevaluated technologies shall be those that are expected to be highly effective in saving energy and have been published by the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan.

Sourse：METI, March 2019[594]

Next, in Japan, ZEH is defined as "a house that achieves significant energy savings while maintaining the quality of the indoor environment by significantly improving the insulation performance of the outer skin and introducing high-efficiency equipment systems, and aims to achieve a net annual primary energy consumption balance of zero by introducing renewable energy and other resources,” and roughly three levels of ZEH are defined qualitatively and quantitatively. The following are the definition of and evaluation criteria of ZEH for detached houses, and different indicators are provided for multi-family dwellings.

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[594]METI, March 2019, https://www.enecho.meti.go.jp/category/saving_and_new/saving/enterprise/support/pdf/1903_followup_summary.pdf

Table 137 Definition and Evaluation Criteria of ZEH for Detached Houses in Japan

Type (Name)		Requirement					
		Envelope standards (UA value)			Primary energy consumption reduction rate		Other requirements and notes
		Region type					
		1・2	3	4〜7	Energy saving only	Including renewable energy, etc.	
『ZEH』		≦0.40	≦0.50	≦0.60	≧20%	≧100%	Introduction of renewable energy
	『ZEH+』	〃	〃	〃	≧25%	〃	In addition to the above, satisfy at least two of *5.
Nearly ZEH		〃	〃	〃	≧20%	≧75% ＜100%	Introduction of renewable energy
	Nearly ZEH+	〃	〃	〃	≧25%	〃	In addition to the above, satisfy at least two of *5.
ZEH Oriented		〃	〃	〃	≧20%	—	For target regions in the table below.
							Introduction of renewable energy not mandatory.

Region type	1・2	3〜5	6・7
UA value [W/m^{2}K]	0.3	0.4	0.5

(1) Further enhancement of envelope performance, (2) advanced energy management, (3) measures to expand onsite consumption using electric vehicles

*1 The advanced envelope standard, based on the 2016 energy conservation standards (for such requirements as ηAC value as well as ensuring airtightness and condensation-proof performance) for Regions 1 to 8,

sets the UA value of 0.4 W/m^2 K for Regions 1 and 2, 0.5 W/m^2 K or less for Region 3, and 0.6 W/m^2 K or less for Regions 4 to 7.

*2 Renewable energy is limited to onsite energy and includes the amount of electricity sold in addition to the amount consumed onsite. (This is limited to the amount of surplus electricity sold.)

*3 Primary energy consumption is calculated using the residential calculation method (heating/cooling, ventilation, hot water supply, and lighting (other primary energy consumption is excluded)) for residential portions and the non-residential calculation method (heating/cooling, ventilation, hot water supply, lighting, and elevators (other primary energy consumption is excluded)) for shared portions of buildings.

*4 Excluding the electricity generated by solar power generation facilities and the amount sold out of electricity generated by cogeneration facilities.

*5 There is an additional requirement for ZEH+ to satisfy at least two of the three conditions below.

Sourse：METI, April 2020[595]

Next, the definitions of ZEB and ZEH in foreign countries are as follows.

Table 138 Definition of ZEB overseas

	DOE	NREL	REHVA	Netherlands
Publication Period	2015	2006 2010	2013	2014
Target stage	Evaluation during operation (actual values)	Evaluation at the time of operation (assumed value)	Evaluation during operation (actual values)	Evaluation at the time of operation (assumed value)
Scope of energy consumption	- Electricity consumed for heating/cooling, ventilation, hot water, lighting, and electrical outlets, and energy	- Electricity consumed for heating/cooling, ventilation, hot water, lighting, and electrical outlets, and energy	- Heating, cooling, ventilation, hot water, lighting (excluding outlets, etc.)	- Heating, cooling, ventilation, hot water, lighting (excluding outlets, etc.)

595 METI, April 2020 https://www.enecho.meti.go.jp/category/saving_and_new/saving/general/pdf/roadmap-fu_report2020.pdf

		converted/transferred within the building	converted/transferred within the building		
Renewable Energy (RE) Scope		- In principle, on-site (onsite) is eligible, but offsite (offsite) can also be included, taking into account conditions in narrow areas, etc.	- Definition is divided into cases up to and including onsite (on-site) measures and cases including offsite (off-site) measures.	- On-site only	- On-site only
Other	ZEB Evaluation Criteria	The DOE's September 2015 release notes that some building developers have called for Zero Energy Ready (ZER) buildings in addition to full Zero Energy Buildings, and that a definition may be added in the future.	(1) ZEB: Buildings whose annual primary energy consumption is offset by renewable energy (2) Near ZEB: Buildings that were built to achieve ZEB but whose annual primary energy consumption is not offset by renewable energy due to weather, operating conditions, etc.	(1) PEB: Buildings with net non-renewable energy use of less than 0 kWh/m2 /year (2) ZEB: Buildings with net non-renewable energy use of 0 kWh/m2 /year that are off the grid and do not require any non-renewable energy (3) nZEB: Buildings with net non-renewable energy use of 0 kWh/m2 /year (iii) nZEB: Buildings where the net use of non-renewable energy is 0 kWh/m2year (iv) nnZEB: Buildings where the net use of non-renewable energy is 0 kWh/m2year (v) nnZEB: Buildings where the net use of non-renewable energy is 0 kWh/m2year (vi) nnZEB: Buildings whose annual net use of non-renewable energy is more than 0 kWh/m2year, but the value does not exceed the limit in each country. Translated with www.DeepL.com/Translator (free version)	(1) Buildings with an energy performance coefficient (EPC) as close to zero as possible, which is determined by the building frame and equipment performance.
	Classification of use, etc.	Building, Campus, Portfolio, Community	Building	Building	Residential Buildings, Offices, Health clinical, Health non-clinical, Educational, Retail, Sports

Sourse：Ministry of the Environment, Decenmber 2015[596]

Table 139　Definition of ZEH overseas

	DOE (Department of Energy)	H M Government (Her Majesty Government)	REHVA (Federation of European Heating, Ventilation and Air Conditioning Associations)
Publication Period	2008	2007	2013
Target stage	Evaluation during operation (actual values)	Evaluation at the time of operation (assumed value)	Evaluation at the time of operation (assumed value)
Scope of energy consumption	- Heating, cooling, ventilation, hot water, lighting, appliances and kitchen - Heating, cooling, ventilation, hot water, lighting (appliances and kitchen are excluded)		- Heating, cooling, ventilation, hot water, lighting (excluding appliances and kitchen)
Scope of Renewable Energy	- On-site only	- On-site + Off-site	- On-site only

596 Ministry of the Environment, Decenmber 2015, https://www.env.go.jp/earth/earth/ondanka/zeb/03.pdf

ZEH Evaluation Criteria	(1) ZEH (Zero Energy Home) : A home that achieves net annual energy consumption of zero. (2) ZERH (Zero Energy Ready Home): A home that meets the minimum requirements for the frame and equipment necessary to achieve ZEH when technological innovations in equipment are developed in the future.	Zero Carbon Home: A home with net zero annual carbon dioxide emissions.	(1)PEB (Positive Energy Building): Buildings with net non-renewable energy use of less than 0 kWh/m2year (2) nZEB (Net Zero Energy Building): Buildings whose net use of non-renewable energy is 0 kWh/m2year. (3) nnZEB (Nearly Net Zero Energy Building): Buildings whose annual net use of non-renewable energy is more than 0 kWh/m2 year, but the value does not exceed the limit in each country.

Sourse : METI November 2015[597]

[Trends in related technologies]

In a ZEB/ZEH ROADMAP[598], published by ICEF in March 2017, focus is placed on the climate (temperature and humidity) of each region, and timelines for technology introduction are provided for three types of regions: Moderate & Humid Regions (regions requiring heating, cooling and dehumidification), Cold Regions (regions with high demand for heating) and Hot Regions (regions with high demand for cooling and dehumidification). Technologies are grouped into four technology categories: Passive technology, Active technology, Renewable energy, and Energy management. Below is a roadmap for the Moderate & Humid Regions, to which many countries belong.

[597] METI, November 2015 https://www.meti.go.jp/shingikai/enecho/shoene_shinene/sho_energy/pdf/016_01_02.pdf

[598] ICEF, “ZEB/ZEH ROADMAP -TECHNOLOGY AND INSTITUTION–”, https://www.icef-forum.org/pdf/2018/roadmap/ZEBZEH_Roadmap_ICEF2016.pdf

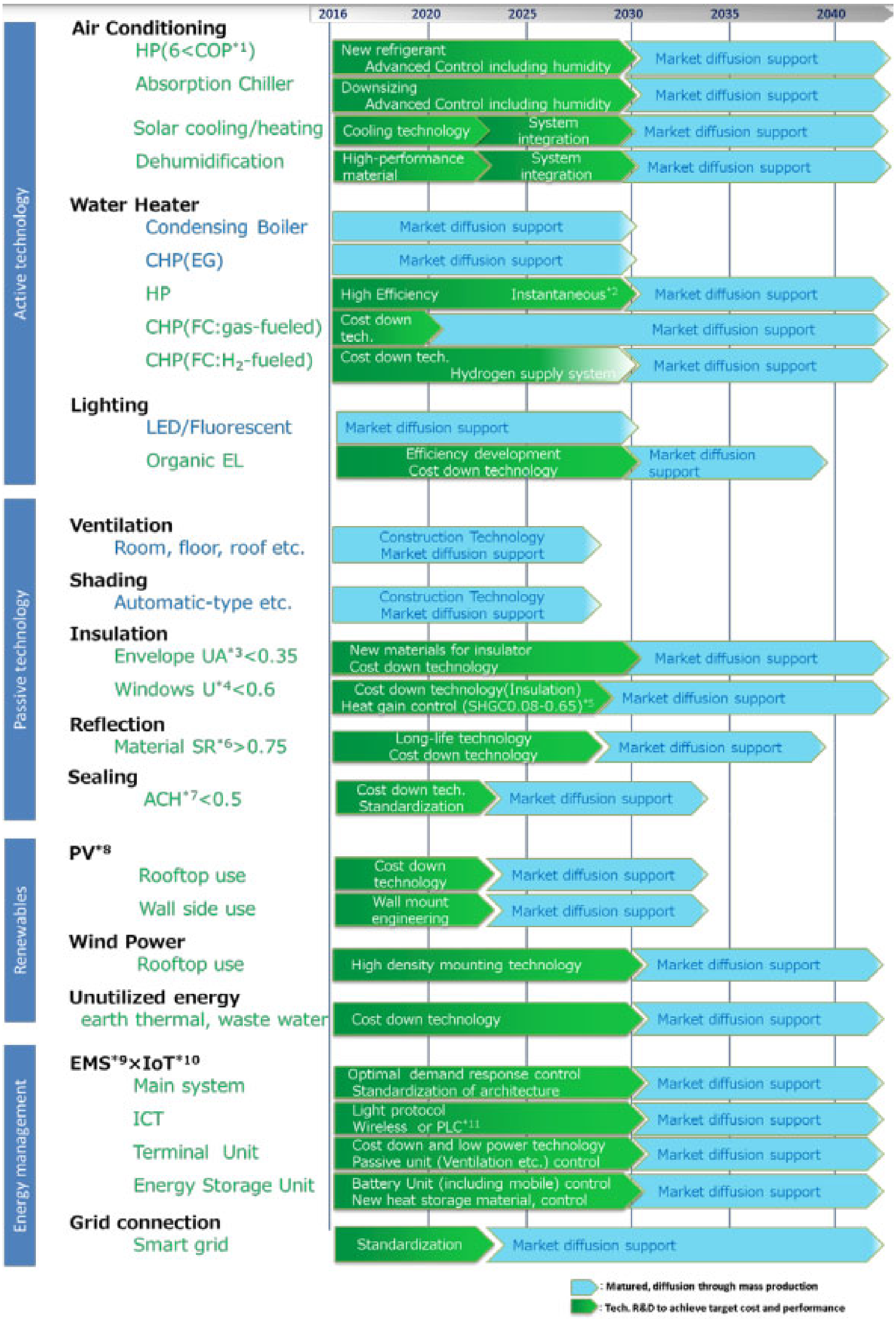

Figure 236　ZEB / ZEH technical loadmap by ICEF

Sourse：ICEF「ZEB/ZEH ROADMAP - TECHNOLOGY AND INSTITUTION -」[599]

599 ICEF、「ZEB/ZEH ROADMAP - TECHNOLOGY AND INSTITUTION -」(2017 年 3 月)、https://www.icef-forum.org/pdf/2018/roadmap/ZEBZEH_Roadmap_ICEF2016.pdf

【Passive technology】

Passive technologies include those related to heat insulation (exterior skin, windows, interior), heat shielding (shading), ventilation, and air tightness.

Regarding "heat insulation," a particularly important element, there are two main types of exterior skin insulation materials in common use today: fiber-based and foam-based, both of which take advantage of gas's property of being resistant to heat transfer. In recent years, with the aim of further improving heat insulation property, the use of "vacuum heat insulator," which improves heat insulation performance by creating a vacuum around the insulation material and reducing heat conduction by gas to as close to zero as possible, and "silica aerogel," a very low-density solid with high heat insulation property, has been pursued. However, due to issues such as their processing difficulty, durability, and cost, they have not become widespread[600]. In Japan, research and development of new insulation materials that will provide significant energy savings and CO2 reductions in homes and buildings is underway.

In addition, with regard to heat insulation of windows, the performance of both the glass and the window frame is important. Recent technological developments have led to the commercialization of products using highly heat insulating plastic window frames and triple-layered glass, but the cost is an issue in expanding the use of these products[601].

[Active technology]

Active technologies mainly include those related to air conditioning, water heating, and lighting. For air conditioning, technologies such as boilers, absorption water chillers/heaters, heat pumps, cogeneration equipment, dehumidifiers, humidifiers, solar systems, and outdoor air cooling systems are used. In particular, boilers, heat pumps, and cogeneration equipment are important technologies that are also common to “water heating.”

A boiler is a piece of equipment that burns fuel to heat a liquid to produce hot water or steam at high pressure that can be used as a heat source or energy source and supplied to others. The thermal efficiency of a typical boiler is around 70%, but recently developed latent heat recovering hot water boilers can increase the thermal efficiency to over 90% by utilizing even the latent heat of the water vapor in the waste gas that is discarded in conventional hot water boilers[602].

A heat pump is a device that collects and transfers heat from the atmosphere or other sources. Electricity is used as a power source to transport heat, so large amounts of heat can be used with small amounts of electricity, leading to energy savings. Heat pumps are available in temperatures ranging from -100°C to 100°C and are used across sectors such as industry, business, and household[603]. In addition, because it can utilize geothermal heat, water heat, and waste heat as well as from the air, it is attracting increasing attention not only as an energy-saving technology, but also from the aspect of utilizing unused energy. Globally, the current utilization for the cooling demand (air conditioners, etc.) is relatively high, and further utilization for the heat demand is an issue. In addition, on the technical side, the diversity of building types, consumer demand patterns, and climatic conditions require enhancements to adapt to different operating environments[604].

Cogeneration equipment is a generic term for systems that produce and supply electricity and heat from heat sources, and is also called "co-gene" or "combined heat and power" in Japan, and

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[600] ICEF、「ZEB/ZEH ROADMAP - TECHNOLOGY AND INSTITUTION -」(March 2017)、https://www.icef-forum.org/pdf/2018/roadmap/ZEBZEH_Roadmap_ICEF2016.pdf

[601] ICEF、「ZEB/ZEH ROADMAP - TECHNOLOGY AND INSTITUTION -」(March 2017)、https://www.icef-forum.org/pdf/2018/roadmap/ZEBZEH_Roadmap_ICEF2016.pdf

[602] ICEF、「ZEB/ZEH ROADMAP - TECHNOLOGY AND INSTITUTION -」(March 2017)、https://www.icef-forum.org/pdf/2018/roadmap/ZEBZEH_Roadmap_ICEF2016.pdf

[603] Heat Pump & Thermal Storage Technology center of Japan (HPTCJ), https://www.hptcj.or.jp/study/tabid/103/Default.aspx

[604] HPT TCP、Annual Report 2020、https://heatpumpingtechnologies.org/annual-report-2020-is-here/

"combined heat and power" (CHP) overseas. Cogeneration methods include generating electricity with an internal combustion engine or fuel cell and utilizing the heat generated in the process, and generating electricity with a steam boiler and steam turbine and utilizing part of the steam as heat. Since the efficiency of gas turbines increases if the combustion temperature is raised, improvements of heat-resistant materials for blades and cooling technology have been made to increase efficiency, and new cycles of devices such as high humidity air gas turbines and supercritical CO2 turbines are currently under development. Fuel cells have already been commercialized for household cogeneration, with polymer electrolyte fuel cells (PEFCs) and solid oxide fuel cells (SOFCs) achieving a power generation efficiency of approximately 40% and 52%, respectively, much higher than gas engines in the same power class. Currently, a hybrid power system, in which SOFC and gas turbine are combined, is under development.

[Renewable Energy / Energy Management][605]

The use of renewable energy and an energy management system (EMS) are also important elements of ZEB and ZEH. Renewable energy sources include solar light, wind power, and renewable energy heat, but solar power generation is the most widely used source worldwide. In addition to further cost reduction and performance improvement in the future, from the viewpoint of installation on buildings, thin and lightweight next-generation solar cells have been being developed to enable solar panels to be mounted on the roofs of houses and other buildings having low load-bearing capacity and on the walls and windows of houses and other buildings. By contrast, the use of renewable energy heat has not progressed well. There are various types of renewable energy heat, including solar heat, geothermal heat, snow and ice heat, hot spring heat, seawater heat, river heat, and sewage heat, and solar heat and geothermal heat are the most widely utilized sources worldwide. Challenges in introducing these systems include lack of price competitiveness (high initial cost), competition with power generation technologies, and lack of awareness. The largest portion of introduced solar water heaters is accounted for by China (about 75% of the world's total), and their introduction is progressing also in Turkey and India. In Europe, efforts have been made to promote the use of renewable energy heat in district heating and cooling, which is described below.

EMS is an energy management technology that acquires, stores, integrates, and optimizes data not only for single devices in a building, but also for the entire system, including solar power generation, EVs, and grid connections. It is also called HEMS for homes, BEMS for buildings, FEMS for factories, and CEMS for entire regions. Standardization of interfaces for HEMS is being pursued worldwide, with KNX (KONNEX) in Europe, SEP2.0 (Smart Energy Profile 2.0) in the United States, and ECHONET Lite in Japan having achieved de jure status as international standards, and collaboration between SEP2.0 and ECHONET Lite is in progress. As for BEMS, BACnet, developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) in the United States, is registered as an international standard ISO 16484-5 and is widely used internationally. Trends in the fusion and coordination of standards are drawing attention in anticipation of further expansion of their use in the future.

According to Japan's "Energy Conservation Technology Strategy 2016," in the future, not only mere visualization, but also initiatives to evaluate and automatically optimize energy use by the group, community, region and city through advanced EMS using IoT and AI, and efforts to further encourage energy-saving behavior of consumers by returning the energy consumption data to residents, etc. and utilizing nudges, etc., are also required. In addition, for the promotion of energy conservation through EMS, further utilization of data on actual energy use is important, and it is necessary to develop infrastructure that allows various types of data to be obtained and used in a low-cost and open manner[606].

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[605] ICEF、「ZEB/ZEH ROADMAP - TECHNOLOGY AND INSTITUTION -」(March 2017)、https://www.icef-forum.org/pdf/2018/roadmap/ZEBZEH_Roadmap_ICEF2016.pdf

[606] NEDO https://www.nedo.go.jp/news/press/AA5_101157.html

In Japan, in July 2019, METI and NEDO revised the "Key Technologies" in the Energy Conservation Technology Strategy 2016, indicating the demand technologies in the ZEB/ZEH and LCCM housing sectors as follows[607]:

Table 140　Energy Saving Technology Strategy 2016(ZEB/ZEH・LCCM)

Hardware (Technology Development)	Software (Use of Technology, Systems)
High-performance facade technology	
- Exterior skin technology Highly heat-insulating, highly heat-shielding (light-shielding), and airtight building materials - Natural energy utilization technology Natural daylighting and heat collection, natural ventilation, evaporative cooling - Variable exterior skin performance technology Dynamic insulation, movable louvers, variable performance glass - Energy-saving renovation technology Double-skinning, high airtight installation technology	- Design, installation, and evaluation technology BIM, simulation, VR, evaluation index development - Control and operation optimization technology Optimal coordinated control of blinds, ventilation openings, louvers, etc., in conjunction with weather and room use information, and coordinated control with air conditioning and lighting systems
High-efficiency air conditioning technology	
- High-efficiency heat source equipment High-efficiency heat pumps for air conditioning, high-efficiency absorption water chiller/heaters, technology to reduce standby power consumption - Highly efficient heat medium transfer High-efficiency pumps, high-efficiency blowers, etc. - Highly efficient outdoor air treatment unit Desiccant (dehumidification/humidification) air conditioning - High-efficiency air conditioning units Latent heat-sensible heat separation air conditioning (radiant air conditioning, etc.), hybrid air conditioning (air conditioning with natural ventilation, etc.), task-and-ambient air conditioning (personal air conditioning) - Life cycle renovation technology Parts replacement support - Unused heat utilization technology Technology to utilize renewable energy heat (geothermal, well water, solar heat, etc.), biomass and others, cogeneration waste heat utilization	- Remote control and management using IoT, control and operation optimization using AI, DR-supporting operation technology, and control linked to the outer skin - Control system upgrading technology - Design technology for capacity optimization (compact, robust design)
High-efficiency water heating technology	
- High-efficiency heat source equipment High-efficiency heat pumps for water heating (high-efficiency heat exchangers, high-	- Remote control and management using IoT, control and operation optimization using AI, and DR operation technology

[607] NEDO https://www.nedo.go.jp/news/press/AA5_101157.html

efficiency compressors, high-performance refrigerants), high-efficiency water heaters (latent heat recovery exchangers), technology to reduce standby power consumption, stationary fuel cells (ENE-FARM) - Life cycle renovation technology Parts replacement support - Unused heat utilization technology Technology to utilize renewable energy heat (geothermal, well water, solar heat, etc.), biomass and others, cogeneration waste heat utilization	- Solar heat utilization design - Control system upgrading technology
High-efficiency lighting technology	
- Technology to improve the efficiency of lighting fixtures (alone) LED lighting, OLED lighting, optical ducts - Lighting system efficiency improvement technology Daylight utilization, task ambient, architectural lighting, sensors (infrared, optical applications, spectroscopy, human detection)	Control and remote management through the use of IoT, control and operation optimization through the use of AI, and optimization in conjunction with daylight
Systems and evaluation technologies that simultaneously realize comfort/productivity, etc. and energy savings	
IoT/sensing technology, task ambient air conditioning and lighting control, airflow control technology and systems, personal environmental control systems, interactive technology	User estimation and adaptive control technologies, systems and evaluation technologies that take comfort and productivity into account
Design, evaluation, and operation technologies for ZEB/ZEH and LCCM homes, innovative energy management technologies (xEMS)	
- IoT/sensing technology - Electricity storage and thermal storage technologies (heat pump water heaters, thermal storage tanks, EVs, stationary storage batteries, fuel cells, etc.) that are responsible for load regulation and multi-input PCS that interconnect these technologies with renewable energy. - Energy (electricity and heat) transfer technology between individuals, buildings, and regions - Technology for integrating equipment and systems (passive + active integration, combination of renewable energy and unused heat, supply-demand coordination, etc.)	- ZEB/ZEH and LCCM housing design/evaluation technology BIM/simulation/VR, software for predicting energy-saving effects, etc., operational status and energy-saving margin evaluation tools - Control and operation optimization technology BEMS, HEMS, CEMS (including regional and city units), control and design technology for integrated equipment and systems, equipment data acquisition, storage, and analysis technology using IoT/AI/Big Data, renewable energy generation and DR prediction technology, consumer behavior analysis and behavioral economic analysis (nudge technology), control technology for mobility in facilities, conversion to direct current

Sourse：JICA Study Team

In addition to technological development, a major challenge for the spread of ZEB/ZEH is cost reduction.

One of the projects of the Horizon 2020 Framework Program for promoting research and innovation, a seven-year program conducted in Europe from 2014 to 2020, is the AZEB (Affordable

Zero Energy Buildings) project[608]. The goal of the project is to significantly reduce the life cycle costs of nearly Zero Energy Buildings (nZEB). To this end, a common methodology (AZEB methodology) was developed that can be applied in all European countries, integrating existing solutions in various areas related to ZEB. The AZEB methodology organizes what is required of stakeholders in the planning, design, construction, and use and maintenance phases of nZEB. The methodology also analyzes the following three perspectives important for the reduction of the nZEB cost, and presents solutions.

- ✓ Quantifying costs and environmental impacts at each stage of the life cycle
- ✓ Cost-effective use of technologies and services (analysis of economy, market share, technical data, etc.)
- ✓ Productivity improvement in the value chain (efforts to eliminate waste that generates unnecessary costs)

In Japan, similar efforts have been made to develop and publish "Design Guidelines (for design engineers)" and "Web Program Calculation Sheets" for each application and size with regard to ZEB[609]. In each country, efforts are underway to promote ZEB and ZEH in terms of implementation, including optimization of the combination of existing technologies and quantification of cost-effectiveness, in addition to the development of elemental technologies.

[International standardization of ZEB]

In addition to the aforementioned standardization in each country, efforts are underway for the international standardization of ZEB. TC205, one of the technical committees of the International Organization for Standardization (ISO), has been developing standards for acceptable indoor environments and effective energy conservation in the design of new structures and renovation of existing buildings. [610]

In September 2021, the technical specification "Methodology for achieving nonresidential zero-energy buildings (ZEBs)," sponsored by Japan and proposed to the ISO, was formally approved and established as Technical Specification TS23764 (Methodology for achieving nonresidential zero-energy buildings (ZEBs)) after deliberations by experts from various countries at the ISO. TS23764 advocates a step-by-step approach to ZEB realization, outlining the basic considerations to be made during the entire ZEB realization process, from the design to the operation and maintenance stages. [611]

Table 141 Guiding principles in the six processes outlined in TS23764

(1)	In the planning stage, have a clear policy to realize ZEB in three steps*: Step 1: ZEB Ready, Step 2: Nearly ZEB, Step 3: (Net)ZEB. Do not adhere to the method of realizing ZEB in a single (Net)Zero Energy Building step.
(2)	During the design phase, identify the appropriate passive and active design strategies and choose suitable material and equipment certified to national and international standards as much as possible.
(3)	At the time of construction, the material and equipment chosen are correctly installed and worked on in accordance with the drawings and specifications.
(4)	After the building is completed, the primary energy consumption target in the design phase will be achieved.
(5)	After the building is put into operation, check for any differences between the target values at the time of design and the measured primary energy consumption values during actual operation.
(6)	If possible, use simulation software to regularly calculate and validate the primary energy consumption after the start of operation.
(*) ➢ ZEB Ready: Buildings that proactively achieve (Net) ZEB through enhanced insulation appropriate for the their purpose and climate, a load-bearing envelope and shading, high-performance energy-saving equipment, and optimized energy consumption through data integration and verification.	

608 Affordable Zero Energy Buildings, https://azeb.eu/solutions/
609 METI, https://www.enecho.meti.go.jp/category/saving_and_new/saving/enterprise/support/index02.html
610 Institute of International Harmonization for Building and Housing (IIBH), http://www.iibh.org/tc205.htm
611 The Japanese Business Alliance for Smart Energy Worldwide, https://www.jase-w.org/press-release-iso-ts23764/

- Nearly ZEB: Buildings that have almost achieved (Net) ZEB, i.e., buildings that meet the ZEB Ready criteria and use renewable energy to achieve nearly zero annual primary energy consumption.
- (Net) ZEB: Buildings that meet the ZEB Ready criteria and have zero or negative annual primary energy consumption

Sourse : JICA Study Team based on Information from The Japanese Business Alliance for Smart Energy Worldwide [612]and ISO[613]

[Policy and technology trends of ZEB/ZEH in Japan]

The Sixth Strategic Energy Plan (announced October 2021) states, "For non-residential buildings, the target has been set to achieve ZEB in new public buildings, including those built by the Japanese government, by 2020, while for residential buildings, the goal has been to achieve ZEH in more than half of the custom-built detached houses built by house manufacturers and others by 2020. To that end, demonstration projects, introduction support measures, and other initiatives have been implemented. Although the 2020 target for non-residential buildings has been achieved, the ZEB diffusion ratio for new construction is less than 1.0%, and for residential buildings, the ZEH ratio for new custom-built detached houses in FY2019 was about 20%, making it difficult to achieve the 2020 target. In light of this situation, more work needs to be done to further strengthen regulations and support towards 2030, taking into account the different characteristics of different regions and building types." The goal is to ensure energy conservation performance at ZEH/ZEB levels for new homes and buildings built in FY2030 and beyond. [614]Specific initiatives include: [615]

- By FY2025, compliance with energy conservation standards will be mandatory for residences and small-scale buildings that are not subject to the obligation to comply with energy conservation standards.
- By FY2030, consistently raise inducement standards and top runner residence standards, and also gradually raise the level of energy conservation standards.
- Support for renovation and reconstruction of existing homes and buildings.
- Development and dissemination of building materials and construction methods that excel in energy-saving performance and are easy to use for renovation.
- Mandatory labeling of energy conservation performance when selling or leasing new homes.

In August 2021, the Japanese government compiled a report titled "Future of the Energy Conservation Measures for Housing and Buildings toward Decarbonized Society." In addition to energy conservation targets and measures, the report sets a renewable energy target of 60% of new detached houses having solar power generation equipment by 2030.[616]

The Japanese government is striving to promote the technological development and wide acceptance of ZEB/ZEH by the private businesses by supporting demonstration projects, among other

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612 The Japanese Business Alliance for Smart Energy Worldwide https://www.jase-w.org/press-release-iso-ts23764/

613 ISO, ISO/TS 23764:2021(en) Methodology for achieving non-residential zero-energy buildings (ZEBs), https://www.iso.org/obp/ui/#iso:std:iso:ts:23764:ed-1:v1:en

614 Conform to the enhanced envelope standard for residences and reduce primary energy consumption excluding renewable energy by 20% from the current energy conservation standard values. For buildings, reduce primary energy consumption excluding renewable energy by 30% or 40% (20% for small-scale buildings) from the current energy conservation standard value, depending on the use. (20% for small-scale buildings).

615 METI, October 2021, The 6th Strategic Energy Plan https://www.meti.go.jp/press/2021/10/20211022005/20211022005.html

616 Ministry of Land, Infrastructure, Transport and Tourism, August 2021 https://www.mlit.go.jp/jutakukentiku/house/jutakukentiku_house_tk4_000188.html

means. The following are examples of acclaimed ZEB/ZEH projects in Japan.

- ✓ Taisei Corporation: ZEB Demonstration Building at Taisei Advanced Center of Technology

The ZEB Demonstration Building at Taisei Advanced Center of Technology is a new ZEB structure completed in May 2014. It was constructed to verify the feasibility of ZEB in urban areas and to demonstrate the effectiveness of various technologies and energy management in real-life situations. After construction, the building has actually been used as office space and achieved an annual energy balance of zero in the first year of operation, making it the first building in Japan to achieve ZEB (ZEB on site) independently. Key technologies are:

- ■ Exterior wall design incorporating ZEB-enabling technologies

PV, daylighting system, natural ventilation system, etc. are packaged as modules or units and incorporated into the exterior wall design. The daylighting and ventilation units have their size and positions optimized to create a comfortable indoor environment, while the rest of the wall is used as power generation units, creating an exterior wall design that makes full use of the natural energy available from the outer environment.

- ■ Low-light task ambient lighting system[617]

A high-quality light environment with a sense of brightness despite the low illumination level was achieved by combining indirect lighting with a daylighting system that can deliver consistent natural light to the back of the room. In addition, task ambience control using high-precision human detection sensors provides high energy efficiency and comfort, reducing lighting energy by 86% compared to a typical office.

- ■ Task ambient air conditioning system using exhaust heat

The air-conditioning energy consumption was reduced by 76% compared to that of typical offices by adopting a hybrid natural ventilation system with automatic ventilation balancing outside weather and indoor environment, manual ventilation utilizing BEMS visualization, and ultra-high efficiency ambient air conditioning using fuel cell exhaust heat. Furthermore, human detection sensors are used to automatically control the amount of outside air and the opening and closing of the air outlet. Workers can also adjust the airflow according to their preference from PC, achieving both highly satisfactory work environment and energy conservation.

Figure 237　Task Ambient Air Conditioning System

Sourse：TODA CORPORATION[618]

- ✓ Takenaka Corporation:Takenaka Corporation Kanto Branch

Takenaka Corporation Kanto Branch was a renovation project that aims to turn an existing

[617] Task Ambient Air Conditioning System : A system that controls the "task," which is the area in which a person is working, and the "ambient," which is the surrounding spatial area, through separate mechanisms to control the entire area efficiently and comfortably.

[618] TODA CORPORATION, https://www.toda.co.jp/tech/comfortable/taskamb.html

building into a net-zero or even positive energy building. In addition to introducing various energy-saving technologies centered on passive methods, the project also sought to add further value by improving comfort and BCP performance, becoming the first ZEB retrofit for an occupied office building in Japan.

On the exterior, the existing glass panels were replaced with high-insulation products, while the blinds and single-panel glass were installed on the outside of the existing window frames for better thermal insulation.

The heat-sourced air conditioning system was planned to make maximum use of renewable energy, with geothermal heat directly used for radiant cooling in summer and solar heat used to regenerate desiccants. In winter, geothermal heat is used to heat source water for geothermal heat pumps, and solar heat for warm air.

✓ Daiwa House Industry: SMA×ECO TOWN Harumidai

SMA×ECO TOWN Harumidai is an example of a consistent effort to save CO2 and energy in a housing development, extending from project planning to housing and exterior planning to post-sales support, covering a long timeline and wide physical areas.

Photovoltaic power generation and lithium-ion storage batteries have been installed in the common areas of the town, along with all the detached houses, to utilize renewable energy and shift energy peaks. In addition, HEMS is installed in each house to visualize energy. By collecting such data, the company visualizes the energy status of the entire housing development, ranks the energy conservation contribution, and raising environmental awareness among the residents. According to 2015 data, the ZEH rate, obtained by dividing primary energy creation by primary energy consumption, averaged 124.79%, achieving net zero energy for the entire area.

(b) Heat pump

Although issues related to electric power are often at the center of discussions on energy carbon reduction, the reducing carbon in thermal energy source is actually a very important area for CO2 emission reduction. According to the IEA, heat is the world's largest energy end-use, accounting for almost half of global final energy consumption in 2021, significantly more than electricity (20%) and transportation (30%). 51% of thermal energy is consumed in industry and the remaining 46% in buildings (mainly for heating and hot water). [619]

Regarding thermal energy, the required temperature range varies depending on the application. An example classification can be: low temperature (consumer use) below 100°C, mainly used for air conditioning and hot water supply; low temperature (industrial use) between 100 and 200°C, mainly used in light industry such as food processing; high temperature (industrial use) above 200°C, mainly used in heavy industry such as metal processing. The main fuels that supply these thermal energies are (1) fossil fuels such as coal and gas, (2) electricity, and (3) renewable energy. Fossil fuels currently account for the largest share, used to provide heat in the form of cogeneration, boilers, and combustion furnaces. On the other hand, if electricity is used as fuel, heat pumps and electric furnaces are used. [620]

Efforts are underway to promote lower carbon in heat energy by improving efficiency through cogeneration, electrification, and promoting the use of renewable energy heat, where heat pumps are particularly promising.

The IEA's "Net Zero by 2050" report, published in May 2021, lists heat pump as a key technology for emission reductions by 2050, after solar, wind, and electric vehicles, with heat pumps providing 55% of heating demand in 2050 (7.0% in 2020) [621].

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619 IEA, Heating, https://www.iea.org/fuels-and-technologies/heating

620 METI, https://www.enecho.meti.go.jp/about/special/johoteikyo/netsu.html

621 IEA, Net Zero by 2050, https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-

Looking at each are, in the industrial sector, electricity will account for about 40% of heat demand in 2030 and about 65% in 2050, with heat pumps playing a particularly important role in electrifying heat demand in the low temperature range (below 100°C) and some medium temperature ranges (100-400°C) (about 30% of the total heat demand in 2050).

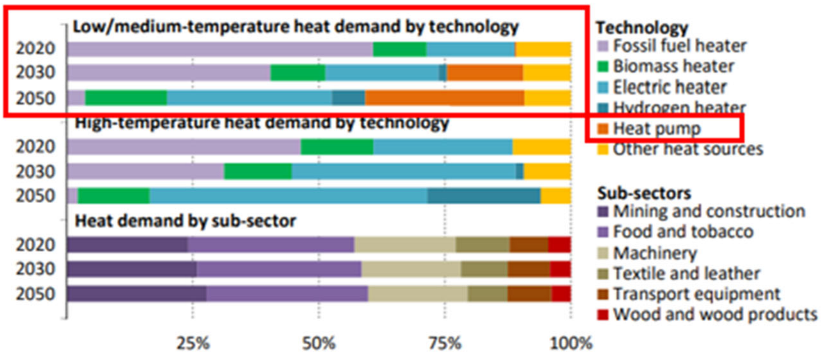

Figure 238 Share of heating technology by temperature level in light industries in the NZE
Sourse : IEA, Net Zero by 2050(P128)

In the building sector, as of 2020, the use of heat pumps in heating demand was a small fraction, with fossil fuel-based technologies accounting for the majority. However, the 2050 Net Zero scenario assumes that beginning in 2025, there will be no new sales of fossil fuel boilers (except models compatible with hydrogen) and that sales of heat pumps will increase rapidly, with total of 1.8 billion heat pumps in place by 2050. As a result, by 2050, electricity will provide 66% of the energy use in buildings (33% in 2020).

The IEA's Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) has summarized its efforts to support heat pump technologies as follows.

Challenges for the development and acceptance of heat pumps themselves include cost (both initial and operating), raising awareness, and installation to existing buildings. Therefore, in the short term, government subsidies and awareness-raising through labeling schemes, etc., can be effective, while with regard to operating costs, fossil fuel subsidies and rising electricity prices can be barriers to the introduction of heat pumps. In addition, technological innovation and international cooperation will be required to lower costs for higher penetration in markets where the technology is currently not widely used.

Integration with other technologies and services is another important perspective. For example, energy management in combination with other building equipment is in progress as well as the use of heat pumps in combination with waste heat, renewable energy, and other low-carbon energy sources in the community. Furthermore, as more variable renewable energy sources become available, heat pumps -by themselves or as a component in demand response (DR) together with storage technology and on-site renewable energy, etc.- are expected to contribute to greater flexibility in the electric power system. In addition, efforts toward coupling electricity and heat sectors are underway, particularly in Europe, and investments in heat pumps are being made to improve energy efficiency by electrifying the heat sector and further utilizing wind- and solar-derived electricity and surplus heat.

Table 142 Efforts to support heat pump technology

	Short-term measures	Innovations needed
Development and acceptance	Incentives for low-carbon heating technologies	Facilitate demonstrations for innovative heat pump designs specific to important market segments (e.g., retrofit of existing

10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf

		buildings), building types (e.g., multi-family housing), and climate zones (e.g., cold, warm-and- humid)
	Labeling system	International cooperation to lower costs
	Elimination of subsidies for fossil fuels	
Integration (with other technologies and services)	Promote appropriate utilization of end-user data (develop of metering infrastructure)	Support the development of technologies to integrate heating/cooling/ storage with on-site renewables
	Use of waste heat, renewable heat, and other low-carbon energy sources, utilizing local energy infrastructure	Update regulations to accommodate innovative business models and market designs that contribute to greater flexibility in the power system
	Planning a new low-temperature network using large-scale heat pumps and waste heat resources	Heat pump utilization through sector coupling

Sourse：JICA Study Team based on Information from HPT TCP[622]

(c) Refrigeration and air conditioning equipment

The fastest growing demand for electricity in buildings is for cooling. According to the IEA, only about 15% of households in emerging and developing countries own air conditioners (ACs) as of 2020, and the diffusion of ACs and more demand for electricity are expected with future economic growth.

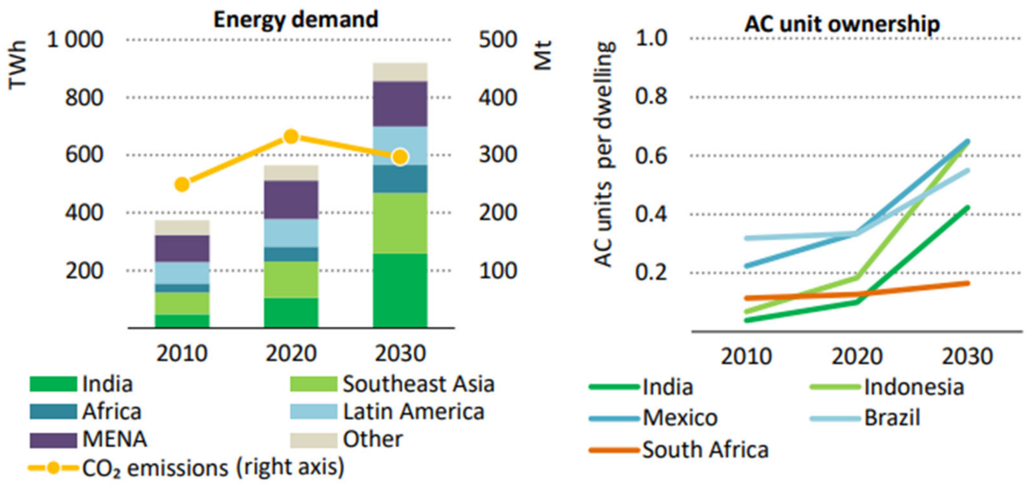

Figure 239 Energy demand and CO2 emissions from cooling in EMDEs and AC units per household in IEA climate-driven scenarios

Sourse : IEA, Financing Clean Energy Transitions in Emerging and Developing Economies(P153)

[Policies to induce AC power savings]

Measures taken in many countries to promote energy-saving ACs include labeling schemes and the establishment of minimum energy performance standards (MEPS). In fact, more than 80 countries have already established MEPS for AC, covering more than 85% of cooling energy consumption in the residential sector. However, these standards vary widely from country to country, and continuous strengthening of standards is needed. Another issue is that in some countries, such as Indonesia and Thailand, room AC labeling have different standards for inverter-compatible and non-inverter-compatible machines to protect local companies, and the acceptance of high-efficiency AC remains at a low level.

622 HPT TCP、Annual Report 2020、https://heatpumpingtechnologies.org/annual-report-2020-is-here/

According to the IEA, one of the challenges in expanding the use of high-efficiency ACs is that, despite their market availability, most consumers prioritize price and purchase models that are two to three times less efficient. As shown in below Figure, the general efficiency rating of ACs sold on the market (typical models available) is 10-30% better than the least efficient product (minimum average), but the market average is not significantly different from the least efficient product. Therefore, by implementing appropriate energy efficiency standards, AC energy efficiency could be improved by approximately 50% by 2030 to avoid being locked into inefficient equipment.

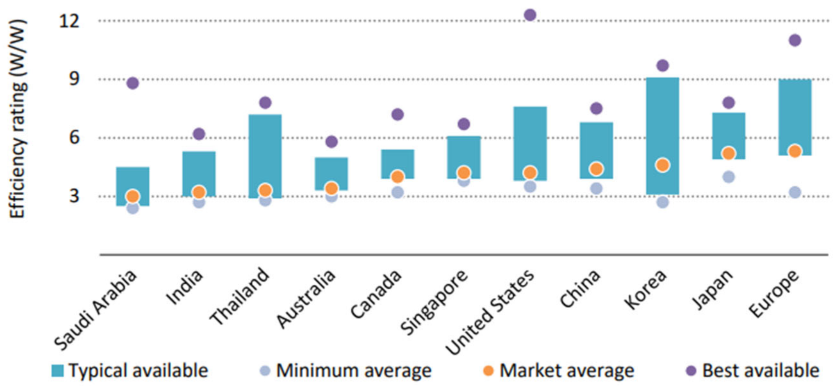

Figure 240 Efficiency ratings of available AC units and market average

Sourse : IEA, Financing Clean Energy Transitions in Emerging and Developing Economies(P155)

[Widespread use of inverter machines and evaluation of their energy-saving performance]

In addition, the widespread use of inverter models and other energy-efficient air conditioners can make a significant contribution to saving AC energy. An air conditioner equipped with an inverter -a technology that controls voltage, current, and frequency- can precisely control the motor of the compressor, the core of any AC. Together with improvements to conventional motors and heat exchangers, inverter-equipped ACs can reduce power consumption by about 58% compared to inverter-less models. [623]

Because inverter models are more expensive than non-inverters, they are not widely used in Southeast Asia, the Middle East, or Africa. In addition, in order to promote inverter machines, it is important to develop a system to evaluate their energy-saving performance. Developing countries are also promoting the establishment of Minimum Energy Performance Standards (MEPS) and labeling systems as energy conservation measures. Until now, the reference for AC has been the Energy Efficiency Ratio (EER) at rated capacity operation, where the performance of inverter models, which operate at optimum conditions in response to temperature changes, could not be properly evaluated using this indicator. To this end, Japan, led by the air conditioning industry, has developed an international standard (ISO 16358) for evaluating cooling seasonal performance factor (CSPF) in 2013, and has proposed to ASEAN countries a simplified method for testing and evaluating the efficiency of this ISO 16358. In addition to participating in seminars and other events held by energy efficiency and conservation policy bodies and standardization organizations in each country, Japan has cooperated in the adoption of standards and evaluation methods for energy efficiency and conservation measures in each country. [624]

[623] DAIKIN, https://www.daikin.co.jp/csr/environment/climatechange/inverter

[624] Overseas Environmental Cooperation Center, Japan, https://www.oecc.or.jp/cms/wp-content/uploads/2018/04/P9_%E6%97%A5%E5%86%B7%E5%B7%A5%E3%81%AE%E5%8F%96%E7%B5%84%E3%81%BF_%E7%AC%A0%E5%8E%9F%E5%8F%82%E4%BA%8B.pdf

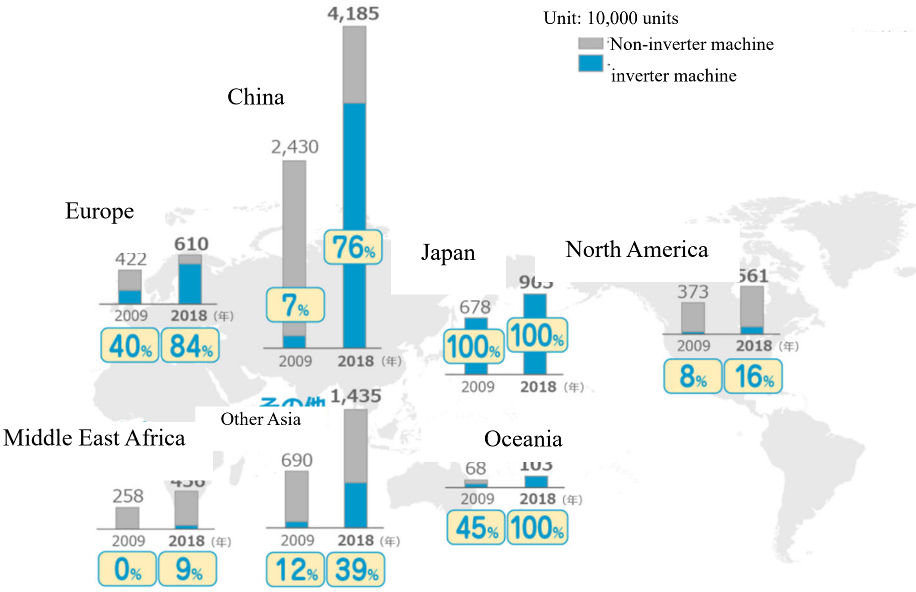

Figure 241 Residential AC market demand and percentage of inverter models (2018)

Note: Residential air conditioners refer to residential ductless air conditioners excluding window-installed and portable types. Residential ducted air conditioners included only for North America.

Sourse : DAIKIN[625]

ASEAN is trying to develop a unified standard for inverters.

[Low GWP and non-Freon refrigerants]

In addition, with the strengthening of global warming countermeasures in recent years, there is a demand for refrigerants with low GWP [626]and non-fluorocarbons. Refrigerants used in refrigeration and air conditioning equipment are being converted from ozone-depleting specified CFCs to hydrofluorocarbons (HFCs), an alternative to CFCs, but HFCs are problematic because of their high greenhouse effect. As a result, international HFC regulations are being tightened, particularly with the 2016 Montreal Protocol amendment, which establishes a new obligation to phase out HFC production and consumption, requiring developed countries to reduce their HFC production and consumption by 85% of reference year levels by 2036. On the other hand, many next-generation refrigerants, including green refrigerants that have an extremely low impact on global warming, face technical challenges in order to achieve the same or better equipment performance as conventional HFC refrigerants, as well as safety and cost issues. At present, the use of next-generation refrigerants in refrigeration and air conditioning equipment has not expanded globally[627].

(d) Life cycle of building

In order to promote carbon reduction and decarbonization of buildings, it is important to encourage favorable approaches not only at the use stage, such as the aforementioned ZEB and ZEH, but also throughout the entire life cycle, including the stages of building material production, construction, renovation, demolition, final disposal, and reuse.

According to the IEA, the manufacture, transport, and use of all construction materials for the building resulted in 3.5 Gt of energy and process CO2 emissions in 2019. This amounts to 10% of all energy sector emissions. Demand for building material for construction and renovation is increasing

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[625] DAIKIN, https://www.daikin.co.jp/csr/information/lecture/act01

[626] Global warming potential (a value that expresses the strength of the global warming effect when CO2 is set to 1)

[627] NEDO、https://www.nedo.go.jp/activities/ZZJP_100140.html

due to economic growth and population growth, and despite improvements in manufacturing processes for construction materials such as steel and cement, emissions associated with those products are rising, especially in emerging economies.

As shown in the Figure below, the main drivers of demand for cement and steel for building construction are the increase in floor area and the average height of buildings. Since 2000, the total floor area of all types of buildings worldwide has grown by almost 60%, adding 90 billion m^2 globally. In addition, since 2000, the number of new buildings taller than 150 m has increased by a factor of about five, with the average height rising from 170 m to 230 m.

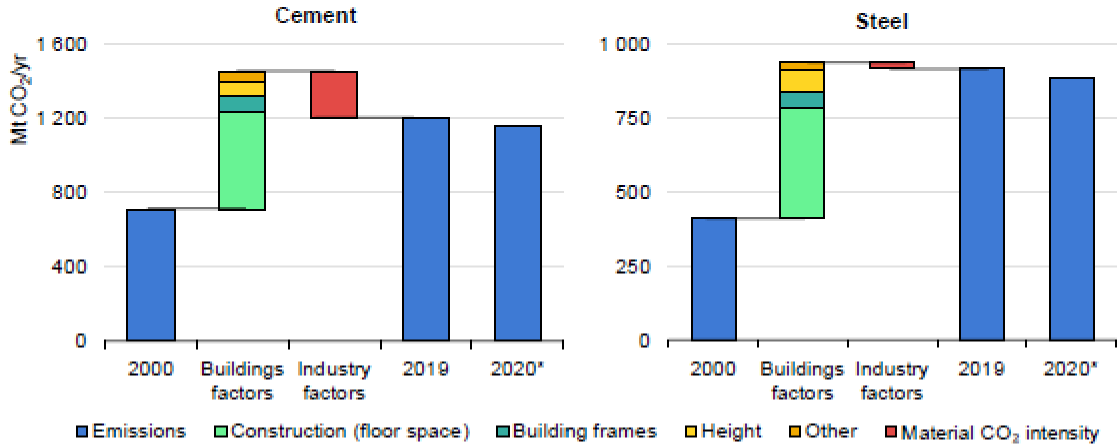

Figure 242 Factor Analysis of Increased Demand for Construction Cement and Steel

Souse：IEA, Energy Technology Perspectives 2020

The key to reduce building CO2 emissions from construction material is to extend the life of each building, optimize the structure, and make material stronger. Using less structural elements and optimizing the design can reduce concrete and steel by 20-25% and 35%, respectively, but life extension makes the largest contribution, accounting for more than 40% of the cumulative reduction.

Specific measures are as follows.

✓ Enhancing material properties: Enhancing material properties is an effective way to reduce the amount of material required for construction, potentially resulting in significant emission reduction. Quality standards must prohibit the use of low-quality concrete, which can lead to premature demolition of buildings. Optimizing the size of the structure, the strength of the concrete, and the mix of concrete can further reduce the demand for cement while providing the same performance. The lightweight element also reduces life-cycle emissions, especially from transportation. For example, cold-formed steel framing, which has been widely used since the 1990s for interior non-load-bearing partition walls in commercial buildings, is now beginning to be adopted for structural applications in mid-rise and multi-unit residential buildings.

✓ Structural Optimization: Structural optimization is an innovative design or composite frame that avoids over-using material while ensuring that the building is structurally sound. Optimization of the structure will reduce demand for cement by about 15% and for steel by about 15%.

✓ Prefabrication and precast construction methods: Prefabrication and precast construction are methods in which building structures and components are manufactured in advance at a factory, transported to the site, and assembled. As the structural components and parts ares manufactured in a factory, their sizes, shapes, and production processes can be more closely controlled, helping to reduce the use of building materials and shorten the construction process. Precast concrete also has a lower cement-to-water ratio, which increases the durability of the product. Digital processes such as 3D printing also have potential.

✓ Renovation: Renovation offers the greatest potential for material savings by extending life expectancy of structures. Building renovations generally require 40 to 80 times less material in terms of mass than rebuilding from scratch, thus saving steel and cement. However, retrofitting could be expensive. In the case of high-rise office buildings, for example, the cost of renovation could equal the cost of demolition and reconstruction.

✓ Reuse and Recycling: Reuse and recycling of cement and steel components can reduce the need for materials. However, the challenge for this approach is the cost of transporting heavy blocks over long distances. There may be potential for recovery and reuse of non-hydrated cement from spent concrete, but the technology for this has not yet reached the commercial stage. Recycling of concrete aggregate is possible, but the potential emission reductions are marginal due to the need for transportation, the fact that aggregate is carbon-less and irrelevant for carbon reduction, and the need to add cement to facilitate recycling.

(ii) Trends in the development and social implementation of technologies and services in the countries covered by the field survey

(a) India

In India, the Energy Conservation Building Code (ECBC) has been implemented as a voluntary framework under the Energy Conservation Act 2001. In 2017, the ECBC was updated to specify energy efficiency standards for design and construction of commercial buildings above a certain size. [628] See the summary below.

Table 143 Summary of ECBC(2017 Update)

Scope	Description
Building	New and existing commercial construction*2 above a certain size. *1 *1: Power load of 100 kW or greater, or contract demand of 120 kVA or greater. *2: Hotels, educational institutions, hospitals, shopping malls, commercial buildings, etc.
Equipment/system	(1) Exterior skin (open windows, exterior skin other than windows, daylighting, airtightness, etc.) (2) Equipment including heating, ventilation, and air conditioning (3) Lighting (indoor/outdoor) (4) Voltage transformers, motors, renewable energy systems *Reference standard: The National Building Code of India 2016 (NBC). In addition, the whole building performance (WBP) must be calculated using energy simulation software approved by BEE.
Mandatory requirements for certification	(1) Energy performance index ratio (EPI ratio) is 1.0 or lower. EPI: annual energy consumption (kWh) divided by unit area of building (1.0 m^2) In this case the EPI ratio is the standard building EPI divided by the proposed building EPI (2) Equipment/systems must satisfy the above requirements (1) to (4) applicable.
Classification	ECBC Building / ECBC+ Building / Super ECBC Building Each classification has different requirements for equipment/system types (1) through (4) as well as for the total building performance (WBP).

In 2018, the Indian government launched the Eco-Niwas Samhita (ENS) as ECBC for residence and set the Building Envelope standard in Part 1. Also, in 2019 the Energy Efficiency Label for Residential Buildings was launched to provide consumers with information on residential energy efficiency

[628] Ministry of Power, BEE," Energy Conservation Building Code 2017", https://beeindia.gov.in/sites/default/files/BEE_ECBC%202017.pdf

standards. [629]

In addition, the Indian Green Building Council (IGBC) has been established under the Federation of Indian Industry, which is responsible for evaluation, certification, and human resource development related to green building.

The IGBC has announced its "IGBC Net Zero vision by 2050," with the goal of making all new buildings Net Zero by 2030 and all buildings (new and existing) Net Zero by 2050. A roadmap will developed then updated every five years starting in 2025 to achieve this goal[630].

The IGBC has already developed a number of Green rating systems for different types of buildings [631]and some central and state authorities in India have endorsed this rating system and provided their own incentives to encourage green building practices[632].

In 2018, the IGBC developed the IGBC Net Zero Energy rating system as a tool to help designers employ energy efficiency concepts and appropriate renewable energy sources to construct net zero energy buildings [633]. As of January 2022, 20+ Net Zero Energy projects have cleared their targets (were registered), while 65+ projects are in progress toward achievement, with 280+ organizations and companies committed to work toward Net Zero. [634]

Table 144 Summary of IGBC Net Zero Energy rating system

Scope	Description
Building	New and existing commercial construction (Offices, IT parks, banks, shopping malls, hotels, hospitals, airports, convention centers, educational institutions, factories, etc.)
Equipment/system	(1) Exterior skin (roof, walls, glass) (2) Air conditioning (chillers, pumps, fans, motors, etc.) (3) Lighting (indoor/outdoor), daylighting (4) Equipment (electrical appliances, office equipment, etc.) (5) Renewable energy
Mandatory requirements for certification	(1) Meet IGBC ratings (minimum energy performance requirements) for each building category. (2) Energy performance index ratio (EPI ratio) of 1.0 or below. In this case the EPI ratio is the actual building EPI divided by the proposed building EPI (3) Demonstrate that the energy performance of key equipment meets energy-efficient building code requirements (as defined in ECBC 2017)
Classification	Net Zero Energy: National Excellence level Net Zero Energy Platinum: Global Leadership level

Both mandatory and voluntary programs for developing performance standards and labeling exist for individual machines, with mandatory equipment being air conditioners, refrigerators, televisions, LED, etc. (subject to regular updates). [635]

Other measures include the Super-Efficient Equipment Programme (SEEP), which encourages the

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[629] BEE, https://beeindia.gov.in/content/ecbc-residential

[630] From materials provided by IGBC

[631] IGBC, https://igbc.in/igbc/redirectHtml.htm?redVal=showratingSysnosign

[632] IGBC, https://igbc.in/igbc/redirectHtml.htm?redVal=showGovtIncentivesnosign

[633] IGBC Net Zero Energy BuildingsRating System Pilot Version (November 2018), https://igbc.in/igbc/html_pdfs/IGBC%20Net%20Zero%20Energy%20Buildings%20Rating%20System_%20Pilot_Nov%20_2018.pdf

[634] From materials provided by IGBC

[635] BEE, Standards & Labeling, https://beeindia.gov.in/content/standards-labeling

market diffusion of high-efficiency equipment. The first target is ceiling fans, with the goal of increasing the production and diffusion of fans that are about 50% more efficient than the market average by providing time-limited incentives for fan manufacturers to sell superior products at discount[636].

Also, in 2019, the "India Cooling Action Plan" was published to reduce energy demand for cooling, outlining reduction targets (20-25% reduction in cooling demand and 25-30% reduction in refrigerant demand) and measures to be taken by FY2037. [637]

(b) Indonesia

In Indonesia, the following four national energy conservation standards (SNI) for buildings have been developed to improve energy efficiency in buildings. Compliance with the standard is not mandatory and is used as a reference for construction businesses[638].

- ✓ Energy conservation for building envelope (OTTV & RTTV < 35 W/m2) SNI 03-6389-2011
- ✓ Energy conservation for air conditioning system in building (temperature: 24oC - 27oC and humidity 60% ± 5%) SNI 03-6390-2011
- ✓ Energy conservation for lighting system in building (standard of lighting intensity for the office, residential, industry, hospital, mall, etc)) SNI 03-6197-2011
- ✓ Energy audit procedure for building SNI 03-6196-2011

In addition, Green Building Council Indonesia (GBC Indonesia), an industry organization, is working to promote green building. It develops assessment tools and green building certifications for buildings (new and existing) and homes, and organizes educational activities on green building. [639]

Minimum Energy Performance Standards (MEPS) and labeling schemes have been introduced for individual machines. Each standard is set by MEPS based on Indonesia national standards (SNI) and energy performance testing standards (EPTS) [640]. MEPS are mandatory standard for fluorescent light bulbs and air conditioners, while voluntary for other equipment. It will be extended to refrigerators, fans, electronic ballasts, electric motors, LED bulbs, washing machines, well pumps, irons, and TVs.

(c) Thailand

Under the Energy Conservation Promotion Act B.E. 2535, Thailand has created the Building Energy Code (BEC) for energy-saving design standards for structures (excluding factories) with total floor area of 2,000 square meters or larger.

In November 2020, the Thai government reviewed the BEC enacted in 2009, requiring that new construction or renovation of buildings with total floor area of 2,000 square meters or larger must meet certain energy conservation standards for building materials, air conditioning, lighting, and design. Nine types of buildings covered are theaters, hotels, service facilities, hospitals, educational facilities, office buildings, commercial facilities, multi-family housing, stadiums and conference halls - facilities where people gather[641]. In December 2021, a ministerial ordinance was announced, detailing the calculation and certification methods for each standard[642]. In addition to the expansion of household equipment that may be subject to MEPS and HEPS in the future, it is expected that the

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636 BEE, SEEP, https://beeindia.gov.in/content/seep-0

637 Ozone Cell, Ministry of Environment, Forest & Climate Change, Government of India,"India Cooling Action Plan", http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf

638 IEA, https://www.iea.org/policies/2522-national-energy-efficiency-standard-for-buildings-2011

639 Green Building Council Indonesia, https://www.gbcindonesia.org/web

640 APERC, https://aperc.or.jp/file/2016/4/28/Indonesia_Compendium_2015_-_Final.pdf . SNI standards for electrical appliances and equipment are drafted and registered at the National Standardization Agency (Badan Standardisasi Nasional or BSN). (https://www.bsn.go.id/)

641 Enviliance ASIA 2020.11.26 https://enviliance.com/regions/southeast-asia/th/report_1359

642 Enviliance ASIA 2022.1.12 https://enviliance.com/regions/southeast-asia/th/report_5172

application of new equipment introduced in the building and industrial sectors will also be studied and standards will be developed. There is a need to find a way to control the market (for energy-efficient equipment that meets standards) by promoting MEPS and HEPS.

For individual machines, minimum energy performance standards (MEPS, (mandatory/voluntary) and high-level energy performance standards (HEPS, voluntary) have been introduced. DEDE and the Thai Industrial Standards Institute (TISI) are jointly responsible for implementing the MEPS program. HEPS is jointly implemented by DEDE and EGAT to issue labels for electrical appliances as well as for non-electrical and industrial appliances [643].

(d) Morocco

In Morocco, the Ministry of Industry and Trade [644] is responsible for energy efficiency policies for shopping centers, factories, and ports. The Ministry of National Planning, Urban Planning, Housing and City Policy[645]leads the energy policy for new homes.

A buildings decree (No. 2-13-874) was announced in 2014 establishing minimum technical requirements for thermal performance in new constructions. Specific thermal requirements have been established for each of Morocco's six climate zones [646]. In addition, energy conservation in public buildings is being promoted through the introduction of energy management systems, LED and solar thermal systems, together with the formulation of a financial support framework. For example, a program to promote renewable energy and energy conservation in mosques, energy efficiency initiatives have been implemented in some 900 mosques, with the first 100 mosques saving energy by 41-63% in the first year[647]. The Eco-Binayate building labeling system has also been developed by the AMEE. A bill is currently awaiting implementation that would provide a superior labeling for more efficient buildings (giving further preferential treatment for those that exceed standards).

Minimum Energy Performance Standards (MEPS) and labeling schemes have been introduced for individual machines. MEPS was introduced in 2018 and covers air conditioning [648]. The labeling system made mandatory in 2011 also covers refrigerators and freezers, air conditioners, cooking equipment, cleaning equipment, and household lights[649].

Morocco has also acknowledged the cooling energy as its immediate challenge. The current air conditioner penetration rate is below 20%, but it is expected to reach 40% by 2030. Capital investment, including energy-saving measures, will be necessary to meet the future increase in summer cooling energy demand.

While efforts to conserve energy are actively being made, no efforts are being made to achieve zero energy combined with renewable energy.

On the other hand, since local needs for energy conservation and decarbonization are increasing, it is necessary to develop the requisite human resources, design a system for promotion, and raise awareness for energy conservation in order to advance energy conservation, including ZEB diffusion.

643 Ministry of the Environment December 2015 https://www.env.go.jp/earth/coop/lowcarbon-asia/region/data/thailand_climate_change_policy_20151224.pdf

Ministry of Industry and Trade：https://www.mcinet.gov.ma/

Ministry of National Territory Planning, Land Planning, Housing and City Policy：http://www.mhpv.gov.ma/

IEA, https://www.iea.org/policies/8570-decree-n-2-13-874-on-thermal-regulation-of-buildings?country=Morocco&qs=morocco

Ministry of Energy Transition and Sustainable Development, https://www.mem.gov.ma/en/Pages/secteur.aspx?e=3

IEA, https://www.iea.org/policies/7683-meps-for-air-conditioners?country=Morocco&qs=morocco

IEA, https://www.iea.org/policies/1898-moroccan-standard-nm-142300-on-labelling-of-cooling-cooking-and-cleaning-appliances-and-indoor-lighting?country=Morocco&qs=morocco

(iii) Advantages and strengths of Japanese companies

The results of interviews with relevant Japanese industry groups and individual companies on Japanese technologies and services.

Table 145 Advantages and strengths of Japanese companies

[ZEB]

Advantages and strengths of Japanese companies	Current challenges	Note
・ZEB-related technologies that Japanese companies have competitive edge in are inverter and other air conditioning, building materials, glass insulation, and building design capabilities, among others. ・Good after-sales service (China is not good in this area).	・Japan side's intentions not always aligned with local demands. Identifying counterpart requirements is the key.	(International development) ・ISO standardization of ZEB (finalized in September 2021, TS23764) (Business model) ・For developing countries, "lifestyle proposals" offering not standalone hardware but a combination of systems, services, and overall operations are a must. (Ideal support by the Japanese government) ・Ask each country to introduce bidding standards for their local municipalities that take into account not only the initial price but also the total cost throughout life cycles. Even if Japanese products are less expensive when the maintenance costs are added, other countries may still win the bidding just because they offer lower initial costs.

[Heat pump (HP)]

Advantages and strengths of Japanese companies	Current challenges	Note
・One example of industrial HP application is a project in Thailand using a model that can heat and cool simultaneously (capability unique to a Japanese manufacturer). This type of HP has been used in JICA and NEDO demonstration projects and JCM, showing much potential.	・Product recognition and costs are the main challenges when promoting HP in ASEAN. ・Japanese products are over-engineered for developing countries. The cost issue may be resolved by reviewing specifications to meet local needs. ・Chinese manufacturers are ready to make products that are effectively improved versions of Japanese	(International initiatives by HPTCJ) ・Established the Asian Heat Pump Thermal Storage Technology Network (AHPNW) together with six other countries - China, South Korea, Vietnam, India, Indonesia, and Thailand. ・Joint research on heat pump and thermal storage technologies with international organizations such as the IEA and IRENA.

	technologies and products to enter other markets, becoming formidable competitors.	

[Refrigeration and air conditioning equipment]

Advantages and strengths of Japanese companies	Current challenges	Note
・Inverters and refrigerants offered in developing countries are limited to products already used in Japan and therefore reliable (Some Chinese manufacturers in developing countries are offering propane refrigerant not widely used in their own country, raising safety concerns). ・Mildly flammable refrigerants can be offered together with methods for safety evaluation and wide acceptance. ・India (where inverter penetration is about 20%) is a promising market because Chinese manufacturers cannot enter easily.	・ Discussion with local manufacturers lacking inverter technology.[650] ・ Inverters advantages in intermediate climates are lost in countries where temperatures are always high. In addition, the performance of heat pumps drops in places where boilers work better because the temperature can be as low as minus 10 degrees Celsius. Local temperature patterns must be established to figure out which technology works best. ・Once a certain country has taken control of distribution networks in that area, it will be very difficult for any other country to reverse the situation (examples of other countries taking the lead: China's entry into Pakistan, China and South Korea's entry into Africa).	(International initiatives by JRAIA [651]) ・Advance initiatives to establish standards for correctly evaluating performance and can be accepted by developing countries (targeting Asia in general, ASEAN and Pakistan in particular).[652] ・Promote trainings at overseas testing laboratories to support correct performance assessment. ・Member of the Initiative for Fluorocarbon (IFL) led by the Ministry of the Environment of Japan. The IFL will lead disposal and refrigerant recovery programs while also support developing countries.

ASEAN is a region that has the potential to become a foothold for overseas expansion of Japanese ZEB companies. The Japan Business Alliance for Smart Energy Worldwide launched the ZEB Promotion Working Group in 2017 to promote and expand the concept of ZEB in the region, especially in the warm and humid countries of Asia, and has been working to spread the ZEB technology and expertise in commercial buildings mainly in the ASEAN countries. The Working Group has been developing international standards that will serve as a basis for the formulation of related measures in each country.

In September 2021, the technical specification that Japan sponsored and proposed to ISO was formalized as TS23764 (Methodology for achieving nonresidential zero-energy buildings (ZEBs))

Thailamd amd Indonesia are among the ASEAN countries with many local manufacturers and lagging behind in the introduction of inverters

JRAIA : Japan Refrigeration and Air Conditioning Industry Association

[652] CSPF (Cooling-Stage Power Factor) standards need to be promoted to correctly evaluate the performance of inverters (For details, see (4) Buildings (1) Worldwide Trends in Development and Social Implementation of Technology and Services (c) Air-Conditioning Equipment).

[653](For details, see (4) Buildings (1) Trends in the global development and social implementation of technologies and services (a) ZEBs). The step-by-step approach can facilitate ZEB initiatives in ASEAN countries where (Net)ZEB faces technical and financial challenges. The scheme may also incorporate certification for procurement of materials, performance evaluation and maintenance after the start of operation to enhance the advantage of reliable Japanese products[654]. In the process of finalizing TS23764, discussions were held in WG2 (Design of Energy Efficient Building) of TC205 (Design for the Built Environment), one of the ISO technical committees. As a result of requesting and promoting bilateral cooperation with ASEAN countries, the Philippines, Malaysia, and Singapore were registered as voting members (P-members) in TC205 in FY 2019 showing the effectiveness of collaboration with ASEAN countries that was instrumental in having the standard officialized.

Furthermore , through the activities of the Japan Business Alliance for Smart Energy Worldwide, the ZEB Award was added in 2019 to the ASEAN Energy Award, which recognizes best practices for energy sustainability in ASEAN. The first ZEB Award was won by Singapore, followed by Malaysia, Thailand, and Indonesia[655]. In addition, in order to build a favorable environment for business-led diffusion of low-carbon technologies in the ASEAN region, the Japanese government proposed the Cleaner Energy Future Initiative for ASEAN (CEFIA). When this Initiative was launched in 2019, ZEB was chosen as its flagship project[656]. These examples show the growing interest within ASEAN countries for ZEB in collaboration with Japan.

As for individual equipment, the strengths of both heat pumps as well as refrigeration and air-conditioning equipment are their high quality and reliability that are based on technologies developed indigenously and widely used in Japan. On the other hand, specification and price gaps with local needs exist. In addition, more Chinese companies with price advantage are expanding into developing countries. Japan needs to emphasize not the initial installation cost but the advantages of its products over the entire life cycle, including their energy-saving performance and after-sales service, as well as highlighting the additional value created by combining systems and services, instead of focusing on individual products.

Table 146 Initiatives in ASEAN by the Heat Pump and Thermal Storage Center of Japan

Initiatives in ASEAN by the Heat Pump and Thermal Storage Center of Japan (HPTCJ)

The HPTCJ is engaged in promotion, surveys, and research of heat pumps and thermal storage systems inside and outside Japan. As a member of the Asian Heat Pump and Thermal Storage Technology Network (AHPNW) [657], the HPTCJ, together with six other Asian member countries, issued a joint declaration in October 2017 announcing the promotion of heat pump water heaters as the main theme of AHPNW especially in Asia, where energy consumption is expected to grow.

■Initiatives of the Southeast Asia HP Water Heater and Thermal Storage System Promotion Committee

In order to steadily implement the above Joint Declaration, the Southeast Asia HP Water Heater and Thermal Storage Systems Promotion Committee was established in 2018 (active over three years). [658]

- ✓ Target countries: Thailand, Vietnam, Indonesia
- ✓ Objectives: Raise awareness, understand local needs, build local networks
- ✓ Approach: Analyze HP dissemination issues from the perspectives of awareness, sector-specific needs, costs, and other angles.

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653 Japanese Business Alliance for Smart Energy Worldwide, https://www.jase-w.org/press-release-iso-ts23764/
654 METI, March 2020, https://www.meti.go.jp/meti_lib/report/2019FY/000516.pdf
655 ASEAN Center for Energy, https://aseanenergy.org/work/award/
656 CEFIA, https://www.cefia-dp.go.jp/fp/zeb/01
657 The 7 member countries are China, India, Japan, Korea, Vietnam, Indonesia, and Thailand.
658 The committee includes heat pump manufacturers, general contractors, and electric power companies.

✓ Target sectors: Commercial (especially hotels and hospitals)[659]

The survey results indicate that the main issues are awareness (heat pump technology itself is not recognized) and cost (Japanese products are over-engineered and overpriced for local market). In addition, the number of commercial buildings such as hotels is expected to increase in the surveyed countries as the standard of living and the number of tourists rise, and the energy-saving potential of HP installation (to meet demand for hot water supply) in these buildings is expected to grow in the future. To build local networks, local workshops and interviews have been organized, with promotional activities with Green DC in Vietnam and MASKEEI in Indonesia still ongoing.

■Case study of industrial HP application in ASEAN (Thailand)

Thailand is the most energy-efficient country in ASEAN. Japanese HP production lines were first built in Thailand, and there are many HP factories there. An example of HP utilization in the industrial field is a model (proprietary to a Japanese manufacturer) that can heat and cool simultaneously. Many factories in Thailand operate in the food and beverage sector where both heating and cooling are required, making them a good match for the technology. JICA and NEDO projects had demonstrated that Thailand has sufficient potential for simultaneous heating, as also indicated by introduction to JCM. On the other hand, Thailand's industrial HP installation rate is low (which is same in Japan). Whether to develop the system in Japan and bring it to the local market or to run parallel development it in Japan and the local market depends on future scenarios, but there is a possibility of further implementations.

（５） Urban planning

(i) Trends in the development and social implementation of technologies and services worldwide

According to C40, a network of the world's largest cities working to combat climate change, urban areas are responsible for two-thirds of the world's final energy consumption and 70% of CO2 emissions. [660] Cities are composed of various elements, including the aforementioned "power and energy," "transportation and traffic," "industry," and "buildings," requiring cross-sector efforts in addition to sector-specific technologies and services that contribute to carbon reduction and decarbonization.

（a） Smart city

Recent years have seen the development of "smart cities" in many parts of the world that try to address various urban issues such as environment, energy, transportation, and medical/health, utilizing new technologies such as ICT for overall optimization.

Smart city concept is diverse and has changed over time. According to a document compiled by the Ministry of Land, Infrastructure, Transport and Tourism in 2018, a smart city is "a sustainable city or district where management (planning, maintenance, management and operation, etc.) is conducted to address various urban issues while utilizing new technologies such as ICT to achieve overall optimization. [661] Most smart cities used to focus on urban infrastructure development initiatives to solve a variety of urban issues (e.g., tight housing demand, traffic congestion, water purification and wastewater treatment). In recent years, however, efforts to create new services using digital technology (e.g., Mobility as a Service, or MaaS) and to improve the quality of life have become a major global trend. While the focus in around 2010 was on sector-specific projects, in recent years, the number of cross-sector initiatives that utilize ICT to address a wide range of fields, such as the environment,

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[659] In Southeast Asia, the commercial use was selected because some people in Southeast Asia said that residential use does not require hot water heating in the first place, and industrial use is not versatile enough.

[660] C40 CITIES、https://www.c40.org/why_cities

[661] Ministry of Land, Infrastructure, Transport and Tourism, https://www.mlit.go.jp/report/press/toshi07_hh_000126.html

energy, transportation, and medical/health care, has been increasing.

Table 147　Smart City Case Studies

City	Project lead	Description
Amsterdam	Municipality	Pilot projects in environmental and energy public services, health care, agriculture, etc. aimed at reducing CO_2 emissions. Weather data and waterway/canal maintenance data are simultaneously analyzed to predict floods.
Copenhagen	Municipality	Data is collected from streetlights, trash cans, sewage treatment systems, cell phones, etc. to optimize traffic signal control, improve air pollution, and cut CO_2 emissions. Data is also provided to private companies, etc. through trading market
Singapore	Central government	Creation of a 3D model of the entire country and a database linking information to buildings, civil engineering infrastructure, etc. Build a new city with an all-round smart environment (energy, transportation, logistics system) and administrative system.
Toronto	Google subsidiary	Sensors are installed throughout the city to constantly collect information on traffic flow, air pollution, energy use, traveler behavior patterns, etc. and take this information into urban design.
San Diego	GE, AT&T, Intel...	Building an urban environment using smart streetlights to control traffic lights, acquire pedestrian and vehicle data, and provide data to startups.

Sourse : JICA Study Team based on Information from Cabinet Office [662]

In particular, digital native companies such as GAFA and BAT (Baidu, Alibaba, and Tencent) have recently emerged as platform providers in smart city development, and demonstration projects are progressing around the world to optimize and streamline infrastructure operations and improve convenience and comfort for residents through new services that utilize digital technology. The City Architectures of Google, Cisco, Alibaba, and Siemens, all of which are pursuing social implementations in this field, have nearly identical configurations and aim to integrate and coordinate control of all connected systems by leveraging AI and big data. For example, Cisco, which is involved in many smart city developments, especially in Europe, has introduced the Kinetic for Cities to build a solution mainly aimed at improving the efficiency of urban administration using its own network technology. [663]

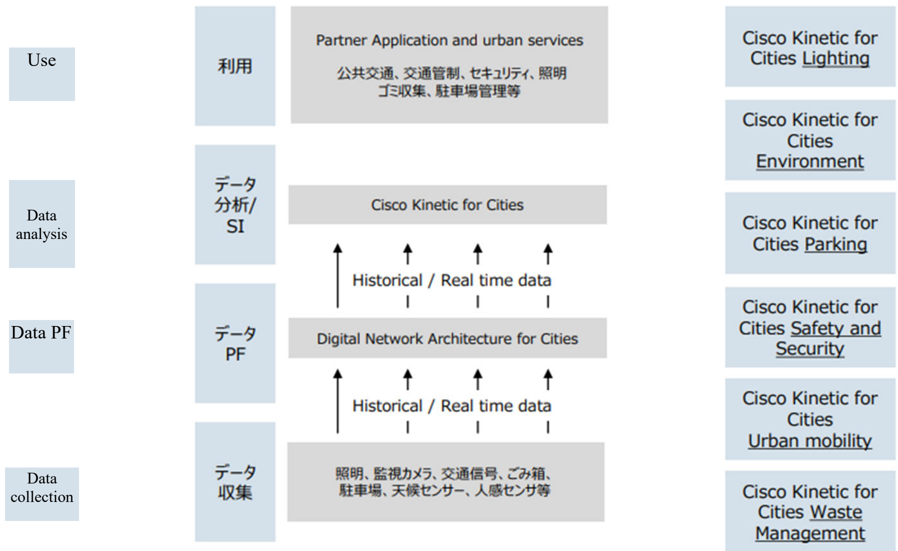

Figure 243　Cisco's envisioned smart city business

Sourse : Nomura Research Institute

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[662] Cabinet Office, November 2018, https://www.chisou.go.jp/tiiki/kokusentoc/supercity/dai2/shiryou1.pdf

[663] NRI, May 2019, https://www.nri.com/-/media/Corporate/jp/Files/PDF/journal/2019/20190426_.pdf?la=ja-JP&hash=044467300E0FB6503A84F275CA2AEAA0649BE482

The progress of digital technology in China through public-private partnerships has been particularly remarkable. Under the Xi Jinping administration, each city is promoting policies to demonstrate and realize digital innovation (Beijing: automated driving with Baidu, Hangzhou: smart city with Alibaba, Shenzhen: healthcare with Tencent, among others).

In the field of urban infrastructure enhancement, Japan has accumulated experience and expertise in multi-dimensional urban development projects, including transit-oriented development (TOD) and environment-friendly approaches, and has marketed these as its strengths. However, as mentioned above, emerging countries are now focusing shift from the conventional needs of urban infrastructure development to the future standardization of the use of digital technology. This will require more cross-sector activities and urban development support that incorporating digital technology in addition to the conventional approaches.

Under the circumstance, the Japanese government, in order to promote collaboration among smart city projects and cross-sector data linkage, has set forth the basic policy for promoting smart city projects as well as presenting smart city architecture (a blueprint for the entire system) at the Integrated Innovation Strategy Promotion Council under the Cabinet Office[664] . It is now necessary to exploit the interconnected cross-sector systems to consider not only individual technologies but also rules and framework designs from very high levels rather than focusing on partial optimization. The US and European countries have been leading these architecture-centric high-level discussions.

[Smart city projects in developed countries]

Smart city projects in developed countries often aim to make existing cities more comfortable with most advanced digital technology.

(Europe)

In Europe, where people are generally environmentally conscious, sustainable urbanization is a priority, focusing on carbon reduction and decarbonization of energy and transportation sectors using ICT. In 2009, the European Commission developed the Strategic Energy Technology Plan (SET Plan) as key technological strategy for energy and climate change. One of the actions to implement the SET Plan is the Smart Cities Initiative, with the goal of creating 25 to 30 smart cities in Europe, each being an advanced low-carbon model actively aiming to reduce GHG emissions by 40% by 2020. Three key areas -buildings, regional energy networks, and transportation- were chosen for implementing advanced measures, including the use of renewable energy for heating and cooling demand, the establishment of a smart grid that integrates and optimally controls buildings/equipment/renewable energy power generation, and the use of alternative fuels for transportation[665].

In 2015, the Integrated SET-PLAN was adopted, building on the aforementioned SET Plan and setting forth a new policy. The new goal for smart cities was the planning and implementation of 100 Positive Energy Districts (PEDs) by 2025 for sustainable urbanization. A PED is a region that has achieved zero imported energy and zero CO_2 emissions by leveraging renewable energy sources. The new PLAN lists the following examples of the technologies needed to realize the project, indicating that an energy system that is more cross-sector and incorporates digital technologies is required[666].

- ✓ Energy conservation, energy use efficiency, and EMS technology for each building and region.
- ✓ Technology for maximum and optimal utilization of local energy (PV, solar thermal, geothermal, waste power, etc.).
- ✓ Integrated technology for energy systems built on ICT platforms.

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664 It divides functions, data, assets, etc. into layers, visualizes the relationship between the components of each layer, and promotes common understanding among the parties involved.

665 JETRO, February 2010, https://www.jetro.go.jp/ext_images/jfile/report/07000258/eu_setplan.pdf

666 European Commission、Strategic Energy Technologies Information Systems「SET-Plan ACTION n°3.2 Implementation Plan」(June 2018) , https://setis.ec.europa.eu/system/files/setplan_smartcities_implementationplan.pdf

- ✓ Long-term energy (electricity and heat) storage technology.
- ✓ Technology for integrating EVs into energy systems.
- ✓ Distributed ledger technology to support the prosumerization of citizens (producers-consumers)

A wide range of non-technical agenda have also been raised, including harmonization with existing laws and regulations, encouraging stakeholder participation, appropriate cost sharing, establishment of funding schemes, capacity building, and advocating open innovation.

(USA)

The definition of a smart city by Smart Cities Council, the largest industry group in the US, can be summarized as: a city that incorporates digital technology into all urban functions and collects, interconnects, and analyzes data to help people make better decisions. While the characteristics of the initiatives vary from state to state and city to city, the use of digital technology is increasing, with giant IT companies such as GAFA, IBM, Cisco, and IBM participating in smart city development.

For example, New York City is focusing on the environment and cybersecurity. In April 2019, the state announced the NYC Green New Deal, a plan to address global warming, which aims to reduce GHG emissions by nearly 30% by 2030 by introducing more renewable energy and mandatory large building retrofits, with a $14 billion investment and city code revisions. In order to become a smart city, the NYC has prioritized cyber security, which is a prerequisite for the use of IoT, aiming to be a global leader in this field by incubating cyber security startups and developing talents in that field. San Francisco, California, is working to manage administrative data as a strategic asset and share it as open data. The city believes that sharing open data will advance analysis, research, performance visualization, app development, etc., and develop a data-driven ecosystem, which in turn is expected to create a virtuous cycle between better quality of life for citizens, efficient service delivery, and creation of new businesses[667].

[Smart city projects in emerging countries]

Numerous state-led smart city projects are ongoing in China, India, and ASEAN as well as in developed countries. These initiatives in emerging countries can be characterized as projects to improve energy supply and other basic urban functions in order to address social issues caused by population growth and rapid urbanization. On the other hand, the lack of existing infrastructure and regulations also opens the opportunities for leapfrog development[668].

(China)

Smart cities in China focus on digitalization. The National New City Plan released by the State Council in 2014 explicitly stated that new digital technologies such as IoT, cloud computing, and big data would be used to build smart cities. In addition, the 13th Five-Year Plan (2016-2020) was the first five-year plan to stipulate smart city initiatives. A total of 500 smart city projects in the preparation stage or under construction. Alibaba, a leader in smart city development in China, unveiled its City Brainsystemin 2016, which uses artificial intelligence to manage and leverage a city's big data. The concept of the system is to utilize all real-time city data to immediately correct operational flaws in the city and optimize the city's public resources as a whole, initially in the area of transportation in the city of Hangzhou. By analyzing images from roadside network cameras, the system can automatically switch traffic signals to respond to traffic conditions, smoothly guide emergency vehicles by detecting traffic accidents, and automatically report vehicle abnormalities to the police. In the future, it is expected to cover all elements of a city, including public transportation, buildings, and agricultural land, to propose solutions for various urban issues.

(India)

In India, the government has declared its Smart City Mission, a policy to build 100 smart cities throughout the country by 2022. The total investment is expected to be over 2 trillion rupees (about 3.2 trillion yen). While many cities aim to develop basic and critical infrastructure for daily life , some

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[667] JETRO, October 2015, https://www.jetro.go.jp/ext_images/_Reports/02/bbaea2a997300b76/reportsNY_201510.pdf

[668] The spread of new services, etc., in emerging countries where existing social infrastructure is not yet in place, leapfrogging the technological progress made by developed countries.

major cities such as Delhi aim to solve existing problems by utilizing IT and latest technologies. India has public digital resource called India Stack which is based on the Aadhaar national ID system. Individual biometric data is registered in the Aadhaar and also linked to taxpayer identification numbers and bank accounts. This allows for the smooth delivery of subsidies and public services, as well as electronic payments. The India Stack has attracted attention from emerging countries, where many citizens lack official means of proving their identity. The government is developing the Modular and Open Source Identity Platform (MOSIP), which will make the India Stack architecture publicly available so that countries outside India can develop their own digital public goods mechanisms. Discussions towards their introduction are reportedly ongoing with Asian and African countries, among others[669].

(ASEAN)

In ASEAN, the ASEAN Smart City Network (ASCN) was launched in 2018. 26 cities from 10 ASEAN countries were chosen to promote smart city development projects through collaboration with the private sector and other countries[670]. The ASCN has established strategic objectives for sustainable urbanization in six areas (civic and social, health and wellbeing, safety and security, quality environment, built infrastructure, and industry and innovation). The ASEAN Sustainable Urbanization Strategy (ASUS) defines 18 sub-areas corresponding to those six areas, summarizing opportunities and challenges for smart city development.

Figure 244 ASCN demonstration 26 cities in 10 countries

Table 148 Sectors and 18 Subthemes of ASCN

6 areas	18 sub-areas
Civic & Social	・Social cohesion ・Inclusive and equitable growth ・Culture and heritage ・Tourism
Health & Wellbeing	・Housing & home ・Healthcare ・Other public services
Safety & Security	・Personal safety and security ・Cyber security
Quality environment	・Water, waste, sanitation ・Energy ・Food
Built infrastructure	・Mobility ・Building & construction ・Urban resilience
Industry & Innovation	・Entrepreneurship and innovation ・Trade, commerce ・Education

Sourse：JICA Study Team based on Information from Prime Minister's residence information, ASCN information

Among ASEAN countries, Singapore is one of the world's most advanced in smart city projects, while many countries have yet to develop basic urban functions. Although needs vary greatly from country to country, a common challenge for many is resolving the traffic congestion following rapid urbanization. The eight ASUS priority initiatives include two transportation and traffic topics: the implementation and improvement of the Bus Rapid Transit (BRT) system, and the development and enhancement of traffic management systems. While projects like MaaS rolled out in other countries have yet to take off, Grab and Go-Jek are already two major players in the ridesharing business. Both

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669 JETRO, June 2020, https://www.jetro.go.jp/biznews/2020/06/61cb3c1eeec1c160.html

670 ASEAN、ASEAN Smart Cities Network、https://asean.org/asean/asean-smart-cities-network/#

companies are expanding their services beyond ridesharing, from payment and customer platforms to finance, entertainment, to support form home and business[671].

[Developments in international standardization][672]

As noted above, smart city projects have increasingly become cross-sector efforts leveraging ICT. There are various components and technologies to be utilized, and myriads of implementation approaches, making it difficult to decide where and how to start. To solve this problem, various standardization organizations such as the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the International Telecommunication Union (ITU) have been working to create standards. But the proliferation of some 10,000 smart city standards has created a new problem of not knowing which one to refer to.

Below is a list of currently established standards for IoT smart cities by main standardization bodies. As the number of examples of social implementation increases, in addition to general evaluation, performance indicators for disaster management and other specific areas are now being developed, together with general assessment criteria.

Table 149 Standardization Trends and Evaluation Indicators (KPI) for IoT Smart Cities

Standards organization	Standard number	Standard name	Year
ISO	ISO37120	Sustainable development of communities -- Indicators for urban services and quality of life	1st edition: 2014, 2nd edition: October 2018
	ISO37122	Sustainable cities and communities — Indicators for smart cities	2019
	ISO37123	Sustainable cities and communities — Indicators for resilient cities	2019
	ISO37153	Smart community infrastructures — Maturity model for assessment and improvement	2017
ITU-T	Y.4900	Overview of key performance indicators in smart sustainable cities	2016
	Y.4901	Key performance indicators related to the use of information and communication technology in smart sustainable cities	2016
	Y.4902	Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities	2016
	Y.4903	Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals	2016
ISO/IEC	JTC1ISO/IEC30146	Information technology — Smart city ICT indicators	2019
ETSI	TS103463-1	Key Performance Indicators for Sustainable Digital Multiservice Areas	2017
ETSI	TS103463-2	Global KPIs for Sustainable Digital Multi-Service Areas	2019
ITU, UNECE	—	U4SSC Key Performance Indicators for Smart Sustainable Cities	—

Sourse : Ministry of Internal Affairs and Communications, March 2020

Developed countries, especially in Europe and the United States, are working to develop international standards and to create a market environment in which their technologies and services are highly valued, in order to increase their competitiveness in the international development of smart city development. In Europe, approximately 2.4 billion yen is being invested over three years in social implementation projects related to IoT smart cities. They aim to lower the hurdles for social implementation projects by choosing the optimal standard from a group of existing standards building,

[671] NRI, June 2020, https://www.nri.com/-/media/Corporate/jp/Files/PDF/journal/2020/20200617.pdf?la=ja-JP&hash=9B6712242380252D0690BF2FB4478AE1E7B6A2BC

[672] PwC, March 2020, https://www.soumu.go.jp/main_content/000690772.pdf

starting a cycle wherein the results of social implementation lead to improvements in technology and standards, encouraging further standardization. In the United States, the National Institute of Standards and Technology (NIST) is taking the lead efforts similar to Europe.

(b) Urban mobility

In cities, a large amount of energy is consumed by the transportation sector in addition to energy supply and buildings. On top of the vehicle carbon reduction through electrification and fuel conversion described in 1-1-2, infrastructure development, diversification of mobility usage patterns, and the resulting changes in people's attitudes toward vehicle ownership could lead to carbon reduction in the transportation sector.

C40 has categorized the opportunities for the transportation sector to decarbonize cities into the following four groups[673].

- ✓ Promote Transit-Oriented Development (TOD).
- ✓ Promote travel by public transportation, walking, and bicycle.
- ✓ Realization of next-generation vehicles.
- ✓ Realization of next-generation freight transportation and delivery.

Transit-oriented development (TOD) is an urban planning method based on public transportation to avoid a society becoming too dependent on automobiles. TOD efforts range from micro to macro perspectives, but typical examples include close coupling of suburban residential development and public transportation development, revitalization of city centers based on public transportation, focused urban development around key railroad stations, urban structural design and land use control with public transportation use in mind[674]. Since Japan has a wealth of experience in urban development centering on railroad stations in Tokyo and elsewhere,TOD can be a strength for exporting its infrastructure.

Efforts to promote travel by public transportation, walking, and bicycle include, on the hardware side, the introduction of Bus Rapid Transit (BRT) on major roads and reconstruction of major stations to promote their use. On the software side there are the introduction of automatic toll collection systems, dynamic pricing on roads and parking lots, and the installation of bicycle and pedestrian lanes are some examples.

Efforts to realize next-generation freight transportation and delivery include the promotion of joint transportation and delivery in intra-regional goods movement, promotion of low-carbon logistics hubs, modal shift through cooperation among logistics companies and cargo owners, and diversification of receiving methods to reduce re-deliveries.

The above initiatives are tied closely with urban development. Global studies in regional and urban spatial designs are ongoing to identify spatial designs accommodating the introduction of new mobility services, and to redesign spaces following the expansion of new mobility services. For example, the US Council on Urban Transportation has released a new urban planning concept that envisions new mobility services, including the provision of multiple modes of transportation throughout the city, roadway design and real-time traffic control in anticipation of automated driving, and control of excess vehicles in each region[675]. Particularly, in developing countries where new cities are built from scratch, the relationship between urban development and mobility may evolve in a leapfrog fashion, different from the pattern in developed countries where transportation operators, public transportation, and various regulations already exist.

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673 C40「Focused acceleration: NOVEMBER 2017 A strategic approach to climate action in cities to 2030(November 2017)」https://www.c40.org/researches/mckinsey-center-for-business-and-environment

674 Environmental Innovation Information Organization, https://www.eic.or.jp/ecoterm/?act=view&serial=2811

675 METI, October 2018, https://www.meti.go.jp/shingikai/mono_info_service/smart_mobility_challenge/pdf/20181017_02.pdf

In addition, "Mobility as a Service (MaaS)" is attracting attention as an approach to diversify mobility usage patterns. MaaS in general refers to new mobility services enabled by IoT and AI. Types of new mobility services include car sharing, demand transportation, multi-modal services, logistics, parking space sharing, coordination between mobility services and peripheral services, and connected car services.

Technically MaaS refers to multimodal services that can find the best combination of public transportation and various other traffic modes and provide search, reservation, payment, and other services all at once. Applications are being built and commercialized throughout the world but mainly in Europe and the United States, including RIDESCOUT in North America, moovel in Germany, SMILE in Vienna, Austria, and Whim in Finland, among others. In Asia there are DiDi in China, Ola in India, Go-Jek in Indonesia, and other companies rolling out car-dispatch services within each country.

A report published in 2018 called WHIMPACT, which evaluated the impact of Whim (using 2017 data), noted that based on the distance Whim users travelled on their CitiBikes, they reduced 20 tons of CO2 compared to moving the same distance by private car[676]. In addition, the 2019 edition of the report announced transportation mode shift among Whim users, as the use of private cars decreased from 40% to 20% and the use of public transportation increased from 48% to 74% [677]. Various services are being developed in various countries, leading to high expectations that users will switch from private cars to public transportation, resulting in less CO2 emissions. At the same time, how much will the use of these services help save energy and realize decarbonization needs to be carefully examined by analyzing user data.

The introduction of the new mobility services described above creates new challenges for institutions, regulations, safety, and business practices. Countries that are introducing new mobility services are seeking to understand the issues and to adapt their services to the actual conditions in their own countries through demonstration projects for these services.

(c) District Heating

Approximately 50% of the world's final energy consumption is for heating, mainly in the industrial and consumer sectors. Furthermore, the primary energy input suffers loss before final energy consumption, mostly is discharged as heat and wasted (unutilized thermal energy). Effective reduction and recovery of this unutilized thermal energy through reuse and conversion will greatly contribute to further energy savings in the consumer, industrial, and other sectors.

Thermal energy is used in the consumer sector chiefly for air conditioning (mainly heating), water heating, and cooking. These demands account for nearly 80% of final energy consumption in buildings. In the industrial sector, large heat demand and heat loss come from the chemical industry, pulp/paper/paper-based manufacturing industry, and petroleum/coal products manufacturing industry. Effective use of heat in these areas (introduction of high-efficiency equipment, reuse of waste heat, etc.) can make a significant contribution to energy savings and GHG emissions reduction in the consumer and industrial sectors.

This section details district heating projects in cities leveraging available heat sources.

[District heating]

District heating is a system in which cold water, hot water, steam, and other heat-transfer media collected at one or several heat supply facilities are supplied to multiple buildings and houses through

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676 MaaS Global, "Whimpact 2018 One year of Mobility as a Service with Whim", https://whimapp.com/wp-content/uploads/2019/10/191004_Whimpact_report_1920x1080.pdf.

677 Ramboll, "WHIMPACT Insights from the world's first Mobility-as-a-Service (MaaS) system", https://ramboll.com/-/media/files/rfi/publications/Ramboll_whimpact-2019.pdf.

conduits to provide cooling, heating, and hot water. Exhaust heat from factories, etc. (unused heat) and renewable energy heat may also be used. This centralized system can supply energy very efficiently. The term district heating and cooling, or DHC, is commonly used outside Japan.

Plant equipment for heating includes boilers, chillers, heat pumps, heat storage tanks, cogeneration systems, and district conduits[678]. High temperature heat sources can be thermal power plants, waste heat from cleaning plants, factories, among others, while low temperature sources include substations, underground cables, and subways. Such unused heat sources are used, for example, to supply steam from thermal power plants to nearby factories, or to supply factory waste heat to large neighboring residential complexes for heating and hot water. They may also be incorporated into the district heating systems for further utilization as mentioned above.

In its appendix for key technologies in the Strategic Innovation for Energy Conservation Technology 2016 Key, the Japanese government had summarized the major district heating technologies as below.

Table 150 Major district heating technologies

Individual technology	Elemental technology and development project
Online heat transport	Heat pump technology, cogeneration technology, sensoring/IoT control technology, heat conduit...
Offline heat transport	Latent heat storage technology (silica gel and water system, zeolite and water system, encapsulation, emulsion, etc.), chemical heat storage (chloride, oxide-water chemicals), high thermal performance container technology, cold heat storage technology for mobile vehicles, lightweight hydrogen storage alloy technology, analysis (pinch) technology...

Online transport: highly efficient heat transportation within a specific area, using ICT to optimally control heat supply and demand.

Off-line heat transport: heat transport over relatively long distances, using thermal storage technology, heat transport systems, among others, to optimally control heat supply and demand.

Sourse : JICA Study Team based on Information from METI Energy Saving Technology Strategy 2016

According to METI's "DHC of the Future - District Heating and Cooling[679]", district heating and cooling (DHC) has the following four strengths.

(1) Carbon reduction and decarbonization of entire city blocks
(2) Energy management for city blocks
(3) City block resilience (BCD)
(4) Collaboration with community projects for regional development

(1) Carbon reduction and decarbonization of entire city blocks includes the provision of energy-saving technologies that take advantage of economies of scale as well as new and advanced energy-saving technologies. Estimates based on Japanese metropolitan and regional city models show that the introduction of various DHC technologies can reduce CO2 emissions of entire city blocks by more than 40% by 2030.

(2) For energy management in city blocks, CGS and thermal storage tanks can be used to balance electricity supply and demand, while sharing information with consumers can help optimal control of heat and electricity. As buildings with different uses in the region will be centrally managed by the EMS, it will become possible to optimize control within the region while accepting a variety of energy sources, such as electricity derived from renewable energy, unused and renewable heat, biogas, and hydrogen.

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678 Japan Heat Supply Business Association, https://www.jdhc.or.jp/what/

679 METI, January 2021, https://www.meti.go.jp/shingikai/energy_environment/2050_gas_jigyo/pdf/005_09_00.pdf

(3) With regard to city block resilience (BCD), during a power or water outage in disaster, electricity and heat supply can be sustained by utilizing the daily supply systems. Facilities can also be used as local disaster response hubs by utilizing the water inside heat storage tanks for disaster prevention and daily use in city blocks, as well as supplying electricity and heat to nearby public facilities in emergencies.

(4) With regard to collaboration with urban projects for regional development, DHC can lead to local production and consumption of energy as well as utilization of renewable energy and unused thermal energy through regional energy projects. Together with aforementioned energy management function for city blocks and the BCD (Building Climate Change) function for city blocks, this could be a solution for regional revitalization.

Thus, DHC can be a solution not only for air pollution and energy conservation but also for various other agenda such as improving customer service, strengthening local BPC, and regional revitalization.

Europe has been the global leader in deploying district heating and cooling. District heating and cooling originally started in Europe, where people learned to supply heat energy as hot water and steam to all buildings in an area to survive very cold winter. The system has now spread throughout Europe and beyond, including cold places like Russia, the US, and Canada as well as China and South Korea.

Europe is now focusing on the effective use of heat as a way to decarbonization. According to EUROHEAT&POWER, an organization based in Europe promoting sustainable heating and cooling, there are approximately 6,000 district heating systems in the continent, covering 12% of its total heat demand. With urbanization expected to continue in Europe, the market for district heating, most efficient in densely populated areas, is expected to keep growing. The main focus of the EU Strategy on Heating and Cooling, published by the European Commission in 2016, is on building decarbonization. On the supply side it recommends decarbonization and efficient use of energy by combining renewable power with district heating and cooling. On the demand side the renovation of existing buildings for better energy performance and switch to smart buildings are recommended. The report mentions various challenges for making the approach more popular, such as the lack of knowledge among building owners, lack of funds (especially for properties to be leased and public buildings), and lack of experts in the field, all of which may require providing information and incentives to building owners and offer incentives, among other measures, to be solved.

Below Figure shows the historical development of European district heating networks. Newer systems show higher energy efficiency using heat sources with lower temperatures. Lowering the temperature of the heat supply can reduce the temperature difference between the hot water inside the pipe and the outside environment, leading to lower transport losses. The lower temperature also enables the use of various heat sources, such as geothermal and solar heat that are not suited to generate high-temperature heat as fossil fuels. Current technologies focus on improving energy efficiency and flexibility as well as integrating renewable and surplus energy already available. For this reason, state-of-the-art control systems (e.g., supply and demand adjustment, best mix of various energy sources) based on the vast amount of data accumulated on a daily basis are being utilized.

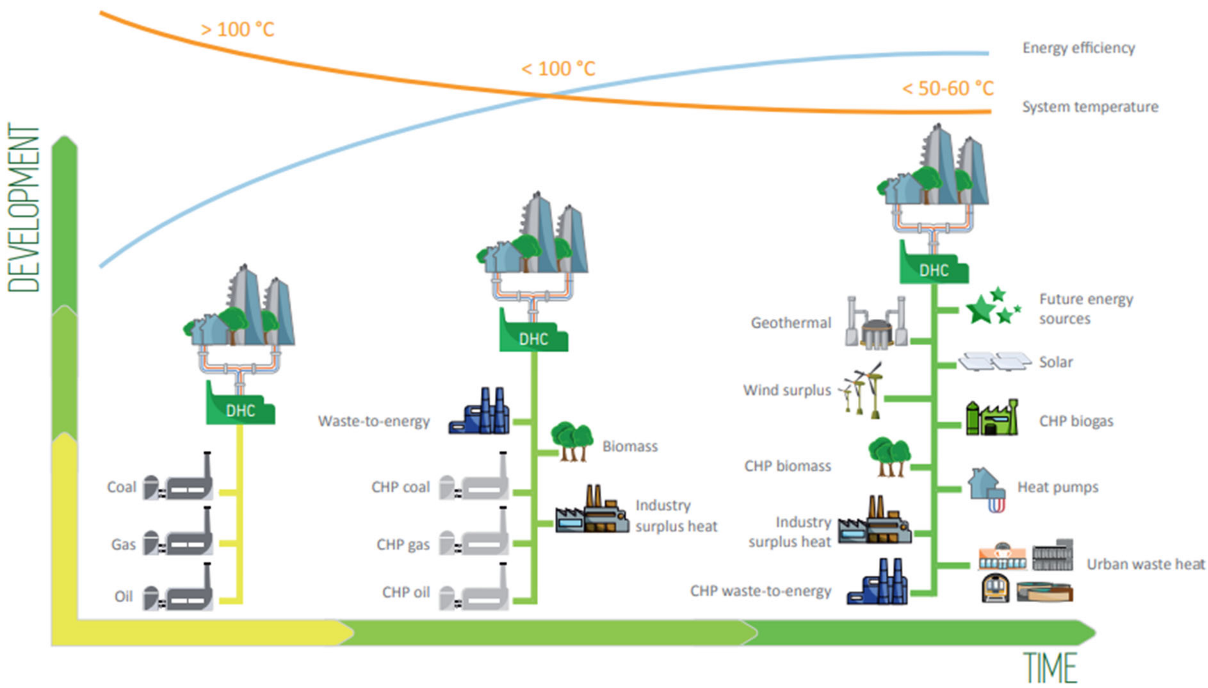

Figure 245 Historical Development of District Heat Supply Networks

Sourse：EUROHEAT & POWER[680]

Examples of advanced efforts in Europe are described below[681].

✓ The Greater Copenhagen area - integrated district heating system

In Copenhagen, district heat providers owned by the municipality and consumers have built an integrated district heating system. Heat is generated efficiently by waste incinerators (25%) and power plants (70%), with only 5.0% of heat coming from boiler facilities, indicating the advanced status of using renewable energy for heat supply system. The heat supply network is interconnected with two CHP plants, three large waste incinerators and 20 regional heat suppliers for optimal heat generation and operation. The steam system operated by the largest heat supplier, HOFOR, has also been converted to a hot water system. The Greater Copenhagen System now has the following plans.

- Shifting CHP plant fuels from coal and natural gas to mostly straw and wood.
- Increase thermal storage capacity significantly with larger tanks and underground storage.
- Increase the number of district cooling systems from 5 to 20 or more by working together with district heating facilities such as chilled water storage, hot/cold water cogeneration, and seasonal storage.
- Shifting large volume consumers, each having a total heat output of 1,000 GWh equivalent or higher, from individual gas boilers to district heating systems.
- Install larger heat pumps and electric boilers to compensate for wind power fluctuations.
- Reduce heat loss by shifting part of the ultra-high temperature network to low-temperature networks.

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680 EUROHEAT & POWER, DISTRICT HEATING AND COOLING A MODERN SOLUTION TO TRADITIONAL CHALLENGES

681 State of Green, District heat supply Urban energy efficiency, https://stateofgreen.com/jp/uploads/2018/10/12788.pdf?time=1616139324

- ✓ HafenCity Hamburg - district heating

Hamburg is a pioneer in district heating, with 19% of all households connected to the city's district heating network. HafenCity is a 155-hectare port district created in the center of Hamburg as an entirely new urban zone and is currently the largest urban center project in Europe. All buildings in HafenCity are connected to the district heating system. Steam turbines and fuel cells are used in demonstration plants, their residual heat used to heat buildings. A new CHP plant and the installation of solar water heater to residences are also planned. 90% of primary energy is usable.

[Technical developments in Japan's district heating]

In Japan, DHC started as air pollution control measures, then evolved to have better energy and BCP performances. Currently, DHC systems are installed in approximately 140 regions throughout Japan, mainly in the Tokyo metropolitan area. Some examples of these district heating projects in Japan are described below.

- ✓ Tamachi Station East Exit North Area DHC: Smart energy network[682]

Tamachi Station East Exit North Area DHC is a joint enterprise by public and private entities (including Minato City, Aiiku Hospital, Tokyo Gas Engineering Solutions, and Tokyo Gas) working together to create a low-carbon and disaster-resistant community. The entire city block has achieved a 45% reduction in CO2 emissions against 1990 levels by building a smart energy network centered on a gas cogeneration system (CGS) and the actively using renewable energy.

A smart energy network is a system that maximizes the use of renewable and unused energy sources to save energy and improves energy security by introducing CGS. The core of the system is the Smart Energy Network Energy Management System (SENEMS), which centrally manages and optimally controls energy supply and demand. The SENEMS enables the automatic optimization of supply and demand planning and control by managing CGS, heat source equipment, and air conditioner in real time to lower carbon emissions from the entire area. Data from the SENEMS can also be used to provide energy-related services such as data analysis, performance validation, visualization, and energy conservation proposals.

- ✓ Nakanoshima 2-chome and 3-chome area DHC: utilization of unused energy

Nakanoshima 2- and 3-Chome Area DHC is a district heating project using river water (thermal energy from heat flux), an unutilized energy source. This is the only DHC in Japan that takes the geographical advantage of having two rivers in one project area. Daibiru Corporation, Kansai Electric Power, and Kanden Realty & Development jointly planned to reconstruct buildings in the area. The basic project concepts were the full use of river water heat, high-efficiency heat recovery equipment, large-scale thermal ice storage tanks, and effective use of substation waste heat. After energy supply to the buildings had started, the network has been extended to neighboring hotels and commercial facilities. Compared to the references in the enforcement regulations of the Act on the Rational Use of Energy, the actual energy conservation performance in FY2018 were 32% for 3-Chome and 51% for 2-Chome, with 2-Chome having an outstanding result being one of the most energy-efficient area in Japan[683].

Other examples of the effective use of underdeveloped or renewable energy include the use of geothermal heat in the Tokyo Skytree area -the first DHC of this kind in Japan- and the use of sewage recycling heat and solar heat at Sasashima Live 24 in Nagoya.

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[682] Tokyo Gas Engineering Solutions Corporation, https://www.tokyogas-es.co.jp/case/redevelopment/area_tamachi.html

[683] Japan Heat Supply Business Association, https://www.jdhc.or.jp/wp_kanri/wp-content/uploads/2020/02/DHC50%E5%91%A8%E5%B9%B4_web-Cut_%E4%B8%AD%E4%B9%8B%E5%B3%B623%E4%B8%81%E7%9B%AE.pdf

(ii) Trends in the development and social implementation of technologies and services in the countries covered by the field survey

(a) India

In India, the Ministry of Housing and Urban Affairs (MoHUA) is in charge of smart city policies. As in other countries, the definition of smart city in India varies. In any case, the purpose of smart city projects is to build cities that can provide core infrastructure, better quality of life, clean and sustainable environment , and smart solutions. The nine core infrastructures are: 1) adequate water supply; 2) stable electricity supply; 3) sanitation, including waste management; 4) efficient urban mobility and public transportation; 5) affordable housing, especially for the poor; 6) robust IT connectivity and digitalization; 7) sustainable environment; 8) safety and security for citizens, especially women, children, and the elderly; and (9) health and education[684].

In 2015, Smart Cities Mission [685]was launched to establish 100 smart cities in India (by June 2023) to absorb the population influx from rural areas to urban areas and to serve as receptacles for the growing middle class. Investment for the Smart Cities Mission is expected to go beyond two trillion rupees (almost 3.2 trillion yen). 480 billion rupees (about 768 billion yen) will come from central government subsidies. The rest will be raised independently by state governments and municipalities through various schemes, including public-private partnerships[686]. Each project is approved by the state government, while the implementation of each project will be screened by the Smart City Special Purpose Vehicle (SPV)[687]. Looking into these projects, urban transportation and energy take the center stage. In the urban development area (having around 40% of the budget allocated) there are plans for introducing pedestrian- and bicycle-friendly roads, public buses, electric and CNG buses, among others. In the energy area, there are projects for, among others, the introduction of solar power generation (e.g., build solar parks, install PV panels on roofs of state-owned buildings) and LEDs as well as the development of power distribution networks[688].

The MoHUA has the ClimateSmart Cities Assessment Framework (CSCAF) to assess cities for their climate change action performance. The Framework defines five categories of smart city projects: (1) Urban Planning, Green Cover & Biodiversity; (2) Energy & Green Buildings; (3) Mobility & Air Quality; (4) Water Management; and (5) Waste Management. There are total of 28 KPIs, each given a Level of 1 to 5. This method is used to monitor and publish the overall level of each city and individual KPIs[689].

Table 151 Indicators for each category in CSCAF 2.0

Category	Indicators	Quantitative/qualitative target
Urban Planning, Green Cover & Bio diversity	Rejuvenation & Conservation of Water Bodies & Open Areas	Rejuvenation & conservation of water bodies & open areas
	Proportion of Green Cover	Proportion of green cover
	Urban Biodiversity	Urban biodiversity
	Disaster Resilience	Disaster resilience
	City Climate Action Plan	City climate action plan
Energy and Green	Total electricity consumption in the city	Total electricity consumption in the city

684 Ministry of Urban Development ,"Smart Cities Mission Statement & Guideline(June 2015) ", https://smartnet.niua.org/sites/default/files/resources/smartcityguidelines.pdf

685 SMART CITIES MISSION, https://smartcities.gov.in/about-the-mission

638 PWC, June 2019, https://www.pwc.com/jp/ja/knowledge/newsletters/electricity/201906.html

687 SPVs are established with budgetary allocations from the central and provincial governments for urban planning, development, and management. SPVs are funded 50:50 by the state and the Urban and Local Development Board (ULB), although some companies and financial institutions may participate in a non-majority manner. Funds may be raised through the establishment of a financial intermediary function in some states, through the collection of user fees or other charges, or through the use of central government funds or schemes other than smart cities. (JETRO, August 2019, https://www.jetro.go.jp/biz/areareports/special/2019/0801/10f5048a14b14184.html)

688 From an interview with MoHUA

689 National Institute of Urban Affairs, ClimateSmart Cities Assessment Framework 2.0, https://niua.org/c-cube/c-cube-documents

Buildings	Total electrical energy in the city derived from renewable sources	Total electrical energy in the city derived from renewable sources
	Fossil fuel consumption in the city	Fossil fuel consumption in the city
	Energy efficient street lighting in the city	Energy efficient street lighting in the city
	Promotion of green buildings	Promotion of green buildings
	Green Building Adoption	Green building adoption
Mobility & Air Quality	Clean Technologies Shared Vehicles	Clean technology shared vehicles
	Availability of Public Transport	Availability of public transport
	Percentage of coverage of Non Motorized Transport (NMT) network (pedestrian and bicycle) in the city	Percentage of coverage of Non-Motorized Transport network (pedestrian and bicycle) in the city.
	Percentage of coverage of Non Motorized Transport (NMT) network (pedestrian and bicycle) in the city	Percentage of coverage of Non-Motorized Transport network (pedestrian and bicycle) in the city.
	Level of Air Pollution (Monitoring)	Level of air pollution
	Clean Air Action Plan (Planning and Implementation)	Clean air action plan
Water Management	Water Resources Management	Water resource management
	Extent of Non-Revenue Water	Extent of Non-Revenue Water [690](NRW)
	Wastewater Recycle and Reuse	Wastewater recycle and reuse
	Flood / Water Stagnation Risk Management	Flood/ water stagnation risk management
	Energy-Efficient Water Supply System	Energy-efficient water supply system
	Energy-Efficient Wastewater Management System	Energy-efficient wastewater supply system
Waste Management	Waste Minimization Initiatives Undertaken by the City	Plastic waste management, 3R, household hazardous waste disposal, and industrial waste disposal
	Extent of Dry Waste Recovered & Recycled	Dry waste collection and treatment, 3R for plastic waste
	Construction & Demolition (C&D) Waste Management	Construction and demolition (C&D) waste management
	Extent of Wet Waste Processed	Extent of wet waste processed
	Scientific Landfill Availability & Operations	Scientific landfill availability & operations
	Landfill/ Dumpsite Scientific Remediation	Landfills/dumpsite scientificremediation

Souse : JICA Study Team based on Information from ClimateSmart Cities Assessment Framework 2.0

[690] Estimated water loss, including leaks, uncertain metering, unbilled and unauthorized connections (stolen water).

In light of the importance of local-level efforts in smart city projects, a Climate Center has been founded under the National Institute of Urban Affairs (NIUA) to support local projects[691].

(b) Indonesia

In Indonesia, there are concerns about various problems caused by rapid urbanization, such as housing, traffic congestion, and air pollution. To address these concerns, the Indonesian government has developed the National Urban Development Policy and Strategy 2015- 2045 as the long-term policy and strategy for urban development up to 2045.

Figure 246 Future Indonesian Cities 2045 : Sustainable Competitive City 5 Pilars

Sourse : National Development Planning Agency(Bappenas) [692]

100 Smart Cities project is one of the initiatives launched by the Ministry of Communication and Information in 2017 to implement this policy and strategy. Several relevant ministries and agencies will work together in this project to formulate a high-level national design, enact regulations, manage progress, among other activities. Each City will be responsible for formulation and implementation of its master plan for smart city development. Bandung in 2013 and Jakarta in 2014 became pioneers in developing smart cities. The scheme has expanded to 25 cities in 2017, followed by the development of smart technology in 100 cities throughout the country over the next three years. DKI Jakarta, Banyuwangi, and Makassar have been chosen by the ASEAN Smart City Network (ASCN) launched in 2018. Many other cities have also set their development goals tailored to their own regional characteristics[693].

(c) Thailand

Thailand's Smart City Development Initiative was launched in October 2017 following the Prime Minister's Office Decree No. 267/2560 on the Establishment of the National Smart City Commission. The decree established the National Smart City Commission chaired by the Prime Minister. Its project

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691 NIUA, https://www.niua.org/climate_centre_for_cities

692 https://www.unescap.org/sites/default/files/Session%202-%20Hayu%20Parasati%20-Indonesia.pdf

693 YCP Solidiance, Can Indonesia Achieve '100 Smart Cities' by 2045? Accelerating Implementation Through Business Collaboration (AUGUST 2020)

management office is staffed jointly by the Ministry of Transport, the Ministry of Digital Economy and Society (MDES), and the Ministry of Energy. In the digital sector in particular, a framework for smart city project was established, including the reorganization of the Software Industry Promotion Agency (SIPA) under the MDES into the Digital Economy Promotion Agency (DEPA). Initially, under the Thailand 4.0 initiative [694], three cities -Phuket in the south, Chiang Mai in the north, and Khon Kaen in the northeast- were chosen. This target was later extended to develop 100 smart cities by 2022. Top priority has been given to the development of Bangkok, Chonburi (part of the Eastern Economic Corridor: EEC), and Phuket, which have been chosen as ACSCN candidate cities[695].

In Thailand, smart cities must meet at least one of the six criteria of Smart Environment, Smart Mobility, Smart Living, Smart Citizen, Smart Energy, Smart Economy, or Smart Governance. The National Smart Cities Commission will decide whether a candidate city satisfies this requirement. Once a smart city project is accepted, the urban developers involved are qualified to apply for tax and non-tax benefits from the Board of Investment of Thailand (BOI) and other authorities[696].

Table 152 Seven Themes for Smart Cities in Thailand

Theme	Initiative	Criteria (draft)
Smart Environment	Positive, highly efficient, and systematic management of water resources, climate actions, and conservation of natural resources.	Compliance with international standards for water, air, and green space quality management.
Smart Mobility	Improved convenience, efficiency, safety, and environmental considerations in travel and transportation.	・Commuter satisfaction: 60% or higher. ・Traffic accident casualties: 12 or less per 100,000 inhabitants.
Smart Living	Provide services that help improve the standard of living, such as medical services for people's health and well-being, also improve public safety by monitoring crimes.	Habitability index: 80% or higher per year.
Smart Citizen	Train citizens and provide learning opportunities for using technology to benefit both the economy and their livelihoods.	Increase in the number of citizens with digital literacy skills: 70% or higher per year.
Smart Energy	Improve energy efficiency and leverage renewable energy.	Improve energy efficiency and clean energy use: 1.0% or hither per year.
Smart Economy	Create networks and business collaboration, start innovations for business transformation (e.g., smart agriculture, smart tourism).	Higher annual income for citizens: 250,000baths or higher per capita.
Smart Governance	Develop systems to give citizens easy and quick access to government services, improve access to information, and promote citizens' participation.	・Percentage of citizens accessing useful online content: 60% or higher. ・Citizens' participation in public service development: 60% or higher.

Sourse：DEPA[697]

In addition, urban data management is one of the requirements for smart city certification in Thailand. DEPA recommends the development of City Data Platform (CDP) to integrate information gathered from various sectors, including government agencies, private businesses, and citizens, and maximize its usage while protecting personal information. The Agency has also developed and published a framework for developing a CDP[698].

As of October 2021, 54 Smart City had been proposed. 39 are under review by the National

694 Thailand 4.0: An ambitious long-term vision that aims to move Thailand into a value-added society by accelerating the digitalization of its economy and society, and to become a developed country in the next 20 years.

695 JETRO, August 2019, https://www.jetro.go.jp/biz/areareports/special/2019/0801/2a3db5f0d050195c.html

696 DEPA、https://www.depa.or.th/th/smart-city-plan

697 DEPA, https://www.depa.or.th/en/smart-city-plan

698 DEPA, https://www.depa.or.th/th/smart-city-plan

Smart City Commission and 15 have been approved. An example for energy/environment project is the ⑫Wangchan Vally Smart City (Rayong Province). The development is led by the PTT in cooperation with the National Science and Technology Development Agency (NSTDA). The aim is to create an innovative ecosystem that can lead Southeast Asia, developing infrastructure comparable to other international cities in terms of quality of life and the environment. Major projects include the development of a solid waste management system, a real-time weather and air quality monitoring system, and an energy management system. It will also works on highly efficient renewable energy generation and EV bus operation with data analysis[699]. Projects for rural cities are often not focused on energy because they have the entire province in scope and a full range of measures need to be implemented.

Outside of these cities, there is One Bangkok,[700]a multi-purpose district project in central Bangkok. Major Thai conglomerate realtor TCC Assets (Thailand) Co. Limited, major Thai utility Gulf Energy Development Public Company Limited, Tokyo Gas Engineering Solutions, and Mitsui & Co. are planning to jointly build district cooling and power distribution facilities on the premise to supply and sell chilled water and electricity exclusively for 30 years starting in 2022[701].

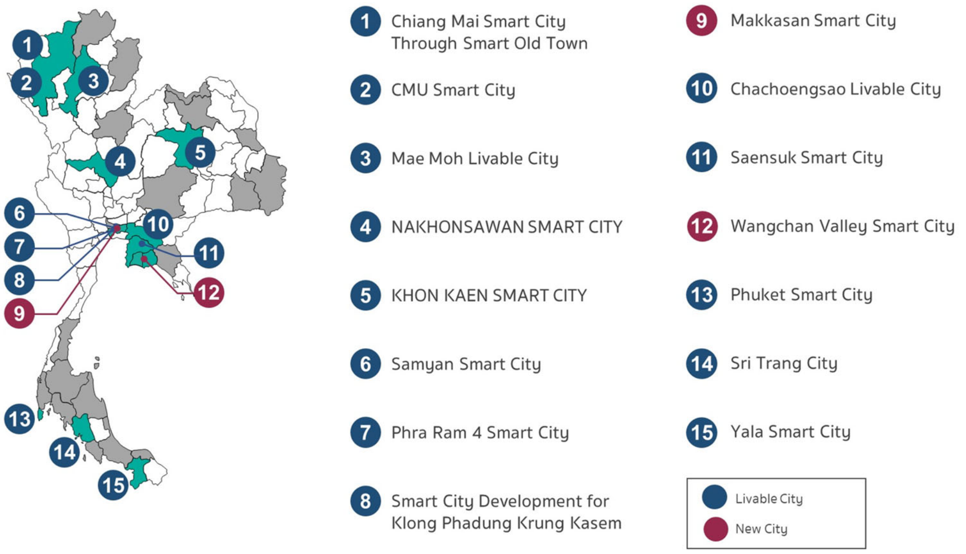

Figure 247 Smart Cities in Thailand (15 approved projects) (as of October 2021)

Sourse：DEPA[702]

(d) Morocco

In Morocco, the Ministry of Industry and Trade[703] is responsible for energy efficiency policies for shopping centers, factories, and ports. The Ministry of National Planning, Urban Planning, Housing and City Policy[704]leads the energy policy for new homes.

The goal is to turn major cities such as Casablanca, Rabat, and Marrakech into smart cities and interconnect them with each other. In addition, while various services will be organized by each city, key platforms and interfaces will be unified by the Moroccan government for country-level consistency. Casablanca aims to drive economic development by improving public services and

699 DEPA, https://www.depa.or.th/en/smart-city-plan

700 One Bangkok is a mixed-use project to develop a total of 16 buildings, including offices and hotels, on a 17-hectare site in central Bangkok, with construction to be completed in phases starting in 2023.

701 MITSUI & CO., LTD. January 2020 https://www.mitsui.com/jp/ja/topics/2020/1230433_11239.html

702 DEPA, https://www.depa.or.th/en/smart-city-plan

703 Ministry of Energy Transition and Sustainable Development, https://www.mem.gov.ma/en/Pages/secteur.aspx?e=3

704 The Ministry of National Planning, Urban Planning, Housing and City Policy http://www.mhpv.gov.ma/

ensuring security with AI. AI applications are expected to be used in areas such as reducing traffic congestion, improving energy performance, and making buildings smarter[705].

(iii) Advantages and strengths of Japanese companies

The results of interviews with relevant Japanese industry groups and individual companies on Japanese technologies and services.

[Urban development]

Advantages and strengths of Japanese companies	Current challenges	Note
・Projects creating comfortable space on limited land (small-scale projects centering on train stations or bus terminals)	・Japanese business ideas are often oriented towards assumptions valid only inside the country. There are gaps between local requirements and technologies or services Japan wants to offer. ・There is weakness in building a system (Japan's government and businesses working together upstream and downstream to identify and respond to local requirements carefully) to understand subtle needs of target countries and addressing them. ・Companies competing against each other in Japan have to work together in overseas market? ・Japanese companies cannot make money in a race for bottom price featuring low-tech low-quality products.	(Business model) ・Combining and packaging decarbonization technologies will help. Combine low-cost uncomplicated technologies and sell them together with technologies for managing them (at a markup). ・Build a business model integrating local needs (quality of life, safety and security) and environmental actions. (Ideal support by the Japanese government) ・Assistance for legal challenges faced by commercial projects. After G2G talks are finalized, local laws and regulations may become a problem in the next step where private businesses start working on project implementation.

Smart city projects are one of Japanese government's key policies for infrastructure export. In the past meetings of the Management Council for Infrastructure Strategy at the Prime Minister's Office, it had been acknowledged that Japanese companies have accumulated experience and expertise in the field of urban infrastructure enhancement, such as Transit-Oriented Development (TOD), eco-friendly urban planning, disaster-resistant urban development, and other forms of multi-dimensional urban projects, all of which were have been marketed as strengths. On the other hand, it has been understood that, in addition to these approaches, cities need to be made smarter by adding cross-sector methodologies and digital technologies to differentiate Japan from competitor countries[706].

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705 JETRO 2019.10.10 https://www.jetro.go.jp/biz/areareports/2019/819e18e3c5ac2276.html

706 Prime Minister's Residence, October 2019, https://www.kantei.go.jp/jp/singi/keikyou/dai44/siryou1.pdf

Table 153 Japan exporting smart city projects - current status and challenges

<table>
<tr><th>Area</th><th>Current status</th><th>Challenge</th></tr>
<tr><td>Urban infrastructure development</td><td>✓ High-quality property development and TOD initiatives by realtors and railroad operators, from design and construction to management and operation.
✓ Government support for private businesses: e.g., support for joining upstream processes during inter-government dialogues, financial support by JOIN.</td><td>✓ Ability to handle cross-sector projects.
✓ Ensure business feasibility to entice private businesses.
✓ Involvement from the inception stage to propose optimal urban development for the partner city and provide superior Japanese products and services that satisfy partner requirements.</td></tr>
<tr><td>Digital technology featured in urban projects</td><td>✓ Some Japanese companies are developing biometrics and other elemental technologies, building data platforms, and creating privacy-conscious data use models to succeed in markets outside Japan.
✓ Government support for private businesses: feasibility study and demonstration projects.
✓ Cooperation in government-led urban development using digital technology from different countries.
✓ Inside Japan: advances in support for the use of digital technology by municipalities through demonstration projects, etc., and in efforts to create an urban OS and super city frameworks, among others.</td><td>✓ Giant IT companies are entering the market as demand for digitalization in urban development grows. Competition with traditional realtors and others businesses has intensified. Japanese companies must stay competitive by establishing a suitable business model for responding to subtle digitalization needs of partner cities.
✓ The Japanese government also need to grow out of just supporting individual researches or demonstration projects and be more involved with inception-level tasks and, to that end, collaborate with different ministries and agencies to consistently engage in upstream and downstream activities.
✓ Build a framework to utilize achievements inside Japan for successfully entering markets outside the country</td></tr>
</table>

Sourse : Prime Minister's Residence, October 2019, https://www.kantei.go.jp/jp/singi/keikyou/dai44/siryou1.pdf

Based on the above findings, the Japanese government has established a platform to strengthen inter-agency collaboration for enhancing its ability to engage in cross-sectoral projects and to utilize achievements inside Japan for reaching out to overseas markets (especially in urban development utilizing digital technology)[707]. In addition, in order to accelerate smart city initiatives through public-

[707] Specifically, the Smart City Task Force (established in February 2019 under the Innovation Policy Enhancement Promotion Team. Comprised of officials equivalent to the heads of the relevant government ministries and agencies)" for Japan, the task force has added overseas expansion as a theme.

private partnerships, the Smart City Public-Private Partnership Platform has been established, with members from private businesses, universities and research institutes, local authorities, and relevant ministries and agencies. A total of 627 organizations (as of January 31, 2022), including consortiums and councils, local authorities, businesses, universities, and research institutes related to smart cities, as well as relevant ministries and agencies are members of the Platform[708].

ASEAN is the region particularly important for Japan in the context of smart city projects outside the country. In order to promote smart cities initiatives at each location within the ASEAN Smart Cities Network (ASCN) [709]through collaboration by both Japan and ASEAN, the two parties have been organizing ASEAN Smart Cities Network High-Level Meetings since October 2019 to share ASEAN requirements and also Japan's expertise and technologies, as well as to provide a place for finding private business partners for public organizations. It was through these meetings that Japan and ASEAN countries founded the Japan Association for Smart Cities in ASEAN (JASCA). The JASCA's purpose is to share information on Japan's smart city technologies and experience with ASEAN countries prior to entering local market, and to build network for both public and private sector relationships in partner countries. In addition, in December 2020, it was decided to invest a total of 1 billion yen in Smart JAMP. This project will accept proposals from 26 cities in ten ASEAN countries and conduct researches required for project planning.

1.3 Analysis of Current Situation and Perspective in Electric Power Sector
(Regarding measures in generation, power system and demand sides to cope with massive introduction of VRE)

The impact of massive introduction of variable renewable energy (VRE) into the power grid system is based on electrical theory and power engineering, and can be said to be basically the same for any power grid system. Therefore, the menu of basic countermeasures is the same, and more efficient countermeasures can be obtained by matching the situation and actual situation of each power system.

(1) Power system in general

When connecting VRE such as photovoltaic (PV) and wind power (wind turbine: WT) to the power grid, examining voltage fluctuations and power flow fluctuations at the connection point and keeping the impact on the power grid within a specified range are the prerequisite conditions for grid connection.

In particular, when introducing massive PV/WT, etc., it will be necessary to take measures to satisfy the system interconnection conditions, depending on the status of the interconnected power system.

Problems such as voltage fluctuations and power flow fluctuations at the connection point are local problems at the connection point to the power system of VRE such as large-capacity PV/WT; the combination of battery for power system can be an effective countermeasure in many cases.

In addition, if the renewable energy ratio in the power supply mix increases due to the introduction of a large amount of renewable energy, which will cause the reduction of capacity to adjust the frequency because of lower proportion of thermal and hydropower generation, there arises a risk that the problem of increased frequency fluctuations will become conspicuous in the whole power system. In particular, it is important to take countermeasures against so-called duck curves during the daytime when PV power generation output increases.

The countermeasures for this problem and the countermeasures for electric power storage batteries are effective, but on the other hand, the countermeasure by stopping the operation of

[708] Smart City Public-Private Partnership Platform, https://www.mlit.go.jp/scpf/index.html

[709] It was established at the 32nd ASEAN Summit in April 2018 as a joint platform for cities from 10 ASEAN member countries to work toward the common goal of smart and sustainable urban development. Twenty-six pilot cities have been selected from each country. (https://asean.org/our-communities/asean-smart-cities-network/)

renewable energy is also effective.

In addition, it has been pointed out that the inertia will decrease due to the significant decrease in the ratio of thermal and hydroelectric power generation, and it is inevitably important to analyze and study the power system in order to understand the specific problems.

In particular, because of the sudden change in voltage phase and frequency drop that occurs during a power failure accident, a large number of power conditioner system models that do not meet the Fault Ride Through (FRT) requirements for continued operation under grid disturbance (non-FRT compliant models) will be shut down, and this phenomenon may further contribute to frequency reduction. Therefore, it is important to understand the rate of change of frequency (RoCoF), etc., through analysis and study.

Each of the above problems becomes more eminent if the power system is smaller and more fragile. Therefore, in many power systems under development process, more appropriate measures are required in introducing massive VRE such as PV and WT. In other words, without appropriate measures, it is unlikely to expect massive introduction of VRE.

For these reasons, it is necessary to confirm the details of the system status in order to examine whether there are measures necessary for the introduction of large-capacity PV/WT and massive introduction of renewable energy. Various information such as development plans, long-term transmission development plans, grid codes, annual supply and demand balance plans, renewable energy introduction targets, and output forecasts for renewable energy sources are required.

In addition, as the renewable energy ratio in the power supply configuration increases, the accuracy of renewable energy output assumptions will greatly affect frequency fluctuation suppression measures. As PV/WT output estimates depend on weather forecasts, it is essential to secure weather information and improve the accuracy of weather forecasts.

For large-capacity PV/WT, countermeasures are taken based on output forecasts and forecasts in a relatively narrow local area; so relatively accurate forecasts and forecasts can be expected. Therefore, it is expected that appropriate and efficient countermeasures such as storage batteries will be relatively easily implemented.

In addition, strengthening (expanding) the general power grid system will also contribute to the introduction of large-capacity PV/WT.

On the other hand, frequency fluctuation suppression measures are a problem for the entire power grid system; so it is necessary to proceed step by step while confirming the effects of measures based on the accumulation of data over a long period of time.

Furthermore, once the massive introduction of roof-top PV etc. begins owing to the incentive programs such as the feed-in tariff system (FIT), the impact will expand across the area, and voltage fluctuations and power flow, as well as frequency fluctuations, increase. Since the number of locations where the problem of fluctuation becomes conspicuous increases, there is also the risk that countermeasures will need to be implemented at many locations. Moreover, it is difficult to accurately predict where and when problems will occur. Therefore, it is also necessary to take measures against the introduction of such an unspecified large amount of renewable energy in a reliable step-by-step manner, while confirming the status of voltage fluctuations, etc. for each of them.

（2） Power generation side

If the VRE ratio in the power supply mix increases due to the massive introduction of VRE represented by photovoltaic power generation (PV) and wind power generation (WT), this increase in the VRE ratio will lead to the increase of frequency fluctuation factors. It is also pointed out that decrease in generation ratio of thermal and hydropower will cause a risk of the decrease in the frequency adjustment capability.

For this reason, securing the necessary amount of governor free (GF) and load frequency control (LFC), which are the frequency adjustment capabilities of thermal (hydro) power generators, is a major factor. In daily operation, securing the required amount of LFC is essential is inevitable, and for this purpose, the central load dispatching center's supply and demand management, including VRE output forecasting, is also an important factor. In addition, in order to operate efficiently, the economic load distribution control (EDC) that controls the generator output by calculating the economic output distribution of thermal and hydro power generators with different efficiencies according to changes in electric power demand is also important.

In order to precisely implement the supply and demand operation of the above-mentioned central load dispatching center, the automatic generator control (AGC: Automatic Generation Control) that automatically performs LFC and EDC should be implemented by the energy management system (EMS: Energy Management System), which is indispensable.

In addition, as the ratio of thermal (and hydro) power generation is declining, it will be necessary to increase the output fluctuation range of each generator in order to ensure the implementation of AGC.

(3) Power System side

A decrease in the ratio of thermal (hydro) power generation leads to a decrease in short-circuit and ground fault currents, and the greater sensitivity to voltage fluctuations will result in increased voltage fluctuations.

For this reason, voltage/reactive power control (VQC) is used to maintain voltage stability, maintain appropriate voltage from the perspective of equipment, and reduce power transmission loss against the ever-changing grid voltage. It will become more important to control power, transformer taps and phase modifying equipment to regulate system voltage and reactive power.

When a large amount of roof-top PV is introduced into a distribution system, the power flow in the distribution line may be drastically reduced or reverse power flow may occur, causing the Ferranti phenomenon in which the voltage rises. In extreme cases, overvoltage may damage equipment, so countermeasures are required.

In addition, in conventional power distribution systems, when a large number of PV, EV, and BESS are connected, it becomes difficult to monitor and manage voltage. It is also important to improve the reliability of supply through automatic recovery in the event of an accident.

(4) Demand side

Controlling consumer equipment is also one of the measures to suppress output fluctuations of renewable energy power sources. Smart grids utilize information and communication technology (ICT) to visualize energy information and attempt to rationalize energy use, including on the consumer side. It contributes to mitigating adverse effects on the grid by making adjustments in accordance with the supply-demand plan, including the output forecast of renewable energy sources.

Smart grids have various elements such as DR, smart meters, xEMS, V2G/H, G2V, etc., and it is expected that peak cuts, peak shifts, etc. will shift demand on the time axis and suppress demand itself. In addition, V2G/H, G2V, and heat pump equipment with a heat storage layer are energy storage equipment on the consumer side. It is also possible to obtain a similar effect to that of battery system in power grid etc. if they are operated effectively. In this case, the minimization of electricity charges becomes an incentive for consumers to introduce the system.

In the future, it is expected that there will be an increase in the number of cases in which storage batteries are installed alongside solar power from the perspective of responding to natural disasters. Again, with appropriate control system, these will contribute to suppression of output fluctuations.