

Chapter 5 Recommended Priority Technologies and Measures

Considering that the main adopters of technologies on the energy demand side are consumers, and that these consumers are diverse, technologies relevant to Mongolia's energy transition have been categorized into priority technologies that can contribute to the transition, and other potentially applicable technologies that can support it.

5.1 Priority Technologies and Measures on the Energy Demand Side

5.1.1 Industry Sector

(1) Priority Technologies

Electrification and fuel switching are the most important to achieve CN. Since it is impossible to predict future trends in terms of which of these technologies will be more widely used, it is necessary to promote both as well as the policies of countries around the world, including Japan.

In the industrial sector, the mining and manufacturing sectors consume the largest amount of energy. Given that the mining industry contributes significantly to GDP and has strong capital resources, CN initiatives led by the mining sector are considered the most feasible. For this reason, "mine electrification" and "carbon neutral (CN) fuel production" were identified as priority technologies from the perspective of electrification and fuel conversion in the mining industry, and those for other industries were organized as potentially applicable technologies and measures.

As part of Mongolia's future policy, it is expected that new industries will emerge through high value-added mineral processing and diversification of manufacturing and other sectors. Therefore, it is desirable to consider the introduction of energy-saving and low-carbon equipment by industry sector as these developments occur.

1) Mine Electrification

Electrification of mines is expected to suppress exhaust gas emissions from mining equipment that uses fossil fuels and to contribute to the reduction of carbon dioxide emissions from mines in total from the perspective of improving the efficiency of mine operations derived from electrification. Electrification initiatives in the mining industry are currently a global trend.

In fact, electrification is the most advanced decarbonization initiative in mining. One of Mongolia's major mining companies is working toward the introduction of battery-switchable electric truck technology beginning in 2023, with an initial partial implementation planned to be operational in December 2024.

Electrification of large mining equipment, especially haul trucks, is one of the biggest barriers to achieving net zero. That is, these large EVs have high capital costs and require infrastructure improvements. This would entail significant investment and prohibitive downtime. In addition, the challenge of mounting a battery large enough to provide the required energy density in a limited space has yet to be solved. On the other hand, small vehicles such as personnel carriers, transporters, loaders, and small haulers, by contrast, can be easily retrofitted with batteries. There are two main options for electrification of large mining equipment: battery electric vehicles (BEVs) and hydrogen-fueled fuel cell vehicles (FCVs). BEVs are generally best suited for low weight hauling of 200 tons or less. On the other hand, FCVs have the energy density and flexibility to transport more than 200 tons. However, the introduction of FCVs in Mongolia is likely to be a long-term prospect because of the need to produce green hydrogen at low cost in order to be economically feasible (profitable for the business) and reduce emissions.

For example, there are several major manufacturers of trolley-assisted trucks, but no single company can provide all electrification solutions to drive decarbonization, and industry collaboration is essential. They are joining forces with mining companies, energy producers, infrastructure providers, and others to address electrification.

One of the biggest electrification challenges facing the mining industry today is the lack of access

to a reliable and robust transmission system due to its remote location. The mines in the Umnugobi region of Mongolia are no exception, relying on China for operational power. Therefore, in addition to connecting to the grid, it is worth considering the introduction of renewable energy in mining areas, along with the development of microgrids. The Umnugobi area has favourable solar and wind conditions, and the potential for introducing renewable energy such as solar and wind power is very high; therefore, local production for local consumption of energy is considered highly feasible. Comprehensive measures that include these sources of power supply will be necessary for electrification of mines.

The total investment in the underground mine development and electrification project at the Oyu Tolgoi mine in Mongolia, as announced by Rio Tinto, a major shareholder in OT, is estimated to exceed US\$7 billion (approximately 1 trillion JPY). The budget includes the development of the mine located 1.3 kilometers underground, electrification, and the introduction of advanced communications and safety technologies. The main initiatives are as follows:

- Electrification of underground mining operations: Transition from diesel-powered to electric equipment
- Smart mining technology: Implementation of wireless networks, personal location information systems (PLI), and related technologies
- Block caving technology: An efficient mining method that utilizes gravity

There are four key technical aspects of electrification. The first is the introduction of electric heavy machinery, with a transition underway from conventional diesel-powered equipment to electric trucks and excavators. This will reduce greenhouse gas emissions and mine ventilation costs. The second is smart mining technology. This includes SmartCap, a sensor mounted on workers' helmets that measures brain waves and detects fatigue and drowsiness in real time, and the Personal Location Information System (PLI), which tracks worker's locations in real time to enhance safety. The third is automation and remote operation. Many of the equipment operating at depths of 1.3 km underground can be remotely or automatically operated, which will enable efficient mining while minimizing staffing in hazardous areas. The fourth is integration with renewable energy, and plans are underway to integrate renewable energy sources such as solar and wind power into mine operations in the future.

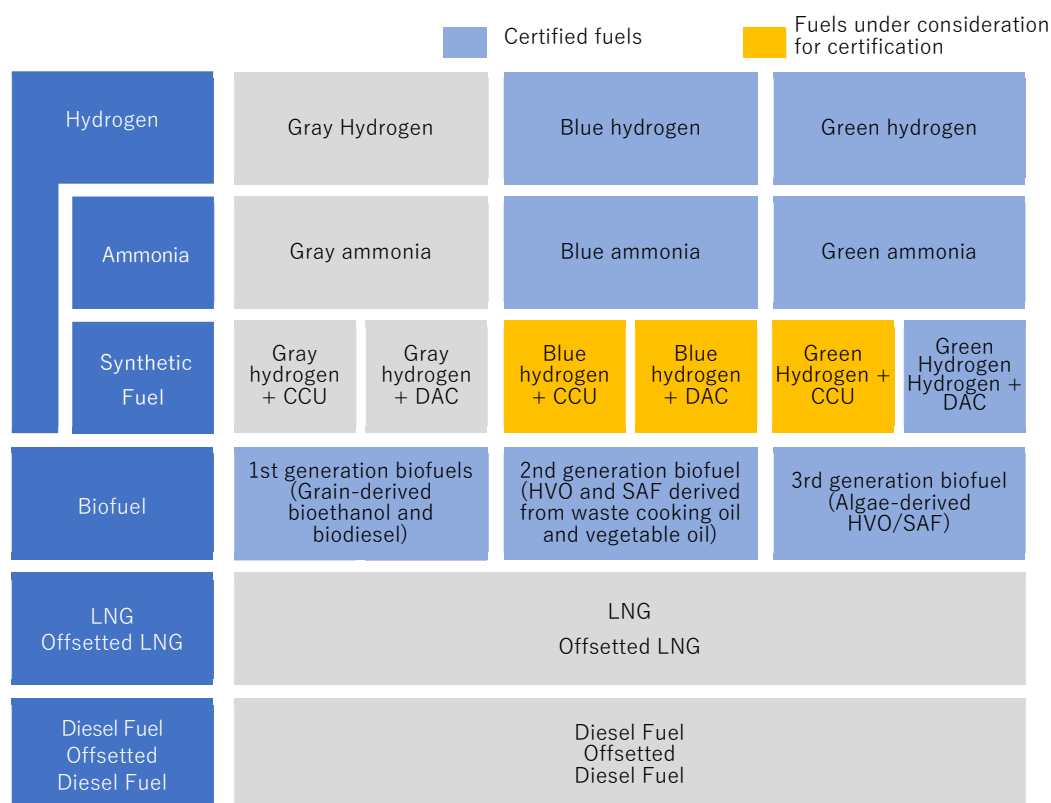
Although no detailed cost breakdown by technology for the electrification project that Rio Tinto is pursuing at the Oyu Tolgoi mine has been officially released, the portion directly related to electrification is estimated to be approximately \$3-4 billion. The assumed breakdown is as follows:

- Electrification of heavy machinery (30%): Costs of introducing electric trucks, excavators, and associated machinery.
- Power infrastructure development (25%): Construction of underground power grids and substations
- Smart mining technology (15%): Sensors, wireless communications, worker monitoring, and associated technologies
- Automation and remote operation (20%): Automated operation and remote control systems
- Safety and environmental measures (10%): Ventilation, heat exhaust, emissions treatment, and other related measures

2) Carbon neutral (CN) fuel production

CN fuel refers to fuel that does not emit carbon dioxide in any of its various stages of raw material production/supply, manufacturing, and consumption. There are two main types of CN fuels: those made from green hydrogen and those made from biomass. Green hydrogen is made from renewable electricity and water, while biofuels made from biomass are considered carbon neutral because the

absorption of carbon dioxide during the growing process is balanced ($\pm$ zero) with its emission during use. In the EU, where CN fuels are being increasingly adopted, they are defined as follows: CN fuels have the advantage of being Drop-In-Fuel, meaning that they can be used directly just like conventional fuels in the existing equipment.



Source: Prepared by the survey team based on data of Arthur D. Little

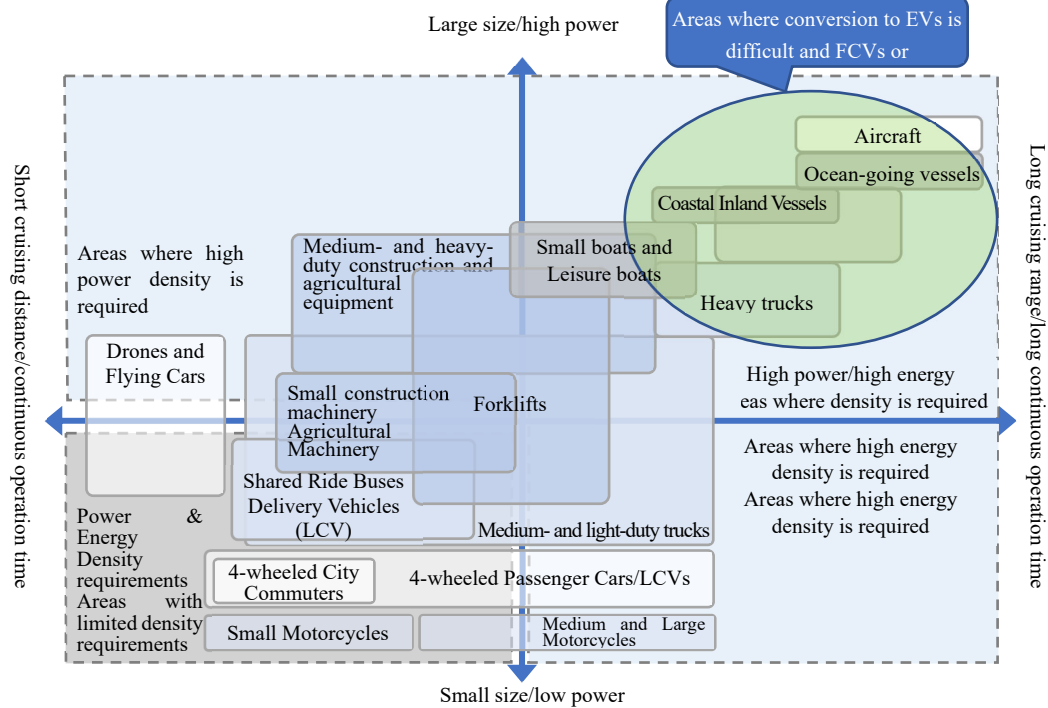
Figure 5-1 Fuels Certified as CN Fuels in the EU

In Mines, mining trucks with payloads of several hundred tons and a height of more than 7 meters, as large as a two-story house, are always in use, requiring very powerful motive power. Diesel engines are main source of power in mines, with enough power to move large equipment such as mining trucks. However, conventional diesel engines are a major source of greenhouse gas emissions, and data from Rio Tinto, one of the world's leading resource companies, indicates that CO₂ emissions from diesel engines used in mine mobile equipment and rail transport account for approximately 13% of the total greenhouse gas emissions from mining operations.

Rio Tinto has announced that it will switch all fossil fuel-based diesel used by the company to carbon neutral fuel (hereinafter referred to as "CN diesel"). The company plans to replace all conventional diesel consumption with renewable CN diesel at its Boron mine in California and the Kennecott copper mine in Utah. Rio Tinto is the major shareholder (66%) of OT and this policy is expected to be applied to OT as well.

The use of CN fuels is important for energy transition in industry, both to drive sustainable growth through the development of the CN fuel industry itself and to decarbonize various sectors through the adoption of CN fuels across industries. This section provides an overview.

As mentioned above, the conversion of mining equipment to EVs is an effective means toward CN in mining operations, but the feasibility of introducing EVs depends on the technological characteristics of the equipment that uses the energy. As shown in the figure below, certain applications of transportation equipment—particularly those in the upper right of the figure—are difficult and unsuitable for electrification due to their technical characteristics. This should be taken into account when planning energy transitions.

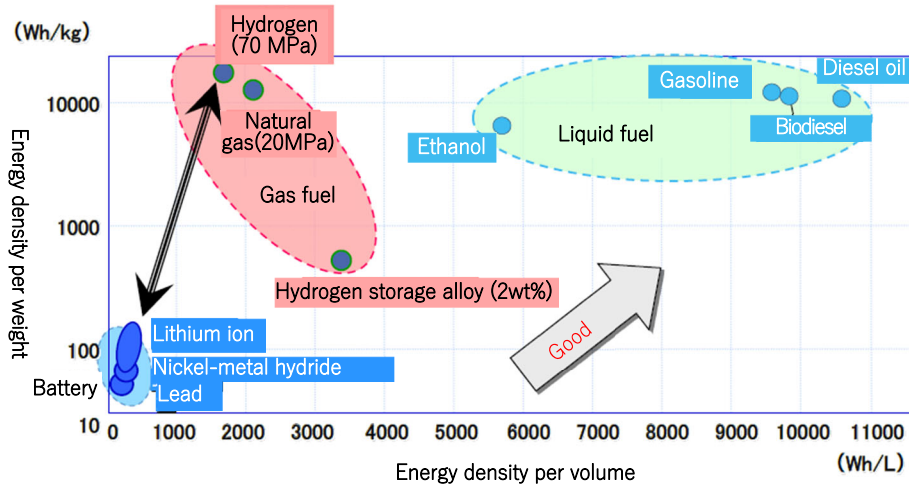


Source: Prepared by the survey team based on data of Arthur D. Little

Figure 5-2 Technical Characteristics of Major Transportation Equipment

A comparison of energy density by fuel type is shown below.

Comparison of energy density

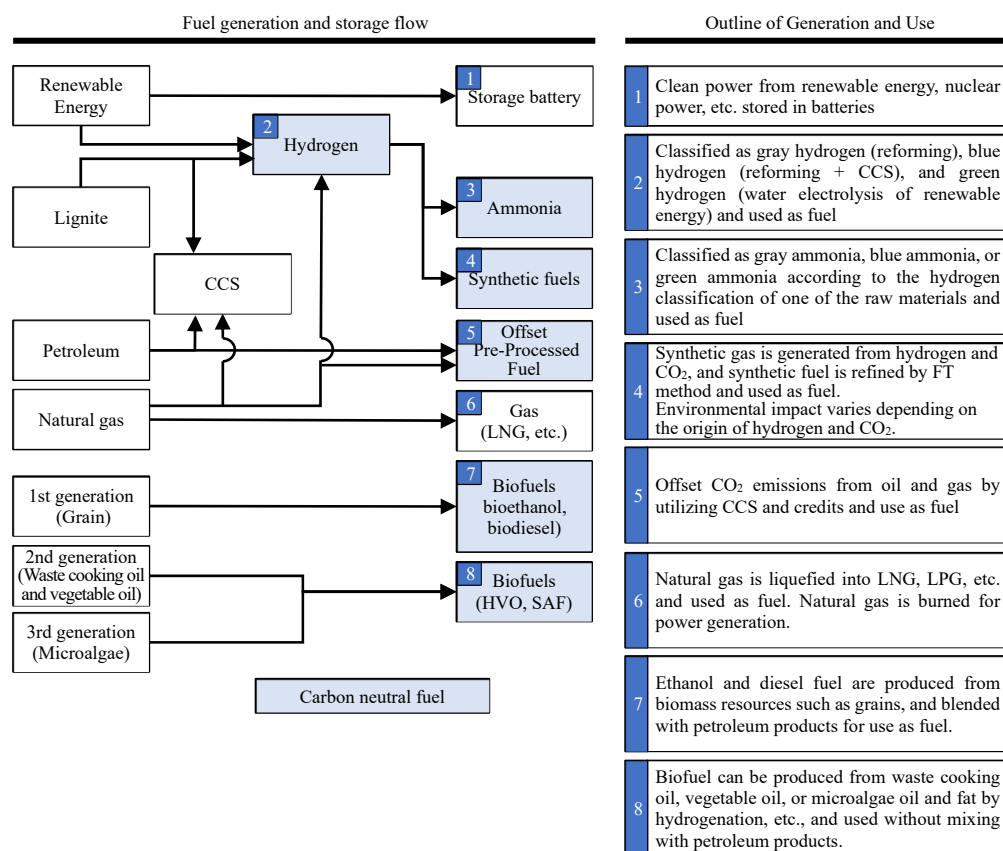


Source: From Toyota Motor Corporation website

Figure 5-3 Fuel Energy Density

Typical examples of industries that require high power output and high energy density include aviation and mining. Except for some small aircraft, electrification in these sectors is currently considered technically difficult. Vehicles used for mining and transportation in mining operations require extremely high power and large payload capacities and are often so massive that they cannot be operated on public roads. Diesel engine vehicles are the mainstream for these vehicles, and battery-powered EVs are not easily adapted to this field. Therefore, non-fossil fuels with high output and high energy density are needed as alternatives to conventional fossil fuels.

As shown in the figure below, CN fuels include hydrogen (Figure 2), ammonia (3), synthetic fuels (4), offset fuels (5), and biofuels (7, 8). Each of these can be produced from a variety of feedstocks. Depending on the type of CN fuel, there may also be potential for production in Mongolia.



Source: Prepared by the survey team based on data of Arthur D. Little

Figure 5-4 CN Fuel Production Flow

One of the technologies to produce CN fuel is Power-To-Liquid (PTL). This method of producing CN fuel from green power (wind and solar power) is being researched and developed in many countries and is considered to be a suitable technology for Mongolia, which has abundant renewable energy (RE) potential. In the future, as green power derived from Mongolia's abundant renewable energy (RE) sources—such as wind and solar—becomes more widely available, the introduction of PTL technology is expected to be more promising than other production methods. This technology enables the production of CN fuels such as e-diesel and e-gasoline, and ultimately Sustainable Aviation Fuel (SAF).

In Mongolia, which possesses vast grassland areas, CN fuels made from biomass are also considered highly applicable. Among these, sweet sorghum, which is attracting attention as a raw material for bioethanol, is resistant to drought and can adapt to a wide range of climatic conditions, making it possible to cultivate it even in semi-arid regions such as Mongolia. It can be grown in a four-month growing season, avoiding the harsh winter season (November to March).

Sweet sorghum has the following characteristics

1. Drought resistance: With deep roots, sweet sorghum is highly resistant to drought and can be grown in semi-arid regions.
2. Broad adaptability: It grows relatively well in over-humid soils and a wide range of soil pH conditions.
3. Short growing period: The crop has a short growing cycle of 4 to 5 months.

Bioethanol can be blended with diesel or gasoline to reduce carbon emissions.

As described above, efforts to promote CN fuels—including their production and distribution—play a crucial role in decarbonizing mining operations.

(2) Other Potentially Applicable Technologies and Measures

Other key technologies with potential application in the industrial sector are listed below. There are other technologies that could be applied in various industries, but those with particularly high impact are listed. Furthermore, securing heat supply for factories and offices is crucial in industry, and it is desirable to also consider power-to-heat conversion technology and thermal energy storage.

Table 5-1 Other Potentially Applicable Technologies and Measures

Target	Technology/Measure	Overview
Mining Industry	Efficiently Improvement in Mine Operations	Energy conservation is promoted by improving the efficiency of mining operations through the introduction of technologies such as autonomous vehicles, fleet management systems, remote maintenance services, and trolley-assisted mining equipment.
	Concentrated Solar Power (CSP)	CSP generates electricity by concentrating sunlight using mirrors to produce heat, which is then used to generate steam that drives a turbine. The integration of thermal energy storage systems is also feasible. This technology is particularly suitable for major mining regions with high direct solar radiation levels (1,900–2,100 kWh/m ² /year).
Cement Industry	CO ₂ -SUICOM (including construction industry)	CO ₂ is absorbed during concrete curing by replacing more than half of the cement used in its production with a special admixture (γ-C2S) or industrial by-products.
	Introduction of Various Energy-saving Facilities	Various energy-saving technologies are introduced, including waste heat power generation, slag grinding, roller mill pre-crushing, high-efficiency coolers, improved separators, vertical coal mills, vertical raw material mills.
Steelmaking Industry	Introduction of Various Energy-saving Facilities	The following technologies listed in the ASEAN Technology Customized List are introduced. Although only electric furnaces currently exist in Mongolia, both blast furnaces and electric furnaces are included due to the possibility of constructing blast furnaces in the future. Electric Furnace: Environmentally Conscious High Efficiency Electric Furnace (ECOARC), shell rotary drive electric furnace, medium temperature batch-type scrap preheating, and others. Blast Furnace: Coal drying and conditioning system for coke oven (CMC), sintering system - cooler exhaust heat recovery system (WHRS), coke dry quenching system (CDQ), blast furnace top pressure recovery power generation system (TRT), and others.
Overall	Heat Utilization of High Temperature Engineering Test Reactors	High Temperature Engineering Test Reactors (HTTRs), achieve high overall efficiency in nuclear power generation through cogeneration and heat recovery. The recovered heat can be utilized during off-peak power generation periods for applications such as oil refining, petrochemical production, plastics manufacturing, and hydrogen production.
	Heat Pump Technology	Industrial heat pumps can facilitate inter-process heat integration in manufacturing and other industries, while ground source heat pumps can be contributed to energy savings in heat applications.
	High-efficiency Motors	Electricity consumption in industrial processes that use motors can be significantly reduced by switching to motors with an efficiency class of IE3 (premium efficiency) or higher.
	Thermal Insulation Technology	In labour-intensive industries in Mongolia, such as light manufacturing and food industry, a considerable amount of heating energy can be reduced by applying technologies such as thermal insulation and Low-E glass.
	Carbon Credits	Carbon credits are a mechanism that enables the trading of greenhouse gas emission reduction as credits. Since the usage becomes a source of revenue, it will nurture the company's movement of active engagement in CO ₂ emission reduction efforts.
	Carbon Tax	Since it is difficult for small and medium-sized enterprises (SMEs) to achieve decarbonization toward CN on a self-sustaining basis, the implementation of measures such as a carbon tax is expected to encourage them, generate tax revenues, and promote further measures.

Source: Prepared by the survey team

5.1.2 Transportation Sector

Based on the analysis of the issues discussed in the Trends in Energy Transition in Transportation section, the following table summarizes the various federal technologies that could be used to address these issues.

Table 5-2 Japanese technologies that are expected to be introduced

Transportation	Technology	Japanese companies with technology and expertise
Road transportation	EV, PHEV, FCV (including buses)	• Eco-friendly vehicles from Japanese automakers
	EV chargers, quick charge standard (CHAdeMO)	• Japanese companies' EV chargers • A type of quick charging standard for EV
	V2X (Vehicle to Home)	• The power stored in the batteries of EVs and PHEVs is expected to be used in the home and as a regulator of renewable energy sources, such as reverse power flow to the grid.
	Hydrogen station	• Hydrogen station
Railroad Transportation	Technologies for railroad electrification	• Mast Transit System • Examples of railway electrification in Japan • Electric trains manufactured by Japanese railway vehicle manufacturers • Railway electrical equipment manufactured by Japanese electrical equipment manufacturers • Fuel cell vehicles
Air transportation	SAF	• Ethanol-based “ATJ” • Innovative FT synthesis technology with advancing technical development • CO electrolysis equipment under demonstration for practical application •
	Introduction of new technologies	• Electrification of equipment, electrification of propulsion systems, research and development of hydrogen aircraft, engine efficiency improvement
	Improvement of flight operations	• Optimization of flight planning • Optimization of takeoff and effectiveness
	Others	• Introduction of hydrant refueling systems
	Conversion of airports to CN	• ZEB for Airport Building Facilities • Conversion of airport vehicles to EVs and FCVs • Conversion of aviation lights to LED • Introduction of GPUs • Improvement of ground driving
Other	Urban Ropeways(Cable cars)	• Japanese-affiliated company's self-propelled ropeway

Source: Prepared by the survey team

(1) ET-related technologies for road transportation

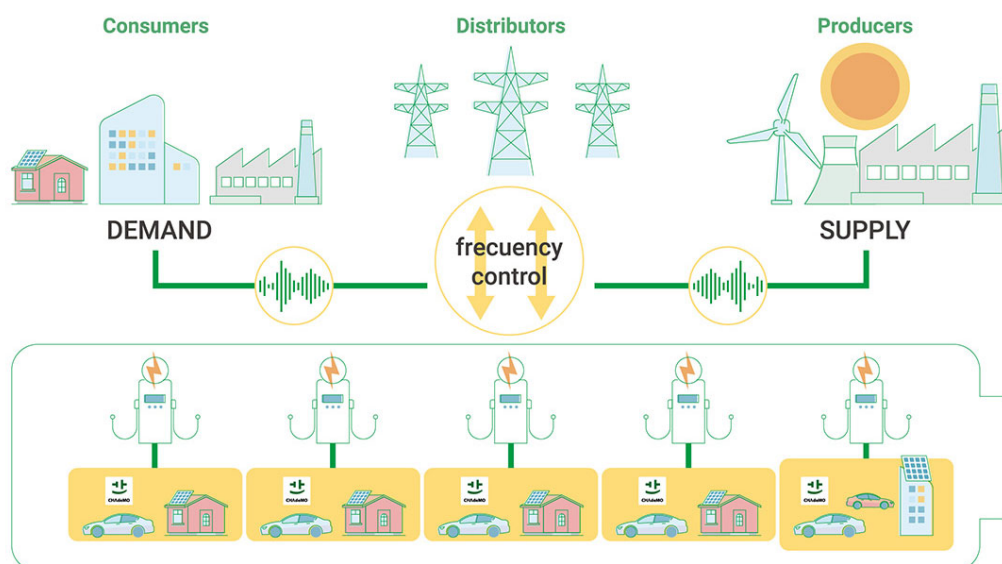
The following is a summary of technologies that can be provided by Japan in road transportation.

1) V2X (Vehicle to Everything)

V2X stands for "Vehicle-to-Everything," and is a generic term for connecting and coordinating vehicles and everything else through communication technology. V2H (Vehicle-to-Home) and V2G (Vehicle-to-Grid) are examples of energy management using EVs.

V2H is a technology that uses EV batteries as a household power source. It can supplement household electricity demand and also function as an emergency power source in the event of a power outage.

V2G is a technology that connects EV batteries to the power grid to balance the supply and demand of electricity. By utilizing the batteries of electric vehicles (EVs) as storage batteries, storing surplus power and discharging it when necessary, it can support the spread of renewable energy, which is easily affected by weather conditions, and improve the stability of the power grid.



Source: CHAdeMO Council website

Figure 5-5 How V2X works

2) Introduction of CN-enabled vehicle ancillary equipment Quick Charging Standard (CHAdeMO)

CHAdeMO is a quick charging standard for EVs developed in Japan. It is characterized by rapid charging, bi-directional power supply, and compatibility with a wide range of vehicle types.

CHAdeMO is a highly safe charging standard because it uses CAN (Controller Area Network) communication between the EV and the charger to monitor the battery status while charging, so that if an abnormality occurs during charging, appropriate action will be taken with the information through CAN.

CHAdeMO is compatible with DC rapid recharging, which can recharge EV batteries in a short period of time and can output a maximum of 400 kW. It also supports bi-directional power supply, allowing V2H and V2G EV batteries to be supplied to homes and the power grid.

The technology may also be applicable to EVs in Mongolia.

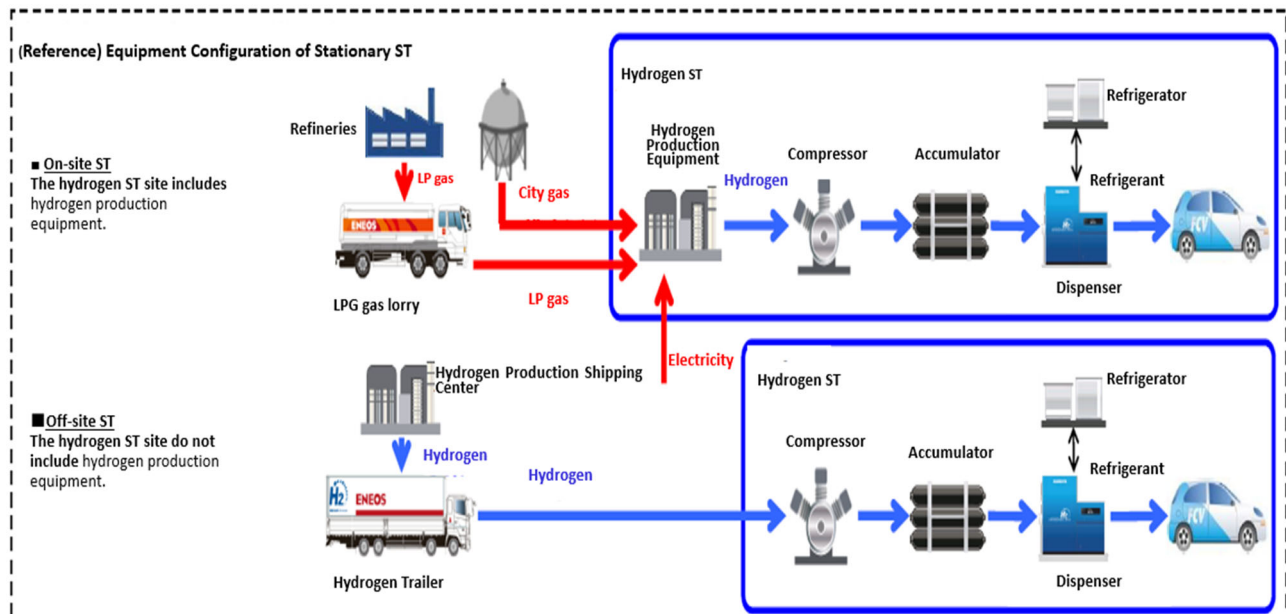
Compatible						ChaoJi
	CHAdEMO	GB/T	US-COMBO CCS1	EUR-COMBO CCS2	Tesla	
Connector						
Inlet						
	✓	✓	✓	✓		
	✓		✓	✓		
	✓			✓		
	✓	✓	✓	✓		
		✓				
Protocol	CAN		PLC		CAN	
Max Power	400kW 1000x400	185kW 750x250	200kW 600x400	350kW 900x400	?	Future ? ? ✓ ✓ CAN 900kW 1500x600 - - 2020 Target
Market Power	150kW	125kW	150kW	350kW	120kW	
Connectors #	27,500	300,000	3,000	11,000	20,000	
Start @	2009	2013	2014	2013	2012	

Source: CHAdEMO Council data

Figure 5-6 Overview of the CHAdEMO standard

3) Hydrogen Supply Chain and Hydrogen Stations

Hydrogen stations can be classified into three types depending on the hydrogen supply method: on-site, off-site, and mobile. On-site hydrogen stations produce hydrogen from city gas, LPG, and other resources at the station. There is a possibility that hydrogen station technology will be applied to the production of green hydrogen in Mongolia in the future.



Source: ENEOS Hydrogen Station Strategy (ENEOS Corporation, October 18, 2022)

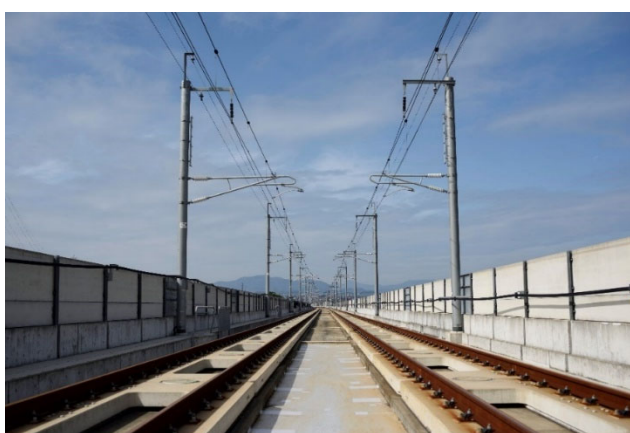
Figure 5-7 Hydrogen station equipment configuration

(2) ET-related Japanese Technologies in Rail Transportation

The following is a summary of technologies that can be provided by Japan in railroad transportation.

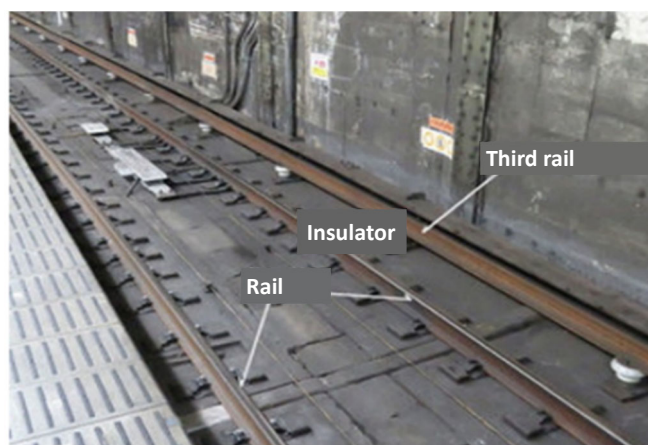
1) Electrification of railroads

Currently, railway transportation in Mongolia primarily relies on diesel fuel as its main power source, resulting in a situation where the environmental impact is high. Electrification of railroads offers advantages such as reduction of CO₂ emissions, improvement of energy efficiency, reduction of operating costs, and reduction of noise. There are two types of electrification methods: overhead rail and third rail. The overhead rail system supplies power from overhead wires installed on top of the train, which enables high-speed operation and is suitable for supplying power over long distances. The third-gauge rail system supplies power from a third-gauge rail installed next to the rails and does not require overhead wires, making it suitable for use in tunnels and low-ceilinged locations, and is therefore often used mainly in subways.



Source: From the website of the Japan Railway Construction, Transport and Technology Agency

Figure 5-8 Overhead Train Line System



Source: Yokohama City website

Figure 5-9 Third rail system

In the case of Mongolia, overhead train line system with high power supply efficiency is adopted because long-distance backbone transportation is performed above ground, and the third-gauge system is considered applicable to the metro being considered in UB City because it can effectively utilize a narrow tunnel cross section.

2) Introduction of a new mass transit system

a) Linear Metro

A linear metro is a subway propelled by the magnetic attraction and repulsion of linear motors (LIM) and reaction plates (RP). Unlike conventional steel-wheeled subways, it uses a "non-adhesive running" system that does not rely on the frictional force between the wheels and rails. While most subway cars use cylindrical rotating motors, linear motors are characterized by their flat plate-like structure. When electricity is applied to the linear motor attached to the bogie at the bottom of the car body, magnetic force is generated between it and the reaction plate laid in the center of the track, and the attraction and repulsion of the magnetic force is used to propel the car body.

In Mongolia, a feasibility study on a metro was carried out in UB city from July 2024 to February 2025. Since the construction of a metro is generally expected to incur large construction costs, adopting a linear metro, which has lower construction costs than a metro, is also considered an effective method.

Tokyo Metro is currently conducting a demonstration experiment to use regenerative power in station facilities by using auxiliary power supply equipment in station buildings.



Source: Yokohama City Transportation Bureau website

Figure 5-10 Linear Metro (Yokohama Municipal Subway Green Line)

b) LRT

LRT technology in Japan is being introduced to improve the efficiency of urban transportation and reduce environmental impact. Features include the introduction of low-floor vehicles, the development of dedicated tracks, and the reduction of environmental impact.

LRT does not require underground or elevated bridges and can be constructed above ground, making it more cost-effective than other public transportation systems. The per-kilometer project cost of regular railroads currently under construction in Japan is approximately 260 - 60 billion JPY/km, while Utsunomiya Light Rail, the most recently commercialized LRT, is approximately 4.7 billion JPY/km³⁷, indicating a large difference in project costs between regular railroads and LRT.

Challenges in introducing LRT include physical constraints such as road structure and location of stops (physical issues), the need to review laws and regulations (institutional issues), and securing costs for infrastructure development and vehicle renewal (financial issues).

³⁷ From the Detailed Survey on Issues of Introduction of Railway Tracks, etc. (FY2022), Cabinet Office, Government of Japan.

In Japan, there are several examples of LRT projects such as Toyama Light Rail in Toyama Prefecture and Haga-Utsunomiya LRT in Utsunomiya City, Tochigi Prefecture, and they have expertise in solving the above-mentioned issues.

FS for the introduction of LRT is underway in UB City as well, and it is expected to be utilized.



Source: Ministry of Land, Infrastructure, Transport and Tourism HP (https://www.mlit.go.jp/road/sisaku/lrt/lrt_index.html)

Figure 5-11 Haga-Utsunomiya Light Rail Line

(3) ET-related Mainichi Technology in Air Transportation

1) Introduction of SAF

In order to reduce CO₂ emissions in the aviation sector, the use of SAFs with CO₂ reduction effects is considered essential. According to the International Air Transport Association (IATA) estimates, in order to achieve net zero emissions in the air transportation sector in 2050, about 4 The International Air Transport Association (IATA) estimates that approximately 450 million kiloliters of SAF will be required to achieve net zero emissions in the air transportation sector by 2050.

Against this backdrop, ENEOS, Idemitsu Kosan, JGC Holdings, and other companies in Japan are launching demonstration plants for SAF production and developing technologies for the SAF production process.

ENEOS is constructing a SAF production (HEFA: Hydroprocessed Esters and Fatty Acids)) plant using waste cooking oil and developing technology for an innovative Fischer-Tropsch (FT) synthesis process, and is working to achieve self-sustained commercialization by 2040. Idemitsu Kosan is also working with Toshiba Corporation and Toyo Engineering Corporation to develop technology to produce e-SAF from CO₂ and hydrogen (PtL).

The table below summarizes the applicability of these technologies to Mongolia. Mongolia has a large potential for renewable energy, and the possibility of utilizing this potential to produce green hydrogen and to store CO₂ generated in the fossil fuel utilization process is being studied. Since both of these technologies are still in the demonstration or technological development stage in Japan, we would like to add that they are applicable from a long-term perspective.

The following is a summary of the technologies that Japan can offer in the air transportation field from the following perspectives.

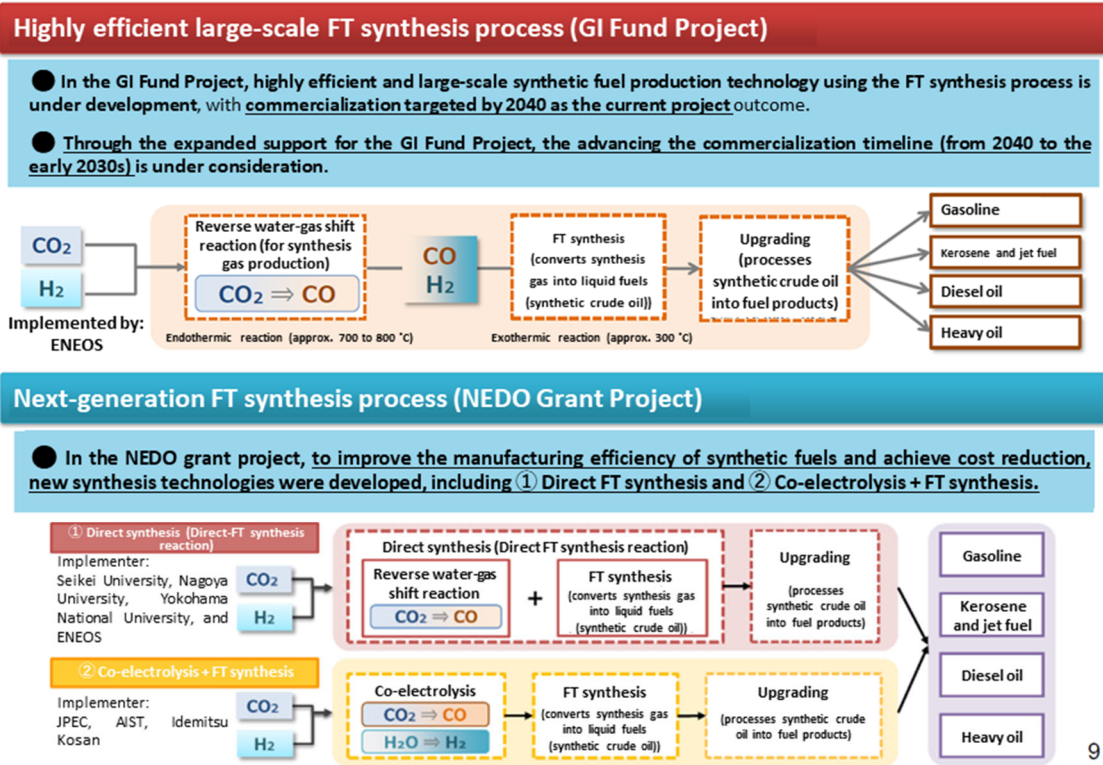
Table 5-3 Technology Development Trends for FT Synthesis

Manufacturing Technology	HEFA	ATJ	PtL
Major players	Japanese-affiliated petroleum wholesalers, engineering companies, etc.	Japanese-affiliated petroleum wholesalers, engineering companies, etc.	Japanese-affiliated petroleum wholesalers, engineering companies, etc.
Technical feasibility requirements	It is essential to investigate the potential of raw materials (used cooking oil (UCO) and animal fat) and establish an efficient collection network.	Bioethanol is the main raw material, and there are challenges in procuring raw materials.	It has the potential for application in Mongolia, which has great potential for renewable energy, because it produces green hydrogen through water electrolysis and synthesizes it with CO ₂ to make liquid fuel. The feasibility is high if CO ₂ , another raw material, can be secured on a large scale through industrial waste gas and direct air capture (DAC).
Applicability to Mongolia	△	△	○

Source: Prepared by the survey team

The innovative FT synthesis process being developed by ENEOS and others as a production technology for SAF is a synthetic fuel made from CO₂ and hydrogen, which is produced using a highly efficient catalyst to minimize the formation of byproducts and reduce production costs. In Japan, ENEOS is participating in the Green Innovation Fund Project of the New Energy and Industrial Technology Development Organization (NEDO), and has started a plant-scale scale-up demonstration in FY2022.

Similarly, JPEC, AIST, Idemitsu Kosan, and others have constructed a bench plant for integrated production using the co-electrolysis + FT synthesis process, and are conducting a demonstration of synthetic fuel production from CO₂ and water.



Source: Interim Report 2023, Public-Private Consultative Group to Promote the Introduction of Synthetic Fuels (e-fuel), Resources and Fuels Direct Department, Agency for Natural Resources and Energy.

Figure 5-12 R&D for innovative FT synthesis process

2) Decarbonization of Airport Facilities

To decarbonize airports, it is crucial to pursue integrated efforts encompassing airport facilities, airport vehicles, aircraft, and airport access. This involves promoting energy conservation to reduce greenhouse gas emissions (primarily CO₂, but also including nitrogen dioxide, fluorocarbons, etc.) and actively utilizing renewable energy sources such as solar power, hydrogen, and geothermal energy to advance initiatives like establishing airports as renewable energy hubs.

Table 5-4 Technology Development Trends for FT Synthesis

Measures	Main Contents
Airport Facilities	Energy efficiency and ZEB conversion of airport buildings such as terminals, control towers, and administrative buildings Conversion of aviation lighting to LED
Airport Vehicles	Conversion of airport vehicles to EVs and FCVs Installation of charging stations and hydrogen stations Utilization of biomass fuel
Aircraft	Reduced taxiing distance through taxiway development / Ground Power Units (GPUs) for parked aircraft: Fixed or mobile ground equipment supplying power and air conditioning to parked aircraft
Promotion of Renewable Energy Adoption	Solar power generation, hydrogen, geothermal heat pumps
Cross Sectoral Initiatives	Energy management, regional collaboration and resilience measures

Source: Prepared by the survey team

5.1.3 Residential and Commercial Sector

In the following section on trends in energy transition within the residential and commercial sectors, Japanese technologies with potential to address the identified challenges and strategic directions are introduced. However, as discussed previously, technological solutions alone are not sufficient; effective interventions must also include institutional design and capacity development.

(1) Priority Technologies

1) ZEB/ZEH

ZEB/ZEH stands for "Net Zero Energy Building" and "Net Zero Energy House," respectively. These refer to buildings that aim to achieve a net-zero balance of primary energy consumption—such as oil and coal—against the annual standard value, by utilizing energy-saving technologies with high efficiency and high thermal insulation, along with energy-generating technologies such as photovoltaic and wind power generation. The key difference between ZEB and ZEH is that ZEB refers to commercial or public buildings, while ZEH refers to residential houses. Both aim to reduce their annual primary energy consumption to zero through a combination of energy conservation and renewable energy. high efficiency and high insulation, and energy-creating technologies such as solar and wind power generation.

The difference between ZEB and ZEH lies in the type of buildings they target: ZEB refers to energy measures for buildings such as offices, factories, and schools, while ZEH refers to energy measures for general residential houses that aim for net-zero energy balance through both energy conservation and renewable energy.

ZEB is categorized into different types depending on the energy balance between renewable energy and energy conservation, as well as the amount of energy consumption reduction. Although it is necessary to clear very difficult standards to achieve full ZEB, it is possible to aim for ZEB step by step by setting intermediate goals such as Nearly ZEB.

Table 5-5 Types of ZEB

Type of ZEB	Requirement
ZEB	A building that achieves net-zero annual energy balance and zero primary energy consumption through renewable energy and energy conservation.
Nearly ZEB	A building with an annual energy balance of 25% or less through renewable energy and conservation, and a primary energy consumption between 75% and less than 100% of the standard value.
ZEB Ready	A building that can reduce primary energy consumption by 50% or more through energy conservation.
ZEB Oriented	ZEB targets buildings with a total floor area of 10,000 m² or more. - Offices, factories, and schools: buildings that achieve 40% or more reduction in energy consumption through energy conservation. - Hotels, hospitals, department stores, and restaurants: buildings that achieve 30% or more reduction in energy consumption through energy conservation.

Source: "What is GX DiG ZEB 2023.11.28".

ZEH is categorized into different types based on the reduction rate of primary energy consumption, which includes both insulation and energy-saving measures, as well as renewable energy.

Table 5-6 Types of ZEH

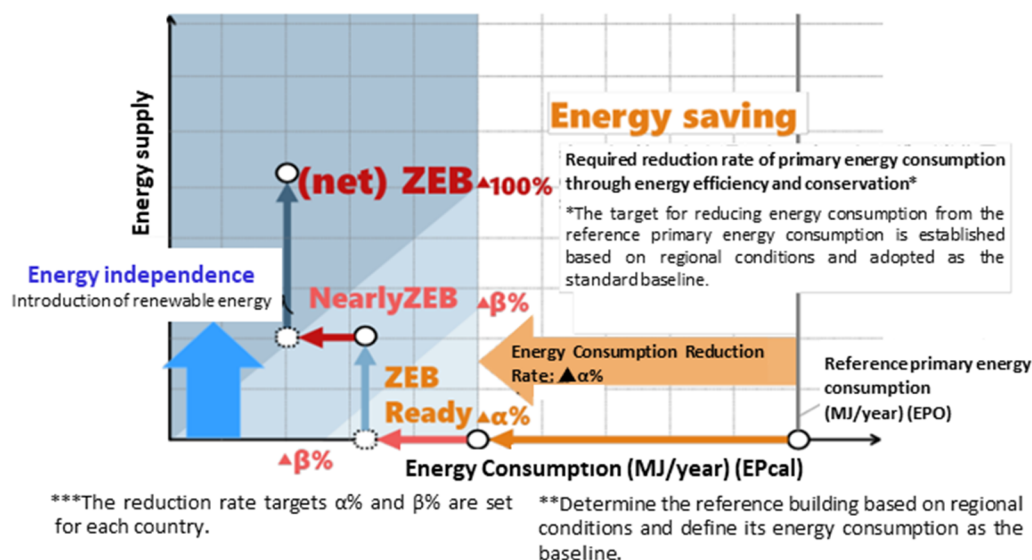
ZEH Type	Requirement
ZEH	Over 20% reduction through insulation and energy conservation, and over 100% including renewable energy.
ZEH +	Over 25% reduction through insulation and energy conservation, and over 100% including renewable energy. Meets certain conditions such as further enhancement of building envelope performance.

Nearly ZEH	Over 20% reduction through insulation and energy conservation, and between 75% and less than 100% including renewable energy. Targeted for regions where renewable energy is not sufficient, such as cold climates or areas with low solar radiation.
Nearly ZEH + Insulation	Over 25% reduction through insulation and energy conservation, and between 75% and less than 100% including renewable energy. - Targeted for regions where renewable energy is not sufficient, such as cold climates or areas with low solar radiation. - Meets certain conditions such as further enhancement of building envelope performance.
ZEH Oriented	Over 20% reduction through insulation and energy conservation. Targeted for urban areas with limited space, where renewable energy is not sufficient.

Source: "SDGs ACTION! 2022.05.10

ZEB is a concept that was applied for and established as an international standard by the Japan Association for the Promotion of Businesses for Energy Saving (JASE-W), with the aim of promoting energy conservation overseas by utilizing advanced technologies and reducing greenhouse gas emissions with renewable energy.

Although the ultimate goal of achieving ZEB is now clearly understood, its realization is limited by practical barriers such as high initial investment costs. However, due to the long-life cycle of buildings, designing and constructing more energy-efficient buildings is considered a present effort to reduce greenhouse gases rather than a future one. Thus, accelerating the movement toward ZEB has become a key challenge. From this perspective, TS23764 proposes a step-by-step approach to achieving (net) ZEB. Its objective is to present a practical method for realizing ZEB in order to accelerate its adoption. In other words, ISO/TS23764 proposes a practical ZEB approach and outlines the considerations throughout the entire process of realizing ZEB, from the design to the operation and maintenance. This aligns well with the situation in Mongolia, where a stepwise approach to energy conservation in residential and commercial buildings is needed in view of the 2050 targets.



Source: ISO/TS23764

Figure 5-13 ZEB Family Concept

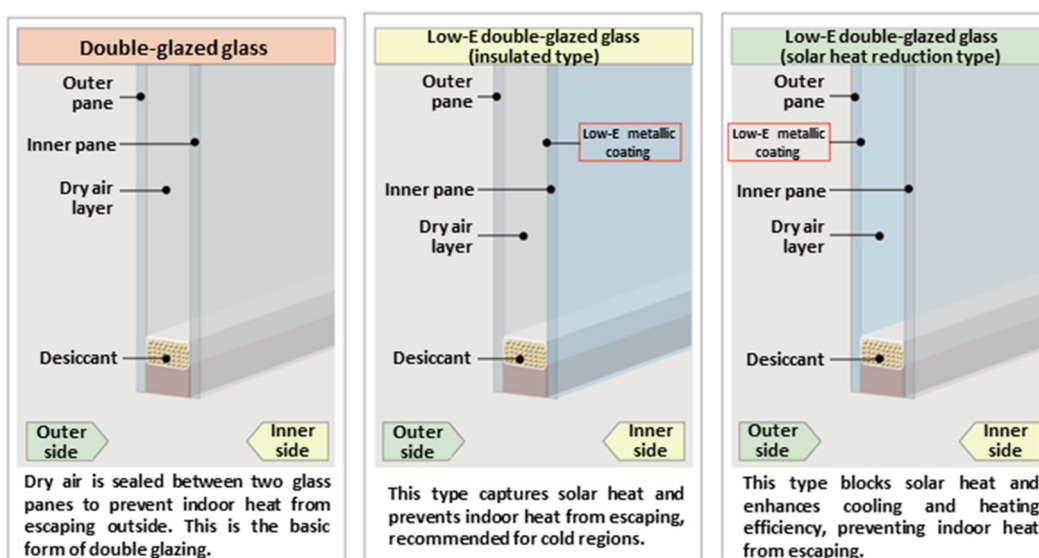
TS23764 provides guidelines for the entire process of planning, design, construction, and operation, and its principles are considered to align with the challenges faced in Mongolia. These challenges include improving and steadily enforcing energy-conscious building regulations, fostering knowledge about insulation, enhancing access to energy-saving products, and reducing barriers to energy-saving investments. The following table shows the results of the study.

Table 5-7 Guiding Principles in the Six Processes Identified in TS23764

1.	In the planning phase, a clear policy is adopted to achieve ZEB in three steps, ZEB Ready→ Nearly ZEB→ (Net)ZEB, rather than relying on a single-step approach to reach (Net) Zero Energy Building.
2.	In the design phase, appropriate passive and active design strategies are identified, and materials and equipment certified under national and international standards are selected whenever possible.
3.	During construction, the selected materials and equipment should be properly installed in accordance with the drawings and specifications.
4.	After the building is completed, the target primary energy consumption set during the design phase should be achieved.
5.	Once the building is in operation, verify whether there are any discrepancies between the target values established during the design phase and the actual measured primary energy consumption.
6.	If possible, use simulation software to periodically calculate and verify primary energy consumption after the start of operation.

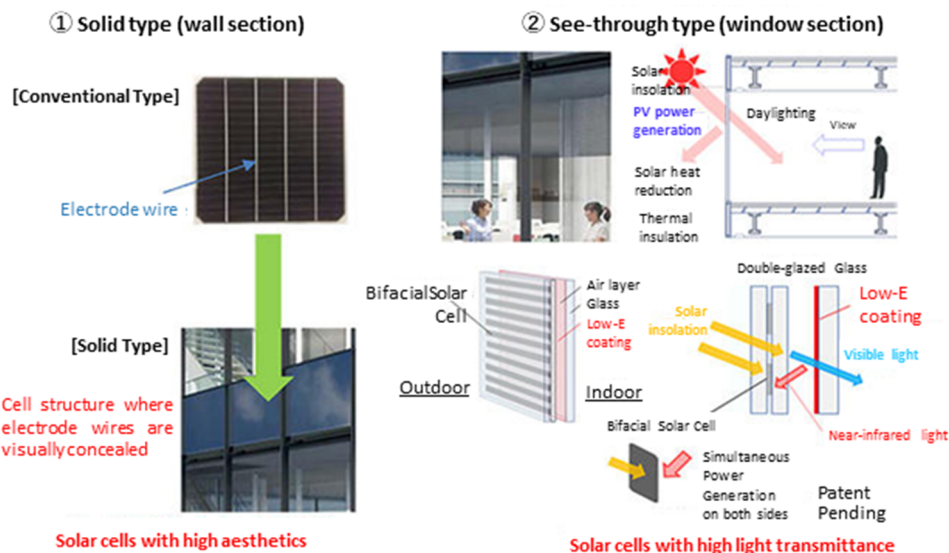
Source: Prepared by the survey team

In addition, Japan has already developed the equipment, material and know-how for constructing ZEBs. The transfer of these resources is expected to contribute to strengthening the capacity of the Mongolian government. In turn, this can support the future adoption and expansion of energy saving measures in residential and commercial buildings. For example, in Mongolia, where glass technology remains a technical challenge, AGC manufactures Low-E double-glazed glass and BIPV, which are key products that significantly contribute to ZEB construction.



Source: Ministry of the Environment

Figure 5-14 Overview of Low-E Double-Glazed Glass



Source: Taisei Corporation website

Figure 5-15 Overview of BIPV

In addition, the benefits and considerations regarding the introduction of BIPV are outlined below. It should be noted that in Japan, there are examples showing that the additional costs associated with converting existing buildings to ZEB can be recovered within approximately 20 years through reduced running costs.³⁸

2) Ground Source Heat Pumps

Mongolia experiences extremely cold conditions in winter, with outdoor temperatures dropping as low as -20°C . In such an environment, it becomes difficult to extract sufficient heat for heating using a standard air-source heat pump, resulting in a reduced coefficient of performance (COP). As a countermeasure, the introduction of ground source heat pumps, which utilize stable underground heat available year-round at depths of up to approximately 200 meters—is being considered. As examples of past efforts by Japanese companies to utilize geothermal energy in Mongolia, Shimizu Corporation introduced ground source heat pumps in kindergartens and schools in Zuunmod as part of "FY2012 Bilateral Offset Credit Scheme MRV Model Demonstration Study" and General Heat Pump Industry Co., Ltd. conducted feasibility studies and demonstration projects using the Ministry of Environment and JICA's support scheme. In particular, the demonstration project by General Heat Pump Industry Co., Ltd. achieved a COP of 2.96, demonstrating the technical feasibility of introducing the technology.

On the other hand, as for the cost of individual equipment units at the time of purchasing, there is a reported case in which a water-cooled heat pump chiller (3250W x 1300L x 1800H) was installed in Mongolia, with a unit cost of 330,000 JPY/kW.³⁹ In addition to the borehole method, cost reduction technologies such as the foundation pile method and the horizontal method have been developed. However, the cost remains high. Therefore, it is difficult to achieve widespread adoption through corporate efforts alone. It is necessary to create an energy-saving market in which reliable energy-saving products and technologies are not simply outcompeted by options with lower initial costs, while also aiming to reduce costs through broader adoption. Accordingly, key challenges for implementation include reducing installation costs, as described above, gaining the

³⁸ ZEB (Net Zero Energy Building) briefing session: Examples of existing buildings converted to ZEB and how to proceed (Ministry of the Environment)

³⁹ Report on the project to support the formation of a decarbonized city through the promotion of building and renewable energy in cold regions in UB, commissioned by the Intercity Cooperation Project for the Realization of a Decarbonized Society in FY2021

understanding of heating energy suppliers, and securing support from the Mongolian government and municipalities such as through the development of institutional frameworks and legislation.

In addition, when heat generated by ground source heat pumps is used for air conditioning and hot water supply in buildings, the thermal efficiency ultimately decreases to approximately 50, assuming coal's calorific value is set at 100. This is because the amount of usable heat on the supply side decreases when considering a power generation efficiency of 20%⁴⁰ for coal-fired power plants and transmission loss of 14%⁴¹. Taking into account the COP of air conditioners and water heaters, the final usable heat is estimated to be around 50 to 60.

In contrast, the thermal efficiency of district heating systems, which are widely used in Mongolia, drops to 42 when the heat value of coal is set at 100. This is because the efficiency of converting coal to hot water is 60%⁴², and additional heat loss of 30%⁴³ occurs during the distribution to buildings in UB.

Table 5-8 Thermal Efficiency Comparison of Ground Source Heat Pumps and District Heat Supply

Ground Source Heat Pump (HP)							
Coal 100		Power Generation Efficiency	Transmission Loss		Building	HP Air Conditioner	Converter Loss
		20%	14%			COP = 3.0	5%
		20.0	17.2			51.6	49.0
Coal 100		Power Generation Efficiency	Transmission Loss		Building	HP Hot Water Supply	Converter Loss
		20%	14%			COP = 3.5	5%
		20.0	17.2			60.2	57.2
District Heat Supply							
Coal 100					Boiler Efficiency	Power Generation Efficiency	Heat Loss
					80%	20%	30%
					80.0	20.0	42.0
				Efficiency of converting coal to hot water			

Source: Compiled by the survey team

Compared to district heat supply, where the amount of heat delivered to the demand side drops about 30%, ground source heat pumps maintain about 50%, resulting in better thermal efficiency. However, considering the district heat supply is currently the foundational heat system supporting Mongolia, and that ground source heat pumps are more expensive to install, it is believed that a

⁴⁰ Survey team confirmed on site

⁴¹ Final Report: Mongolia Information gathering and confirmation study for low/carbonization and stabilization of power system, JICA

⁴² Boiler efficiency 80% minus power generation efficiency 20%

⁴³ Calculated based on the hot water temperature of 96°C at a point 600 m away from the power plant during the field survey and the average pipe length (5 km) for the supply to the city.

hybrid heating society emphasizing both cost and efficiency can be realized through the appropriate use of both technologies.

(2) Other Potentially Applicable Technologies and Measures

Other potentially applicable technologies in the consumer sector are listed below. Note that the adoption of high-efficiency air conditioners, LEDs, etc. are considered to be included in ZEB/ZEH and are not listed here. Furthermore, securing heat supply is crucial, and it is desirable to also consider technologies for converting electricity to heat (Power-to-Heat) and thermal energy storage.

Table 5-9 Other Potentially Applicable Technologies and Measures

Target	Technology/measure	Overview
Ger Districts	Instant houses (alternative to ger)	Inexpensive and well insulated small dwellings can be constructed in a very short time. While local companies are attempting to commercialize similar housings, a cautious approach to introduction, including technology transfer, is necessary because of the potential to deprive construction workers in the ger areas of their livelihoods.
	3D printer housing (alternative to Bayshin)	
	Improved Fuel	Household fuel with enhanced environmental performance by blending biomass and other materials to reduce coal content.
Housing Complexes	Water-saving Showerheads	Water consumption and thermal energy for water heating can be reduced by limiting the use of hot water.
Commercial Buildings	Energy Management	Energy visualization in buildings can be implemented through the installation of measurement devices and BEMS, with continuous auditing and improvement encouraged.
Overall	Demand-Side Peak Load Management	Demand-side peak load reduction combining smart meters with dynamic pricing structures (time-of-use rates, peak-time rates)

Source: Prepared by the survey team

5.2 Priority Technologies and Measures on the Energy Supply Side

5.2.1 Identification of Priority Technologies and Measures

This section examines the technologies and measures that should be prioritized on the energy supply side in Mongolia (technologies that are already in widespread use, such as solar power, wind power, and general hydropower, are excluded from consideration in this chapter). First, the following list of technologies and measures are listed to examine the applicability of new and renewable energy sources in Mongolia.

Table 5-10 Listing of Technologies and Measures to be Considered for Applicability in Mongolia

	Technology/measure	Summary of Technologies and Strategies
1	Perovskite photovoltaic power generation	Lightweight, thin photovoltaics that can be easily installed on walls and rooftops of homes and buildings. It can be used as an energy supply source when reverse power flow is available and permitted.
2	Storage battery (BESS) to suppress frequency fluctuations caused by VRE	Ancillary storage batteries to regard VRE such as photovoltaic and wind power generation as a farm power source.
3	Interconnected mini-grid (MW-class VRE + BESS with grid connection)	Energy supply in areas where it is difficult to build more transmission and distribution lines. Energy for local consumption is supplied by VRE in the area without the need to expand power transmission and distribution lines.
4	Pumped storage power generation	Equipment for peak shifting that uses excess renewable energy to pump water, and generate power during times of grid power shortages, which can be used to absorb VRE fluctuations as well as for blackout starts, etc.
5	Geothermal power generation	A facility that generates electricity by extracting steam from an underground heat source.
6	Hydrogen-fuelled technology	Hydrogen is produced from renewable energy and used as an energy source for electricity and heat.
7	Ammonia-fuelled technology	Hydrogen is produced from renewable energy and converted into ammonia, which is easy to handle, and used as an energy source for electricity and heat.
8	Conversion of existing thermal power plants to biomass co-firing	Co-firing of biomass as fuel for existing coal power plants.
9	New biomass-fired thermal power plant, power generation from waste materials, new CFB boiler	New construction of biomass power plant using dead wood etc. as fuel. New construction of waste power plant using CFB (Circulating Fluidized Bed) boiler that can burn a variety of fuels with high efficiency.
10	Power generation from waste (garbage-derived biogas)	Biogas generated from landfilled waste (including sludge generated from sewage treatment) is collected as fuel and used for power generation.
11	CC(U)S/EOR addition to existing thermal power plant	Technology to capture and store CO ₂ emitted from existing coal-fired power plants. This technology is used to recover oil remaining underground as well as to convert it into chemical fuels.
12	IGCC(IGFC) + CC(U)S	A facility that gasifies coal to generate electricity at high efficiency as a combined cycle power generation.
13	CBM fuelled GTCC + CCS	Methane gas contained in coal seams is recovered and used for gas combined cycle power generation.
14	Small (micro) nuclear power	A new type of nuclear power generation that is small, low-power, and safe.
15	Nuclear fusion	A technology that combines atomic nuclei to produce energy. Deuterium, which is used as fuel, is abundant in seawater.

Source: Prepared by the survey team

5.2.2 Outline of Each Technology and Measure

(1) Perovskite Photovoltaic Power Generation

1) Technology Overview

Solar cells made of materials with a perovskite structure. Lightweight and flexible, they can be installed on building walls and low load-bearing roofs, where silicon solar cells are difficult to install. They can also be installed on electric vehicles and drones to extend their driving and flying distances. The system can be considered an energy-saving facility on the customer side, but it can also supply electricity by reverse power flow.

<Advantages>

- Lightweight and flexible, allowing installation on buildings and other structures that have been difficult to install in the past.

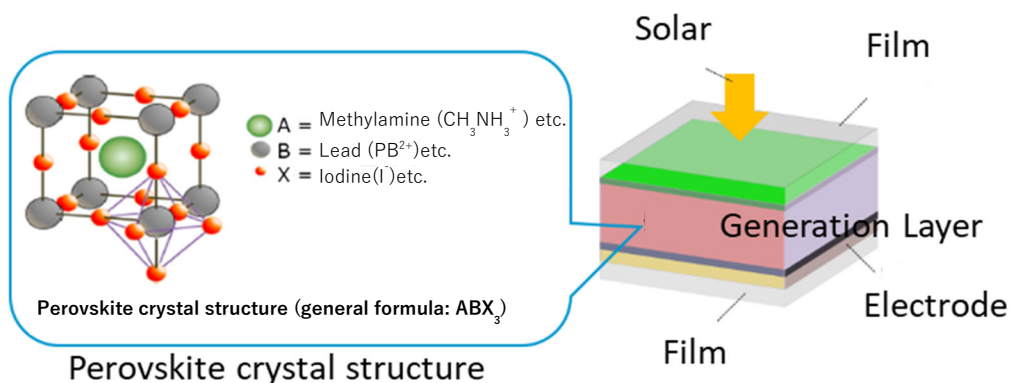
<Issues>

- Conventional solar power has a cost advantage for large-scale installation at sites with sufficient space.
- Durability has not been confirmed at this stage.

2) Mechanism

As shown in the figure below, perovskite solar cells, like other solar cells, consist of a "power generation layer," "electrode," "hole transport layer," and "electron transport layer," in a five-layer sandwich-like structure with the power generation layer (perovskite layer) at the center, a hole transport layer and an electron transport layer, and two electrodes on the outermost side.

The energy conversion efficiency is about 15% as of 2024 (conventional silicon solar cells are about 14% - 20%).



Source: Agency for Natural Resources and Energy

Figure 5-16 Structure of Perovskite Photovoltaics

3) Cost

The Ministry of Economy, Trade and Industry in Japan has set a target of 9 UScent/kWh for the cost of perovskite power generation as of 2030. At present, the durability is assumed to be about 10 years, and some issues including the establishment of disposal methods and recycling technology remain.

4) Achievements in Japan

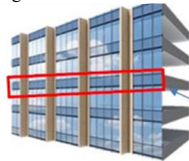
In Japan, the focus is shifting from demonstration projects to full-scale projects. (See figure below).

Image of completed redevelopment project



Film-type perovskite solar cell (PSC)

Image of PSC installation



Inside of the outer wall of the spandrel section



The images and perspectives in this document are at the planning stage and may be subject to change due to future administrative guidance, etc.

Source: Sekisui Chemical

Figure 5-17 Left: Uchisaiwai-cho South Tower (to be completed in March 2027)
Right figure: Demonstration Facility in Yokosuka Thermal Power Plant (2023)

5) Application to Mongolia

This technology is specifically effective when it is installed mainly in the urban areas such as UB city, however, since durability is an issue at this time, even if it is applied, it should first be used in installations where it can be replaced (such as materials for ger or indoor use), or a demonstration project including weather resistance checks can be considered.

(2) Storage Battery (BESS) to Suppress Frequency Fluctuations Caused by VRE

1) Technology Overview

Variable Renewable Energy (VRE) such as photovoltaic and wind power generation constantly fluctuates in power output depending on the weather. When these fluctuations become large relative to the grid capacity, the grid frequency may deviate from the allowable regulated value. For this reason, some of BESS are installed to suppress the fluctuations caused by VRE.

Since the purpose of BESS is to suppress the frequency fluctuations, it can be installed anywhere in the grid. However, if BESS is installed in an area where VRE is concentrated, it is also possible to control the grid voltage fluctuations in that area.

<Advantages>

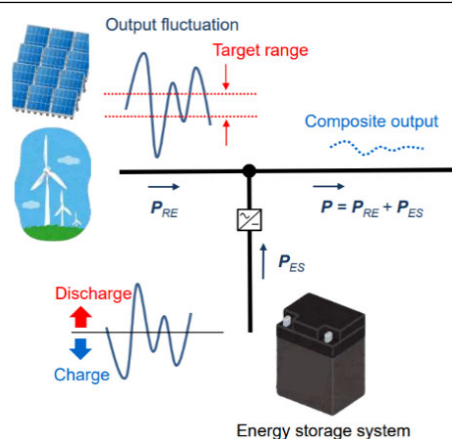
- BESS can be installed anywhere. There are no location restrictions like with adjustable speed pumped storage hydro plants
- BESS can be easily relocated.
- The construction period for BESS is 1-2 years, which is much shorter than that for adjustable speed pumped storage hydro power plants.
- The Mongolian grid code requires the installation of BESS for VRE. Regardless of whether this function is used or not, it is only necessary to add the control of this function to the BESS functions in the future. The cost remains the same.

<Issue>

- None in particular

2) Mechanism

Install storage batteries to suppress frequency fluctuations caused by VRE output fluctuations. (See figure below)

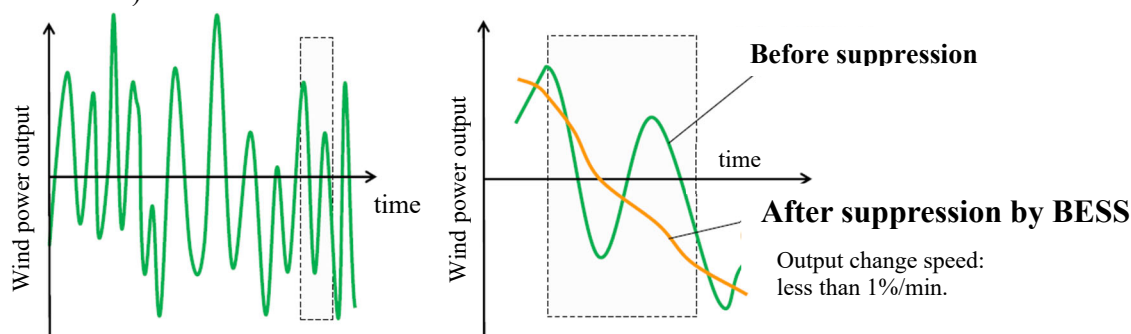


Source: Prepared by the survey team

Figure 5-18 VRE Output Fluctuation Suppression by BESS

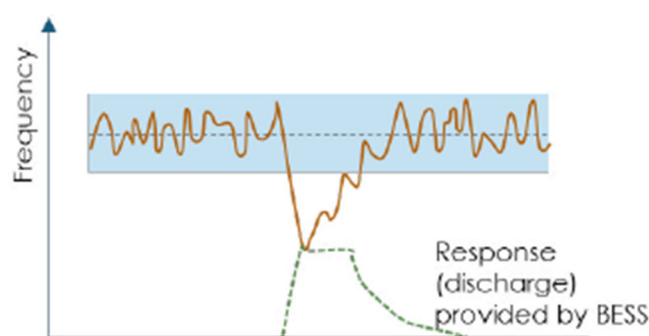
For example, since 2016, Hokkaido in Japan has required wind power operators to limit the one-minute output fluctuation of wind power to less than 1% of the rated output.

However, to reduce the burden on wind power operators and ensure efficient operations, the countermeasures were revised to have electric power companies install large-scale BESSs on the grid side in 2023. In this case, the grid frequency is monitored to control the BESS. (See figure below)



Source: Prepared by the survey team based on data from Hokkaido Electric Power Co.

Figure 5-19 Wind Power Output Fluctuation Suppression by BESS

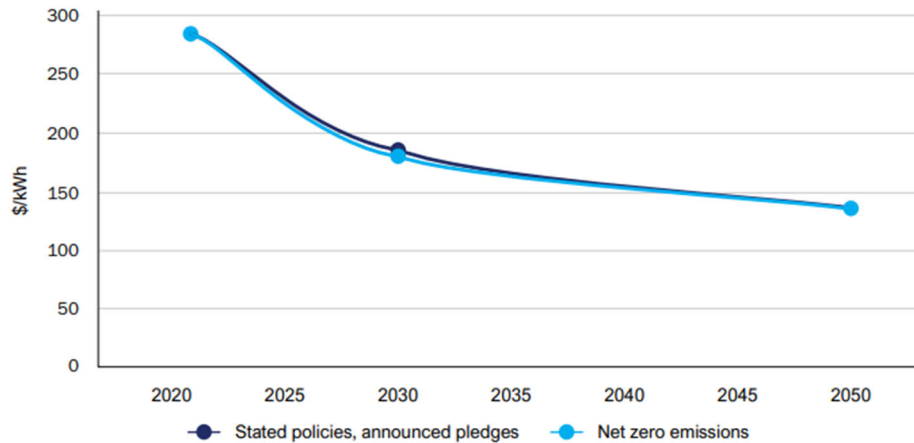


Source: WB data

Figure 5-20 Grid Frequency Fluctuation Suppression by BESS

3) Cost

According to IEA and WB data, the cost of BESS for the grid is expected to halve from about 300 USD per kWh at present to about 150 USD around 2050, as shown below for a 4-hour time capacity system, for example. (see figure below)



Source: Prepared by WB based on IEA data

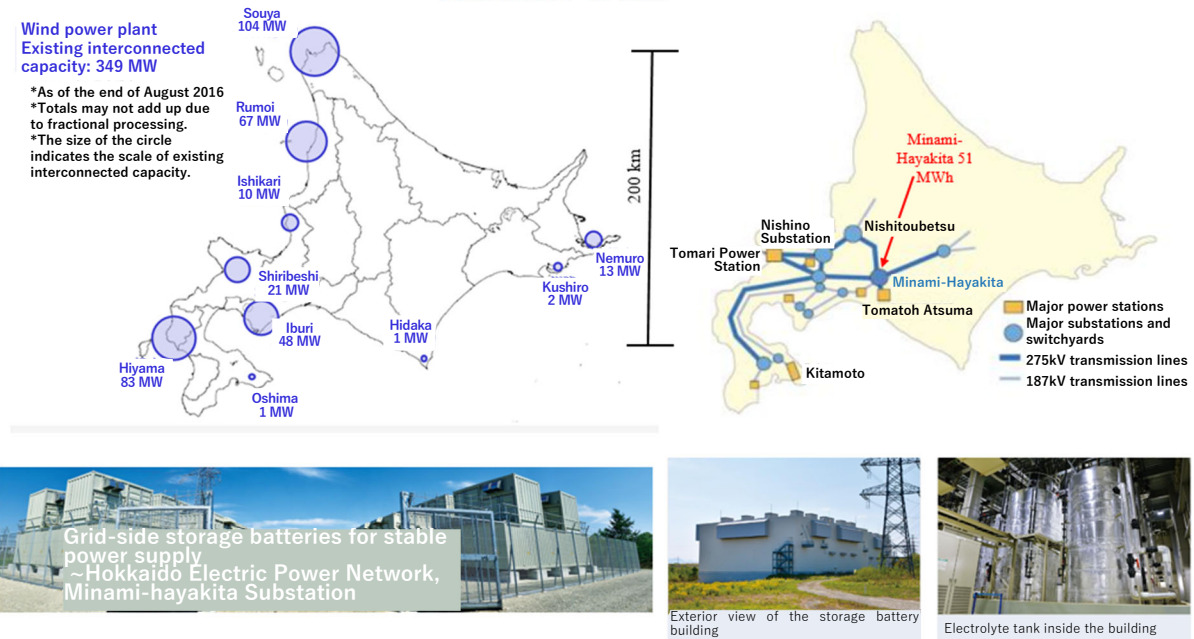
Figure 5-21 Unit Cost per kWh of BESS for Grid (example of 4-hour capacity system)

4) Actual Cases in Japan

The figure below shows an actual example of a 51 MWh BESS, which also has a grid frequency control function, installed by Hokkaido Electric Power Company in 2022 in collaboration with several wind power companies.

Wind Power total : 349 MW

BESS : 51 MWh (17 MW × 3 hours) 150 m × 45m , April 2022
Redox Flow 40 cells



Source: Prepared by the survey team based on data from Hokkaido Electric Power Co.

Figure 5-22 Overview of BESS Installed at the Minami-Hayakita Substation of Hokkaido Electric Power Co.

5) Application to Mongolia

The installation ratio of VRE is expected to increase in Mongolia in the future. In addition to BESS that is simply used to adjust supply-demand balance, it will be necessary to install BESS that also has the function of suppressing short-period grid frequency fluctuations in the future.

(3) Interconnected Mini-grid (MW-class VRE + BESS with grid connection)

1) Technology Overview

Rural electrification is often carried out in an off-grid manner without grid interconnection due to the absence of major power grid lines in the neighborhood or the capacity of the power grid is too small to interconnect. In this case, the grid is not connected to the main power grid but is an independent mini-grid configuration consisting mainly of a diesel generator and distribution system, often in the output order of a few MW.

In considering energy transition, diesel generators emitting CO₂ will be replaced with solar PV and other VRE. At the same time, the installation of BESS is essential to stabilize the supply from VRE.

To stabilize supply within the mini-grid, the idea is not to further expand power supply facilities and BESS within the region, but to replenish power from the local grid or neighboring mini-grids that have been connected in advance in the event of supply instability or accidents. In this case, the interconnection lines between the mini-grid and the local grid, or the mini-grid and the neighboring mini-grid are used only in case of emergency, so the transmission capacity can be small and weak. It also does not need to be reliable, and only one power line is needed.

In cases where the distance of the transmission line already connected to the region is long and the cost of reinforcement is high, there is also the idea of installing a VRE power supply and BESS within the region to create a mini-grid, thereby avoiding reinforcement work on the grid side so as not to increase the supply from the grid.

<Advantages>

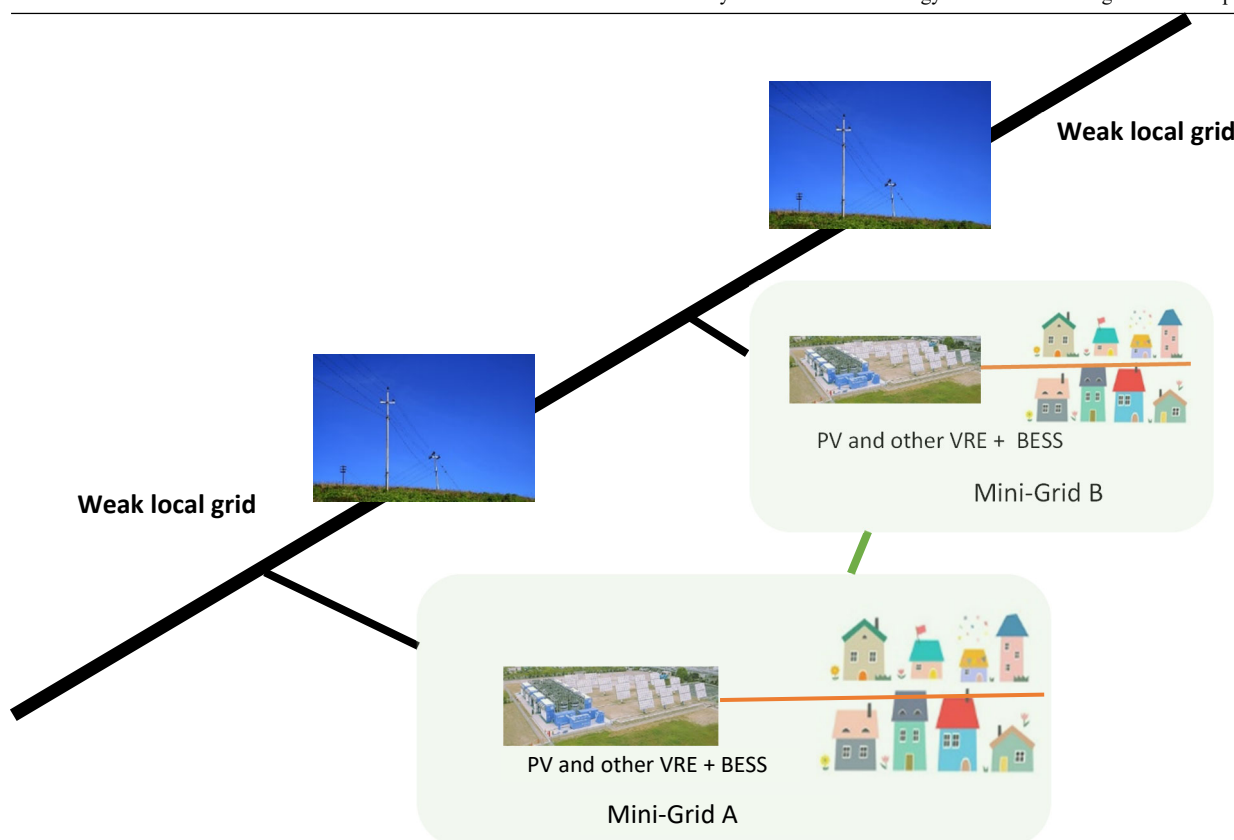
- This system mitigates long-term power outages in the event of an accident in the area, whereas a completely off-grid system would result in long-term power outages.
- Transmission losses from the substation to the point of demand are reduced or eliminated.
- Expansion of transmission lines due to annual demand growth will be reduced.
- Decarbonization is possible.

<Issue>

- None in particular

2) Mechanism

The outline of an interconnected mini-grid is shown in the figure below.



Source: Prepared by the survey team

Figure 5-23 Interconnected Mini-Grid

3) Cost

To achieve self-sufficiency of electricity within the region, a BESS with a long-time capacity is needed.

The following is an estimate based on the assumption that the charging capacity of BESS is half the rated capacity of PV x 5 hours x 3 days.

PV system 1MW	0.5 Million USD
BESS (1MW× 0.5× 5h× 3d = 7.5 MWh)	2.2 Million USD

4) Examples in Japan

In Japan, there are few examples of rural electrification of VRE + BESS because grid connection is the basis except for remote islands. However, there is an example of PV + BESS + EV mini-grid in Katsurao Village, Fukushima Prefecture as a reconstruction project after the earthquake. (See figure below)



Residents	488 (as of 2/1/2023), approx. 110 houses
Self-supplied power lines	5km
Solar PV	1.2MW
BESS	Approx. 3MWh (capacity equivalent to 72 hours of maximum area demand)
EV charge/discharge units	2 units (can be discharged in an emergency to supply power to the mini-grid)
Stand-alone lighting	3 units

Source: Katsurao Creative Power Corporation, Katsurao Village

Figure 5-24 Katsurao Smart Community

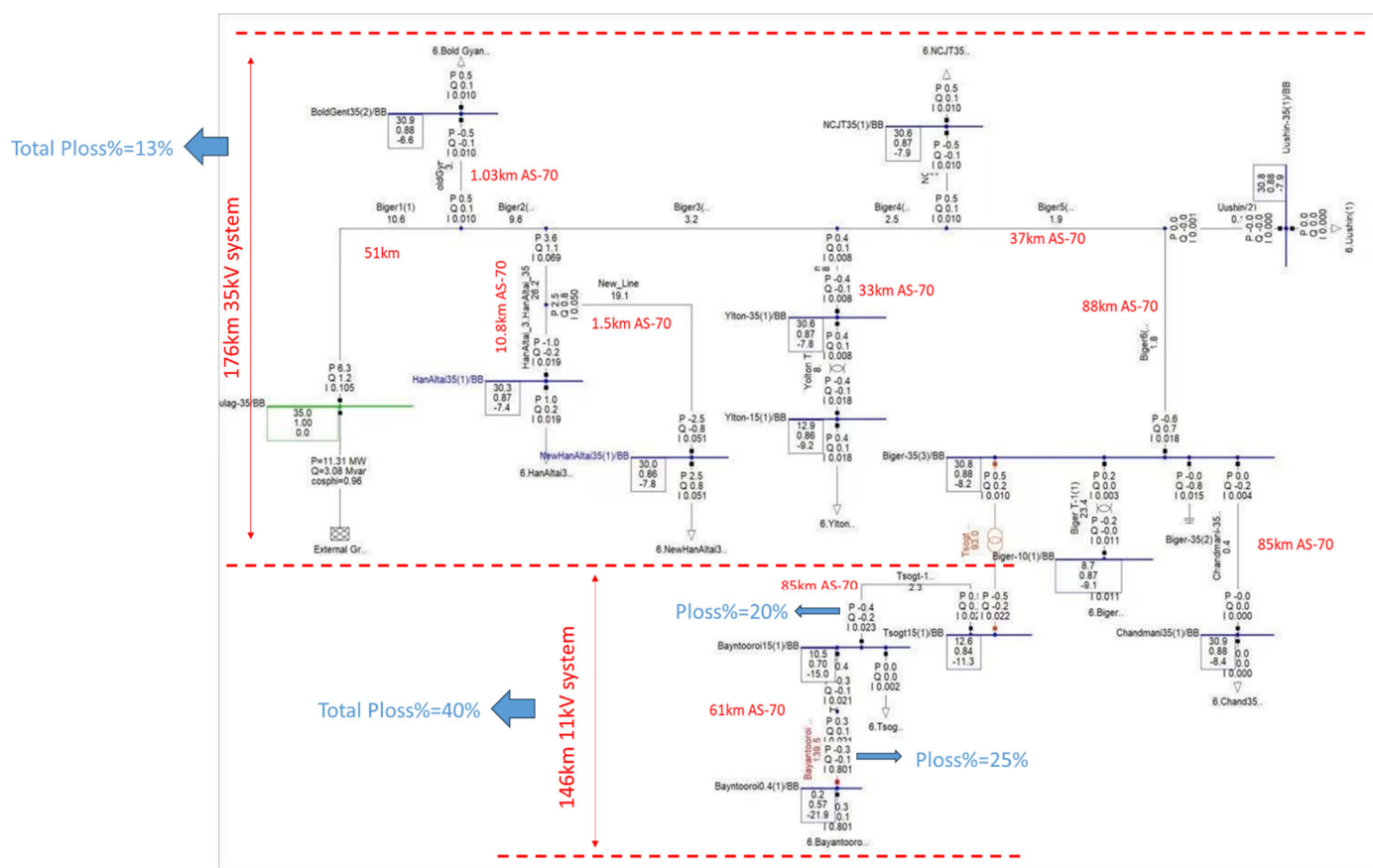
5) Application to Mongolia

When JST visited a substation in the South Gobi area during our second field survey, JST heard about a situation where electric power was being transmitted over 35 kV distribution lines of 300-

500km long, resulting in very large transmission and distribution losses and voltage drops. In such a case, it would be more beneficial in terms of transmission and distribution losses to install VREs and BESSs to avoid the reinforcement of distribution lines.

In rural areas of Mongolia, it is considered that many areas are supplied by very long-distance distribution lines, so it would be possible to greatly reduce transmission and distribution losses by installing VRE and BESS and converting the area to a mini-grid.

For example, in the sample data below obtained from NDC, when the losses in each of the 35kV and 11kV transmission systems are calculated, the total transmission loss ("Total Ploss") in the 35kV system is 13%. Considering that the typical loss of a BESS is 20%, there is no effect of applying the mini-grid here. However, the 11 kV system has a total transmission loss of 40%, which is considered to be a benefit of installing mini-grid. Furthermore, the interconnected mini-grid system will eliminate the need to expand transmission and substation facilities such as 11kV transmission lines and 35/11kV transformers even if demand increases in the future.



Source: Prepared by the survey team based on NDC data.

Figure 5-25 Mongolia 35kV/11kV System Sample Data

(4) Pumped Storage Power Generation

1) Technology Overview

Pumped storage power generation is a system in which two reservoirs, the upper and lower reservoirs, are connected by a channel, and a pump and generator are installed in the middle to absorb surplus power and generate electricity when there is a shortage, and has a wealth of experience around the world. Pumped storage power generation can be used in a variety of ways, depending on how it is used.

<Advantages>

- Economic operation, in which pumped storage is operated using electricity with low unit

cost and power is generated during times when the unit cost is high.

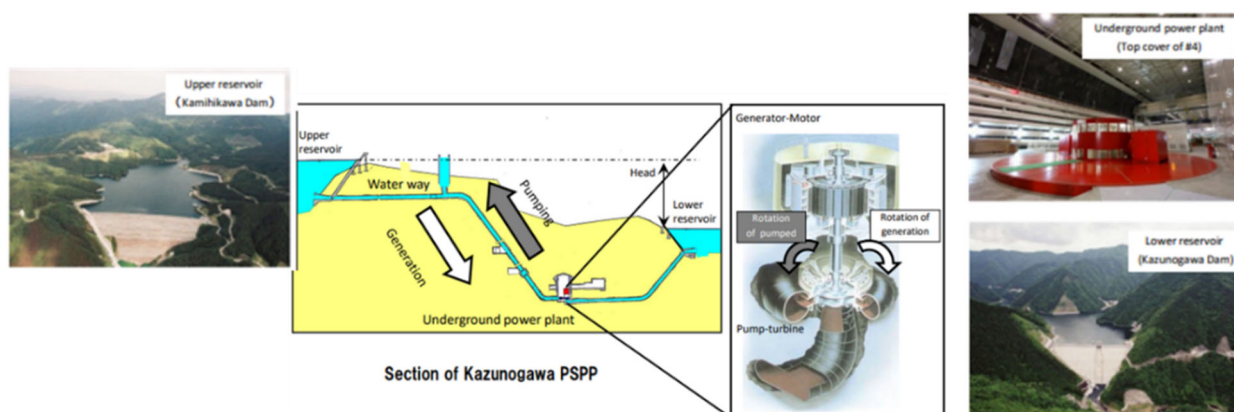
- Use as a spinning reserve (reserve capacity that can be operated for short periods of time).
- Use as load-following capacity to adjust frequency.
- Use as synchronous regulating capacity to adjust for voltage fluctuations.
- Use as a starting point for power generation from a black start.
- Longer life than storage batteries

< Issues >

- Need to plan without affecting existing water use.
- Large-scale construction work
- Requires more time from planning to construction than storage batteries.

2) Mechanism

Pumped storage facilities generally consist of the following equipment, which can be combined with various pond capacities, drop-offs, and flow rates depending on topographical and climatic conditions.



Source: Tokyo Electric Power Co.

Figure 5-26 How Pumped Storage Power Generation Works (example from TEPCO's Kazunogawa Power Station)

3) Cost

In addition to construction and maintenance costs, a pumped storage power generation requires pumped-storage resources because other power generation resources are used to pump up the water. In many cases, this pumped-storage resource is generally surplus, inexpensive electricity, such as nuclear power generation that operates steadily throughout the day and solar power generation that generates a surplus during the daytime. Generally, the amount of electricity that can be generated compared to the electricity consumed for pumping water is about 70%.

The unit cost of pumped storage power generation in Japan (excluding pumped storage resources) is about 9 UScent/kWh. If, for example, 12 UScent/kWh of electricity is used for pumping, the total unit cost of pumped storage is 21 UScent/kWh.

4) Achievements in Japan

The following table shows the actual results of pumped storage power generation facilities at TEPCO, which started the introduction in 1965 and gradually expanded the scope of application and improved the generating capacity of single units.

Table 5-11 Achievements of Pumped Storage Power Generation Facilities at TEPCO

Plant Name	Type of Plant	Commissioning Year of First Unit	Plant Capacity	Effective Head	No. of Units	Turbine Output
Yagisawa	Pumped & Natural Flow	1965	240MW	93.5m	3	87MW
Azumi		1969	623MW	134.9m	6	109MW
Midono		1969	245MW	79.8m	4	64MW
Shin-Takasegawa		1979	1,280MW	229.0m	4	336MW
Tanbara	Closed-loop Pumped	1982	1,200MW	518.0m	4	308MW
Imaichi		1988	1,050MW	524.0m	3	360MW
Shiobara		1994	900MW	338.0m	3	308MW
Kazunogawa		1999	1,200MW (to be 1,600MW)	714.0m	4	412MW
Kannagawa		2005	940MW (to be 2,820MW)	653.0m	6	482MW

Source: Prepared by the survey team based on data from TEPCO

5) Application to Mongolia

A pumped storage power generation is a technology technically feasible in Mongolia depending on the terrain. According to the Ministry of Energy (MOE), there is a plan to construct a 100 MW pumped storage hydropower plant in Selenge Province. Whether it is economically viable requires a comprehensive assessment, as it is a technology that contributes to grid stabilization—not only through simple economic operation but also through its value as a peak power supply and its role in expanding renewable energy integration.

(5) Geothermal Power Generation

1) Technology Overview

Geothermal power generation is a renewable energy source that generates electricity by turning a steam turbine using steam generated from an underground heat source. The power output is not affected by weather conditions, so it has the advantage of being used in a stable manner.

Generally, potential exists in areas with many volcanoes. Wells called "geothermal wells" (steam wells and production wells) are dug to extract steam, but generally require drilling of more than 1,000 meters, and the initial survey to confirm that the wells can provide a stable amount of heat is very expensive.

In some cases, the residual heat after being used for power generation is also used for agricultural purposes (e.g., greenhouse cultivation) and for community and tourism use.

<Advantages>

- Stable operation with little fluctuation can be expected.

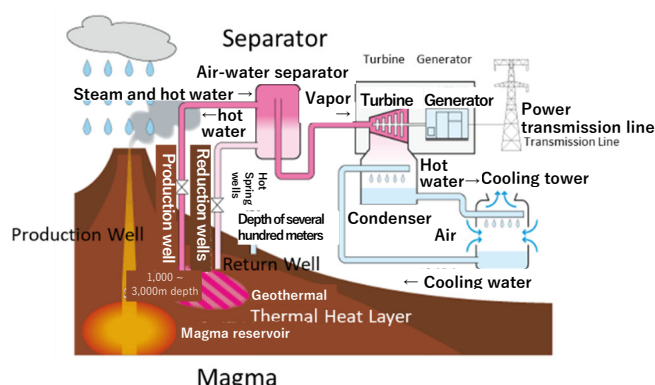
<Issues>

- Costly research to find suitable sites.

2) Mechanism

The following figure shows the mechanism of a geothermal power generation system called the flash method, which is widely used in practical applications. Only steam is extracted from the steam and hot water obtained from the production well by a water-air separator, and power is generated by turning a turbine to turn a generator (single-flash method). The steam that has finished generating power is returned to liquid in the condenser and returned to the underground through the reduction well together with the separated hot water. There is also a method in which

the hot water separated by the gas-water separator is introduced into a flasher (pressure reducer) to extract low-pressure steam, which is used for power generation to increase power generation efficiency (double-flash method).



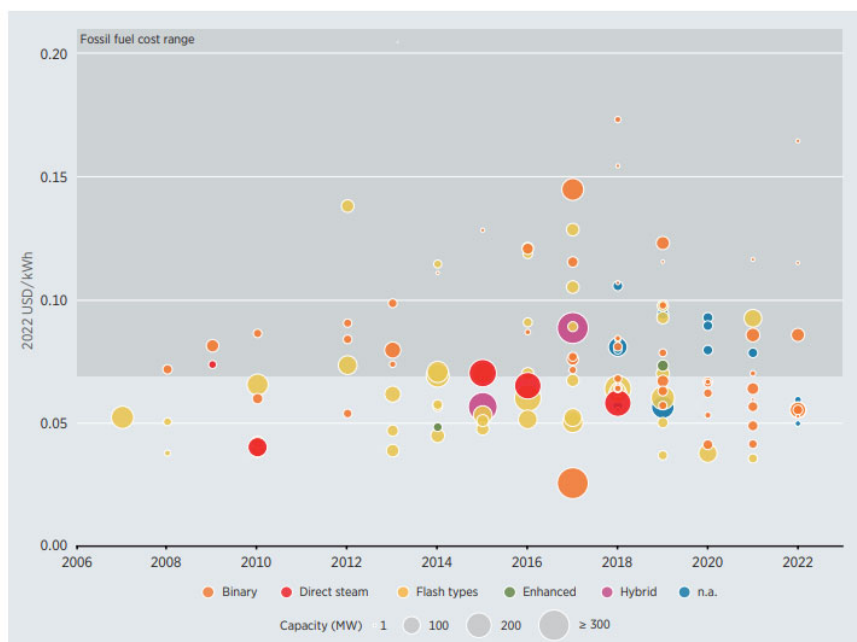
Source: Japan Energy and Metals National Corporation

Figure 5-27 How Geothermal Power is Generated (example of single-flash system)

Other methods include the dry steam method, in which the steam obtained from the production well contains little or no hot water and a simple moisture removal process is used to turn the turbine, and the binary method, in which a medium with a low boiling point is used to vaporize it to turn the turbine when only hot water is available due to the low underground temperature.

3) Cost

According to "Renewable Power Generation Costs in 2022" published by IRENA, the global geothermal power generation costs (LCOE) from 2007 to 2022 are shown below and are approximately 0.05 USD/kWh - 0.10 USD/kWh.



Source: IRENA

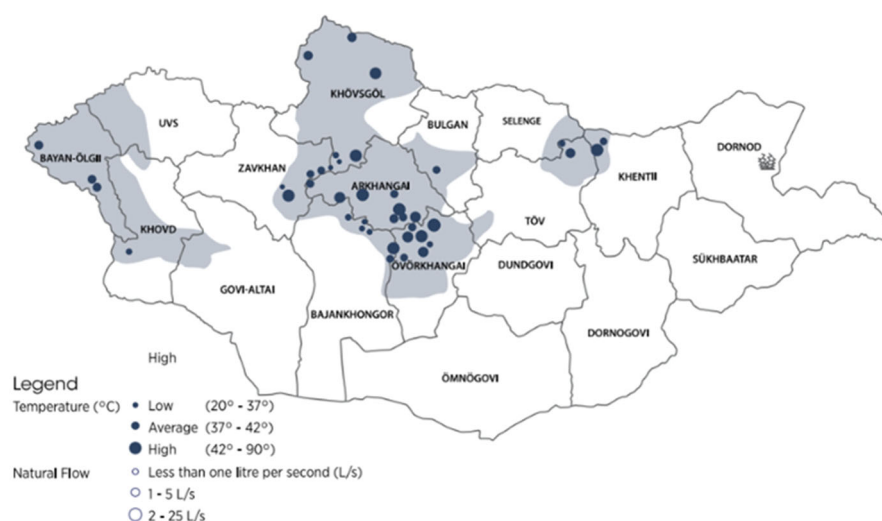
Figure 5-28 Geothermal Power Generation Cost (LCOE) by Technology and Project Size

4) Achievements in Japan

Japan is a volcano rich country and is considered to have the third largest geothermal resource in the world after the United States and Indonesia. According to the Japan Organization for Metals and Energy Security (JOGMEC), the installed capacity of geothermal power generation in Japan is approximately 540 MW as of FY2019, and the amount of electricity generated is 2,472 GWh, or 0.2% of total electricity generation including other power generation.

5) Application to Mongolia

Mongolia is on a solidified tectonic plate and theoretically does not have significant potential for geothermal power generation. Meanwhile, according to the "Mongolia Renewables Readiness Assessment 2016, IRENA," the hot water is identified at the surface in Mongolia as follows, and it may be possible to utilize this for local heat supplying system.



Source: IRENA

Figure 5-29 Geothermal Potential Map in Mongolia

(6) Hydrogen-fuelled Technology

1) Technology Overview

This section describes technologies which use hydrogen as fuel. Currently, research is underway to use hydrogen as fuel in gas turbines and boilers. Thermal power generation and heat supply facilities can be decarbonized by converting the fuel to hydrogen.

Mongolia, especially the South Gobi region, has excellent potential for solar and wind power generation, and is expected to produce a large amount of CO₂-free green hydrogen through electrolysis. The production of lignite-derived blue hydrogen using a combination of CCS/CCUS is also a possibility. Currently, there are no CCS/CCUS facilities in practical use in Mongolia, and it is necessary to investigate suitable storage sites and evaluate economic feasibility.

Advantages and Issues of hydrogen utilization in Mongolia are described below.

<Advantages>

- Provides electricity and heat at the same time.
- No CO₂ and soot emissions, leading to improvement of air pollution.
- Provides a means of storing renewable electricity for longer periods than storage batteries.
- Adopting power generation methods with inertial forces, such as gas turbines, contributes to grid stabilization.

<Issues>

- The distance between UB City, which is the largest demand area, and areas with high

renewable energy potential are far away from each other.

- Limited experience with gas fuels. Additionally, hydrogen itself is flammable and has a wide explosive range, making it difficult to handle.
- Lack of water resources for hydrogen production in the South Gobi region.

For reference, the following table shows the consumption of hydrogen and pure water used as a raw material for hydrogen in the S-H scenario mentioned in the Chapter 6 as one of the Energy Transition Supply Scenarios, which requires 12,645 thousand tonnes (35,000 tonnes per day) of pure water in 2050. In reality, 3 - 4 times as much water will be needed for the purification process of the water and for cooling the hydrogen production facilities.

Table 5-12 Consumption of Hydrogen and Pure Water in S-H Scenario

Year	2035	2040	2045	2050
Hydrogen consumption [thousand tonnes]	94	468	937	1,405
Pure water consumption [thousand tonnes]	843	4,215	8,430	12,645

Source: Prepared by the survey team

There are two possible locations for hydrogen production: either in the vicinity of UB City, where the greatest demand is expected, or in the South Gobi region, which has high renewable energy potential.

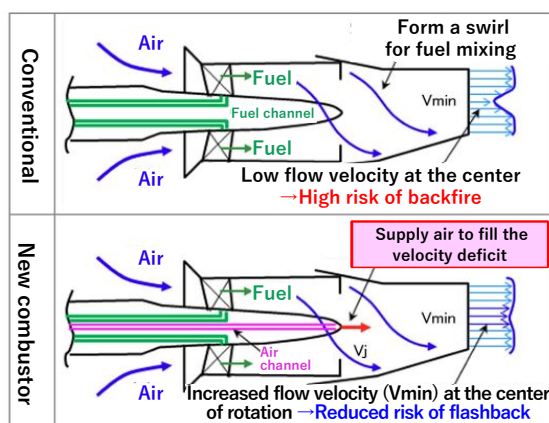
In the case of hydrogen production in the vicinity of UB City, it is easier to procure water resources than in the South Gobi region.

During the third trip, we interviewed the Water Resources Agency and the UB Municipal Waterworks Bureau regarding available water resources in the vicinity of UB City. Mongolia is implementing three water supply projects under an agreement with the Millennium Challenge Corporation of the United States starting January 31, 2019. One of these projects is planning to reprocess wastewater from the Central Wastewater Treatment Plant and use it as cooling water for existing power plants. The reprocessing facility is scheduled to start operation in October 2025 and is capable of reprocessing 50,000 tonnes of wastewater per day. In the future, there are plans to increase the reprocessing capacity to 150,000 tonnes per day. A proposal to use this reprocessed water to produce hydrogen was presented. On the other hand, there is concern that the cost will be higher than using groundwater (taken from wells), as it consumes five times more energy. In addition, the production of green hydrogen requires the transmission of electricity generated from renewable energy sources in the South Gobi and other areas to the UB City area, which requires investment in transmission facilities such as transmission lines and switchyards.

Producing hydrogen in South Gobi has the advantage of not incurring the cost of transmitting renewable electricity. On the other hand, securing water resources and a means to transport hydrogen to the point of demand will be an issue. Regarding water resources, the hydrogen production pilot project plans to use groundwater. However, mining is thriving in the South Gobi region, and groundwater resources are already becoming scarce. When hydrogen production goes into full scale in the future, competition for the use of groundwater resources will arise, and there is a possibility that sufficient water resources will not be secured. In order to ensure a stable supply of water resources, measures such as water transportation from the northern part of the country, where water resources are relatively abundant, will be necessary. Truck or pipeline can be used as a hydrogen transportation method to UB City and other demand centers. The distance from the South Gobi to UB City is approximately 500 - 600 km. Generally, for a distance of approximately 500 km, the transportation cost by pipeline is 0.1 - 1 USD/kg-H₂ and by truck is 1 - 2 USD/kg-H₂, so transportation by pipeline is economically advantageous. However, investment is required for pipeline development.

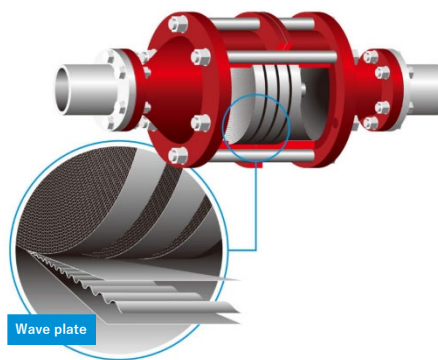
2) Mechanism

The main problem in using hydrogen as a fuel is the stability of combustion. Hydrogen burns faster than natural gas and is prone to backfires, which can burn out the fuel system. In addition, the temperature distribution of the flame is uneven, and more thermal NO_x is produced in the hot parts of the flame. For this reason, combustors that provide backfire prevention and uniform combustion have been developed for gas turbines. In boilers, low-NO_x burners and flame arresters have been introduced to suppress the generation of localized high temperatures, and countermeasures are being taken.



Source: Mitsubishi Heavy Industries, Ltd.

Figure 5-30 Gas Turbine New Type Combustor



Source: Miura Industry

Figure 5-31 Flame Arrester Schematic

3) Cost

The cost of electricity generation will vary greatly depending on the price of hydrogen. The table below shows an estimate of the price of green hydrogen production in the South Gobi region of Mongolia, the actual price of hydrogen in Japan in 2020 and the price targets for 2030 and 2050, and the cost of power generation for two models of gas turbines, the Mitsubishi Heavy Industries H-25 gas turbine and the M701 JAC gas turbine, in hydrogen-only operation at each point in time. The production costs of green hydrogen in Mongolia shown in this table are the estimated production costs in the South Gobi region for 2020 and 2030, calculated in a study on the application of green hydrogen in Mongolia conducted by the New Climate Institute in 2021. The cost of power generation in Mongolia does not include the cost of fuel transportation, and assumes local production for local consumption in the South Gobi region.

The price of green hydrogen in Mongolia is lower than in Japan due to its abundant renewable energy, and is estimated to be around 25 UScent/Nm³ in 2030 due to the lower cost of water electrolysis equipment in the future. However, when used as fuel for gas turbine power generation, the cost is 21.6 UScent/kWh, which is expensive compared to the typical cost of 8 - 9 UScent/kWh for gas-fired power generation in Japan. For application after 2040, further reduction of renewable energy costs, water electrolysis equipment costs, and water procurement costs are needed. Also, compared to the larger M701 JAC, the H-25 has a lower thermal efficiency and consumes more fuel per kWh, making it more sensitive to hydrogen prices.

Table 5-13 Estimated Cost of Power Generation in Gas Turbines

Country	Item	2020	2030	2050
Mongolia	Price of hydrogen [UScent/Nm ³]	29.5	25.0	-
	Generation cost(H-25) [UScent/kWh]	34.1	29.2	-

	Generation cost (M701JAC) [UScent/kWh]	25.0	21.6	-
Japan	Price of hydrogen [UScent/Nm ³]	100	30	20
	Generation cost (H-25) [UScent/kWh]	111.5	35.4	24.4
	Generation cost (M701JAC) [UScent/kWh]	79.3	25.8	18.0

Source: Prepared by the survey team, from New Climate Institute, Green Hydrogen Applications in Mongolia Technology potential and policy options (2021), and Mitsubishi Heavy Industries Hydrogen Power Handbook.

For reference, the table below shows the estimated cost per kg of steam for Miura Industries' AI-2500 16S (multi-tube once-through boiler, equivalent evaporation: 2,500 kg/h, hydrogen consumption: 576.8 Nm³/h).

Table 5-14 Steam Cost Estimates for Hydrogen Boilers

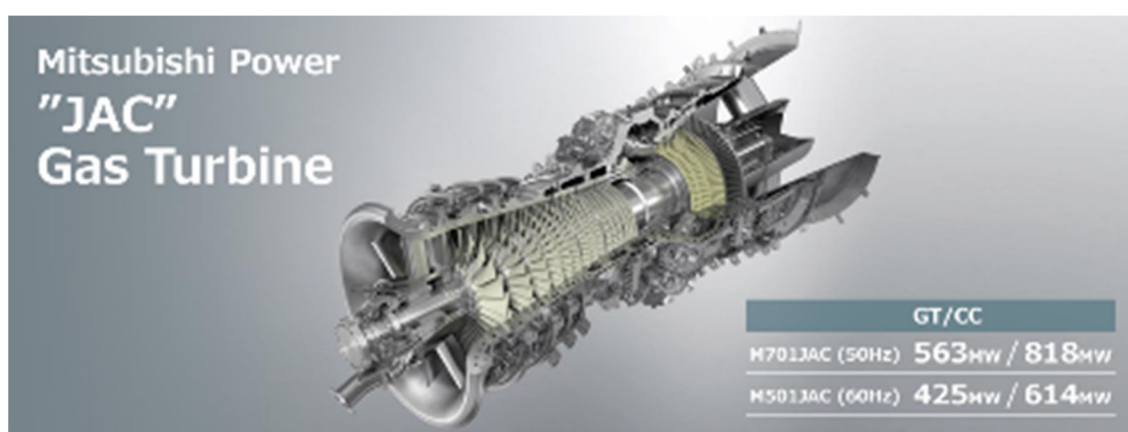
Country	Item	2020	2030	2050
Mongolia	Price of hydrogen [UScent/Nm ³]	29.5	25	-
	Steam cost [UScent/kg]	6.8	5.8	-
Japan	Price of hydrogen [UScent/Nm ³]	100	30	20
	Steam cost [UScent/kg]	23.1	6.9	4.6

Source: Prepared by the survey team based on data from Miura Industry

4) Achievements in Japan

Japanese manufacturers are actively developing technologies for hydrogen utilization in large gas turbines, small- and medium-sized gas turbines and boilers.

Large gas turbines which equip pre-mix type combustors are already capable of operating with 30% hydrogen co-firing. Combustors capable of 100% hydrogen combustion are currently in the development stage, and are expected to be commercially available in the 2030s.



Source: Mitsubishi Heavy Industries, Ltd.

Figure 5-32 Large Scale Gas Turbine with Hydrogen Co-firing Capability

As part of a NEDO project shown in the diagram below, a demonstration experiment was conducted on a cogeneration system using a 1 MW class hydrogen-fired gas turbine,, achieving the world's first supply of heat and power from a hydrogen-only combustion system.



Source: NEDO

Figure 5-33 Kobe Port Island Demonstration Plant

In a chemical plant located in Osaka Prefecture, hydrogen boilers have been implemented. By using the byproduct hydrogen generated in the caustic soda production process in the hydrogen boiler, the plant is able to decarbonize and reduce fuel costs.



Source: Miura Industry

Figure 5-34 Hydrogen Boiler Facilities implemented in Chemical Plant

5) Application to Mongolia

In Mongolia, the city of UB and areas with high renewable energy potential are far apart, and the establishment of a hydrogen supply infrastructure is a critical issue, especially when considering the introduction of large gas turbines that consume a large amount of hydrogen. It is necessary to either produce green hydrogen in the South Gobi region and supply it to UB City via a gas pipeline, or to strengthen transmission lines to transmit renewable energy to the vicinity of UB City, where hydrogen will be produced. In either case, the cost of transporting or producing hydrogen would be a burden.

Therefore, the introduction of small- and medium-sized gas turbines or boilers that can be locally produced for local consumption is considered realistic. Small- and medium-sized hydrogen gas turbines with generating capacities in the range of kW-class to small MW-class are suitable for the demands of local cities in Mongolia.

Currently, hydrogen combustion is a technology in the demonstration stage in Japan as well, and it will be operated only after the hydrogen infrastructure is in place, so the start of its application in Mongolia is set for 2036 or later.

(7) Ammonia-fuelled Technology

1) Technology Overview

This section describes Japanese technologies that use ammonia directly as fuel. Ammonia, like hydrogen, is attracting attention as an alternative fuel because it does not emit CO₂ when burned, and development of co-firing in large coal-fired power plants and dedicated gas turbines is underway.

Ammonia is generally produced by synthesizing hydrogen and nitrogen using the Haber-Bosch process, but the hydrogen used in this process is conventionally derived from fossil fuels and generates CO₂ during production. By using green hydrogen, green ammonia can be produced without CO₂ emissions during the manufacturing process.

Furthermore, ammonia can be viewed as a hydrogen carrier. The following table shows the properties of liquefied hydrogen and ammonia as hydrogen carriers. Liquefied hydrogen requires cooling to -253°C and is difficult to handle, whereas ammonia is at about -33°C, and the technology for transporting it has already been established. However, since dehydrogenation facilities (cracking facilities) and a considerable amount of energy are required to extract hydrogen from ammonia, the direct use of ammonia as a fuel would have advantage.

Table 5-15 Properties of Liquefied Hydrogen and Ammonia as Hydrogen Carriers

Carrier	Liquefied hydrogen	Ammonia
Volume (vs. atmospheric hydrogen)	Approx. 1/800	Approx. 1/1,300
Conditions to become liquid, toxicity	-253°C, normal pressure No toxicity	-33°C, normal pressure Toxicity, corrosive
Additional facilities for high purity	Not required	Necessary (during dehydrogenation)
Energy loss due to characteristic change, etc.	Current: 25-35% Future: 18%	Hydrogenation: 7-18% Dehydrogenation: 20% or less
Utilization of existing infrastructure, availability	International transportation is not possible (new construction required). Domestic delivery is possible.	Possible (chemical tankers, etc.)
Technical issues	Need to develop large marine transportation technology (large liquefiers, carriers, etc.)	Need to develop technology to expand direct use and dehydrogenation facilities

Source: Excerpts from Ministry of Economy, Trade and Industry data, prepared by the survey team

Advantages and Issues of ammonia utilization are described below.

<Advantages>

- Become a clean means of power generation and heat supply, similar to hydrogen.
- Transport and storage technologies have already been established and are in general use.
- Co-firing with coal-fired power plants is possible.
- Can be used as hydrogen by dehydrogenation.

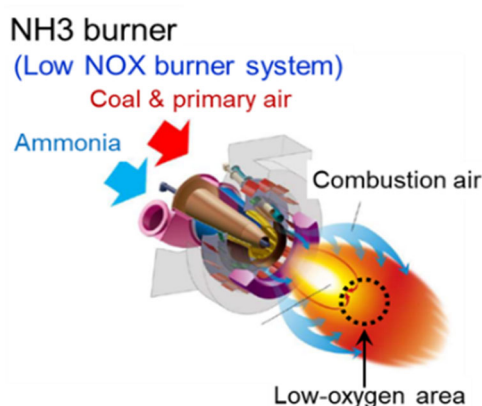
<Issues>

- The technological maturity level of direct utilization is inferior to that of hydrogen utilization.
- Toxic and must be handled with care.
- Lack of water resources for hydrogen production in the South Gobi region.

2) Mechanism

The combustion properties of ammonia are similar to those of pulverized coal, which is why its co-combustion in coal-fired power plants has been the main focus of research. Existing coal-fired power plants can be converted to ammonia co-firing. The scope of retrofitting is basically limited to the burner and fuel system, and decarbonization can be achieved at a relatively low cost compared to building a new power plant. A schematic diagram of an ammonia co-firing burner is

shown below. The ammonia co-firing burner can be used with both pulverized coal and ammonia, and by using two-stage combustion, NO_x emissions can be reduced to the same level as conventional pulverized coal power generation.



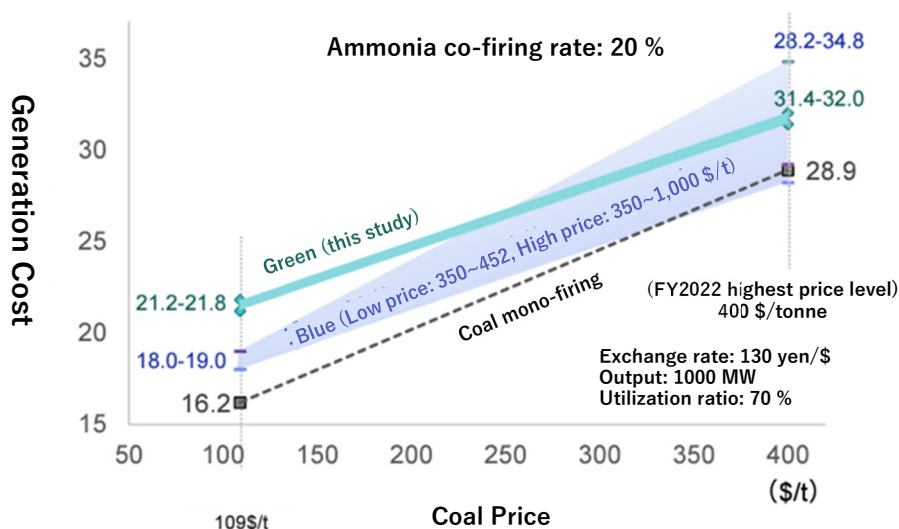
Source: IHI

Figure 5-35 Ammonia Mixed Combustion Burner Schematic

The use of ammonia in gas turbines has also been studied, but its combustion rate is slower than that of conventional gas fuels, making it difficult to stabilize combustion. NO_x generation at high-temperature spots and combustion vibration would be the challenge.

3) Cost

For reference, the following figure shows a power generation cost analysis of a 20% co-firing coal-fired power plant in Japan, based on data from the Power Generation Cost Verification Working Group of the Ministry of Economy, Trade, and Industry (METI). The cost of 20% co-firing with green ammonia is estimated to be 21.2 - 32.0 JPY/kWh (16.3 - 24.6 UScent/kWh when using the exchange rate of 130 JPY/USD in the figure). It should be noted, however, that in the case of Japan, green ammonia relies on imports, and the cost of transporting the fuel is significant.



Source: Ministry of Economy, Trade and Industry, Power Generation Cost Verification Working Group

Figure 5-36 Sensitivity Analysis of Unit Power Generation Cost at 20% Ammonia Co-firing Based on Coal Price and Ammonia Price

This section also discusses the supply cost of ammonia and liquid hydrogen, which are generally compared as hydrogen carriers. Since ammonia is produced from hydrogen, its production cost will be higher than that of hydrogen. However, ammonia can be liquefied at -33°C , making it more advantageous than liquid hydrogen in terms of transportation and storage. Liquefied hydrogen must be maintained at a cryogenic temperature of -253°C , which incurs costs for liquefaction, transportation, and storage. For longer transport distances and longer storage periods, ammonia is considered to be more economical than liquefied hydrogen in terms of overall supply chain costs. Currently, although ammonia can be transported and stored with existing infrastructure, direct utilization technology is less mature than hydrogen utilization technology, so methods to convert hydrogen to ammonia for transport and storage, and then extract and utilize hydrogen through cracking are being considered. However, the high cost of cracking may result in a less economical alternative to liquefied hydrogen supply.

4) Achievements in Japan

At JERA's Hekinan Thermal Power Plant, the world's first demonstration test of 20% ammonia co-firing in a large commercial unit was conducted and completed in June 2024. In the future, construction work will be carried out for commercial operation with 20% co-firing, with the aim of establishing ammonia conversion technology as a fuel in thermal power generation by March 2025.



Source: JERA

Figure 5-37 JERA Hekinan Thermal Power Plant

For use in gas turbines, demonstration tests are already underway. In June 2022, a case was reported where a 2,000 kW gas turbine successfully shifted from 70% ammonia co-firing to 100% mono-firing. A newly developed combustor was used, and a greenhouse gas reduction rate of over 99% was achieved.



Source: IHI

Figure 5-38 Ammonia Gas Turbine

5) Application to Mongolia

Ammonia co-firing may be applied to existing coal power plants such as TPP4. On the other hand, many of the power plants in Mongolia are Russian-made, and it is necessary to closely examine whether it is possible to modify the burners. Ammonia gas turbines are currently being tested in Japan with relatively small capacities, and it is expected that they will be introduced in the 2040s or later, when the hydrogen and ammonia infrastructure will be in place.

(8) Conversion of Existing Thermal Power Plants to Biomass Co-firing

1) Technology Overview

In Japan, many existing coal-fired power plants are operating with 3 - 5% biomass co-firing. 3 - 5% biomass co-firing can be implemented without modification of existing boilers. Therefore, if the biomass co-firing rate is around 3 - 5%, the cost increase due to biomass is small and not enough to affect the unit cost of power generation. In the case of the CFB boiler, 100% biomass-only combustion operation is possible.

<Advantages>

- Reduction of CO₂ emission is possible by partial modification of existing thermal power plant.

<Issues>

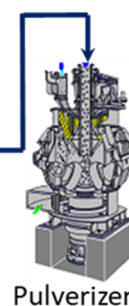
- Consideration of individual modification points is necessary for each power plant according to its co-firing ratio.
- Establishment of a continuous supply system for biomass fuel is necessary.

2) Mechanism

The following diagram shows a comparison of the calorific value of biomass. Biomass is a plant that absorbs CO₂ during the tree growth stage and can be used as a carbon-free fuel. There are various types of biomass, including wood pellets and thinned wood chips. These biomass fuels are pulverized by existing coal pulverizers or dedicated biomass pulverizers and fed to the boiler. As shown in the figure below, each type of biomass has a different calorific value.

The biomass is grinding in a pulverizer.

	Wood pellets	Chips from thinned wood
Photos		
Bulk density	0.7	0.1~0.3
Calorific value	4,500kcal/kg	2,500~3,500kcal/kg



Source: Prepared by the survey team

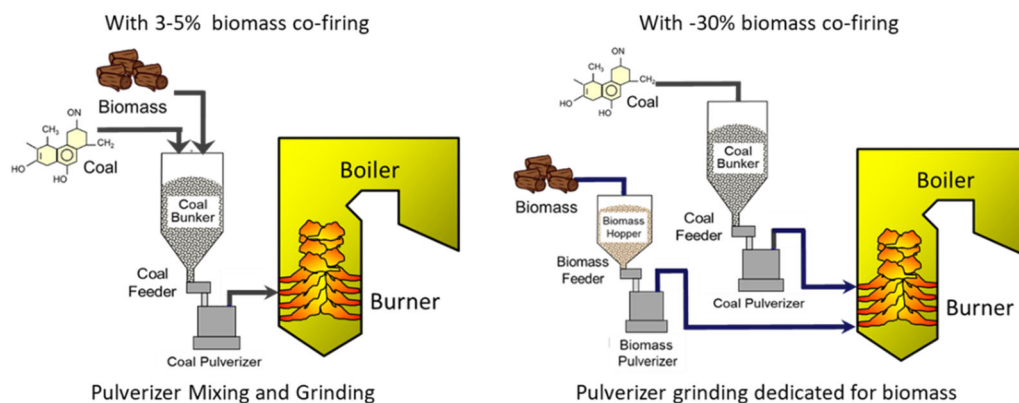
Figure 5-39 Comparison of Calorific Values of Biomass**3) Cost**

Cost depends on the class of power generation equipment, type of biomass, and co-firing ratio.

4) Achievements in Japan

The following figures show biomass co-firing rates and pulverized coal pulverizers. The left side of the figure shows a biomass co-firing system in which biomass is mixed with pulverized coal pulverizers, and the right side shows a biomass co-firing system in which a dedicated biomass pulverizer is added. As shown in the figure, if the biomass co-firing ratio is 3 - 5%, biomass co-firing operation can be performed by mixing biomass with existing pulverized coal pulverizers. If the biomass co-firing ratio is 30% or higher, a biomass-only pulverizer should be added.

In Japan, large boilers for commercial use are operated with a biomass co-firing ratio of 3 - 5% by using coal pulverizers, while small and medium-sized boilers are operated with biomass dedicated firing by using CFB boilers.



Source: Prepared by the survey team

Figure 5-40 Biomass Co-firing Rate and Coal Pulverizer**5) Application to Mongolia**

Conventional pulverized coal boilers are used in TPP4. Therefore, to introduce biomass co-firing in TPP4, it is necessary to consider whether to use a pulverized coal mixing and grinding system or to add a dedicated biomass pulverizer.

(9) New Biomass-fired Thermal Power Plant, Power Generation from waste materials, New CFB Boiler

1) Technology Overview

Many CFB boilers are in operation in Japan, Europe, and the United States. In addition to coal, biomass and waste materials such as tires are used as fuel in these CFB boilers.

<Advantages>

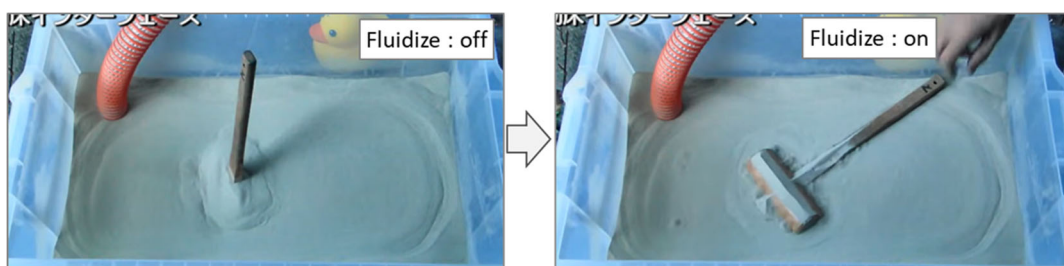
- Can burn a relatively wide variety of fuels without pulverization.
- Boiler efficiency is relatively high compared to other biomass or waste dedicated boilers.

<Issues>

- Drying process may be required for high water content fuels such as raw garbage.
- The structure is more complicated than other boilers for biomass and waste combustion.

2) Mechanism

The figure below shows the CFB experimental installation, where the CFB interface is a fluidized bed like a "sea of sand". When air is blown upward against the sand in the container, the gravity of the sand competes with the external force of the air to lift the sand, causing the sand to lift and the whole area to move like a uniform fluid.



Source: Intellectual Property Diagram

Figure 5-41 CFB Experimental Facility

3) Cost

17-40UScent/kWh - Depends on the class of power generation facility and the type of biomass.

4) Achievements in Japan

Several manufacturers in Japan have installed a number of power generation facilities that burn various fuels in CFB boilers as shown in the figure below, most of which have a steam flow rate of 200t/h and generator output of 50 - 60 MW.



Source: Sumitomo Heavy Industries website

Figure 5-42 Sumitomo Heavy Industries' CFB Boilers and Various Fuels

5) Application to Mongolia

Power generation facilities using CFB boilers are medium-sized and can burn a variety of biomass and waste materials. Therefore, it is one of the most suitable facilities for the future of Mongolia, which aims to reduce CO₂ emissions.

(10) Power Generation from Waste (garbage-derived biogas)

1) Technology Overview

In Japan, biogas power generation is mainly used in the agricultural sector. Biogas power generation is a carbon-neutral form of power generation that can reduce "carbon dioxide" emissions. In addition to power generation, biogas power generation also produces two by-products. Waste heat generated during the biogas production process. In addition, digestate containing nitrogen, phosphate, and potassium is obtained.

<Advantages>

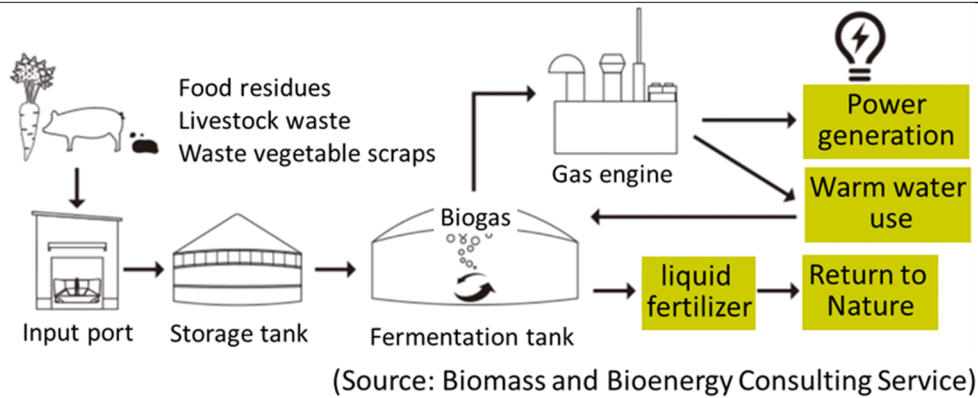
- Waste materials such as garbage to be disposed of can be utilized to reduce CO₂ emissions
- By-products from the biogas refining process can be utilized.

<Issues>

- Need to establish a continuous supply system of garbage and other materials to be used as fuel
- Odor may be generated in the fermentation process.

2) Mechanism

The following figure shows a garbage-derived biogas power generation system. Biogas power generation uses combustible gas derived from biomass as fuel. The combustible gas is generated by fermentation of livestock manure, food waste, wood waste, etc.



Source: Biomass, Bioenergy Consulting Services

Figure 5-43 Garbage-derived Biogas Power Generation Facility

3) Cost

35UScent/kWh- (for 2MW class system)

4) Achievements in Japan

The average size of biogas power generation facilities in Japan is about 400 kW, and most of them are less than 2,000 kW. In addition, the cost of power generation equipment increases to add load regulation and outage countermeasure functions.

5) Application to Mongolia

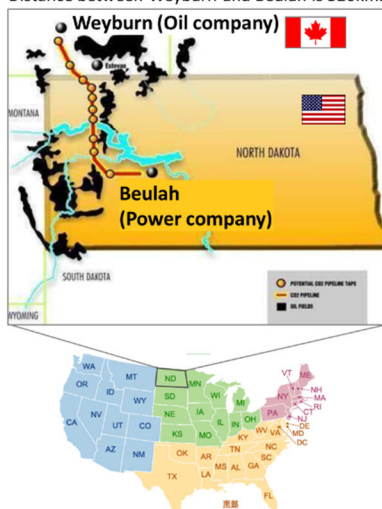
The availability of livestock manure, food waste, and wood waste is an important condition for introducing biogas power generation in Mongolia.

(11) CC(U)S/EOR Addition to Existing Thermal Power Plant

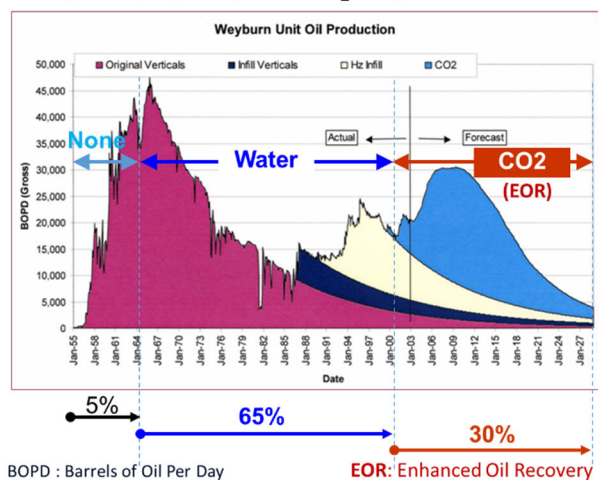
1) Technology Overview

EOR using CO₂ recovered from power plants is shown in the figure below; CCS and EOR technologies are well established and operated mainly in Europe and the United States, respectively. As a typical example, CO₂ recovered from the Beulah power plant in the U.S. is transported by pipeline to the Weyburn oil field in Canada and used as EOR/EGR in oil and gas fields.

Distance between Weyburn and Beulah is 320km.



[Example] Weyburn CO₂ Project-Forecast



Source: Weyburn-Midale Carbon Dioxide Project

Figure 5-44 EOR Using CO₂ Recovered from Power Plants

<Advantages>

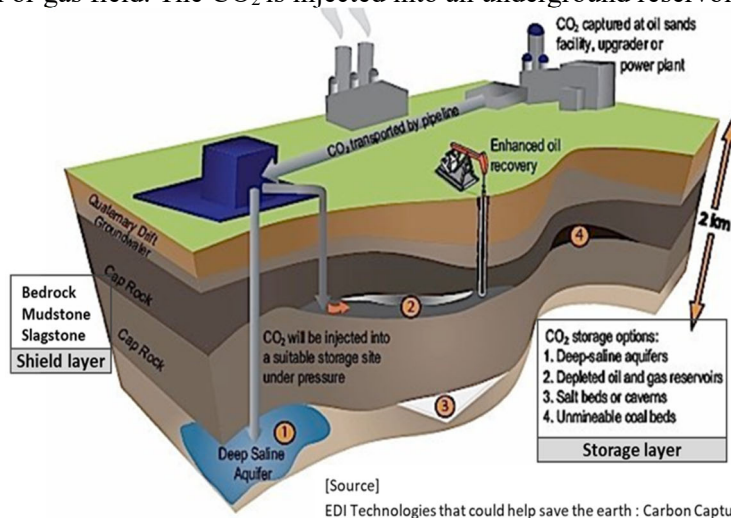
- Continuous use of existing coal-fired power plants is possible.

<Issues>

- A site for CO₂ recovery equipment needs to be located near the power plant.
- Power and heat are required to operate the CO₂ recovery system, which reduces the power output of the power plant.
- Need a suitable site for CO₂ storage/EOR and CO₂ transportation to the site.

2) Mechanism

The following figure shows the mechanism of EOR using CO₂ recovered from power plants. As shown in the figure, CO₂ recovered from a thermal power plant is transported through a pipeline to an oil or gas field. The CO₂ is injected into an underground reservoir and stored underground.



Source: EDI Technology that could help save the earth: Carbon Capture and Storage

Figure 5-45 Mechanism of EOR Using CO₂ Captured from Power Plants

3) Cost (cost of electricity generation with CCS)

21UScent/kWh (Coal-fired power plant in Japan)

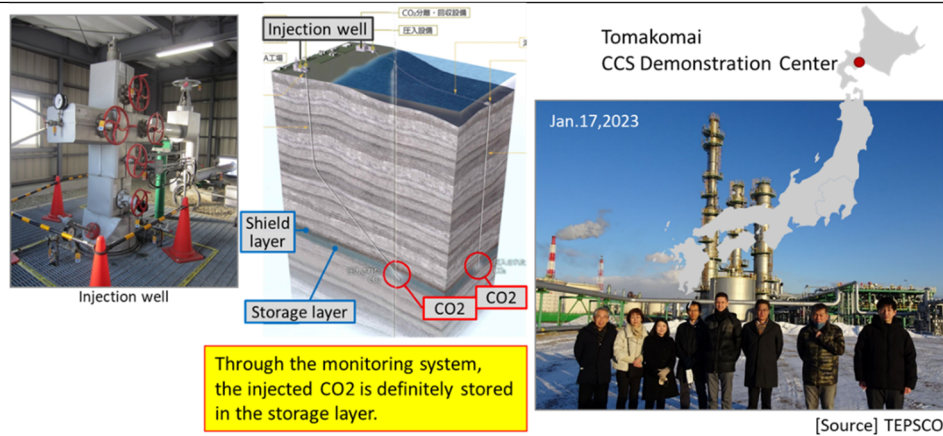
10UScent/kWh (Coal-fired power plant in Indonesia)

7.7UScent/kWh (gas-fired power plant in Azerbaijan)

The above power generation costs include the costs required for CO₂ capture, transport, and storage, and the differences in costs in each country are mainly due to differences in the cost of transporting CO₂ to the storage sites.

4) Achievements in Japan

In Japan, the Tomakomai CCS demonstration center (see figure below) achieved 300,000 tons of CO₂ storage in November 2019.



Source: Prepared by the survey team.

Figure 5-46 Tomakomai CCS Demonstration Center

5) Application to Mongolia

If EOR/EGR with CCS is to be implemented in Mongolia, it is necessary to study the storage potential of CCS, as well as the distance from the power plant to the EOR/EGR and its economic feasibility.

(12) IGCC⁴⁴ (IGFC)⁴⁵ + CC(U)S

1) Technical Overview

IGCC is highly efficient and environmentally friendly coal-fired power plant. Its efficiency is about 20% higher than that of conventional coal-fired power plants, which means that CO₂ emissions can be reduced and SO_x, NO_x, and soot emissions are low. However, since CO₂ emissions cannot be eliminated by applying IGCC, the introduction of CCS is necessary to achieve zero emissions.

<Advantages>

- Highly efficient use of coal and reduction of CO₂ emissions
- Coal ash is discharged as glassy slag, which can be used as roadbed material etc.

<Issues>

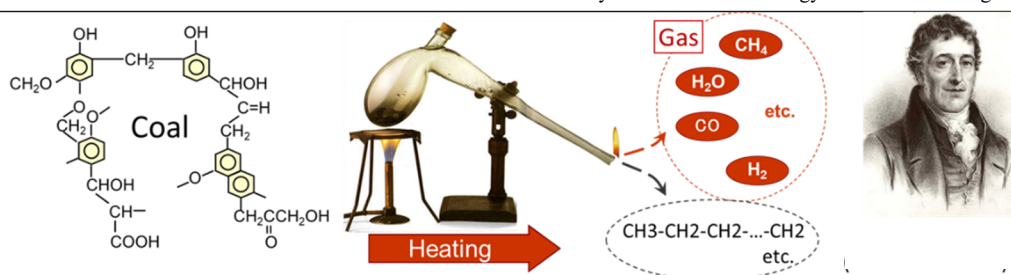
- Installation of CC(U)S is necessary to realize energy transition.
- IGCCs currently in operation in Japan have large power output and are not suitable for the current Mongolian power system.

2) Mechanism

The following figure shows the first indirect heating gasification system devised. The first gasification system was invented by William Murdoch (1754-1839) and involved indirect heating (dry distillation furnace)/coal pyrolysis/gasification of volatile matter.

⁴⁴ IGCC: Integrated Coal Gasification Combined Cycle

⁴⁵ IGFC: Integrated Coal Gasification Fuel Cell Combined Cycle



Source: Prepared by the survey team

Figure 5-47 The First Indirect Heating Gasification System Invented

3) Cost

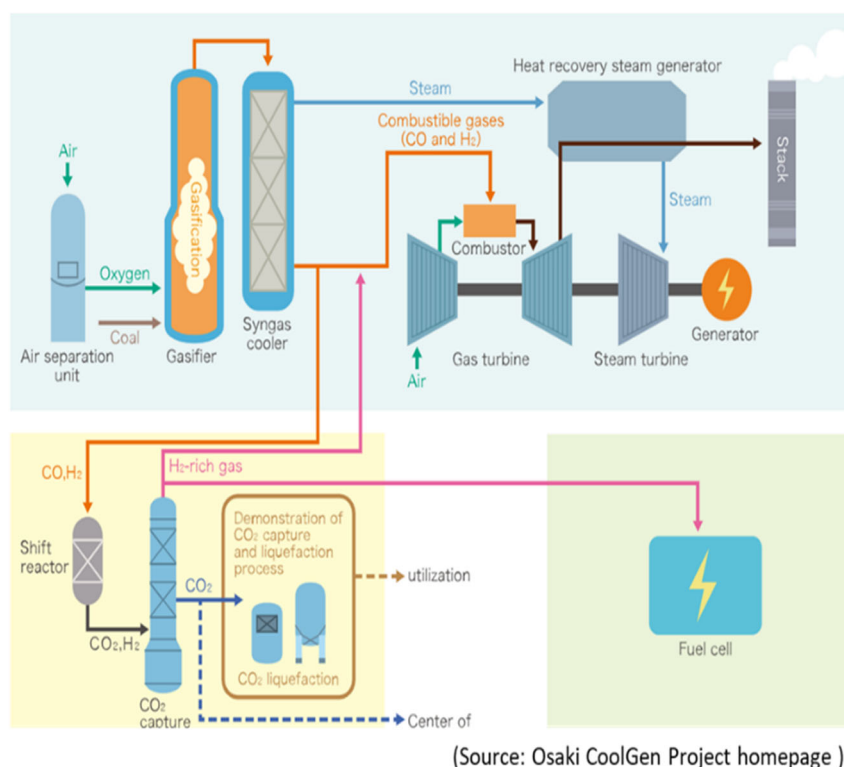
About 1.2 - 1.3 times that of conventional coal-fired power (depending on system size).

In addition, a CO₂ recovery system needs to be added to perform CCS, which is estimated to cost 1.4 times more than a power generation system, and 2.4 times more if the power generation system is included. In addition, CO₂ transport lines and drilling costs are required to store CO₂ in the reservoir.

4) Achievements in Japan

In Japan, an air-blown IGCC commercial unit (500 MW) started operation in 2023. In addition, an oxygen blown IGCC demonstration unit (166 MW) is under demonstration testing at Osaki Cool Gen as of 2024.

The following figure shows the configuration of the oxygen-blown IGCC demonstrator.



Source: Osaki CoolGen website

Figure 5-48 Oxygen-blown IGCC System Configuration Diagram

5) Application to Mongolia

The size of IGCC commercial units in Japan is in the 500 MW class, which is not applicable to the

current scale of the Mongolian power system. In addition, the Japanese manufacturer of IGCC has no current plans to deploy IGCC overseas, making its application to Mongolia difficult.

(13) CBM⁴⁶ Fuelled GTCC+CCS

1) Technology Overview

Large-scale demonstration efforts for CBM have begun in Australia and are steadily producing results. Projects related to CBM have also been announced in the United States, Canada, the United Kingdom, and other countries around the world.

<Advantages>

- Expected to be utilized as a domestically produced gas without relying on foreign countries.
- CBM production can be increased by injecting CO₂ generated in the coal seam from which the CBM is extracted.

<Issues>

- Continuous supply of CBM needs to be investigated.
- Installation of CC(U)S is necessary to realize energy transition.

2) Mechanism

Within a coal seam, there is a gas produced during coal formation, known as coalbed methane (CBM). CBM consists primarily of methane gas, the same gas as natural gas. Development of CBM is done in boreholes (hundreds to thousands of meters depth) from the surface, as shown in the figure at right, and depending on conditions, one several thousand cubic meters of CBM can be recovered per day from a borehole well. It can also be used as a feedstock for next-generation energy sources such as hydrogen and DME (dimethyl ether). In addition, the production of CBM (CO₂-ECBM) can be increased by separating and recovering the carbon dioxide produced during combustion and injecting it into the coal bed to fix it.

3) Cost.

Around 10UScent /kWh.

(CBM prices are almost at the same level as LNG prices. CBM is usually co-fired with natural gas in GTCC, so the unit cost of power generation is assumed to be similar to that of LNG.)



(Source: Montana Bureau of Mines and Geology Information Pamphlet 6 2012)

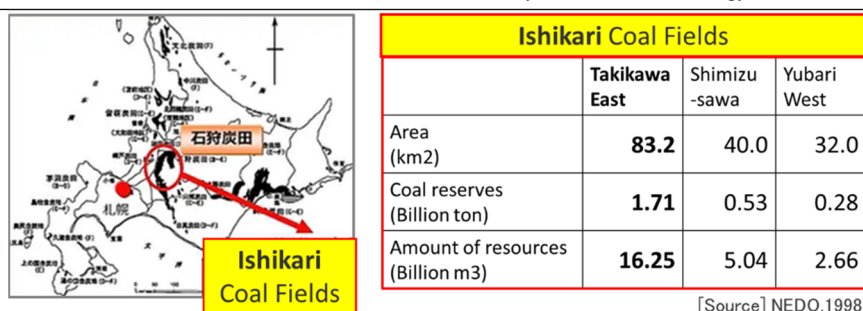
Source: Montana Bureau of Mines and Geology

Figure 5-49 CBM Extraction Method

4) Achievements in Japan

The following figure shows the status of CBM development in Ishikari and its potential.

⁴⁶ CBM: Coal Bed Methane



Source: NEDO 1998

Figure 5-50 CBM Development Status and Potential in Ishikari

5) Application to Mongolia

The following figure shows a map of CBM development in Mongolia, where coal fields suitable for CBM are discussed. The plan is also to be determined based on further hearings and field surveys.



Source: JOGMEC 2018

Figure 5-51 CBM Development Map in Mongolia

(14) Small (micro) nuclear power

1) Technology Overview

Small Modular Reactors (SMRs) are nuclear fission reactors that are smaller than conventional nuclear reactors. While conventional nuclear power plants have a capacity of about 1 GW each, SMR has a capacity of less than 300 MW. In addition, Micro Modular Reactors (MMRs), which were originally defined as reactors with a capacity of 1 MW or less, have expanded in scope over the years to include modules with a capacity of 15 MW or less by the IAEA definition, but current commercial MMR has a capacity of 20 MW or less as of 2024.

The term SMR refers only to size, capacity, and modular structure, and does not specify differences in reactor type or process; a variety of SMR structures have been proposed, including scaled-down versions of existing 1 GW-class reactors, molten salt reactors, gas-cooled reactors, thermal and neutron reactors, fast neutron reactors and so on. Demonstration tests and R&D for these technologies are underway worldwide as of 2024.

The difference between SMRs and MMRs lies not only in their size but also in the internal structure of the reactors. Essentially, SMRs are downsized versions of conventional 1GW-class BWRs, designed to operate without external power sources by utilizing thermal circulation. MMRs often feature a design in which uranium is arranged in particle form and the reactor core is filled with solid materials, avoiding the use of fluids. In other words, while traditional nuclear reactors and SMRs typically have fluid-filled cores, MMRs are characterized by having a solid-state core. However, this distinction reflects the current understanding, and it is possible that SMRs may also adopt solid-state core in the future.

The intended use of MMRs differs from conventional nuclear power plants, focusing instead on applications such as nuclear power stations mounted on ships (British-made), propulsion sources for icebreakers, power generation on reef islands, and electricity supply in remote depopulated areas. The joint venture between Hitachi, Ltd. and GE is currently constructing four 300MW SMRs in Canada. Mitsubishi Heavy Industries is developing a mobile MMR that can be transported by road and conducting demonstration tests. IHI had contracted six 80MW SMRs in the United States as backup power sources for VRE, but the plan has been suspended due to inflation in the U.S. since 2023.

The High Temperature Engineering Test Reactor (HTTR) uses ceramic materials, primarily graphite, in its core to extract heat generated by uranium fission. While conventional nuclear reactors that use metal cladding, the HTTR employs helium gas as a coolant. Typical reactors can only reach temperatures of around 300°C, resulting in a power generation efficiency of about 30%, the HTTR can extract heat at approximately 1000°C (currently around 900°C) thanks to the use of heat-resistant ceramic materials. By utilizing a gas turbine generator, thermal efficiency can exceed 50%. Furthermore, the heat from the HTTR can be used not only for power generation but also for heating and chemical industry applications.

The ceramic coating used for the fuel of the HTTR is highly heat resistant and will not break even at 1600°C. Even in the event of an accident such as a pipe breakage and a loss of helium gas as coolant, the heat generated in the reactor core will be cleared from the reactor vessel surface, eliminating the risk of fuel breakage. The advantages of the HTTR include high heat utilization efficiency due to the use of high-temperature heat, enhanced safety, and simplified facilities for dealing with abnormal situations. From a comprehensive perspective that includes economic efficiency, the HTTR is an outstanding nuclear reactor.

The HTTR (maximum thermal output: 30 MW) at the Oarai Nuclear Engineering Institute of the Japan Atomic Energy Agency (JAEA) will start operation on March 1, 2024, and the performance of reactor operation is being tested. MHI has announced that it will contribute to the decarbonization of industry by developing an HTTR plant that can produce large amounts of hydrogen in a stable manner. As of 2024, the 30 MW HTTR developed by MHI is estimated to cost 4 billion JPY per unit (estimated), but HTTRs are also being developed in the United States, the United Kingdom, and France.

2) Notes for Technology Installation

Regarding SMR, notes are as follows;

- It is maintenance-free, with minimal staffing, capable of operating for 20 to 25 years without human intervention.
- By combining SMRs with cogeneration generation systems, the generated heat can be used not only for power generation but also for district heating, seawater desalination, and hydrogen production.
- Many SMR designs incorporate safety and environmental considerations, such as fast reactors and thorium fuel reactors, which help reduce the amount of nuclear waste.
- Since SMRs are manufactured in a factory and transported to the installation site, the number of workdays required at the construction site can be significantly reduced.
- Based on lessons learned from past nuclear accidents, SMRs are evaluated as having high safety and a low risk of radioactive materials dispersion.
- With a single fuel supply, SMRs can operate for 20 to 25 years without the need for fuel replacement, contributing to reduced construction costs and shorter construction periods.
- SMRs are designed to be load-following, which differs from the traditional concept of nuclear power plants being used solely as baseload power sources.
- Due to their small installation footprint and shortened construction period, SMRs are well-suited for use in remote or sparsely populated areas.
- Long fuel cycle and standardization of modules help reduce the risk of radioactive

material dispersion.

- Widespread adoption requires proper management of radioactive waste.
- Although standardized modular design reduces the cost of SMR construction, the cost of power generation of SMR may be equal to or higher than that of conventional 1GW-class reactors.

Regarding HTTR, notes are as follows.

- High resistance to core meltdown: Its heat generation per unit volume is only a fraction, several tens of times smaller, than that of light water reactors, and its large fuel surface area facilitates efficient heat removal, making cooling easier.
- High resistance to runaway: Graphite increases its ability to absorb neutrons as its temperature rises. Therefore, even in the event of an accident in which the control rods do not operate, graphite absorbs neutrons and suppresses fission.
- Non-explosive of the HTTR plants: As water is not required for cooling, hydrogen and steam explosions will not occur unless water is introduced.
- No corrosiveness: Since helium is not corrosive, there is no need to use corrosion-resistant materials for heat exchangers and reactor vessels. Proven heat-resistant materials can be used, eliminating the need for new material development.
- Easy maintenance: Unlike lead and molten salt, helium is transparent, making it easy to see inside the reactor and respond to problems without heating to maintain cooling.
- Low radiolysis effects: The amount of fission per unit volume is several tens of times lower than that of light water reactor, and fewer neutrons are emitted, so the neutron shielding of the reactor body and building is simpler than that of light water reactor. Therefore, construction and decommissioning costs can be lower.
- Less waste nuclear fuels: Since the core is less likely to melt down, nuclear fuel with higher plutonium content (about 20%) can be used, which, combined with high thermal efficiency, reduces the amount of waste nuclear fuel to one fifth comparing to the amount of generated electric power. Storage and management costs of waste nuclear fuel can also be reduced.
- High construction cost of HTTR: When HTTR is used as a small modular reactor (SMR), the construction cost per capacity is higher than that of a 1GW class reactor.

3) Cost of SMR and HTTR

The most of the SMR cost is shared at the time of module manufacturing. For example, MHI (Mitsubishi Heavy Industry) estimates the cost of 300 MW SMR is about 80 billion JPY (500 million USD). Although the construction cost of a single SMR is less than that of a conventional 1GW-class nuclear power plant, meeting energy demand would require multiple SMRs, potentially resulting in higher overall construction costs. As a result, SMRs are unlikely to benefit from economies of scale when compared to a 1GW-class nuclear power plant, and economies of scale could be lost when SMRs are compared to large-scale reactors.

Although the cost of a 300 MW SMR is estimated to be between 6 to 8 US cents per kWh, even a 100 MW SMR is projected to cost around 7 to 9 US cents per kWh. Considering that the cost of existing nuclear power plants in the United States is approximately 6 US cents per kWh (based on the leveled cost of electricity), and in Japan it is about 12 US cents per kWh, SMRs may be more advantageous than conventional 1 GW-class large nuclear power plants when maintenance costs are also taken into account.

By the economic evaluation of a Power-Generation-Dedicated HTTR plant, the power generation cost is estimated that it is about 8 JPY per kWh. This is 4 JPY per kWh lower than the cost of Japan's current light water reactors, indicating that HTTR is a more economical reactor in the Japanese context. However, since the electricity generation cost of 1 GW-class nuclear power plants worldwide ranges from 5 to 7 US cents per kWh, HTTR may be considered relatively

expensive in comparison.⁴⁷

4) Current Activities in Japan

As of 2025, SMRs and HTTRs are still in the demonstration phase in Japan whereas they have entered the commercial phase in China. In Japan, companies such as MHI (Mitsubishi Heavy Industries) and Hitachi, Ltd. are developing SMRs and MMRs. The table below shows the current trends of companies involved in the development of SMRs and MMRs.

Table 5-16 SMR and MMR Development Companies (as of 2022)

Company	Current Development Status
Japanese companies MMR (15 MW or less)	MHI, Toshiba Corporation, Hitachi, Ltd., and others are developing and will commercialize by 2035. Capacity of 1 MW to supply heat at 850 degrees Celsius, estimated at 300 million JPY per unit. They will be installed underground to generate electricity, supply heat, and be used in commercial ships and navy ships.
Japanese companies SMR (16-300MW)	SMRs are developed by Toshiba, Hitachi, Ltd. and Mitsubishi Heavy Industries, the capacity is 300MW, 80 billion JPY per unit. Hitachi, Ltd. has an export contract for 4 units to Canada and plans to start operation in 2028. There have been many inquiries from U.S. companies.
SMRs by NuScale Power Corporation in the U.S.A	NuScale Power Corporation has a project for 6 SMR units with a total capacity of 720 MW at 3 billion USD (450 billion JPY). 100 USD/MWh (10 US cents per kWh) is the LCOE of 120MW-SMR. However, the project was cancelled due to soaring equipment costs in 2025.
HTTR by MHI (Mitsubishi Heavy Industry) in Japan.	It is developed by MHI, but it is also developed in the U.S., U.K., and France; 30MW, 4 billion JPY per unit; installed underground to supply heat with 1,000°C for use in power generation, heat supply, ships, and military facilities; the LCOE is less than 5 JPY per kWh (5 US cents per kWh)
Fast Reactors by TerraPower, LLC. in the U.S.A	Terra Power, LLC. is developing a demonstration fast reactor with a power output of 345 MW under the supporting program of the U.S. Department of Energy. It aims to start commercial operation in 2030.
Nuclear power plant on ship by Core Power, Ltd.	More than a dozen Japanese companies, including Onomichi Dockyard Co., Ltd, and Imabari Shipbuilding Co., Ltd., have invested about USD 80 million (about 10 billion JPY) to Core Power, Ltd, a British company involving the development of a floating nuclear power plant on ships.
High-efficiency boilers in Japan	Clean Planet Inc. announced the development progress of high efficiency boiler in 2023. It is 4 billion JPY for 30MW, 40 billion JPY for 300MW, mass production system to be established after 2030, this is used for power generation, industrial heat supply, and hydrogen production. It will be commercialized around 2035, and the LCOE is less than 5 JPY per kWh (5 US cent /kWh).
SMRs in China	The world's first commercial SMR will be China's Linglong One (125 MW), which has been announced to go on sale by the end of 2026. While its economic viability has yet to be verified, it could potentially be the first commercial product of its kind globally.

Source: Compiled by the survey team from various sources.

5) Application to Mongolia

Mongolia's nuclear power action plan established in 2009 consists of the following stages:

The first stage is from 2009 to 2012, the target is to focus on the establishment of NEA,

⁴⁷ Japan Atomic Energy Agency's High Temperature Gas-cooled Reactor Research and Development Center website as of March 2024.

development of legal frameworks, and human resource training.

The second Stage is from 2012 to 2017, the target is to focus on feasibility studies (F/S), construction of research reactors, and establishment of research centres.

The third stage is from 2017 to 2021, the target to focus on the construction of nuclear power plant.

However, as of 2025, the country is still in the process of implementing Stage 1. This delay is partly due to the nuclear accident in Japan in 2011, which raised public awareness regarding a risk associated with a nuclear power and issues of waste disposal, which led to a nationwide debate on the issue. During this period, France and Russia were in discussions with Mongolia about nuclear power projects, but no significant progress has been made.

As Mongolia's uranium industry begins to emerge, uranium mining and production are expected to become a future pillar of the country's resource-based economy, alongside coal and other minerals. To utilize this uranium as a domestic energy source, the introduction of nuclear power can be considered because nuclear power could serve as a new form of domestic energy that complements electricity generated from coal.

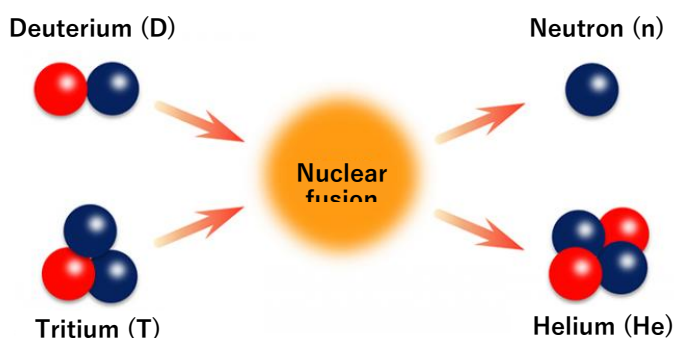
Since nuclear power requires advanced technology and a high level of safety, it is essential to share Japan's experience and knowledge regarding technology introduction, operational practices, and methods for gaining public understanding from local residents help Mongolia build a national consensus on the introduction of nuclear power.

(15) Nuclear Fusion

1) Outline of Nuclear Fusion Technology

Nuclear fusion is a reaction in which the nuclei of light elements such as hydrogen fuse together to form heavier nuclei such as helium. In the D-T fusion reaction, the nuclei of deuterium (D) and tritium (T) fuse to produce helium and a neutron.

When nuclear fusion occurs, hydrogen is heated to several thousand degrees, creating a plasma state in which the protons and electrons of hydrogen nuclei move freely. By controlling this high-temperature plasma, atomic nuclei can collide, releasing a large amount of energy that can be used for power generation and other applications.



Source: Website from International Fusion Energy Research Center, National Institutes for Quantum Science and Technology

Figure 5-52 Principle of Deuterium and Tritium Fusion

Although nuclear fusion reactors have been researched for a long time, as of 2025, the reactors remain at the stage of basic research. While some experts foresee practical implementation by 2040, the likelihood of this becoming a reality at present cannot be considered high.

2) Status of Research and Development of Nuclear Fusion

a) International Thermonuclear Experimental Reactor

ITER (International Thermonuclear Experimental Reactor) is an international project to realize an experimental nuclear fusion reactor. ITER is expected to have an estimated capacity of 500 MW, with an anticipated thermal output of 17 MWh. The current development cost is approximately 2 trillion JPY (USD 20 billion) and ITER development will continue until 2050. However, the development of ITER has been significantly delayed. One of the main reasons is that its components are being provided by participating countries, which has led to delays in delivery and issues with the quality of the supplied parts.

ITER is a tokamak-type fusion reactor and has long been anticipated as a promising fusion device. At the core of the system, a donut-shaped plasma heated to 100 million degrees Celsius is generated, where fusion reactions between deuterium and tritium in a plasma state occur. The ITER reactor contains superconducting coils, and when electric current is applied, the atoms inside become plasma. The structure is enormous, with a ring height of approximately 7 meters and an outer diameter of the donut-shaped chamber reaching 16 meters. Beneath the fusion reactor, there is a device designed to absorb the intense heat flow from the plasma.

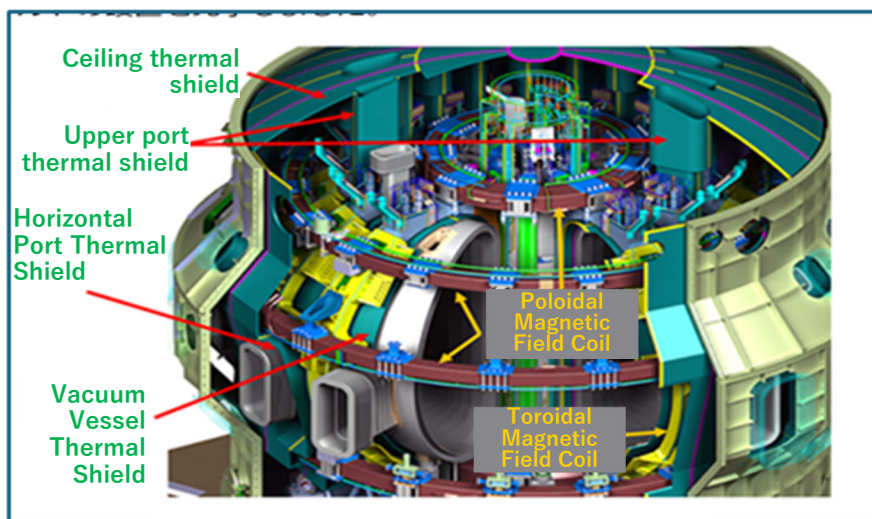
The tokamak-type fusion reactor generates nuclear fusion by injecting deuterium and tritium into a chamber heated to 100-million-degree Celsius. However, since radioactive materials are produced, containment systems are required, making the equipment large and complex. Recently, advances in laser technology have enabled temperatures as high as 1 billion degrees, drawing attention to fusion reactors that do not use deuterium or tritium and therefore do not produce radioactive materials.

b) Japanese Fusion Reactor

Japan's fusion reactor is overseen by National Institutes for Quantum Science and Technology (QST), and the facility is in Naka City, Ibaraki Prefecture. It is considered one of the largest fusion experimental devices in the world. This fusion reactor, known as "JT-60SA", aims to develop advanced technologies for tokamak type fusion reactors. According to QST, the reactor began operation in May 2023, successfully generated a plasma state and full-scale operation is scheduled for 2025.

To initiate nuclear fusion reactions, the plasma must be heated to over 100 million degrees Celsius, and atomic nuclei must collide at a speed of 1,000 kilometers per second. As of May 2023, the temperature that can be achieved is around 10 million degrees Celsius. QST aims to improve the equipment over the next five years to maintain plasma at 100 million degrees Celsius for 100 seconds.

In order to extract energy from continuous nuclear fusion reactions, it is necessary to maintain plasma at temperatures above 100 million degrees Celsius for extended periods. This requires the development of materials that can withstand such extreme conditions. As a result, fusion development faces many challenges, and the target timeline for realization has been repeatedly postponed. However, in recent years, large-scale investments have been made in venture companies in the EU, Japan, and the U.S., accelerating the development of fusion technology. In China, a national research institute has announced that it has succeeded in an experiment in which it was confined plasma for 400 seconds. In Japan, a private company is developing a fusion reactor that uses hydrogen and boron instead of deuterium and tritium and does not emit radioactivity.



Source: HP of Japan Quantum Science and Technology Agency

Figure 5-53 Structure of JT-60SA

c) Nuclear Fusion Development in the U.S.A

Currently, private companies are actively engaged in nuclear fusion development in the United States. Notably, it is not major corporations but startups that are leading the way, working on a variety of fusion technologies. There are about 50 major fusion start-up companies in the world, and the Fusion Industry Association of the United States estimates that the cumulative investment of the 50 companies invested by July 2023 will amount to USD 6.2 billion. Regarding the practicality of nuclear fusion, the association conducted a survey on the expected timeline for commercialization, and out of 40 companies that responded, 26 companies answered, “by 2035.” However, fusion development has faced repeated delays in the past, and whether the enthusiasm of developers will lead to actual realization remains uncertain.

3) Cost of nuclear fusion

According to a report by Nuclear Fusion Council, Atomic energy Commission, Cabinet Office of Japan, the estimated construction cost for a fusion power plant with the same output capacity as a current nuclear power plant (1,100 MW) is approximately 500 billion JPY. As a trial calculation, for a 300 MW fusion power plant, the cost would be about one-third of that: 150 billion JPY for the fusion reactor and 10 billion JPY for the power generator, with a total of around 160 billion JPY. In terms of electricity generation cost, both the 1,100 MW and 300 MW fusion plants are estimated to produce electricity at a cost of 7 to 8 US cents per kWh, which is comparable to the cost of electricity generated by currently known Small Modular Reactors (SMRs). It is therefore projected that future fusion reactors will require investment amounts similar to those of 1 GW-class nuclear power plants and will achieve comparable electricity generation costs.

4) Achievements of Nuclear Fusion in Japan

Currently, the general prediction for the commercialization of fusion power generation technology is expected to be in the 2040's or later. The commercialization of fusion power still faces many technical challenges, such as controlling high-temperature, high-density plasma and securing a supply of tritium., and to solve these issues, research and development is being conducted in the following three phases to achieve the respective goals.

- Phase I: Establishment of scientific feasibility (current phase)

During plasma generation, achieving the critical plasma condition, in which the energy released from actual fusion reactions becomes significant.

➤ Phase 2: Establishment of scientific and technical feasibility

Achieving the self-ignition condition, in which fusion plasma can be sustained by fusion energy even without heating; advancing reactor engineering technologies through the construction of experimental fusion reactors; developing materials capable of withstanding fusion neutrons, which are the energy source; and establishing technologies to extract heat from fusion energy.

➤ Phase 3: Establishment of technical demonstration and economic feasibility

Amid efforts to construct prototype fusion reactors and begin actual power generation, with the aim of addressing key challenges to improve economic viability, Japan convened the “7th Expert Meeting on Strengthening Innovation Policy: Fusion Strategy” in 2024. This meeting marked the beginning of discussions toward revising the “Fusion Energy Innovation Strategy.” As part of its future direction, Japan intends to steadily advance fusion research and development by leveraging private-sector creativity and expertise, while also promoting international collaboration through initiatives such as the ITER project, with a target timeline extending to 2030.

5) Application to Mongolia

As described above, currently, startup companies in the United States are fiercely competing in the development of fusion reactors. Meanwhile, China is also actively pursuing fusion technology, with more than ten state-owned facilities working on reactor development. Globally, the race to develop fusion reactors is intensifying.

However, according to most third-party forecasts, a fusion reactor that meets both safety and cost-effectiveness standards is unlikely to emerge before the 2040's. If fusion reactors become a reality, some believe they could solve major global issues such as the global warming and the depletion of energy resources.

On the other hand, for example, the fuel used in tokamak-type fusion reactors is deuterium and tritium, while laser-type fusion uses hydrogen and iodine. Although these substances are typically found in seawater or near marine environments, it is considered unlikely that they can be produced in Mongolia. Therefore, the feasibility of fusion power generation is highly dependent on technological developments, such as the emergence of methods using alternative substances for fuels. At present, the outlook for power generation through nuclear fusion remains uncertain.

Fusion reactors, which do not emit radiation, are regarded as the successor to conventional nuclear power generation and are expected to provide a permanently sustainable energy source. For Mongolia, fusion energy should be positioned as part of a "Post-2050 Energy Strategy" or as the utilization of "ultimate clean energy." It is important that Mongolia actively gathers information from the European Union, China, Japan, the United States, and other relevant countries. Such efforts will enable Mongolia to understand global trends in energy transformation and will serve as a valuable foundation for formulating national energy strategies over the next five to ten years.

5.2.3 Consideration of the Feasibility of Introduction toward the Year 2050

(1) Level of Introduction of Each Technology/Measure toward 2050

The following table summarizes the level of implementation and evaluation items for each of the selected technologies and measures for the period 2025-2030 (short-term), 2031-2035 (medium-term), and 2036 and beyond (long-term). The darker the green color in the table, the higher the level of introduction, which is defined as follows.

Table 5-17 Definition of implementation levels

Color in the table	Definition
White	Difficult to develop
Light green	Initial implementation begins, including pilots.
Green	Full-scale introduction is underway.
Dark green	The technology becomes more widely used and mature.

Source: Prepared by the survey team

Table 5-18 Level of adoption and evaluation items for each technology/measure

Measure		Start of application in Mongolia				Evaluation items					
		2025-2030	2031-2035	2036-2040	CN (2050)	Technical maturity	CO ₂ reduction effect	Power generation unit cost	Power system stability and Inertia	Technical applicability to Mongolia	Potential (including fuel supply)
		After 5 years (short term)	After 10 years (medium term)	After 15 years (Long-term A)	After 25 years (Long-term B)						
1	Perovskite photovoltaic power generation					B	A	B	C	B	A
						Practical application will be promoted in Japan in the future. At present, durability is an issue.	Highly effective in reducing CO ₂ emissions. Depends on the scale and amount of electricity generated.	Target cost in 2030 is expected to be around 9 UScent/kWh.	No inertia on its own.	The possibility of application will increase in areas with site constraints, such as urban areas. Durability and weather resistance must be confirmed.	Expected to be used in urban areas as building wall material, etc.
2	Storage battery (BESS) to suppress frequency fluctuations caused by VRE					A	B	B	B	A	A
						In Japan, the introduction of this system is already in full swing.	The introduction of storage batteries as a means of introducing renewable energy.	The storage batteries are an additional cost to the normal renewable energy.	The storage batteries themselves can be used to adjust the active power.	This technology is planned to be applied to the grid code.	Necessary to expand the introduction of renewable energy. Also has great potential.
3	Interconnected mini-Grid (MW Class VRE + BESS with grid connection)					B	B	B	B	B	A
						Technically feasible, but generally more expensive.	Effect in introducing renewable energy, but the scale is not large.	Considerably higher, but should be considered in comparison with alternative methods.	Partial connection to the grid is desirable.	Operation control is difficult in rural areas.	In areas where diesel power generation is currently used, it can be considered as an alternative power source.
4	Pumped storage hydropower generation					A	B	B	A	B	B
						The technology is mature in Japan.	Introduction of pumped storage power generation as a means to introduce renewable energy.	Generally, the unit cost of power generation is lower than that of storage batteries.	Contribution to grid stabilization is significant.	Sites need to be found.	A large number of sites cannot be expected.
5	Geothermal power generation					A	A	C	B	C	C
						The technology is mature.	It is a power source with a high annual operating rate and does not generate CO ₂ .	The cost of power generation is more than 20 UScent/kWh (in Japan). The cost of drilling to investigate geothermal power potential is also expensive.	Inertia is present, but generally constantly operated.	A hot hydrothermal zone of 200-300°C is needed, but currently not confirmed.	Hot springs of about 90°C at the surface exist. Geothermal potential as power generation is considered low.
6	Hydrogen-fuelled technology					B	A	C	A	A	B
						Development and demonstration of GT by MHI and Kawasaki Heavy Industries, and that of boiler by Miura Industry	Depends on the amount of co-firing. No CO ₂ emissions except at startup in case of dedicated firing	Fuel cost is higher than conventional fossil fuels	With inertia	Local production and local consumption of hydrogen by small/medium-sized GT and hydrogen boiler may be introduced as early as possible	Need to secure water resources for green hydrogen production. Need to study water transportation method to the demand area.
7	Ammonia-fuelled technology					B	B	C	A	B	B
						Development and demonstration by MHI and IHI	Depends on the amount of co-firing. No CO ₂ emissions except at startup in case of dedicated firing	Fuel cost is higher than conventional fossil fuels	With inertia	Mixed-firing modification is realistic, but can it be applied to existing Russian-made thermal power plants	Need to secure water resources for green hydrogen production as raw material. Need to consider transportation method to the demand area
8	Conversion of existing thermal power plants to biomass fuel co-firing					A	B	B	A	B	B
						Technically mature	Depends on the amount of co-firing	Depends on fuel cost	Performance equivalent to that of Coal-fired plant can be expected	Requires equipment modification Securing construction schedule is an issue	Concerns about the overall amount of biomass fuel in Mongolia
9	New biomass-fired thermal power plant, power generation from waste materials, new CFB boiler					A	A	B	B	A	B
						Technically mature	Possible to reduce	Depends on fuel cost	Biomass-fired power is inferior to coal-fired power Load adjusting capability of waste-derived biomass power generation cannot be expected	Site selection is the key point	Concerns about the overall amount of biomass fuel in Mongolia
10	Power generation from waste (garbage-derived biogas)					A	A	B	B	B	B
						Technically mature	Possible to reduce	Depends on fuel cost	Load adjustment capability cannot be expected	Site selection is the key point	Concerns about the overall amount of biomass fuel in Mongolia
11	CC(U)S/EOR addition to existing thermal power plant					B	B	B	B	B	B
						Demonstration test Level at Tomakomai	Depends on the amount of CO ₂ recovery	Efficiency decreases	CO ₂ recovery system is unsuitable for load changes	Is it physically and mechanically feasible to add to the existing system	Potential research is necessary
12	IGCC(IGFC)+C C(U)S					B	B	B	B	C	B
						Commercial machines may have large power output	Depends on the amount of CO ₂ recovery	Generation cost increase	CCS plants are for base load operation	Currently, MHI has no plan for new plant	Potential research is necessary
13	CBM fuelled GTCC + CCS					B	A	B	B	B	B
						Australia leads the pilot phase	With application of CCS, reductions will be significant	Efficiency decrease	CCS plants are for baseload Operation	Depends on production area/volume	Depends on CBM production capacity
14	Small (micro) nuclear power					B	A	B	B	A	A
						Research reactors, demonstration reactors, etc. are in operation or planned worldwide	High annual operating rate with CO ₂ -free power source	Economies of scale are unlikely. HTGRs are expected to be superior to LWRs.	HTGRs are expected to have the same level of load regulation and inertia as thermal power plants.	In principle, large amounts of water are not required (except for LWRs)	Uranium resources are abundant.
15	Nuclear fusion					C	A	C	B	C	C
						Elemental development research is currently underway in various countries.	High annual operating rate with CO ₂ -free power source	Large initial investment	Doubtful about load adjustment capability	Excessive output	Need to secure water and tritium

Source: Prepared by the survey team

The survey team identifies the following technologies and measures as those with high potential for widespread application in Mongolia by 2050. Among these, storage batteries and mini-grids are expected to be a means (measure) to expand the introduction of renewable energy. Hydrogen-fuelled technology/small (micro) nuclear power, biomass, and waste are technologies that could also be used for heat utilization.

- Storage batteries (BESS) to suppress frequency fluctuations caused by VRE
- Interconnected mini-grid (MW-class VRE + storage batteries with grid connection)
- Hydrogen-fuelled technology (hydrogen-fuelled CHP, etc.)/small (micro) nuclear power
- New biomass-fired thermal power plant, power generation from waste materials, CFB boilers

The following technologies are considered to have the potential for full-scale introduction by 2050, but will not become mature and widespread technologies. The reasons for this are as follows

Even if the durability and weather resistance of perovskite photovoltaics (Measure 1 in the above table) are confirmed, the availability of land for photovoltaics in Mongolia is enormous, so even if it spreads, it is likely to be limited to urban areas with site constraints, and its applicability is not expected to be very high.

Pumped storage hydropower generation (Measure 4 in the above table), which can demonstrate similar effects to storage batteries, is a measure that can greatly contribute to the expansion of renewable energy, but in order to achieve mass adoption of this measure, it is necessary to find suitable sites for pumped storage power generation. Conversely, if progress is made in discovering such sites, the use of pumped storage power generation may increase.

Ammonia-fuelled technology (Measure 7 in the above table) is expected to be developed worldwide, including co-firing with coal, but this technology, which requires further conversion of hydrogen to ammonia, may increase costs.

For conversion of existing thermal power plant to biomass co-firing (Measure 8 in the above table), it is unlikely that suitable sites will be abundant, given the technical difficulties of combining existing facilities with new facilities and the risk of construction work on existing facilities in operation.

For power generation from waste (garbage-derived biogas) (Measure 10 in the above table), the use of biogas from sewage treatment plants is considered promising, but it depends on the construction plans for sewage treatment plants and is not likely to become widespread enough to be significant.

CC(U)S/EOR addition to existing thermal power plant (Measure 11 in the above table) is raised as a possibility, but no economically or technically suitable site, including the installation of CCS equipment, has been identified at this time.

CBM fuelled GTCC + CCS (Measure 13 in the above table) is assumed to have limited forms of use as a set with CCS, as CCS must be used as a set for the purpose of decarbonization, although there are discussions of coal fields suitable for CBM within Mongolia.

(2) Results of Interviews with the Mongolian Energy Private Sector Regarding Each Technology and Measure

The following are the results of interviews with the Energy Committee of the Mongolian Chamber of Commerce and Industry (an industry group consisting of 104 organizations including private companies in the Mongolian energy sector) regarding the promising potential and direction of each of the technologies and measures in which private sector participation can be expected.

- Perovskite photovoltaic power generation needs to be confirmed for durability under the Mongolian climate.
- Storage batteries with renewable energy are a good idea, but there is concern that the

cost of selling renewable energy will increase (an additional price is necessary to cover this cost).

- Microgrid for local production for local consumption is a good idea.
- Hydrogen gas turbine power generation is of interest if such a technology can be developed. South Gobi has great renewable energy potential, but lacks the water resources to produce hydrogen.
- Biomass co-firing and dedicated combustion power generation needs to consider what resources can be used as fuel.
- It seems that waste power generation is being implemented as a F/S project in the suburbs of UB City, but it would be expensive if only power generation is taken up, so it would be better to include heat supply as well.
- It is necessary to confirm whether biogas power generation from waste will produce gas at low temperatures.

5.3 CO₂ Capture and EOR/CCS for Coal Use

5.3.1 CO₂ Emissions from Coal Use

(1) Coal utilization and CO₂ emissions

The Mongolian government intends to support and implement the construction of more than six coal-fired power plants through private investment, led by the Tavantolgoi 450 MW thermal power plant, based on the "Mega Projects" action plan for 2024 - 2028, and new construction is expected to continue to progress. As a result, CO₂ emissions associated with coal-fired power generation are expected to increase in the future.

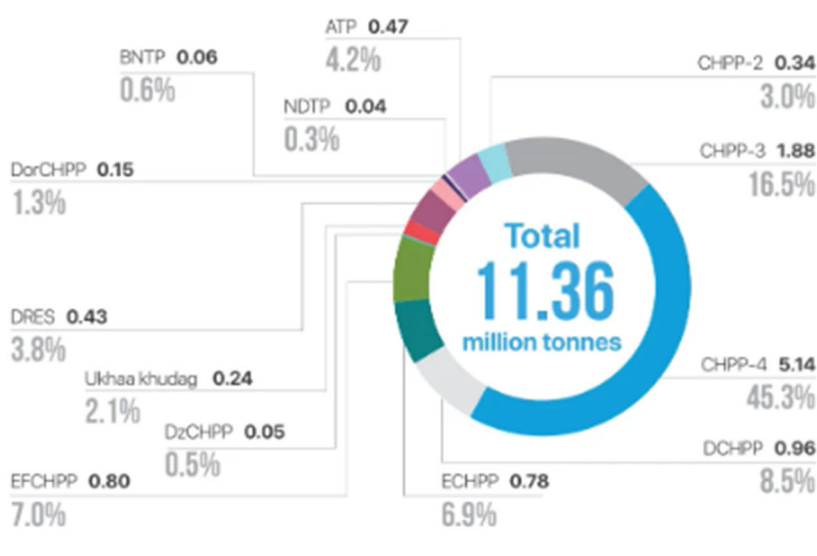
In order to understand the current situation, JST investigated CO₂ emissions from coal-fired power generation.

The figure below shows the CO₂ emissions from thermal power plants from 2019 to 2023. Both fuels are coal, with emissions reaching 11.36 million tons in 2023. In addition, the CO₂ emissions of Mongolia's BAU (without measures) in the 2020 NDC are estimated to be 49.01 million tons, and emissions from coal-fired power plants account for 23% of this amount. Thus, emissions from coal-fired power plants are very large among the total emissions and are an important issue for future emission reductions.

CO₂ emissions released from energy sources

Million tonnes

Sources	CO ₂ Emissions				
	2019	2020	2021	2022	2023
CHPP-2	0.34	0.33	0.33	0.34	0.34
CHPP-3	1.69	1.75	1.84	1.87	1.88
CHPP-4	4.24	4.39	4.73	4.95	5.14
DCHPP	0.74	0.80	0.79	0.91	0.96
ECHPP	0.47	0.48	0.60	0.77	0.78
EFCHPP	0.75	0.72	0.77	0.80	0.80
Ukhaa khudag	0.23	0.21	0.20	0.22	0.24
DRES	0.41	0.40	0.42	0.42	0.43
DzCHPP	0.05	0.09	0.08	0.05	0.06
DorCHPP	0.13	0.14	0.14	0.15	0.15
BNTD	0.06	0.06	0.06	0.06	0.07
NDTP	0.04	0.04	0.04	0.04	0.04
ATP	0.33	0.35	0.34	0.38	0.47
Total	9.48	9.76	10.34	10.96	11.36



Source: Energy Regulatory Commission Statistics on Energy Performance 2023 (<https://erc.gov.mn/web/en/news/896>)

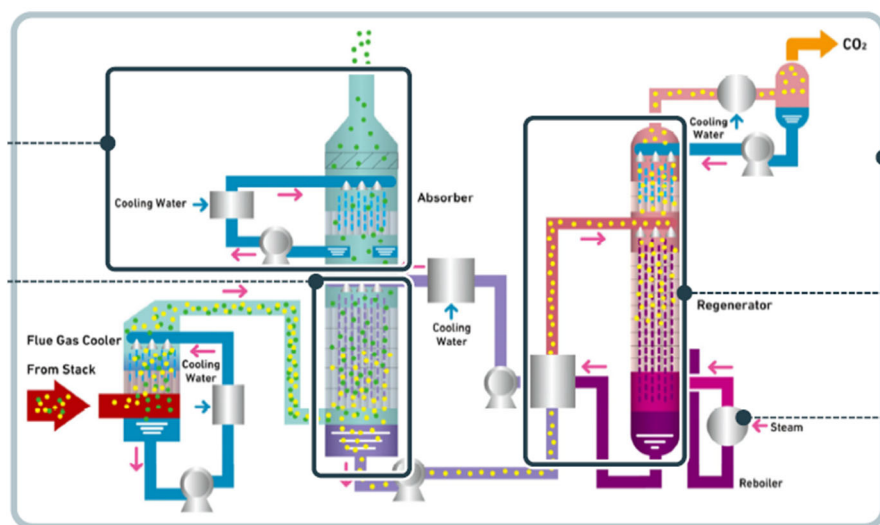
Figure 5-54 CO₂ Emissions from Thermal Power Plants

(2) CO₂ Capture Technology

CO₂ capture and recovery technologies are being researched and developed around the world, and the mainstream technology currently in practical use is chemical absorption using amine-based absorbent solutions. This process is already in operation on a commercial basis, but since it requires a lot of energy to desorb CO₂ from the absorbent solution and the equipment cost is high, improvements are still being made to reduce the cost. In addition, membrane separation methods and processes using solid absorbents are also in the research stage.

The cost of CO₂ capture by the chemical absorption method is currently estimated to be about 4,500 JPY/t-CO₂, but is expected to be reduced to 1,500 JPY/t-CO₂ in the 2030s and further to

1,000 JPY/t-CO₂ by 2050. If Mongolia is considering the introduction of this technology in the short to medium term, it is realistic to adopt the chemical absorption method, which is currently well established. The figure below is a flow diagram of the CO₂ recovery process using the chemical absorption method, showing the flow of selective absorption, separation, and recovery of CO₂ from exhaust gas.



Source: Mitsubishi Heavy Industries, Ltd.

Figure 5-55 CO₂ recovery process by chemical absorption

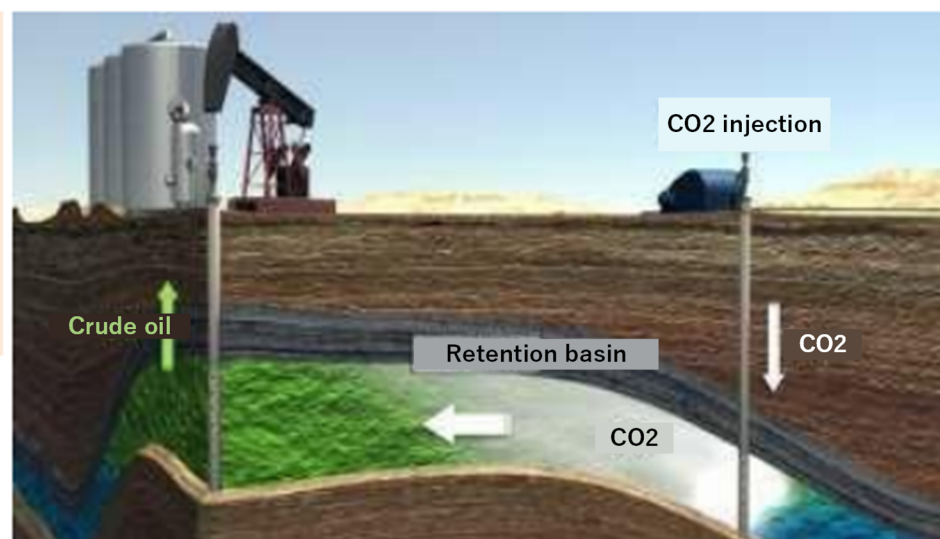
(3) Consideration of EOR

The basic principle for reducing CO₂ emissions is to save energy and improve facility efficiency, but it is important to utilize CCUS (effective utilization of CO₂), EOR (enhanced oil recovery), and CCS (geological storage) for the portion that cannot be fully controlled. However, the economic feasibility of EOR needs to be determined before it can be introduced.

Figure 5-56 show an overview diagram of EOR and EGR technologies and an example of CO₂ injection in Japan.

The effectiveness of EOR depends on the following geological conditions

- Depth: Suitable reservoir depths range from 1,000 to 3,000 m. CO₂ mixes well with oil in a supercritical state, increasing recovery efficiency.
- Pressure and temperature: 10 MPa or higher and 40 to 120°C are desirable, as CO₂ is stable in liquid form.
- Residual oil volume: The amount of recoverable residual oil must be large.
- Sealability: An impermeable "cap layer" is required above the reservoir to prevent CO₂ leakage.
- Permeability: Moderate rock permeability is required for CO₂ to spread evenly within the formation.



Sources: EOR/EGR technology overview and CO₂ injection case study in Japan 2022.10.07

Figure 5-56 Schematic of EOR

Although EOR technology with CO₂ has a high initial investment, it contributes to a higher payback in the long term. Therefore, for a project to be economically viable, it is necessary to have an economic plan that takes into account the cost of CO₂ supply, transportation costs, and technology implementation costs. Therefore, the following study was conducted on Mongolian oil fields.

<Feasibility of EOR Application to Mongolian Oil Fields>

Lots 19 and 21 in eastern Mongolia are owned by the Chinese state-owned PetroChina Daqing Tamsag, which started oil extraction in 2012 and reached its peak in 2015. Currently, the company is using the water-aggression method and polymers, but the crude oil supply is insufficient for the planned refinery to be built (1.5Mt capacity), and there is an urgent need to increase production.

Figure 5-57 show the results of CO₂-EOR scoring analysis⁴⁸ for Mongolia's A oil field (Block 19 and Block 21), which shows the effectiveness of CO₂ utilization. In addition, good CO₂ injection EOR results have been reported for the Hailer oil field near the China border.

Based on the above, a rough estimate of the EOR profitability of Block 19 was made.

Figure 5-58 show that the estimated reserves of Block 19 are 179.08Mt, one of the largest in the country.

⁴⁸ Analyses of the Field Development Plan and EOR Screening based on Reservoir Properties of the "A" Field in Mongolia, Anuudari Arvis and Bo Hyun Chon* Department of Energy Resources Engineering, Inha University.

Table 11: Scoring results for EOR methods

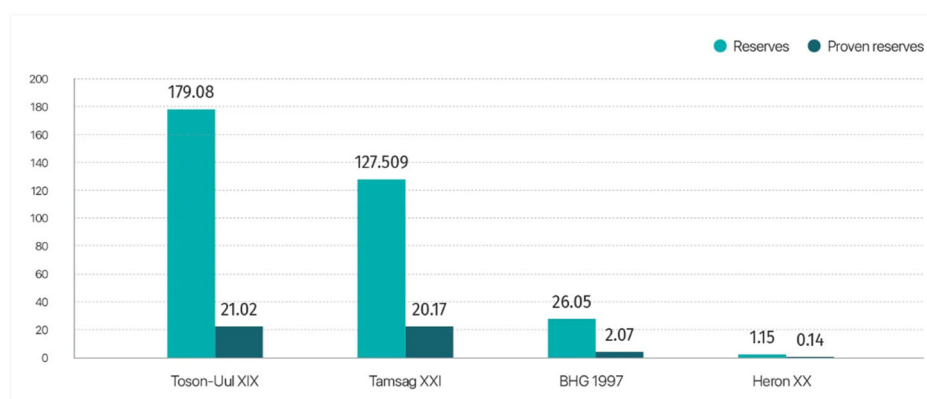
ULZ Formation, LLZ Formation & Tsagaantsav Formation: Result of the screening criteria for EOR methods									
EOR Method	ULZ	LLZ	Tsagaantsav	ULZ	LLZ	Tsagaantsav	ULZ	LLZ	Tsagaantsav
Compatibility			Averaged result			EOR ranking result			
Gas injection methods (Miscible)									
1 Nitrogen and flue gas	0.58	0.58	0.58	0.575			6		
2 Hydrocarbon	0.76	0.76	0.76	0.763			3		
3 CO ₂	0.88	0.96	0.90	0.913			1		
4 Immiscible gases	0.91	0.91	0.91	0.913			1		
0 = Not Applicable (N/A)									
0.3 = Barely applicable									
0.5 = Normal									
0.7 = Recommended									
1 = Strongly Recommended									

Source: Analyses of the Field Development Plan and EOR Screening based on Reservoir Properties of the "A" Field in Mongolia, by. Anudari Arvis and Bo Hyun Chon* Department of Energy Resources Engineering, Inha University.

Figure 5-57 EOR Scoring Analysis by CO₂

As shown in the figure below, the estimated reserves of Block 19 are estimated to be 179.08Mt, which is one of the largest class of currently operating fields.⁴⁹

RESERVES OF OIL FIELDS IN MONGOLIA (MILLION TONNES)



Source: MRPAM

Source: MRPAM

Figure 5-58 Estimated and Proved Reserves of Oil Field Blocks

<Estimated Increased Crude Oil Production and Profitability>

Therefore, if the unit cost is multiplied by the assumed recovery rate based on proved reserves, which is a more reliable measure of recoverability for the incremental crude oil production from CO₂ in Block 19, the table below shows the unit cost. The table below shows the estimated results of the production increase and its sales price according to the EOR recovery rate. The EOR increase recovery rate varies greatly depending on the characteristics of the oil field (depth, temperature,

⁴⁹ MRPAM

viscosity, permeability, etc.), but is generally around 10 - 20%, so the recovery rate is assumed in this range.

Table 5-19 Estimated Sales Price of Increased Crude Oil Production from EOR

EOR Recovery Rate (%)	Increased production (Mt)	Selling price (M USD) ⁵⁰	Remarks
5	1.0	539	
10	2.1	1,079	
15	3.1	1,618	
20	4.2	2,157	

Source: "Market Insider" as of 2024/12

Although profits are expected, a future challenge is to evaluate the economic feasibility, including capital investment and transportation costs. The pros and cons of introducing EOR will require detailed verification through simulations and test drilling.

(4) Consideration of CCS

If EOR is not economically viable, CCS (Carbon Capture and Storage), which stores CO₂ underground, is an option.

Suitable sites for CCS must meet the following requirements:⁵¹

- Storage capacity: the reservoir must have sufficient pore space to store the planned amount of CO₂.
- Injectivity: the reservoir shall not cause a pressure increase in the vicinity of the injection well that exceeds acceptable limits.
- Containment capacity: The reservoir must be free of faults and other leakage pathways, and must be able to hold CO₂ stably for a long period of time.
- Well integrity: The existing and new wells must be able to adequately manage the risk of CO₂ leakage.

Selection of a suitable site requires a comprehensive investigation of geological, geographical, and technological factors.

In Mongolia, a legal framework is being developed, although no formal policy or legislation on CCS implementation is in place. Some institutions have already started to investigate suitable sites for CCS, and the results of seismic surveys around the Baganuur coal mine suggest the possibility of CO₂ sequestration.

(5) Consideration of Pilot Projects

To confirm the practicality of EOR and CCS, it is important to conduct demonstration tests through pilot projects, which will require securing a CO₂ supply source.

The most promising CO₂ source for CO₂ is the Choibalsan coal-fired power plant.

⁵⁰ Converted as crude oil unit price = USD70/barrel
<https://markets.businessinsider.com/commodities/oil-price?type=wti%29>

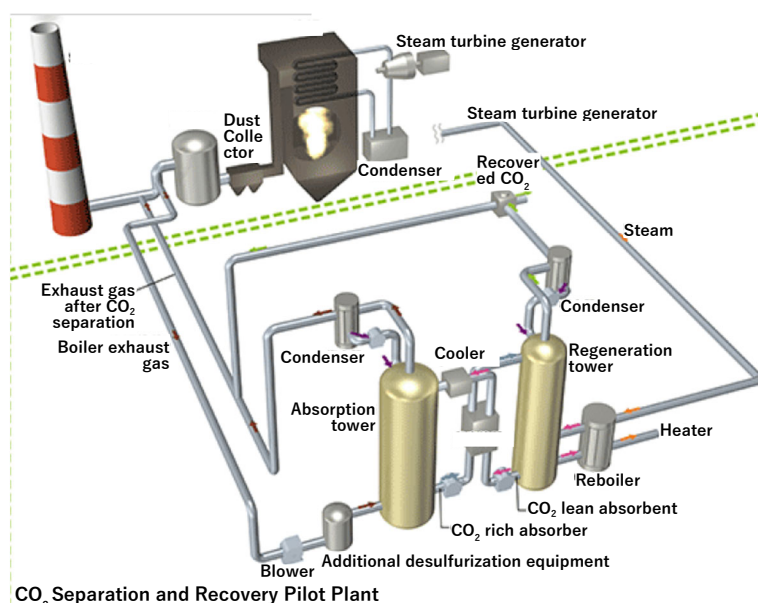
⁵¹ (<https://www.jogmec.go.jp/content/300378181.pdf>)

This power plant is located approximately 700 km east of UB and is the largest energy supply facility in eastern Mongolia. The current facility (36 MW) is aging and there are concerns about declining power generation efficiency and environmental impact, and plans are underway to build a new 50 MW facility.⁵²

It would be effective to install a small pilot unit at this power plant in order to conduct a demonstration test of CO₂ separation and recovery.

Since the degree of degradation of amine-based absorbent solution varies depending on the characteristics of the exhaust gas, verification with actual gas is desirable. Another advantage is the relatively close proximity of the candidate EOR fields 19 and 21.

Figure 5-59 show a schematic diagram of the CO₂ separation and recovery pilot plant and the process flow using the chemical absorption method.



Source: Toshiba Energy Systems

Figure 5-59 CO₂ Separation and Recovery Pilot Plant Schematic

<CO₂ transport and injection test>

CO₂ emissions from the CO₂ separation and recovery Choibalsan power plant (50 MW) are estimated to be 700 - 800 tons/day.

The scale of the pilot system is targeted to be "1/10th of the scale of full-scale installation (100 tons/day)," and a compact container-type system is suitable.

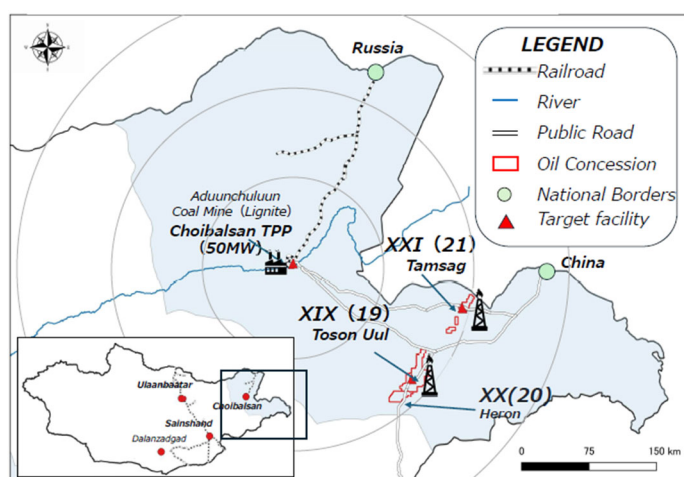
The separated and recovered CO₂ will be transported to Mining Area 19 for an injection test.

The mine site 19 is located about 210 km from the power plant and can be transported by truck or pipeline due to its well-developed roads.

Figure 5-60 show the location of the Choibalsan power plant and mining areas 19 and 20.

In the test, the effectiveness of EOR will be confirmed by compressing CO₂ to a high pressure of about 10 MPa and injecting it into the depleted oil field.

⁵² (<https://montsame.mn/jp/read/299731>)



Source: Prepared by the survey team from data

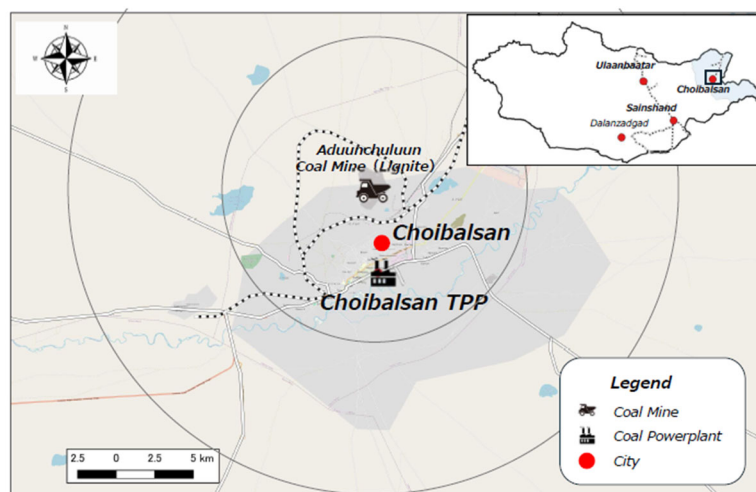
Figure 5-60 Location map of Choibalsan power plant and oil blocks 19 and 20

<Survey of suitable CCS sites>

In parallel with the survey of suitable EOR sites, a survey of suitable CCS sites will be conducted.

In addition to depleted oil fields that are candidates for EOR, we will examine whether there are suitable sites in the vicinity of the pilot units that can be used for storage.

A 25 km radius from the Aduunchuluun lignite coal mine near the Choibalsan power plant is considered a good candidate. Figure 5-61 shows the location.



Source: Prepared by the survey team

Figure 5-61 Potential CCS sites near Choibalsan power plant

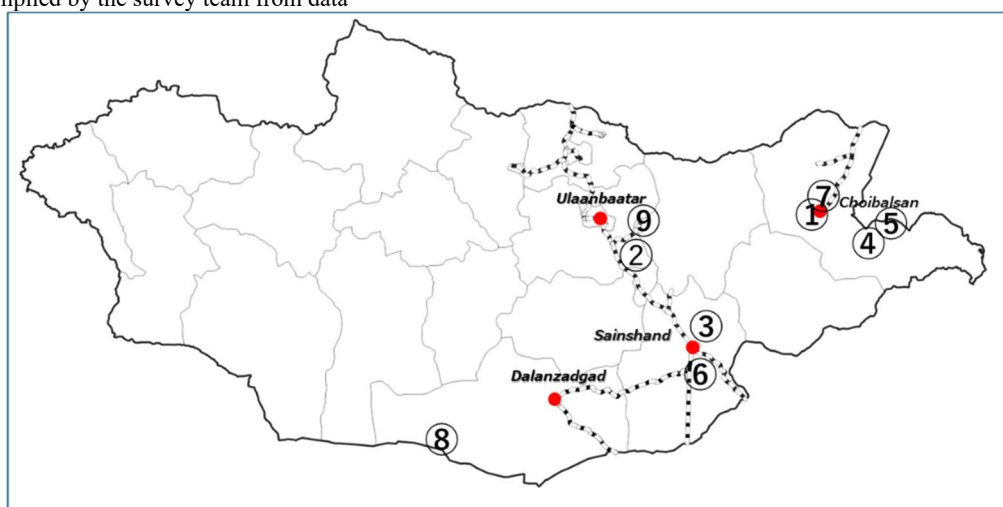
(6) Proposal

For the future introduction of EOR and CCS in Mongolia, it is desirable to conduct pilot projects to collect basic information. This report introduces several candidate sites with limited information, but other sites such as Table 5-20 ,Figure 5-62 can also be considered as candidate sites.

Table 5-20 List of candidate sites for pilot projects

NO	Project	Candidate site	Characteristics	Remarks
1	CO ₂ Separation and Recovery	Choibalsan Coal-fired power plant	➤ New coal-fired power plant (50MW) under construction ➤ Close to oil fields 19 and 21 (210km)	Introduced as a strong candidate in this report
2		Buuruljuut coal-fired power plant	➤ Large-scale thermal power plant (150 MW x 4 units) under construction (to be completed in 2028)	The surrounding area is planned to be developed as an industrial technology park.
3		Sainshand Oil refinery	➤ Distant (530 km) from oil fields 19,21, pipeline laid	Proximity to Block 97
4	EOR demonstration	Block 19	➤ Largest reserve block	Introduced as a leading candidate in this report
5		Block 21	➤ The 2nd largest mining area in terms of reserves	
6		Block 97	➤ Unsurveyed concessions	Lack of basic information, most proximate to refinery
7	CCS Demonstration	Aduunchuluun lignite coal mine	➤ Near Choibalsan power plant ➤ MAK's pre-FS to store gas from a coal gasification project using lignite from the coal mine	Introduced as a leading candidate site in this report (FS conducted by Unico International)
8		Nariin Sukhait Coal Mine	➤ During the CBM development demonstration, Enhanced Gas Recovery (EGR) using CO₂ can be considered in the future if stable gas gushing is expected.	Feasibility of CBM development is under consideration.
9		Baganuur coal mine	➤ Closest potential storage site to UB CHP4	Preliminary survey shows potential for storage within a 30 km radius.

Source: Compiled by the survey team from data



Source: Compiled by the survey team from data

Figure 5-62 Location of candidate sites

5.4 Carbon Recycling

5.4.1 Japanese Carbon Recycling Technology

The Japanese government has set a goal of achieving carbon neutrality by 2050 and is focusing on promoting "carbon recycling technologies" that reuse CO₂ as a resource rather than an emission. Some of the technologies have already been put to practical use, and efforts are underway in the following areas.

- Concrete technology: Concrete that absorbs CO₂ has been developed and immobilized in building materials. Examples: "T-eConcrete®/Carbon-Recycle" by Taisei Corporation and "CO₂-SUICOM®" by Kajima Corporation.
- Biotech: Utilizes microorganisms and algae to generate biofuels and other products from CO₂. Some companies, such as Euglena, have started commercialization.
- Chemical raw material synthesis technology: Synthesizes chemical products such as methanol, ethanol, and dimethyl ether from CO₂
- Methane generation: Synthetic natural gas (methane) is produced by reacting renewable energy-derived hydrogen with CO₂

However, the challenges to commercialization are cost and energy consumption. The recovery and utilization process requires high energy, and the combination with renewable energy is key. Initial investment control and technological innovation are essential for large-scale deployment.

5.4.2 Potential for Introduction in Mongolia

Promising carbon recycling projects in Mongolia include the following areas

(1) Methane Generation from Renewable Energy

Mongolia has abundant wind and solar power, and the technology to generate hydrogen and react it with CO₂ to obtain synthetic natural gas (methane) can be applied to areas with underdeveloped infrastructure.

(2) CO₂ Fixed Concrete

In Mongolia, where demand for construction is increasing, CO₂-fixing concrete can be used for both infrastructure development and environmental impact. The cost of introduction is also relatively low, offering economic advantages.

(3) Fuel and resource conversion using biotechnology

In Mongolia, where agriculture and cattle raising are major industries, biofuel production using microalgae will contribute to the reduction of CO₂ emissions from these sectors.

(4) Greenhouse agriculture using CO₂

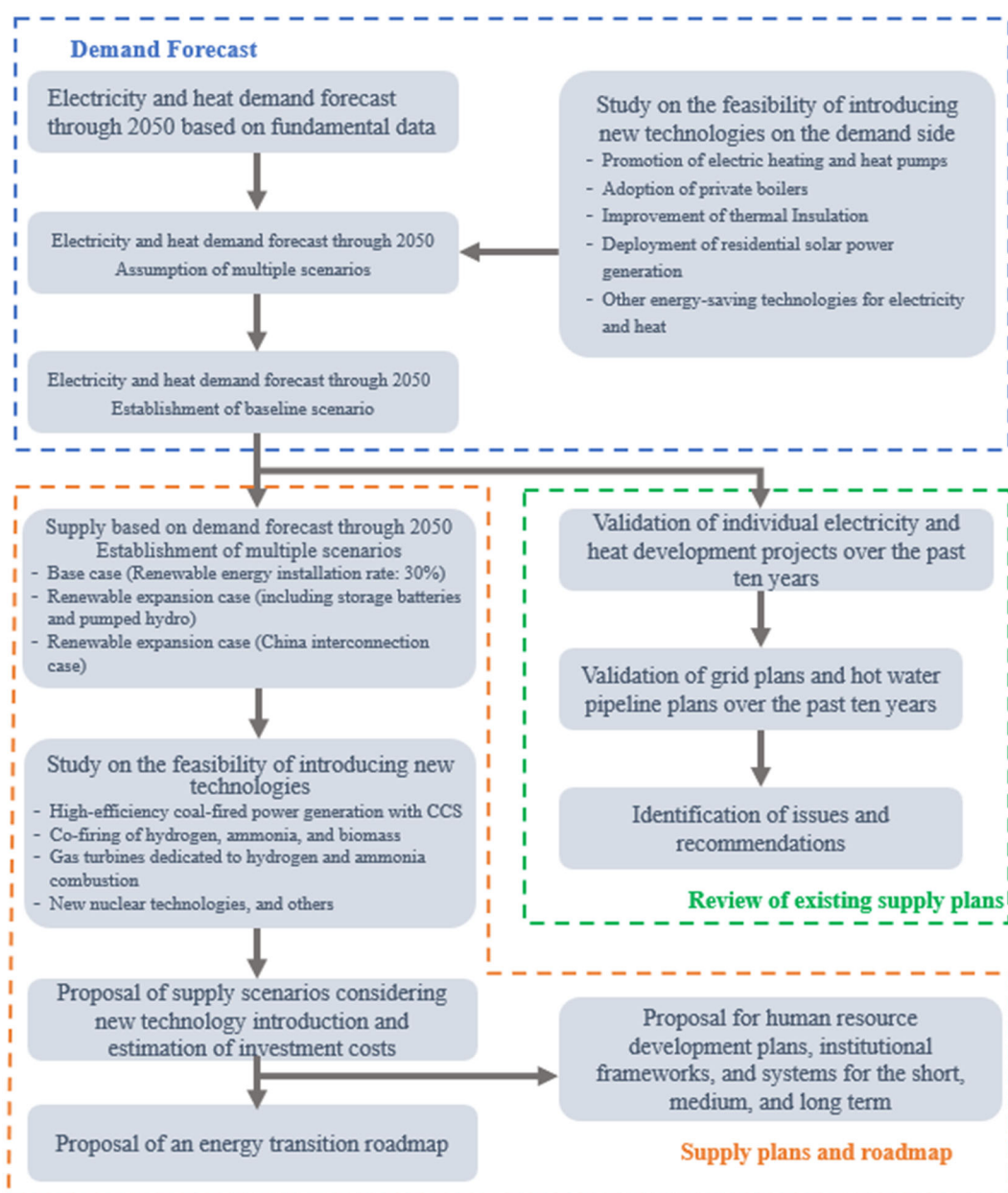
In greenhouse agriculture, which is spreading under harsh climatic conditions, increasing CO₂ concentration is expected to promote crop growth and improve yields.

In the future, Japan may promote exchanges of views with Mongolia in these areas and, if requested, support the decarbonization of Mongolia through Japanese technology.

Chapter 6 Energy Transition Roadmap and Action Plan

6.1 Policy for the Development of the Energy Transition Roadmap

A two-stage analysis process will be developed for the preparation of Mongolia's Energy Transition Roadmap. In the first phase, the country's primary and final energy demand will be analyzed in the manner outlined in the energy supply and demand modelling work in the figure below. Macroeconomic scenarios will be developed based on Mongolia's actual energy data (e.g., energy balance tables) with reference to existing literature from Mongolia and other donors, and energy demand analysis will be conducted. The data will be input into the conversion section of the energy supply and demand model to estimate the country's primary energy supply to the year 2050, and CO₂ emissions will be calculated to create a BAU case. In the second phase, multiple scenarios for carbon neutrality will be examined and a direction for achieving carbon neutrality in Mongolia by 2050 will be proposed.



Source: Prepared by the survey team

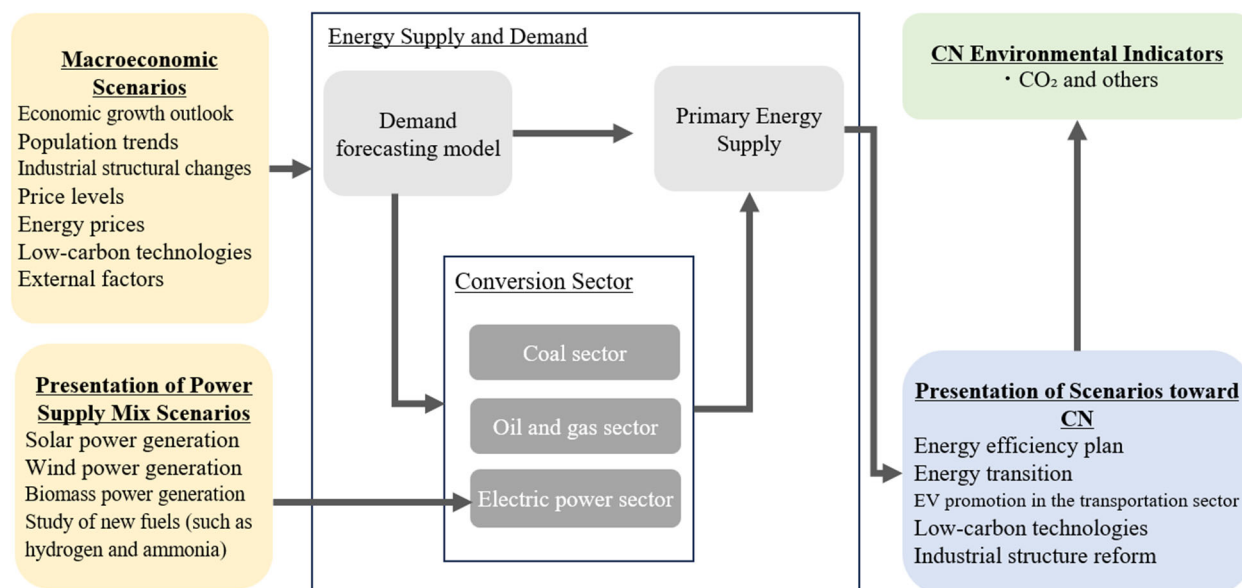
Figure 6-1 Workflow of demand assumption, supply planning, and roadmap preparation

6.2 Energy Demand and Supply Structure Projection

6.2.1 Energy demand forecast

(1) Model Overview and BAU Setting

This energy demand model analysis used an econometric model. This model analysis is an integrated econometric simulation system using the Simple-E⁵³ software. The overall model consists of a "macroeconomic scenario," a "demand forecast model," a "power supply configuration scenario," a "primary energy supply," and a "scenario toward CN," as shown in the figure below. This integrated econometric analysis model makes it relatively easy to verify the interrelationship between relevant macroeconomic indicators and energy demand, and to explain future changes in energy demand based on trends in economic activity.



Source: Prepared by the survey team.

Figure 6-2 Overview of the work implementation of the energy demand and supply model

The following assumptions are made in order to introduce the above energy demand and supply model scheme and to build the basic scenario (BAU) of the specific model.

- Using data from ADB, IEA's "World energy balance 2023" (1990-2022), ERC and other sources as a platform, supplemented by relevant data published by the Mongolian government, an energy demand forecasting model will be constructed until 2050.
- BAU assumes a scenario that develops by 2050 with the current energy demand structure and does not take into account the effects of current government improvement efforts and other measures.
- CO₂ emissions from the energy sector are calculated based on the guidance presented by the United Nations Framework Convention on Climate Change (UNFCCC) guidelines (2006 IPCC Guidelines for National Greenhouse Gas Inventories).

⁵³ Simple-E is an integrated simulation system of econometric tools developed in Japan. The tool supports the entire process from data preparation to model building and simulation (forecasting). Simple-E was created as an add-in application for Microsoft Excel and takes full advantage of Excel's native spreadsheet capabilities. At the same time, it integrates data entry, model building, testing, forecasting, and simulation processes, and integrates and controls Excel's function capabilities to provide a variety of estimation options including ordinary least squares method (OLS), autoregressive, and nonlinear.

(2) Model Scale, Estimation Period, and Data Collection

The estimation period for this integrated econometric model is 27 years, from 2023 to 2050. The model consists of 61 estimating equations, 265 defining equations, and a total of 326 formulas, which are computed in the model by simultaneous equations. For the actual data, macro indicator data such as economic, population, and price data and electricity sector data up to 1990-2023 and other energy-related data up to 2000-2022 were used.

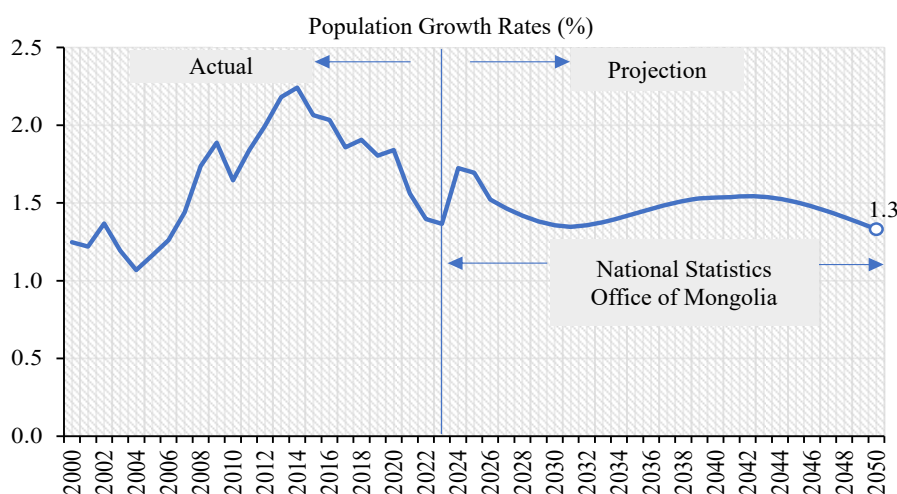
Mongolian macroeconomic performance data were obtained from ADB, IMF, National Statistics Office of Mongolia, and United Nations Statistics Division (UNSTAT), while energy sector performance data The data for the energy sector were obtained from the IEA, ERC, ERIA, and other sources.

(3) Assumptions

1) Population

According to statistics from the National Statistical Office of Mongolia, the country's population will be 3,397,000 at the end of 2023. The country's population grew at an average annual rate of 1.57% until 2000-2023. Mongolia's population growth rate has been unstable over the past 23 years due to the major historical and political factor of regime change and the accompanying economic and social factors.

The National Bureau of Statistics estimates long-term population projections through 2050. In this model, the Bureau's population estimates through 2023-2050 were used in the forecasting model as exogenous variables. The details are shown in the figure below. According to the population projection results, the population will increase at an average annual rate of 1.4% until 2023-2050, and the total population in 2050 will be 5,004,000.



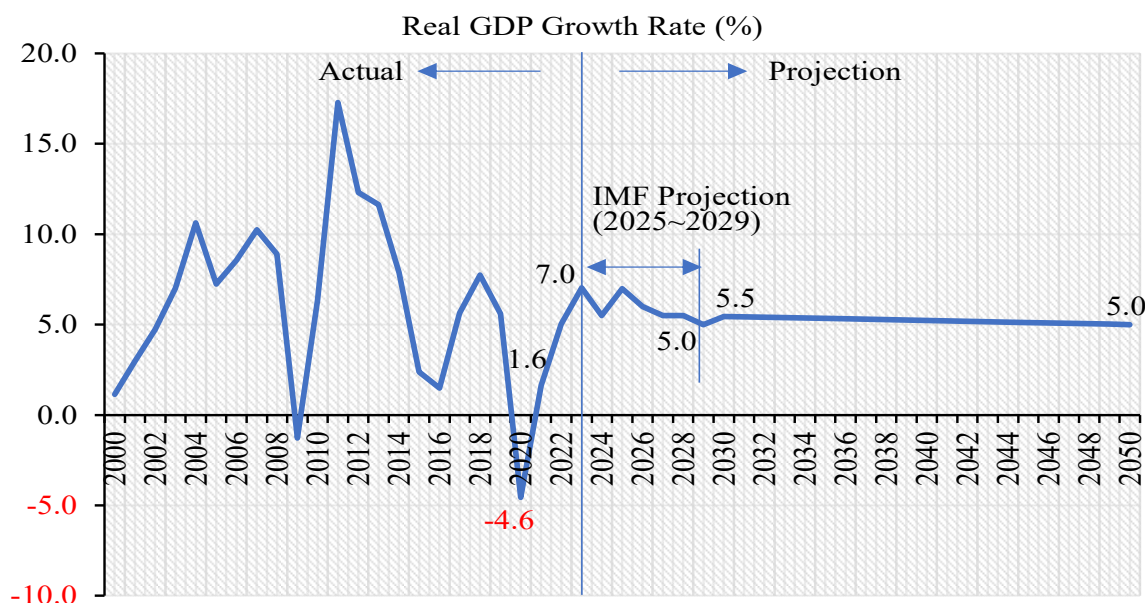
Source: National Statistics Office of Mongolia

Figure 6-3 Population Growth Rates (2000-2050)

2) Economic Growth

Since 2000, Mongolia's economic growth was severely damaged by the Lehman Brothers collapse in 2008, political unrest in 2014 and COVID-19 in 2020. Although other years have presented high economic growth, stable economic development is an important issue for the country, as inflation has remained high. In making this estimate, JST adopted the short-term economic growth rate estimated by the IMF (released in April 2024) for the period from 2023-2029, and assumed a

reduction from 5.5% to 5.0% for the period from 2030 to 2050.⁵⁴ The chart below shows the economic growth rate for each year.



Source: 2000-2023: ADB, Key indicators for Asia and the Pacific 2023.

2024: IMF

2025-2029: IMF Projection, April 2024.

2030-2050: Projections (potential GDP)

Figure 6-4 Economic Growth Rates (2000-2050)

6.2.2 Energy Supply Plan

(1) Basic Approach to BAU Assumption for Heat and Electricity Supply Systems in Response to Final Demand Projections

The main power plants in Mongolia are coal-fired combined heat and power plants (CHP), which are primarily used to supply heat for heating during the harsh winter season and produce electricity as a byproduct. Therefore, even though it is called a power plant, its main role is actually to supply heat, and in planning, the amount of electricity supply is determined subordinately from the required heat supply demand value. (Basic concept: If there is a shortage of electricity supply due to CHP, etc. that can supply heat, this is handled by RE).

For this reason, in calculating BAU, it was decided that all heat demand would be supplied from CHP, and at the same time, electricity supplied from CHP would be obtained from the assumed ratio of heat supply to electricity supply. The remaining electricity supply was then assumed to be provided by RE (hydro, PV, wind). (HOB was assumed to be all CHP in the long-term range of ET, since electricity demand will increase more than heat demand in the future.)

The existing diesel power generation was assumed to be replaced by RE by 2030, since it is small in scale and can become ET using existing technology. The existing hydropower generation was assumed to be the level in 2023, which was the lowest in the past 10 years. For the new VRE scenario, both solar and wind power have high potential. Since it is difficult to determine their generation rates, calculations were performed assuming a 50% share for each.

⁵⁴ According to the Long-Term Vision 2050, a national strategy announced by the Mongolian government in May 2020, the country's long-term development plan sets out specific policy goals: "Through economic diversification and industrialization, we will achieve a dramatic transformation from a consumer country to a manufacturing country, and from an importing country to an exporting country," and "increase per capita GDP to US\$12,000 in 2030 and to approximately US\$38,000 by 2050, three times the 2030 level." To achieve this goal, the government has indicated that it will maintain an economic growth rate of 5-6% going forward.

Electricity imports from other countries were assumed to be zero by 2030 in accordance with government policy.⁵⁵

Based on information and requests from the Ministry of Energy, new hydropower projects which were identified as Erdeneburen Hydro (90 MW, 366 GWh/year, commissioning in 2029), Baidrag Hydro (30 MW, 58.9 GWh/year, commissioning in 2029), Egiin Hydro (315 MW, 606 GWh/year, commissioning in 2033), and an adjustable speed pumped storage hydro (100 MW, commissioning in 2031) were incorporated to the BAU. As an additional note, the reasons for not including other hydropower development projects in the BAU setting are as follows.

In general, the construction of hydropower plants requires a long construction period due to the large scale of civil engineering work involved, and plans tend to be delayed due to land and site constraints, water rights, and other issues. On the other hand, the construction period for photovoltaic and wind power generation is much shorter than that for hydropower, especially for photovoltaic, which takes only one or two years, and Mongolia has 2,200 GW of photovoltaic potential and 1,100 GW of wind power potential, for a total of 3,300 GW. Of course, JST is not denying hydropower, and believe that hydropower development should be pursued steadily. However, in the BAU for this energy transition, since VRE has approximately 2,000 times more potential than hydropower, and the construction period is shorter, JST have set VRE, which has very high additionality, as the priority power source for development.

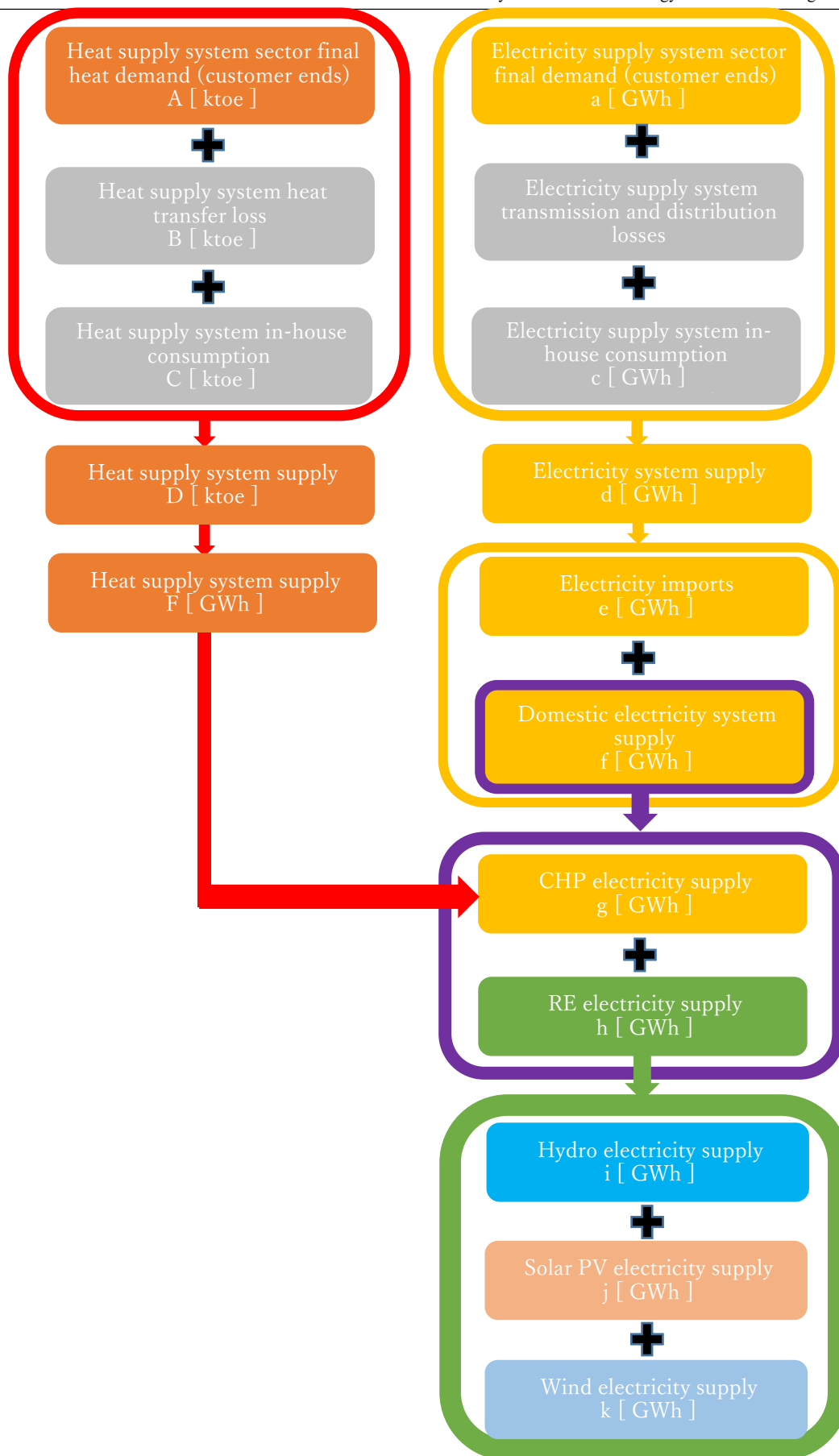
(2) Study Conditions for the Assumption of BAU for Heat Supply System and Electricity Supply System

The heat supply and electricity supply volumes were calculated from the assumed final heat demand and assumed final electricity demand, based on their respective assumed transmission loss rates and assumed in-house consumption⁵⁶ rates. However, RE's own consumption of electricity was assumed to be zero, and all electricity consumption was assumed to be self-consumed by the fossil fuel power supply.

The procedure for BAU supply assumptions is shown in Figure 6-5 and the conditions of study are shown in Table 6-1.

⁵⁵ Government policy heard from a member of the National Energy Reform Commission during the third on-site investigation in March 2025

⁵⁶ Unavailable waste thermal energy due to heat radiation throughout the plant as well as electricity consumed by equipment within the plant site.



Source: Prepared by the survey team

Figure 6-5 BAU Assumption Procedure of Supply System

Table 6-1 Study Conditions for the BAU Supply Estimation

No.	Classification	Item Name	Unit	Conditions
1	Heat	Annual heat supply system sector final heat demand (customer end)	ktoe	Assumed value calculated in 6.2.3
2	Heat	Annual heat supply system heat transfer loss rate	%	4% (average of actual results for 2013-2022)
3	Heat	Annual in-house heat consumption rate	%	10% (average of actual results for 2020-2022)
4	Heat	Share of bituminous coal consumption Bituminous / (Lignite + Bituminous)	-	0.35 (actual values for 2022)
5	Electricity	Annual electricity supply system sector final electricity demand (at ends of demand)	GWh	Assumed value calculated in 6.2.3
6	Electricity	Annual electricity supply system transmission and distribution loss ratio	%	12% (average of actual results for 2021-2023)
7	Electricity	Annual electricity supply system own consumption rate (fossil fuel)	%	14% (average of actual results for 2014-2023)
8	Electricity	Annual electricity imports	GWh	2,427 GWh by 2026 (same as actual results in 2023) Zero by 2030 (reflects government policy)
9	Electricity	Heat - Electricity unit conversion constant	GWh	1 ktoe = 11.63 GWh
10	Electricity	Annual ratio of heat and electricity supply for the coal-fired CHP	-	Based on historical results 30 (electricity) / 70 (heat) = 0.428571
11	Electricity	Annual diesel power supply	GWh	Assumed to be zero by 2030
12	Electricity	Annual hydropower supply (existing)	GWh	48 GWh (strictly conservative, lowest value in the last 10 years, 2023)
13	Electricity	Generation share of solar and wind solar / (solar + wind) wind / (solar + wind)	-	0.5 (assumption) 0.5 (assumption)

Source: Prepared by the survey team

(3) Conditions for Estimating BAU Generation Capacity in the Electricity Supply System

The installed capacity of power generation (MW) was calculated from the electricity supply (GWh) for each type of power generation based on the assumed utilization of the facilities for each type of power generation.

As described in Sections 1.2.51 and 17.3.1 of the Mongolian Grid Code, the study conditions were set as follows

The output (MW) of the BESS for solar PV application was calculated by multiplying the solar PV installed capacity (MW) by 0.2, which is the installed output (MW) of the BESS.

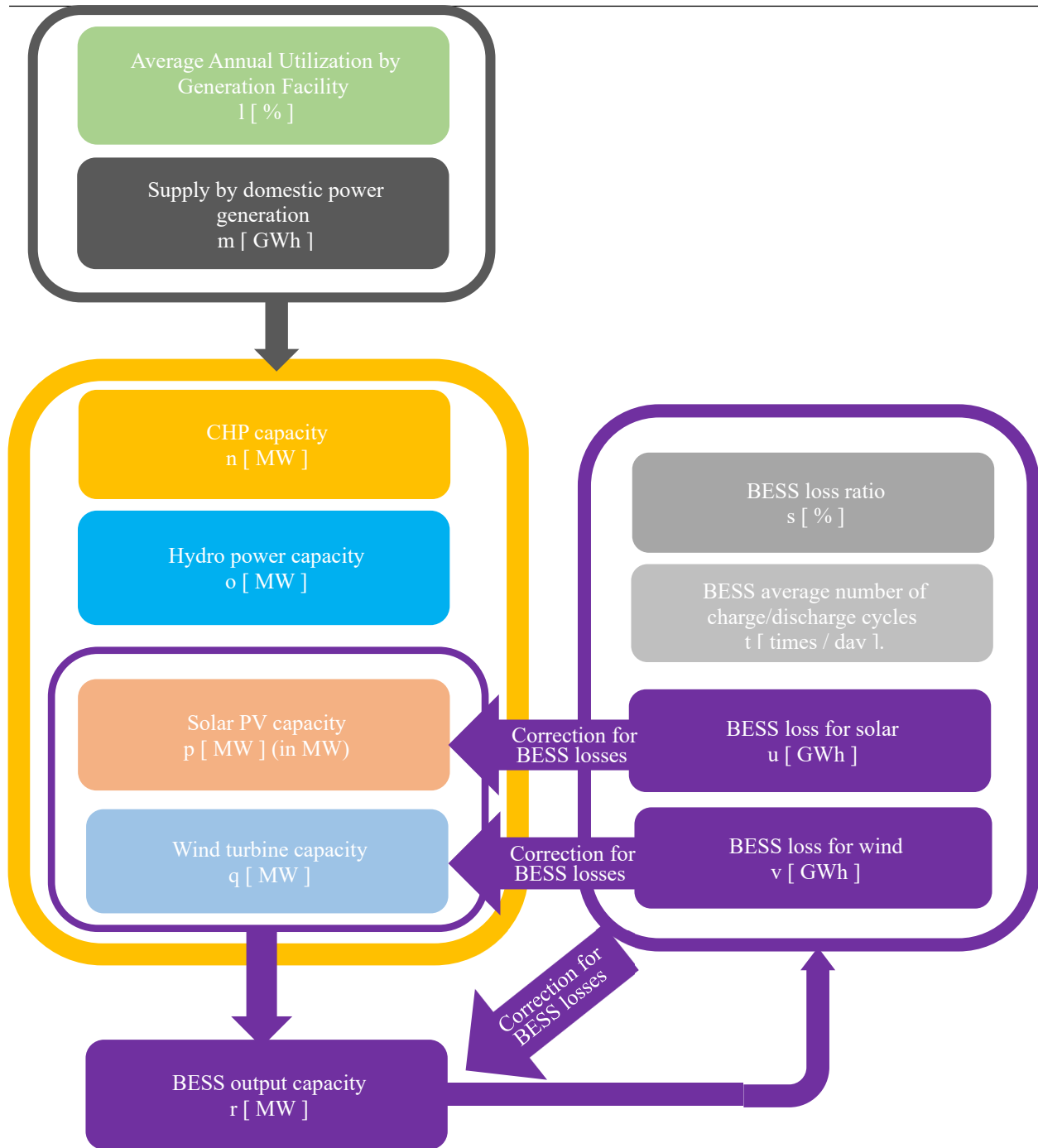
The output (MW) of the BESS for wind application is the wind installed capacity (MW) multiplied by 0.4, which is the installed output (MW) of the BESS.

The charge and discharge time capacity (Hour) for both is specified as 4 hours.

The installed capacities (MW) of PV and wind were corrected to compensate for the power loss of the BESS.

Finally, the BESS installed output (MW) was corrected to compensate for the BESS power losses.

The procedure for the BAU generation installed capacity assumptions is shown in Figure 6-6 and the study conditions are shown in Table 6-2.



Source: Prepared by the survey team

Figure 6-6 Procedures for Estimating the BAU Generation Capacity

Table 6-2 Study Conditions for Estimating the BAU Generation Capacity

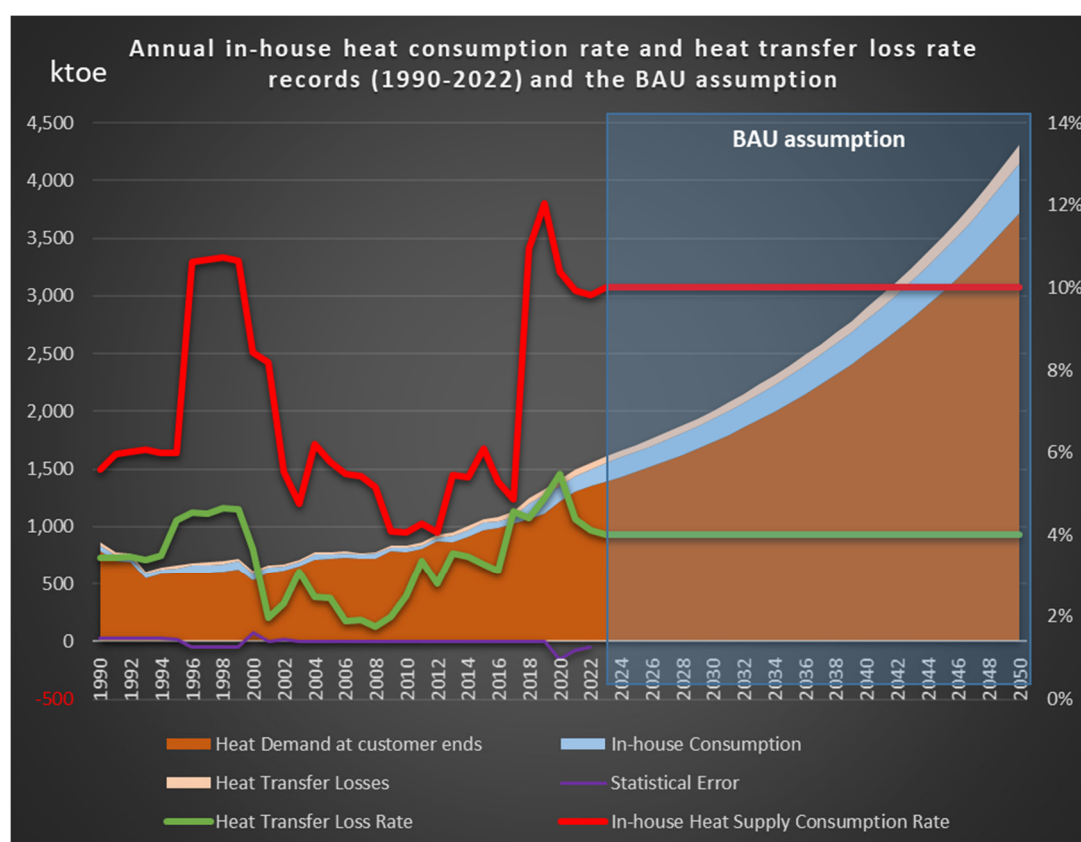
No.	Item Name	Unit	Conditions
1	Average annual utilization rate by power generation type Coal CHP	%	60% (assumed with some margin compared to actual 64% in 2023)
2	Average annual utilization rate by power generation type Hydro power (existing)	%	21.1% (on par with 2023 results)
3	Average annual utilization rate by generation type Solar PV	%	20.0% (on par with 2023 results)
4	Average annual utilization rate by power generation type Wind Turbine	%	39.1% (same as 2023) (on par with 2023 results)
5	Power loss rate of BESS	%	20% (typical value) (typical value)
6	Number of charge/discharge times per day for BESS	times/day	1.0 (assumption)

Source: Prepared by the survey team

(4) BAU Supply Assumptions for the Heat Supply System

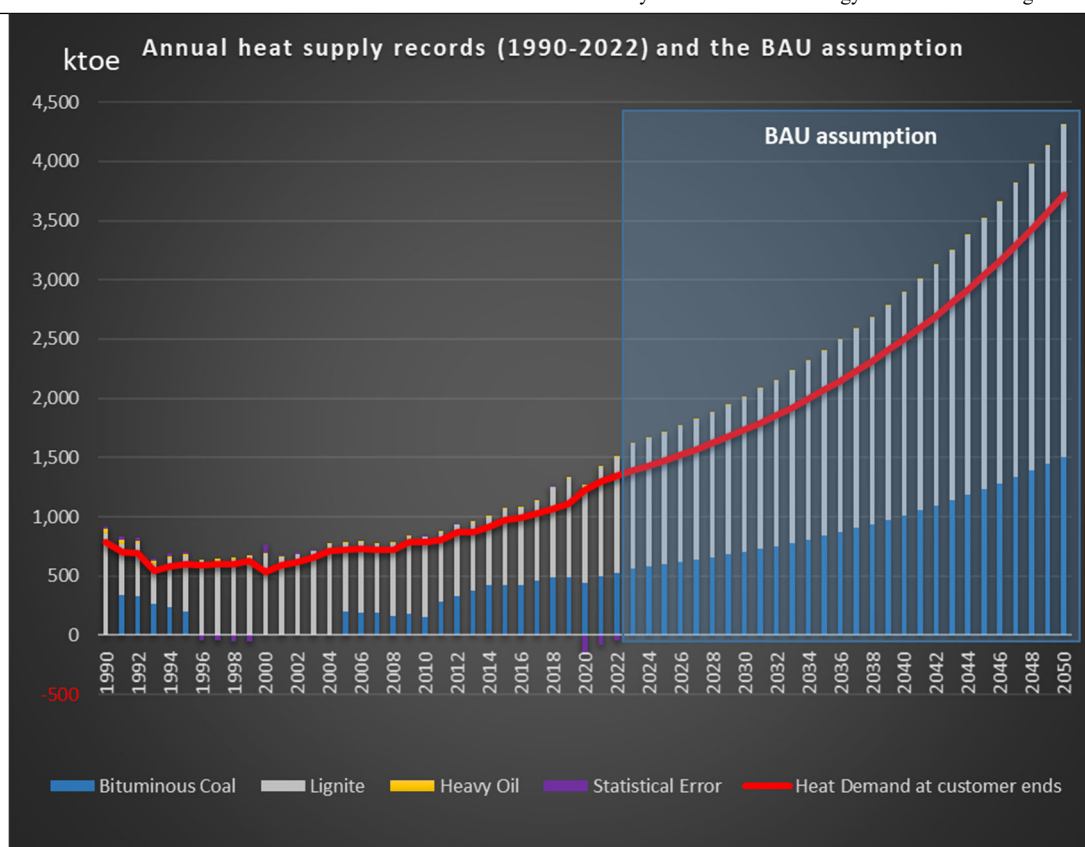
The actual heat in-house consumption rate and heat transfer loss rate of the heat supply system up to 2050 and the BAU forecast are shown in Figure 6-7.

In addition, the actual heat supply and BAU assumptions for the heat supply system are shown in Figure 6-8 and heat supply balance tables are shown in Table 6-3.



Source: Prepared by the survey team

Figure 6-7 Annual In-house Heat Consumption Rate and Heat Transfer Loss Rate Records and the BAU Assumption



Source: Prepared by the survey team

Figure 6-8 Annual Heat Supply Records and the BAU Assumption

Table 6-3 Heat Supply Balance

Unit: ktoe	2022 Actual	2030	2035	2040	2045	2050
Total heat supply	1,505	2,007	2,397	2,892	3,515	4,307
Bituminous coal	527 (35%)	702 (35%)	839 (35%)	1,012 (35%)	1,230 (35%)	1,507 (35%)
Lignite	977 (65%)	1,304 (65%)	1,558 (65%)	1,879 (65%)	2,284 (65%)	2,799 (65%)
Heavy oil	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
In-house consumption	148 (10%)	201 (10%)	240 (10%)	289 (10%)	352 (10%)	431 (10%)
Heat transfer loss	56 (4%)	72 (4%)	86 (4%)	104 (4%)	127 (4%)	155 (4%)
Statistical Error	-46	0	0	0	0	0
Heat demand at customer ends	1,348 (90%)	1,734 (86%)	2,071 (86%)	2,498 (86%)	3,037 (86%)	3,721 (86%)

Source: Prepared by the survey team

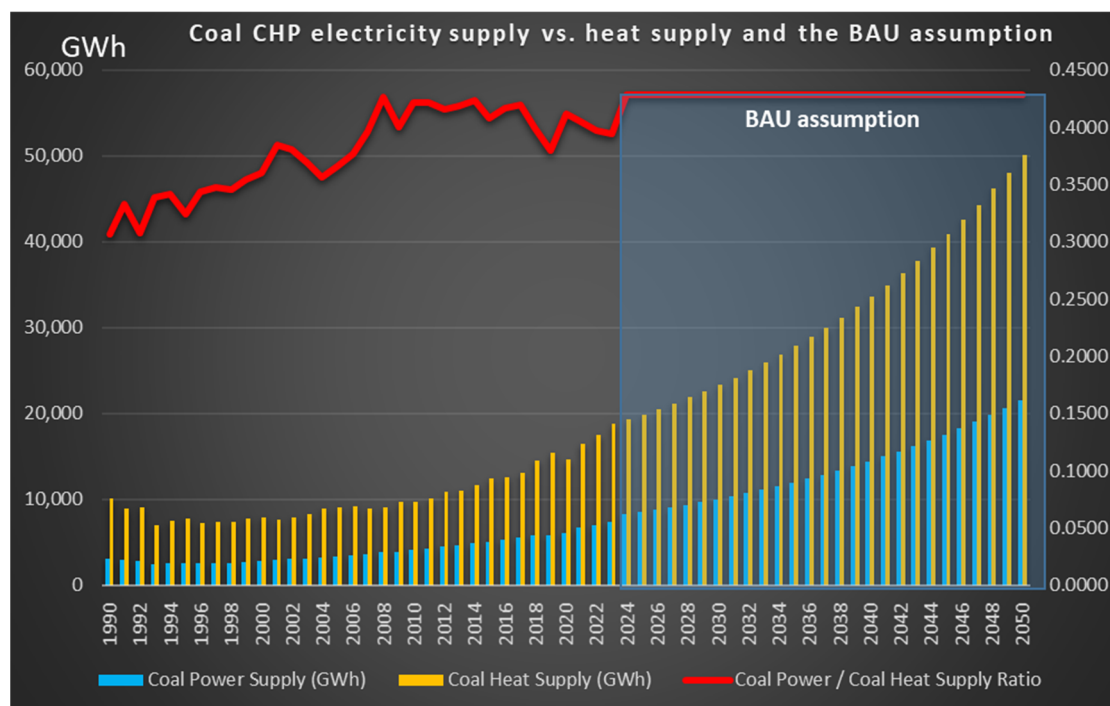
(5) BAU Supply Assumptions for the Electricity Supply System

The relationship between coal CHP electricity supply and heat supply is shown in Figure 6-9. Actual electricity supply system electricity in-house consumption rate and transmission and distribution loss rate through 2050 and BAU assumptions are shown in Figure 6-10.

In addition, actual power supply system power generation end generation, imports, and demand

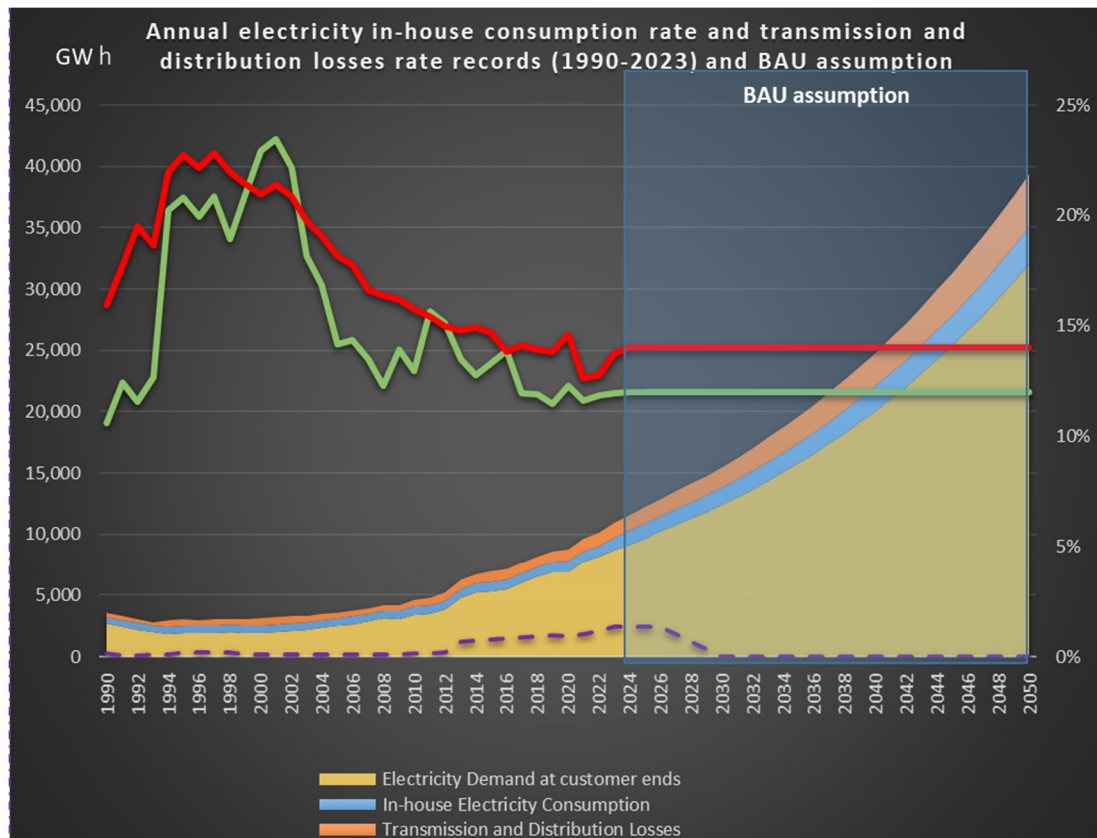
and BAU assumptions are shown in Figure 6-11. The electricity supply balance table is shown in Table 6-4, the composition ratio is shown in Figure 6-12., and the composition ratio table is shown in Table 6-5.

Comparing supply composition ratios on an energy basis (GWh) in 2023 and 2050, the composition ratio of coal CHP in 2023 will decrease from 67.6% to 54.5% in 2050, a decrease of 13.1 percentage points. Imports would decrease by 22.2 percentage points from 22.2% to 0%, PV would increase by 19.1 percentage points from 1.8% to 20.9%, and wind would increase by 19.1 percentage points from 4.9% to 20.9%. The RE share would increase by 38.4 percentage points from 7.1% to 45.5%.



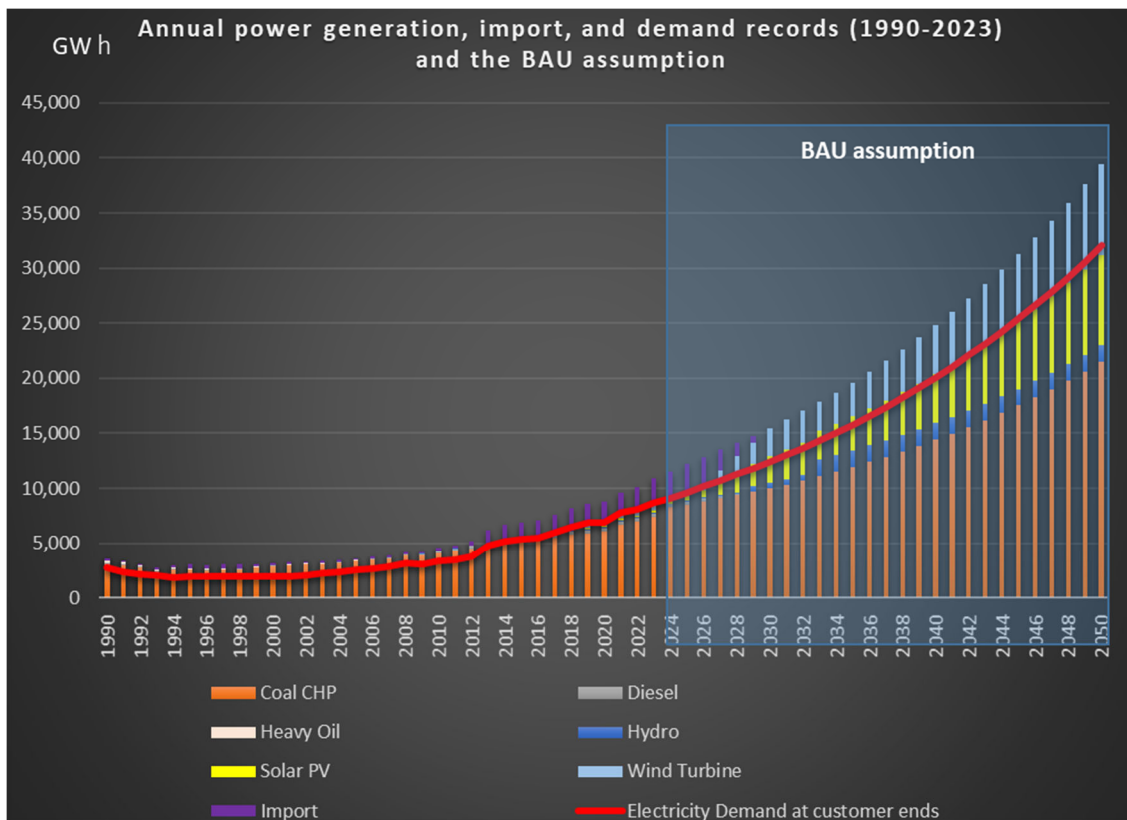
Source: Prepared by the survey team

Figure 6-9 Coal CHP Electricity Supply vs. Heat Supply and the BAU Assumption



Source: Prepared by the survey team

Figure 6-10 Annual Electricity In-house Consumption Rate and Transmission and Distribution Losses Rate and the BAU Assumption



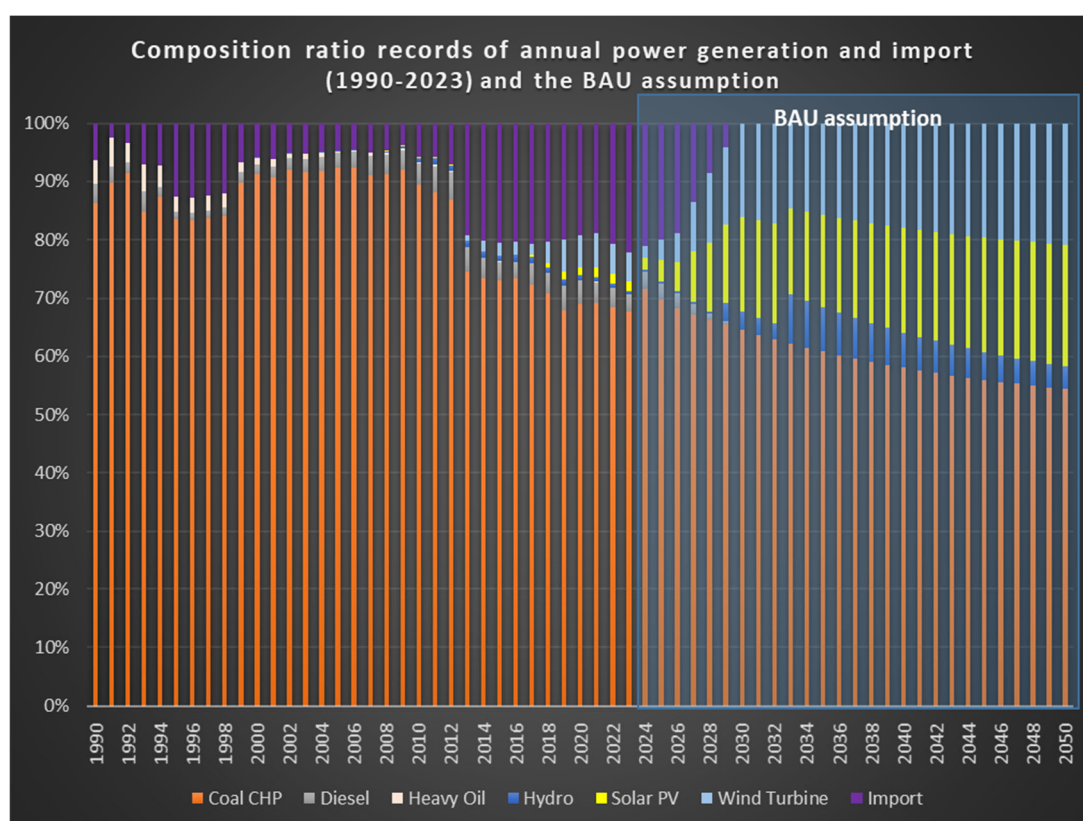
Source: Prepared by the survey team

Figure 6-11 Annual Power Generation, Imports, and Demand Records and the BAU Assumptions

Table 6-4 Electricity Supply Balance (Energy Basis) under the BAU Assumption

Unit : GWh	2023 Actual	2030	2035	2040	2045	2050
Domestic Power Generation at generator ends total	8,483	15,480	19,624	24,822	31,300	39,415
Coal CHP	7,377	9,996	11,943	14,408	17,516	21,462
Diesel PP	334	0	0	0	0	0
Heavy Oil	0	0	0	0	0	0
Hydro	48	473	1,504	1,504	1,504	1,504
Solar PV	193	2,505	3,088	4,455	6,140	8,225
Wind Turbine	532	2,505	3,088	4,455	6,140	8,225
Import	2,427	0	0	0	0	0
Total Supply	10,910	15,480	19,624	24,822	31,300	39,415
Electricity In-house consumption	1,059	1,399	1,672	2,017	2,452	3,005
Transmission and Distribution Losses	1,179	1,690	2,154	2,737	3,462	4,369
Electricity Demand at customer ends	8,672	12,390	15,798	20,068	25,386	32,041
Total Consumption	10,910	15,480	19,624	24,822	31,300	39,415
In-house Electricity Consumption Rate (Fossil fuels)	13.7%	14.0%	14.0%	14.0%	14.0%	14.0%
Transmission and Distribution Loss Rate	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%

Source: Prepared by the survey team



Source: Prepared by the survey team

Figure 6-12 Composition Ratio Records of Annual Power Generation and Import and the BAU Assumption

Table 6-5 Composition of Electricity Supply by Type (Energy Basis) under the BAU Assumption

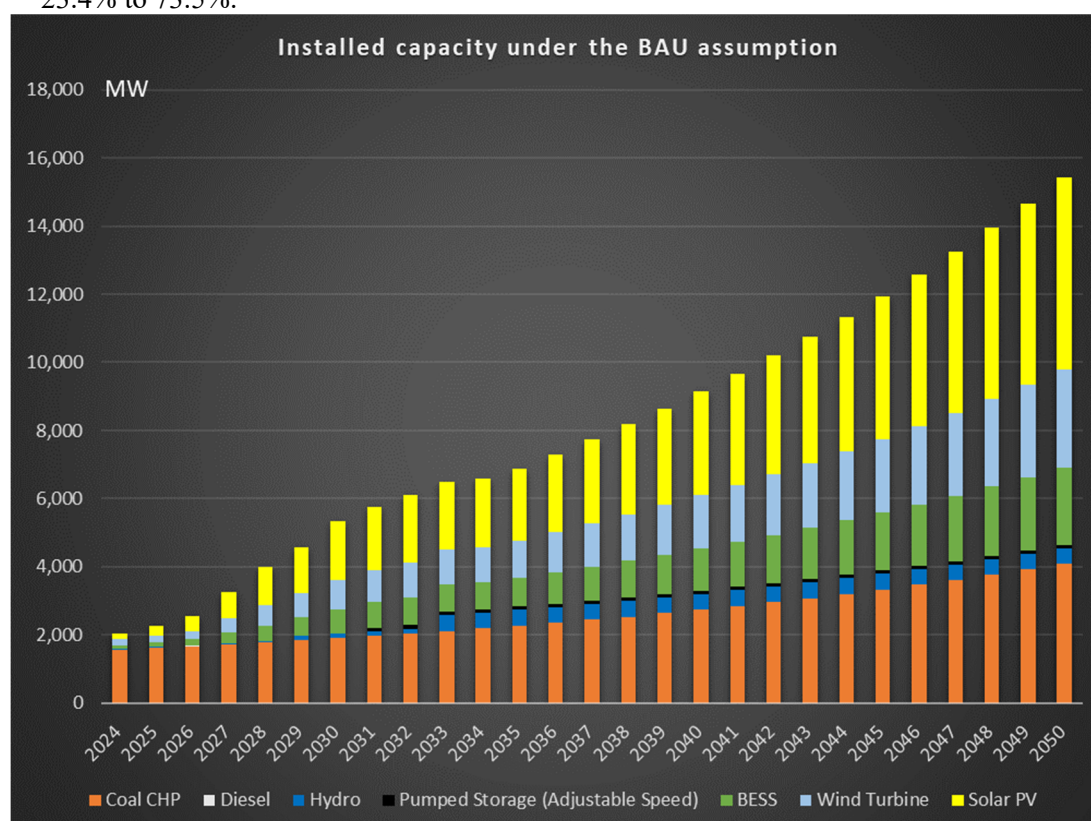
	2023 Actual	2030	2035	2040	2045	2050
Domestic power at generator ends total	77.8%	100.0%	100.0%	100.0%	100.0%	100.0%
Coal CHP	67.6%	64.6%	60.9%	58.0%	56.0%	54.5%
Diesel	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy oil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	0.4%	3.1%	7.7%	6.1%	4.8%	3.8%
Solar PV	1.8%	16.2%	15.7%	17.9%	19.6%	20.9%
Wind Turbine	4.9%	16.2%	15.7%	17.9%	19.6%	20.9%
Import	22.2%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Prepared by the survey team

(6) BAU Power Supply Capacity Projections

BAU assumptions for power supply equipment volume (MW) and composition are: Figure 6-13, Figure 6-14, Table 6-6, Table 6-7.

Comparing the composition of domestic installed power capacity (MW) in 2023 and 2050, the composition of coal CHP in 2023 will increase from 76.2% to 26.5% in 2050, a decrease of 49.7 percentage points. For solar PV, the share would increase 28.3 percentage points from 8.2% to 36.5%; for wind, 9.6 percentage points from 9.0% to 18.6%; for pumped storage (adjustable speed), 0.6 percentage points from 0% to 0.6%; and for BESS, 10.1 percentage points from 4.7% to 14.8%. The RE ratio including pumped storage and BESS will increase by 50.1 percentage points from 23.4% to 73.5%.



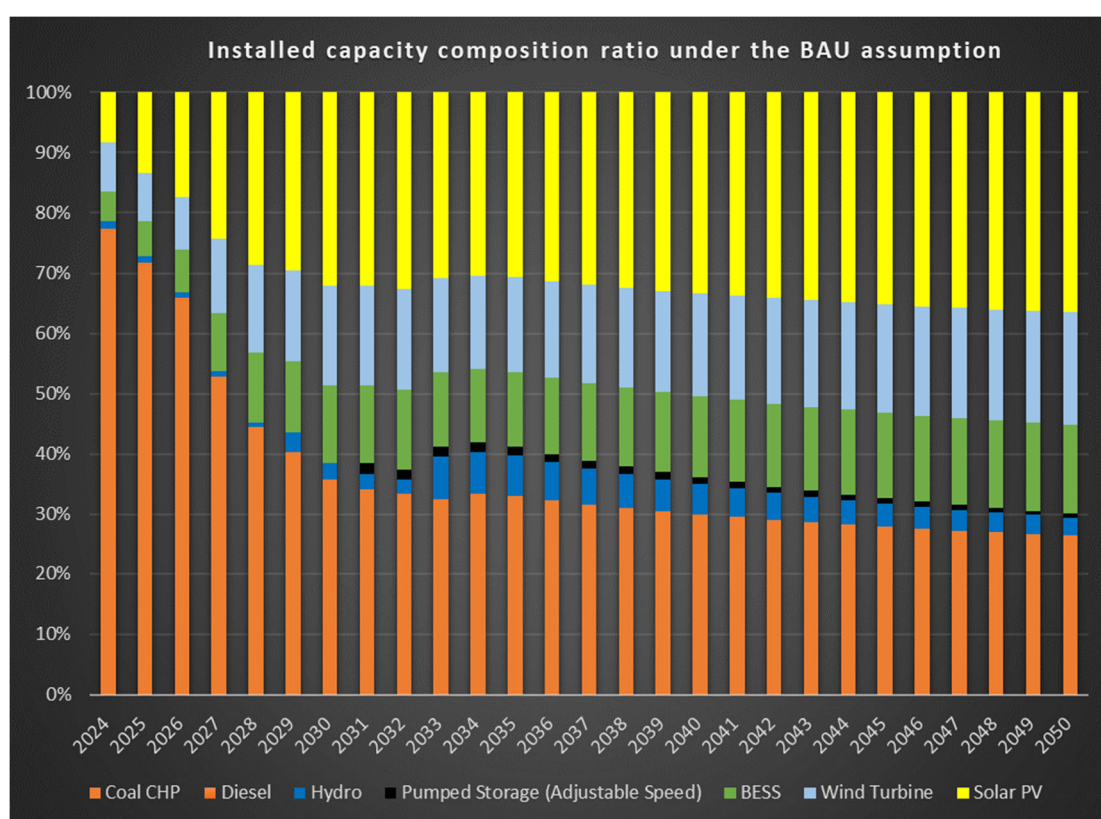
Source: Prepared by the survey team

Figure 6-13 Installed Capacity under the BAU Assumptions

Table 6-6 Installed Capacity under the BAU Assumption

Unit : MW	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,902	2,272	2,741	3,333	4,083
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	1,716	2,115	3,051	4,205	5,633
Wind Turbine	155	877	1,081	1,559	2,149	2,878
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	694	855	1,234	1,701	2,278
Total	1,724	5,334	6,885	9,146	11,948	15,434

Source: Prepared by the survey team



Source: Prepared by the survey team

Figure 6-14 Installed Capacity Composition Ratio under the BAU Assumption**Table 6-7 Installed Capacity Composition Ratio under the BAU Assumption**

	2023 Actual	2030	2035	2040 2045	2045	2050
Coal CHP	76.2%	35.7%	33.0%	30.0%	27.9%	26.5%
Diesel	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	1.5%	2.7%	6.7%	5.0%	3.9%	3.0%
Solar PV	8.2%	32.2%	30.7%	33.4%	35.2%	36.5%
Wind Turbine	9.0%	16.4%	15.7%	17.0%	18.0%	18.6%
Pumped Storage (Adjustable Speed)	0.0%	0.0%	1.5%	1.1%	0.8%	0.6%

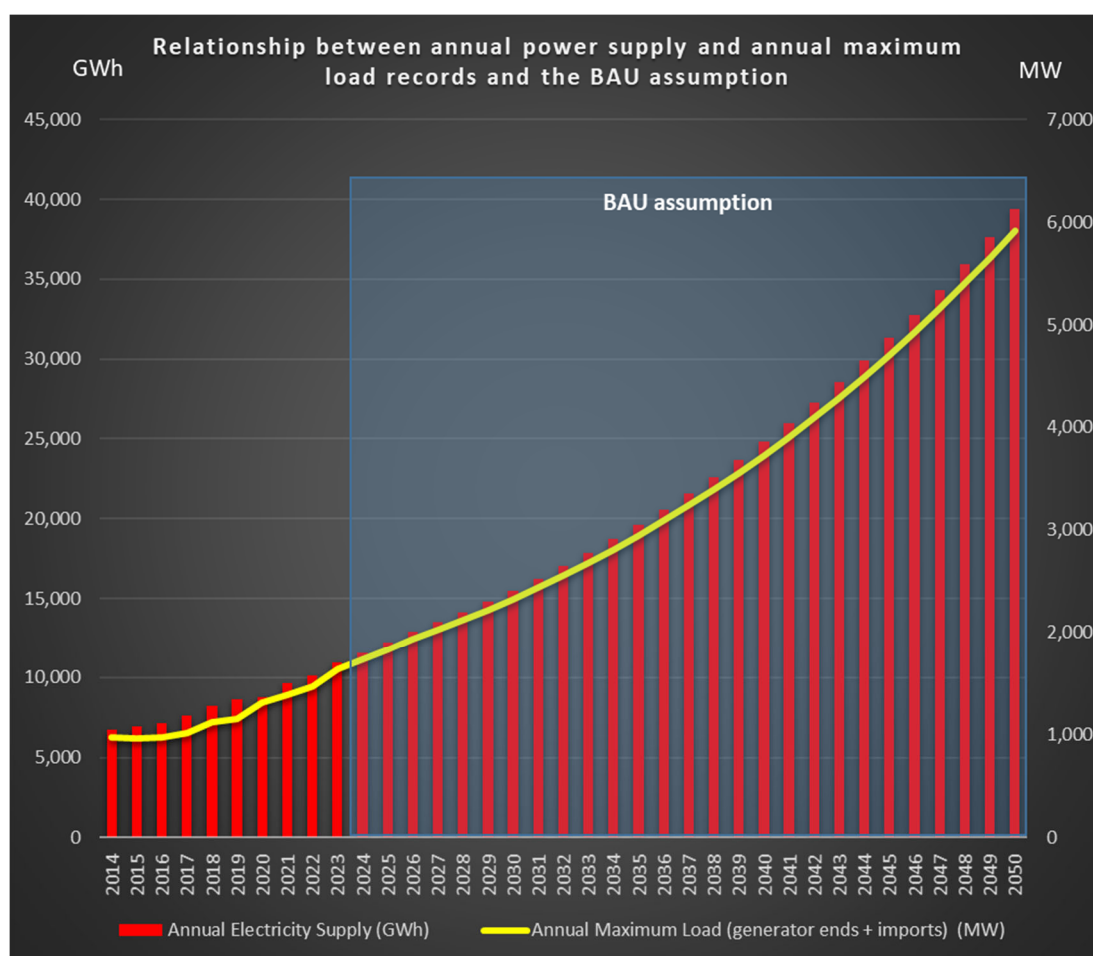
BESS	4.7%	13.0%	12.4%	13.5%	14.2%	14.8%
Total	100%	100%	100%	100%	100%	100%

Source: Prepared by the survey team

(7) Supply Reserves of the Electricity Supply System

Before examining the supply reserve of the electricity supply system, it is necessary to assume the annual maximum load (generator end output + imported power) (MW). Since the annual electricity supply (GWh) and the annual maximum load (generator end output + imported power) (MW) are correlated as shown in Figure 6-15, the assumed demand factor was determined from the actual demand factor and the annual maximum load was assumed based on this.

The demand factors for the years 2014-2023 are shown in Table 6-8. The smallest demand factors in 2020 and 2023 are 76.1%. Since a smaller demand factor means a larger maximum load and more stringent conditions in terms of facility planning, the demand factor for BAU was set to 76%, about the lowest 2023 level, as shown in Figure 6-16.



Source: Prepared by the survey team

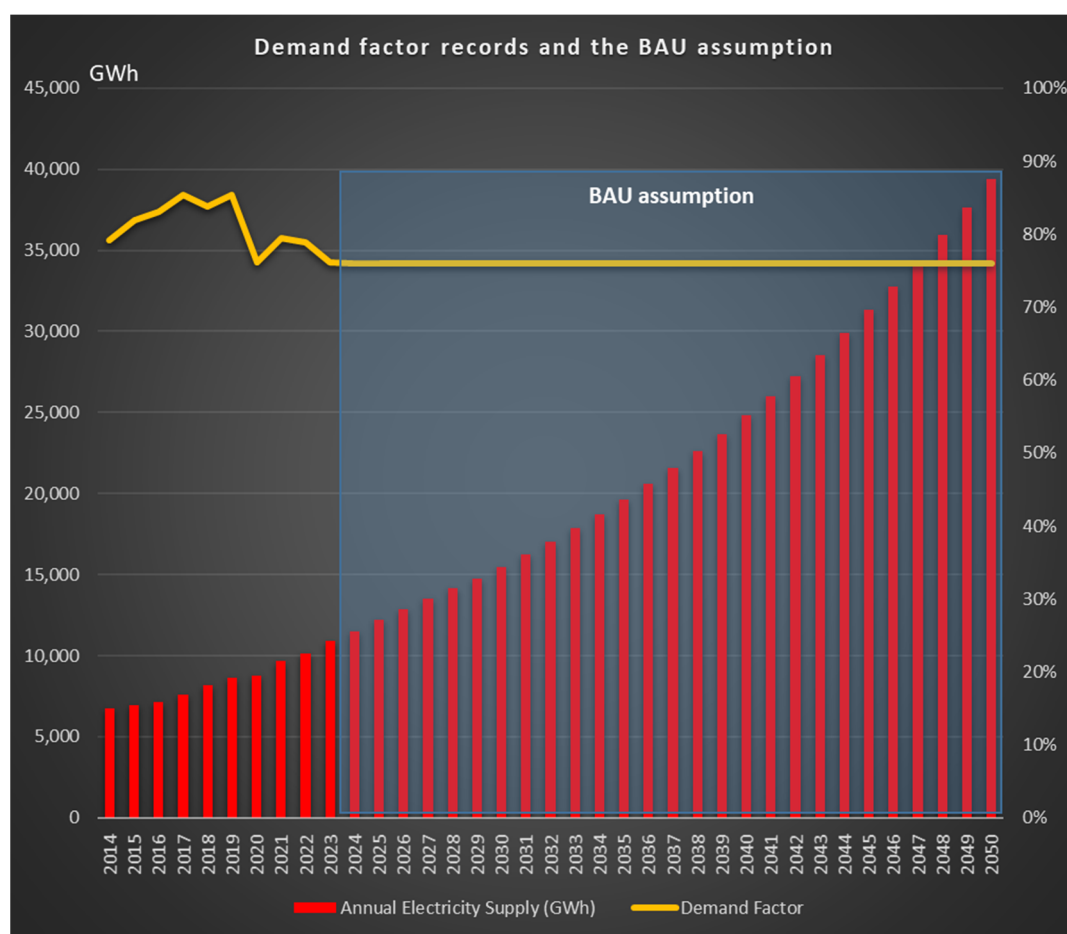
Figure 6-15 Relationship between Annual Power Supply (GWh) and Annual Maximum Load (MW) Records and the BAU Assumption

Table 6-8 Demand Factor Records

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Annual Electricity Supply (GWh)	6,725	6,930	7,113	7,602	8,200	8,622	8,755	9,648	10,142	10,910
Annual Maximum Load (generator end + import) (MW)	969	965	975	1,016	1,117	1,153	1,309	1,387	1,469	1,636
Import (MW) *Included in the above	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	294
Demand Factor	79.2%	82.0%	83.1%	85.4%	83.8%	85.4%	76.1%	79.4%	78.8%	76.1%

Note: Annual maximum load values are based on NDC data.

Source: Prepared by the survey team



Source: Prepared by the survey team

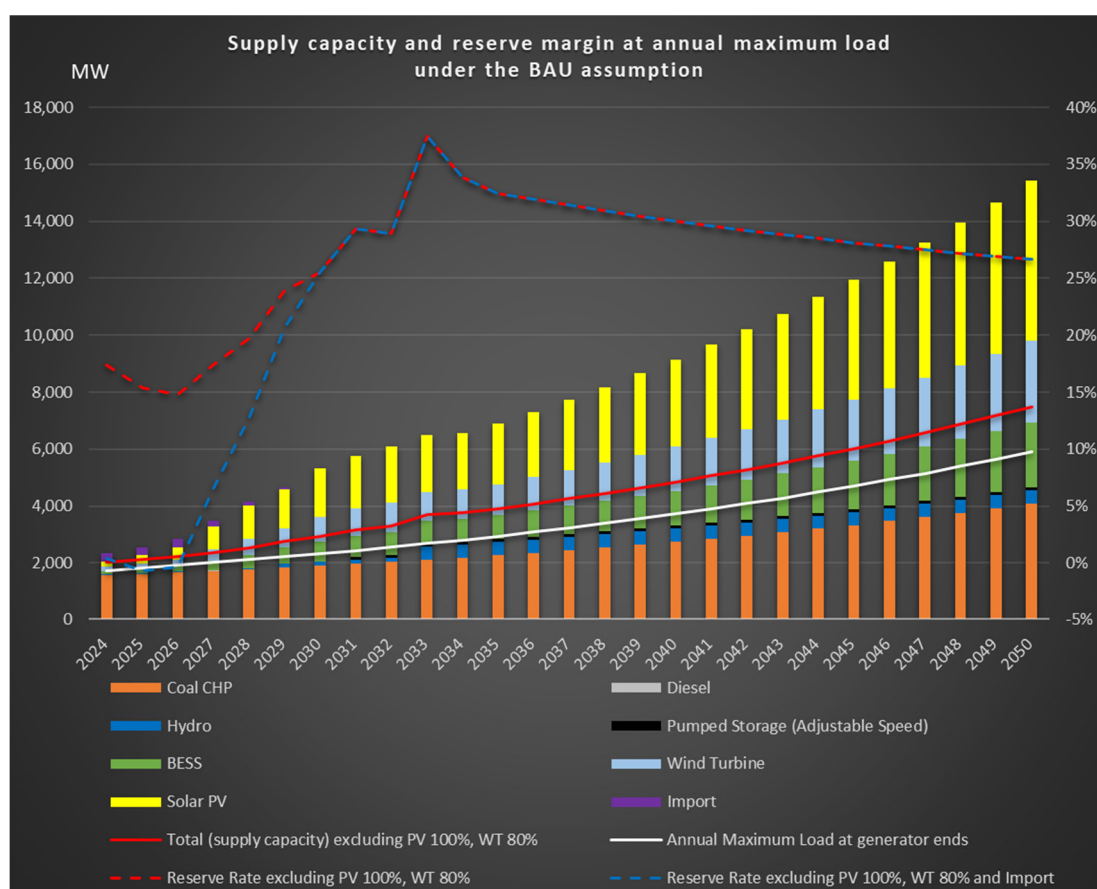
Figure 6-16 Demand Factor Records and the BAU Assumption

As for supply capacity, as with the calculation by NDC, PV was not factored into supply capacity, wind power was factored in at 20%, and BESS was factored in. Since the Mongolian government intends to suspend electricity imports by 2030, the reserve ratio until 2030 was also calculated with reference to the case where imported electricity is not factored in. The imported power was assumed to be the same as in 2023, due to the capacity limit of the transmission line, to be gradually decreased from 2023 levels through 2030.

The results of the supply reserve ratio calculations are shown in Figure 6-17 and Table 6-9.

Comparing the supply reserve ratio in 2023 and 2050, the reserve ratio excluding 100% solar PV and 80% of wind turbine in 2023 increases from 7.2% to 26.6% in 2050, an increase of 19.4 percentage points, due to the contribution of hydro and wind power development. In general, 10%

is an appropriate reserve. Note that excluding imported power, the reserve capacity will increase from -10.8% in 2023 to 26.6% in 2050, an increase of 37.4 percentage points.



Source: prepared by the survey team

Figure 6-17 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load under the BAU Assumption

Table 6-9 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load under the BAU Assumption

	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,902	2,272	2,741	3,333	4,083
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	1,716	2,115	3,051	4,205	5,633
Wind Turbine	155	877	1,081	1,559	2,149	2,878
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	694	855	1,234	1,701	2,278
Total capacity	1,724	5,334	6,885	9,146	11,948	15,434
Import	294	0	0	0	0	0
Total	2,018	5,334	6,885	9,146	11,948	15,434
Total (supply capacity) excluding PV 100%, WT 80%	1,753	2,917	3,905	4,848	6,024	7,498
Annual Maximum Load at generator ends	1,636	2,325	2,948	3,728	4,701	5,920
Reserve Rate excluding PV 100%, WT 80%	7.2%	25.5%	32.5%	30.0%	28.1%	26.6%
Reserve Rate excluding PV 100%, WT 80% and Import	-10.8%	25.5%	32.5%	30.0%	28.1%	26.6%

Source: Prepared by the survey team

6.2.3 BAU Projections of Energy Supply and Demand Structure

(1) Macroeconomic Forecast Results

The table below shows the results of the macroeconomic model projections. As stated in the assumptions, the economic growth rate from 2023 to 2029 will be based on the IMF's forecast, and from 2030 to 2050, the economic growth rate will fall from 5.5% to 5.0% due to the long-term development policy outlined in the national strategy "Long-Term Vision 2050." The industrial structure is projected in line with the actual structure and shows structural changes through 2050. Looking at individual industries, the services and mining sectors account for 24.8% and 23.0% of GDP, respectively, in 2023, with both sectors accounting for nearly half of GDP. The shares of both sectors increase by 0.4 and 2.9 percentage points, respectively, by 2050, making mining the sector that contributes the most to GDP. Manufacturing expands from 9.0% in 2023 to 10.7% in 2050, but manufacturing's contribution to GDP remains low.

Table 6-10 Macroeconomic Estimates (1990 - 2050)

	Units	Actual					Forecast			Average annual growth rate (%)	
		1990	2000	2010	2020	2023	2030	2040	2050	1990/2023	2023/2050
Real GDP	Billion	7,586	7,521	14,092	26,655	30,454	44,910	75,481	124,154	4.3	5.3
GDP Growth Rate	MNT %	-3.2	1.1	6.4	-4.6	7.0	5.5	5.2	5.0		
Industry Composition											
Agriculture, forestry and fisheries	%	12.5	27.4	11.7	13.0	13.0	12.2	11.3	10.6		
Mining	%	12.5	10.8	21.5	23.3	23.0	24.0	25.0	25.9		
Manufacturing	%	23.0	9.2	9.1	10.1	9.0	9.4	10.0	10.7		
Construction	%	5.7	2.2	2.6	3.7	3.3	3.3	3.3	3.3		
Transportation & Warehousing	%	9.8	7.6	6.9	3.8	4.7	4.6	4.4	4.3		
Service Industry	%	28.0	21.8	27.1	23.9	24.8	24.9	25.1	25.2		
Public	%	8.5	21.0	21.0	22.3	22.2	21.6	20.8	20.0		
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		

Source: 2000-2023: ADB, Key indicators for Asia and the Pacific 2023.

2024-2029: IMF Projection, April 2024.

2030-2050: Prepared by the survey team

For population, we estimated the urban and rural population and number of households based on the National Bureau of Statistics estimates, supplemented by ADB statistical data. The results are shown in the table below. Mongolia's population will increase at an average annual rate of 1.4% from 2023 to 2050, reaching 5,004,000 in 2050. the rural population accounted for a high 43.0% of the total population around 1990, but with increasing urbanization, the rural population will shrink to 27.0% in 2023 and further to 20.1% in 2050. The rural population will shrink to 27.0% in 2023 and 20.1% in 2050 due to urbanization. The urbanization trend, in which economic development relocates the rural population to the cities, is clearly seen in the number of households: the number of urban households increases from 680,000 in 2023 to 1.17 million in 2050, an average annual growth rate of 2.0%.

Table 6-11 Population Estimates (1990 - 2050)

	Units	Actual					Projection			Average annual	
		1990	2000	2010	2020	2023	2030	2040	2050	1990/2023	2023/2050
Population	million	215.3	237.5	265.4	325.3	339.7	376.7	433.3	500.4	1.4	1.4
Population Growth Rate	people %	5.4	2.7	1.2	1.8	0.8	1.3	1.5	1.4		
Urban Population	million	122.7	136.1	191.1	231.6	248.0	282.9	336.9	399.9	2.2	1.8
Rural Population	million people	92.7	101.3	74.3	93.7	91.7	93.8	96.5	100.5	-0.0	0.3
Urban Population Ratio	%	57.0	57.3	72.0	71.2	73.0	75.1	77.7	79.9		
Rural Population Ratio	%	43.0	42.7	28.0	28.8	27.0	24.9	22.3	20.1		
Households: Urban	10,000 households	24	30	46	61	68	79	97	117	3.2	2.0
Rural	10,000 households	20	25	28	30	31	33	35	38	1.3	0.9

Source: Prepared by the survey team

(2) Projected final energy demand (BAU)

1) By final energy sector

The table below summarizes the projected final energy demand by sector. Mongolia's final energy demand will increase at an average annual rate of 3.8% from 4,550 ktoe (1,000 tons of oil equivalent) in 2022 to 12,949 ktoe in 2050. The industrial sector (including mining) will be the largest energy demanding sector by 2050, accounting for 31.4% of total final energy demand. 22.5% will be used by households, 22.4% by transportation, 14.1% by business, and 1.3% by agriculture, forestry, and fisheries. In the industrial sector, mining accounts for a particularly large share.

Two points deserve special mention. First, only heat supply is included in commercial energy demand. In current statistical data, commercial electricity is included in the industrial category, making it impossible to separate it. Second, "other unknown" energy demand accounts for approximately 10%. "Other unknown" statistics are a characteristic of energy statistics in many developing countries, and represent energy demand that is unclearly classified due to an underdeveloped statistical data collection system. As statistical data collection systems improve, this phenomenon will gradually be returned to the sectors to which it should be classified. In Mongolia's case, energy consumed in the "other unknown" sector in 2023 will primarily consist of coal (70.8%) and electricity (18.0%).

Table 6-12 Energy Demand Projections by Final Energy Sector (BAU, 2000 - 2050)

	Unit	Actual				Projection			CAGR (%)	
		2000	2010	2020	2022	2030	2040	2050	2000/2022	2022/2050
Industry	ktoe	472	848	1,358	1,439	1,915	2,801	4,066	5.2	3.8
Transport	ktoe	321	478	934	1,017	1,543	2,308	2,899	5.4	3.8
Residential	ktoe	426	870	958	998	1,359	2,005	2,918	3.9	3.9
Commercial	ktoe	144	206	406	494	699	1,114	1,823	5.8	4.8
Agriculture	ktoe	27	62	107	103	119	140	163	6.3	1.6
Other	ktoe	73	207	398	499	663	864	1,081	9.1	2.8
Non-Energy	ktoe	2	3	0	0	0	0	0	-100.0	
Total	ktoe	1,465	2,674	4,161	4,550	6,297	9,233	12,949	5.3	3.8
Share (%)										
Industry	%	32.2	31.7	32.6	31.6	30.4	30.3	31.4		
Transport	%	21.9	17.9	22.4	22.4	24.5	25.0	22.4		
Residential	%	29.1	32.5	23.0	21.9	21.6	21.7	22.5		
Commercial	%	9.8	7.7	9.8	10.9	11.1	12.1	14.1		
Agriculture	%	1.8	2.3	2.6	2.3	1.9	1.5	1.3		
Other	%	5.0	7.7	9.6	11.0	10.5	9.4	8.3		
Non-Energy	%	0.1	0.1	0.0	0.0	0.0	0.0	0.0		
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0		

Source: Prepared by the survey team

2) By energy source

The table below summarizes the estimated final sector demand by energy source. Looking at demand by energy source in the final sector, the major changes in the period 2022-2050 are projected to be a contraction of biomass and an increase in the rate of electrification. 2050 shares of each energy source are: oil 31.8% (gasoline 13.7%, jet fuel 0.1%, diesel 18.0%), heat 28.7%, electricity 21.3%, coal 17.7% (coke 0.3%), and biomass 0.4%. Other characteristics can be summarized as follows.

- Coal demand increased at an average annual rate of 3.8% over the estimation period, accounting for 17.4% of final energy demand in 2050, up 0.1 percentage points from 17.3% in 2022. Half of coal consumption is consumed by the residential sector (50.5%),

15.5% by the industrial sector, and 33.9% by other unknown sources.

- Electricity and heat demand are the most important sources of energy supply. As the future electrification rate expands, electricity demand in the period 2022-2050 will increase at an average annual rate of 5.0%, reaching 2,755 ktoe in 2050, and its share of final energy demand will increase from 15.3% in 2022 to 21.3% in 2050. heat in 2050 If the share of demand (28.7%) is included, the share of thermoelectricity demand will reach 50.0%.
- In the transportation sector, diesel, gasoline, and jet fuel are the main fuels consumed. For diesel, demand increased at an average annual rate of 3.5% from 901 ktoe in 2022 to 2,332 ktoe in 2050, while gasoline demand increased at an average annual rate of 3.2% from 728 ktoe in 2022 to 1,775 ktoe in 2050. A small number of EV passenger cars (2030 target: 30,000) will be introduced as a result of Mongolian government policy guidance, and this electricity demand is accounted for in the forecast model.
- Biomass is consumed mainly in the household sector. While traditional biomass is the main source of energy for households (mainly in rural areas), many rural areas effectively use agricultural and livestock wastes as fuel. The model estimates a slight increase in biomass demand from 46 ktoe in 2022 to 48 ktoe in 2050.

Table 6-13 Final Energy Sector Demand Projections by Energy Source (BAU, 2000 - 2050)

	Unit	Actual				Projection			CAGR (%)	
		2000	2010	2020	2022	2030	2040	2050	2000/2022	2022/2050
Coal	ktoe	286	650	708	788	1,077	1,592	2,248	4.7	3.8
Coke	ktoe	0	71	17	28	33	37	41		1.4
Gasoline	ktoe	250	305	627	728	982	1,496	1,775	5.0	3.2
Jet Fuel	ktoe	0	0	1	2	16	17	17		7.9
Diesel	ktoe	149	458	942	901	1,330	1,807	2,332	8.5	3.5
Lubricant	ktoe	2	3	0	0	0	0	0	-100.0	
Biomass	ktoe	67	94	46	46	47	48	48	-1.7	0.2
Charcoal	ktoe	16	22	13	13	14	15	15	-0.9	0.6
Electricity	ktoe	164	290	586	696	1,065	1,726	2,755	6.8	5.0
Heat	ktoe	530	782	1,219	1,348	1,733	2,496	3,717	4.3	3.7
Total	ktoe	1,464	2,675	4,159	4,550	6,297	9,233	12,949	5.3	3.8
Share (%)										
Coal	%	19.5	24.3	17.0	17.3	17.1	17.2	17.4		
Coke	%	0.0	2.7	0.4	0.6	0.5	0.4	0.3		
Gasoline	%	17.1	11.4	15.1	16.0	15.6	16.2	13.7		
Jet Fuel	%	0.0	0.0	0.0	0.0	0.3	0.2	0.1		
Diesel	%	10.2	17.1	22.6	19.8	21.1	19.6	18.0		
Lubricant	%	0.1	0.1	0.0	0.0	0.0	0.0	0.0		
Biomass	%	4.6	3.5	1.1	1.0	0.7	0.5	0.4		
Charcoal	%	1.1	0.8	0.3	0.3	0.2	0.2	0.1		
Electricity	%	11.2	10.8	14.1	15.3	16.9	18.7	21.3		
Heat	%	36.2	29.2	29.3	29.6	27.5	27.0	28.7		
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0		

Source: Prepared by the survey team

(3) Primary Energy Supply (BAU)

The table below shows Mongolia's primary energy supply from 2000 to 2050. Primary energy supply increases at an average annual rate of 3.9% from 6,492 ktoe in 2022 to 18,854 ktoe in 2050. 2022- The average energy elasticity for the 2050 forecast period is 0.73. The GDP intensity of

primary energy consumption is reduced from 213toe/Billion MNT in 2022 to 152toe/Billion MNT in 2050, an improvement of about 28.7%. Other main characteristics are as follows.

- The composition of primary energy supply in 2050 is 69.2% coal, 21.8% petroleum, and 8.7% renewable energy, resulting in a 91.3% dependence on fossil fuels.
- Coal consumption will increase at an average annual rate of 4.0% from 4,366 ktoe in 2022 to 13,042 ktoe in 2050. About 80% of coal consumption is supplied to combined heat and power plants, and less than 20% of total coal consumption is in the final sector.
- Petroleum consumption is primarily gasoline and diesel in the transportation sector, and diesel consumption in the industrial sector. There is a small demand for jet fuel, but in small quantities. The agricultural sector also consumes a small amount of diesel.
- The share of renewable energy increases from 2.5% in 2022 to 8.7% in 2050, with solar PV and wind power each contributing 4.1% in 2050, and hydro and biomass power only slightly.

Table 6-14 Primary Energy Supply Projections (BAU, 2000 - 2050)

	Unit	Actual				Projection			CAGR (%)	
		2000	2010	2020	2022	2030	2040	2050	2000/2022	2022/2050
Coal	ktoe	1,817	2,806	3,874	4,366	6,105	8,839	13,042	4.1	4.0
Coke	ktoe	0	103	25	40	47	53	59		1.4
Oil	ktoe	434	830	1,698	1,742	2,316	3,308	4,115	6.5	3.1
Hydro	ktoe	0	3	7	5	4	4	4		-0.7
Solar	ktoe	0	1	10	16	234	446	770		14.8
Wind	ktoe	0	0	41	44	234	446	770		10.8
Biomass	ktoe	132	182	98	98	89	92	94	-1.3	-0.1
Electricity (import)	ktoe	13	21	141	179	0	0	0	12.7	-100.0
Total	ktoe	2,397	3,946	5,895	6,492	9,028	13,187	18,854	4.6	3.9
Share (%)										
Coal	%	75.8	71.1	65.7	67.3	67.6	67.0	69.2		
Coke	%	0.0	2.6	0.4	0.6	0.5	0.4	0.3		
Oil	%	18.1	21.0	28.8	26.8	25.7	25.1	21.8		
Hydro	%	0.0	0.1	0.1	0.1	0.0	0.0	0.0		
Solar	%	0.0	0.0	0.2	0.2	2.6	3.4	4.1		
Wind	%	0.0	0.0	0.7	0.7	2.6	3.4	4.1		
Biomass	%	5.5	4.6	1.7	1.5	1.0	0.7	0.5		
Electricity (import)	%	0.5	0.5	2.4	2.8	0.0	0.0	0.0		
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0		

Source: Prepared by the survey team

(4) Estimated greenhouse gas (CO₂equivalent) emissions (BAU)

Based on the above primary energy supply projection results, Mongolia's energy sector emissions of greenhouse gases (tons of carbon dioxide equivalent) are shown in the table below. Fossil fuel-derived GHG emissions from the energy sector will increase at an average annual rate of 3.8% from 23,898,000 t-CO₂ in 2022 to 67,793,000 t-CO₂ in 2050. Due to the structure of Mongolia's energy consumption, which is mainly coal-dependent, coal accounted for 81.7% of total CO₂ emissions in 2022 (0.3% was coke), while oil accounted for 18.3%. Mongolia's energy demand will continue to increase as its economy continues to grow, so its dependence on fossil fuels will remain high by 2050.

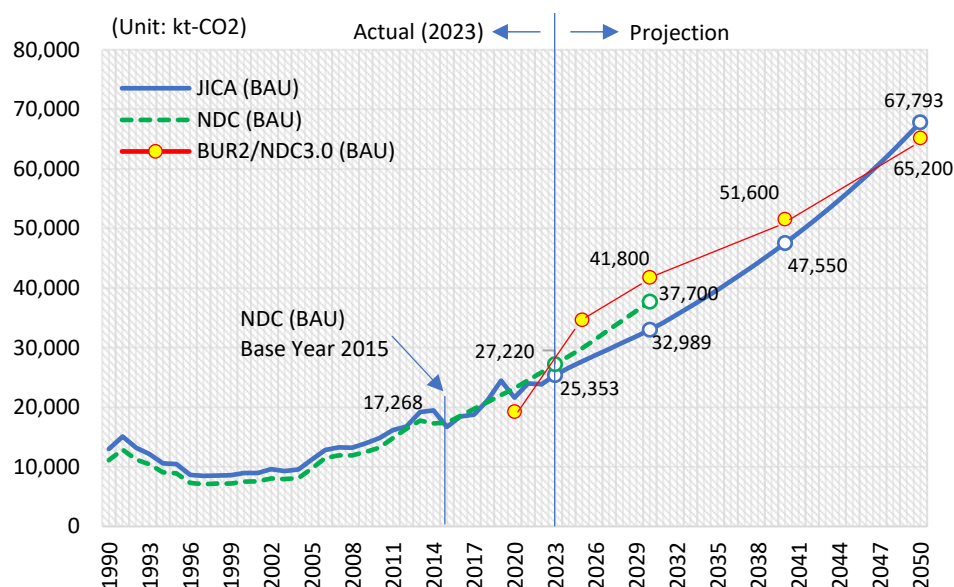
Table 6-15 Estimated CO₂ emissions from the energy sector (BAU, 2000 - 2050)

	Unit	Actual				Projection			CAGR (%)	
		2000	2010	2020	2022	2030	2040	2050	2000/2022	2022/2050
Coal	kt-CO ₂	7,683	11,866	16,382	18,462	25,816	37,377	55,150	4.1	4.0
Coke	kt-CO ₂	0	408	99	158	185	212	234		1.4
Oil	kt-CO ₂	1,298	2,511	5,127	5,277	6,987	9,962	12,409	6.6	3.1
Total	kt-CO ₂	8,982	14,785	21,608	23,898	32,989	47,550	67,793	4.5	3.8
Share (%)										
Coal	%	85.5	80.3	75.8	77.3	78.3	78.6	81.4		
Coke	%	0.0	2.8	0.5	0.7	0.6	0.4	0.3		
Oil	%	14.5	17.0	23.7	22.1	21.2	20.9	18.3		
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0		

Source: Prepared by the survey team

On the other hand, according to the National Determined Contributions (NDCs) submitted by the Mongolian government to the UNFCCC on September 21, 2016, CO₂ emissions from the energy sector through 2030 are shown to be 37.7 million t-CO₂ in the BAU case. In the latest Second Biennial Update Report (BUR2) submitted to the UNFCCC on November 15, 2023, and NDC 3.0 submitted on September 24, 2025⁵⁷, the BAU figure for 2030 was revised to 41.8 million t-CO₂, 51.6 million t-CO₂ for 2040, and 65.2 million t-CO₂ for 2040 and 65.2 million t-CO₂ for 2050.

In the BAU case of the project, CO₂ emissions up to 2023-2046 are slightly lower than in the BAU cases of NDCs and BUR2/NDC 3.0, but in 2047-2050, the project's estimates are slightly higher and reversed. The difference in the results is mainly due to the different time periods of the actual statistical data used: the actual data used for the NDCs estimation is up to 2014, while the actual data used for the BUR2/NDC 3.0 estimation is up to 2020. The projection for this project uses actual data for the year 2022, which clearly shows a decrease in energy demand due to the impact of COVID-19.



Source: Prepared by the survey team

Figure 6-18 NDC and BUR2/NDC3.0 vs. CO₂ emissions of this project estimate (1990 - 2050)

⁵⁷ The NDC 3.0 submitted to the UNFCCC on September 24, 2025, maintained the BAU case from BUR2 and did not calculate a new BAU. See "Mongolia NDC 3.0", page 7.
https://unfccc.int/sites/default/files/2025-09/Mongolia%20NDC3_0%20under%20UNFCCC_PA%20FINAL.pdf

6.3 Preparation of final energy consumption projections

6.3.1 Low-Carbon and Energy Efficiency Potential in the Industrial Sector

(1) Policies for Energy Transition under Industrial Decarbonization and Energy Efficiency Scenarios

In developing energy efficiency scenarios for the industrial sector, the following three energy transition policies were established to provide a long-term perspective through 2050, while taking into consideration the consistency with existing initiatives by national and local governments, as well as other donors, based on insights obtained from the trend survey.

1) (1) Leading Efforts in Electrification and Conversion to CN Fuels in the Mining Industry, and Promoting their Adoption Across Other Sectors

Small and medium-sized enterprises (SMEs), which account for 97% of the Mongolian economy, face financial and day-to-day operational difficulties in implementing medium- and long-term measures, while the mining industry, with its high energy consumption and capital strength, offers the most conducive environment for advancing decarbonization efforts within the industrial sector. Therefore, it is important for the Mongolian economy as a whole to decarbonize by taking the lead in promoting electrification and CN-fuel initiatives, thereby driving and contributing to the decarbonization of other industries. This is because, for example, mining equipment is often similar to construction equipment, and the trend toward electrification of mining equipment is likely to spread to the construction industry, where energy consumption is relatively high. Furthermore, the spread of CN fuels may ultimately affect the use of diesel in agriculture and other sectors, which in turn may spread to other sectors such as transportation, and the spillover effects of electrification and CN fuel conversion efforts are high.

2) Institutional and Systemic Development by the National Government for Decarbonization

Establishment and stabilization of electricity supply will be important to promote electrification and CN fuel conversion in the mining industry. Therefore, infrastructure must be provided to facilitate electrification, including grid expansion and the introduction of power sources and their subsidies. In addition, the subsequent decarbonization of power supply sources is expected to reduce GHG emissions in the industry as a whole.

Institutional support, such as carbon credits and energy efficiency market building, is important, as energy efficiency market building will contribute to improving the international competitiveness of industry, and carbon credits will create a trend toward decarbonizing markets. If the carbon credit market is functioning properly, the decarbonization of the entire industry can be anticipated for the greenhouse gases still remaining in 2050.

In addition, since it is difficult for SMEs to decarbonize toward CN on their own, they will need to be encouraged by a carbon tax and other incentives to obtain tax revenue, and supported by a decarbonization incentive system based on this incentive.

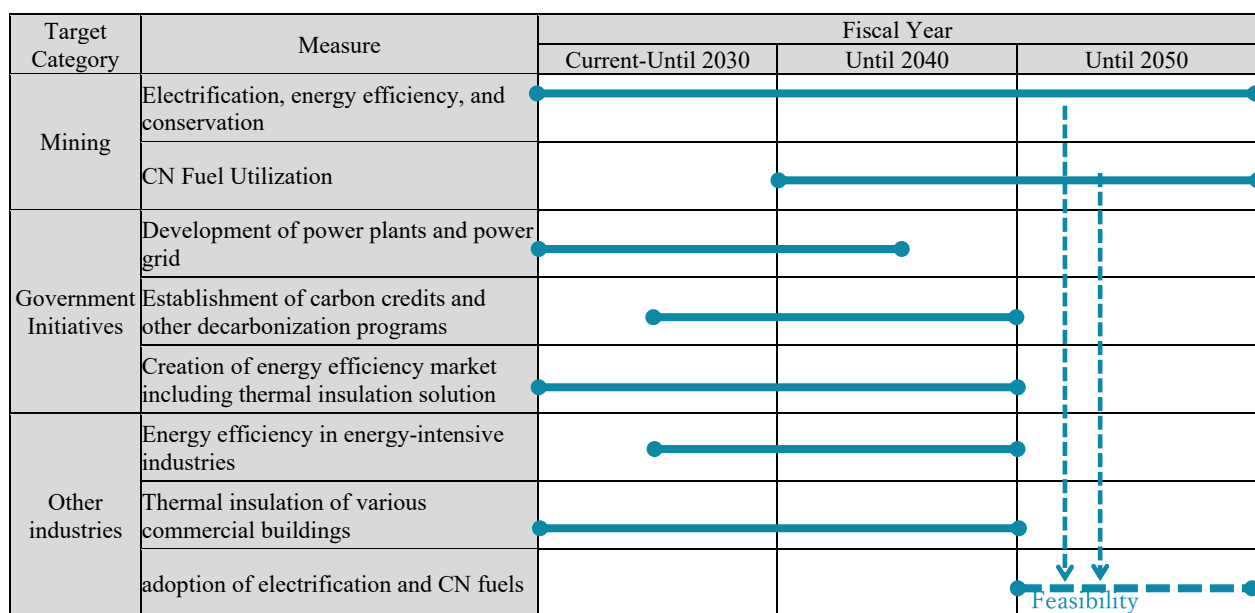
3) Promotion of Energy Efficiency in Other Industries

It will be important to promote the introduction of energy-efficient equipment in energy-intensive industries and insulation measures in individual SMEs. As far as can be ascertained, steel, chemicals, and cement are among the energy-intensive industries, and the introduction of energy-efficient technologies specific to these industries should be promoted. In particular, when new manufacturing industries emerge as a result of future industrial diversification and high value-adding, the introduction of energy-efficient equipment unique to their processes will be promoted as well. In addition, individual SMEs may be manufacturing in facilities that are connected to the

local heat supply but are not well insulated, and therefore, reducing thermal energy loss through insulation will be a major measure.

(2) Steps toward Decarbonization and Energy Efficiency

The following diagram shows the steps of decarbonization and energy efficiency based on the three policies presented above. By achieving decarbonization in the mining industry by 2050, it is intended that the spread of electrification and the use of CN fuels will extend to other industries; however, the realization of decarbonization in other industries without using carbon credits is expected to extend beyond 2050.



● Implementation period of improvement projects and related projects.

Source: Prepared by the survey team

Figure 6-19 Steps toward Decarbonization and Energy Efficiency

(3) Development of Decarbonization and Energy Efficiency Potential Scenarios

Decarbonization and energy efficiency potential scenarios for each major industry category were developed as shown in the table below. It is estimated that 1.5 million tons/year of refineries will be in operation by 2027, but this is not considered in this scenario due to the uncertainty of the project and the difficulty of predicting the amount and form of utilization on the demand side of products. Therefore, it should be noted that the scenario will require revision when petroleum products become more widely used.

In addition, the numerical targets in the decarbonization plans of major mines listed in the table are as follows, and it should be noted that, unless supply-side decarbonization is achieved by 2050, carbon neutrality will not be possible without the use of carbon credits.

2025: 30% reduction in CO₂ emissions (compared to 2018)

2030: 50% reduction compared to 2018

2050: Achieve 100% reduction (net zero), consisting of 77% direct CO₂ emission reductions and 23% through the purchase of RECs and carbon credits.

Table 6-16 Low Carbon and Energy Saving Potential Scenarios

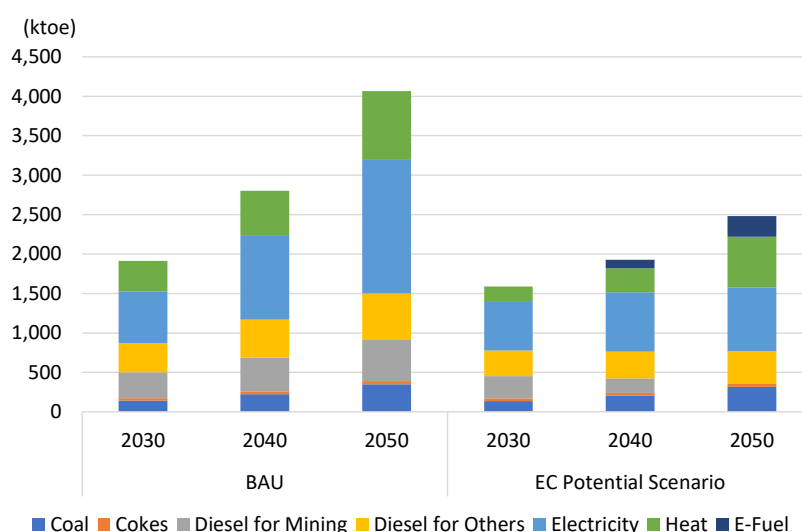
Classification	Energy Form	Energy efficiency and Decarbonization Potential Scenarios (Changes from the BAU case)	Rationale/Reason
Mining	Coal	✓ Electrification will shift all of energy use to electricity by 2050	✓ See decarbonization plans for major mines
	Coke	✓ No coke use at present and in the future	
	Diesel	✓ Electrification will shift 45% of energy use to electricity by 2050 ✓ A 5% reduction by 2050 due to efficiency improvements ✓ A 50% shift to CN fuels (produced by PTL) between 2030 and 2050 through the introduction of CN fuels	✓ See decarbonization plans of major mines ✓ Conservatively consider efficiency figures based on the fact that fuel-efficient construction equipment in Japan has a CO ₂ emission reduction rate of more than 10%.
	Electricity	✓ A 73.5% reduction between 2030 and 2050 through introduction of own renewable energy and other measures	✓ See decarbonization plans for major mines. ✓ Since Umnugobi's mining electricity demand is about 47% of the total, and the area is suitable for solar power, it is assumed that all electricity will be provided by introducing own renewable energy and storage batteries. ✓ In other areas (53%), it was assumed that the daytime (half-day) electricity would be self-supplied.
	Heat	✓ Electrification will shift all to electricity between 2030 and 2050.	✓ See decarbonization plans for major mines. ✓ Since heating of the mine tunnels and other areas is anticipated, it is assumed that these can be replaced with electric alternatives.
Heavy industry	Coal, diesel	✓ A 30% reduction by 2040 by improving production process efficiency and introducing energy-efficient equipment	✓ Assuming that energy is used in production activities, the maximum value was adopted from the energy consumption efficiency figures available in Japan, which showed a reduction of approximately 30% in energy consumption efficiency from 1970 to 1985, the period when energy conservation was at its most advanced.
	Coke	✓ A 15% reduction by 2050 by introducing energy-efficient equipment	✓ It is assumed that 50% of the use is for reductant purposes and 50% for energy supply, of which 30% is further reduced through the introduction of energy-efficient equipment. (Similar to Japan's energy consumption efficiency figures above)
	Electricity	✓ A 30% reduction by 2040 through the introduction of energy-efficient equipment	✓ Assuming use mainly in the steel industry (electric furnaces), and taking into account the CO ₂ reduction targets of major Japanese steel companies (30% reduction between 2013 and 2030)
	Heat	✓ A 45% reduction by 2040 through building insulation	✓ Assuming indoor heating, it corresponds to building insulation in other industries
Other industries	Coal	✓ A 37.5% reduction by 2040 through thermal insulation and introduction of energy-efficient equipment	✓ Assuming 50% of energy use is for indoor heating and 50% for production activities, and of the heating portion, 45% is reduced through thermal insulation, while 30% of the production portion is reduced through the installation of energy-efficient equipment.
	Coke	✓ No coke use at present and in the future	
	Diesel	✓ A 30% reduction by 2040 by improving production process efficiency and introducing energy-efficient equipment	✓ Assuming that it will be used in production activities, the maximum value used is the approximately 30% reduction in energy consumption efficiency achieved in Japan from 1970 to 1985.
	Electricity	✓ A 30% reduction by 2040 by improving production process efficiency and introducing energy-efficient equipment ✓ A 30% reduction by 2040 by introducing in-house renewable energy	✓ Assuming that it will be used in production activities, the maximum value used is the approximately 30% reduction in energy consumption efficiency achieved in Japan from 1970 to 1985. ✓ Refer to the report of a factory inspection case study, which showed that the introduction of renewable energy in the entire site area could cover up to 30% of the electricity demand.

	Heat	✓ A 45% reduction by 2040 through building insulation	✓ Follows the reduction rate of the private sector, which has been studied in detail and conservatively, although the factory studied states that 50% of heat can be reduced by insulation, even in winter.
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Source: Prepared by the survey team

(4) Estimation of Industrial Energy Consumption under Decarbonization and Energy Efficiency Potential Scenarios

Based on the BAU case, the industrial energy consumption forecast was estimated reflecting the decarbonization and energy efficiency potential scenarios described above. In this estimation, it is necessary to calculate the amount of coal, coke, diesel, electricity, and heat used in each industry category based on the IAEA's current and projected figures. For this reason, the year 2022, the latest year for which IAEA data is available, was used as the base year for the respective consumption volumes; then the allocation and calculation were made by referring to information such as total energy consumption by industry classification and energy consumption by designated operators, based on sources including "STATISTICS ON ENERGY PERFORMANCE 2023 (ENERGY REGULATORY COMMISSION)" and the National Statistics Office in Mongolia. Note that the establishment of more detailed and consistent energy statistics for industries will be a future issue for this estimation, as there were variations in the descriptions of industry classifications in various statistics, not allowing a uniform and consistent analysis.



Source: Prepared by the survey team

Figure 6-20 Industrial Energy Consumption Projections Reflecting Decarbonization and Energy Efficiency Potential Scenarios

6.3.2 Low-carbon and energy saving potential of the transportation sector

(1) Energy Transition Policies for the Transportation Sector

According to the IEA World Energy Statistics and Balances, 22.4% of Mongolia's energy consumption in 2022 will be consumed by the transportation sector, which is the second largest after the industrial sector with 31.6%. emissions in 2022, second only to the heat and power supply sector, which accounted for 12.8% of Mongolia's total CO₂ emissions and 65.1% of the country's total CO₂ emissions. Thus, low carbonization and energy saving in the transportation sector in Mongolia is a major challenge. Based on the current status of each transportation sector in Mongolia, JST examined the direction of energy transition in the road transportation, railroad, and airline sectors, which are major sources of energy consumption.

1) Road Transportation

Road transportation is expected to experience a rise in transportation demand, as the number of vehicles passing technical inspections has increased by 56.8% from 2018 to 2024 and is expected to continue to increase. Energy consumed by vehicles accounts for 71% of the transportation sector,

and the most significant challenge in achieving energy transition is how to achieve energy transition in vehicles. In this direction, it is necessary to promote the spread of HVs in the short term and EVs, FCVs, and hydrogen vehicles in the long term, and to develop vehicles with low environmental impact during operation based on the assumption that green electricity and green hydrogen will be supplied. Currently, the Ministry of Roads and Transport has announced plans to promote the introduction of EVs in Mongolia, but the replacement with EVs is limited.

FCVs are expected to be used mainly in FC trucks (Hydrogen fuel cell truck) and FC buses (Hydrogen fuel cell bus) for long-distance transportation, but there are currently no plans to introduce FCVs.

In the freight sector, a major source of emissions, older vehicles remain widely used. As part of urban air pollution countermeasures, the government requires imported vehicles to provide proof of compliance with emissions standards. While standards may be raised to Euro 6 levels in the future, however, replacement with zero-emission vehicles like EVs remains limited. In UB City, where traffic demand is particularly high and traffic congestion is a serious social issue, the road transportation network has not been able to keep up with the rapid increase in the number of vehicles coming into the city. However, the road transportation network has not kept pace with this growth, resulting in frequent traffic congestion and longer travel times. Therefore, a modal shift to public transportation is urgently needed, and it is highly necessary to develop mass transit systems, including metro and BRT, as soon as possible.

2) Rail Transportation

In rail transportation, transportation demand is expected to increase in the future, as Mongolian Railways is planning and constructing rail lines. The direction of energy transition is the electrification of railroads.

Currently, all railroad lines in Mongolia are non-electrified, and their energy efficiency is low compared to other countries' railroad networks. Although there is an intention to electrify the railways in the future, there is no concrete plan for the development of electrification. Therefore, it is necessary to formulate a concrete development plan to realize electrification at an early stage. In addition, electrification will require an increase in the supply of green power, mainly renewable energy, rather than the conventional internal combustion-fired power.

In the case of railroad electrification, there may be branch lines where transportation demand is not high and profitability cannot be fully expected, and fuel cell vehicles may be introduced on these lines.

As mentioned in the previous section, the current situation in which supply is not keeping up with demand for transportation, it is highly necessary to develop mass transit systems such as metro, BRT, tram, and cable cars in UB City, which is already under consideration.

3) Air Transportation

Air transportation is expected to continue to see an increase in transportation demand. As for the direction of energy transition, as indicated in the ICAO(International Civil Aviation Organization)'s policy, conversion to SAF is promising for long-haul routes. The introduction of SAF in aviation fuel has become an international effort, with the EU aiming to increase the use of SAF to 6% by 2030 and 70% by 2050. Mongolia is a member of the ICAO and is committed to reducing CO₂ emissions in accordance with ICAO policies.

CAAM is conducting research on SAF production to capture these trends. According to CAAM, it will explore the feasibility of domestic SAF production to leverage the potential of domestic renewable energy sources and eliminate import dependency for aviation fuel. In addition, MIAT Mongolian Airlines, the flag carrier of the country, has demonstrated 28 best practice initiatives for energy conservation, including shorter flight times, through the Open Air Lines service starting in 2023. Operational improvements include efforts to reduce energy consumption in existing

operations, such as flight path optimization, more efficient takeoffs and landings, and more efficient ground operations, as well as the introduction of advanced air traffic management systems.

Additionally, while aircraft technology development is underway in various countries, energy transition through the introduction of new technologies such as electric aircraft and fuel cell aircraft is conceivable for short- and medium-haul routes.

(2) Energy Conservation and Energy Transition Steps by Transportation Sector

Based on the above, Mongolia's energy transition steps in the transportation sector are shown in the table below. The currently planned measures in each sector are shown in black, and the measures that the study team discussed for energy transition are shown in red. While the timing is based on the hearings, the measures studied by the study team in red are timed to achieve the energy transition in 2050.

Table 6-17 Directions for Energy Transition in the Transportation Sector

Year		2025	2030	2035	2040	2045	2050
Road Transportation	Fossil fuel vehicles EVs and FCVs, Hydrogen Vehicles	20,000 EVs in 2026	2030_EV 130,000 units 2030_Stage transition of passenger cars, trucks, and buses to EVs and FCVs begins				Completion of conversion of passenger cars, trucks, and buses to EVs and FCVs
	UB City BRT Introduction of	2026_Start of construction	2030_Opening				
Rail transportation	Electrification of UB Railway		2030_Electrification project starts in the southern part of the country Start of electrification		2040_Electrification of 2040_Electrification project in the north		2050_Electrification of MN Railway completed
	Electrification of MN Railroad			2035_Start of electrification project		2045_Electrification of MN Railway completed	
	Electrification of private railroads			2035_Electrification project start		2045_Electrification of MN Railway completed	
	Introduction of UB City Metro	~2025 FS · Design 2026 Onward_Scheduled Construction Start	2030_Open for business				
	Introduction of UB City Tram	2025_Start of Line 1 & 2 construction	2027_Line 2 starts operation 2028_Line 1 starts operation				
Air Transportation	SAF introduction		2030_SAF introduction 6	2035_introduction of SAF 20	2040_SAF introduction 34	2045_SAF introduction 42	2050_SAF introduction SAF introduction 70 SAF reduces CO ₂ emissions by 55% of total air transportation
	Technological innovation (introduction of electrification, use of hydrogen, etc.)					New technology 21 Contribution to CO ₂ reduction	
	Improvement of flight operation		2030_5% by operation improvement CO ₂ reduction contribution	2035_Improvement of flight operation contributes to 11% CO ₂ reduction			
Other	UB City Cable car Introduction of	2024_Start of Line 1 construction 2025_Start of Line 2 construction	2026_Line 1 starts operation 2027_Line 2 begins operation				

Source: Prepared by the survey team

(3) Establishment of low-carbon and energy-saving potentials by transportation sector

The "introduction of UB City BRT" and "promotion of conversion of fossil fuel vehicles to HVs, EVs, FCVs, and hydrogen vehicles" are on the menu for energy conservation and energy conversion in the road transportation sector. The introduction of the UB City BRT will contribute to a reduction in the number of passenger cars and the distance they travel. The "promotion of the introduction of HVs, EVs, FCVs, and hydrogen vehicles" will gradually reduce the consumption of fossil fuels by promoting the spread of HVs in the short term and EVs, FCVs, and hydrogen vehicles in the long term, thereby eliminating the use of fossil fuels in the future. The electricity and hydrogen consumed by the replaced EVs and FCVs will be derived from renewable energy sources to achieve energy transition in the road transportation sector.

The menu of energy conservation and energy transition in rail transportation includes "introduction of UB City Metro", "introduction of UB City Tram", and "conversion of road freight to rail transportation". These will achieve energy savings by converting road transportation to energy-efficient rail transportation through the introduction of mass transit and a change in transportation methods.

The menu of energy conservation and energy conversion for air transportation includes "introduction of SAF," "technological innovation," and "operational improvement. The "introduction of SAF" is to gradually increase the ratio of SAF in aviation fuel to 70% by 2050, which will contribute to a 55% reduction in overall CO₂ emissions from air transportation, "technological innovation" is to reduce CO₂ emissions by 21% through the adoption of innovative aviation technologies, and "operational improvement" is to reduce CO₂ emissions by 11% through rational aviation operations. emissions by 11% through streamlined airline operations.

Other energy-saving and energy-conversion measures in transportation include the "introduction of the UB City Cable Car". The cable car will contribute to energy conservation by reducing the traffic volume of passenger cars and buses. In addition, ET will be achieved by using electricity consumed by the cable car from renewable energy sources.

Table 6-18 Establishing Low Carbon and Energy Saving Potential by Transportation Sector

Sector	Energy Saving/ ET Sectors to be	Initiatives	Low-carbon and energy saving potential
Road Passenger	Rail passengers	Introduction of BRT in UB cities	✓ Reduce passenger car traffic by introducing BRT.
Road Transportation	Overall road transportation	Promote shift from fossil fuel vehicles to HV, EV, FCV, and hydrogen vehicles	✓ In the short term, increase the proportion of HVs. ✓ Gasoline vehicles will be gradually reduced and by 2050 all gasoline vehicles will be converted to EVs, FCVs, and hydrogen vehicles. ✓ Achieve ET in road transportation by using renewable energy sources for electricity and hydrogen consumption.
Rail passengers	Overall road transportation	Introduction of UB City Metro	✓ Reduce the amount of passenger cars, buses, and other traffic by introducing a metro system.
	Road Passenger	Introduction of UB City Tram	✓ Reduce the amount of traffic such as passenger cars and buses by introducing streetcars.
Rail freight	Road freight	Conversion of road freight to rail freight	✓ Promote conversion to rail freight with better energy efficiency indicators.
Overall rail transportation	Overall rail transportation	Electrification of railroads	✓ Achieve ET by ensuring that electricity consumed by rail is of renewable energy origin.
Air transportation as a whole	Air transportation as a whole	Introduction of SAF	✓ Replace 70% of aviation fuel with SAF by 2050, contributing to a 55% reduction in overall air transportation CO ₂ emissions.
		Technological Innovation	✓ Contribute to a 21% reduction in CO ₂ emissions by 2050.
		Operational Improvement	✓ Contribute to an 11% reduction in CO ₂ emissions by 2050.
Others	Road Passenger	Introduction of cable cars in UB City	✓ Reduce traffic volume of passenger cars and buses by introducing cable cars. ✓ ET will be achieved by using electricity consumed by cable cars that is derived from renewable energy sources.

Source: Prepared by the survey team

The table below shows the estimated energy conversion for each menu.

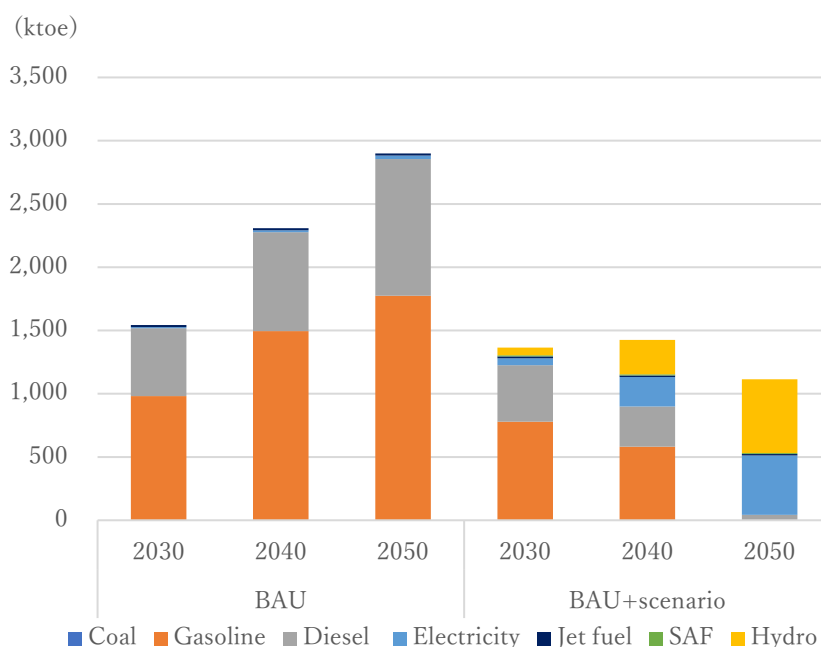
Table 6-19 Energy Conversion by Transportation Sector

Sector	Initiatives	Converted Energy (GJ)
Road transportation	Promote conversion from fossil fuel vehicles to HVs, EVs, FCVs, and hydrogen vehicles	86,722,702
	Introduction of BRT in UB cities	197,723
	Conversion of freight vehicles to rail transportation	
Rail transportation	Electrification of railroads	5,994,743
	Introduction of UB City Metro	121,197
	Introduction of UB City Tram	1,415,898
Air Transportation	Introduction of SAF	0
	Technology Innovation	147,280
	Operational Improvements	77,147
Other Transportation	Introduction of UB City Cable Car	483

Source: Prepared by the survey team

(4) Calculation of energy consumption forecasts for the transportation sector under low-carbon and energy-saving potential scenarios

Based on the BAU case, JST forecasted energy consumption in the transportation sector, reflecting the low-carbon and energy-saving potential scenarios described above. The results are shown below.



Source: Prepared by the survey team

Figure 6-21 Energy consumption forecast for the transportation sector reflecting low-carbon and energy-saving potential scenarios

6.3.3 Decarbonization and energy efficiency potential of the private sector

(1) Energy Transition Policies in the Decarbonization and Energy Efficiency Scenarios for the

Private Sector

In developing energy efficiency and decarbonization scenarios for the private sector, the following three energy transition policies were established to provide a long-term perspective through 2050, while taking into consideration the consistency with existing initiatives by national and local governments, as well as other donors, based on the insights obtained from the trend survey.

1) Continuous Promotion of Energy Efficiency and Renewable Energy

Building insulation refurbishment has been carried out on a large scale for existing buildings with the support of the GIZ and the EU, and this initiative is expected to continue progressing steadily in the future. In addition, the current government and UB City are advocating an increase in the number of buildings with green building certification, and as indicated in the issue analysis, energy efficiency regulations for new buildings are expected to be realized as an extension of this trend. In addition, the government anticipates realizing the energy-generating potential of ZEB/ZEH in the future, based on the fact that green building initiatives and the promotion of ZEB/ZEH are not mutually exclusive, but can be harmonized.

2) Government-led and Proactive Development

As indicated in the status survey, a favorable market is being established for some energy-efficient products, such as thermal insulation materials, for which good performance and low cost are highly regarded; however, a favorable market has not yet been established for ground source heatpumps, insulated windows, and other energy-efficient equipment, and accessibility is restricted for builders and other related parties. It would be effective to introduce such technologies for which markets have not yet been established by introducing them in government buildings ahead of others, or by gradually applying regulations to promote the healthy growth of the market. The energy transition direction is based on the premise that such government-led and proactive initiatives will improve the accessibility of technology to the private sector, and new technologies will be introduced starting with public buildings.

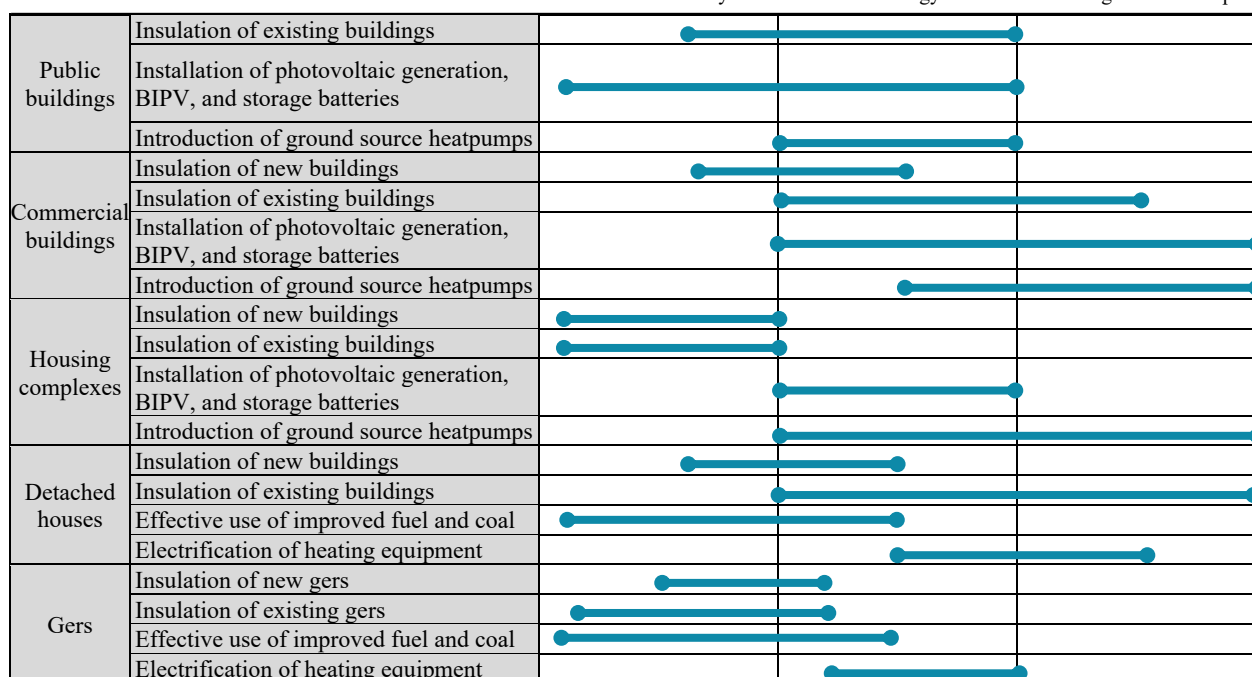
3) Transition to Electric Heating and away From Coal

As mentioned in the current situation survey, the use of coal stoves has a significant impact on urban air pollution due to smoke emissions, and there is an urgent need to reduce or eliminate the use of coal stoves. On the other hand, the current survey suggests that the use of coal stoves is limited to men or adults due to the risk of fire and carbon monoxide poisoning, which has a negative impact on the lives and livelihoods of single mothers and other vulnerable groups in society. Since transitioning to electric heating is considered the most effective measure to reduce air pollution—especially while promoting its widespread adoption among such households—the policy aims to eliminate the use of coal stoves entirely by 2050 and replace them with electric stoves.

(2) Steps toward Decarbonization and Energy Efficiency for Each Target Building

The following diagram shows the steps toward energy efficiency for each target building based on the three policies presented above. While new buildings are expected to shift relatively quickly due to the implementation of legal systems and supportive measures, existing buildings are difficult to insulate and will be retrofitted at the time of building renewal, so the timing cannot be controlled. Therefore, it is scheduled to be implemented after measures for new buildings, and the project period is also set to be longer than that for new buildings.

Target Category	Measure	Fiscal Year		
		Current-Until 2030	Until 2040	Until 2050
	Insulation of new buildings			



● : Period of implementation for improvement projects and associated measures

Source: Prepared by the survey team

Figure 6-22 Steps toward Energy Efficiency for Each Target Building

(3) Defining Decarbonization and Energy Efficiency Potentials by Energy Type

The decarbonization and energy efficiency potentials of various technologies were set as shown in the following two tables, referring to the energy-saving effects of existing literature.

Table 6-20 Decarbonization and Energy Efficiency Potentials of Various Technologies

Energy-saving technology	Reduction target	Reduction rate
Insulation of new buildings	Heating energy consumption	45%
Insulation of existing buildings	Heating energy consumption	45%
Introduction of photovoltaic generation, BIPV, and storage batteries	Electric energy consumption	25%
Introduction of ground source heatpumps	Heating energy consumption	25%
Electrification of heating equipment	Coal consumption	Converted to electricity usage
Insulation of new gers	Heating energy consumption	25%
Insulation of existing gers	Heating energy consumption	25%
Effective use of improved fuel and coal	Coal consumption	20% (shift to biomass)

Source: Prepared by the survey team

Table 6-21 Basis for Setting Decarbonization and Energy Efficiency Potentials

Energy efficiency technologies	Basis for setting
Insulation of buildings	✓ In the Japanese ZEB design guidelines, a 50% reduction from the reference primary energy consumption is advocated through energy efficiency to achieve ZEB Ready.
	✓ On the other hand, in the Mongolian building retrofit demonstration, approximately 42% to 58% energy savings were achieved by insulation alone, and more than half of them were below 50%, so 45% (achieved in 90% of the demonstration facilities) was

	adopted as the safe side. ⁵⁸	
Introduction of photovoltaic generation, BIPV, and storage batteries	✓	In order to achieve Nearly ZEB, the Japanese ZEB design guidelines advocate a 75% reduction from the reference primary energy consumption by promoting energy efficiency and renewable energy for ZEB Ready.
	✓	Considering that 50% of the energy savings in Japan are achieved through ZEB Ready standards, and taking into account the spread of BIPV, the share of renewable energy was set at 25%.
Introduction of ground source heatpumps	✓	The project targets new buildings because it is difficult to install ground source heatpumps in urban areas where existing structures are present due to site conditions.
	✓	In Norway, where ground source heatpumps are most widely adopted and installed in roughly one out of every four households ⁵⁹ , a 25% adoption rate was assumed.
	✓	Since COP 2.97 has been achieved in the case of General Heat Pump Industry, it is assumed that 1/3 of the heat quantity is converted to electricity.
Electrification of heating equipment	✓	By installing electric heaters, it is assumed that the energy used for coal will be converted to electricity.
Insulation of gers	✓	Some studies have shown that insulation can reduce heat load by 70% ⁶⁰ . However, there is no commercialization of insulation for gers, including the one developed by UNDP, which is the closest to practical use.
	✓	Since the UNDP's ger insulation did not take the ger floor insulation into account, the energy saving of 25%, approximately half of the existing building insulation, was estimated as a very conservative figure.
Effective use of improved fuel and coal	✓	Improved fuel mixed with 20% biomass has been developed as a countermeasure against air pollution, and although it is not yet widely used, it is assumed that its use will reach 100% in the future.

Source: Prepared by the survey team

Based on the decarbonization and energy efficiency steps for each target building and the decarbonization and energy efficiency potential of the various technologies mentioned above, a decarbonization and energy efficiency potential scenario was created as shown in the figure below. Since it was difficult to calculate the energy consumption of public buildings, commercial buildings, and housing complexes separately in the existing data collection, the scenarios below were created by grouping them together, taking into account the fact that the measures are similar.

Table 6-22 Defining Decarbonization and Energy Efficiency Potential Scenarios

Classification	Energy form	Decarbonization and energy efficiency potential scenarios
Public buildings, commercial buildings, and residential complexes	Coal	✓ Assume no coal use at present and in the future.
	Electricity	✓ Assume a linear reduction from the 2022 BAU case (latest year of existing statistics) to achieve a 25% decrease by 2050.
	Heat	✓ Assume a linear reduction from the 2022 BAU case (latest year of existing statistics) to achieve a 45% decrease by 2050. ✓ Assume any increase beyond the BAU case after 2031 is uniformly reduced by 45%. ✓ Assume that after the 2031 BAU case, 50% of the thermal increase in new construction—excluding the above reductions—is reduced. One-third of this reduction is shifted to electricity use.
Detached houses	Coal	✓ Assume a linear reduction from the 2030 BAU case to achieve a 45% decrease by 2050. ✓ Assume any increase beyond BAU case after 2033 is uniformly reduced by 45%. ✓ Assume a linear reduction from the 2024 BAU case to achieve a 20% decrease by 2050 (improved fuel)
	Electricity	✓ Assume a linear conversion of the 2035 BAU case to electricity consumption by

⁵⁸ ENERGY EFFICIENCY IN THE BUILDING SECTOR FOR A MORE SUSTAINABLE MONGOLIA (GIZ et al.)

⁵⁹ <https://www.jraia.or.jp/webmagazine/detail.html?n=470&g=683>

⁶⁰ Development of methods to improve insulation of traditional mobile homes in Mongolia (PUREV et al.)

		2050. ✓ Assume all increases in coal consumption after the 2035 BAU case are converted to electricity
	Heat	✓ Assume no use of heat at present and in the future
Gers	Coal	✓ Assume a linear reduction from the 2024 BAU case to achieve a 25% decrease by 2050.
		✓ Assume any increase beyond the BAU case after 2026 is uniformly reduced by 25%.
		✓ Assume biomass (dung) and charcoal consumption are included in ger coal consumption.
		✓ Assume a linear reduction from the 2024 BAU case to achieve a 20% decrease by 2050 (improved fuels).
	Electricity	✓ Assume the 2032 BAU case coal consumption is converted to electricity consumption evenly through 2050.
		✓ Assume all increases in coal consumption after the 2032 BAU case are converted to electricity.
	Heat	✓ Assume no use of heat at present and in the future.

Source: Prepared by the survey team

(4) Estimation of Energy Consumption in the Residential and Commercial Sectors under Decarbonization and Energy Efficiency Potential Scenarios

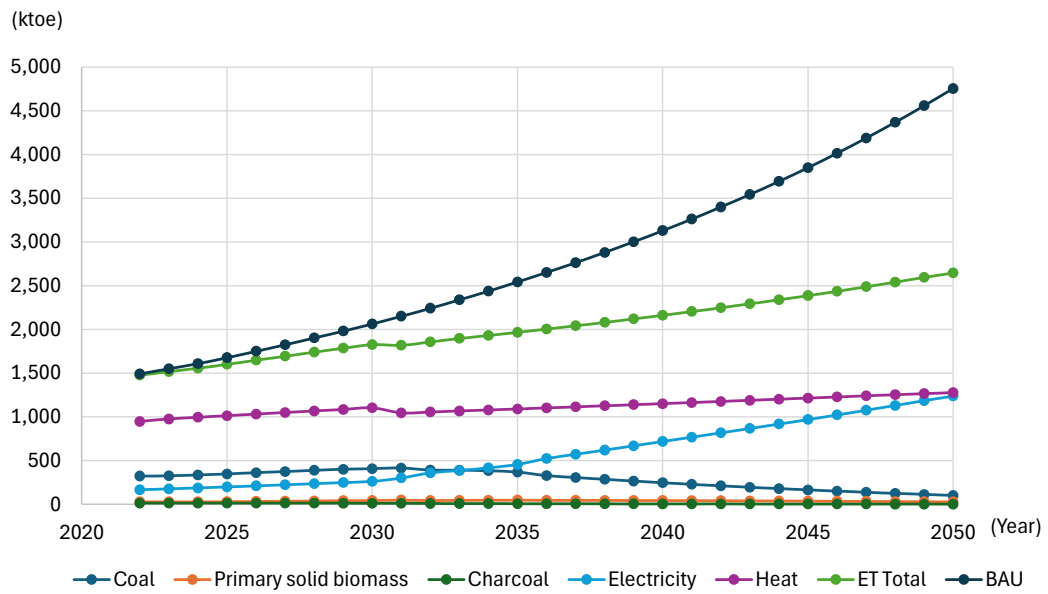
Based on the BAU case, energy consumption in the residential and commercial sectors was estimated by incorporating the above decarbonization and energy efficiency potential scenarios. In this calculation, it is necessary to calculate the amount of coal, electricity, and heat used in each building based on the IAEA's current and projected figures.

For this reason, the year 2022—the latest year for which IAEA data is available—was used as the base year for estimating overall energy consumption. The energy use ratio was calculated, and the ratio was prorated accordingly, based on information such as consumption by energy type, average energy consumption by building type, the number of households purchasing various types of energy, and the number of households by location (e.g., ger districts), as provided in the following sources:

- STATISTICS ON ENERGY PERFORMANCE 2022 (ENERGY REGULATORY COMMISSION)
- Mongolian Statistical Yearbook 2022 (National Statistics Office of Mongolia)
- Low Energy Efficiency Action Plan Ulaanbaatar (UB City)
- Mongolia's Energy Efficiency Indicators 2019 (ERIA)

On the other hand, for example, the latest data in "Mongolia's Energy Efficiency Indicators 2019 (ERIA)" is from 2015, so data for 2022 is not available in some cases. Therefore, it should be noted that improving the accuracy of this estimation by collecting latest data is a task for the future.

The estimation of energy consumption in the residential and commercial sectors, reflecting the decarbonization and energy efficiency potential scenarios, resulted in a projected consumption of 2,645 ktoe in 2050—approximately a 44% reduction from the BAU case (4,755 ktoe). Of this amount, 94 ktoe (about 2%) is assumed to be generated and supplied on the demand side by renewable energy.



Source: Prepared by the survey team

Figure 6-23 Energy Consumption Projections for the Residential and Commercial Sectors Reflecting Decarbonization and Energy Efficiency Potential Scenarios

6.3.4 Final energy demand forecast reflecting the low-carbon and energy saving potential scenarios

(1) Final energy demand forecast after energy conservation implementation

1) By final sector

The total final sector energy demand is reduced by 43.8% in S-B against BAU in the estimated results for 2050. By sector, the largest reduction is seen in the business sector, with a 65.0% reduction, followed by a 61.8% reduction in the transportation sector, a 39.0% reduction in the industrial sector, and a 38.1% reduction in the residential sector. For the agriculture, forestry, and fisheries sectors, no measures were taken at the local point because their energy demand is not high. For other unknown sectors, effective measures cannot be taken because energy use patterns cannot be ascertained, and no action has been taken at the local point, but new measures will need to be taken based on future surveys.

Table 6-23 Projected final energy demand after energy conservation implementation (2022 - 2050)

	Unit	2022	2030		2040		2050		2050
		BAU	BAU	S-B	BAU	S-B	BAU	S-B	BAU/S-B
Industry	ktoe	1,439	1,915	1,587	2,801	1,926	4,066	2,481	-39.0
Transport	ktoe	1,017	1,543	1,363	2,308	1,418	2,899	1,107	-61.8
Residential	ktoe	998	1,359	1,226	2,005	1,470	2,918	1,805	-38.1
Commercial	ktoe	494	699	601	1,114	567	1,823	637	-65.0
Agriculture	ktoe	103	119	119	140	140	163	163	0.0
Other	ktoe	499	663	663	864	864	1,081	1,081	0.0
Total	ktoe	4,550	6,297	5,560	9,233	6,385	12,949	7,274	-43.8
Share (%)									
Industry	%	31.6	30.4	28.6	30.3	30.2	31.4	34.1	
Transport	%	22.4	24.5	24.5	25.0	22.2	22.4	15.2	
Residential	%	21.9	21.6	22.0	21.7	23.0	22.5	24.8	
Commercial	%	10.9	11.1	10.8	12.1	8.9	14.1	8.8	
Agriculture	%	2.3	1.9	2.1	1.5	2.2	1.3	2.2	
Other	%	11.0	10.5	11.9	9.4	13.5	8.3	14.9	
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Source: Prepared by the survey team

2) By final sector energy source

Looking at the final sector by energy source, the share of fossil fuels has been significantly reduced, and newly introduced clean energy sources such as hydrogen, SAF, and synthetic fuels have been introduced, diversifying the energy supply sources. Characteristically, gasoline, jet fuel, and diesel demand as of 2050 are 100%, 82.3%, and 74.5% lower, respectively, in S-B relative to BAU. On the other hand, electricity demand in the same year is slightly higher by 0.5%, and the electrification rate is increased from 21.3% to 38.1%. the share of clean energy in 2050 is increasing for energy with no CO₂ emissions, including synthetic fuel 3.6%, hydrogen 8.0%, and SAF 0.1%.

Table 6-24 Projected demand by final energy source after implementation of low-carbon and energy conservation (2022 - 2050)

	Unit	2022	2030		2040		2050		2050
		BAU	BAU	S-B	BAU	S-B	BAU	S-B	BAU/S-B
Coal	ktoe	788	1,077	1,019	1,592	1,074	2,248	1,180	-47.5
Coke	ktoe	28	33	31	37	34	41	35	-15.0
Gasoline	ktoe	728	982	778	1,496	578	1,775	0	-100.0
Jet Fuel	ktoe	2	16	14	17	7	17	3	-82.3
Diesel	ktoe	901	1,330	1,153	1,807	958	2,332	594	-74.5
Biomass	ktoe	46	47	62	48	61	48	47	-3.1
Charcoal	ktoe	13	14	12	15	4	15	1	-90.7
Electricity	ktoe	696	1,065	1,070	1,726	1,881	2,755	2,768	0.5
Heat	ktoe	1,348	1,733	1,351	2,496	1,400	3,717	1,792	-51.8
Hydrogen	ktoe	0	0	61	0	274	0	585	
SAF	ktoe	0	0	8	0	8	0	8	
E-Fuel	ktoe	0	0	0	0	106	0	260	
Total	ktoe	4,550	6,297	5,560	9,233	6,385	12,949	7,274	-43.8
Share (%)									
Coal	%	17.9	17.6	18.9	17.7	17.3	17.7	16.7	
Oil	%	35.8	37.0	35.0	35.9	24.2	31.8	8.2	
Biomass	%	1.0	1.0	1.3	0.7	1.0	0.5	0.7	
Electricity	%	0.3	16.9	19.2	18.7	29.5	21.3	38.1	
Heat	%	15.3	27.5	24.3	27.0	21.9	28.7	24.6	
Hydrogen	%	29.6	0.0	1.1	0.0	4.3	0.0	8.0	
SAF	%	0.0	0.0	0.1	0.0	0.1	0.0	0.1	
E-Fuel	%	0.0	0.0	0.0	0.0	1.7	0.0	3.6	
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Source: Prepared by the survey team

(2) Energy Demand Projections for the Industrial Sector after Implementation of Energy Conservation

Based on the energy conservation measures for the industrial sector described up to the above, the forecast results for BAU and S-B are shown in the table below. According to the measures, the energy demand of the industrial sector in 2050 will be 2,481 ktoe, a 39.0% decrease in S-B compared to BAU. The focus of the measure is the conversion of diesel to synthetic fuels (by means of electricity from renewable energy sources) and the transfer of heat supply to electricity. 2050 estimates show a significant reduction of 62.8% in diesel demand and a 26.1% reduction in heat supply. Meanwhile, synthetic fuels of renewable energy origin replace diesel demand, accounting for a 10.5% share of total energy demand in the industrial sector.

Table 6-25 Projected energy demand in the industrial sector after implementation of low-carbon and energy conservation (2022 - 2050)

	Unit	2022	2030		2040		2050		2050
		BAU	BAU	S-B	BAU	S-B	BAU	S-B	BAU/S-B
Coal	ktoe	102	142	139	223	208	349	317	-9.2
Coke	ktoe	28	33	31	37	34	41	35	-15.0
Diesel	ktoe	541	696	608	908	523	1,112	414	-62.8
Electricity	ktoe	432	657	627	1,061	752	1,692	811	-52.0
Heat	ktoe	335	386	183	571	302	872	644	-26.1
E-Fuel	ktoe	0	0	0	0	106	0	260	
Total	ktoe	1,438	1,915	1,587	2,801	1,926	4,066	2,481	-39.0
Share (%)									
Coal	%	7.1	7.4	8.7	8.0	10.8	8.6	12.8	
Coke	%	1.9	1.7	2.0	1.3	1.8	1.0	1.4	
Diesel	%	37.6	36.4	38.3	32.4	27.1	27.4	16.7	
Electricity	%	30.0	34.3	39.5	37.9	39.1	41.6	32.7	
Heat	%	23.3	20.2	11.5	20.4	15.7	21.4	25.9	
E-Fuel	%	0.0	0.0	0.0	0.0	5.5	0.0	10.5	
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Source: Prepared by the survey team

(3) Energy demand forecast for the transportation sector after implementation of energy conservation

The table below shows the projected results for S-B relative to BAU in the transportation sector: the projected results for 2050 show a 61.8% reduction in S-B relative to BAU for energy demand in the sector. Due to the bold energy transition policy, the energy reductions are large and the energy mix has changed significantly. In particular, gasoline demand is converted to electricity, diesel demand to hydrogen, and jet fuel demand to SAF, all with lower CO₂ emissions relative to BAU, with an energy mix of 0% gasoline, 52.9% hydrogen, 42.5% electricity, and 0.8% SAF in 2050 S-B.

Table 6-26 Energy Demand Projections for Transportation Sector after Implementation of Low Carbon and Energy Conservation (2022 - 2050)

	Unit	2022	2030		2040		2050		2050
		BAU	BAU	S-B	BAU	S-B	BAU	S-B	BAU/S-B
Coal	ktoe	10	0	0	0	0	0	0	
Gasoline	ktoe	728	982	778	1,496	578	1,775	0	-100.0
Jet Fuel	ktoe	2	16	14	17	7	17	3	-82.3
Diesel	ktoe	277	537	447	781	317	1,080	40	-96.3
Electricity	ktoe	0	8	54	15	233	27	470	1,645.5
Hydrogen	ktoe	0	0	61	0	274	0	585	
SAF	ktoe	0	0	8	0	8	0	8	
Total	ktoe	1,017	1,543	1,363	2,308	1,418	2,899	1,107	-61.8
Share (%)									
Coal	%	1.0	0.0	0.0	0.0	0.0	0.0	0.0	
Gasoline	%	71.6	63.6	57.1	64.8	40.8	61.2	0.0	
Jet Fuel	%	0.2	1.1	1.1	0.7	0.5	0.6	0.3	
Diesel	%	27.2	34.8	32.8	33.8	22.3	37.3	3.6	
Electricity	%	0.0	0.5	4.0	0.6	16.5	0.9	42.5	
Hydrogen	%	0.0	0.0	4.5	0.0	19.3	0.0	52.9	
SAF	%	0.0	0.0	0.6	0.0	0.6	0.0	0.8	
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Source: Prepared by the survey team

(4) Energy demand forecast for the consumer sector after implementation of energy conservation

1) Household sector

According to the analysis of low-carbon and energy saving potentials in the residential sector, energy saving measures in the residential sector will focus on improving the efficiency of electricity and heat supply, and energy demand for coal, traditional biomass (agricultural waste, firewood, etc.), charcoal, etc. will be converted to electricity. Demand for coal, traditional biomass, and charcoal will gradually be converted to electricity and eventually will not be used. Instead, electricity demand will expand significantly by 57.2%, and the electrification rate will reach 68.5% in the same year. Heat supply shrinks by 53.8% to 438 ktoe in S-B, compared to BAU in 2050, due to improved thermal efficiency. Overall, the household sector's energy demand in S-B is reduced by 38.1% to 1,806 ktoe relative to BAU in 2050.

Table 6-27 Projected energy demand in the household sector after implementation of low-carbon and energy conservation (2022 - 2050)

	Unit	2022	2030		2040		2050		2050
		BAU	BAU	S-B	BAU	S-B	BAU	S-B	BAU/S-B
Coal	ktoe	322	461	407	750	246	1,136	100	-91.2
Biomass	ktoe	28	29	44	30	43	30	29	-5.0
Charcoal	ktoe	13	14	12	15	4	15	1	-90.7
Electricity	ktoe	167	273	261	473	718	787	1,238	57.2
Heat	ktoe	468	582	501	739	459	949	438	-53.8
Total	ktoe	998	1,359	1,225	2,005	1,470	2,918	1,806	-38.1
Share (%)									
Coal	%	32.3	34.0	33.2	37.4	16.7	38.9	5.5	
Biomass	%	2.8	2.1	3.6	1.5	2.9	1.0	1.6	
Charcoal	%	1.3	1.0	0.9	0.7	0.3	0.5	0.1	
Electricity	%	16.7	20.1	21.3	23.6	48.8	27.0	68.5	
Heat	%	46.9	42.9	40.9	36.8	31.2	32.5	24.3	
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Source: Prepared by the survey team

2) Business sector

In the Mongolian actual energy statistics, only heat supply is accounted for commercial energy consumption. The table and figure below show the results of S-B estimation based on the energy saving potential for commercial heat supply analyzed in section 6.3.3. The commercial heat supply shows a 65.0% reduction compared to BAU in the S-B in 2050 due to thermal efficiency improvement measures and conversion to electricity.

Table 6-28 Projected energy demand in the commercial sector after implementation of low-carbon and energy-saving measures (2022 - 2050)

	Unit	2022	2030		2040		2050		2050
		BAU	BAU	S-B	BAU	S-B	BAU	S-B	BAU/S-B
Electricity	ktoe	0	0	0	0	0	0	0	
Heat	ktoe	494	699	601	1,114	567	1,823	637	-65.0
Total	ktoe	494	699	601	1,114	567	1,823	637	-65.0
Share (%)									
Electricity	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Heat	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Source: Prepared by the survey team

(5) Energy Demand Projections for the Agriculture, Forestry, and Fisheries Sector after Implementation of Energy Conservation

According to 2022 results, energy consumption in the agriculture, forestry, and fisheries sector accounts for only 2.3% of the final sector. Diesel is consumed as the main energy source, accounting for 80.1% of the total. The actual consumption of diesel needs to be further confirmed, but it is believed to be used mainly for agricultural tractors. The forecast results at the current point do not take into account the energy saving potential of this sector, but the fuel conversion of agricultural tractors will be considered in the future according to the study.

Other than diesel, electricity, heat supply, and biomass are the other energy consumed in the statistics, but all of them consume only a small amount and are consumed mainly in the livestock industry.

Table 6-29 Energy Demand Projections for the Agriculture, Forestry, and Fisheries Sector after Energy Conservation Implementation (2022 - 2050)

	Unit	2022	2030		2040		2050		2050
		BAU	BAU	S-B	BAU	S-B	BAU	S-B	BAU/S-B
Coal	ktoe	1	0	0	0	0	0	0	
Diesel	ktoe	82	97	97	118	118	140	140	0.0
Biomass	ktoe	5	5	5	5	5	5	5	0.0
Electricity	ktoe	7	8	8	9	9	10	10	0.0
Heat	ktoe	7	8	8	8	8	8	8	0.0
Total	ktoe	102	119	119	140	140	163	163	0.0
Share (%)									
Coal	%	1.0	0.0	0.0	0.0	0.0	0.0	0.0	
Diesel	%	80.1	81.9	81.9	84.1	84.1	85.9	85.9	
Biomass	%	4.9	4.2	4.2	3.6	3.6	3.1	3.1	
Electricity	%	7.2	7.0	7.0	6.5	6.5	6.0	6.0	
Heat	%	6.8	6.8	6.8	5.8	5.8	5.0	5.0	
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Source: Prepared by the survey team

(6) Energy Demand Projections for Other Unknown Sectors after Energy Conservation Implementation

Other Unknown Sectors are listed in the energy balance table for Mongolia. Energy consumption whose classification cannot be confirmed before the statistical system is complete in the economic development process of many countries is allocated to this sector. It is assumed that the statistics of this sector will gradually disappear from the balance table according to the completeness of the statistical system.

In 2022, 70.8% of the energy consumption of the Other Unknown Sector is coal, 18.0% is electricity, and the rest is heat supply (8.6%) and biomass (2.6%). The energy demand forecast for the sector until 2050 was projected following the trend of actual data. Since the energy use pattern of this sector could not be confirmed and energy conservation measures could not be taken, the results of the forecast to 2050 were maintained in their current state at the local point.

Table 6-30 Energy demand forecast for other unknown sectors after energy conservation implementation (2022 - 2050)

	Unit	2022	2030		2040		2050		2050
		BAU	BAU	S-B	BAU	S-B	BAU	S-B	BAU/S-B
Coal	ktoe	353	473	473	620	620	763	763	0.0
Biomass	ktoe	13	13	13	13	13	13	13	0.0
Electricity	ktoe	90	120	120	168	168	239	239	0.0
Heat	ktoe	43	58	58	64	64	66	66	0.0
Total	ktoe	499	663	663	864	864	1,081	1,081	0.0
Share (%)									
Coal	%	70.8	71.3	71.3	71.7	71.7	70.6	70.6	
Biomass	%	2.6	2.0	2.0	1.5	1.5	1.2	1.2	
Electricity	%	18.0	18.0	18.0	19.4	19.4	22.1	22.1	
Heat	%	8.6	8.7	8.7	7.4	7.4	6.1	6.1	
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Source: Prepared by the survey team

6.4 Creation of Energy Transition Supply Scenarios

6.4.1 Scenario Setting

Heat and electricity supply scenarios are set up using the BAU case as a baseline. The following scenarios are to be determined based on comments from MOE and NDC as common assumptions for each scenario.

When considering energy transitions for Mongolia, it is important to consider electricity and heat supply as a set, rather than considering energy transitions for heat and electricity supply separately. Therefore, it is necessary to consider how to transition the heat supply from coal CHP, which is the current heat source, before considering the transition of electricity.

Specifically, it is essential to first determine the scenario for converting the heat supply from coal CHP to primary energy supply.

(1) Supply-side Scenario Policy

If electricity supply is simply considered, developing a large amount of VRE in the South Gobi Desert⁶¹ has high potential for VRE. However, the problem is how to supply heat to urban areas, and it is difficult to supply heat directly from VRE.

Furthermore, Table 5-18 in Chapter 5 evaluates the adoption levels and assessments of each technology and measure. Based on this, nuclear power and hydrogen are considered viable options for equipment capable of supplying heat to cities by 2050.

Therefore, the supply scenarios for energy transition in Mongolia are as follows, targeting the heat supply system by coal CHP calculated by BAU.

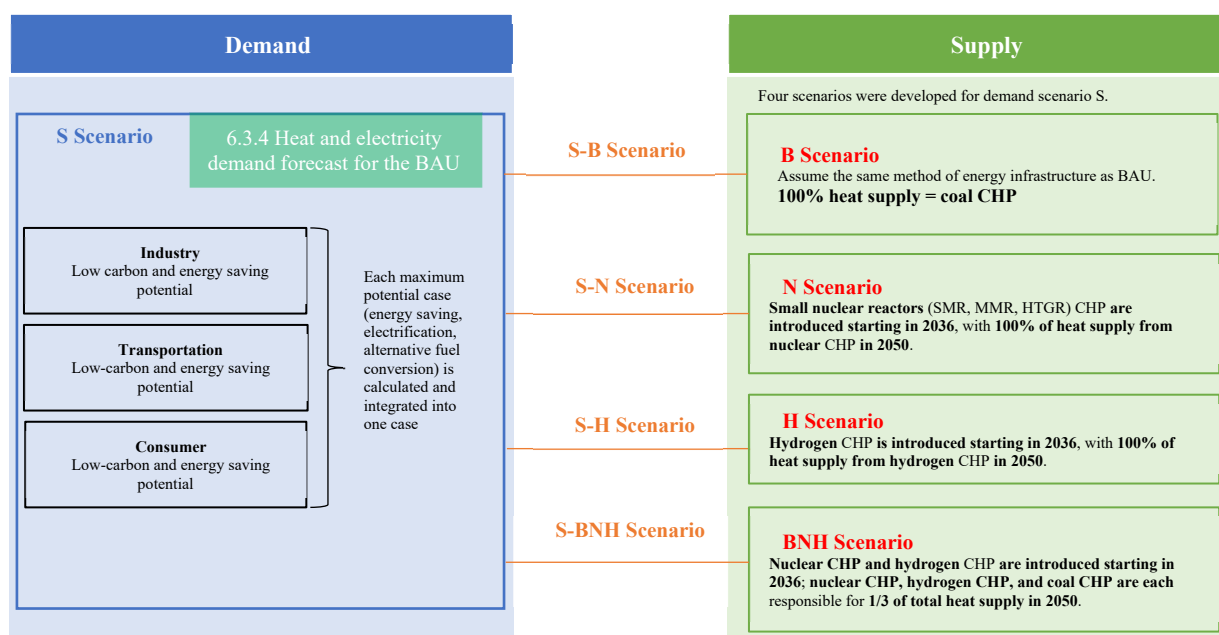
- A) Conversion from coal CHP to green hydrogen system
- B) Conversion from coal CHP to nuclear power
- C) Equal structure of coal CHP, green hydrogen, and nuclear power (each heat supply allocation is 1/3)

The rationale behind the above settings is that, in addition to the limitation of not being able to examine numerous scenarios, it was considered that establishing simplified options A and B would make the effects easier to observe. Furthermore, setting option C as a combination proposal would facilitate a comprehensive comparative evaluation.

⁶¹ According to Ministry of Energy data, solar PV potential is 2,200 GW and wind 1,100 GW; total for both is 3,300 GW.

6.4.2 Supply Structure by Scenario

Figure 6-24 were studied. The electricity shortfall was assumed to be supplied by solar and wind power (each with a 50% allocation), as in BAU.



Source: Prepared by the survey team

Figure 6-24 ET Study Scenarios for Heat and Power Supply Systems

The constants required to calculate the annual electricity generation (GWh) and installed capacity (MW) of the nuclear and hydrogen CHPs are assumed as shown in Table 6-31.

Since the thermal efficiency (No. 3) of hydrogen CHP is higher than that of coal CHP and nuclear CHP, the annual ratio of heat to electricity supply is about 1.6 times higher than that of coal CHP and nuclear CHP.

Table 6-31 Constants Required to Calculate Annual Electricity (GWh) and Installed Capacity (MW) of Nuclear CHP and Hydrogen CHP

No.	Classification	Item	Nuclear CHP	Hydrogen CHP
1	Heat	Annual heat supply system in-house consumption rate	10% Same as coal CHP	10% Same as coal CHP
2	Electricity	Annual electricity supply system in-house consumption rate	14% Same as coal CHP	10.8%
3	Electricity	Annual ratio of heat to electricity supply for CHP	30 (electricity)/70 (heat) = 0.428571 Same as coal CHP	40 (electricity) / 60 (heat) = 0.666667
4	Electricity	Average of annual utilization rate	60% Same as coal CHP	60% Same as coal CHP

Source: Prepared by the survey team

The constants used to calculate the amount of hydrogen production required for hydrogen CHP and the amount of electricity required for hydrogen production were assumed as shown in Table 6-32.

Table 6-32 Constants Used to Calculate the Amount of Hydrogen Production Required for Hydrogen CHP and the Amount of Electricity Required for Hydrogen Production

No.	Item	Constant
1	Thermal energy conversion factor per unit of hydrogen (Nm ³)	2.5843×10^{-7} ktoe / Nm ³
2	Energy generation efficiency of extractable (heat + electricity) energy	85%
3	Electricity required to produce 1 resource unit (Nm ³) of hydrogen	4.9 kWh / Nm ³

Source: Prepared by the survey team

Assuming that VRE generates 1 GWh of electricity, the heat and electricity supply from hydrogen CHP would be as follows

The heat supply excluding in-house consumption would be 0.02421 ktoe (0.28154 GWh) and the electricity supply would be 0.18603 GWh. In other words, the energy conversion efficiency from the VRE power supply is 28.2% for heat supply, 18.6% for electricity supply, and 46.8% overall.

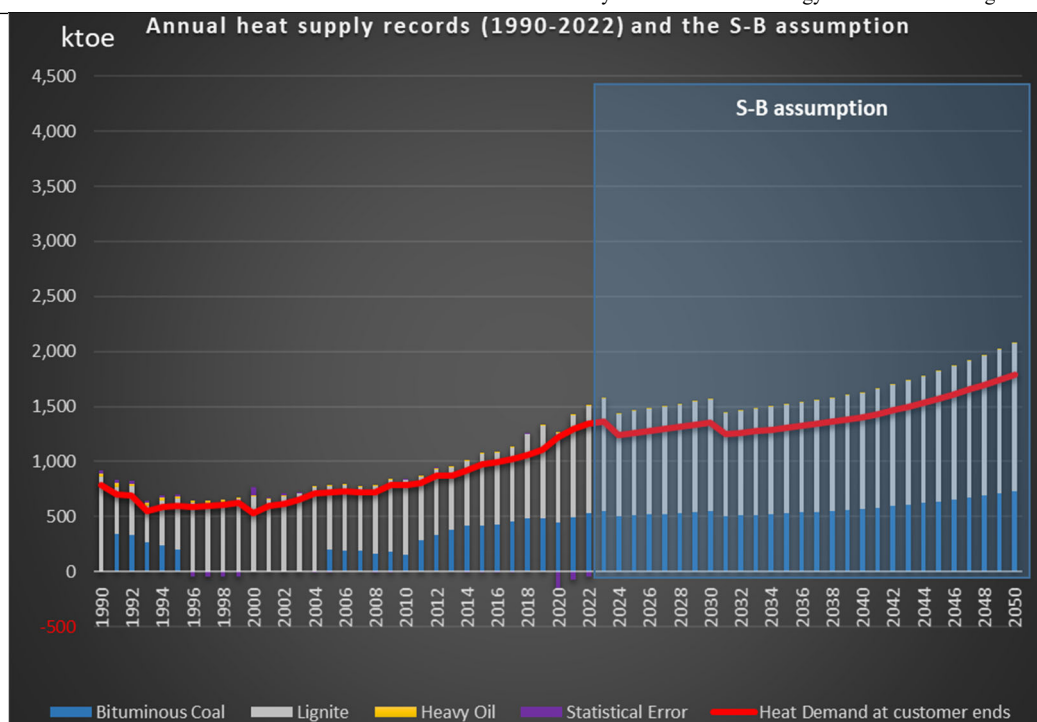
- Hydrogen produced from 1GWh by VRE power generation 204,082 Nm³
- Energy extracted from VRE-generated hydrogen 0.04483 ktoe (0.52137 GWh)
- Heat supplied by CHP from VRE-generated hydrogen 0.02690 ktoe (0.31282 GWh)
- Electricity supplied by CHP from VRE-generated hydrogen 0.20855 GWh
- Heat supplied by CHP from VRE-generated hydrogen (excluding in-house consumption) 0.02421 ktoe (0.28154 GWh)
- Electricity supplied by CHP from VRE-generated hydrogen (excluding in-house consumption) 0.18603 GWh

(1) S-B Scenario

The only difference is the heat demand projection, which differs from BAU. The heat supply system is supplied 100% from coal CHP as in the BAU scenario.

1) Heat Supply System Calculation Results for the S-B Scenario

The calculation results of the heat supply of the heat supply system in the S-B scenario are shown in Figure 6-25 and Table 6-33.



Source: Prepared by the survey team

Figure 6-25 Actual Heat Supply Records and the S-B Scenario

Table 6-33 Heat Supply Balance under the S-B Scenario

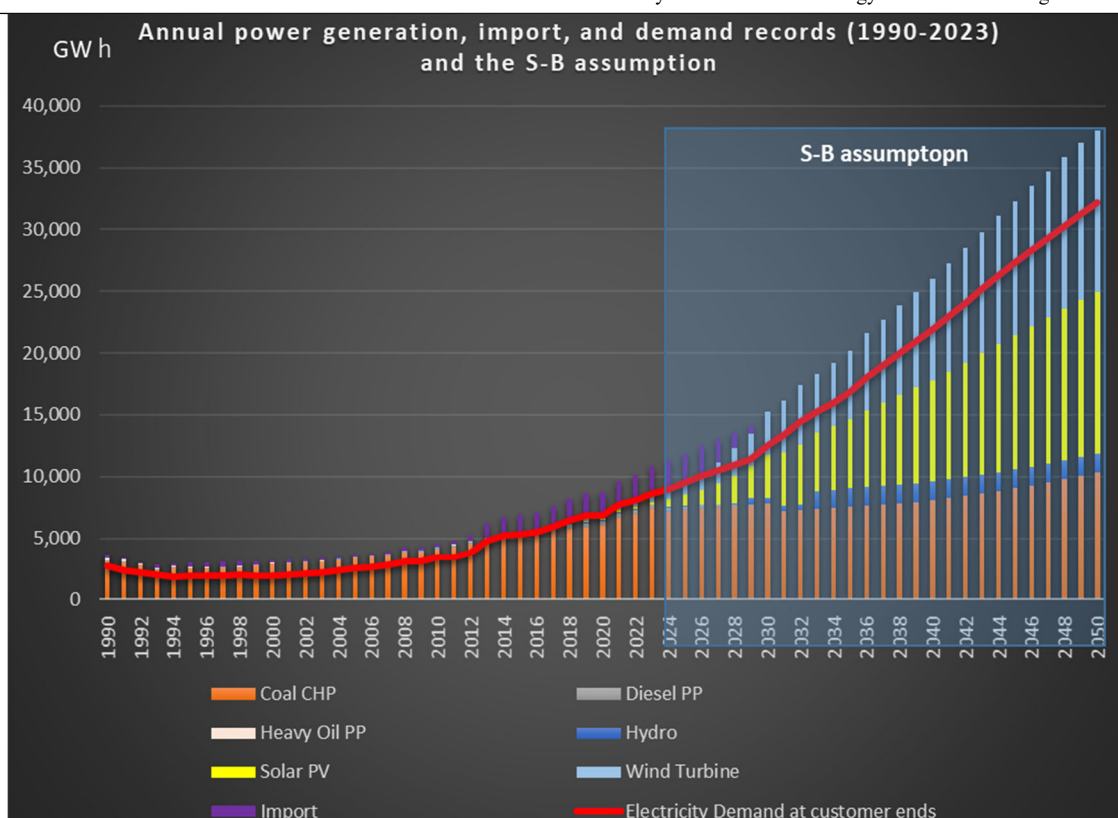
Unit: ktoe	2022 Actual	2030	2035	2040	2045	2050
Total heat supply	1,505	1,564	1,512	1,620	1,818	2,074
Bituminous coal	527 (35%)	547 (35%)	529 (35%)	567 (35%)	636 (35%)	726 (35%)
Lignite	977 (65%)	1,016 (65%)	982 (65%)	1,053 (65%)	1,181 (65%)	1,347 (65%)
Heavy oil	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
In-house consumption	148 (10%)	156 (10%)	151 (10%)	162 (10%)	182 (10%)	207 (10%)
Heat transfer loss	56 (4%)	56 (4%)	54 (4%)	58 (4%)	65 (4%)	75 (4%)
Statistical Error	-46	0	0	0	0	0
Heat demand at customer ends	1,348 (90%)	1,351 (86%)	1,306 (86%)	1,400 (86%)	1,570 (86%)	1,792 (86%)

Source: Prepared by the survey team

2) Electricity Supply System Calculation Results for the S-B Scenario

The results of power generation calculations for the S-B scenario of the electricity supply system are shown in Figure 6-26 and Table 6-34. The composition on an energy basis is shown in Figure 6-27 and Table 6-35.

The installed capacity (MW) is Figure 6-28 and Table 6-36. The installed capacity composition ratio is shown in Figure 6-29 and Table 6-37. The supply capacity (MW) and reserve rate at annual maximum load are shown in Figure 6-30 and Table 6-38.



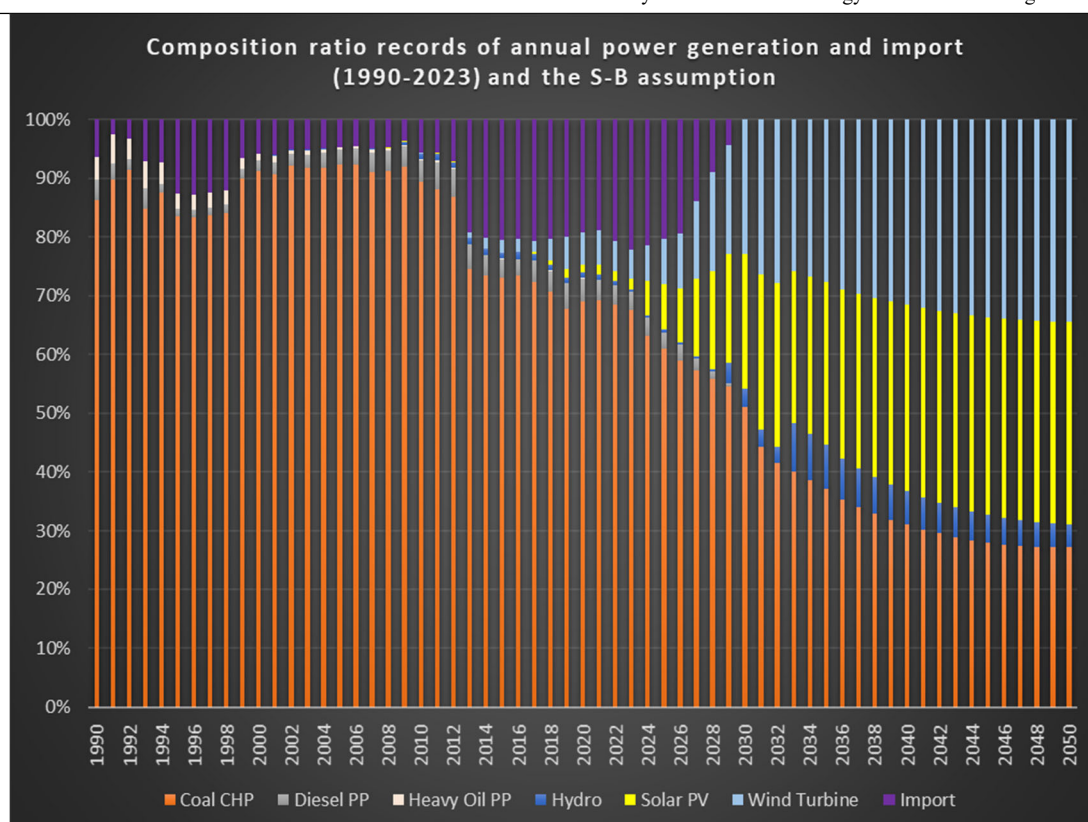
Source: Prepared by the survey team.

Figure 6-26 Annual Power Generation, Imports, and Demand Records and the S-B scenario

Table 6-34 Electricity Supply Balance Table (Energy Basis) under the S-B Scenario

Unit : GWh	2023 Actual	2030	2035	2040	2045	2050
Domestic Power Generation at generator ends total	8,483	15,234	20,224	25,984	32,315	38,031
Coal CHP	7,377	7,789	7,529	8,072	9,054	10,333
Diesel PP	334	0	0	0	0	0
Heavy Oil	0	0	0	0	0	0
Hydro	48	473	1,504	1,504	1,504	1,504
Solar PV	193	3,486	5,596	8,204	10,878	13,097
Wind Turbine	532	3,486	5,596	8,204	10,878	13,097
Import	2,427	0	0	0	0	0
Total Supply	10,910	15,234	20,224	25,984	32,315	38,031
Electricity In-house consumption	1,059	1,090	1,054	1,130	1,268	1,447
Transmission and Distribution Losses	1,179	1,697	2,300	2,983	3,726	4,390
Electricity demand at customer ends	8,672	12,447	16,870	21,872	27,322	32,194
Total Electricity Consumption	10,910	15,234	20,224	25,984	32,315	38,031
Electricity in-house consumption rate (Fossil fuel)	13.7%	14.0%	14.0%	14.0%	14.0%	14.0%
Transmission and Distribution Loss Ratio	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%

Source: Prepared by the survey team



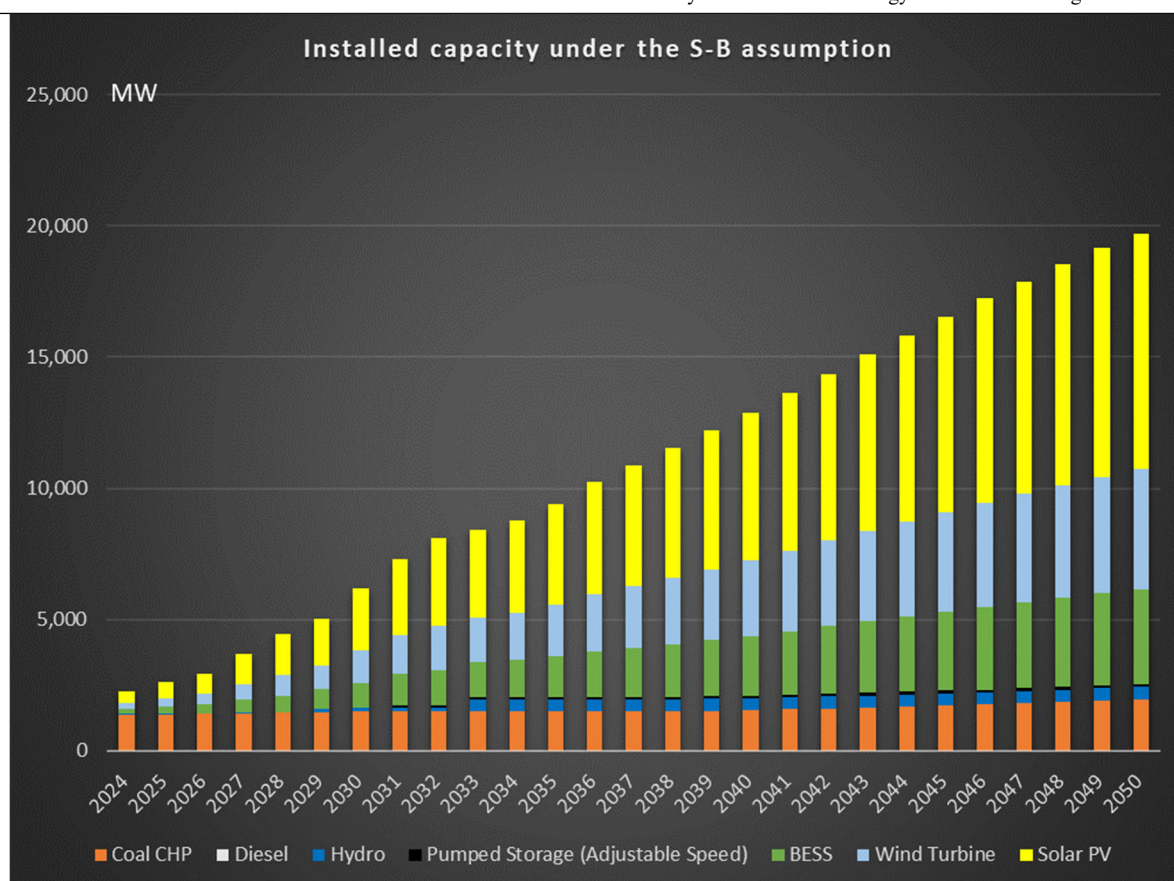
Source: Prepared by the survey team

Figure 6-27 Composition Ratio Records of Annual Power Generation and Import and the S-B Scenario

Table 6-35 Composition of Electricity Supply by Type (Energy Basis) under the S-B Scenario

	2023 Actual	2030	2035	2040	2045	2050
Domestic power at generator ends total	77.8%	100.0%	100.0%	100.0%	100.0%	100.0%
Coal CHP	67.6%	51.1%	37.2%	31.1%	28.0%	27.2%
Diesel	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy Oil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	0.4%	3.1%	7.4%	5.8%	4.7%	4.0%
Solar PV	1.8%	22.9%	27.7%	31.6%	33.7%	34.4%
Wind turbine	4.9%	22.9%	27.7%	31.6%	33.7%	34.4%
Import	22.2%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Prepared by the survey team



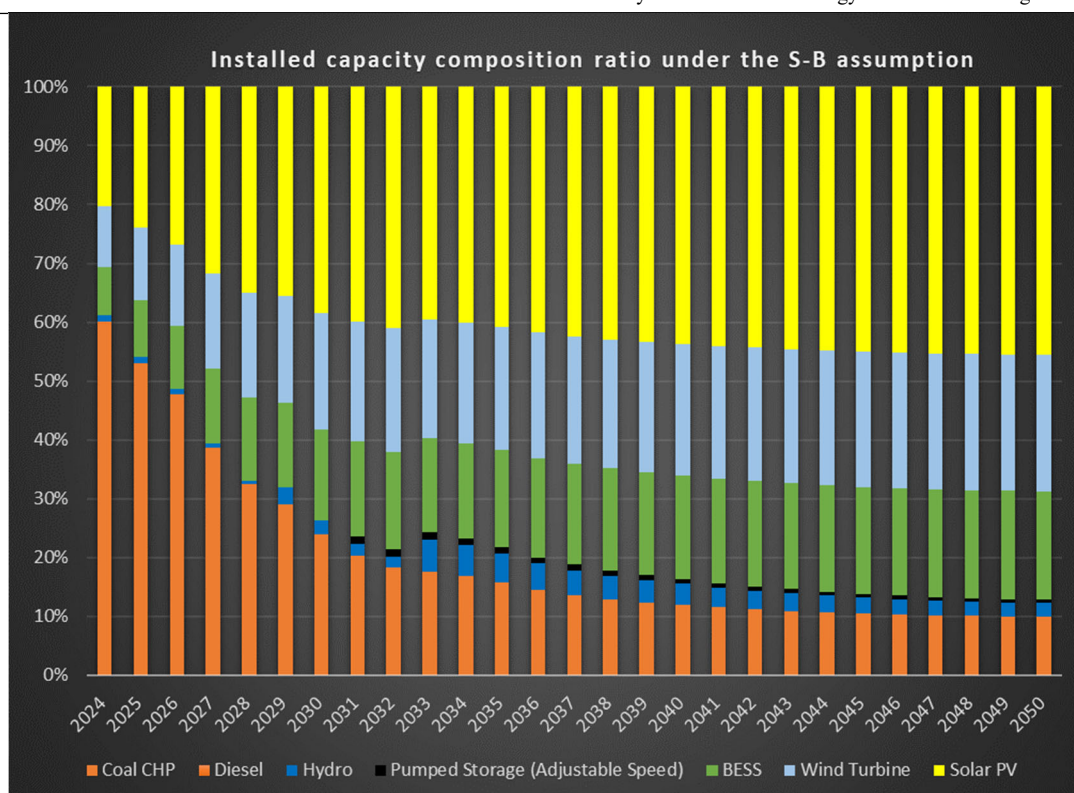
Source: Prepared by the survey team

Figure 6-28 Installed Capacity under the S-B Scenario

Table 6-36 Installed Capacity under the S-B Scenario

Unit : MW	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,482	1,482	1,536	1,723	1,966
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	2,388	3,833	5,619	7,451	8,971
Wind Turbine	155	1,220	1,958	2,871	3,807	4,583
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	966	1,550	2,272	3,013	3,627
Total	1,724	6,201	9,383	12,860	16,554	19,708

Source: Prepared by the survey team



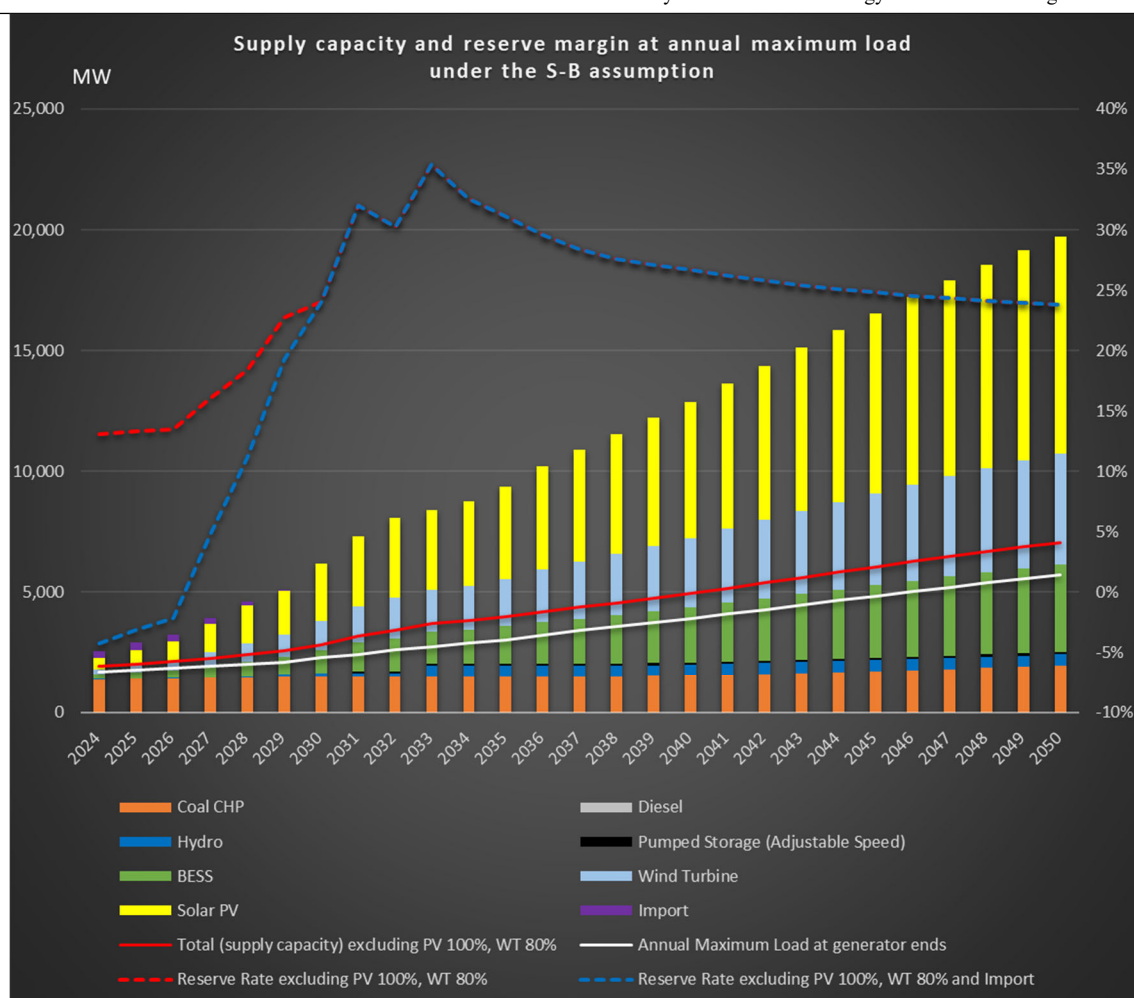
Source: Prepared by the survey team

Figure 6-29 Installed Capacity Composition Ratio under the S-B Scenario

Table 6-37 Installed Capacity Composition Ratio under the S-B Scenario

	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	76.2%	23.9%	15.8%	11.9%	10.4%	10.0%
Diesel	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	1.5%	2.4%	4.9%	3.6%	2.8%	2.3%
Solar PV	8.2%	38.5%	40.8%	43.7%	45.0%	45.5%
Wind Turbine	9.0%	19.7%	20.9%	22.3%	23.0%	23.3%
Pumped Storage (Adjustable Speed)	0.0%	0.0%	1.1%	0.8%	0.6%	0.5%
BESS	4.7%	15.6%	16.5%	17.7%	18.2%	18.4%
Total	100%	100%	100%	100%	100%	100%

Source: Prepared by the survey team



Source: Prepared by the survey team

**Figure 6-30 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load
under the S-B Scenario**

**Table 6-38 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load
under the S-B Scenario**

	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,482	1,482	1,536	1,723	1,966
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	2,388	3,833	5,619	7,451	8,971
Wind Turbine	155	1,220	1,958	2,871	3,807	4,583
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	966	1,550	2,272	3,013	3,627
Total capacity	1,724	6,201	9,383	12,860	16,554	19,708
Import	294	0	0	0	0	0
Total	2,018	6,201	9,383	12,860	16,554	19,708
Total (supply capacity) excluding PV 100%, WT 80%	1,753	2,837	3,984	4,943	6,058	7,071
Annual Maximum Load at generator ends	1,636	2,288	3,038	3,903	4,854	5,712
Reserve Rate excluding PV 100%, WT 80%	7.2%	24.0%	31.2%	26.7%	24.8%	23.8%
Reserve Rate excluding PV 100%, WT 80% and Import	-10.8%	24.0%	31.2%	26.7%	24.8%	23.8%

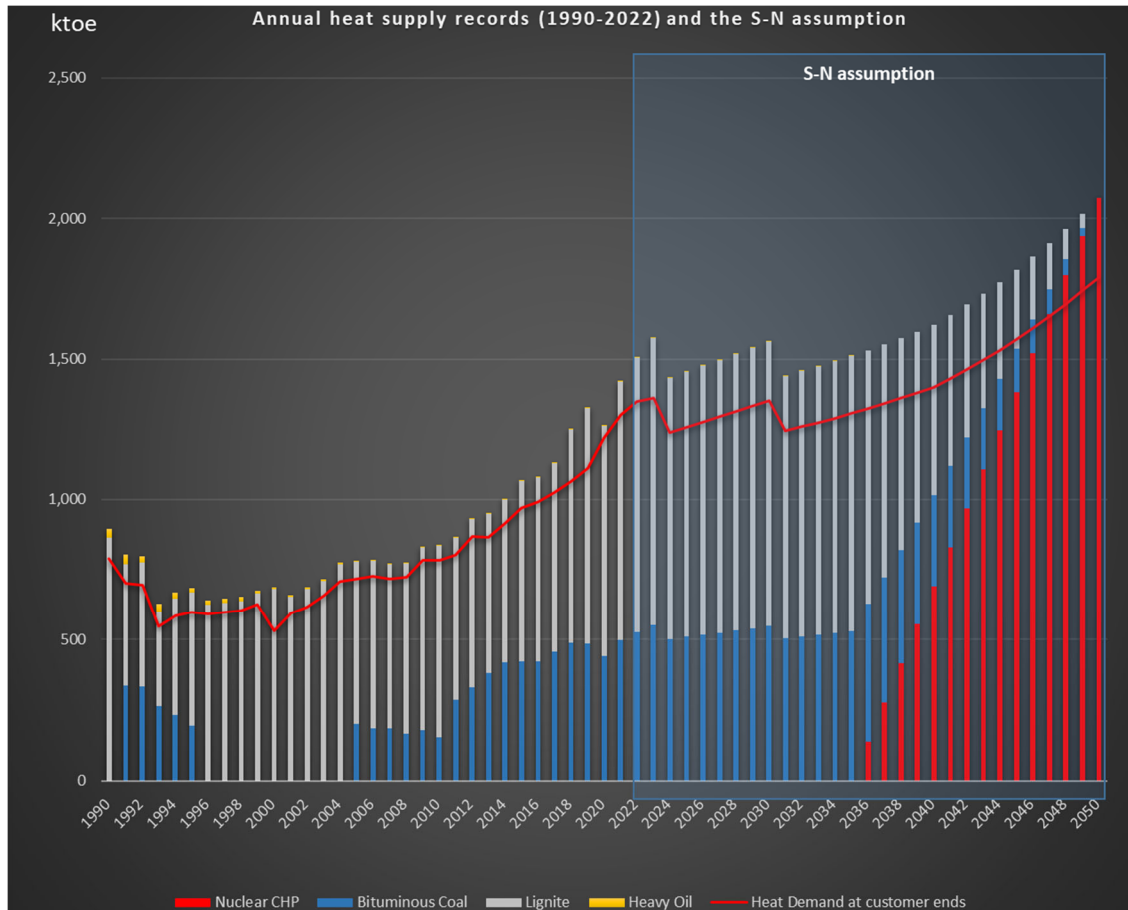
Source: Prepared by the survey team

(2) S-N Scenario

This scenario is based on the introduction of small nuclear reactors (SMR, MMR, HTGR) CHP into the heat supply system starting in 2036, with 100% of heat supply from nuclear CHP in 2050.

1) Heat Supply System Calculation Results for the S-N Scenario

The calculation results of the heat supply of the heat supply system in the S-N scenario are shown in Figure 6-31 and Table 6-39.



Source: Prepared by the survey team.

Figure 6-31 Actual Heat Supply Records and the S-N Scenario

Table 6-39 Heat Supply Balance under the S-N Scenario

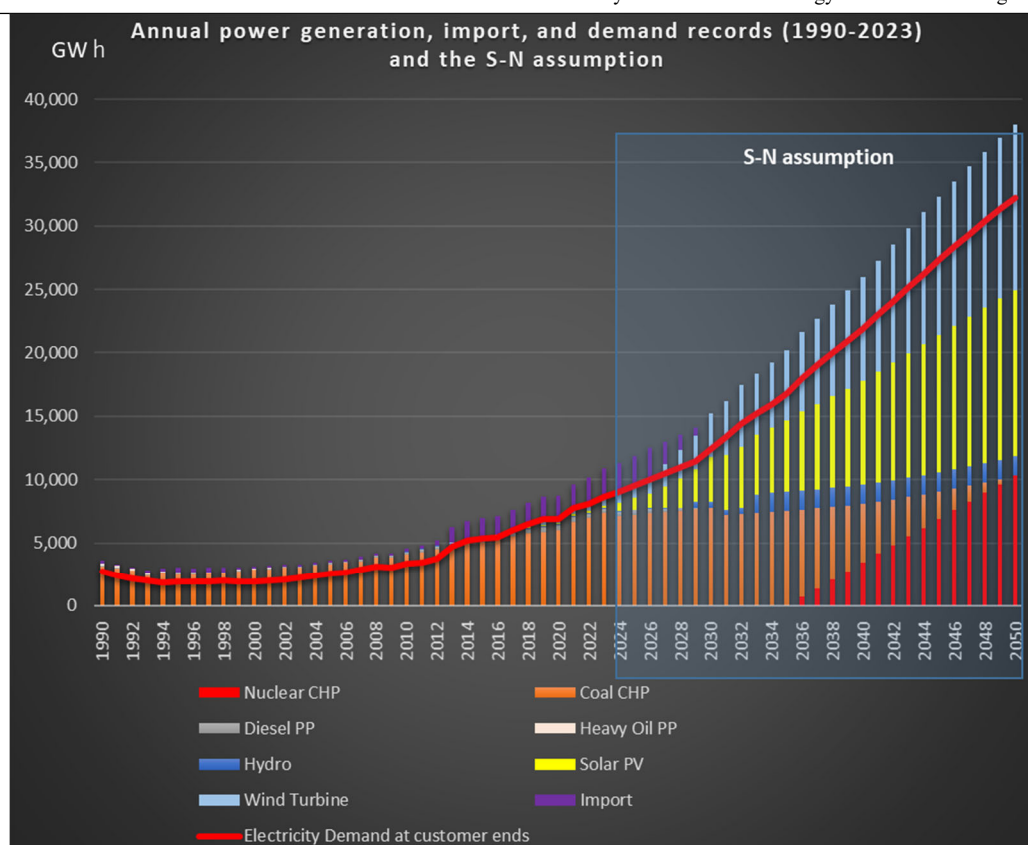
Unit: ktoe	2022 Actual	2030	2035	2040	2045	2050
Total heat supply	1,505	1,564	1,512	1,620	1,818	2,074
Bituminous coal	527 (35%)	547 (35%)	529 (35%)	325 (20%)	152 (8%)	0 (0%)
Lignite	977 (65%)	1,016 (65%)	982 (65%)	604 (37%)	283 (16%)	0 (0%)
Heavy Oil	1 (0%)	1 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)
Nuclear CHP	0 (0%)	0 (0%)	0 (0%)	691 (43%)	1,383 (76%)	2,074 (100%)
In-house consumption	148 (10%)	156 (10%)	151 (10%)	162 (10%)	182 (10%)	207 (10%)
Heat transfer loss	56 (4%)	56 (4%)	54 (4%)	58 (4%)	65 (4%)	75 (4%)
Statistical Error	-46	0	0	0	0	0
Heat demand at customer ends	1,348 (90%)	1,351 (86%)	1,306 (86%)	1,400 (86%)	1,570 (86%)	1,792 (86%)

Source: Prepared by the survey team

2) Electricity Supply System Calculation Results for the S-N Scenario

The results of power generation calculations for the S-N scenario of the electricity supply system are shown in Figure 6-32 and Table 6-40. The composition ratio on an energy basis is Figure 6-33 and Table 6-41.

In addition, the amount capacity (MW) is shown in Figure 6-34 and Table 6-42 . The installed capacity composition ratio is shown in Figure 6-35 and Table 6-43. The supply capacity (MW) and reserve rate at annual maximum load are Figure 6-36 and Table 6-44.



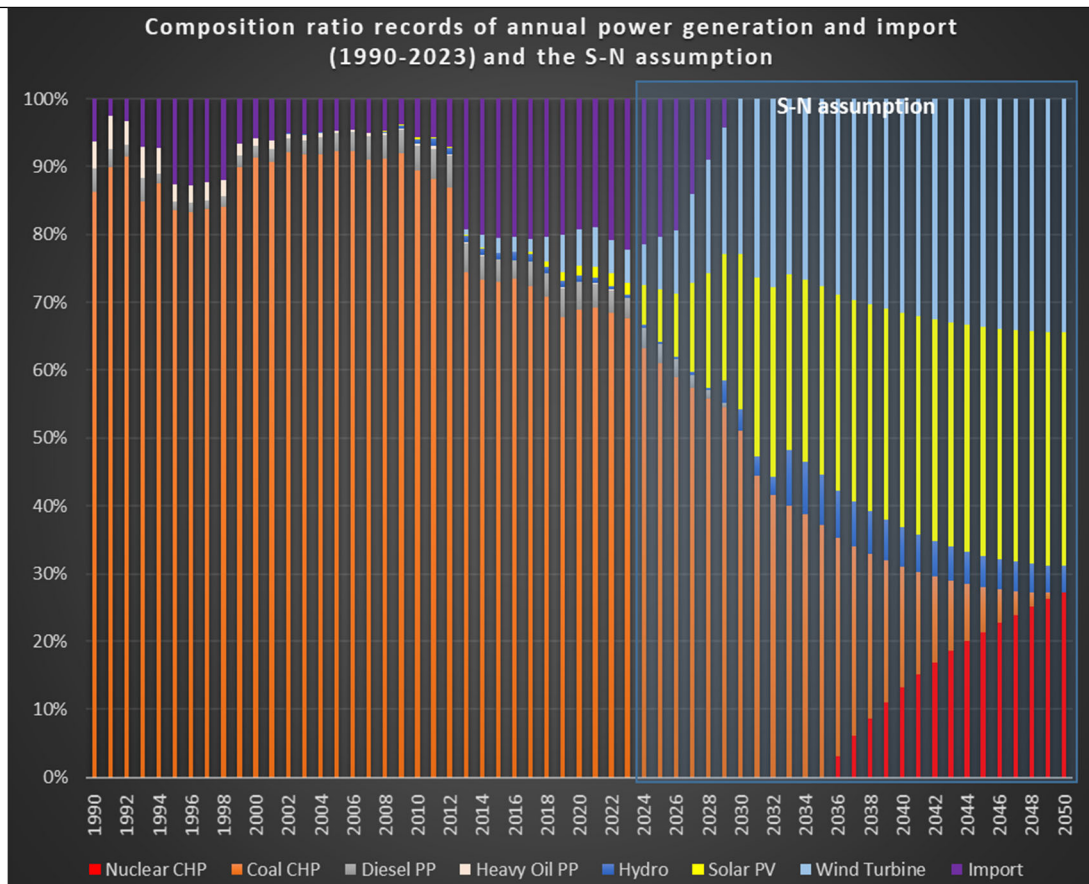
Source: Prepared by the survey team

Figure 6-32 Annual Power Generation, Import, and Demand Records and the S-N Scenario

Table 6-40 Electricity Supply Balance (Energy Basis) under the S-N Scenario

Unit : GWh	2023 Actual	2030	2035	2040	2045	2050
Domestic Power Generation at generator ends total	8,483	15,234	20,224	25,984	32,315	38,031
Coal CHP	7,377	7,789	7,529	4,631	2,167	0
Diesel PP	334	0	0	0	0	0
Heavy Oil	0	0	0	0	0	0
Hydro	48	473	1,504	1,504	1,504	1,504
Solar PV	193	3,486	5,596	8,202	10,876	13,095
Wind Turbine	532	3,486	5,596	8,202	10,876	13,095
Nuclear CHP	0	0	0	3,446	6,892	10,338
Import	2,427	0	0	0	0	0
Total Supply	10,910	15,234	20,224	25,984	32,315	38,031
Electricity In-house consumption	1,059	1,090	1,054	1,130	1,268	1,447
Transmission and Distribution Losses	1,179	1,697	2,300	2,983	3,726	4,390
Electricity Demand at customer ends	8,672	12,447	16,870	21,872	27,322	32,194
Total Consumption	10,910	15,234	20,224	25,984	32,315	38,031
In-house Electricity Consumption Rate (Fossil fuels)	13.7%	14.0%	14.0%	14.0%	14.0%	14.0%
Transmission and Distribution Loss Rate	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%

Source: Prepared by the survey team



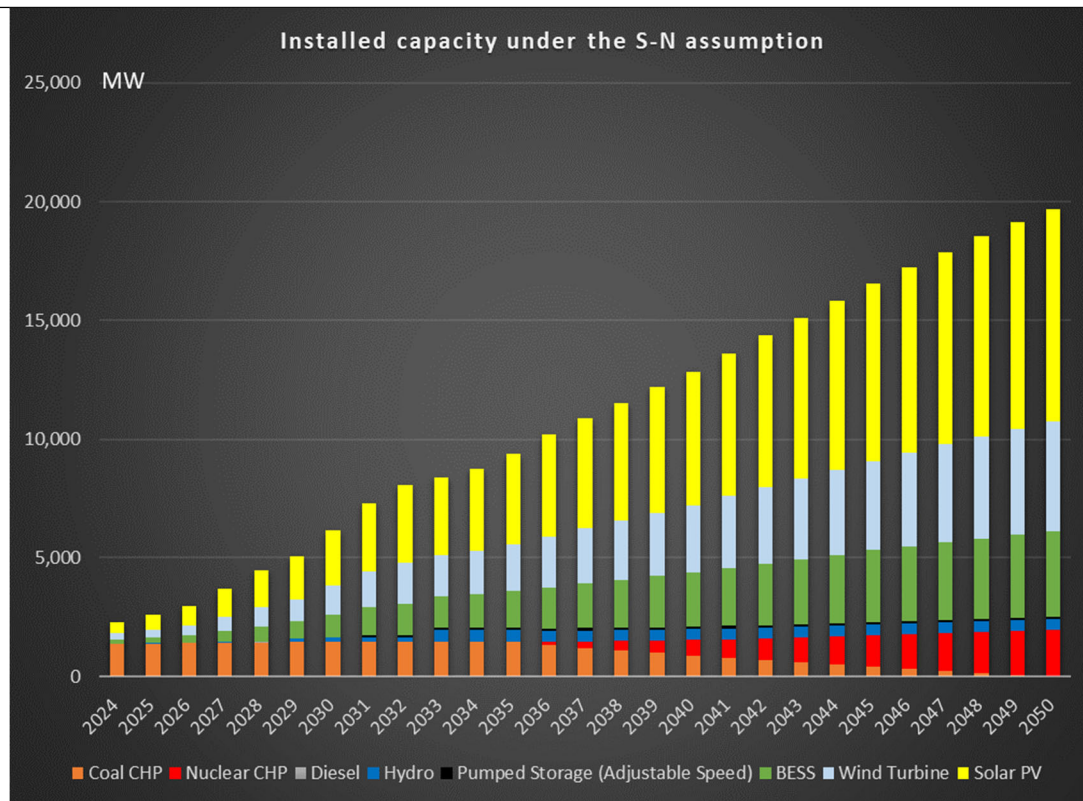
Source: Prepared by the survey team

Figure 6-33 Composition Ratio Records of Annual Power Generation and Import and the S-N Scenario

Table 6-41 Composition of Electricity Supply by Type (Energy Basis) under the S-N Scenario

	2023 Actual	2030	2035	2040	2045	2050
Domestic power at generator ends total	77.8%	100.0%	100.0%	100.0%	100.0%	100.0%
Coal CHP	67.6%	51.1%	37.2%	17.8%	6.7%	0.0%
Diesel	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy oil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	0.4%	3.1%	7.4%	5.8%	4.7%	4.0%
Solar PV	1.8%	22.9%	27.7%	31.6%	33.7%	34.4%
Wind Turbine	4.9%	22.9%	27.7%	31.6%	33.7%	34.4%
Nuclear CHP	0.0%	0.0%	0.0%	13.3%	21.3%	27.2%
Import	22.2%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Prepared by the survey team



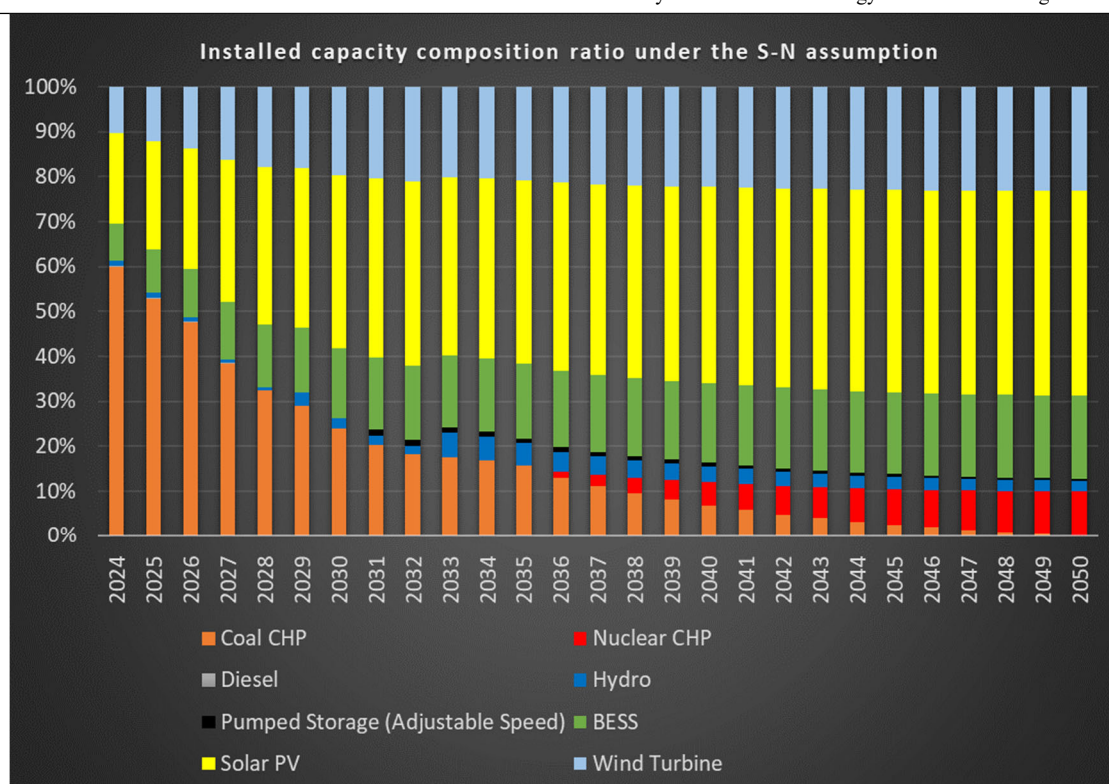
Source: Prepared by the survey team

Figure 6-34 Installed Capacity under the S-N Scenario

Table 6-42 Installed Capacity under the S-N Scenario

Unit : MW	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,482	1,482	881	412	0
Nuclear CHP	0	0	0	656	1,311	1,967
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	2,388	3,833	5,618	7,450	8,969
Wind Turbine	155	1,220	1,958	2,870	3,806	4,583
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	966	1,550	2,272	3,012	3,627
Total	1724	6,201	9,383	12,858	16,553	19,706

Source: Prepared by the survey team

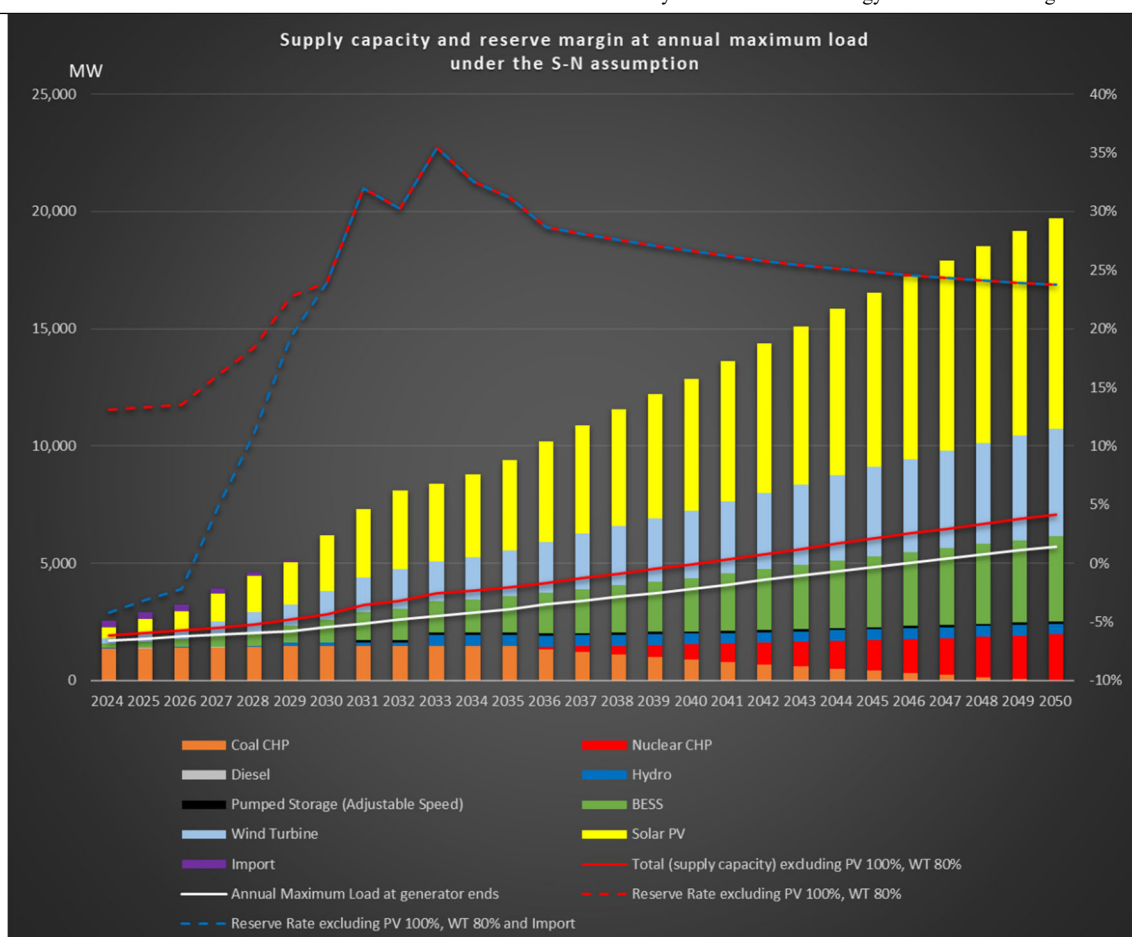


Source: Prepared by the survey team

Figure 6-35 Installed Capacity Composition Ratio under the S-N Scenario**Table 6-43 Installed Capacity Composition Ratio under the S-N Scenario**

	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	76.2%	23.9%	15.8%	6.9%	2.5%	0.0%
Nuclear CHP	0.0%	0.0%	0.0%	5.1%	7.9%	10.0%
Diesel	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	1.5%	2.4%	4.9%	3.6%	2.8%	2.3%
Solar PV	8.2%	38.5%	40.8%	43.7%	45.0%	45.5%
Wind Turbine	9.0%	19.7%	20.9%	22.3%	23.0%	23.3%
Pumped Storage (Adjustable Speed)	0.0%	0.0%	1.1%	0.8%	0.6%	0.5%
BESS	4.7%	15.6%	16.5%	17.7%	18.2%	18.4%
Total	100%	100%	100%	100%	100%	100%

Source: Prepared by the survey team



Source: Prepared by the survey team

Figure 6-36 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load under the S-N Scenario

Table 6-44 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load under the S-N Scenario

	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,482	1,482	881	412	0
Nuclear CHP	0	0	0	656	1,311	1,967
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	2,388	3,833	5,618	7,450	8,969
Wind Turbine	155	1,220	1,958	2,870	3,806	4,583
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	966	1,550	2,272	3,012	3,627
Total capacity	1,724	6,201	9,383	12,858	16,553	19,706
Import	294	0	0	0	0	0
Total	2,018	6,201	9,383	12,858	16,553	19,706
Total (supply capacity) excluding PV 100%, WT 80%	1,753	2,837	3,984	4,944	6,058	7,071
Annual Maximum Load at generator ends	1,636	2,288	3,038	3,903	4,854	5,712
Reserve Rate excluding PV 100%, WT 80%	7.2%	24.0%	31.2%	26.7%	24.8%	23.8%
Reserve Rate excluding PV 100%, WT 80% and Import	-10.8%	24.0%	31.2%	26.7%	24.8%	23.8%

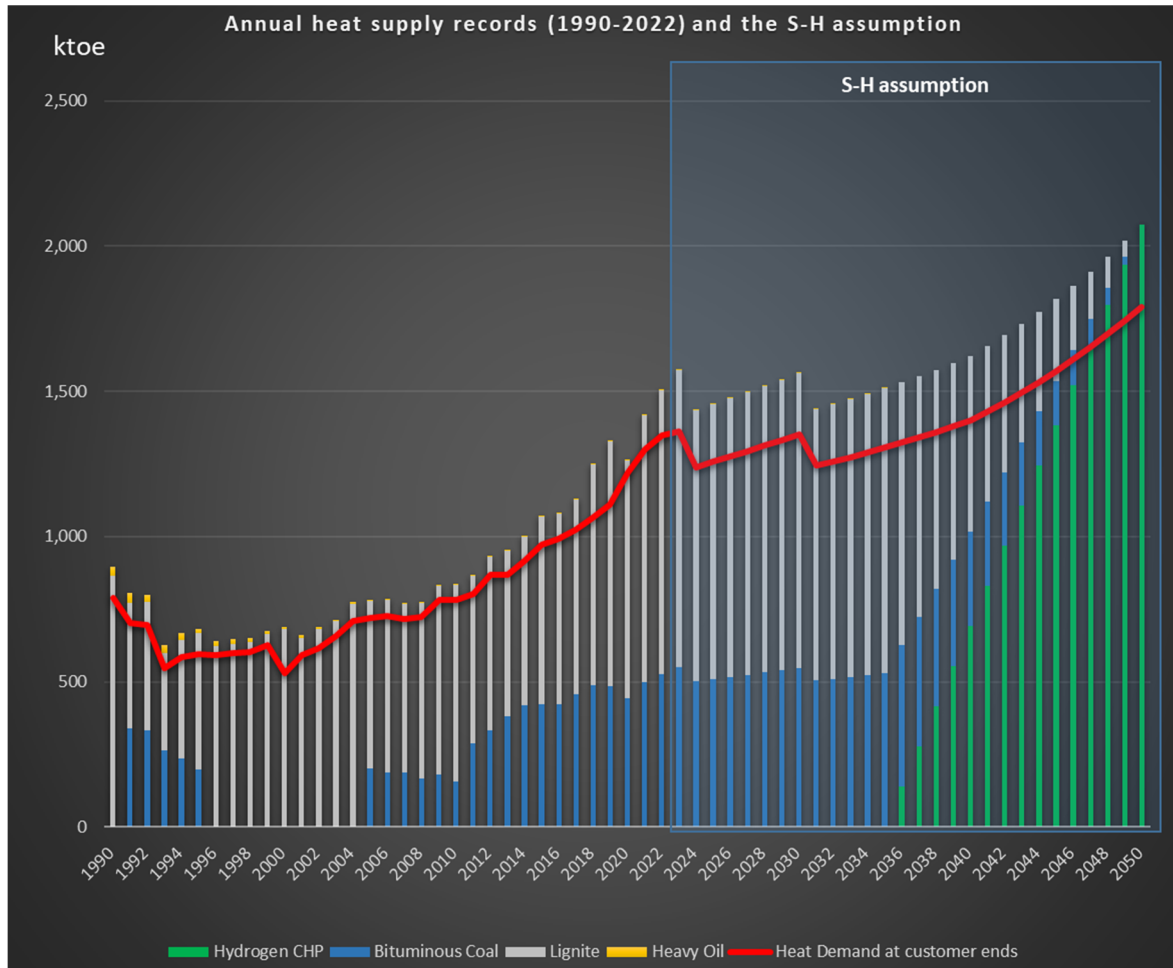
Source: Prepared by the survey team

(3) S-H Scenario

This is a scenario in which hydrogen CHP is introduced into the heat supply system starting in 2036, and heat supply from hydrogen CHP will be 100% by 2050.

1) Heat Supply System Calculation Results for the S-H Scenario

The calculation results of the heat supply of the heat supply system in the S-H scenario are shown in Figure 6-37 and Table 6-45.



Source: Prepared by the survey team.

Figure 6-37 Actual Heat Supply Records and the S-H Scenario

Table 6-45 Heat Supply Balance under the S-H Scenario

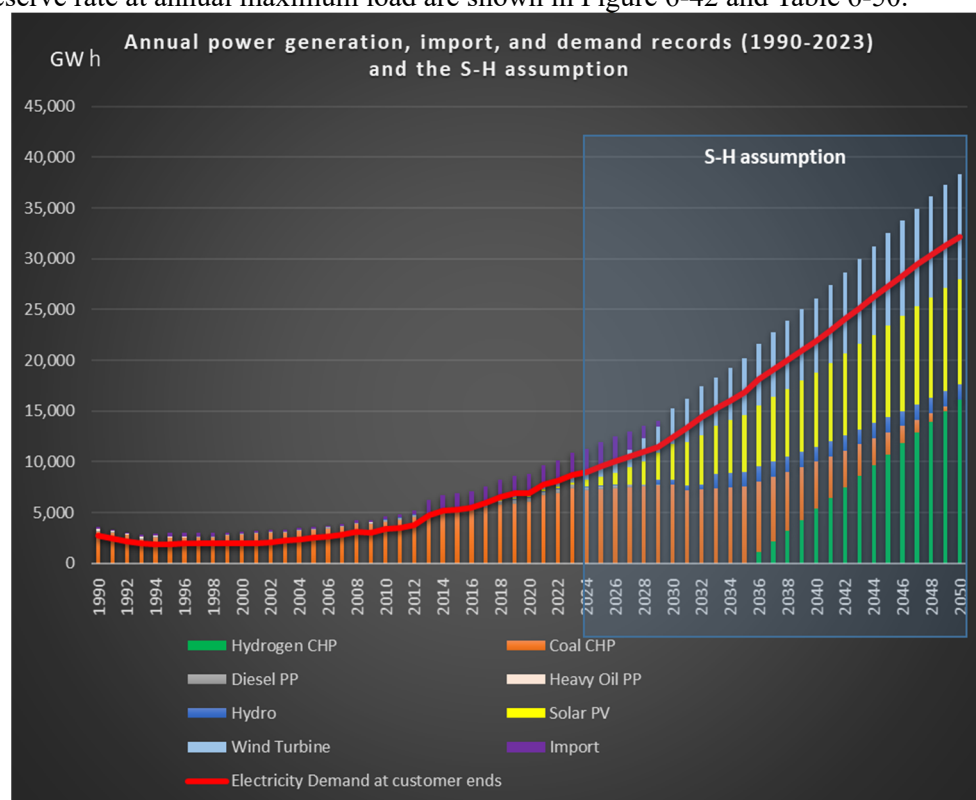
Unit: ktoe	2022 Actual	2030	2035	2040	2045	2050
Total heat supply	1,505	1,564	1,512	1,620	1,818	2,074
Bituminous coal	527 (35%)	547 (35%)	529 (35%)	325 (20%)	152 (8%)	0 (0%)
Lignite	977 (65%)	1,016 (65%)	982 (65%)	604 (37%)	283 (16%)	0 (0%)
Heavy oil	1 (0%)	1 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)
Hydrogen CHP	0 (0%)	0 (0%)	0 (0%)	691 (43%)	1,383 (76%)	2,074 (100%)
In-house consumption	148 (10%)	156 (10%)	151 (10%)	162 (10%)	182 (10%)	207 (10%)
Heat transfer loss	56 (4%)	56 (4%)	54 (4%)	58 (4%)	65 (4%)	75 (4%)
Statistical Error	-46	0	0	0	0	0
Heat demand at customer ends	1,348 (90%)	1,351 (86%)	1,306 (86%)	1,400 (86%)	1,570 (86%)	1,792 (86%)

Source: Prepared by the survey team

2) Electricity Supply System Calculation Results for the S-H Scenario

The results of power generation calculations for the S-H scenario of the electricity supply system are shown in Figure 6-38 and Table 6-46. The composition ratio on an energy basis is shown in Figure 6-39 and Table 6-47.

In addition, the installed capacity (MW) is shown in Figure 6-40 and Table 6-48. The installed capacity composition ratio is shown in Figure 6-41 and Table 6-49. The supply capacity (MW) and reserve rate at annual maximum load are shown in Figure 6-42 and Table 6-50.



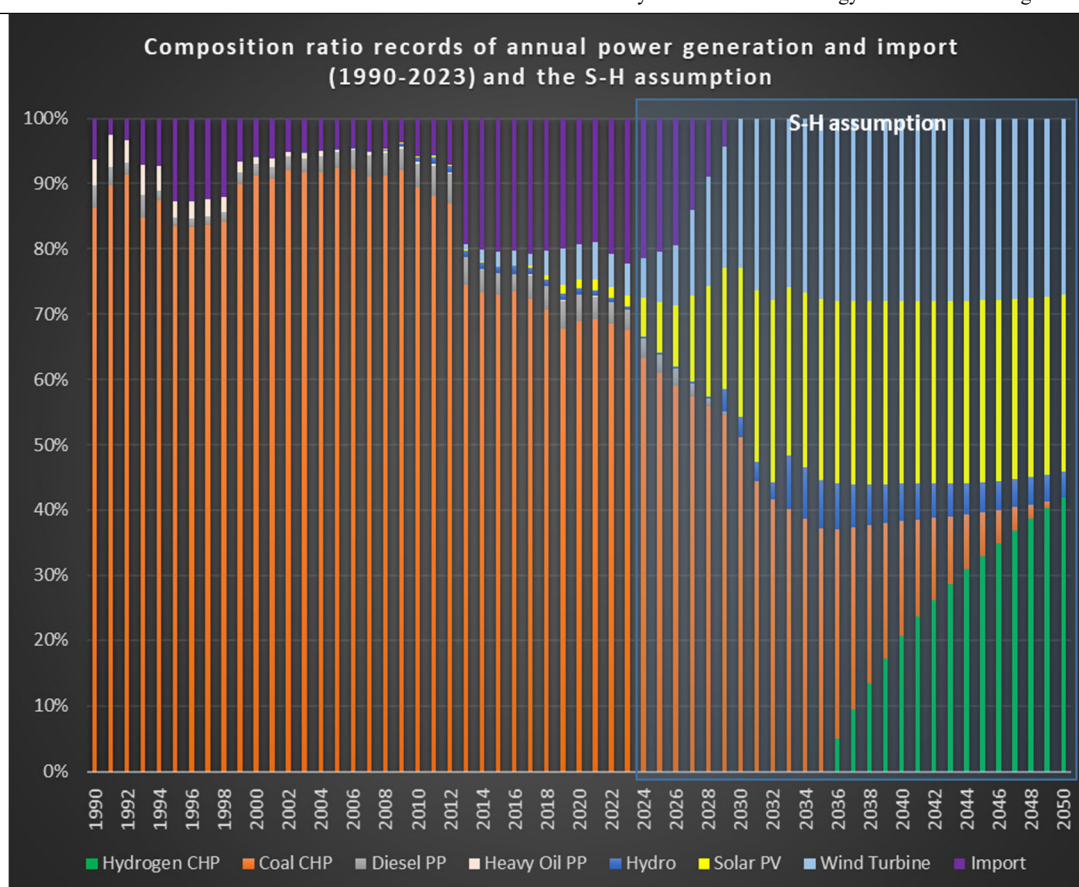
Source: Prepared by the survey team

Figure 6-38 Annual Power Generation, Import, and Demand Records and the S-H Scenario

Table 6-46 Electricity Supply Balance (Energy Basis) under the S-H Scenario

Unit GWh	2023 Actual	2030	2035	2040	2045	2050
Domestic Power Generation at generator ends total	8,483	15,234	20,224	26,082	32,508	38,321
Coal CHP	7,377	7,789	7,529	4,631	2,167	0
Diesel	334	0	0	0	0	0
Heavy oil	0	0	0	0	0	0
Hydro	48	473	1,504	1,504	1,504	1,504
Solar PV	193	3,486	5,596	7,293	9,058	10,368
Wind Turbine	532	3,486	5,596	7,293	9,058	10,368
Hydrogen CHP	0	0	0	5,360	10,720	16,081
Import	2,427	0	0	0	0	0
Total Supply	10,910	15,234	20,224	26,082	32,508	38,321
Electricity in-house consumption	1,059	1,090	1,054	1,227	1,461	1,737
Transmission and distribution losses	1,179	1,697	2,300	2,983	3,726	4,390
Electricity demand at customer ends	8,672	12,447	16,870	21,872	27,322	32,194
Total Electricity Consumption	10,910	15,234	20,224	26,082	32,508	38,321
Electricity in-house consumption rate (fossil fuels and hydrogen)	13.7%	14.0%	14.0%	14.0%	14.0%	14.0%
Transmission and Distribution Loss Ratio	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%

Source: Prepared by the survey team



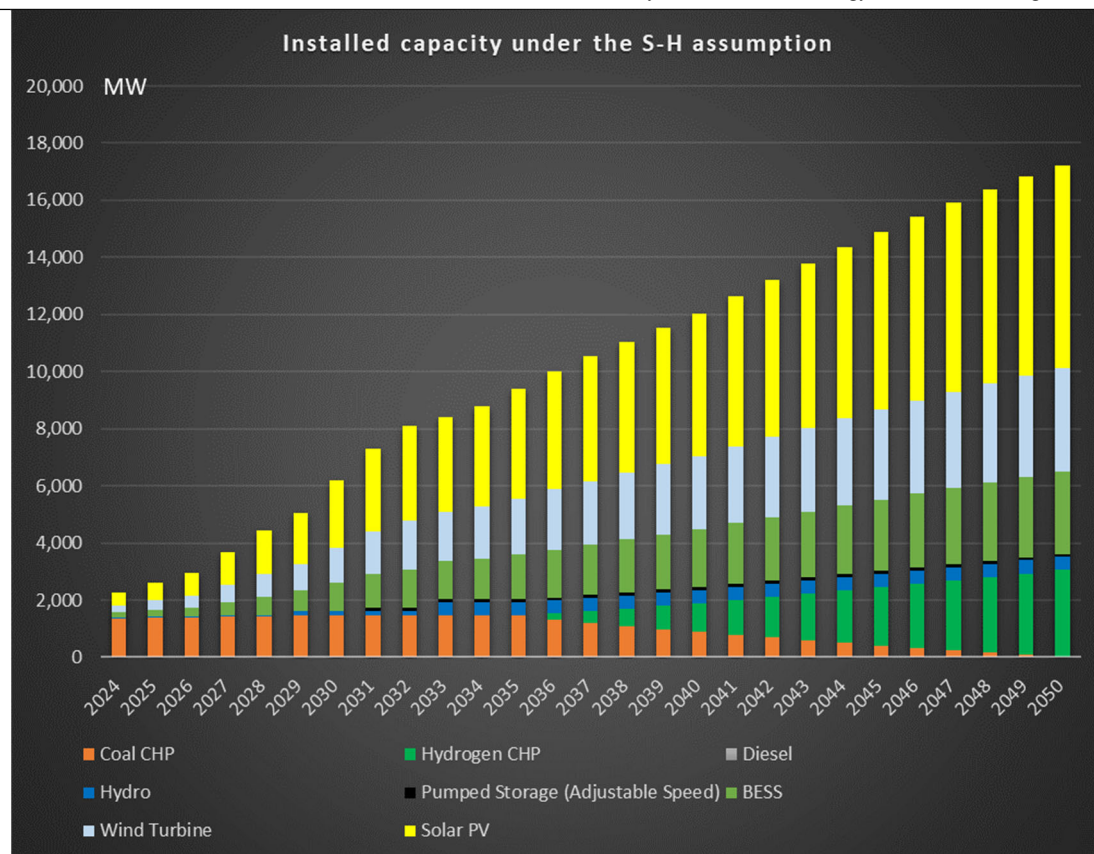
Source: Prepared by the survey team

**Figure 6-39 Composition Ratio Records of Annual Power Generation and Import
and the S-H Scenario**

Table 6-47 Composition of Electricity Supply by Type (Energy Basis) under the S-H Scenario

	2023 Actual	2030	2035	2040	2045	2050
Domestic power at generator ends total	77.8%	100.0%	100.0%	100.0%	100.0%	100.0%
Coal CHP	67.6%	51.1%	37.2%	17.8%	6.7%	0.0%
Diesel	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy oil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	0.4%	3.1%	7.4%	5.8%	4.6%	3.9%
Solar PV	1.8%	22.9%	27.7%	28.0%	27.9%	27.1%
Wind Turbine	4.9%	22.9%	27.7%	28.0%	27.9%	27.1%
Hydrogen CHP	0.0%	0.0%	0.0%	20.6%	33.0%	42.0%
Import	22.2%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Prepared by the survey team



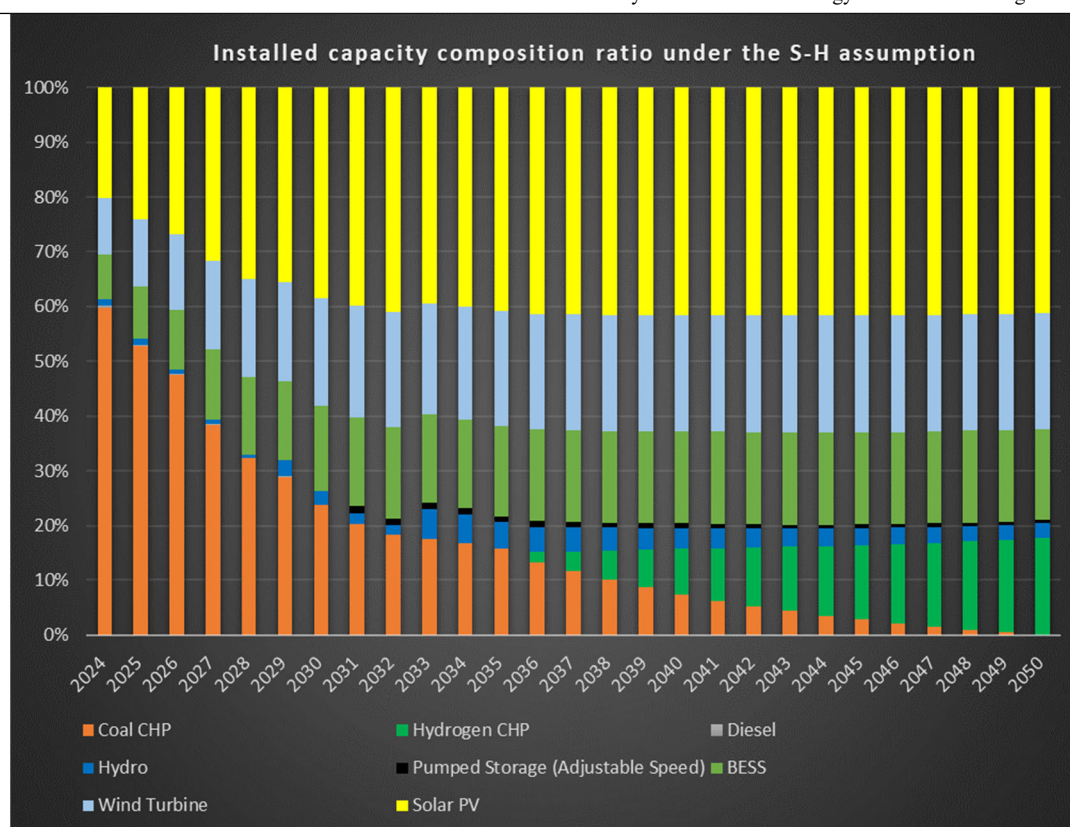
Source: Prepared by the survey team

Figure 6-40 Installed Capacity under the S-H Scenario

Table 6-48 Installed Capacity under the S-H Scenario

Unit : MW	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,482	1,482	881	412	0
Hydrogen CHP	0	0	0	1,020	2,040	3,059
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	2,388	3,833	4,995	6,204	7,101
Wind Turbine	155	1,220	1,958	2,552	3,170	3,628
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	966	1,550	2,020	2,509	2,872
Total	1,724	6,201	9,383	12,030	14,896	17,222

Source: Prepared by the survey team



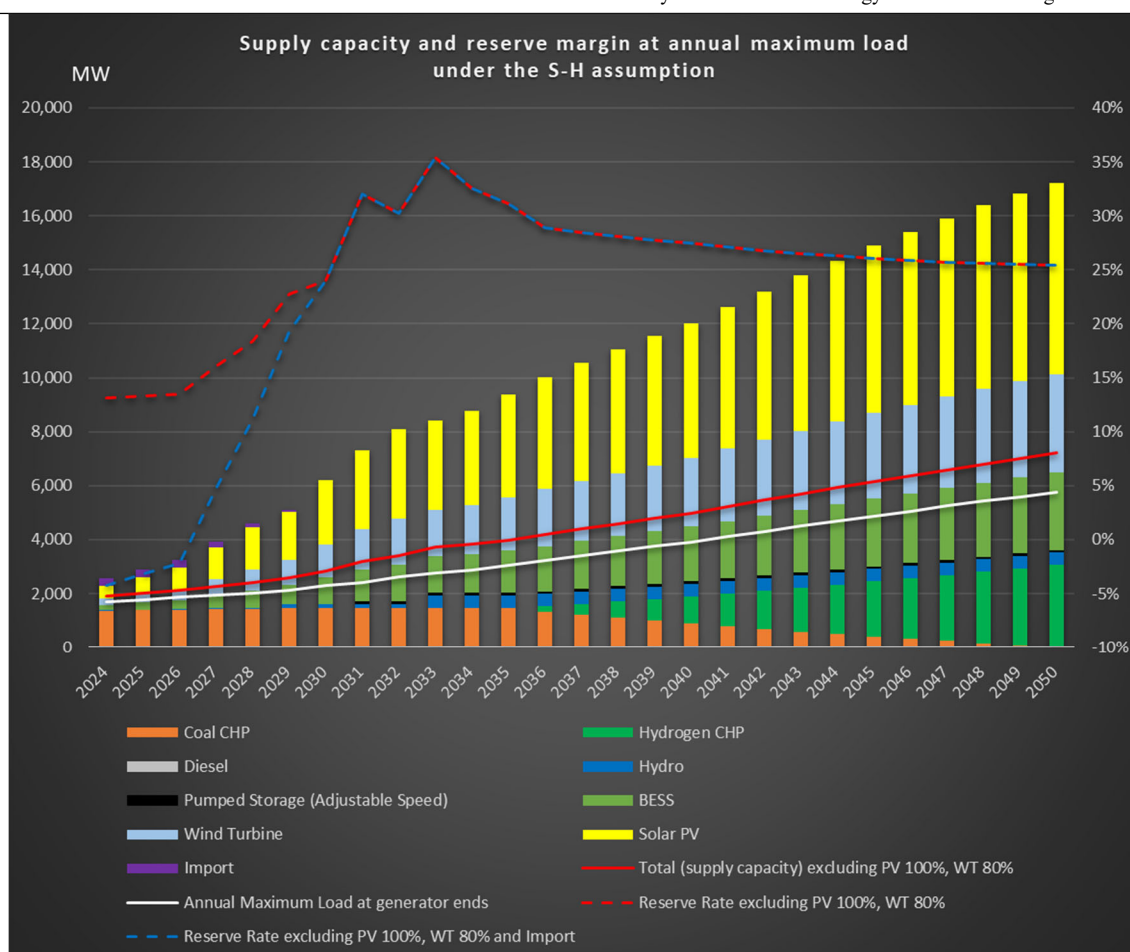
Source: Prepared by the survey team

Figure 6-41 Installed Capacity Composition Ratio under the S-H Scenario

Table 6-49 Installed Capacity Composition Ratio under the S-H Scenario

	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	76.2%	23.9%	15.8%	7.3%	2.8%	0.0%
Hydrogen CHP	0.0%	0.0%	0.0%	8.5%	13.7%	17.8%
Diesel	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	1.5%	2.4%	4.9%	3.8%	3.1%	2.7%
Solar PV	8.2%	38.5%	40.8%	41.5%	41.7%	41.2%
Wind Turbine	9.0%	19.7%	20.9%	21.2%	21.3%	21.1%
Pumped Storage (Adjustable Speed)	0.0%	0.0%	1.1%	0.8%	0.7%	0.6%
BESS	4.7%	15.6%	16.5%	16.8%	16.8%	16.7%
Total	100%	100%	100%	100%	100%	100%

Source: Prepared by the survey team



Source: Prepared by the survey team

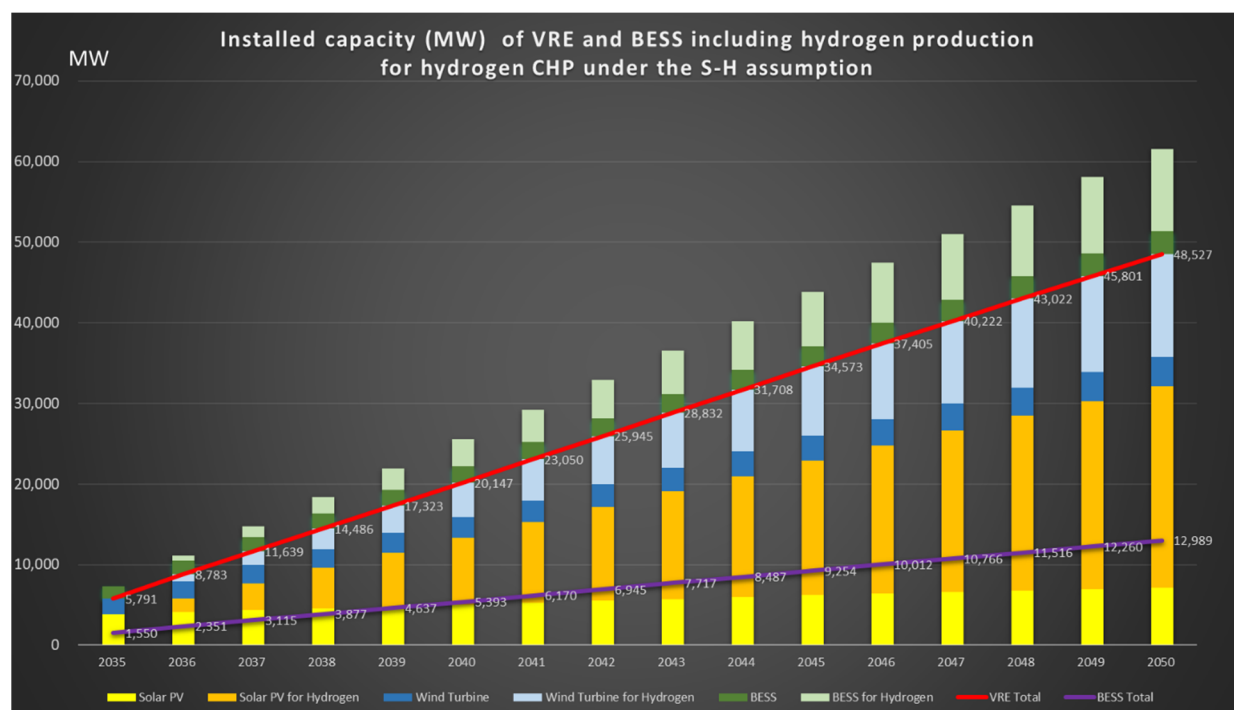
Figure 6-42 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load under the S-H Scenario

Table 6-50 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load under the S-H Scenario

	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,482	1,482	881	412	0
Hydrogen CHP	0	0	0	1,020	2,040	3,059
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	2,388	3,833	4,995	6,204	7,101
Wind Turbine	155	1,220	1,958	2,552	3,170	3,628
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	966	1,550	2,020	2,509	2,872
Total capacity	1,724	6,201	9,383	12,030	14,896	17,222
Import	294	0	0	0	0	0
Total	2,018	6,201	9,383	12,030	14,896	17,222
Total (supply capacity) excluding PV 100%, WT 80%	1,753	2,837	3,984	4,992	6,156	7,218
Annual Maximum Load at generator ends	1,636	2,288	3,038	3,918	4,883	5,756
Reserve Rate excluding PV 100%, WT 80%	7.2%	24.0%	31.2%	27.4%	26.1%	25.4%
Reserve Rate excluding PV 100%, WT 80% and Import	-10.8%	24.0%	31.2%	27.4%	26.1%	25.4%

Source: Prepared by the survey team

The total installed capacity, including VRE (solar PV + wind) and BESS, required to produce hydrogen for hydrogen CHP is shown in Figure 6-43 and Table 6-51.



Source: Prepared by the survey team.

Figure 6-43 Installed Capacity of VRE and BESS Including Hydrogen Production for Hydrogen CHP under the S-H Scenario

Table 6-51 Installed Capacity of VRE and BESS Including Hydrogen Production for Hydrogen CHP under the S-H Scenario

Unit: MW	2023	2030	2035	2040	2045	2050
Solar PV	141	2,388	3,833	4,995	6,204	7,101
Solar PV for Hydrogen Production	0	0	0	8,335	16,671	25,006
Wind Turbine	155	1,220	1,958	2,552	3,170	3,628
Wind Turbine for Hydrogen Production	0	0	0	4,264	8,527	12,791
VRE (Solar PV + Wind Turbine)	296	3,608	5,791	20,147	34,573	48,527
BESS (MW)	81	966	1,550	2,020	2,509	2,872
BESS (MW) for Hydrogen Production	0	0	0	3,373	6,745	10,118
BESS total	81	966	1,550	5,393	9,254	12,989

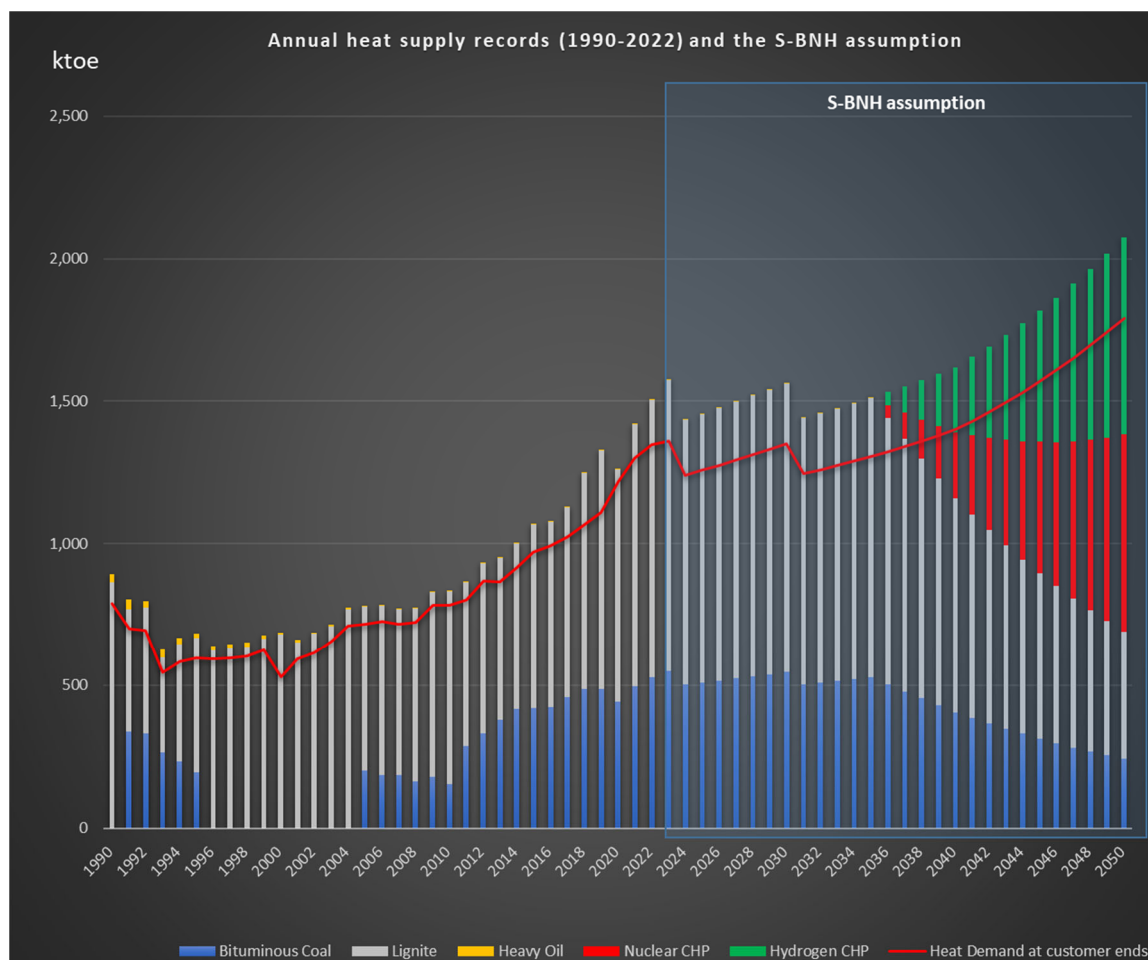
Source: Prepared by the survey team

(4) S-BNH Scenario

This scenario is based on the introduction of nuclear CHP and hydrogen CHP into the heat supply system starting in 2036, and nuclear CHP, hydrogen CHP, and coal CHP each accounting for 1/3 of the total heat supply in 2050.

1) Heat Supply System Calculation Results for the S-BNH Scenario

The calculation results of the heat supply of the heat supply system in the S-BNH scenario are shown in Figure 6-44 and Table 6-52.



Source: Prepared by the survey team.

Figure 6-44 Actual Heat Supply Records and the S-BNH Scenario

Table 6-52 Heat Supply Balance under the S-BNH Scenario

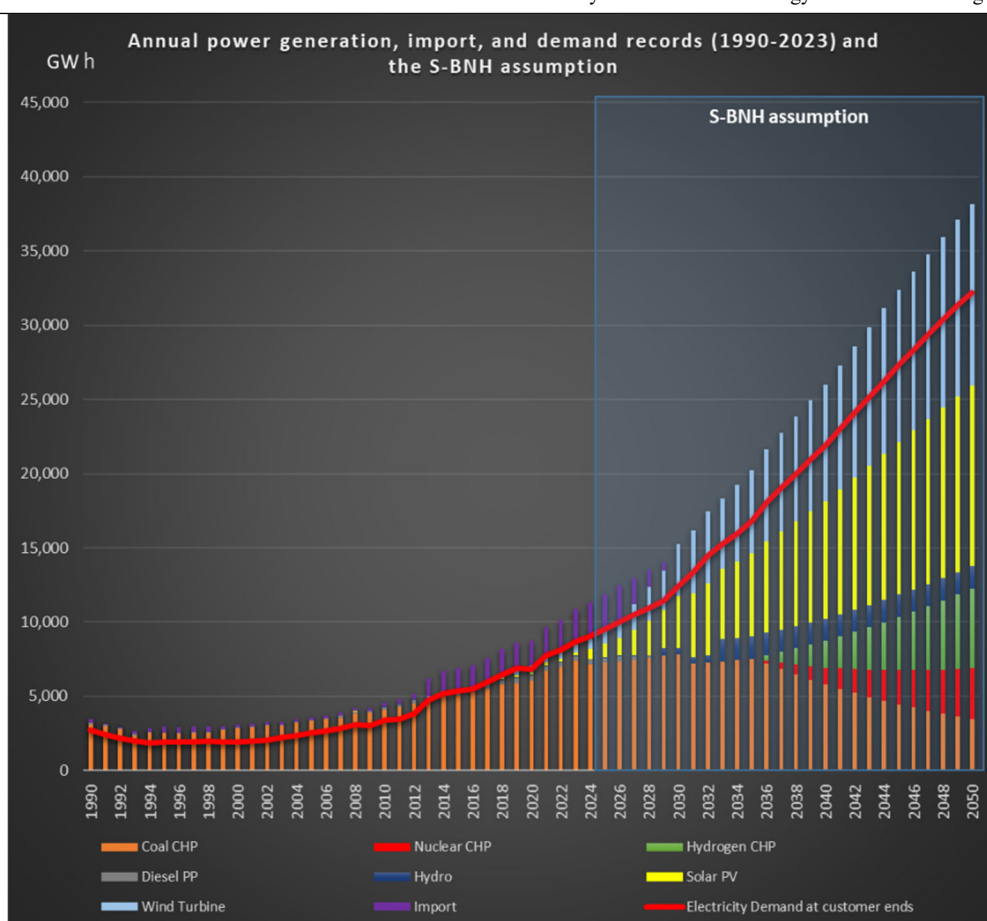
Unit: ktoe	2022 Actual	2030	2035	2040	2045	2050
Total heat supply	1,505	1,564	1,512	1,620	1,818	2,074
Bituminous coal	527 (35%)	547 (35%)	529 (35%)	406 (25%)	314 (17%)	242 (12%)
Lignite	977 (65%)	1,016 (65%)	982 (65%)	753 (47%)	583 (32%)	449 (22%)
Heavy oil	1 (0%)	1 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)
Nuclear CHP	0 (0%)	0 (0%)	0 (0%)	230 (14%)	461 (25%)	691 (33%)
Hydrogen CHP	0 (0%)	0 (0%)	0 (0%)	230 (14%)	461 (25%)	691 (33%)
In-house consumption	148 (10%)	156 (10%)	151 (10%)	162 (10%)	182 (10%)	207 (10%)
Heat transfer loss	56 (4%)	56 (4%)	54 (4%)	58 (4%)	65 (4%)	75 (4%)
Statistical error	-46	0	0	0	0	0
Heat demand at customer ends	1,348 (90%)	1,351 (86%)	1,306 (86%)	1,400 (86%)	1,570 (86%)	1,792 (86%)

Source: Prepared by the survey team

2) Electricity Supply System Calculation Results for the S-BNH Scenario

The results of power generation calculations for the S-BNH scenario of the electricity supply system are shown in Figure 6-45 and Table 6-53. The composition on an energy basis is shown in Figure 6-46 and Table 6-54.

In addition, the installed capacity of power sources (MW) is shown in Figure 6-47 and Table 6-55. The installed capacity composition ratio is shown in Figure 6-48 and Table 6-56. The supply capacity (MW) and reserve rate at annual maximum load are shown in Figure 6-49 and Table 6-57.



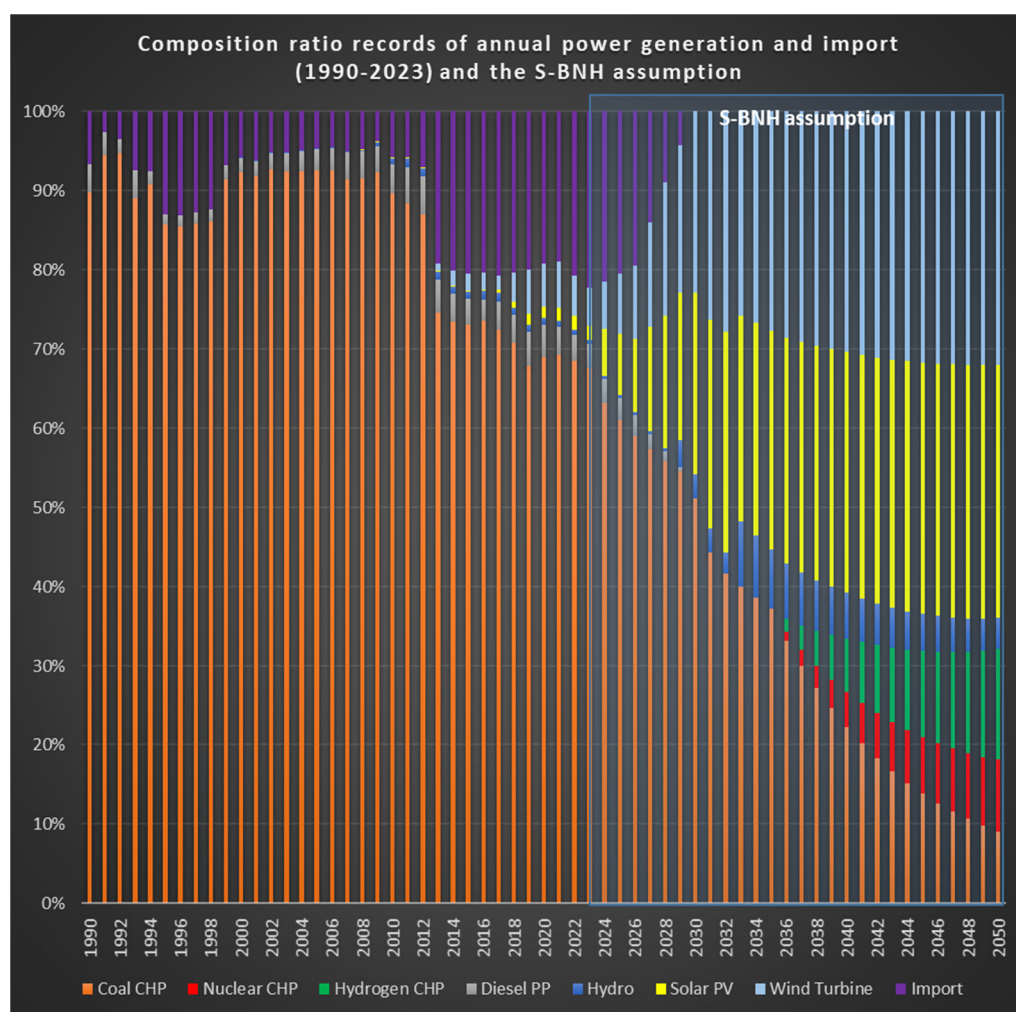
Source: Prepared by the survey team.

Figure 6-45 Annual Power Generation, Import, and Demand Records and the S-BNH Scenario

Table 6-53 Electricity Supply Balance (Energy Basis) under the S-BNH Scenario

Unit : GWh	2023 Actual	2030	2035	2040	2045	2050
Domestic Power Generation at generator ends total	8,483	15,234	20,224	26,017	32,380	38,128
Coal CHP	7,377	7,789	7,529	5,776	4,467	3,446
Diesel	334	0	0	0	0	0
Heavy oil	0	0	0	0	0	0
Hydro	48	473	1,504	1,504	1,504	1,504
Solar PV	193	3,486	5,596	7,901	10,269	12,186
Wind Turbine	532	3,486	5,596	7,901	10,269	12,186
Nuclear CHP	0	0	0	1,149	2,297	3,446
Hydrogen CHP	0	0	0	1,787	3,573	5,360
Import	2,427	0	0	0	0	0
Total Supply	10,910	15,234	20,224	26,017	32,380	38,128
Electricity in-house consumption	1,059	1,090	1,054	1,162	1,333	1,544
Transmission and distribution losses	1,179	1,697	2,300	2,983	3,726	4,390
Electricity demand at customer ends	8,672	12,447	16,870	21,872	27,322	32,194
Total Electricity Consumption	10,910	15,234	20,224	26,017	32,380	38,128
In-house electricity consumption rate (fossil fuel, nuclear power, hydrogen)	13.7%	14.0%	14.0%	14.0%	14.0%	14.0%
Transmission and Distribution Loss Ratio	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%

Source: Prepared by the survey team



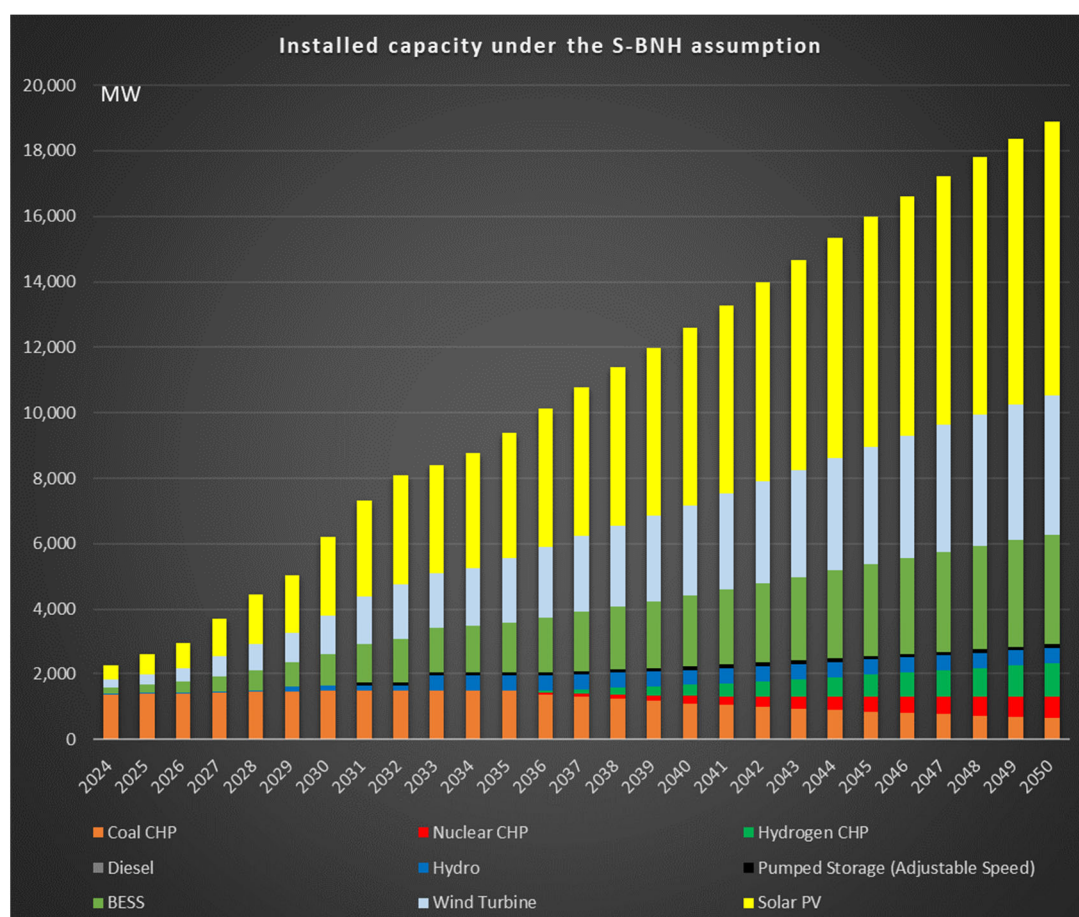
Source: Prepared by the survey team

Figure 6-46 Composition Ratio Records of Annual Power Generation and Import and the S-BNH Scenario

Table 6-54 Composition of Electricity Supply by Type (Energy Basis) under the S-BNH Scenario

	2023 Actual	2030	2035	2040	2045	2050
Domestic power at generator ends total	77.8%	100.0%	100.0%	100.0%	100.0%	100.0%
Coal CHP	67.6%	51.1%	37.2%	22.2%	13.8%	9.0%
Diesel	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy oil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	0.4%	3.1%	7.4%	5.8%	4.6%	3.9%
Solar PV	1.8%	22.9%	27.7%	30.4%	31.7%	32.0%
Wind Turbine	4.9%	22.9%	27.7%	30.4%	31.7%	32.0%
Nuclear CHP	0.0%	0.0%	0.0%	4.4%	7.1%	9.0%
Hydrogen CHP	0.0%	0.0%	0.0%	6.9%	11.0%	14.1%
Import	22.2%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Prepared by the survey team



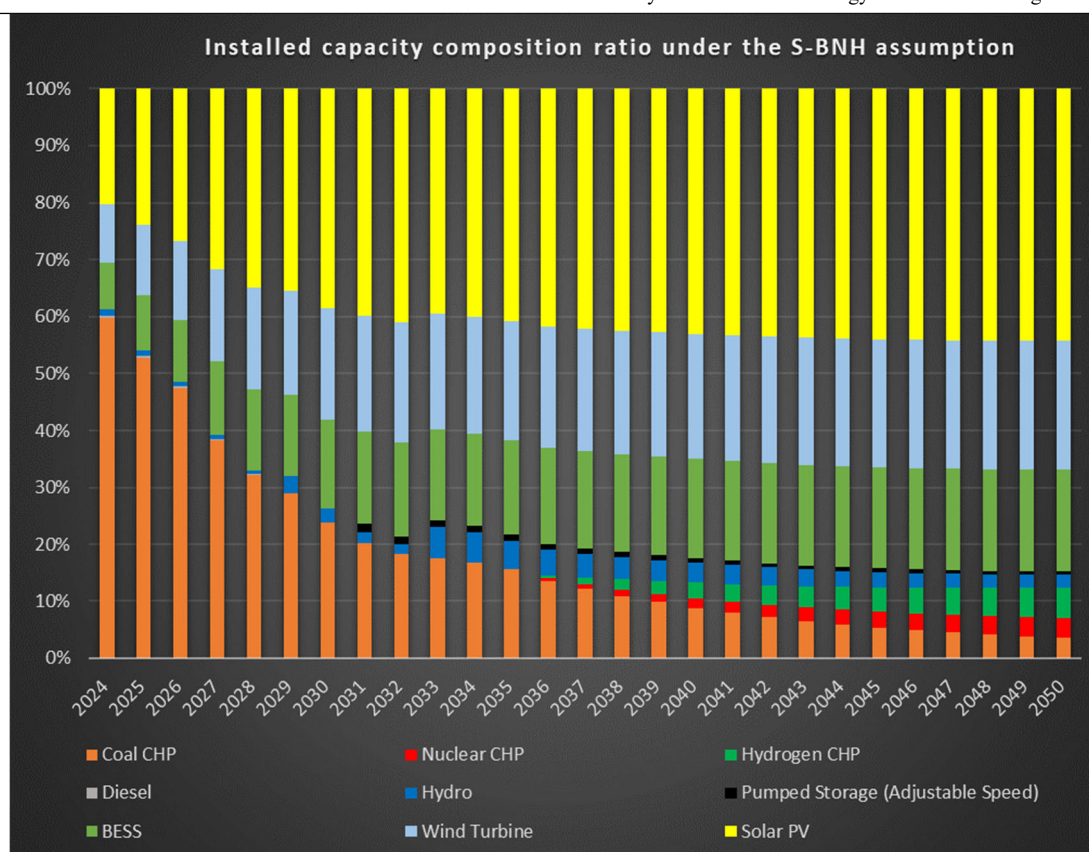
Source: Prepared by the survey team

Figure 6-47 Installed Capacity under the S-BNH Scenario

Table 6-55 Installed Capacity under the S-BNH Scenario

Unit : MW	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,482	1,482	1,099	850	656
Nuclear CHP	0	0	0	219	437	656
Hydrogen CHP	0	0	0	340	680	1,020
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	2,388	3,833	5,411	7,034	8,347
Wind Turbine	155	1,220	1,958	2,765	3,594	4,265
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	966	1,550	2,188	2,844	3,375
Total	1,724	6,201	9,383	12,583	16,000	18,878

Source: Prepared by the survey team



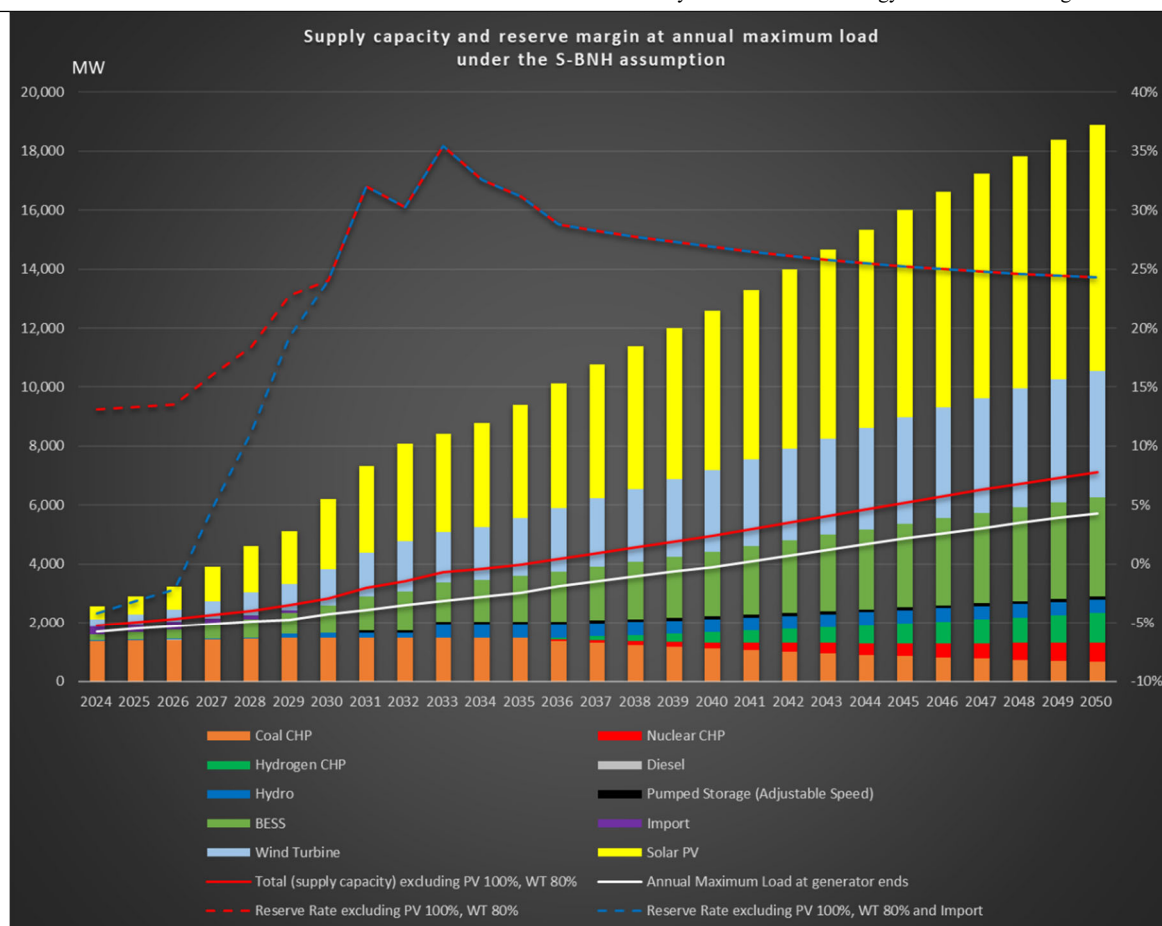
Source: Prepared by the survey team

Figure 6-48 Installed Capacity Composition Ratio under the S-BNH Scenario

Table 6-56 Installed Capacity Composition Ratio under the S-BNH Scenario

	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	76.2%	23.9%	15.8%	8.7%	5.3%	3.5%
Nuclear CHP	0.0%	0.0%	0.0%	1.7%	2.7%	3.5%
Hydrogen CHP	0.0%	0.0%	0.0%	2.7%	4.2%	5.4%
Diesel	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro	1.5%	2.4%	4.9%	3.7%	2.9%	2.4%
Solar PV	8.2%	38.5%	40.8%	43.0%	44.0%	44.2%
Wind Turbine	9.0%	19.7%	20.9%	22.0%	22.5%	22.6%
Pumped Storage (Adjustable Speed)	0.0%	0.0%	1.1%	0.8%	0.6%	0.5%
BESS	4.7%	15.6%	16.5%	17.4%	17.8%	17.9%
Total	100%	100%	100%	100%	100%	100%

Source: Prepared by the survey team



Source: Prepared by the survey team

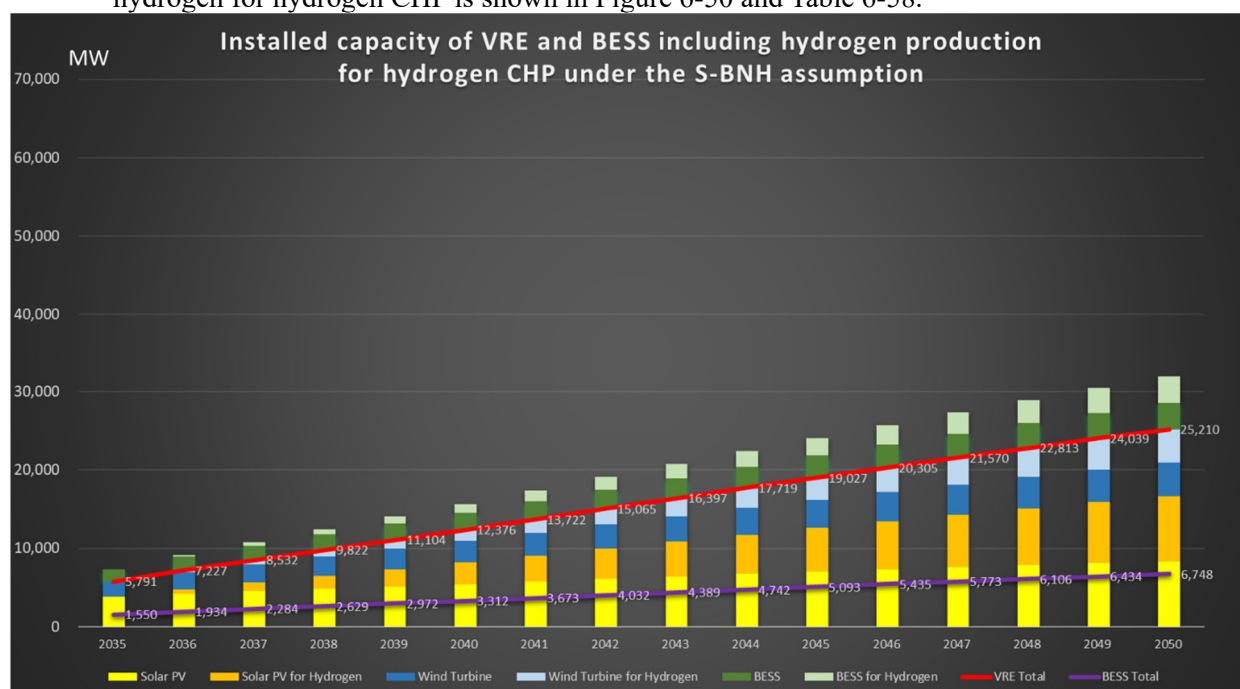
Figure 6-49 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load under the S-BNH Scenario

Table 6-57 Supply Capacity (MW) and Reserve Margin at Annual Maximum Load under the S-BNH Scenario

	2023 Actual	2030	2035	2040	2045	2050
Coal CHP	1,314	1,482	1,482	1,099	850	656
Nuclear CHP				219	437	656
Hydrogen CHP	0	0	0	340	680	1,020
Diesel	7	0	0	0	0	0
Hydro	26	146	461	461	461	461
Solar PV	141	2,388	3,833	5,411	7,034	8,347
Wind Turbine	155	1,220	1,958	2,765	3,594	4,265
Pumped Storage (Adjustable Speed)	0	0	100	100	100	100
BESS	81	966	1,550	2,188	2,844	3,375
Total capacity	1,724	6,201	9,383	12,583	16,000	18,878
Import	294	0	0	0	0	0
Total	2,018	6,201	9,383	12,583	16,000	18,878
Total (supply capacity) excluding PV 100%, WT 80%	1,753	2,837	3,984	4,960	6,091	7,120
Annual Maximum Load at generator ends	1,636	2,288	3,038	3,908	4,864	5,727
Reserve Rate excluding PV 100%, WT 80%	7.2%	24.0%	31.2%	26.9%	25.2%	24.3%
Reserve Rate excluding PV 100%, WT 80% and Import	-10.8%	24.0%	31.2%	26.9%	25.2%	24.3%

Source: Prepared by the survey team

The total installed capacity, including VRE (solar PV + wind) and BESS, required to produce hydrogen for hydrogen CHP is shown in Figure 6-50 and Table 6-58.



Source: Prepared by the survey team.

Figure 6-50 Installed Capacity of VRE and BESS including Hydrogen Production for Hydrogen CHP under the S-BNH Scenario

Table 6-58 Installed Capacity of VRE and BESS including Hydrogen Production for Hydrogen CHP under the S-BNH Scenario

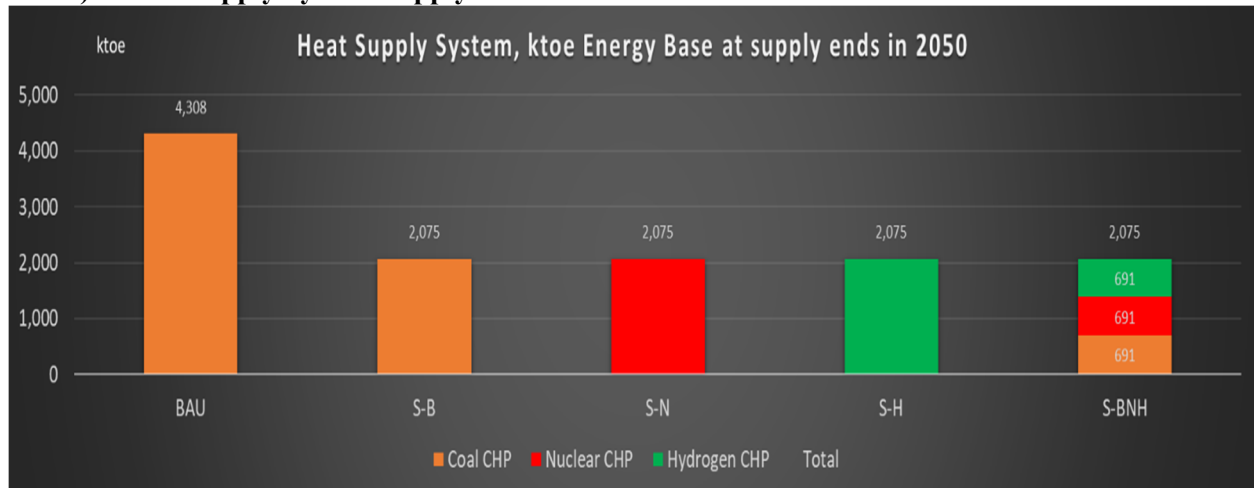
Unit: MW	2023	2030	2035	2040	2045	2050
Solar PV	141	2,388	3,833	5,411	7,034	8,347
Solar PV for Hydrogen Production	0	0	0	2,778	5,557	8,335
Wind Turbine	155	1,220	1,958	2,765	3,594	4,265
Wind Turbine for Hydrogen Production	0	0	0	1,421	2,842	4,264
VRE (Solar PV + Wind Turbine)	296	3,608	5,791	12,376	19,027	25,210
BESS (MW)	81	966	1,550	2,188	2,844	3,375
BESS (MW) for Hydrogen Production	0	0	0	1,124	2,248	3,373
BESS total	81	966	1,550	3,312	5,093	6,748

Source: Prepared by the survey team

(5) Comparison of Each Scenario in 2050

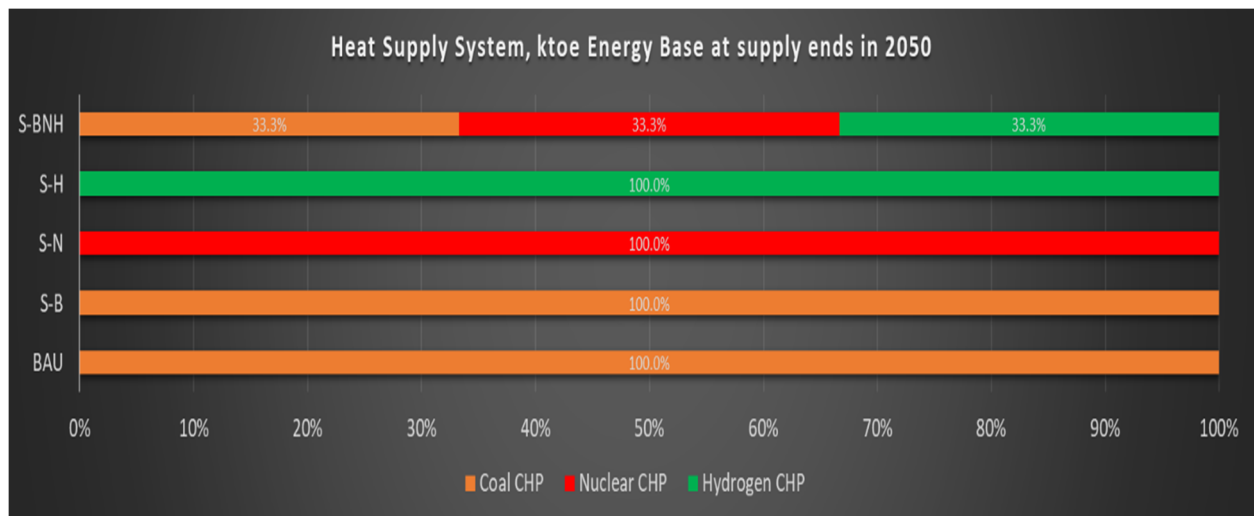
Comparison of each scenario in the 2050 cross-section. (Figure 6-51 , Figure 6-52 , Figure 6-53 , Figure 6-54 , Figure 6-55 , Figure 6-56 , Figure 6-57 , Table 6-59)

1) Heat Supply System Supply in 2050



Source: Prepared by the survey team

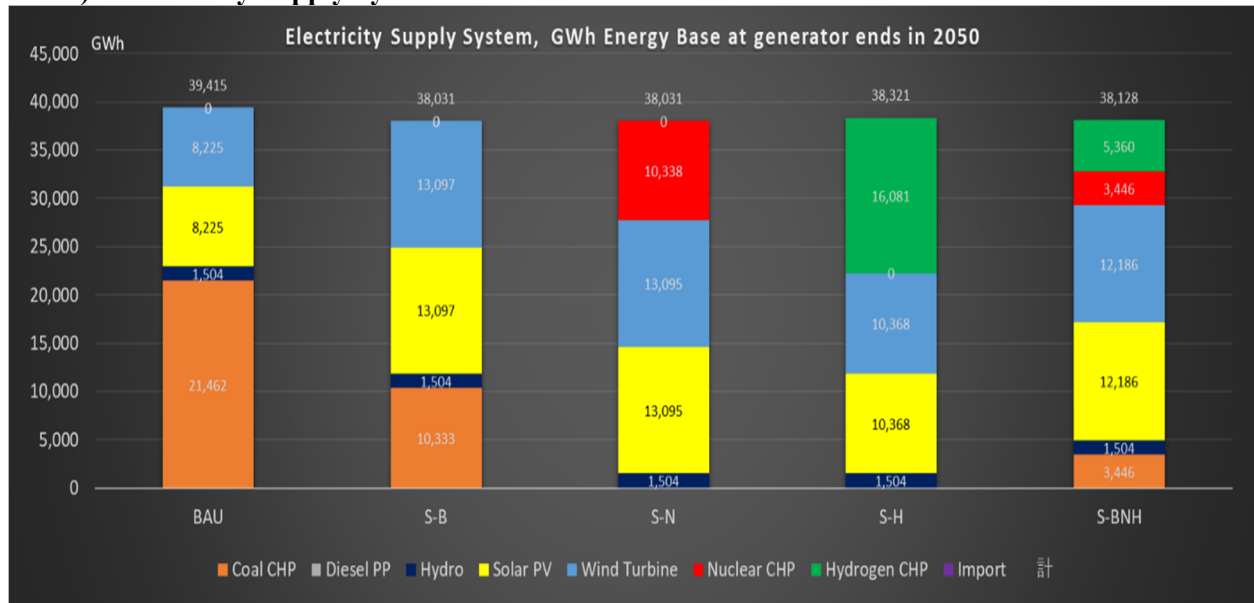
Figure 6-51 Heat Supply at Supply End in 2050 (ktoe Energy Basis)



Source: Prepared by the survey team

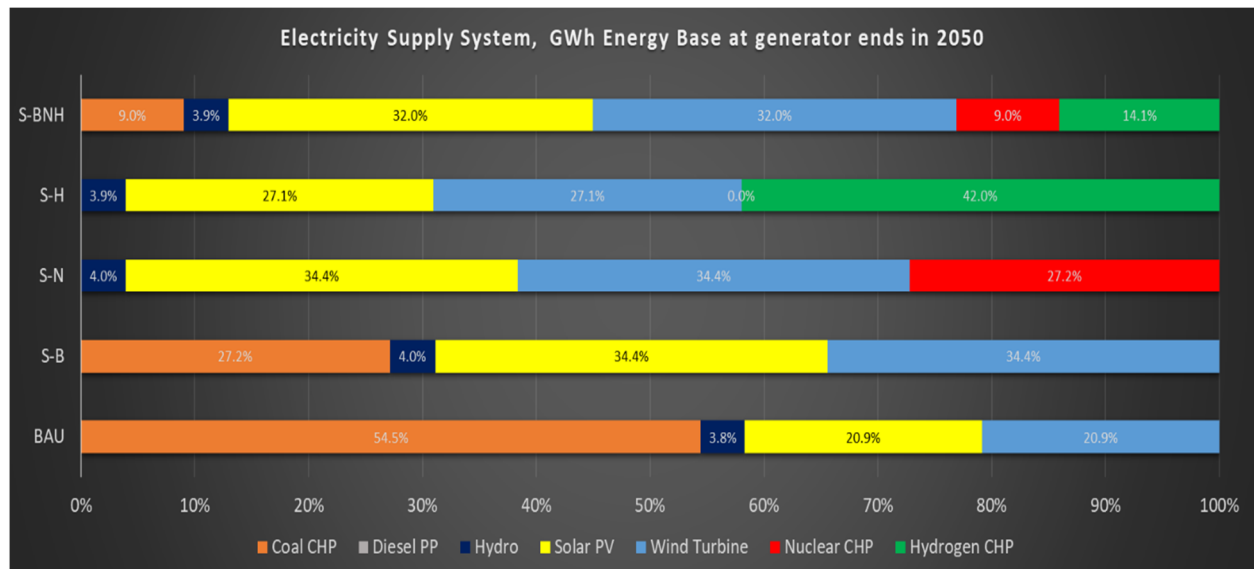
Figure 6-52 Composition Rate of Heat Supply at Supply Ends in 2050 (ktoe Energy Basis)

2) Electricity Supply System in 2050



Source: Prepared by the survey team

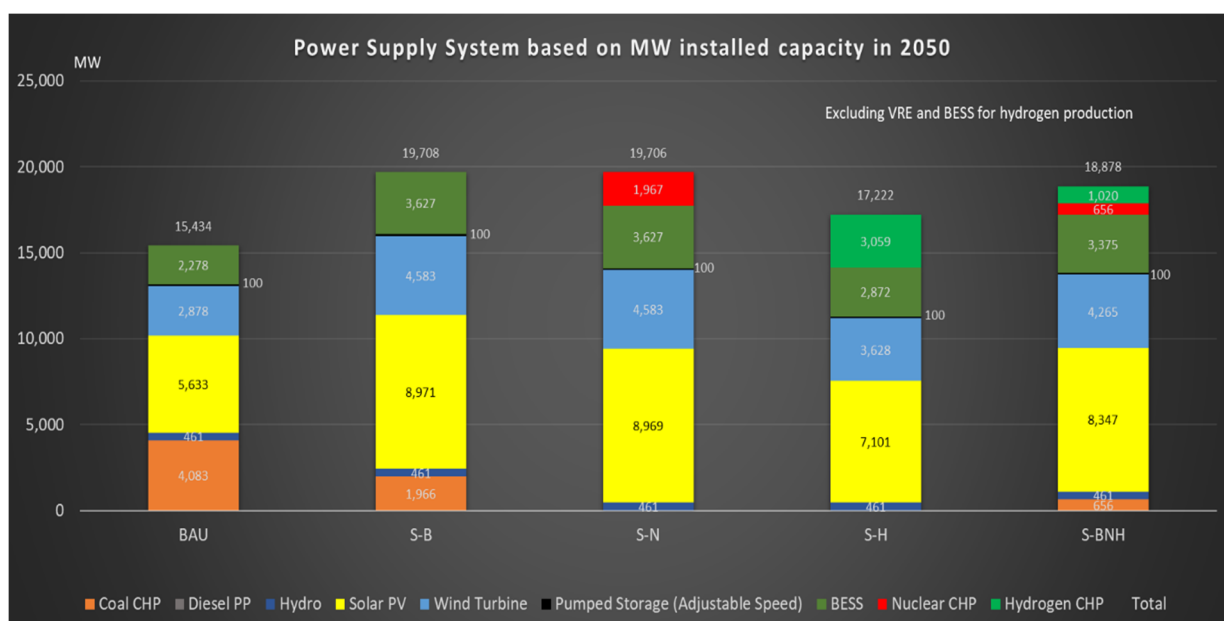
Figure 6-53 Electricity Supply at Generator End in 2050 (GWh Energy Basis)



Source: Prepared by the survey team

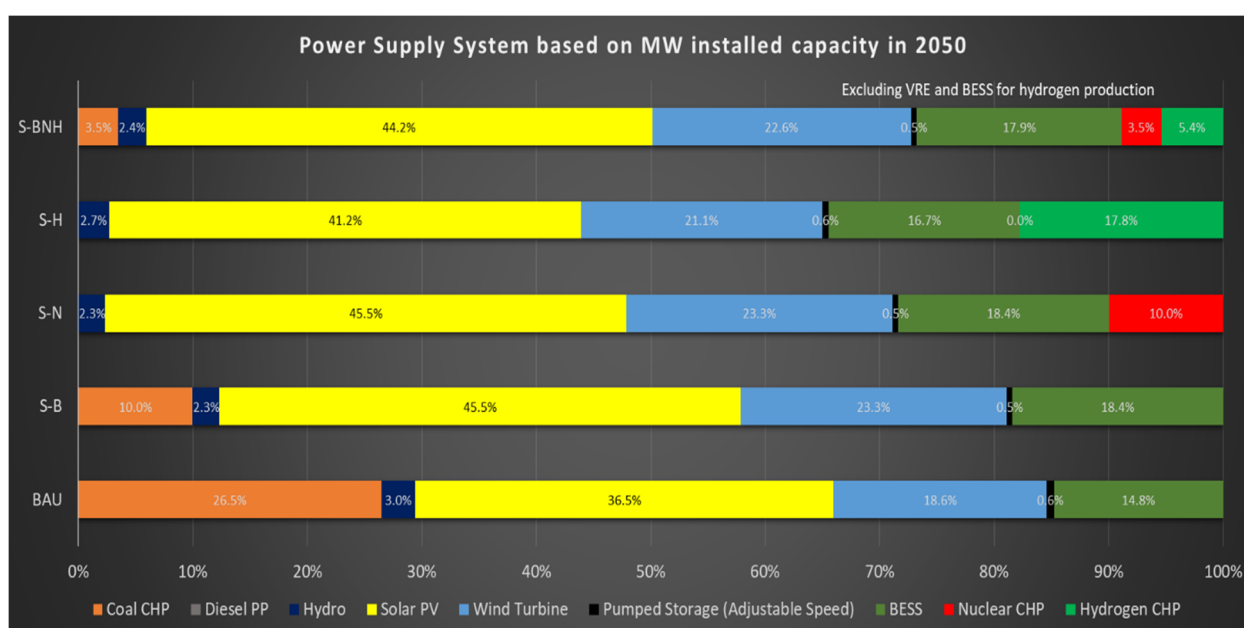
Figure 6-54 Composition Rate of Electricity Supply at Generator End in 2050 (GWh Energy Basis)

3) Installed Capacity of Electricity Supply System in 2050



Source: Prepared by the survey team

Figure 6-55 Power Supply Capacity (MW) in 2050



Source: Prepared by the survey team

Figure 6-56 Composition Rate of Power Supply Capacity (MW) in 2050

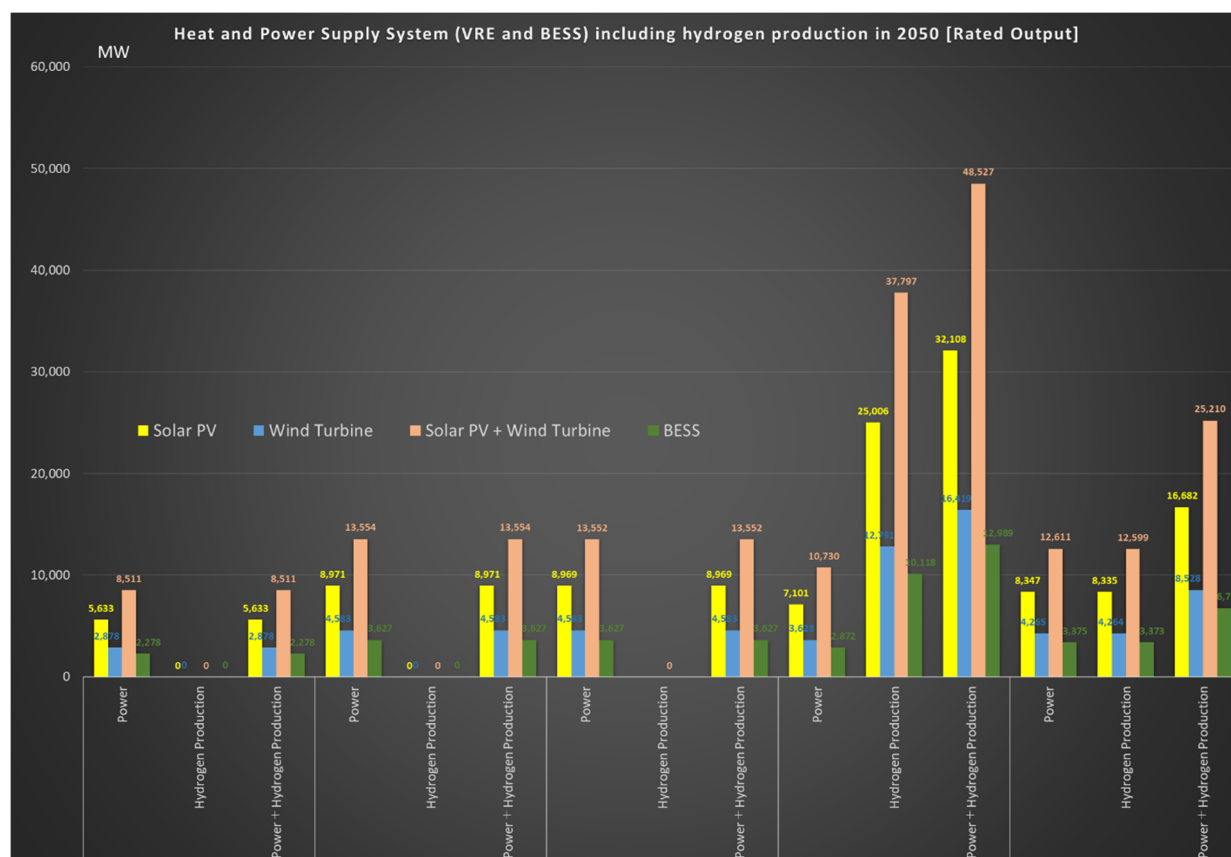
4) VRE and BESS Capacities in Heat and Power Supply Systems in 2050 Including Hydrogen Production

VRE and BESS installed capacity including hydrogen production applications for hydrogen CHP in 2050 is shown in Figure 6-57 and Table 6-59.

The VRE and BESS capacities for hydrogen production for hydrogen CHP in the **S-H** scenario are about **3.5 times** larger than those for electricity supply.

On the other hand, the amount of VRE and BESS equipment for hydrogen production for hydrogen

CHP in the **S-BNH** scenario would require **the same amount of** equipment as for electricity supply.



Source: Prepared by the survey team

Figure 6-57 VRE and BESS Capacities in Heat and Power Supply Systems in 2050 Including Hydrogen Production

Table 6-59 VRE and BESS Capacities in Heat and Power Supply Systems in 2050 Including Hydrogen Production

[MW]	BAU			S-B			S-N			S-H			S-BNH		
	Electricity	Hydrogen production	Electricity+ Hydrogen production	Electricity	Hydrogen production	Electricity+ Hydrogen production	Electricity	Hydrogen production	Electricity+ Hydrogen production	Electricity	Hydrogen production	Electricity+ Hydrogen production	Electricity	Hydrogen production	Electricity+ Hydrogen production
Solar PV	5,633	0	5,633	8,971	0	8,971	8,969	0	8,969	7,101	25,006	32,108	8,347	8,335	16,682
Wind Turbine	2,878	0	2,878	4,583	0	4,583	4,583	0	4,583	3,628	12,791	16,419	4,265	4,264	8,528
Solar PV+ Wind Turbine	8,511	0	8,511	13,554	0	13,554	13,552	0	13,552	10,730	10,730	48,527	12,611	12,599	25,210
BESS	2,278	0	2,278	3,627	0	3,627	3,627	0	3,627	2,872	10,118	12,989	3,375	3,373	6,748

Source: Prepared by the survey team

6.5 CO₂ Emissions by Scenario

The energy transition scenarios developed in Section 6.4 were integrated into the energy supply and demand model to estimate CO₂ emissions. The results are presented in Table 6-60 and Figure 6-58. Compared to BAU (67.79 million tons of CO₂), scenario S-B shows a 57.1% reduction, S-N and S-H both show an 89.5% reduction, and S-BNH a 78.7% reduction.

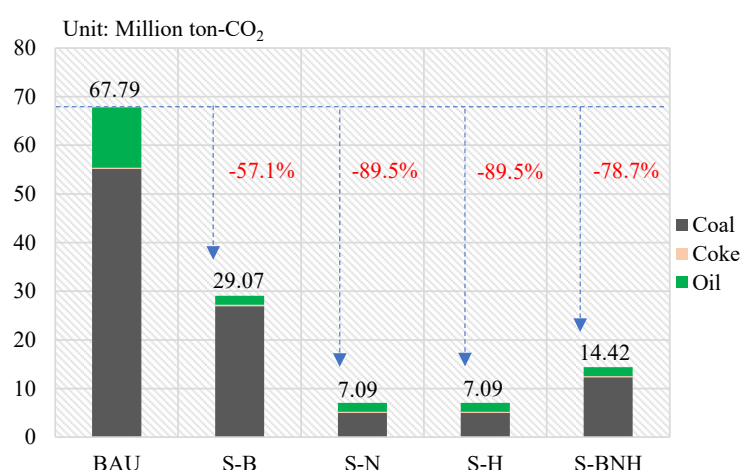
In S-N and S-H, power generation sector CO₂ emissions are nearly zero. Emissions in these scenarios mainly come from coal use in industry and petroleum use in transportation. S-BNH maintains some coal-fired power while promoting nuclear and hydrogen generation, aiming to cut CO₂ emissions significantly through diversified power sources.

The technologies in the supply scenarios yield varying CO₂ reduction effects, but CO₂ emissions alone cannot evaluate their merits. Optimal combinations must consider feasibility, costs, and energy supply security.

Table 6-60 CO₂ Emissions by Scenario and Energy Source (2050)

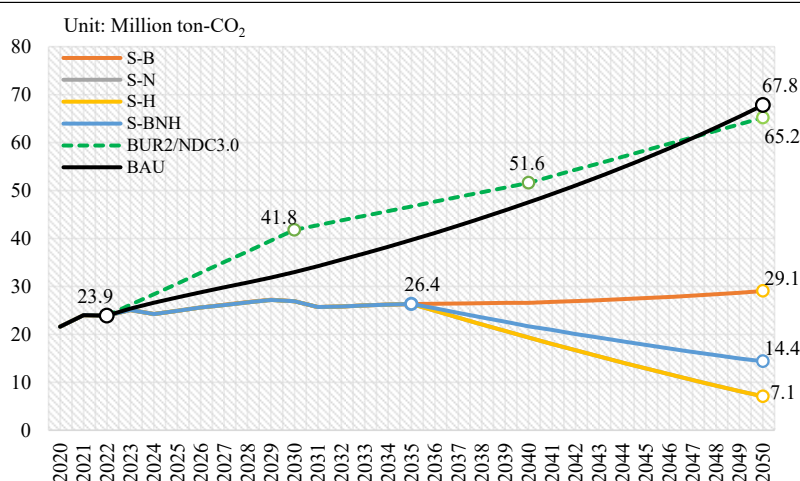
	2050 (Unit: Million ton-CO ₂)					Reduction rate compared to BAU (%)			
	BAU	S-B	S-N	S-H	S-BNH	S-B/BAU	S-N/BAU	S-H/BAU	S-BNH/BAU
Coal	55.15	26.97	4.99	4.99	12.32	-51.1	-91.0	-91.0	-77.7
Coke	0.23	0.23	0.23	0.23	0.23	0.0	0.0	0.0	0.0
Oil	12.41	1.87	1.87	1.87	1.87	-85.0	-85.0	-85.0	-85.0
Total	67.79	29.07	7.09	7.09	14.42	-57.1	-89.5	-89.5	-78.7

Source: Prepared by the survey team



Source: Prepared by the survey team

Figure 6-58 CO₂ Emissions Reduction by Scenario and Energy Source (2050)



Note: S-N scenario shares a line with S-H scenario.

Source: Prepared by the survey team

Figure 6-59 CO₂ Emissions Trends by Scenario (2020-2050)

6.6 Investment and Cost by Scenario

To calculate capital investment and production costs, the Danish Model is used to estimate the investment and production costs for transmission and distribution systems—including solar power, wind power, hydrogen production facilities, and nuclear power—as well as for final energy use. The Danish Model was developed by the Danish Research Institute in Denmark and is widely used in many other countries including Japan.

The Danish Model was designed to forecast carbon-neutral (CN), with a particular focus on comprehensive evaluation of renewable energy, environmental considerations, and economic effects. In this analysis, the Danish Model is applied to calculate capital investment and production costs based on energy prices in Mongolia.

6.6.1 Assumptions and Calculation Method

(1) Assumptions

The following four conditions are assumed when calculating capital investment and production costs.

- In general, capital investment calculations are made for main facilities and ancillary facilities. Specifically, this includes facilities, land, buildings, equipment, transportation vehicles, and software. However, since there is a limit to considering all of these elements, this analysis focuses on facilities such as solar power, wind power, coal-fired CHP, natural gas CHP, hydrogen production facilities, and nuclear power.
- When equipment is introduced from overseas, it is common for engineers from the supplier to stay on-site for several years, and the associated technical service fees are included in the equipment costs.
- In this analysis, costs such as equipment transportation costs, interest payments, land, buildings, utilities, and administrative buildings associated with equipment introduction are not included.
- Based on the above assumptions, capital investment and production cost calculations including fuel consumption are conducted for each type of equipment from 2026 to 2050, using 2025 as the reference year.

(2) Calculation Method of Capital Investment and Production costs

For the calculation of capital investment in this analysis, the following formula is used to determine the “unit facility cost (USD/MWh)” based on the LCOE (Levelized Cost of Electricity: \$/MWh) from the Danish Model:

$$\text{Unit facility cost (USD/MWh)} = (\text{Capital Cost} + \text{Maintenance Cost} + \text{Other Costs}) \div \text{Power Generation (MWh)}$$

The Production cost is calculated using the following components:

$$\text{Annual Production Cost} = \text{Depreciation Cost} + \text{Operation and Maintenance Costs} + \text{Fuel Cost} + \text{Other costs}$$

*Fuel cost includes coal, oil, natural gas, bio, hydrogen, etc. depending on the type of facility.

*Other costs may include the amount of investment costs when CCS and other costs are set in the scenario.

6.6.2 Capital Investment by Scenario

Capital investment by each scenario for each five-year period from 2026 to 2050 are shown below.

Table 6-61 BAU Capital Investments**BAU Electricity Capital Investment**

Tech Area	Technologies	Capital Investment Unit: Million USD					
		26-30	31-35	36-40	41-45	46-50	Total
Solar PV	Silicon PV	1,817	475	856	946	1,114	5,351
Wind power generation	Wind power	1,044	286	646	767	912	3,654
Hydraulic power	Dam-based hydropower	761	2,057				2,818
Coal-fired power	Bituminous coal CHP	591	763	954	1,189	1,488	4,984
Storage batteries	For power conditioning	20	5	12	14	17	69
Transmission line	220kV 600km	366	85	200	246	304	1,201
Total	Total BAU investments	4,598	4,471	2,668	3,162	3,835	18,733

Source: Prepared by the survey team

BAU Capital Investment Required for Final Energy Use

Tech Area	Technologies	Capital Investment Unit: Million USD					
		26-30	31-35	36-40	41-45	46-50	Total
Coal & Coal products	Coal demand for non-power generation purposes	218	252	277	307	349	1,404
	Coal Products	3	3	2	2	2	12
Petroleum products	Gasoline	98	97	79	57	32	363
	Jet fuel	0.4	0.1	0.1	0.0	0.0	0.5
	Diesel	72	63	64	67	70	337
Wood energy	Solid biomass	0.02	0.02	0.02	0.02	0.02	0.11
	Charcoal	0.02	0.02	0.02	0.02	0.02	0.10
Electricity Use	Electricity use in industry and residential sectors	86	112	148	193	253	793
Heat Use	Heat use in industry and residential	57	78	104	138	183	560

	sectors						
Total		535	606	674	763	890	3,469

Source: Prepared by the survey team

Total Capital Investment for BAUs

BAU's Capital Investment Requirements	Capital Investment Unit: Million USD					
	26-30	31-35	36-40	41-45	46-50	Total
Investment in electric power facilities	4,598	4,471	2,668	3,162	3,835	18,733
Capital investment required for final energy demand	535	606	674	763	890	3,469
Capital investment required for DSM	274	893	1,749	2,852	4,213	9,980
Total	5,407	5,970	5,091	6,777	8,938	32,182

Source: Prepared by the survey team

Table 6-62 S-B Capital Investment**S-B Electricity Capital Investment**

Tech Area	Technologies	Capital Investment Unit: Million USD					
		26-30	31-35	36-40	41-45	46-50	Total
Solar PV	Silicon PV	2,264	1,539	1,635	1,502	1,185	8,124
Wind (large scale)	Wind power utility	1,350	1,033	1,232	1,217	971	5,803
Storage batteries	Power balancing battery	25	20	23	23	18	109
Hydraulic power	Dam-based hydropower	761	2,057	0	0	0	2,818
	Pumped-storage hydroelectricity		780	0	0	0	780
Thermal power	Power generation + CHP	215	0	110	376	482	1,182
Biopower generation	Biomass (pellet)	164	0	0	0	0	164
	Waste-based biomass energy	62	0	0	0	0	62
Transmission line	220kV 600km	509	308	381	391	324	1,913
Total		5,350	5,737	3,381	3,507	2,980	20,955

Source: Prepared by the survey team

S-B Capital Investment Required for Final Energy Use

Tech Area	Technologies	Capital Investment Unit: Million USD					
		26-30	31-35	36-40	41-45	46-50	Total
Coal and Coal Products	Coal demand for non-power generation purposes	320	134	0	78	132	663
	Coal products	3.2	2.4	1.8	1.2	0.8	9.0
Petroleum Products	Gasoline	23	0	0	0	0	23
	Diesel	32	0	0	0	0	32
Wood energy	Solid biomass	0.66	0.17	0.00	0.00	0.00	1.00
Hydrogen	Wind power for hydrogen production	234	328	413	480	530	1,985
	Solar power for hydrogen production	392	488	548	593	647	2,668
	Alkaline water electrolysis	91	132	165	191	211	789
Electricity use	Electricity use in industry and residential sectors	92	146	174	199	187	797
Heat Use	Heat use in industry and residential	21	8	3	43	59	135

	sectors						
SAF	Aviation fuel	10.8	0.2	0.1	0.0	0.0	11.0
E-fuel	Wind power for E-fuel production		256	311	360	403	1,330
	Solar power for E-fuel production		380	413	445	492	1,730
	E-Fuel		58	69	77	84	288
Total		1,218	1,933	2,096	2,468	2,745	10,461

Source: Prepared by the survey team

Total Capital Investment for S-B

BAU Required Capital Investment	Capital Investment Unit: Million USD					
	26-30	31-35	36-40	41-45	46-50	Total
Investment in electric power facilities	5,350	5,737	3,381	3,507	2,980	20,955
Capital investment required for final energy demand	1,218	1,933	2,096	2,468	2,745	10,461
Investments and expenses required for DSM	253	731	1,268	1,828	2,398	6,478
Total	6,821	8,401	6,745	7,803	8,123	37,894

Source: Prepared by the survey team

Table 6-63 S-N Capital Investment**S-N Electricity Capital Investment**

Tech Area	Technologies	Capital Investment Unit: Million USD					
		26-30	31-35	36-40	41-45	46-50	Total
Solar PV	Silicon PV	2,264	1,539	1,634	1,502	1,185	8,123
Wind power generation	Windpower utility	1,350	1,033	1,231	1,217	971	5,802
Storage batteries	Power balancing batteries	25	20	23	23	18	109
Nuclear power	SMR			2,567	2,438	1,986	6,991
	CHP			111	111	105	328
Hydraulic power	Dam-based hydraulic power	761	2,057				2,818
	Pumped-storage hydroelectricity		780				780
Thermal power	Bituminous coal CHP	215					215
Bio power	Pellet power	164					164
	Waste power generation	62					62
Transmission line	220kV 600km		509	308	381	381	1,589
Total		4,841	5,938	5,875	5,672	4,655	26,980

Source: Prepared by the survey team

S-N Capital Investment Required for Final Energy Use

Tech Area	Technologies	Capital Investment Unit: Million USD					
		26-30	31-35	36-40	41-45	46-50	Total
Coal and Coal Products	Coal demand for non-power generation purposes	320	134		78	132	663
	Coal products	3	2	2	1	1	9
Petroleum Products	Gasoline	23					23
	Diesel	32					32
Wood energy	Solid biomass	0.7	0.2	0.0	0.0	0.0	1.0
Hydrogen	Wind power for hydrogen	233.6	328	413	480	530	1,985
	Solar power for	391.7	488	548	593	647	2,668

	hydrogen						
	Alkaline water electrolysis	91	132	165	191	211	789
Electricity use	Electricity use in industry and residential sectors	92	146	174	199	187	797
Heat Use	Heat use in industry and residential sectors	21	8	3	43	59	135
SAF	Aircraft fuel	11					11
E-fuel	Wind power for E-fuel production		256	311	360	403	1,330
	Solar power for E-fuel production		380	413	445	492	1,730
	E-fuel		58	69	77	84	288
Total	Total Investment	1,218	1,933	2,096	2,468	2,745	10,461

Source: Prepared by the survey team

Total Capital Investment for S-N

BAU Required Capital Investment	Capital Investment Unit: Million USD					
	26-30	31-35	36-40	41-45	46-50	Total
Investment in electric power facilities	4,841	5,938	5,875	5,672	4,655	26,980
Capital investment required for final energy demand	1,218	1,933	2,096	2,468	2,745	10,461
Investments and expenses required for DSM	253	731	1,268	1,828	2,398	6,478
Total	6,312	8,602	9,239	9,968	9,798	43,919

Source: Prepared by the survey team

Table 6-64 S-H Capital Investment**S-H Power Capital Investment**

Tech Area	Technologies	Capital Investment Unit: Million USD					
		26-30	31-35	36-40	41-45	46-50	Total
Solar PV	Silicon PV	2,264	1,539	1,064	991	700	6,557
Wind power generation	Electric utility wind power	1,350	1,033	802	803	573	4,561
Storage batteries	Power Regulating Batteries	25	20	15	15	11	86
Hydrogen power generation	Solar for hydrogen			7,627	6,835	6,502	20,964
	Wind for hydrogen			5,756	5,543	5,330	16,628
	BESS for hydrogen			108	103	98	309
	Pure water			422	422	422	1,265
	Water transportation cost			208	0	0	208
	Hydrogen Pipeline			1991	0	0	1991
Hydrogen power generation	Hydrogen CHP			5,522	5,432	5,342	16,296
Hydroelectric power	Dam hydropower	761	2,057	0	0	0	2,818
	Pumped hydro	0	849	0	0	0	849
Thermal power	Bituminous coal CHP	215	0	0	0	0	215
Biopower generation	Pellet Power Generation	164	0	0	0	0	164
	Waste power generation	62	0	0	0	0	62
Transmission line	220kV 600km	509	308	248	258	191	1,514
Total		5,350	5,806	23,763	20,401	19,167	74,487

Source: Prepared by the survey team

S-H Capital Investment Required for Final Energy Use

Tech Area	Technologies	Capital Investment Unit: Million USD					
		26-30	31-35	36-40	41-45	46-50	Total
Coal and Coal Products	Coal demand other than power generation	320	134		78	132	663
	Coal products	3	2	2	1	1	9
Petroleum Products	Gasoline	23					23
	Diesel	32					32
Wood energy	Solid biomass	0.7	0.2	0.0	0.0	0.0	1.0
Hydrogen	Wind power for hydrogen	233.6	328	413	480	530	1,985
	Solar power for hydrogen	391.7	488	548	593	647	2,668
	Alkaline water electrolysis	91	132	165	191	211	789
Electricity use	Electricity use in industry and residential sectors	92	146	174	199	187	797
Heat Use	Heat use in industry and residential sectors	21	8	3	43	59	135
SAF	Aircraft fuel	11					11
E-fuel	Wind power for E-fuel production		256	311	360	403	1,330
	Solar power for E-fuel production		380	413	445	492	1,730
	E-fuel		58	69	77	84	288
Total	Total Investment	1,218	1,933	2,096	2,468	2,745	10,461

Source: Prepared by the survey team

Total Capital Investment for S-H

BAU Required Capital Investment	Capital Investment Unit: Million USD					
	26-30	31-35	36-40	41-45	46-50	Total
Investment in electric power facilities	5,350	5,806	23,763	20,401	19,167	74,487
Capital investment required for final energy demand	1,218	1,933	2,096	2,468	2,745	10,461
Investment required for DSM	253	731	1,268	1,828	2,398	6,478
Total	6,821	8,470	27,127	24,697	24,310	91,426

Source: Prepared by the survey team

Table 6-65 S-BNH Capital Investment**S-BNH Electricity Capital Investment**

Tech Area	Technologies	Capital Investment Unit: Million USD					
		26-30	31-35	36-40	41-45	46-50	Total
Solar PV	Silicon PV	2,264	1,539	1,445	1,330	1,024	7,601
Wind power generation	Wind power utility	1,350	1,033	1,089	1,078	838	5,388
Storage batteries	Power Regulating Batteries	25	20	21	20	15	101
Hydrogen Power Generation	Solar for hydrogen			2,542	2,278	2,167	6,988
	Wind for hydrogen			1,919	1,848	1,777	5,543
	BESS for hydrogen			36	34	33	103
	Pure water			112	112	112	337
	Water transportation costs			23	23	23	69
	Hydrogen pipeline			348	348	348	1,044
	Hydrogen CHP			1,841	1,811	1,781	5,432
Hydraulic power	Dam-based hydropower	761	2,057	0	0	0	2,818
	Pumped hydro	0	849	0	0	0	849
Nuclear CHP	SMR (100MW*n)			1,100	697	662	2,459
	CHP			37	37	37	111
Thermal power	Bituminous coal CHP	215	0	0	0	0	215

Bio power generation	Pellett power generation	164	0	0	0	0	164
	Waste power generation	62	0	0	0	0	62
Transmission line	220kV 600km	509	308	337	346	280	1,780
Total	Total Investment	5,350	5,806	10,849	9,962	9,097	41,065

Source: Prepared by the survey team

S-BNH Capital investment required for final energy use

Tech Area	Technologies	Capital Investment Unit: Million USD					Total
		26-30	31-35	36-40	41-45	46-50	
Coal and Coal Products	Coal demand other than power generation	320	134		78	132	663
	Coal products	3	2	2	1	1	9
Petroleum Products	Gasoline	23					23
	Diesel	32					32
Wood energy	Solid biomass	0.7	0.2	0.0	0.0	0.0	1.0
Hydrogen	Wind power for hydrogen	233.6	328	413	480	530	1,985
	Solar power for hydrogen	391.7	488	548	593	647	2,668
	Alkaline water electrolysis	91	132	165	191	211	789
Electricity use	Electricity use in industry and residential sectors	92	146	174	199	187	797
Heat Use	Heat use in industry and residential sectors	21	8	3	43	59	135
SAF	Aircraft fuel	11					11
E-fuel	Wind power for E-fuel production		256	311	360	403	1,330
	Solar power for E-fuel production		380	413	445	492	1,730
	E-fuel		58	69	77	84	288
Total	Total Investment	1,218	1,933	2,096	2,468	2,745	10,461

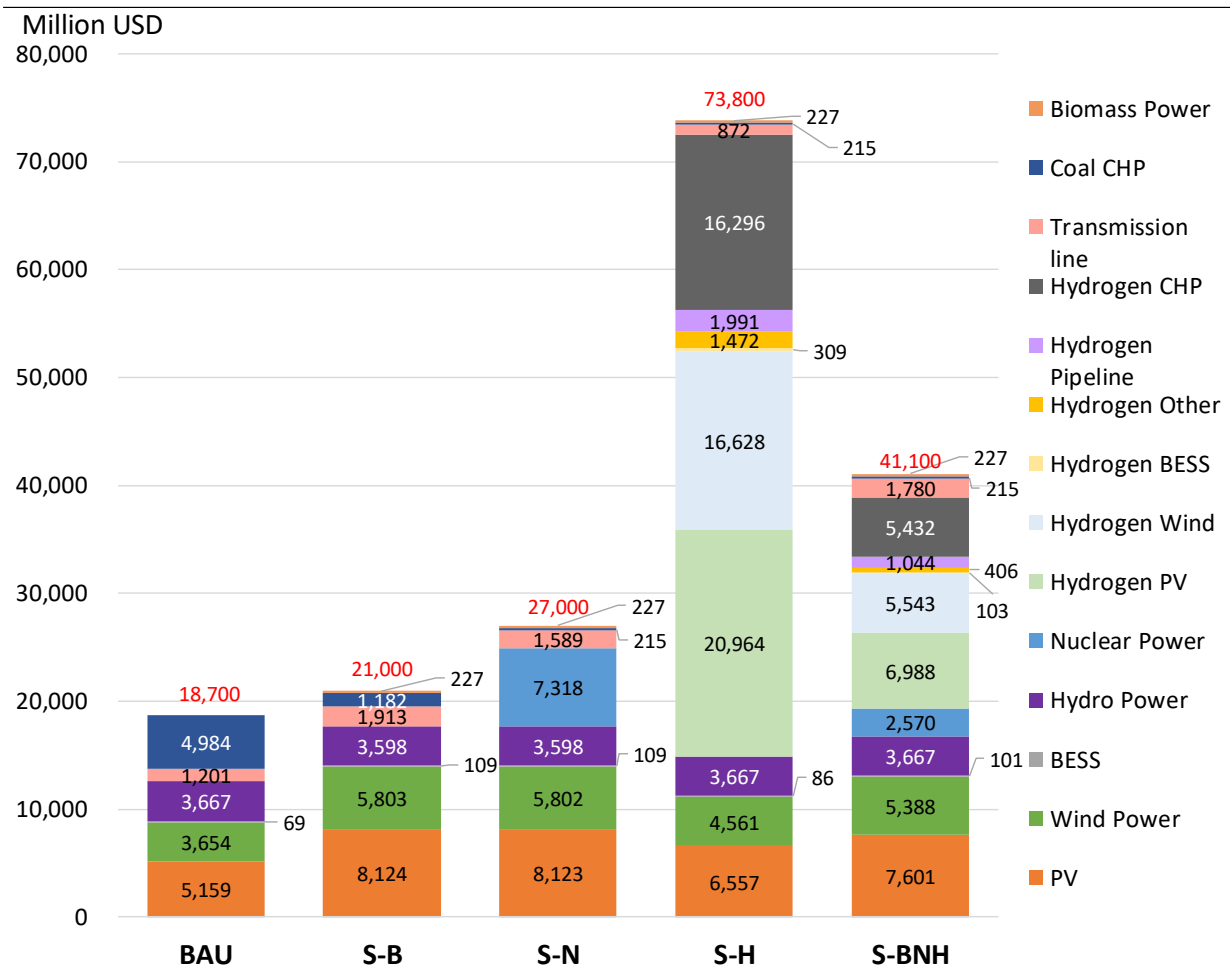
Source: Prepared by the survey team

Total capex for S-BNH

Required investment for BAU	Capital Investment Unit: Million USD					Total
	26-30	31-35	36-40	41-45	46-50	
Investment in electric power facilities	5,350	5,806	10,849	9,962	9,097	41,100
Capital investment required for final energy demand	1,218	1,933	2,096	2,468	2,745	10,461
Investment required for DSM	253	731	1,268	1,828	2,398	6,478
Total	6,821	8,470	14,213	14,258	14,240	58,039

Source: Prepared by the survey team

The above graphs of capital investment from 2026 to 2050 by scenario are shown below.



Source: Compiled by the survey team

Figure 6-60 Estimated cumulative investment for each scenario

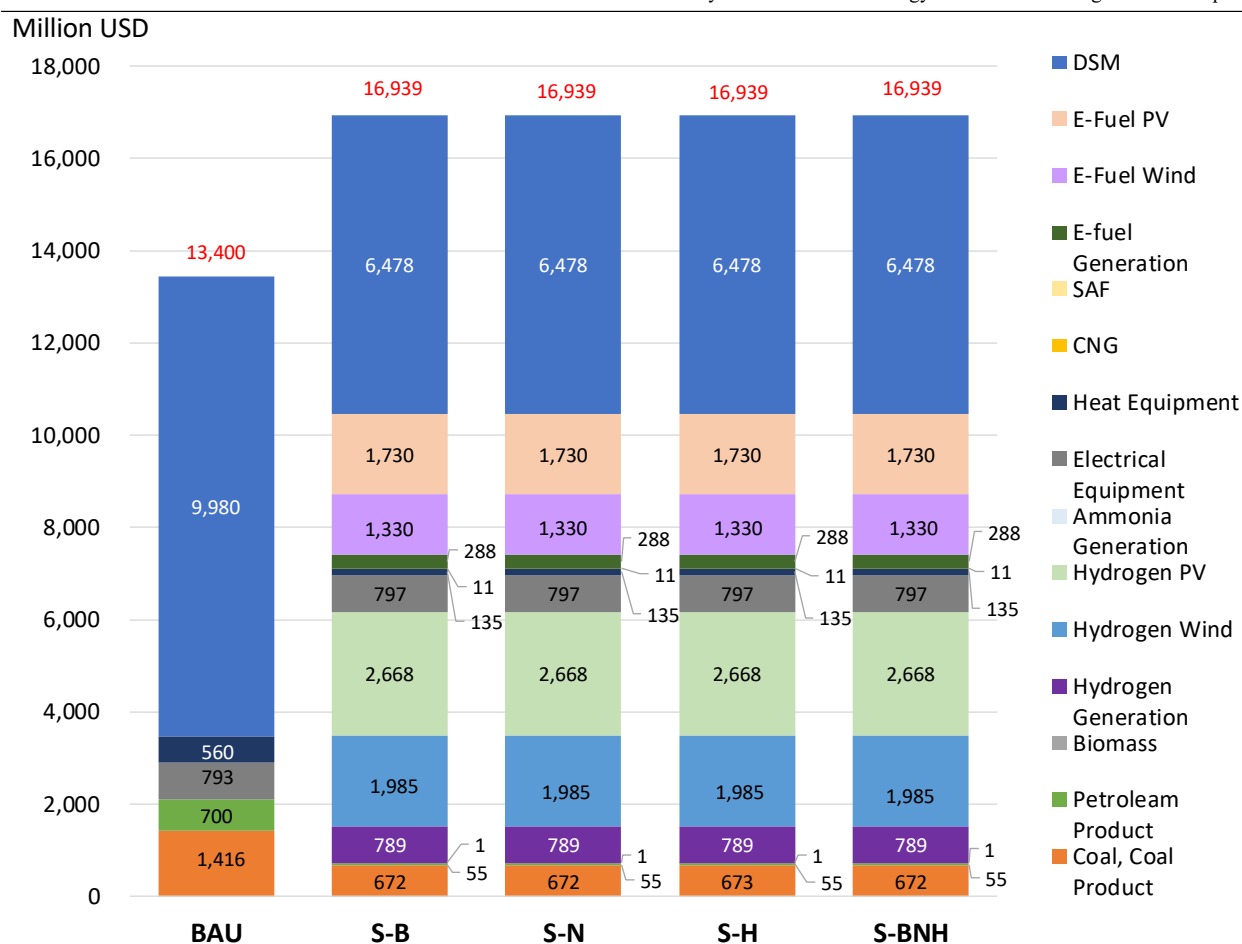


Figure 6-61 Capital Investment in Final Energy Use by Scenario

BAU's electricity capex by 2050 is USD 1.8 billion and S-B's is USD 2.1 billion, a difference of USD 2.1 billion.

6.6.3 Production Cost from 2026 to 2050 by Scenario

Table 6-66 Production Cost by Scenario

BAU Production Cost (in 5-Year Intervals)						Unit: million USD
	26-30	31-35	36-40	41-45	46-50	Total
Cost of electricity generation	4,239	5,557	6,542	7,888	9,601	33,827
Cost of final energy use	12,979	15,567	17,875	19,924	21,680	88,025
Investments and expenses required for DSM	274	893	1,749	2,852	4,213	9,980
Production cost	17,492	22,017	26,166	30,664	35,494	131,832

Source: Prepared by the survey team

S-B Production Cost (in 5-Year Intervals)						Unit: million USD
	26-30	31-35	36-40	41-45	46-50	Total
Cost of electricity generation	4,105	5,344	6,026	7,035	8,112	30,623
Cost of final energy use	11,586	12,320	12,170	11,633	11,023	58,733
Investments and expenses required for DSM	253	731	1,268	1,828	2,398	6,478
Production cost	15,944	18,395	19,464	20,496	21,533	95,834

Source: Prepared by the survey team

S-N Production Cost (in 5-Year Intervals)						Unit: million USD
	26-30	31-35	36-40	41-45	46-50	Total
Cost of electricity	4,105	5,344	7,350	8,070	10,748	35,617

Cost of final energy use	11,586	12,320	12,170	11,633	11,023	58,733
Investments and expenses required for DSM	253	731	1,268	1,828	2,398	6,478
Production cost	15,944	18,395	20,788	21,531	24,169	100,828

Source: Prepared by the survey team

S-H Production Cost (in 5-year Intervals)

Unit: million USD

	26-30	31-35	36-40	41-45	46-50	Total
Cost of electricity	4,109	5,369	11,770	15,226	18,783	55,257
Cost of final energy use	11,586	12,320	12,170	11,633	11,023	58,733
Investments and expenses required for DSM	253	731	1,268	1,828	2,398	6,478
Production cost	15,948	18,420	25,208	28,687	32,204	120,468

Source: Prepared by the survey team

S-BNH Production Cost (in 5-Years Intervals)

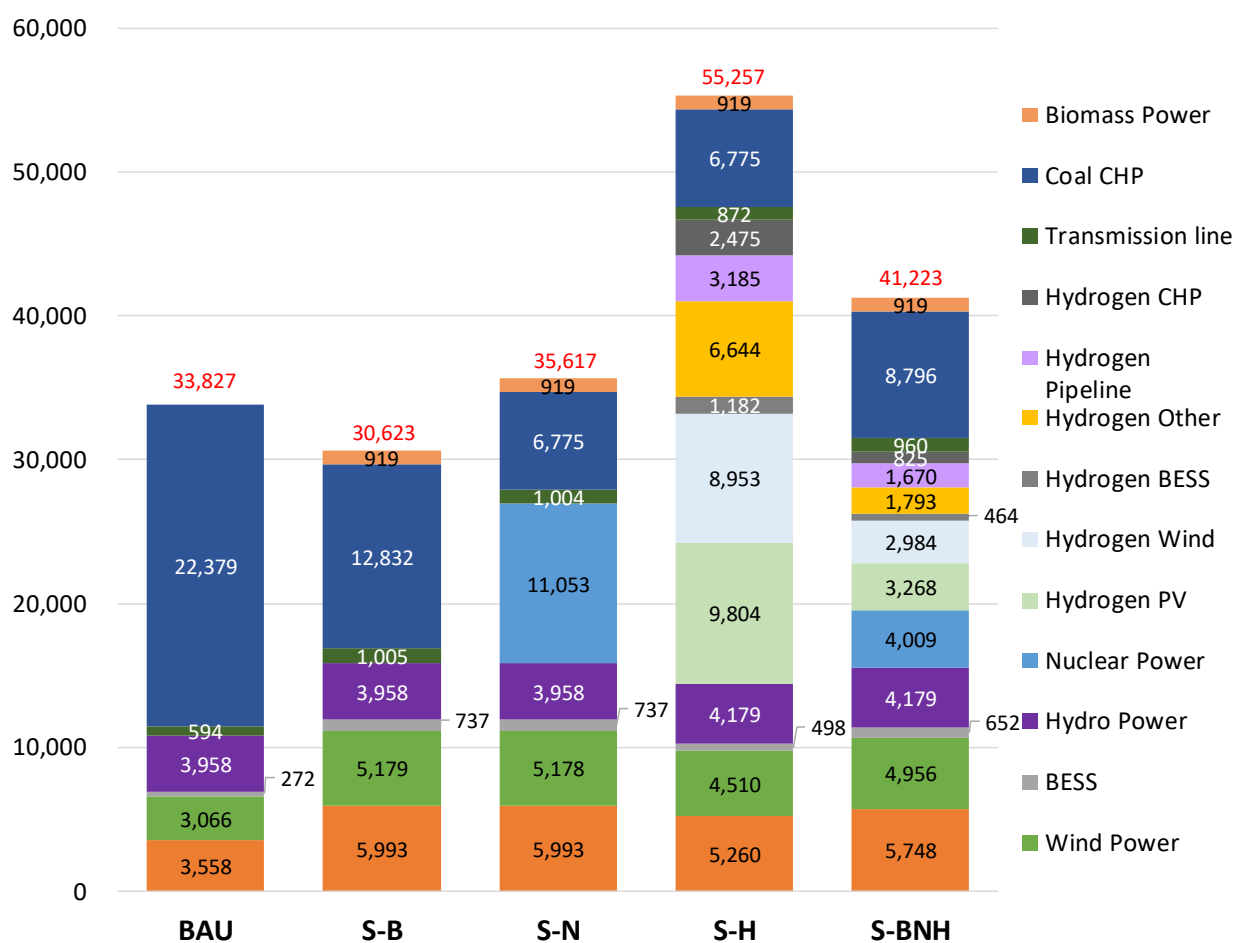
Unit: million USD

	26-30	31-35	36-40	41-45	46-50	Total
Cost of electricity	4,109	5,373	8,667	10,300	12,775	41,223
Cost of final energy use	11,586	12,320	12,170	11,633	11,023	58,733
Investments and expenses required for DSM	253	731	1,268	1,828	2,398	6,478
Production cost	15,948	18,424	22,105	23,761	26,196	106,434

Source: Prepared by the survey team

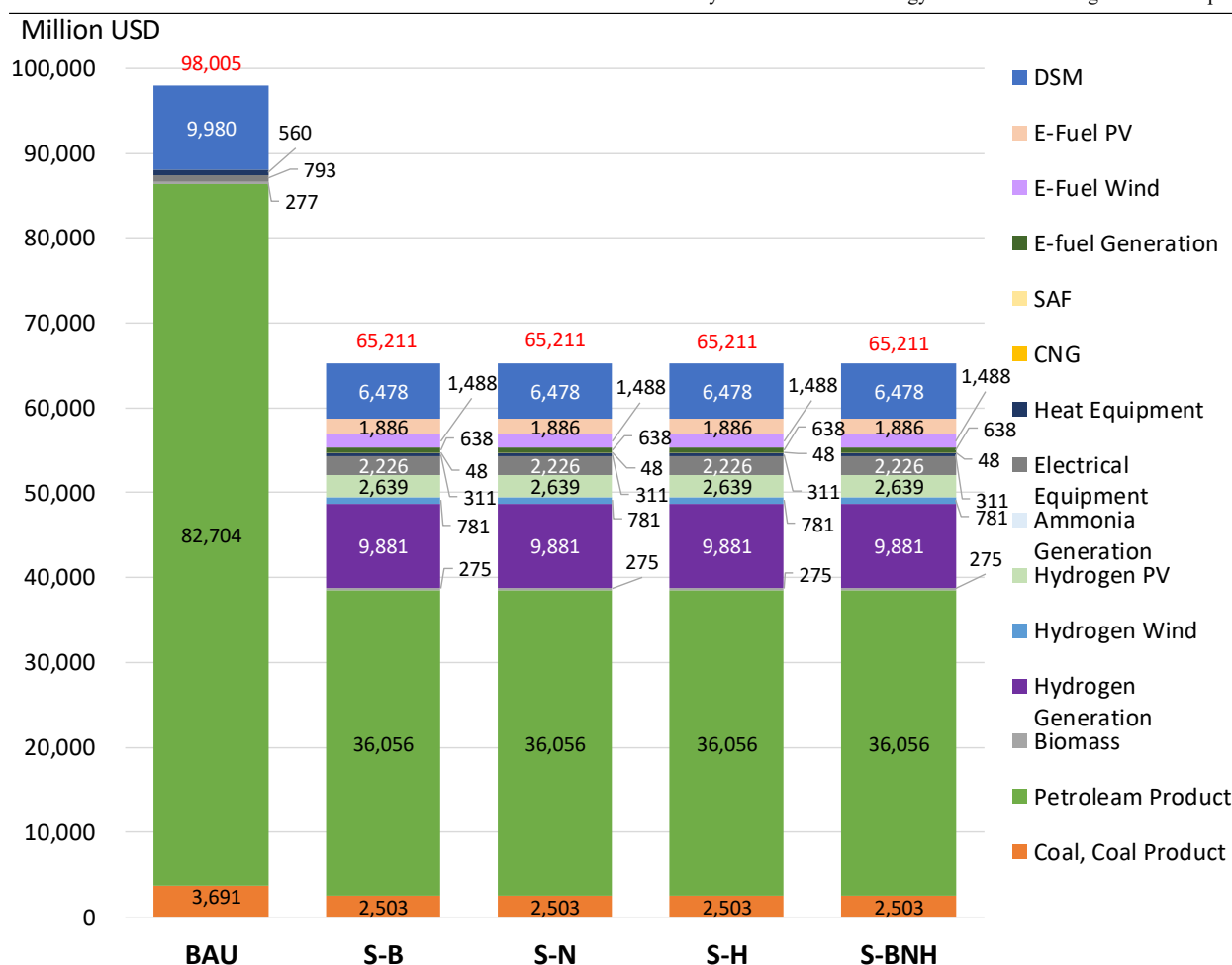
A graph of costs by scenario is shown below.

Million USD



Source: Created by the survey group

Figure 6-62 Electricity Production Cost by Scenario (Including Generation and Transmission)



Source: Created by the survey team

Figure 6-63 Production Cost of Final Energy Use by Scenario

6.6.4 Capital Investment and Costs

<Capital Investment>

- In each scenario, the S-H scenario requires an extremely large amount of investment for electricity: 1.12 times for S-B, 1.44 times for S-N, 3.9 times for S-H, and 2.2 times for S-BNH compared to BAU.
- Capital investment required for final energy utilization has been estimated under two scenarios: BAU and alternative scenarios. In the alternative scenarios, the required investment is approximately three times higher than in the BAU scenario. This is due to the production and use of new energy sources such as hydrogen, SAF, and E-fuel.
- The investments and costs required for DSM (Demand Side Management) energy-saving measures are the highest in the BAU case. In the S-B, S-N, S-H, and S-BNH scenarios, where the use of new energy is proposed, investment in energy-saving measures is approximately 65% of that in the BAU case.
- Comparing the total capital investment in BAU and S-B, S-B is higher by 5.7 billion USD. This is because S-B has increased the installation of solar and wind power while reducing the expansion of coal-fired CHP capacity.
- S-N's total capital investment through 2050 is higher than that of S-B by 6 billion USD, primarily due to the introduction of nuclear power.
- S-H's total capital investment through 2050 is higher than that of S-N by 47 billion USD because of the introduction of large amounts of solar and wind power and hydrogen-fueled CHP.
- S-BNH's total capital investment through 2050 is higher than that of S-N by approximately 14 billion USD, due to the inclusion of hydrogen-fueled CHP in addition

to nuclear power.

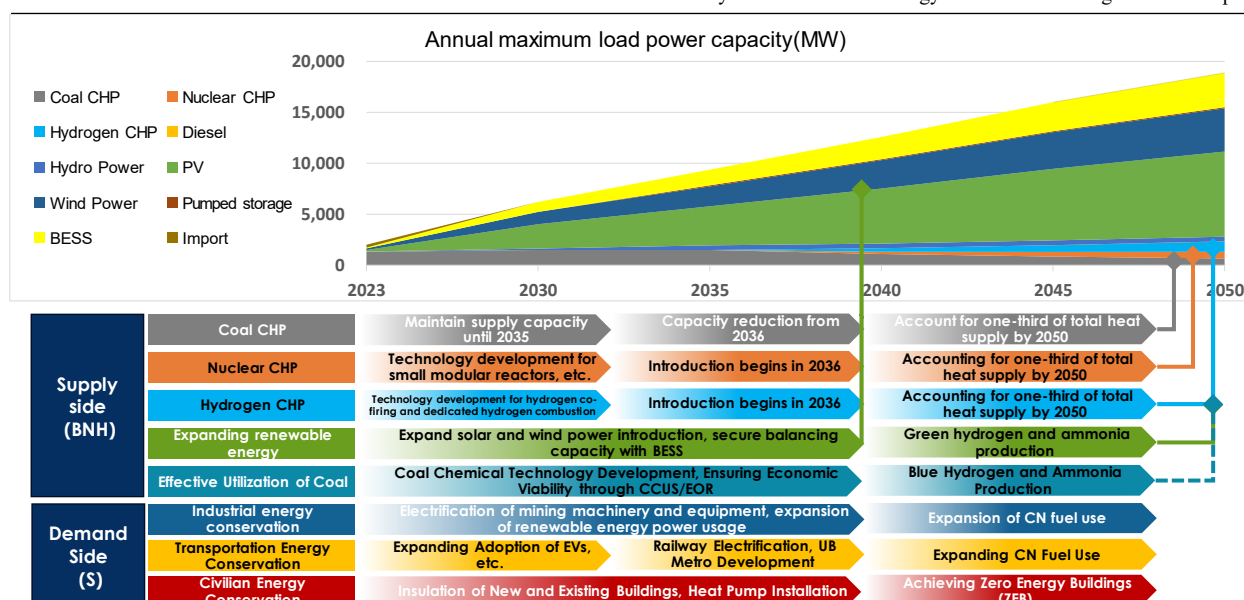
<Production Cost>

- The reason why the production cost of S-B is higher than that of BAU is that S-B includes hydrogen, SAF, and E-Fuel.
- If CCS were introduced to coal-fired CHP in the BAU scenario, the cost of coal-fired power generation would double. The total cost of BAU is almost the same as the production costs of S-B, S-N, S-H, and S-BNH.
- If hydrogen production from solar and wind is reduced in S-H, the production cost of S-H would be less expensive than S-N.
- The unit cost of nuclear power is 6 to 7 US cents per kWh, whereas solar and wind power, when equipped with storage batteries, cost 4 to 6 US cents per kWh—almost the same as nuclear power.

6.7 Proposal for an Energy Transition Roadmap

Based on the case studies discussed above, the S-BNH scenario was deemed the most realistic for the following reasons. The outline of the S-BNH scenario is shown in the figure below.

- Stable energy transition: This scenario does not exclude all other scenarios, allowing for the implementation of energy sector transition policies. In particular, the list of potential future technologies related to energy decarbonization (e.g., nuclear, hydrogen, renewable energy) is constantly evolving as development progresses. This scenario addresses the risk that eliminating any one option could significantly delay the adoption of that technology. However, ongoing review of the roadmap based on technological trends is necessary.
- Continued use of fossil fuels: Mongolia's social structure is heavily dependent on the mining industry, including coal, and its use on the demand side. Reducing fossil fuel use is crucial. However, coal also provides a lifeline for vulnerable groups, such as the poor, during harsh winters, making it difficult to evaluate the impact of economic and environmental factors alone. Therefore, while the use of fossil fuels such as coal will remain to a certain extent on the demand side (mainly civilian and industrial) and supply side even in 2050 were assumed, it is believed that this is a realistic landing point in terms of balancing the economy, society, and environment compared to other scenarios.
- Contribution to achieving net-zero emissions by 2050: Although emissions will not ultimately be zero, achieving net-zero emissions can be realistically considered by incorporating carbon sink measures such as forest carbon capture and CCUS. To realistically reflect this in NDCs and future targets, measures to secure quantitative carbon sinks also need to be considered.



Source: Created by the survey team

Figure 6-64 S-BNH Scenario Overview

6.8 Action Plan

The action plan assuming the S-BNH scenario is shown below. The action plan is divided into medium- to long-term and short- to medium-term challenges and response points, and describes them in terms of each sector within the energy sector and human resource development. The short- to medium-term period extends to 2035, 10 years from the start.

Table 6-67 Action Plan

Period	Action Plan
Short- and Mid-term (until 2035) Initiatives	● A unified government-wide approach to the energy transition is necessary. To this end, an official roadmap should be formulated based on a shared understanding and agreement with relevant ministries and agencies, and each relevant entity shall then incorporate the contents of the roadmap into their own plans and create detailed action plans. ● Demand-side challenges and responses ● Industrial sector: The revitalization of the energy conservation market, including insulation, to mitigate the current increase in energy use should be promoted, and the development of power plants and transmission networks for the electrification of mines shall be focused on. Also, it should be promoted that the establishment of an incentive system to promote the electrification of mines and the introduction of energy-saving BAT (Best Available Technologies) in various industries. ● Transportation sector: For road passenger transport, the development of mass transit systems such as BRT, metro, tram, and cable cars should be promoted to expedite the modal shift to public transport, and the spread of HVs (including PHEVs), EVs, and FCVs should be promoted. For rail transport, early electrification should be achieved, and for freight transport, a shift from road transport to rail freight shall be promoted. For air transport, operational improvements and the introduction of SAF should be promoted. ● Residential sector: The government shall continue and expand the thermal insulation projects for existing buildings being implemented by other donors, while also institutionalizing and implementing thermal insulation for new buildings, taking the lead in improving the thermal insulation performance of public buildings in particular. It should also promote the use of improved fuels that incorporate biomass, and take measures to combat air pollution in UB and other areas. ● In the supply (electricity and heat) sector: 1) construct a small-scale nuclear CHP (expected operational start date : 2036) , and coordinate with international organizations and conduct

	preparatory surveys as soon as possible; 2) construct hydrogen production and hydrogen CHP in demand areas (expected operational start date: 2036), and promptly identify and construct VRE sites for hydrogen production, including transmission plans; 3) identify and develop technologies that will contribute to decarbonization and CO₂ reduction in the short to medium term, such as biomass, CBM, general hydropower, and utilizing geothermal energy in local heat supplying system; and 4) implement large-scale VRE development in the South Gobi region, including transmission and hydrogen pipeline plans. In addition to this roadmap scenario, it is also important to promote various measures that will have an immediate effect on reducing CO₂ emissions, such as introducing an evaluation system that will help improve the thermal efficiency of existing thermal power plants and examining ways to improve the efficiency of current heat supply systems. ● Progress in resource development will greatly contribute to changes in the roadmap. However, continuing to consider the possibility of using new resources is itself important for the stable supply of energy in the future, so it is important to proceed with the following initiatives separately from the roadmap scenarios. ➢ Support for coal gasification utilizing lignite resources which involves CO₂ reduction for air pollution countermeasures and gas-fired power generation ➢ F/S implementation and pilot plant construction of EOR and ECBM using CO₂ as a CO₂ reduction measure ➢ Conducting feasibility studies for the development of unconventional resources such as oil shale and shale gas, and constructing pilot plants ➢ Promoting fuel conversion to HOBs by converting industrial waste, sewage treatment waste, biomass, etc. into fuel for mixed combustion at power plants ● In terms of human resource development, it should be promoted that the exchange of human resources by sending Mongolian students, engineers, and researchers to Japan and accepting Japanese faculty members, promoting joint research between the two countries, and providing career support through collaboration between supervising faculty members, thereby establishing a foundation for international brain circulation.
Medium- to Long-term (to 2050) Issues and Key Points to Address	● Toward 2050, it is important to address the energy sector, which accounts for more than 44% of greenhouse gas emissions and is expected to increase due to future development. ✓ Given Mongolia's coal-dependent social and economic structure, it will not be easy to achieve this goal, and it will require concerted efforts by all levels of society, including industry, consumers, and government. ● Challenges and Responses on the Demand Side ✓ The industrial sector should promote the creation of CN fuel production businesses to promote continuous electrification and CN fuel use in the mining industry. In addition, deepen efforts to ensure that all industries can benefit from the spillover effects of the electrification and CN fuel conversion and decarbonization of the mining industry by establishing and promoting the use of a carbon credit system. ✓ In the transportation sector, road transportation will promote the electrification and hydrogenation of vehicles. In rail transportation, all lines will be electrified or converted to fuel cell vehicles. In the air transportation sector, the use of SAF as aviation fuel will be increased and new technologies will be introduced. ✓ In the residential sector, the short-to-medium-term efforts to insulate public buildings will be extended to commercial buildings and detached houses to achieve an energy consumption pattern that allows for a switch to electrified heating equipment. In addition, the effort to develop legislation and create a market for the introduction of ground source heatpumps is required. ● In the supply (electricity and heat) sector, (1) continuous construction of small nuclear CHP and hydrogen CHP, and (2) continuous construction of VRE in the South Gobi region, including transmission and hydrogen pipeline projects, should be developed in stages. ● With regard to future resources and carbon storage and utilization, based on the local production for local consumption of energy and based on the results of short- and medium-term efforts, the following should be considered: 1) commercialization of SNG, methanol, DME, and hydrogen production through coal gasification, 2) commercialization of EOR and ECBM to increase CO₂ reduction measures during coal use, and 3) unconventional energy resources (CBM, shale gas, etc.). ● To develop human resources to enable these goals, Mongolia should utilize human resources who have returned to Mongolia after studying abroad and conducting joint research in

	Japan, promote interdisciplinary education within Mongolian universities , and build an international brain circulation by strengthening cooperation among industry, government, academia, and government ministries and agencies. Establish a system to continuously nurture core human resources for the energy transition.
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Source: Prepared by the survey team

An example of how to proceed with the underlined sections above is shown below. Items in bullet points indicate that they all need to be carried out in parallel, but the items listed are those that are relatively easy for the Mongolian government to tackle as a survey team, listed in order from top to bottom.

Table 6-68 An example of how to proceed

Response details	Examples of government approaches
Formulating an official roadmap	Cross-ministerial working groups will be formed to focus on themes such as CO ₂ reduction, demand side, supply side, resources, and human resource development, and opinions will be gathered through the participation of NGOs, academia, and industry. The roadmap formulated this time will then be given final approval by the ministries and agencies or the government, as it has been authorized by industry, government, academia, and citizens.
Revitalizing the energy-saving market, including thermal insulation	✓ Strengthening pay-per-use billing, such as installing meters for heat charges ✓ Implementing incentive systems (subsidies, tax breaks, etc.) for energy-saving products such as thermal insulation products or for companies that manufacture them ✓ Establishment of building energy conservation standards, their mandatory implementation, and strengthened audits ✓ Rising electricity and heat tariffs
Establishment of incentive systems to promote the electrification of mines and the introduction of energy-saving BAT in various industries	✓ Award system for companies with excellent energy-saving initiatives ✓ Research, organize, and publish BAT applicable to each industry ✓ Establishment of an energy conservation center to promote the spread of energy conservation diagnosis ✓ Establishment of subsidies and tax incentives for the introduction of EVs and EV chargers ✓ Introduction of benchmarking system and MEPS system
Promoting the spread of HVs (including PHEVs), EVs, and FCVs	✓ Preferential vehicle registration and license plate treatment ✓ Introduction and strengthening of tax incentives and tariff reductions ✓ Promotion of EV use in public and government vehicles ✓ Construction of EV charging stations and hydrogen stations for FCVs ✓ Introduction of purchase subsidies and incentives
Early electrification of railway transport	✓ Formulating a policy and roadmap for achieving electrification ✓ Selecting priority sections for construction ✓ Determining electrification methods and standardizing infrastructure design ✓ Establishing human resource development and maintenance systems
Freight transport shifts to rail freight	✓ Strengthening the competitiveness of rail transport by setting low fares ✓ Modernizing rail infrastructure and increasing capacity, including by promoting double-tracking ✓ Developing logistics hubs and transshipment bases, including by increasing freight stations ✓ Implementing regulations and incentives, such as making rail use mandatory for long-distance transport
Air transport: operational improvements and introduction of SAF	✓ Optimizing operational efficiency by shortening flight routes, optimizing altitude and speed, and reducing ground waiting time.

	✓ Improving fuel efficiency through aircraft upgrades and modifications. ✓ Promoting the introduction of SAF, including by mandating the SAF blend ratio. ✓ Strengthening efforts toward domestic manufacturing.
Institutionalization and enforcement of insulation for new buildings	✓ Developing, publishing, and promoting the use of building energy-saving calculation tools ✓ Introduction of the government's energy-saving building labeling system ✓ Introduction of a system to reduce mortgage interest rates for the purchase of energy-efficient buildings (in conjunction with the labeling system mentioned above) ✓ Establishment of building energy conservation standards, their mandatory implementation, and strengthened audits
Leading the way in improving insulation performance in public buildings	✓ Research, organization, and publication of building energy-saving technology lists and guidelines ✓ Introduction of government energy-saving labelling scheme for public buildings ✓ Introduction of a subsidy system for local governments to install equipment based on energy-saving labeling, etc. ✓ Mandatory energy conservation standards for public buildings
Construction of a small nuclear CHP (expected operational start date: 2036), and coordination with international organizations and preparatory surveys for this purpose	✓ Clearly position nuclear power in Mongolia's basic energy policy. ✓ Establish a government agency to proactively promote nuclear power policy, an organization to construct, operate, and maintain nuclear power plants, and an organization to assess the appropriateness of nuclear technology to be introduced. ✓ Establish relevant laws and standards. ✓ Select nuclear technology to be introduced, potential sites for power plants, and coordinate closely with local communities. ✓ Promote the development of the human resources necessary to implement these initiatives.
Hydrogen production and hydrogen CHP construction (expected operational start date: 2036)	✓ Selection of hydrogen production and hydrogen CHP technologies suitable for implementation in Mongolia ✓ Selection of a hydrogen production site taking into account water supply for hydrogen production (water supply from a separate water pipe, local water intake, etc.) ✓ Selection of a hydrogen CHP site near heat demand areas ✓ Construction of a heat supply hot water pipeline from the hydrogen CHP to consumers, and a power supply grid for consumers
Early determination and construction of VRE sites for hydrogen production	✓ Simultaneous planning of construction of a VRE for hydrogen production and a transmission line from the VRE site to the hydrogen production site for early realization
Hydrogen pipeline planning	✓ Consideration of appropriate transportation methods and safe routes, including selection of hydrogen pipeline specifications taking costs into account
Other	✓ Establishment of a unified organization to consider and promote the realization of a hydrogen CHP-based electricity and heat supply system, and promotion of the necessary human resource development
Identifying and developing technologies that contribute to decarbonization and CO ₂ reduction in the short to medium term, such as biomass, CBM, and general hydropower	✓ Reconfirm and identify technologies that have some degree of advantage and potential in each region domestically and contribute to decarbonization and CO₂ reduction. ✓ Examine the suitability and potential of the identified technologies in the respective regions. ✓ Select highly feasible technologies, development locations, and development entities, and promote development.

Support for coal gasification using lignite resources	✓ Introduction of an incentive system for pilot projects implemented by private companies (including encouraging the use of existing schemes such as the JCM) ✓ Government-led demonstration of lignite coal gasification technology ✓ Creation and publication of guidelines and technology lists based on the above-mentioned demonstrations ✓ Establishment of a carbon pricing system
Implementation of feasibility studies for EOR and ECBM and construction of pilot plants	✓ Introduction of an incentive system for pilot projects implemented by private companies (including encouraging the use of existing schemes such as the JCM) ✓ Government-led feasibility study and demonstration of EOR and ECBM technologies
Conducting feasibility studies for the development of unconventional resources such as oil shale and shale gas, and constructing pilot plants	✓ Research, organization, and publication of advances in mining technology and types of gas composition ✓ Government-led pre-feasibility study ✓ Introduction of an incentive system for pilot projects implemented by private companies
Promoting fuel conversion to HOB and co-firing industrial waste, sewage treatment waste, biomass, etc. as fuel for power plants	✓ Research and analysis of biomass reserves, reserve locations, and co-firing technology ✓ Formulation and publication of biomass utilization guidelines ✓ Introduction of incentive systems (subsidies, tax breaks, etc.) for biomass co-firing ✓ Introduction of an incentive system for pilot projects implemented by private companies (including encouraging the use of existing schemes such as the JCM) ✓ Demonstration of biomass co-firing technology led by the government
Human Resource Development	The Ministry of Education can work with relevant government ministries and agencies to establish a framework and provide coordination and support among related organizations to promote the following initiatives: ✓ Sending Mongolian students, engineers, and researchers to Japan and accepting Japanese faculty members ✓ Promoting joint research between the two countries ✓ Career support through collaboration between supervising faculty ✓ Establishing a system for utilizing and retaining returning human resources

Source: Prepared by the survey team

Chapter 7 Medium- to Long-term Human Resources Development Needs

7.1 Current Situation and Challenges in Human Resource Development in Mongolia

This section provides an overview of the current status of human resource development in science and engineering in Mongolia, as well as the educational system and policy issues surrounding it.

7.1.1 Current Status and Institutional Background of Higher Education in Science and Engineering in Mongolia

(1) Educational System and Programs at Major Universities

Higher education in Mongolia consists of four levels (diploma, bachelor, master, and doctorate), and there are 88 higher education institutions in Mongolia (FY2020/21). They consist of 37 universities (42.1%), 45 institutes (51.1%), 3 colleges (3.4%), and 3 overseas university branches (3.4%).⁶²

The major higher education institutions in Mongolia are the National University of Mongolia and the Mongolian University of Science and Technology. The National University of Mongolia has six faculties, two branches, three national institutes, and several research centers, offering education from undergraduate to doctoral programs. The university is also a comprehensive university that offers education and research in a wide range of fields, including natural sciences, humanities, social sciences, and economics, and is a leading education and research center in Mongolia with 118 organized curricula and a current student population of 21,600.⁶³

The Mongolian University of Science and Technology is specialized in technology and engineering education and research, with 11 faculties, 4 branches, and several technology and engineering institutes and research centers. The Mongolian University of Science and Technology has more faculties than the National University of Mongolia, offers 183 curricula, and has a current student population of 14,368.⁶⁴

(2) Student Enrollment and Academic Progression by Field of Study

The percentage of students enrolled in higher education institutions (universities, junior colleges, graduate schools, etc.) in OECD countries who majored in engineering and technology was 13.9% in 2022.⁶⁵ Other nearby middle-income countries are Uzbekistan with 21.7% (2021), Kazakhstan with 18.5% (2020), and Kyrgyzstan with 11.3% (2024).⁶⁶ On the other hand, in Mongolia, the number of students enrolled in higher education institutions in the 2021/2022 academic year was 148,954, of which 12.8% were majoring in engineering, manufacturing, and construction, a level lower than the OECD average, Kazakhstan, and Uzbekistan, but higher than Kyrgyzstan. The percentage of students majoring in engineering is 12.8%. In Mongolian higher education, 13,966 or 73.1% of students studying engineering, manufacturing, and construction are majoring in engineering, which is divided into five main fields. The largest number of students are in the electrical and energy fields.

⁶² Ministry of Education and Science of Mongolia.(2021). Statistics of the Higher Education Sector 2020-2021 Academic Year. Retrieved from <https://en.moe.gov.mn/post/65490>.

⁶³ Figures listed on the official university website (<https://portal.num.edu.mn/en/>) (viewed April 2025).

⁶⁴ Figures from the official university website at <https://must.edu.mn/en/> (viewed April 2025).

⁶⁵ Percentage of students enrolled in higher education majoring in engineering, manufacturing, and construction as of 2022 extracted from OECD Data Explorer.

⁶⁶ Figures extracted from UNESCO Institute for Statistics (<https://databrowser.uis.unesco.org/>) (viewed June 2025).

Table 7-1 Number of Students by Field of Engineering Higher Education

Discipline	Number of students (persons)
Electricity and Energy	4,925
Civil Engineering and Industrial Architecture	3,725
Construction and Urban Planning	1,819
Machinery and metal manufacturing	1,788
Mining	1,709
Total	13,966

Source: Gerelmaa Baljinnyam et al. (2022) ⁶⁷

A comparison of the ratio of diploma- and bachelor-level students to master- and doctoral-level students by field shows that the electrical engineering field has a large number of students enrolled in diploma- and bachelor-level programs, but fewer students continuing on to master- and doctoral-level programs. This suggests that industry needs bachelor-level engineers for immediate employment. On the other hand, the electric power supply field enrolls a smaller percentage of students in diploma and bachelor's programs than other fields, but the percentage of students who go on to master's and doctoral programs is relatively high. This may indicate a demand for advanced engineers and researchers to support the advancement of the energy sector and sustainable electricity supply.

Table 7-2 Number of Students in Engineering Higher Education by Educational Stage

Field of study	Diploma and Bachelor [persons]	Master and PhD [Persons]	Ratio
Environmental Protection Technology	1,392	77	5.5%
Electrical Engineer	9,612	97	1.0%
Power Supply	409	34	8.3%
Mechanical Engineering	1,988	23	1.2%
Food Engineering	3,023	0	0.0%
Mining Development Technology	3,912	602	15.4%
Mineral enrichment technology	1,702	131	7.7%
Land Management (Planning and Land Registry)	2,150	1,080	50.2%
Construction	6,008	188	3.1%
Construction Engineering	15,186	176	1.2%
Total	45,382	2,408	5.3%

Source: Gerelmaa Baljinnyam et. al (2022) ⁶⁷

As shown in the table above, the percentage of master's and doctoral students in engineering and technology in Mongolia was 5.3%, while the average for OECD countries was 11.3% for master's programs and 16.7% for doctoral programs among all students in engineering, manufacturing, and construction. The difference between these figures indicates that enrollment in master's and doctoral programs is significantly lower in Mongolia, highlighting the challenge of a shortage of highly skilled engineers and researchers.

⁶⁷ Gerelmaa Baljinnyam et al. (2022), Current Situation and Prospects of Higher Education of Engineering and Technology in Mongolia

(3) **Gap between Quality of Education and Needs from Industry**

The demand from industry for higher education quality and practical skill development has not changed over the past decade, and it is believed that further improvement in quality and practical-oriented education are considered necessary. In the Mongolian "Information Collection and Confirmation Survey on Engineering Higher Education" report (2013), it was reported that in terms of the quality of Mongolian higher education, industry has expressed their desire for "not only theoretical but also practical education that is actually useful in industry and international-level education that is comparable to overseas universities. Similarly, according to the World Bank (2023)⁶⁸, large, growing, exporting, and innovative initiatives (so-called Modern Enterprises) have indicated that skills shortages are a significant barrier to their business operations. Although these modern enterprises are a minority in Mongolia as a whole, they play an extremely important role in the growth and modernization of the Mongolian economy, and the lack of skills in the labor force is a potential obstacle to their development.

(4) **Direction of Higher Education Policy and Positioning of the Engineering Field**

Mongolia's higher education policy is considered to have focused on strengthening technical and vocational education and training (TVET) in order to respond to labour market needs.

For example, although the "Vision 2050" does not include specific policy initiatives for engineering in higher education, it emphasizes the strengthening of technical and vocational education and training (TVET) in order to align education with labour market needs.

The Ministry of Education and Science's "Medium-Term Development Plan for the Education Sector" (2021-2030) calls for strengthening public-private partnerships and intersectoral coordination in order to bring TVET up to international standards. As part of this plan, the goal is to develop educators with qualifications equivalent to professional engineers and technicians.

In addition, the policy document⁶⁹ of the Ministry of Education and Science (2020) indicates the need to strengthen partnerships between educational institutions and the private sector to provide education that is more relevant to market demand in both TVET and higher education, but does not provide specific policies for the engineering sector.

In order to promote energy transition, it is essential to develop highly specialized human resources. However, the current policy and educational system seem to lack a clear strategy and framework for this purpose.

7.1.2 **Organizing the Actual Situation on the Ground and Institutional Issues Related to Human Resource Development**

The purpose of this survey is to create a roadmap for human resource development in Mongolia to promote energy transition. To this end, information was collected through a questionnaire survey for the Japanese University Graduated Association of Mongolia (JUGAMO), Japanese universities accepting Mongolian students, Japanese companies utilizing Mongolian human resources, as well as from universities, Colleges of Technology (KOSEN), and government agencies in Mongolia. Based on the knowledge obtained from the survey, as well as the current status of educational institutions and science and engineering education in Mongolia, a model for human resource development in collaboration with Japan and a system for promoting such a model was developed and discussed. The views reported here were provided as reference opinions rather than official positions of each organization.

⁶⁸ World Bank (2023) Skills Demand in Mongolia Main Findings of the Skills Module of the Barometer Survey 2022

⁶⁹ Government of Mongolia.(2020). Towards Mongolia's Long-Term Development Policy Vision 2050: Advancing Education Equity, Efficiency, and Outcomes. Retrieved from <https://en.moe.gov.mn>.

(1) Actual Conditions and Issues Surrounding Human Resource Development

1) Current Situation and Challenges in Accepting Mongolian Students in Japan

University faculty members from both countries confirmed the importance of having academic advisors in both Japan and Mongolia make detailed study abroad plans with the students prior to their arrival in Japan. In particular, in the joint research program of the "Mongolia-Japan Higher Engineering Education Development" (M-JEED), there have been cases where research results have been utilized after the students' return to their home countries due to prior coordination. Furthermore, compared to when the M-JEED program was first launched, the human networks established during their study in Japan are now being utilized by returning international students who are now active as Mongolian university faculty members, and an environment is being formed that facilitates prior coordination for subsequent international students as well. On the other hand, the following issues have been reported in cases where students have studied in Japan without sufficient coordination among laboratories and academic advisors in advance.

- Insufficient information: Insufficient information in English about the study abroad system and research content on the Japanese side is provided, making it difficult to select a department and research theme in consideration of career paths.
- Unclear career path: Foreign students themselves do not have a clear career plan after studying in Japan, or they do not consider it sufficiently, which limits their employment opportunities after returning to their home country.
- Mismatch of research content: Research themes in Japan may not meet the needs of Mongolia, making it difficult to put the results to practical use after returning home.

Although these issues are not common to all Mongolian students, they may be an obstacle for students who lack information gathering and career planning to demonstrate the results of their study abroad.

According to the questionnaire survey (conducted in 2024) for the (JUGAMO⁷⁰ conducted in this study, of the nine Mongolian students in the master's and doctoral programs, four chose their research topics based on "their own interests" and five followed "recommendations from their Japanese academic advisors. These results suggest that the involvement of Mongolian faculty members in the selection of research themes is limited and that prior collaboration and coordination between Mongolian and Japanese faculty members is not always sufficient in some cases. If research themes diverge from the social and technological needs of Mongolia, there is an increased risk of not being able to utilize the knowledge after returning to Mongolia.

In addition, in accepting foreign students from developing countries, including Mongolia, it has been pointed out that the diverse and advanced educational content provided by Japanese university departments and laboratories may not be fully adapted to the current needs of developing countries. Furthermore, the current situation in which a great deal of responsibility and burden is concentrated on Japanese university faculty members with regard to the acceptance of international students and administrative procedures, and the fact that the environment for learning in English at universities and graduate schools is still inadequate are also points that require improvement. In

⁷⁰ JUGAMO (Japanese University Graduated Association of Mongolia) is a networking organization mainly for Mongolians who have studied in Japan, with approximately 2,400 members as of 2024. This survey was conducted at the "Japan Night 2024" party in 2024, utilizing JUGAMO's network to ascertain the actual status of those who have studied in Japan. The survey was distributed and collected on paper to participants on the day of the event, and valid responses were received from a total of 35 people (2 from Japanese language schools, 1 from a vocational college, 6 from a technical college, 17 from bachelor's schools, 8 from master's schools, and 1 from doctoral schools). As this event aimed to welcome foreign students returning to Japan in 2024 to JUGAMO, most of the respondents consisted of young people who had just returned to their home countries. Therefore, the results of this survey are not representative of JUGAMO's overall trends, but can be positioned as important supplementary data for understanding the recent study abroad experience and the actual use of support schemes. The results of interviews with JUGAMO presidents and former presidents were also used in the analysis.

anticipation of an increase in the number of Mongolian personnel wishing to study in Japan in the field of energy transition, it is necessary to address these issues in a systematic and comprehensive manner.

2) Outflow of Human Resources Educated Abroad and its Factors

According to the Mongolian government's Ministry of Labor and Social Security (2024)⁷¹, the 2020 Population and Housing Census reported 122,301 Mongolian nationals living abroad, which is a 14.2% increase from 2010. Those living abroad account for 3.7% to 3.9% of the total population, which is close to the world average (about 3.6%). In addition, 9 out of 10 expatriates fall into the working age group, indicating that the percentage of those over 30 years of age is increasing. In particular, those who were students as of 2010 have tended to remain in their study destination, and furthermore, the number of children between the ages of 0 and 14 has almost doubled. This is attributed to the increase in the number of families residing abroad for long periods of time for study or self-employment. In addition, Mongolian officials have expressed a desire to learn or have their children learn practical knowledge in the Japanese private sector. Given these circumstances, interest in working outside of Mongolia is expected to remain high, and if no measures are taken, the number of migrants is projected to reach 206,600 by 2035, a 68.9% increase over 2020.

Based on interviews with Mongolian human resources working for Japanese companies and Mongolian KOSEs that send human resources to Japan, the following reasons were given for why human resources do not return to Mongolia and stay abroad.

- Disparity in wages and living environment⁷² : For Mongolian nationals working in Japan, working in Japan provides an opportunity to earn a very high income compared to wages in Mongolia. In some cases, there are concerns about returning to the local living environment and wage level after returning to Mongolia, which increases the hurdles to return to their home country.
- Challenges in putting Japanese-acquired knowledge and skills into practice in Mongolia Knowledge and skills acquired in Japan are not necessarily suited to the local environment and social needs in Mongolia, and the lack of a place and system to fully utilize them after returning home is a factor in their hesitation to return home.

3) Weaker Personal Networks with Bachelor-level Students

Japanese university faculty members pointed out that compared to students in master's and doctoral programs, who communicate more closely with each other in the laboratory, students in bachelor's programs tend to have weaker personal networks after returning to their home countries, making it difficult for faculty members to follow up on their careers.

⁷¹ Ministry of Labor and Social Security, Government of Mongolia (2024) Labour market of Mongolia: Mid-term demand and supply forecasting study report

⁷² Regarding the wage gap, according to an official of a Mongolian technical college, the average wage in Mongolia has been increasing, and if this trend continues, a certain number of those who found jobs in Japan after studying abroad and those who found jobs in Japan after graduating from a technical college or university in Mongolia will return to Mongolia. In fact, the Mongolian National News Agency (<https://www.montsame.mn/jp/read/340442>) reports on the average monthly salary per employee at the General Directorate of Social Insurance, which is expected to increase in the fourth quarter of 2023 to In the fourth quarter of 2023, the average monthly wage per employee will be 2,235,400 MNT (approx. 102,000 JPY), which is 2.8 times higher than in 2015. However, there are reports that real wages have stagnated due to inflation.

4) Lack of Basic Research Skills of Students and its Background

Japanese university faculty members who accept students and Mongolian university faculty members confirmed that some Mongolian students studying in Japanese master's programs lack research skills (especially practical experience). It was also pointed out that since Mongolian bachelor's degree programs do not require students to write a thesis as a graduation requirement⁷³, they have limited opportunities to develop basic research skills. Against this background, it is necessary to establish a system to enable students who wish to enter graduate school to acquire research skills in a step-by-step manner.

(2) Current Status and Issues of Systems, Cooperation, and Environmental Improvement to Support Human Resource Development

1) Dispatch of Japanese Faculty Members and Trends in the Formation of Centers of Excellence

According to the related organizations that have dispatched faculty members from Japan to Mongolian universities and KOSENs through the M-JEED and the National Technical College Organization scheme, short-term dispatches of Japanese faculty members to Mongolia, such as on-site lectures, not only provide efficient opportunities for human resource development in Mongolia, but also help the dispatched faculty members to gain their own experience in the country.

The following is information on universities and KOSENs that are currently dispatching faculty members from Japan to Mongolia. In addition, some universities have already established bases in Mongolia and are implementing various initiatives.

Table 7-3 Examples of Dispatching Japanese Faculty

Organization/Project Name	Summary
M-JEED	- A consortium was formed among Japanese universities to implement the Twinning Program. In cooperation with the consortium, faculty members were dispatched to Mongolian universities to support the improvement of their teaching skills and curriculum and syllabus. - The consortium has conducted joint research programs with the Mongolian University of Science and Technology and the National University of Mongolia, with 40 universities and research institutes participating from the Japanese side. Under the program, researchers were invited to Mongolian universities to conduct research activities.
National Institute of Technology	Opened a liaison office at UB in 2016 to provide advice on Mongolian KOSENs and strengthen ties with Japanese universities, KOSENs, and companies. As part of the organization's efforts, faculty members from Japanese KOSENs are visiting Mongolian KOSENs to give classes.

Source: Prepared by the survey team

According to the Japanese government's Ministry of Education, Culture, Sports, Science and Technology (MEXT) "Inter-University Exchange Agreements with Overseas Universities (FY2021 Results)," there are 139 universities that have agreements with Mongolian universities, of which 51 are science universities. In addition, 14 universities have established bases in Mongolia. Furthermore, the agreements with the majority of these universities include the dispatch of faculty members and researchers, training, and other exchanges as part of the agreement's content.

⁷³ Clause 3.6.2 and 4.12.2 of Degree No. A/203 Approval of Revised Academic Policies and Procedures of the National University of Mongolia, issued by the President of The National University of Mongolia (June 2015)

Table 7-4 Japanese Universities with Agreements with Mongolian Universities

Classification	National	Public	Private	Total
Universities with agreements with Mongolian universities (all fields including arts and sciences)	53 universities	11 universities	75 universities	139 universities
Universities with science departments	30 universities	0 universities	21 universities	51 universities
Universities whose agreements include faculty/researcher dispatch, training, and other exchanges	27 universities	0 universities	20 universities	47 universities
Universities with offices in Mongolia	10 universities	0 universities	4 universities	14 universities

Source: Prepared by the survey team from MEXT data ⁷⁴

As shown in the table below, 13 universities are engaged in a variety of activities. "Japanese language education (a)," "School education (b)," "Local support for Japanese researchers (h)" and "Collection of information on the education and research situation in Mongolia (i)" are implemented by many universities. On the other hand, "Overseas training for Japanese staff (f)," "Maintenance of international student network (e)," and "Recruitment activities aimed at inviting local researchers (g)" are implemented by only a few universities and can be said to be limited activities. Overseas training for Japanese staff (f) is discussed in this section, "Maintenance of international student network (e)" is discussed in Section 7.2.3 "Establishment of a system on the Mongolian side" and "Recruitment activities aimed at inviting local researchers (g)" is discussed in Section 7.2.1 "Human resource development through outbound (from Mongolia to Japan)".

Table 7-5 Japanese Universities with a Base in Mongolia and their Initiatives

Classification	Name of University	Main organization (Italics denote provisional translations.)	a	b	c	d	e	f	g	h	i	j
National	Obihiro University of Agriculture and Veterinary Medicine	<i>Obihiro University of Agriculture and Veterinary Medicine Mongolia Office</i>					o			o		
National	Tohoku University	<i>Tohoku University Graduate School of Dentistry Liaison Office</i>			o				o		o	o
National	Akita University	<i>Akita University Mongolia Office</i>			o	o	o			o		
National	Yamagata University	<i>Yamagata University Ulaanbaatar Overseas Office</i>	o	o	o		o				o	o
National	The University of Tokyo	<i>Center for Biodiversity and Ecosystem Restoration, The University of Tokyo</i>								o	o	
National	Nagaoka University of Technology	<i>MUST-NUT Office</i>				o				o	o	o
National	Nagoya University	<i>Nagoya University Satellite Campus, Mongolia</i>		o	o	o	o	o			o	o
National	Kyoto Institute of Technology	<i>International Academic Exchange Club Mongolia Liaison Office</i>					o					o
National	Hiroshima University	<i>Center for Mongolian Studies, Hiroshima University</i>			o	o	o			o	o	o
National	Tokushima University	<i>Office of the University of Tokushima, Mongolian State Medical University</i>									o	
Private	Chiba Institute of Science	<i>Mongolia Exchange Center</i>			o	o				o	o	o
Private	Oberlin University	<i>Oberlin University Ulaanbaatar Office</i>				o	o			o	o	o

⁷⁴ Ministry of Education, Culture, Sports, Science and Technology. (2023). Survey Results on Inter-University Exchange Agreements with Foreign Universities and Centers of Excellence Abroad. Available at: https://www.mext.go.jp/a_menu/koutou/shitu/1287263.htm.

Classification	Name of University	Main organization (<i>Italics denote provisional translations.</i>)	a	b	c	d	e	f	g	h	i	j
Private	Okayama University of Science	<i>Mongolia Exchange Center</i>			○	○				○	○	○
Private	Kurashiki University of Science and the Arts	<i>Mongolia Exchange Center</i>			○	○				○	○	○

Notes: a. Provision of local Japanese language education, b. Provision of school education, c. Recruitment activities aimed at accepting international students, d. Local support for students' study abroad and internship, e. Maintenance and building of networks with returned international students and foreign researchers, f. Overseas training for staff, g. Recruitment activities aimed at inviting local researchers, h. Supporting research conducted by Japanese researchers in the region, i. Gathering information on local educational and research conditions, and j. Public relations activities of the university overseas.

Source: Prepared by the survey team based on MEXT data

2) Lack of Interdisciplinary Education and Research System

In promoting energy transition in Mongolia, it is necessary to address not only technological innovation but also multifaceted issues such as the development of policy and legal frameworks and securing social consensus. These issues are difficult to solve with an engineering approach alone, and interdisciplinary collaboration with law and economics is essential. In addition, Mongolia is said to have weak inter-ministerial collaboration and cooperative systems between industry and government agencies, and there are also challenges in terms of institutional design and strategic planning. Against this background, it is necessary to establish an integrated education and research system that transcends disciplines in order to promote energy transition and its human resource development in a comprehensive manner.

In addition, a survey conducted in 2025 among Mongolian researchers indicated that the future human resources required are those capable of engaging in interdisciplinary and advanced initiatives such as data analysis and AI, as well as those with expertise in specific fields including hydrogen storage and transport, High Voltage Direct Current transmission, and energy policy analysis. In particular, the shortage of personnel who can take responsibility for policy and planning was highlighted, and there is a strong need to cultivate policymakers who can design schemes to financially and fiscally support initiatives related to the environment and energy transition. Against this backdrop, it is considered a key challenge for Mongolia to simultaneously strengthen cross-disciplinary education and research collaboration among universities while also fostering highly specialized human resources.

3) Lack of Industry-Government-Academia Collaboration

In a field involving multiple sectors such as energy transition, it is necessary for universities, companies, and government agencies to collaborate in an integrated manner. However, it is confirmed that in Mongolia, there is no government-led framework or policy for "industry-government-academia collaboration", and systematic efforts have not yet been developed.

However, according to a Mongolian university faculty member, in the field of renewable energy, while the government does not provide subsidies to universities⁷⁵, private companies that operate

⁷⁵ In the "Final Report of the Information Collection and Verification Survey on Engineering Higher Education in Mongolia" conducted in 2013, it is stated that among the university's budget, the government budget covers only fixed costs (personnel, benefits, etc.), and that most of the costs of running the university are covered by classes. During the second field survey, the same explanation was given by a university official, so it appears that the government does not provide a budget for research. On the other hand, according to the Embassy of Japan in Mongolia and the Mongolian Academy of Sciences, the main responsibility for research and development has been transferred from the Ministry of Education to the Ministry of Economic Development in order to support Mongolia's economic growth under the reorganization of ministries in July 2024.

power plants provide research funds, universities conduct research, and public companies (government) that maintain the power grid provide facilities and technical support. This type of collaboration is a common practice in Mongolia. This form of collaboration can be seen as a budding industry-government-academia partnership unique to Mongolia.

4) Inadequacies in Interagency Collaboration and Institutional Design Issues

A survey of government agencies suggested that there may be insufficient inter-ministerial coordination on issues that require the involvement of multiple ministries and agencies. Energy transitions include a wide range of measures, such as the promotion of renewable energy, fossil fuel reduction, and energy efficiency, each of which falls under the responsibilities of a different government agency. In order to effectively implement these measures, it is essential to establish a system in which each ministry and agency plays a clear defined role and works closely with each other.

In addition, in order to promote energy transition, it is essential to secure and develop human resources who can deal with diverse fields such as technology, environment, and policy, etc. Inadequate inter-ministerial coordination may also create challenges in human resource development. Therefore, strengthening inter-ministerial coordination is an urgent issue in order to increase the effectiveness of the entire policy, including human resource development.

7.2 Necessity of a Human Resource Development System Framework Based on International Brain Circulation

A framework for sustainable human resource development in the field of energy transition based on cooperation between Mongolia and Japan is needed. This framework should focus on the development of researchers, engineers, and government officials, and be based on the concept of "international brain circulation," a system that supports the realization of this concept by cross-border mobility of talent and utilize their knowledge and experience in each other's countries.

The purpose of the international brain circulation is to promote economic growth and innovation in each country by sharing knowledge and technology through cross-border talent flows. In developing countries in particular, it is expected that human resources will bring back highly specialized knowledge and technologies acquired in developed countries, thereby contributing to domestic human resource development and industrial development. In developed countries, the incorporation of diverse perspectives and expertise will also generate new ideas and strengthen competitiveness. In order to strategically utilize this international brain circulation mechanism and realize sustainable development for both developing and developed countries, broad cooperation among governments, academic institutions, researchers, and industry is essential.

The Japanese government's "Outline for Development Cooperation," approved by the Cabinet in June 2023, also calls for promoting cooperation with universities and research institutes, creating new solutions to development issues in developing countries, and promoting international brain circulation through exchanges of students and researchers and joint research. It also indicates the strengthening of efforts to improve the scientific and technological capabilities of developing countries by drawing on Japan's experience in modernization and economic development. JICA defines international brain circulation as sustained, two-way mobility of faculty and students between developing countries and Japanese universities and other institutions, and mutually beneficial collaboration such as joint research, human resource development, and social implementation is sustained.

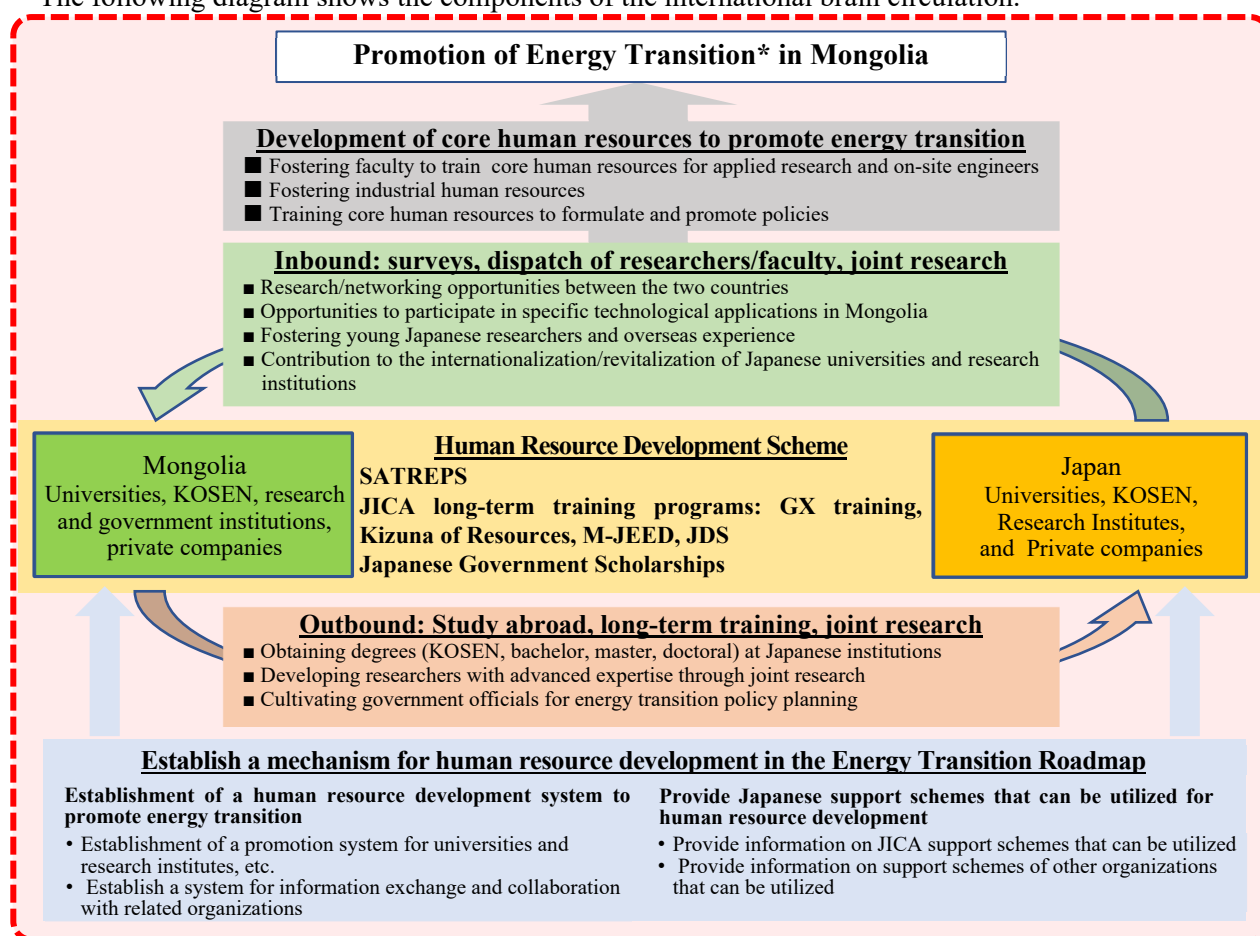
In the previous section, the current situation and challenges were organized based on the information gathered. To address these issues, specific measures based on the four components of the international brain circulation were examined and a mechanism was devised to contribute to the establishment of a sustainable human resource circulation system.

Table 7-6 Components of International Brain Circulation

Element	Outline
Outbound	Initiatives to provide opportunities for faculty members, researchers, and students from Mongolia to visit Japan and learn by utilizing Japanese educational and research resources.
Inbound	Initiatives in which Japanese faculty members, researchers and students are dispatched to Mongolia to conduct local cooperation through short-term or long-term research and educational activities.
Mongolian-side system	Initiatives that include capacity development of Mongolian universities and research institutions, development of educational and research infrastructure, and improvement of local fund-raising capacity.
Japanese side-system	Efforts aimed at building a framework for collaboration among Japanese universities and international joint research, and improving the attractiveness of research centers in Japan.

Source: Prepared by the survey team

The following diagram shows the components of the international brain circulation.

Source: Prepared by the survey team based on JICA document ⁷⁶**Figure 7-1 Brain Circulation Diagram**

7.2.1 Human Resource Development through Outbound (from Mongolia to Japan)

In the context of international brain circulation, outbound means sending high-level human resources and researchers abroad to gain experience in an international research environment, acquire knowledge and skills, and then returning to their home country to apply them. Unlike the brain drain, this system is based on the cyclical development and utilization of human resources.

⁷⁶ JICA Global Agenda No. 8 Education Cluster Project Strategy "Cluster for Strengthening Base Universities

Specifically, it includes the following forms:

- Study abroad for graduate students and young researchers: Participation in long-term programs to earn a degree, or short-term programs under exchange agreements.
- Overseas dispatch of researchers: Conducting research abroad while remaining affiliated with a Mongolian research institution.
- Participation in international joint research: Joining collaborative research projects with foreign institutions

Promoting outbound programs is important as a strategy to improve the research capabilities of researchers in their home countries, enhance their internationality, and encourage their entry into global research networks.

(1) Coordination of Study Abroad Plans by Faculty Members from Both Countries

This includes prior coordination of study abroad plans by Japanese and Mongolian faculty members, and the establishment of a system to develop human resources who can utilize the results of their studies after returning to their home countries through study at Japanese universities. In particular, it is necessary to establish a consistent support system for human resource development from pre-departure to post return, targeting both "research personnel" who work to create new knowledge and technologies at universities and research institutions in Mongolia and are responsible for human resource development through education and research, and "practical personnel" who promote energy projects and solve technical issues in the field. A consistent training support system from pre-study to post-return to Japan is needed.

According to the questionnaire survey for JUGAMO conducted in this study (conducted in 2024), of the 9 Mongolian students in the master's and doctoral programs, 4 chose their research themes based on their "own interests" and 5 followed the "recommendations of their Japanese academic advisors". This result suggests that the involvement of Mongolian faculty members and joint theme setting by both Mongolian and Japanese faculty members are limited.

In the short term, the effect of the study abroad program will be maximized by strengthening pre-study abroad coordination, career development support, and information sharing through existing joint research programs. In the medium- to long-term, a multi-layered development model should be established in accordance with the timeline under an institutionalized and continuous support system, and the partnership between Japan and Mongolia should be strengthened.

The following is a summary of the main initiatives for utilization of the program from study abroad to post-return home.

Table 7-7 List of Initiatives for Utilization of Mongolian Students from Studying Abroad and After Returning Home

Measures	Contents	Period of implementation
Integrated implementation of study abroad, research, and career support by academic advisors in both countries	Mongolian and Japanese academic advisors collaborate to formulate a study abroad plan, and jointly design research themes and individual career plans based on the Energy Transition Roadmap. This integrated approach ensures that activities during study abroad are linked to practical application and establishment after returning to Mongolia.	Short-term to long-term
Establishment of practical and research routes	Two professional career routes will be established to develop human resources for energy transition in Mongolia. Research route: Establishment of a route to develop academic research and writing skills in order to work in research institutes and universities in Mongolia. Practical route: Establish a route to provide specialized education in	Medium to long term

Measures	Contents	Period of implementation
	project management and technology implementation in order to develop human resources who will be active in the field of energy projects.	

Source: Prepared by the survey team

(2) Promoting the Return and Utilization of Human Resources Trained in Japan

In order for human resources trained in Japan to play a sustainable role in the energy transition field in Mongolia, it is essential not only to train them but also to create an environment in which they can return to their home countries and utilize their knowledge and skills.

However, it is not easy in the short term to promote the return of human resources who remain in Japan, given the large economic and social gap that still exists between the two countries in terms of wage levels and living conditions. Therefore, as a practical measure, it is necessary to design systems and support schemes that assume their return and provide incentives for it. In particular, the design of scholarship programs is an important means of promoting return home and encouraging job placement and retention in Mongolia. The following is a list of specific measures that should be undertaken in both Japan and Mongolia.

Table 7-8 Scholarship Programs to Promote the Return of Human Resources Developed in Japan to Mongolia

Measures to be taken	Outline	Implementation Period
Government Scholarship Program	Consider introduction and continuation of a government scholarship program conditional on returning to Mongolia and obtaining employment after studying in Japan. Under the joint collaboration between the Mongolian and Japanese governments, this system provides scholarships for overseas study on the condition that students work in Mongolia for a certain period of time. Specifically, it is envisioned that existing programs such as the "Engineering Higher Education Development Program," which is implemented through Japanese ODA loans will be continued and improved.	Short- to medium-term
Private Sector Partnership Type Scholarship Program ⁷⁷	Encourage private companies engaged in the energy transition sector in Mongolia to sponsor scholarships for students to study specific fields at Japanese universities or graduate schools. After returning to Mongolia, recipients would be required to work for the sponsoring company for a fixed period. In addition, the Mongolian government could reduce the financial burden on companies by providing subsidies or tax incentives, ensuring the stable operation of the program and encouraging active participation from the private sector.	Medium to Long Term

Source: Prepared by the survey team

(3) Strengthening Relationships between Returnees and Japanese Universities

In order to realize a sustainable circulation of human resources in the energy transition field, it is important to establish a system whereby Mongolian students trained in Japan maintain ongoing relationships with Japanese universities and academic advisors after returning to their home countries, and share knowledge and experience. This will not only support the career development of individual returnee students, but also serve to convey the significance and attractiveness of studying in Japan to the next generation.

Particularly in highly specialized fields such as energy transition, it is important to go beyond mere

⁷⁷ According to faculty members at the National University of Mongolia and the Mongolian University of Science and Technology, scholarship programs have been expanding in Mongolia in recent years, where companies offer scholarships to students on the condition that they work for the company after graduation.

exchange and to establish ongoing academic and practical collaboration through specialized networks. Based on such a network, it is expected that research issues and joint research proposals that promote energy transitions between the two countries will become possible, and that opportunities for collaboration, such as inter-university cooperation, will be created.

In order to strengthen cooperation between Japan and Mongolia, this study presents the following specific initiatives, including the development of a follow-up system, the creation of a network of returnees, and support for finding human resources.

Table 7-9 Support Measures to Promote Follow-up and Circulation of Human Resources after Return

Measures to be taken	Outline	Implementation Period
Establishment of follow-up system	To continuously monitor the progress of the returnees' career development and research activities, a monitoring system will be introduced, including online interviews and submission of progress reports 1-2 times a year. Hold debriefing sessions for returnees and provide opportunities for them to share their achievements and challenges with their Japanese universities and academic advisors. Furthermore, a questionnaire survey will be conducted to identify issues and support needs after return to Japan, which will be used to improve support measures.	Short to long-term
Networking and support for local activities	To establish a network of returnees specializing in the field of energy transition in Mongolia and to promote collaboration among experts in the field. Japanese universities will take the lead in holding local workshops on a regular basis, where returnees and local officials will share specific issues such as education, research, policy recommendations, and technology introduction, and discuss solutions. Ongoing support for activities in collaboration with Japanese universities (including establishment and operation of activity centers).	Short to long term
Support for the next generation and search for human resources	The program will provide information to Mongolian students who wish to study in Japan and help them deepen their understanding of life in Japan and their career choices. Conduct orientation for new international students and support their preparation in terms of study and daily life. Identify potential core personnel who will be responsible for the energy transition and cultivate their abilities through appropriate training and education.	Short to long term

Source: Prepared by the survey team

7.2.2 Human Resource Development through Inbound (from Japan to Mongolia)

Inbound in the international brain circulation refers to welcoming high skilled human resources and researchers into Mongolia from overseas. Specifically, it aims to bring knowledge and technology into the country by enabling researchers, experts, and international students to work at Mongolian research institutes, universities, and companies, thereby contributing to the development of domestic science, technology, and industry. This includes the following forms:

- Invitation of overseas researchers and faculty members: Invitation to teach classes or conduct research activities at domestic research institutes or universities for a certain period of time.
- Acceptance of international students: Support for participation in long-term study abroad or short-term programs for the purpose of degree acquisition.

- Conducting international joint research: Promoting joint projects in Mongolia in cooperation with overseas research institutions and companies.

Promoting inbound initiatives is considered an important strategy not only to introduce new perspectives and technologies into the domestic research environment and to stimulate the inflow of knowledge, but also to increase the international competitiveness of Mongolia's science, technology, and industry through international cooperation and network expansion.

(1) Dispatch of Japanese Faculty Members

The purpose of this study is to establish a mechanism for human resource development through knowledge and technology transfer by having Japanese researchers and educators visit Mongolia in order to support the energy transition in Mongolia.

In the short to medium term, it is necessary to strengthen local education and research support and technology transfer through dispatch from Japan, and to develop highly specialized core human resources to promote the energy transition. On the other hand, in the medium to long-term, it is necessary to build a sustainable human resource base, taking into consideration the development of mid-career human resources who will be responsible for practical operations in the field, in addition to highly specialized human resources.

Table 7-10 Response Measures for Dispatching Human Resources for Education, Research, and Technical Assistance in Mongolia

Response Measures	Outline	Period of implementation
Educational support-type dispatch	Faculty members from Japanese universities and KOSENs will give intensive lectures and workshops at Mongolian universities, research institutes, and KOSENs to provide practical knowledge to students and young researchers. Furthermore, the curriculum will be upgraded through the development of teaching materials and improvement of syllabi. Japanese faculty members will support the independent advancement of local education by communicating education and research guidance methods to local faculty members in Mongolia.	Short- to medium-term
Research Support Dispatch	Japanese researchers will stay in Mongolia for a long period of time to conduct joint research with local researchers and students, and transfer technology and knowledge related to energy transition. Through joint research, the program also aims to establish a sustainable research collaboration system.	Short-term to Long-term
Technology Implementation Support Dispatch	Japanese experts and engineers will be dispatched to Mongolian energy-related institutions and companies to support their ability to implement projects and apply technologies on site. The private sector will also provide equipment installation, technical training, and operational support through collaboration between Japanese and Mongolian companies to strengthen on-site technical capabilities.	Medium to Long-Term

Source: Prepared by the survey team

(2) Framework and Prospects for Joint Research between Japan and Mongolia

Inbound joint research is an important framework for deepening mutual cooperation between Japan and Mongolia. In particular, by targeting joint research in fields that are difficult to research in Japan and content that is unique to Mongolia, the interest of Japanese researchers can be increased, and this will help form the basis for applying Japan's technological capabilities and research know-how to Mongolia's actual situation. In this study, a questionnaire survey was conducted among Mongolian researchers and faculty members on research areas related to energy transition, with the aim of obtaining reference information for examining future areas of joint research, including priority technologies and related technologies.

Table 7-11 Summary of Questionnaire Survey

Survey Method	Online questionnaire with multiple questions (e.g., related research topics, research issues/needs, etc.)
Respondents' Basic Profile	- Responses were collected from a total of 23 participants as of September 25, 2025: 6 from the National University of Mongolia, 14 from the Mongolian University of Science and Technology, 1 from the Mongolian Academy of Sciences, 1 from Mongolian Hydrogen Council and 1 from Railway Institute of Mongolia. (Since some respondents hold multiple positions, the total is counted as an extended number) The majority were mid-career faculty members, including 7 associate professors and 7 senior lecturers, along with 2 professors. 2 researchers from research institutes and 4 doctoral students also participated, providing perspectives from the next generation of specialists. Responses were also received from technical staff and research assistants engaged in operational support roles. (Since some respondents are engaged in multiple fields of expertise, the total is counted as an extended number.) By field, 19 out of 23 respondents were involved in power generation (thermal, hydro, nuclear, renewable energy, etc.), followed by 14 respondents in energy policy and system design, 11 in storage and demand-supply balancing (including smart grids), and 9 in transmission, distribution, and substations.
Interest in recommended technologies	[Interest in Recommended Technologies – Demand Side] On the demand side, there was broad interest in energy-saving and efficiency technologies, as well as hydrogen infrastructure, new fuels, and carbon pricing. - The most frequently mentioned area was the introduction of energy-saving equipment (high-efficiency lighting/appliances, insulation materials, etc.), cited by 15 respondents. Insulation technology (11), heat pumps (10), and geothermal heat pumps (10) were also common. - Economic measures for climate change mitigation, such as carbon credits (12) and carbon taxes (8), attracted considerable attention. - Technologies addressing Mongolia-specific challenges were also mentioned, such as hydrogen fueling stations (10) and alternative housing solutions such as ger replacements or 3D-printed housing (9). - Other topics included mine electrification (4) and synthetic fuel production (8). [Interest in Recommended Technologies – Supply Side] On the supply side, respondents showed wide-ranging interest in hydrogen, renewable energy, energy storage, geothermal and pumped storage, and next-generation power generation technologies. “Hydrogen utilization technologies” were the most frequently mentioned, cited by 13 respondents, suggesting strong interest in the potential use of hydrogen as an energy source in Mongolia. “Pumped-storage hydropower” and “geothermal power generation” were each mentioned by 11 respondents, reflecting attention to technologies that provide stable supply from renewable sources. - Emerging technologies such as perovskite solar cells (8), nuclear fusion power (8), and small modular reactors (SMRs, 7) were also highlighted. - Grid-related measures, including “large-scale batteries for renewable frequency stabilization” (8) and “interregional interconnected mini-grids” (8), were regarded as important. - Biomass and waste-to-energy technologies that can substitute for fossil fuels, such as new biomass-fired power plants, waste-to-energy plants, and circulating fluidized bed (CFB) boilers, were mentioned by around seven respondents. [Technologies for Carbon Recycling] Respondents showed strong interest in technologies related to CO₂ capture, storage, and reuse, with particular attention to those nearing practical application, such as synthetic methane and CCS. - The most frequently mentioned was “methane production from renewable energy” (Power-to-Gas, 12 mentions). CCS (Carbon Capture and Storage) was cited by 11 respondents, and CO₂ separation and capture technologies by 10, indicating strong

	interest in CO₂ capture and sequestration. • “CO₂ utilization in greenhouse cultivation” (8) was noted as an important technology for effective CO₂ use. • Other mentions included biofuel production (5), CO₂-absorbing concrete (4), and enhanced oil recovery (EOR) (3).
Research Related to Recommended Technologies	The following are the current research topics related to the recommended technologies identified in this survey: • Renewable energy and heat utilization (e.g., solar thermal, heat storage) • Low-carbon and emerging technologies (e.g., hydrogen, waste utilization) • Advanced nuclear technologies • Carbon recycling technologies (e.g., CO₂ capture and utilization) • Energy planning and policy • Energy systems and equipment (e.g., heat pumps, distributed power sources) Although there was strong interest in “hydrogen utilization technologies” and “CCS,” only a small number of respondents reported that they were actively conducting research in these areas. This result may reflect several factors: respondents may not have disclosed detailed information on their research, or there may be constraints such as limited research facilities, budgets, or personnel.
Needs for industry–academia collaboration and joint research	There is a strong demand for strengthening interdisciplinary collaboration and industry–academia–government partnerships in the following areas: • As for joint research themes, respondents expressed interest in “industry–academia collaboration on grid stabilization for large-scale renewable energy integration” and “joint research centered on renewable energy utilization technologies.” • The necessity of cross-disciplinary initiatives was highlighted, such as legal studies conducted jointly by engineering and law researchers, as well as joint research with the ICT field to leverage smart grid and digital technologies. • Some respondents also emphasized the importance of involving students and young professionals in joint research for the purpose of human resource development, as well as ensuring the active participation of industry. These views underscore that establishing a cooperative framework among universities, industry, and government is essential for realizing the energy transition.
Human resource development in industrial sectors from the researchers’ perspective	Although human resource development has been identified as a challenge across a wide spectrum—from institutional design to on-site technologies and advanced fields—there is a particular need for human resource development in the following industrial sectors: • Practical specialists to address Mongolia’s on-site needs such as heating, ventilation, and district heating systems • Personnel capable of responding to new technologies such as hydrogen energy and small modular reactors • Experts equipped to deal with Mongolia’s specific challenges in cold-climate energy and housing, as well as the capacity to adapt to the introduction of emerging technologies

Source: Prepared by the survey team

Based on the above survey results, the following key perspectives were organized for promoting human resource development to advance the energy transition in Mongolia. First, strengthening the training of specialists in priority areas such as hydrogen, renewable energy, energy storage and grid stabilization, carbon recycling, and small modular reactors will be essential, accompanied by curriculum development at universities, allocation of research funding, and the promotion of human exchange based on the concept of international brain circulation. Second, to foster interdisciplinary and practical professionals capable of policy planning, ICT utilization, and data analysis, the introduction of industry–academia collaboration programs within Mongolia would be effective. In addition, it is important to encourage active industry participation in research, development, and technology demonstrations through initiatives such as in-company training and OJT programs, joint research with industry, and the establishment of specialized courses at universities with corporate cooperation to promote practice-oriented training. Finally, a long-term and comprehensive human resource development strategy should be pursued, including awareness-raising activities for students and engineers and the active use of domestic and international expert networks.

As a result of individual meetings held through workshops conducted in October 2025 (with the Ministry of Energy, ERC, Ministry of Urban Development, Construction and Housing, National University of Mongolia, etc.), Mongolian relevant agencies indicated specific and practical support needs in the energy conservation field. Mongolia enacted the Energy Conservation Law in 2015, introducing an energy management reporting and audit system for energy consumers of a certain size or larger. However, given the challenges and areas for improvement over the past 10 years and the increased market demand for energy conservation due to the electricity tariff hikes implemented since Covid-19, there was a desire for support in the development of systems and standards to further promote energy conservation, as well as human resource development for their implementation. Specifically, to strengthen energy conservation policies and frameworks, requests included the establishment of energy efficiency standards (benchmarking) in the industrial sector, the establishment of an energy conservation center as an implementing agency, and the training of practitioners, as well as the transfer of Japanese experience and expertise in incentives and financing mechanisms. In the residential sector, requests included the establishment of building energy conservation standards, the formulation of energy conservation guidelines, and a performance certification system, both for the development of infrastructure and the training of practitioners. The dissemination of new technologies and business models, such as smart meters and ESCO services⁷⁸, was also cited as an important policy issue. To realize these initiatives, it is necessary not only to establish systems and standards, but also to train engineers and administrative personnel who can operate them in practice. It is also essential to build a foundation and improve the capabilities of relevant Mongolian organizations to make these initiatives sustainable.

7.2.3 Establishment of a System on the Mongolian Side

In order to promote energy transition in Mongolia, it is important to strengthen cooperation among domestic educational institutions, industry, government, and academia, as well as between ministries and agencies, and to develop a comprehensive system that covers multiple fields. This chapter presents specific directions for sustainable human resource development and policy implementation through the introduction of interdisciplinary education, the establishment of pre-master programs, the promotion of industry-government-academia collaboration, and the strengthening of inter-ministerial coordination.

(1) Promotion of Interdisciplinary Collaboration Within Universities

To advance the energy transition, it is not enough to take an engineering perspective on technology adoption; it is essential to address multifaceted issues such as institutional design, establishment of economic incentives, and consensus building among stakeholders. In order to address these issues, it is necessary to establish an educational system that integrates interdisciplinary knowledge across different fields, such as law, economics, and engineering. Through such education, it will be possible to systematically develop highly specialized human resources who can not only handle technology, but also appropriately implement it into systems and society, and formulate and operate effective energy policies.

The importance of such an interdisciplinary approach can be confirmed by actual examples of legal system formation. For example, in Japan, energy-related laws and regulations have been developed mainly by the Ministry of Economy, Trade and Industry (METI) in collaboration with related industry associations and private companies, while incorporating the opinions of experts and academics. In Mongolia, on the other hand, university faculty members are often directly involved in drafting legislation, confirming a closer connection between universities and legal system formation.

In fact, there is a case in which the "Business and Economic Law Center" of the Faculty of Law at the National University of Mongolia was commissioned by a government agency to draft legislation. In addition, graduates of the "Mongolian Research and Education Center for Japanese

⁷⁸ ESCO services are services that cover all costs associated with energy-saving renovations through savings on utility bills.

Law,” established in cooperation with Nagoya University, have completed their master’s and doctoral degrees at Nagoya University and are now serving as faculty members at the National University of Mongolia while participating in legislative drafting.

Against this backdrop, faculty members at the Faculty of Engineering of the National University of Mongolia are beginning to share the need for interdisciplinary educational collaboration beyond the traditional engineering-centered educational framework and have begun to discuss the establishment of a system.

Furthermore, the concept of Management of Technology (MOT), which is being researched by the Institute of Science Tokyo and other institutions⁷⁹, provides an effective framework for promoting such energy transitions. MOT is an interdisciplinary approach that aims to link technological innovation and scientific knowledge with social policy and industrial strategy, and is attracting attention as a method of bridging technology and institutions. Applying this approach to higher education in Mongolia will enable the development of highly specialized human resources who can contribute to institutional development and policy formation, rather than merely training engineers.

Below are specific measures for human resource development based on such interdisciplinary collaboration.

Table 7-12 Measures to Promote Human Resource Development and Policy Collaboration Based on Interdisciplinary Approaches

Measures to be taken	Outline	Time of implementation
Pilot introduction of interdisciplinary educational programs	To promote the energy transition, an interdisciplinary educational program that adds the perspectives of law and economics to engineering will be introduced on a trial basis. In addition to raising awareness of the importance of interdisciplinary cooperation among faculty members and students of related departments in advance, and establishing an intramural auditing system that allows engineering students to audit classes in other departments to monitor student interest and learning effects, basic courses in energy law, contract law, etc. will be established in the School of Engineering. In addition, workshops dealing with legal issues will be held by inviting legal experts from Japan and abroad.	Short-term
Formal introduction of an interdisciplinary curriculum and establishment of a system	Based on the pilot, introduce a cross-faculty program integrating engineering, law, and economics at universities and other institutions, and establish a systematic educational system that also incorporates the MOT (Management of Technology) approach, so that universities can foster leaders in the energy transition and at the same time contribute to the development of laws and systems for policy implementation.	Medium to long-term
Reinforcement of joint research system and policy proposals	In parallel with interdisciplinary education, promote integration of engineering and other fields of study through joint research in cooperation with policy advocacy organizations and universities and research institutions in other countries. Contribute to policy, institutional, and environmental development based on research results, and form the basis for promoting energy transition in Mongolia.	Medium to long-term

Source: Prepared by the survey team

(2) Introduction of laboratory assignment system

In developing human resources to promote energy transition in Mongolia, it is important to establish a system that enables students to acquire the basic skills necessary for research activities at an early stage, starting from the stage when they aim to enter graduate school.

⁷⁹ The Council of Professional Graduate Schools of Management of Technology, which promotes activities to spread MOT in Japan, consists of Institute of Science Tokyo, Nippon Institute of Technology, Tokyo University of Agriculture and Technology, Waseda University, Kwansei Gakuin University, and Yamaguchi University.

In the laboratory assignment system widely implemented in Japanese universities, students are engaged in daily research activities under the supervision of a faculty member, while practically acquiring the basics of being a researcher through seminars, discussions, literature reviews, and presentations at academic conferences. It is expected that the laboratory system will be developed in Mongolia as a system that can be flexibly operated at the discretion of universities and faculty members.

It is therefore recommended to introduce a pilot program in which students are assigned to a faculty member's laboratory during the latter half of the bachelor's program⁸⁰ Under this system, students can systematically acquire research methodology, academic writing, presentation skills, and specialized knowledge through hands-on learning in the laboratory.

In the medium to long-term, this system should be institutionalized as a formal educational process at universities, positioned as a standard preparatory step for students who wish to enter graduate school, and establish a sustainable operational system.

Table 7-13 Introduction of a Laboratory Assignment System to Strengthen Basic Research Skills

Measures to be taken	Outline	Time of implementation
Pilot introduction of laboratory assignment system	Aiming at early acquisition of the basic research skills required in the master's course, a system to assign students to faculty members' laboratories will be introduced on a trial basis. Students will be assigned to the laboratory of a faculty member in the second semester of their bachelor's course or after completion of their bachelor's course, and will learn research methodology, academic writing, presentation skills, and basic knowledge of the energy field through hands-on activities.	Short-term
Institutionalization of laboratory assignment system	Evaluate the results of the pilot introduction and officially introduce the Mongolian version of the laboratory assignment system as a university system. Position the system as a standard preparatory step for students aiming to enter graduate school, and ensure sustainable operation of the system and its university-wide development.	Medium to long term

Source: Prepared by the survey team

(3) Promote Collaboration Among Industry, Government, and Academia

In order to promote energy transition, in addition to the development of technologies and institutional arrangements, it is necessary to have a practical collaboration system to put them into practice in the field. In particular, "industry-government-academia collaboration," in which private companies (industry), universities and research institutions (academia), and the government (government) work together while leveraging their respective strengths, is an essential mechanism for organically linking knowledge and resources and accelerating social implementation.

According to Japan's MEXT, with the advent of the "knowledge society," industry, academia, and government are increasingly motivated to collaborate, each taking on the following roles

- **Industry:** Against the backdrop of globalization and IT progress, industry is responsible for technological development and demonstration experiments, emphasizing the creation of technological seeds, research and development, and human resource development.
- **Academia (universities, etc.):** In addition to practical human resource development and solving social issues in response to the needs of industry, **academia** is responsible for basic research and evaluation, joint research, and lifelong learning.

⁸⁰ At the Mongolian University of Science and Technology, an approach similar to the laboratory assignment system has already been implemented by voluntary faculty members and students, whereby fourth-year university students who wish to enter master's programs sit in faculty members' laboratories to learn specialized knowledge, academic writing, and other subjects.

- **Government (government and public organizations):** responsible for building innovation systems at the national level and supporting the utilization of research results, as well as supporting entrepreneurship and policy support for the creation of new industries in local communities by utilizing the technological seeds of universities.

Innovation and social development in the "knowledge society" will be promoted through collaboration among industry, academia, and government while fulfilling their respective roles.⁸¹

In the field of energy transition in Japan, the "Project for Promoting the Resilience of Autonomous Resource Circulation Systems through Industry-Government-Academia Collaboration" (provisional translation) and "Initiatives for the Realization of a Hydrogen Society" can be identified as examples of Japan's energy transition field. For example, the "Project for Promoting the Resilience of Autonomous Resource Circulation Systems through Industry-Government-Academia Collaboration"⁸² (provisional translation) is a project scheduled to be implemented by the Ministry of Economy, Trade and Industry in FY2024, and is part of efforts to realize GX (Green Transformation). The project will support efforts to create a new resource recycling market that combines decarbonization and economic growth by utilizing the industry-government-academia partnership framework called "Circular Partners"⁸³. The project will also support the creation of a new recycling market for resources. Circular Partners is another industry-government-academia partnership on the circular economy launched by METI in 2023. As of October 2024, approximately 520 companies, universities, and other organizations were participating in this partnership, making it a good example of industry-government-academia collaboration.

In Mongolia, it is important to realize industry-government-academia partnerships to promote energy transitions. In particular, it is important for the private sector to take the lead in building a cooperative framework with the government and universities and research institutions. By leveraging the financial resources, quick decision-making and their market-driven execution capabilities of the private sectors, it is expected that the creation of short-term results and the formation of a medium- to long-term innovation ecosystem will be achieved. In particular, strategic collaboration with government and universities is required for projects that address specific issues in the energy transition sector or for initiatives already underway.

Table 7-14 Industry-Government-Academia Collaboration Projects

Measures to be taken	Overview	Timing of implementation
Implementation of industry-government-academia pilot projects	In project areas that contribute to energy transition, select projects in which the private sector can play a facilitating role and lead discussions with government and universities, and conduct joint research and pilot projects. The results will also be shared with the government and universities.	Short- to medium-term

Source: Prepared by the survey team

(4) Promotion of Inter-Ministerial Collaboration

The Energy Transition is a national project that involves not only technology introduction and industrial promotion, but also complex issues such as social structural change, environmental conservation, and human resource development. Therefore, it cannot be addressed by a single ministry, but it is essential to build a system that promotes institutional design, policy implementation, and human resource development in an integrated manner through cross-sectional cooperation among multiple relevant ministries and agencies.

For example, the Cabinet Office and the Prime Minister's Office should play a central role in overseeing and coordinating the overall policy, while ministries in the economic and industrial

⁸¹ MEXT: https://www.mext.go.jp/b_menu/shingi/gijyutu/gijyutu8/toushin/attach/1332039.htm

⁸² Low Carbon Investment Promotion Organization <https://www.teitanso.or.jp/skgshigen/>

⁸³ Circular Partners membership list: <https://www.cps.go.jp/member-list>

sectors should participate in fostering the energy industry, and ministries in the environmental sector should participate in assessing emission reduction targets and environmental impacts, drawing on their respective expertise. In addition, ministries with jurisdiction over education, research, and vocational training should collaborate with ministries responsible for energy policy to promote curriculum development and research support in line with energy policy and practice. Involvement of fiscal authorities is also essential in securing and allocating financial resources for policies.

In order to address policy issues that span other fields, it is important to develop a coordination mechanism that institutionalizes collaboration while clarifying the roles of the ministries and agencies. In particular, a system is required in which relevant ministries and agencies function in a mutually complementary manner in a series of processes, such as policy planning, institutional design, and the establishment of implementation systems.

Inter-ministerial coordination is also essential from the perspective of human resource development. In particular, the administrative officials and university faculty responsible for formulating and implementing energy policy must have interdisciplinary knowledge across fields such as law, economics, and engineering, as well as an understanding of the policy structure across ministries and agencies.

Specific measures for building an interagency coordination structure and a policy implementation infrastructure to support it is presented below.

Table 7-15 Policies for Developing Policy, Human Resource, and Fiscal Structures through Transversal Collaboration

Measures to be taken	Overview	Implementation Period
Establishment of a policy coordination structure	In order to comprehensively promote the energy transition, a coordination mechanism will be developed for cross-sectional collaboration among related organizations. Institutionalize coordination through establishment of coordination meetings and working groups, and clarification of the division of roles.	Short-term
Strengthening collaboration to develop administrative officials and professional human resources	In order to support the acquisition of interdisciplinary knowledge and practical skills required of administrative officials and university faculty members who are responsible for energy policy, relevant ministries and agencies, universities, and research institutions will collaborate to develop and implement specialized education and training programs.	Short-term
Introduction of a cross-ministry budget system	In order to enable related institutions to jointly plan and implement projects, a cross-sectoral budget framework and financial coordination mechanism should be considered and developed. This will enable flexible and agile policy implementation.	Short-term

Source: Prepared by the survey team

7.2.4 Establishment of a System on the Japanese Side

In order to develop human resources for Mongolia's energy transition and to realize international brain circulation, it is essential to improve the Japanese side's hosting system and effectively utilize support resources. Japanese universities and related institutions should work together with Mongolian higher education institutions and government administration to establish a continuous and strategic cooperative framework to foster professional human resources and improve the quality of international collaboration.

On the Japanese side, the MEXT is implementing various programs such as the World Premier Research Center Program and the Strategic International Collaborative Research Program, while JICA is implementing the Cluster Program for Strengthening Core Universities as well as the JICA Global Agenda and various schemes (e.g., the Development Graduate School Collaboration

Program, JICA Chair, SATREPS, Overseas Cooperation Volunteers, etc.).

Effective use of these schemes and support can make the cooperative relationship with Mongolia more effective. In order to steadily promote human resource development, the key is to provide information at an early stage, develop a system for accepting international students, and build a platform that enables the sharing of knowledge and technology.

In the following, Japanese support resources for human resource development to support Mongolia's energy transition, as well as challenges and solutions for the system for accepting international students will be discussed in detail.

(1) Introduction of Japanese Support Scheme for Human Resource Development

Various schemes that can be utilized by the Japanese side for human resource development to promote the Energy Transition in Mongolia were able to be confirmed. For example, Nagaoka University of Technology, which had been implementing the secretariat of the Twinning Program through M-JEED, concluded an agreement on the Twinning Program with Mongolian University of Science and Technology in March 2024⁸⁴ and will continue the program independently with the university.

In fact, in a survey conducted for JUGAMO (conducted in 2024, 35 respondents), the majority of respondents studied in Japan using either the Japanese Government Scholarship from the MEXT (9 students in total, including 5 bachelor and 4 master or above) or M-JEED (11 students in total, including 9 bachelor and 2 master or above) (20 students in total). These results are based on the characteristics of the respondents and do not represent the overall trends of all JUGAMO members. However, at least among those who responded to the survey, it was confirmed that the use of public scholarship programs constitutes one of the major pathways for studying in Japan.

The following table describes the MEXT and JICA schemes.

Table 7-16 Examples of Support Schemes Provided by Japan

Implementing agency/Program Name	Outline
Implementing agency Entity: MEXT Program name: Japanese Government (MEXT) Scholarship	The purpose of this program is to contribute to the development of Japan and the world by accepting outstanding international students from abroad, thereby contributing to the promotion of international exchange and friendship, the development of human resources in other countries, the advancement of internationalization of universities and other institutions in Japan, the improvement of education and research capabilities through such efforts, and the internationalization and revitalization of society as a whole. The program is open to all fields of study that are acceptable at graduate schools in Japan.
Implementing agency: JICA Program name: GX Human Resources Development Program	This program aims to develop core human resources for developing countries to plan and implement social transformation scenarios toward decarbonization in their own countries. Specifically, the program aims to invite personnel from ministries in charge of the energy sector, think tanks, and electric power utilities to Japan's graduate schools (master's program) to learn the history of energy policy, transition economy model analysis, and electric power utility management. The researchers from the Center for Business and Economic Law at the National University of Mongolia, who are contributing to the development of Mongolia's legal system in various fields, as mentioned in the previous section, may be strong candidates for this program.
Implementing agency: Japan Science and Technology Agency, Japan Agency for Medical	SATREPS aims to improve science and technology, solve global issues, and create innovations through international joint research to enhance the research capacity of developing countries and establish a sustainable framework for activities. Within SATREPS projects, researchers who already possess advanced skills will serve as

⁸⁴ <https://www.nagaokaut.ac.jp/shincyaku/202403/22.html>

Implementing agency/Program Name	Outline
Research and Development, and JICA Program name: International Science and Technology Cooperation Program for Addressing Global Issues (SATREPS)	counterparts, and it is expected that long-term foreign researchers will participate in master's and doctoral programs in Japan.
Implementing agency: JICA Program name: The Project for Human Resource Development Scholarship (JDS)	The aim of JDS is to accept outstanding young administrative officials who are expected to become future leaders in the target countries as international students at Japanese graduate schools, and after their return to their home countries, they will play an active role in planning and implementing social and economic development programs as human resources with expertise acquired during their study in Japan, and eventually contribute to expanding and strengthening the foundation of friendly relations between Japan and the target country as people with a good understanding of Japan.
Implementing agency: JICA Program name: Mongolian-Japan Higher Engineering Education Development (M-JEED)	The Mongolian University of Science and Technology and the National University of Mongolia will be the target institutions of this project to support degree study at Japanese KOSENs and universities and joint research with Japanese universities. The acceptance of new international students for this project has concluded. However, the “Information Gathering and Verification Survey on Engineering Talent Development through Practical Educational Opportunities in Mongolia” (Implementation Period: April 2024 to September 2026) is currently underway. Through this survey, JICA's support approach for the development of engineering human resources, especially for the acquisition of practical skills, which will lead to industrial development, will be examined. The target institutions are assumed to be mainly four-year universities and KOSENs.

Source: Ministry of Education, Culture, Sports, Science and Technology, JICA

(2) System for Accepting International Students

According to university faculty members who have supervised Mongolian students, Japanese universities and research institutions have a wide range of research fields that can meet Mongolia's research needs, and they are well organized to accept Mongolian students. In addition, they confirmed that they continue to have a high interest in fostering Mongolian students and faculty members, and that some universities provide dormitories for international students, tutors to support their daily lives, and support systems for Japanese language study. In addition, a high level of interest in fostering Mongolian students and faculty members is maintained in the future.

On the other hand, in order to establish a more sustainable and effective system for accepting Mongolian students, it is necessary to consider supporting prospective students from the preparation stage of their application for study abroad, strengthening the system for acceptance and training, and establishing a human resource development platform.

It is expected that the development of professional human resources and intellectual collaboration between Mongolia and Japan will be further strengthened through the formation of a sustainable ecosystem for human resource development and exchange between prospective students, universities, research institutions, and companies.

Table 7-17 Measures for Cooperation to Support International Students and Strengthen the Japanese Acceptance System

Response Measures	Outline	Time of implementation
Establishment of support system for students prior to study abroad	Provide an online platform that consolidates information on study abroad programs, scholarships, and research fields in English. Online information sessions will be held regularly for local residents and Mongolians residing abroad to eliminate the information gap.	Short- to medium-term

Response Measures	Outline	Time of implementation
Strengthen the system for accepting international students	Matching of laboratories and academic advisors between Mongolian and Japanese universities will be conducted in advance to adjust the educational content to meet the needs of developing countries such as Mongolia. To reduce the burden on faculty members, outsource daily life and administrative support to specialized staff, international exchange offices, or consultants to facilitate their focus on education and research activities. In parallel, the development of an English-speaking environment will also be promoted.	Short- to medium-term
Establishment of a platform for fostering professional human resources	Establish a sustainable human resource development platform involving Mongolian and Japanese universities, researchers, students, and companies to form an ecosystem through joint research, exchange programs, and technology and knowledge sharing.	Short to long term

Source: Prepared by the survey team

7.3 Roadmap for Human Resource Development

7.3.1 Organize Human Resource Development Based on Technology Life Cycle

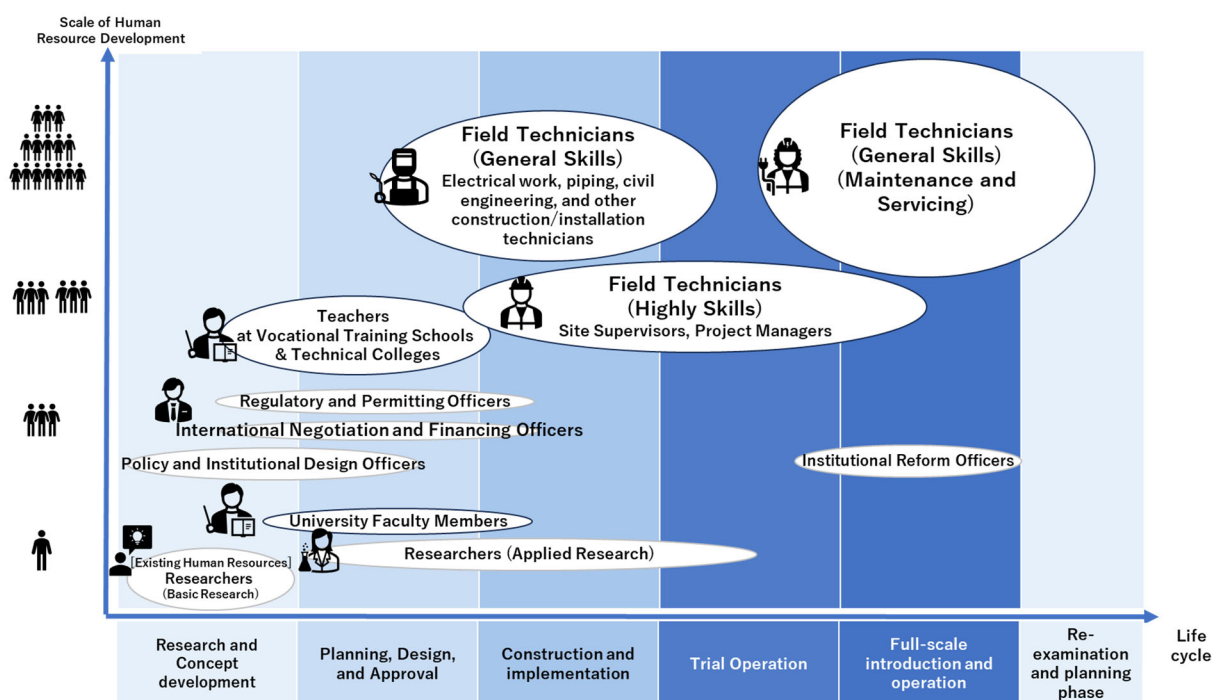
A systematic approach to human resource development is necessary when introducing and deploying new technologies such as energy and infrastructure to society. As a prerequisite, it is necessary to organize the characteristics of each phase in the lifecycle of new technology introduction, and to consider the human resources and education system required for each phase. The table below shows the human resource groups that should be prioritized for development in the process of implementing new technologies in society and the direction of the educational support system for them.

Table 7-18 Human Resource Development and Education System According to the Life Cycle of Technology Implementation

Phase	Overview	Human resources to be fostered and educational support system
Research and Concept development	Initial phase to study the necessity and direction of technology introduction, and to research and plan policies, systems, and technology possibilities.	- Interdisciplinary education (engineering, law, economics) will be introduced to foster <u>researchers and administrative officials</u> who can respond to energy policy and institutional design. - Education and research skills for new technology areas will also be developed for <u>university faculty members and researchers</u>.
Planning, Design, and Approval	This is the phase in which detailed design of technology and systems is carried out, and preparations are made for legal and institutional approvals, securing budgets, etc.	<u>Faculty members and instructors at universities, KOSENs, and vocational training schools</u> are provided with opportunities to develop teaching materials, design curricula, and provide training opportunities to foster a variety of on-site engineers.
Construction and implementation	This is the implementation phase in which technologies and systems are actually built and introduced, such as infrastructure development and equipment installation.	Educational institutions such as KOSENs and vocational training schools will be developed to expand the system that can train many <u>engineers</u> in a practical manner throughout the country.
Trial Implementation	A verification phase in which the introduced technology or system is operated on a limited basis to check and improve performance and issues.	- Opportunities are provided for <u>researchers and advanced technicians</u> to develop their application skills through demonstration projects and on-the-job training (OJT). - Industry-academia-government collaboration will provide trial practical training and training for <u>engineers</u> to facilitate the transition to the full-scale operation phase. - Establish a system for continuous learning and reeducation for <u>engineers in charge of maintenance and operation</u>.
Full-scale introduction and operation	This is the phase in which full-scale operation is started and deployment and promotion of use are promoted to target regions and organizations.	- Promote continuous training of <u>faculty members and instructors at universities, KOSENs, and vocational training schools</u> so that the system for human resource development can be operated independently. - At administrative agencies and universities, review systems and technologies, and retrain human resources capable of responding to the shift to new fields.
Re-examination and planning phase (next generation, improvement, renewal, or decommissioning)	This is the phase in which future plans are reconstructed in anticipation of aging technologies and institutional changes, including next-generation, reuse, and decommissioning.	<u>Administrative officials, university researchers and faculty members</u> redesign their educational programs to accommodate new areas.

Source: Partially modified and prepared by the survey team based on the Ministry of Land, Infrastructure, Transport and Tourism's "Guide to the Introduction of New Technology (2020).

The types of human resources required and the approximate scale of their development throughout the lifecycle of introducing and disseminating new technologies have been organized by category—administrative officials, researchers and faculty members, and field engineers (both highly skilled personnel and general technicians)—as shown in the figure below. It should be noted, however, that this figure represents only a general model based on typical technology introduction processes, and that actual human resource development needs vary significantly depending on the characteristics of the technology and the scale of its deployment. For example, technologies such as power transmission lines and hydrogen pipelines, which require extensive on-site work, may require a large number of general skilled engineers for maintenance and construction, while technologies with highly automated operations such as small modular reactors (SMRs) may require a relatively small number of on-site personnel.



Source: Prepared by the survey team

Figure 7-2 Example of Overall Human Resource Development for a Technology Deployment Life Cycle

7.3.2 Human Resource Image and Human Resource Development Strategies to Support Energy Transition

(1) Organizing Human Resources and Roles for Technology Adoption

Although a wide variety of technologies were identified in this study, the supply sector technologies proposed in the Action Plan (introduction of small nuclear CHP, hydrogen CHP, VRE including power transmission and hydrogen pipeline projects, etc.) and identified human resources to support the introduction of these technologies were focused on. The report classifies the human resources supporting the introduction of these technologies into four categories: administrative officials, researchers/teachers, and on-site engineers (advanced personnel/general skills), and summarizes the main roles and required abilities/personalities for each category.

Table 7-19 Roles and Specific Images of Human Resources Supporting Energy Transition (Supply Side)

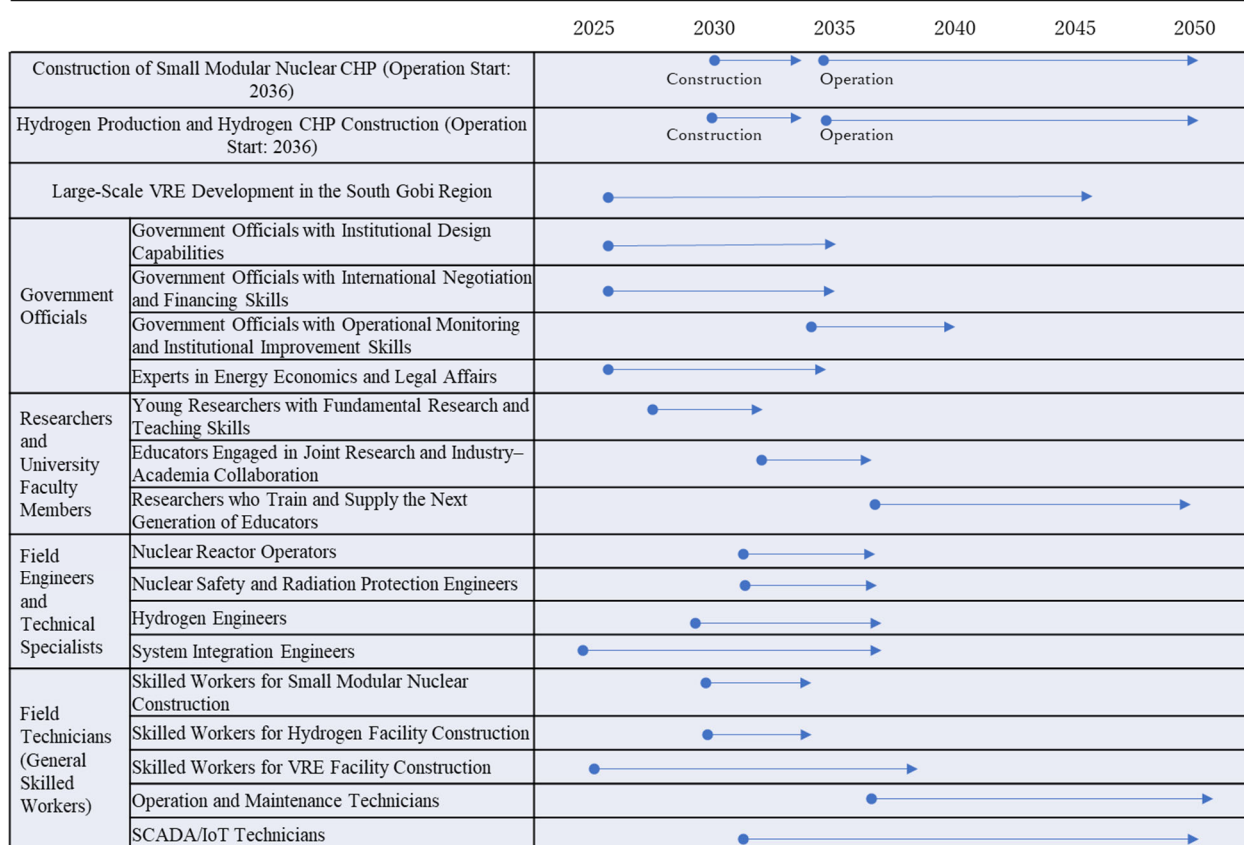
Human Resources	Main roles	Overview and main specific human resources
Administrative officials	Institutional design, international negotiations, operational monitoring, economic and legal experts, etc.	Policy human resources in charge of institutional design and international negotiations. Human resources with capabilities in energy mix optimization, safety regulation, and rate system design, who are responsible for responding to international treaties in the nuclear and hydrogen fields, negotiations with international organizations, and fundraising with international financial institutions and investors. - Administrative officials with institutional design capabilities: Expert personnel in policy making to design energy mix optimization, safety regulations, and tariff systems. - Administrative officials with international negotiation and fundraising capabilities: Human resources responsible for negotiations with the IAEA and international cooperation frameworks, and fundraising from international financial institutions and private investors. - Administrative officials with operational monitoring and institutional improvement capabilities: Practical human resources who monitor the operation of the system after

		the start of operation and promote the strengthening of regulations and institutional improvement. Experts in energy economics and legal affairs: Expert personnel who are responsible for investment profitability evaluation, electricity market design, and the development of international contracts and legal systems.
Researchers and Faculty	Technology development, joint research, applied research, and human resource development	Research and educational personnel responsible for technology development and education: Human resources who promote research on SMR, hydrogen technology, and renewable energy integration, develop industry-academia collaboration and international joint research, and nurture the next generation through university education. - Young researchers with basic research and educational abilities: Human resources who conduct basic and applied research in doctoral programs and cultivate their skills as researchers and educators. - Researchers capable of international joint research and industry-academia collaboration: Human resources who have the research skills to handle applied research, international joint research, and industry-academia collaboration. - Educators who foster and supply the next generation of educators and researchers: Human resources who play a role in fostering the next generation of researchers, educators, and practitioners by sending doctoral graduates to universities, research institutes, and companies.
Field Engineers (Advanced Human Resources)	Reactor Operation, Hydrogen Engineer, System Integration	Personnel with advanced professional qualifications and abundant practical experience who are responsible for operation, safety management, and integrated control. - Reactor operators: Personnel responsible for the operation and safety management of small nuclear CHP. - Nuclear Safety and Radiation Handling Engineers: Personnel specialized in protection and emergency response. - Hydrogen engineers: Engineers who are responsible for the production, storage, transportation, and operation of CHP. - System integration engineers: Personnel who design and manage systems for integrated operation of VRE, CHP, and pipelines. *In addition, thermal energy engineers, power system engineers, chemical process engineers (including catalyst technology), personnel responsible for the safety of high-pressure gas and hydrogen, control system and security engineers, and maintenance and field engineers are also required to be trained.
Field Engineer (General Skills)	Construction installation, maintenance and operation, SCADA operation	Personnel who support the field based on technical qualifications and vocational training for construction, maintenance, and operation. - Small nuclear CHP construction technicians: Personnel with welding, piping, and electrical installation skills necessary for CHP construction. - Hydrogen facility construction technicians: Personnel with skills in hydrogen piping, electrolyzer installation, and CHP construction. - VRE construction technicians: Personnel who are responsible for the construction of renewable energy power plants (civil engineering and electrical grid connection). - Operation and maintenance technicians: Personnel responsible for periodic inspections and emergency response for power plants and hydrogen facilities. - SCADA/IoT technicians: Personnel who operate digital monitoring and remote control systems.

Source: Prepared by the survey team

(2) Short-, Medium -, and Long-term Roadmap for Human Resource Development

The figure below is a roadmap showing the timing for the development of diverse human resources to support energy transitions. The chart systematically organizes the development flow by category, such as government officials, researchers/university faculty, and on-site engineers (advanced human resources/general skills), and indicates when each human resource should be developed in a focused manner.



Source: Prepared by the survey team

Figure 7-3 Roadmap for Human Resource Development in the Energy Sector (2025-2050)

Chapter 8 Various Events

8.1 First Invitation to Japan

8.1.1 Objective

The first invitation to Japan was conducted in January 2025 with the following objectives

- Deepen understanding of policies and technologies that contribute to the realization of energy transition in the energy sector.
- To form a human network necessary for future bilateral cooperation in the field of energy transition.
- To share knowledge on Japanese technologies that can be applicable to Mongolia's needs and challenges in achieving energy transition and decarbonization.

8.1.2 Schedule

The detailed schedule is as follows

Table 8-1 Detailed Schedule of the First Invitation to Japan

Date	Time	Destination	Correspondent	Location
January 19 (Sunday)		Visiting Japan (UB→Narita)		
January 20 (Monday)	10:30- 11:30	Courtesy call JAIF International Cooperation Center for Nuclear Energy (Introduction of initiatives for human resource development and legal system improvement aimed at the smooth implementation of nuclear energy, followed by an exchange of views)	JICC	Nibancho, Tokyo
	14:30- 15:00	Courtesy call Embassy of Mongolia in Japan (Introduction of JICA's preliminary survey activities, followed by an exchange of views)	Embassy	Kamiyama-cho, Tokyo
	16:00- 17:00	Courtesy call Japan Atomic Energy Agency (JAEA) Tokyo Office (Introduction of JICA's technical cooperation activities, followed by an exchange of views)	JAEA	Uchisaiwai-cho, Tokyo
January 21 (Tuesday)	9:00- 11:00	Lecture Institute of Science Tokyo, Laboratory of Zero Carbon Energy, (Introduction of research outcomes of decentralized nuclear energy systems, followed by an exchange of views)	Institute of Science Tokyo	Ookayama, Tokyo
	13:00- 14:30	Lecture TEPCO Power Grid, Inc. (Introduction of measures to expand renewable energy, followed by an exchange of views)	TEPCO PG	Uchisaiwai-cho, Tokyo
	15:00- 16:00	Courtesy call International Division, Agency for Natural Resources and Energy (Introduction and exchange of views on Japan's energy policy, measures to realize decarbonization, and external policies in the resources and energy sectors including AZEC) Courtesy call Nuclear Energy Policy Division, Agency for Natural Resources and Energy	METI, Agency for Natural Resources and Energy	Kasumigaseki, Tokyo
January 22 (Wednesday)	- 14:30	Travel (Haneda→ Shin-Chitose)		Hokkaido
	14:30- 16:30	Courtesy call Hokkaido Government (Introduction of field experiments on coal underground gasification, and so on)	Hokkaido	Sapporo City, Hokkaido
January 23 (Thursday)	9:30- 11:30	Lecture and site visit Hokkaido Heat Supply Corporation, Central Energy Center (Introduction to initiatives on energy efficiency and environmental measures, followed by a site visit)	Hokkaido Heat Supply Corporation	Sapporo City, Hokkaido
	13:30- 15:00	Lecture Muroran Institute of Technology (Introduction of field experiments on coal underground gasification, and so on)	Muroran Institute of Technology	Sapporo City, Hokkaido
January 24 (Friday)	9:00- 11:00	Lecture and site visit Hokkaido Electric Power Network, Inc., Central Load Dispatching Center,(Introduction to initiatives for accelerating	Hokkaido Electric Power Network, Inc.	Sapporo City, Hokkaido

		renewable energy deployment, pilot projects on large-scale storage systems, and regulatory framework development, followed by an exchange of views)		
	13:30- 15:30	Site visit Japan CCS Co., Ltd. (JCCS), Tomakomai CCS Demonstration Center (Presentation on large-scale CCS demonstration projects, followed by a site visit)	JCCS	Tomakomai City
January 25 (Saturday)		Tour of Sapporo City		Sapporo City
January 26 (Sunday)		Travel (Shin-Chitose→ Haneda)		Tokyo
January 27 (Monday)	9:30- 11:30	Lecture JICA Survey Team (Explanation and discussion on the draft of the ET Roadmap and Action Plan for Mongolia)	JICA Survey Team	Kanda Nishiki-cho, Tokyo
	14:00- 15:30	Site visit Shiroyama Hydroelectric Power Plant (Presentation on the operation of Japan's first large-scale pure pumped storage power plant, followed by a site visit)	Kanagawa Prefecture Public Enterprise Agency	Sagamihara City, Kanagawa Prefecture
January 28 (Tuesday)	10:00- 11:20	Lecture Tokyo Hydrogen Museum (Tokyo Suiso-miru) (Tokyo's initiatives in hydrogen-related projects)	Tokyo Metropolitan Government	Shiomi, Tokyo
	14:00- 16:00	Wrap-up by JICA (exchange of views)	JICA	Nibancho, Tokyo
January 29 (Wednesday)		Return from Japan (Narita→UB)		

Source: Prepared by the survey team

8.1.3 Participants

The participants of the first invitation to Japan are as follows.

Table 8-2 List of the 1st Japanese Invitation Participants

	Name	Affiliation / Position
1	D.Dashnyam	Advisor to the Prime Minister (in charge of industrial policy)
2	O. Khuyagtsogt	Director General, the Finance and Investment Department, Ministry of Energy
3	G. Erkhembayar	Director General, the Contracts and Legal Affairs Department, Ministry of Energy
4	Yo. Enkhtuya	Senior Analyst, the Policy and Planning Department, Ministry of Energy
5	E. Tuvshinchuluun	Chairperson, the Energy Regulatory Commission (ERC)
6	G. Baljinnyam	CEO, National Dispatching Center
7	Ch. Elbegsaikhan	President, Baganuur Industry and Technology Park
8	M.Baldorj	Staff member, the Policy and Planning Department (in charge of logistics)
9	M.Manlaijav	Secretary General, Nuclear Energy Commission

Note: Mr. A. Amarbayar (Professor, National University of Mongolia) acted as interpreter throughout the entire meeting.

Mr. E. Tuvshinchuluun (Chairperson, ERC) had to shorten his stay in Mongolia by one day due to urgent matters in Mongolia.

Source: Prepared by the survey team

8.2 Simple-E Training

8.2.1 Objective

In order to improve the accuracy of the Roadmap, this training was conducted in cooperation with the Ministry of Energy (MOE), provided relevant organizations with an opportunity to learn basic analytical theory, energy demand forecasting methods, and software operation techniques using the analytical software "Simple-E" used to calculate the Energy Transition Roadmap. As for the best material for tracking the Mongolia's energy situation, the numerical information from the Roadmap was installed in the Simple-E and manipulated by participants in the training.

Due to limitations in access to Mongolia's currently disclosed energy-related statistical data, there were concerns that the accuracy of the model analysis developed for this project was insufficient. Therefore, the training focused on sharing the know-how of the demand forecasting model with relevant Mongolian organizations, thereby attracting their interest and encouraging the collection of more detailed information. As a result, the direct participation of UB Distribution Company, NDC, and others in this training led to the sharing of new statistical data, resulting in significant synergistic effects in terms of improving the project's analytical results and capacity development in Mongolia.

8.2.2 Schedule

The detailed schedule is as follows

Date: June 19 - 20, 2025 (2 days)

Location: Ministry of Energy (MOE), Seminar Room

Table 8-3 Detailed dates of the "Simple-E" workshop

Date	Time	Activity	Speaker/Respondent	Time
2025 June 19 (Thursday)	9:30-10:00	Registration		30 min.
	10:00-10:05	Opening Remarks	Mr. Akifumi Nishihata JICA Survey Team	5 min.
	10:05-10:10	Opening Remarks	Ministry of Energy (MOE)	5 min.
	10:10-10:20	Introduction of the survey	Mr. Akifumi Nishihata JICA Survey Team	10 min.
	10:20-12:00	Overview of Energy Demand Forecasting Methodology	Chew Chong Siang JICA Survey Team	100 min.
	12:00-13:30	Lunch break		90 min.
	13:30-16:30	Simulation with energy demand forecasting model (1/3)	Chew Chong Siang JICA Survey Team	180 min.
2025 June 20 (Friday)	9:30-10:00	Registration		30 min.
	10:00-12:00	Simulation with energy demand forecasting model (2/3)	Chew Chong Siang JICA Survey Team	120min.
	12:00-13:30	Lunch break		90 min.
	13:30-16:30	Simulation with energy demand forecasting model (3/3)	Chew Chong Siang JICA Survey Team	180 min.
	16:30-16:40	Closing Remarks	Mr. Puntsagbaljir Ministry of Energy (MOE)	10 min.

Note: Simultaneous interpretation by Mr. Amarbayar and Mr. Munkhbayar, Supporter: Mr. Kobayashi, Mr. Nishihata, Ms. Hasegawa

Source: Prepared by the survey team

8.2.3 Participants

The participants were as follows

Thursday, June 19, 2025: 24 participants

Friday, June 20, 2025: 22 participants

Table 8-4 List of participants in the "Simple-E" workshop

Participants	Organization	19-Jun	20-Jun
1 Munkhchuluun.B	Ministry of Energy (MoE)	☐	
2 Puntsagbaljir.B		☐	☐
3 Altanzul.N		☐	
4 Namkhaitseren.M	Energy Regulatory Commission (ERC)	☐	☐
5 Zolbayar.B	"National Power Transmission Grid" SOJC	☐	
6 Batbold.B		☐	☐
7 Enkhmandakh.N	"Ulaanbaatar Electricity Distribution Network" SOJC	☐	
8 Battuvshin.G			☐
9 Dambiiikhorol.D		☐	☐
10 Battsetseg.U		☐	☐
11 Enkhtsetseg.S		☐	☐
12 Nyambayar.D	Mongolian Energy Economics Institute (MEEI)	☐	
13 Chinsetgel.B		☐	☐
14 Myagmarbaatar.D	National Dispatching Center (NDC)	☐	☐
15 Erdenechimeg.A		☐	☐
16 Oyun-Erdene.T		☐	☐
17 Oyundari.S		☐	☐
18 Bat-Orgil.O	Mongolian University of Science and Technology (MUST)	☐	☐
19 Tsolmon.M			☐
20 Tsolmon.Kh		☐	☐
21 Davaatseren.D		☐	
22 Oyun-Erdene.M		☐	☐
23 Munkhtuya.E	National University of Mongolia (NUM)	☐	
24 Amarbayar.A		☐	
25 Purevdalai.E			☐
26 Erdene-Ochir.E	"Ulaanbaatar District Heating Network" SOJC	☐	☐
27 Baljinnyam.B		☐	☐
28 Bat-Erdene.B			☐
29 Amangelid.Kh	Nuclear Energy Commission		☐
30 Bayamjargal			☐
	Total	24	22

Source: Prepared by the survey team

8.3 Business Tour

8.3.1 Purpose

Focusing on technologies recommended in the roadmap, the aim is to achieve the following through the introduction of new Japanese technologies:

- 1) Identification of business opportunities by Japanese companies
- 2) Business matching for the deployment of Japanese companies' technologies and services in Mongolia

8.3.2 Schedule

The schedule, excluding travel days from October 12 to 17, 2025, effectively lasted four days. Key Mongolian institutions crucial for deploying participants' Japanese technologies in Mongolia were determined based on participants' self-nominations or recommendations from the survey team. Each company then conducted visits. Specific examples included visits to UB City Hall and the Ministry of Environment.

8.3.3 Participants

Participants were selected from private companies that possess Japanese technologies that have a relatively large impact on the Energy Transition Roadmap being formulated through this project. The companies and related parties were selected based on public applications and recommendations via industry associations, etc. As a result, a total of four people participated, one from each of the four private companies.

8.4 Workshop

8.4.1 Purpose

The purpose is to deliver and exchange views on the form of support from Japan to Mongolia. presentations on the following themes and, based on their content,

- 1) Findings from this project: Energy Transition Roadmap and Action Plan (JICA survey team)
- 2) Specific themes related to the survey results (Japanese stakeholders) (※ Specific themes :
1) Nuclear power human resource development, 2) Advanced coal utilization addressed,
3) Energy conservation policy)

8.4.2 Schedule

The detailed schedule is as follows.

Table 8-5 Detailed Schedule (Nuclear Human Resource Development)

Date	Time	Visit Location
10/19 (Sun)		Entry (Japan → UB)
10/20 (Mon)	8:30 - 9:30	JICA Briefing
	12:00 - 13:00	Courtesy Call: Embassy
10/21 (Tue)	9:00 - 13:00	Keynote Address
	14:30 - 17:00	Nuclear Energy Agency (NEA)

10/22 (Wed)	9:00 - 13:00	National University of Mongolia (NUM)
	15:00 - 16:00	MJEED Secretariat, JICA Mongolia Office
10/23 (Thu)	9:00 - 13:00	Mongolian University of Science and Technology (MUST)
	15:00 - 16:00	Wrap-up
10/24 (Fri)		Return to Japan (UB→Japan)

Source: Prepared by the survey team

Table 8-6 Detailed Schedule (Advanced Coal Utilization)

Date	Time	Visit Location
10/19 (Sun)		Arrival (Japan → UB)
10/20 (Mon)	8:30 - 9:30	JICA Briefing
	12:00 - 13:00	Courtesy Call: Embassy
10/21 (Tue)	9:00 - 13:00	Keynote Address
	14:30 - 16:00	Mongolian University of Science and Technology (MUST)
	16:00 - 16:30	New Orient Mongolia Co., Ltd
10/22 (Wed)	9:30 - 14:00	Buuruljuult
	16:00 - 17:30	National University of Mongolia (NUM)
10/23 (Thu)	10:00 - 12:00	Erdenes ITP LLC
	14:00 - 16:30	MAK HQ
	17:00 - 18:00	Wrap-up
10/24 (Fri)		Return to Japan (UB→Japan)

Source: Prepared by the survey team

Table 8-7 Detailed Schedule (Energy Conservation Policy)

Date	Time	Visit Location
10/19 (Sun)		Arrival (Japan → UB)
10/20 (Mon)	8:30 - 9:30	JICA Briefing
	12:00 - 13:00	Courtesy Visit: Embassy
10/21 (Tue)	9:00 - 13:00	Keynote Address
	14:30 - 16:30	Energy Regulatory Commission (ERC)
10/22 (Wed)	9:00 - 12:00	National University of Mongolia (NUM)
	14:00 - 16:30	Ministry of Energy
10/23 (Thu)	9:00 - 12:00	Mongolian University of Science and Technology (MUST)
	13:30 - 15:30	Ministry of Urban Planning, Construction, and Housing
	16:00 - 17:00	Wrap-up
10/24 (Fri)		Return to Japan (UB→Japan)

Source: Prepared by the survey team

8.4.3 Participants

Participants are as follows.

Table 8-8 Workshop participants list

	Organization	Affiliation/Position	Name
1	National University Corporation Tokyo University of Science	Institute for Zero Carbon Energy Research, Comprehensive Research Institute Professor	Toru Ohara

2	National University Corporation Tokyo University of Science	Institute for Zero Carbon Energy Research, Institute of Advanced Research Professor	Hiroshi Sagara
3	National University Corporation Muroran Institute of Technology	Graduate School of Engineering Endowed Chair "Unused Resource Energy Engineering" Specially Appointed Professor	Kenichi Itakura
4	Dai Nippon Diamond Consultants Co., Ltd.	New Business Division, Environment and Energy Department Director	Takaaki Mukago
5	General Incorporated Foundation Energy Conservation Center	International Cooperation Headquarters, International Business Cooperation Center International Technical Expert	Katsuhiko Yamamoto

Source: Prepared by the survey team

8.5 Seminar

8.5.1 Purpose

The seminar was primarily aimed at presenting the Energy Transition Roadmap and Action Plan, which were developed after multiple consultations and reflections on the Mongolian side. To reinforce the above and foster a comprehensive understanding on the Mongolian side, lectures were also given on the construction of an energy supply and demand model based on energy statistical data and macroeconomic scenarios, which are issues identified in the study that are closely related to the formulation of the roadmap, as well as the ideal energy statistics for such a model. Furthermore, a lecture was given on the vision for the power system, as one of the roadmap's recommendations calls for the development of a planned power transmission system to develop large-scale renewable energy sources in the Gobi region and use them in urban areas.

8.5.2 Schedule

The detailed schedule is as follows:

Date: December 17, 2025

Venue: Ministry of Energy (MOE), Seminar Room

Table 8-9 Detailed schedule of the seminar

Time	Agenda	Speaker	Duration
9:30-10:00	Registration		30 min
10:00-10:10	Opening Remarks	Mr. Kousuke Shida Japan International Cooperation Agency (JICA)	10 min
10:10-10:50	Outcome of the Survey: Roadmap and Action Plan for the Energy Transition	Mr. Akifumi Nishihata JICA Survey Team	40 min
10:50-11:30	Energy Supply and Demand Forecast and Energy Statistics for Mongolia	Dr. Chew Chong Siang JICA Survey Team	40 min
11:30-11:40	Break		10 min
11:40-12:20	Power Transmission Planning for the Large-Scale Introduction of Renewable Energy	Mr. Hidekazu Takase JICA Survey Team	40 min
12:20-12:30	Feedback and Closing Remarks	Mr. G.Enkhtuvshin Ministry of Energy (MOE)	10 min

Source: Prepared by the survey team

8.5.3 Participants

The people who will share the materials and the participants on the day are as follows.

Table 8-10 List of seminar material sharing targets and participants

No	Name	Organization	Position
1	Enkhtuvshin	MOE	Head of division
2	Ariunbold		Senior expert
3	Tselmuun		Specialist
4	Tushigbat		Expert
5	Gerelt-Od		Senior specialist
6	Altansukh		Senior specialist
7	Oyundavaa		Specialist
8	Jargalmaa		Expert
9	Badarguun		Specialist
10	Namjiljav		Specialist
11	Enkhbaatar		PIU engineer
12	Nyamtssetseg		PIU advisor
13	Enkhtuya		Senior expert
14	Khishigdemberel		RE-Engineer
15	Onon	NDC	Engineer
16	Uurtsolmon		Engineer
17	Tuguldur		Economist
18	Enkhbayasgalan		Engineer
19	Munkh-Erdene		Engineer
20	Gantamir		Engineer
21	Enkhbayasgalan		Engineer
22	Enkhtuvshin	MEEI	Scientific secretary
23	Tsolmon	MUST	Senior lecturer
24	Tuvshinbayar		Senior lecturer
25	Bekhat		Teacher
26	Davaakhuu		Scientific secretary
27	Enkhsaikhan		Professor
28	Nyam		Senior lecturer
29	Turmandakh	NUM	Professor
30	Tuvshin	URECA LLC	Project director
31	Erdenebayar	MMS	Business development
32	Bekhat	MUST*	Professor
33	Nominbileg	ERC	
34	Ganbold	ADB	Expert

Source: Prepared by the survey team

8.6 2nd Invitation to Japan

8.6.1 Purpose

The second invitation to Japan was conducted in January 2026 with the following objectives

- The proposed roadmap and action plan for Mongolia's energy transition are discussed by the participants based on the findings of this study.
- Participants' understanding of Japan's policy initiatives for future decarbonization in the energy and environmental sectors, as well as of the advanced technologies and expertise within the private sector that are anticipated to be applied in Mongolia in the coming years, is enhanced.
- The development of relationships between relevant parties on both the Mongolian and Japanese sides, aimed at exploring possibilities for future cooperation, is being actively promoted.

8.6.2 Schedule

The detailed schedule is as follows:

Table 8-11 Detailed schedule for the 2nd Japan Invitation

Date	Time	Destination	Correspondent	Location
January 25 (Sunday)		Visiting Japan (UB→Narita)		
January 26 (Monday)	10:00~12:00	Lecture Energy Transition Roadmap	JICA Study Team	Tokyo Jimbocho
	14:00~16:00	Lecture Institute of Energy Economics, Japan (Introduction to Japan's nuclear policy, exchange of opinions)	IEEJ	Tokyo Nibancho
January 27 (Tuesday)	10:00~12:00	Tour TEPCO Power Grid, Inc. Central Load Dispatch Center (Introduction to measures to expand the introduction of renewable energy in Japan's power transmission and grid adjustment, and exchange of opinions)	TEPCO PG	Tokyo Uchisaiwaicho
	14:00~16:00	Lecture Energy Conservation Center (Introduction to Japan's energy conservation policies and efforts to achieve energy conservation, and exchange of opinions)	ECCJ	Tokyo Shibaura
January 28 (Wed)	13:30~15:30	Lectures and site visits Takasago Thermal Innovation Center (Introduction and tour of sustainable building (ZEB) examples, green hydrogen production and use examples, etc.)	Takasago Thermal Engineering Co., Ltd.	Ibaraki Prefecture Tsukuba
January 29 (Thursday)	10:00~12:30	Lecture Institute of Energy Economics, Japan (Energy statistical data collection, energy balance table creation method)	IEEJ	Tokyo Kachidoki
	14:00~16:00	Lecture and site visits Japan Electric Power Exchange (Introduction to Japan's electricity deregulation and electricity market, etc., exchange of opinions)	JEPX	Tokyo Shibaura
January 30 (Friday)	10:00~11:00	Courtesy call Agency for Natural Resources and Energy (Energy Basic Policy) plans, etc.)	METI Resources and Energy Agency	Tokyo Kasumigaseki
	14:00~16:00	Opinion Exchange JICA Wrap-up	JICA	Tokyo Nibancho
January 31 (Saturday)		Return from Japan (Narita→UB)		

Source: Prepared by the survey team

8.6.3 Participants

The participants of the second invitational program to Japan are as follows:

Table 8-12 List of participants in the second Japan Invitation Program

	Name	Affiliation / Position
1	M. ENKHTSETSEG	The Grand National Assembly of Mongolia Members of the Grand Duma
2	K. ERDENECHULUUN	Member of Parliament Enkhtsetseg Energy Advisor
3	D. OYUNDARI	Member of Parliament Enkhtsetseg Energy Advisor
4	B. ENKHJARGAL	Deputy Prime Minister's Office Senior Expert
5	P. TOVUUDORJ	Ministry of Energy Director-General of the Policy and Planning Bureau
6	Y. ENKHTUYA	Ministry of Energy Senior Expert, Policy Planning Bureau
7	G. TULGA	Ministry of Energy Senior Staff, Policy Planning Bureau
8	L. MUNKHJARGAL	Ministry of Energy Director of Policy Planning and External Relations Division
9	L. ZAYA	Energy Regulatory Commission Senior staff member of the Energy Conservation Division
10	N. BATBAYAR	Energy Regulatory Commission License Bureau Officer
11	S. TSENCBAYAR	National Dispatch Center Monitoring Engineer, Technology and Monitoring Division
12	E. TUGULDUR	National Dispatch Center Trade Economist
13	G. MANLAIJAV	Nuclear Energy Commission Secretary General
14	A. TURSUKH	Nuclear Research Center of National University of Mongolia Researcher, Nuclear Physics Research Center, National University of Mongolia

Note: Adiyabat Amarbayar (Professor at the National University of Mongolia) acted as interpreter throughout the entire meeting.

Source: Prepared by the survey team

Chapter 9 Recommendations

9.1 Recommendations for Mongolia

As President U. Khurelsukh stated at COP27 in 2022, "by 2050, we are setting the goal of zeroing the gap between greenhouse gas emissions and absorption, Mongolia's achievement of net-zero emissions by 2050 is drawing global attention.

In particular, energy transition is considered one of the most critical challenges for Mongolia, where CO₂ emissions per GDP based on purchasing power parity are the second highest in the world (after Turkmenistan), and the energy mix remains heavily dependent on fossil fuels. These issues stem from Mongolia's unique challenges including the fact that approximately 90% of the electricity generated is generated from coal-fired power plants, and heating demand—driven by the country's cold climate—accounts for around 60% of total final energy consumption. These factors are intricately connected to a complex mix of social, economic, and environmental aspects.

This study was conducted with the aim of collecting and analysing information on the sectors targeted for energy transition in Mongolia, considering the country's goal of achieving carbon neutrality in 2050. Based on Mongolia's energy conditions, the study also aimed to examine and propose a future cooperation policy that achieves the best balance between affordable energy supply and low carbon emissions.

This roadmap presented in Chapter 6 is based on the use of technologies that are practical and feasible, such as insulation and energy efficiency improvements to reduce future increases in energy demand. At the same time, it highlights the potential of future decarbonization technologies for electricity and heat supply, including nuclear power and hydrogen. The roadmap also explores the potential use of domestic resources such as coal bed methane (CBM), oil, and biomass as alternative fuels to coal. In addition, it places emphasis on the development of human resources to advance the energy transition.

As presented in this Energy Transition Roadmap, achieving energy transition will not be easy without the concerted efforts of industry, government, and academia. This includes cooperation among ministries and agencies in the areas of energy demand, supply, and resources, as well as human resource development and financing. Furthermore, it is essential that the roadmap be continuously revised and improved to accurately reflect the ever-changing technologies and global circumstances. Therefore, it should be emphasized that establishing a cross-sectoral framework is urgently needed. Hopefully, the contents of this Energy Transition Roadmap will contribute to the establishment of a smooth system in Mongolia, and that the contents of the Action Plan will serve as a catalyst for Mongolia to take its first step toward achieving carbon neutrality.

