Democratic Socialist Republic of Sri Lanka

The Project for Capacity Development of the Power Sector Master Plan Implementation Program

Capacity Assessment Report

October 2020

Japan International Cooperation Agency (JICA)

Chubu Electric Power Co., Inc.

Nippon Koei Co., Ltd.

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ABREVIATIONS

Word	Original
ADB	Asian Development Bank
AGC	Automatic Generation Control
ASEAN	Association of South East Asian Nations
CA	Capacity Assessment
CD	Capacity Development
CEB	Ceylon Electricity Board
CF	Corporate Finance
C/P	Counterpart
CPC	Ceylon Petroleum Corporation
CPI	Consumer Price Index
CPIs	Carbon Pricing Instruments
CS	Corporate Strategy
CSC	Consumer Service Center
DD	Distribution Division
DG	Diesel Generator
EE	Electrical Engineer
FIT	Feed in Tariff
FRT	Fault Ride Through
GHG	Greenhouse Gas
GM	General Manager
GMS	Greater Mekong Sub-region
GOSL	Government of Sri Lanka
GSS	Grid Substation
IFC	International Finance Corporation
IPP	Independent Power Producer
JEPIC	Japan Electric Power Information Center
JICA	Japan International Cooperation Agency
KPI	Key Performance Indicators
LECO	Lanka Electricity Company
LOLP	Loss of Load Probability
LTGEP	Long Term Generation Expansion Plan
LTTDP	Long Term Transmission Development Plan
MOPE	Ministry of Power and Energy
MP	Master Plan
NAMA	Nationally Appropriate Mitigation Action
NCRE	Non-Conventional Renewable Energy
NDC	Nationally Determined Contribution
NSCC	National System Control Center
OH	Overhead
OJT	On the Job Training
ORE	Other Renewable Energy
PAA	Project Approving Agency
PAC	Project Approving Committee
PDM	Project Design Matrix
PIR	Price Increase Rate
PMR	The Partnership for Market Readiness
PPP	Private Power Producer
PSPP	Pumped Storage Power Plant
PUCSL	Public Utility Commission of Sri Lanka
RE	Renewable Energy
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAS	Substation Automation System
SCADA	Supervisory Control and Data Acquisition System

SCC	System Control Center
SEA	Sustainable Energy Authority
SPA	Seller Participation Agreement
SPP	Solar Power Plant
SVC	Static Var Compensator
TF	Transformer
TGPB	Transmission and Generation Planning Branch
TOU	Time-of-Use
UG	Underground
VRE	Variable Renewable Energy
WG	Working Group
WPP	Wind Power Plant

Chapter 1 Introduction

1.1 Background

1.1.1 Background of the Project

The Power Sector Master Plan in Sri Lanka (MP) was formulated in FY 2017 by assistance of Japan International Cooperation Agency (JICA). In the Master Plan, three (3) scenarios were examined as i) Scenario mainly focused on Economic Efficiency, ii) Scenario mainly focused on reduction of Environmental Burden and iii) Scenario focused on balance between Energy Safety, Economical Efficiency and Environmental Burden. Ministry of Power and Energy (MOPE) and Ceylon Electricity Board (CEB) have selected iii) Scenario focused on balance between Energy Safety, Economical Efficiency and Environmental Burden among three (3) scenarios as first priority. Since Sri Lanka has abundant potential of Renewable Energy (RE), coordination between investment plan in power sector and flexibility of power system operation is essential for smooth integration of expected large amount of installation of Renewable Energy (RE). In the coordination, it will be taken both power supply reliability and cost into consideration. The Master Plan suggested that improvement and sophistication of operation in power distribution sector should be high priority for achievement the scenario.

Purposes of "the Project for Capacity Development of the Power Sector Master Plan Implementation Program" (the Project) are to examine appropriate treatment of introduction of Variable Renewable Energy (VRE), to examine countermeasures for improvement of power supply reliability and reinforcement of transmission/distribution line, to assist reviewing power system Grid Code and improvement of prediction/management skill on growing VRE output and to strengthen capacity of organization for management finance condition of CEB, in order to realize appropriate structure each type of power facilities with high promotion of VRE.

1.1.2 Outline of the Project

In the Project, three (3) themes are set as below;

i) Strengthening capacity of corporate strategy and system planning related to Variable Renewable Energy
ii) Building capacity of power system operation and power system development for transmission network in response to increased share of VRE
iii) Building capacity of operation in power distribution

Three (3) Working Groups (WGs) are established for each theme and work together to solve the theme. Member of the WGs are consisted of Engineers of Counterpart (C/P) and member of JICA Expert Team.

(1) Overall Goal

Stability and reliability of transmission and distribution networks are maintained/improved even with increased share of VRE (Variable Renewable Energy)

(2) Project Purpose

Institutional Capacity for improving transmission and distribution operational reliability is enhanced to get prepared for increased share of VRE planned in LTGEP (Long Term Generation Expansion Plan)

(3) Output

1: Capacity of corporate strategy and planning for VRE is enhanced
2: Capacity of system development and operation for transmission network in response to increased share of VRE is enhanced
3: Capacity of distribution network operation is improved

(4) Activity

＜Activities of Working Group 1＞

1-1 Corporate Strategy and Planning for VRE

1-1-1 To assess the impact of the introduction of VRE on CEB corporate finance taking into consideration of the future business scenarios

1-1-2 To advice on the planning and procurement for VRE purchases

1-1-3 To advice on the planning and procurement for VRE purchases

＜Activities of Working Group 2＞

2-1 RE Technical Evaluation

2-1-1 To review VRE projects (existing and future plan) and Grid Codes for VRE

2-1-2 To analyze issues and impact of transmission system considering increased share of VRE (e.g. update of system enhancement)

2-1-3 To conduct trainings on advances system analysis

2-2 Countermeasures for Increased Share of VRE

2-2-1 To conduct trainings on how to handle the increased share of VRE (e.g. system analysis, frequency adjustment, suppress output when surplus power occurs, etc.)

2-2-2 To consider measures for adjusting power fluctuations (e.g. PSPP, Batteries, EV, Hydrogen, etc.)

2-2-3 To Identify the requirement of Renewable Desk at System Control Center (SCC)

2-2-4 To conduct study to confirm the response ability for load fluctuation and forecast power generation in preparation for the future increased

2-2-5 Conduct the on-site trainings for planning PSPP

＜Activities of Working Group 3＞

3-1 Outage Reduction

3-1-1 To analyze the current situation and causes of outage at each Distribution Division of CEB and LECO

3-1-2 To conduct trainings on how to improve reliability for each Distribution Division

3-1-3 To conduct study at pilot site to reduce duration of outage (to improve recovery time) by installing faulty point detecting facilities

3-1-4 To evaluate cost effectiveness of pilot project of Activity 3-1-3

3-2 Load Fluctuation Suppression

3-2-1 To analyze fluctuation (output, voltage) on distribution system caused by VRE by installing measuring instrument

3-2-2 To conduct study at a pilot site to confirm the response ability for load fluctuation by installing batteries at distribution substation or distribution line

(5) JICA Expert

Fourteen (14) Japanese experts are dispatching to Sri Lanka

- Team Leader/ Electric Power Strategy
- Deputy Team Leader/ Electric Power Strategy
- System and Policy of Electric Power
- Renewable Energy
- Finance
- Supply and Demand Management
- Power System (Planning/ Operation)
- Power System (System Analysis)
- Meteorological Forecast/ Demand Forecast
- Energy Management (Battery)
- Distribution Technology
- Distribution (Planning/ Design/ Construction)/ Coordinator
- Hydraulic Civil Engineering (Planning/ Design/ Construction)
- Geology

1.2 Capacity Assessment

1.2.1 Capacity Development

Purpose of the Project is enhancement of capacity of organization in CEB. Capacity Development (CD) in the Project includes technical seminars on related themes, On the Job Training (OJT) at actual sites of power system operation and distribution line, training of self-solution by Counterparts (C/Ps) about facing their problems, Seminar in Japan and so on. JICA Expert Team will technically support these activities in CD to make effective and efficient implementation and to enhance capacity and knowledge of engineers in power system and power distribution sector under increasing VRE.

Expected results of the Project is that C/Ps acquire their abilities to achieve the targets and establish appropriate system for their achievement.

At the end of the Project, C/Ps and JICA Expert Team will evaluate degrees of achievement about CD on each target of the Project and will discuss measures for future development of C/Ps with refer to results of the Project. CD report will be prepared with results of the CD at the end of the Project.

1.2.2 Project Design Matrix

Project Design Matrix (PDM) is prepared to clarify the targets of the Project. PDM shows achievable goal, purposes and outputs clearly.

In order to fix the target values in the Project, status at the beginning of the Project should be grasped as baseline.

On the other hand, C/P and JICA Expert Team will conduct project monitoring periodically. In the monitoring, progress from the baseline status for each content in PDM will be checked and C/P and JICA Expert Team discuss appropriate measures for certain achievement to the targets. Target should be set as quantitative values as much as possible for precise monitoring. PDM is shown in Appendix 1.

1.2.3 Capacity Assessment

Capacity Assessment (CA) is conducted at the beginning of the Project for grasping baseline status and for setting up target values to achievement. CA is conducted from the view point of capacity in personal, organization and system. CA is taken both target values and methods of measuring achievement status to the targets into consideration. Financial status in CEB, analysis on electricity tariff and methods for measuring soundness of financial status are considered for assessment of organizations.

1.3 Implementation of Capacity Assessment

1.3.1 Project Implementation under COVID-19 Pandemic Situation

Initially, the Project planned launching from March 2020, however, COVID-19 worldwide pandemic situation push the start of the Project back to May 2020. Since COVID-19 situation disturbed visiting Sri Lanka from Japan, JICA Expert Team tried conducting project activities from Japan remotely. CA also conducted from Japan remotely via video conference and e-mail system. CA conducted from May 2020 to July 2020.

1.3.2 Implementation Method of Capacity Assessment

CA was implemented through questionnaire and interview via video conference.

JICA Expert Team sent Assessment Sheets (questionnaires on CA) in May 2020 and C/P (CEB) replied the answer to Assessment Sheets in June 2020. Supplementary hearing on the assessment was conducted via video conference system.

It should be noted that some of confirmation on present status and setting up the targets will be done after visiting Sri Lanka, because no survey at actual site can conduct during remote work.

Assessment items and procedures is shown in Figure 1.1.

◆ **Organizations to be assessed**

CEB　Related organization　MOPE　SEA　LECO　PUCSL

◆ **Method of Assessment**

Questionnaire, Assessment Sheet and interview　（Remote work from Japan）

◆ **Outline of Assessment Items**

【General & WG1】

SAIFI	LOLP
SAIDI	Error of Power Prediction
CEB finance condition	Understanding on VRE Technical Matter
CEB Profit	Understanding VRE installation procedure
Corporate Strategy on VRE	

【WG2】

Grid Codes on Electric power System	Adjustment of Power Fluctuation
RE connection to Power System	Training Materials
Power System Analysis	Power Supply/Demand Operation
Handling increased RE	Building Power System Planning

【WG3】

Reliability and Quality in Distribution Line	Installation Battery to Distribution line
O & M in Distribution Line	Understanding of Power Outage Measures
Condition of Power Fluctuation	Understanding of Power Fluctuation

◆ **Capacity Assessment (CA) and Capacity Development (CD)**

CA (Baseline) → Activity & Monitoring Assistance by JICA Experts → Development of Capacity Achieve the Targets

Capacity Assessment
- System, Policy & Finance
- Power System Operation
- Distribution Line Operation

Activity
- Monitoring & Evaluation
- Capacity Development assisted by JICA Expert Team

Achievement to Targets
- Handling Master Plan
- Installation of VRE

(Source: JICA Expert Team)

Figure 1.1　Assessment Items and Procedures

Chapter 2 Basic Information of Sri Lanka

2.1 Basic Information

2.1.1 Population

Population of Sri Lanka is 21 million. (As of 2016)

2.1.2 GDP

Nominal GDP in Sri Lanka in FY 2018 is 88.9 billion USD and GDP per capita is 4,102 USD. Economic growth rate in FY 2018 is 3.2%.
Comparison with other neighbor countries on GDP is shown in Table 2.1.
After end of domestic conflict, Sri Lanka had recorded 9.1% in economic growth rate in FY 2012 as the highest value in their past experiences by high demands and lively economic activities. Sri Lanka is keeping constant economic growth as 4.5% in FY 2016, 3.4% in FY 2017 and 3.2% in FY 2018.

Table 2.1 Comparison with GDP in neighbor countries

Country	GDP per capita	Economic growth rate	Remarks
Sri Lanka	4,102 USD	3.2%	In FY2018
Indonesia	3,927 USD	5.2%	In FY2018
Thai	7,187 USD	4.1%	In FY2018
Philippine	3,104 USD	6.2%	In FY2018
India	2,015 USD	6.8%	In FY2018
Japan	39,304 USD	0.3%	In FY2018

(Source: Ministry of Foreign Affairs in Japan Web Site, IMF Statistical data)

2.1.3 CPI (Consumer Price Index)

Comparison with CPI or Price Increase Rate (PIR) between Sri Lanka and neighbor countries is shown in Table 2.2.

Table 2.2 Comparison with CPI between Sri Lanka and neighbor countries

Country	CPI or PIR (%)	Remarks
Sri Lanka	2.1	In FY2018 (FY2013 based)
Indonesia	3.1	In FY2018 PIR
Thai	1.9	In FY2018 (FY2015 based)
Philippine	5.2	In FY2018 PIR
India	4.6	In FY2019 PIR
Japan	2.0	In FY2019 (FY2015 based)

(Source: Ministry of Foreign Affairs, Ministry of Public Management in Japan Web Site)

2.2 Basic Information in Power Sector

2.2.1 Peak Demand

Peak demand in past five (5) years in Sri Lanka is shown in Table 2.3.

Table 2.3 Peak Demand in past five (5) years in Sri Lanka

Peak Demand (MW)				
2014	2015	2016	2017	2018
2,152	2,283	2,453	2,523	2,616

(Source: CEB Annual Report 2018)

2.2.2 Yearly Generation in Each Kind of Power Plant

Generated power in each kind of generation in 2019 is shown in Table 2.4.

Table 2.4 Generated Power in Each Kind of Generation

	Generated Power (GWh) (Result in 2019)					
	Thermal Power (Oil)	Thermal Power (Coal)	Hydro Power	Wind Power	Solar Power Biomass Power	Rooftop PV
CEB	2,137	5,361	3,783	0	—	—
PPP	2,875	—	1,011	348	220	141

PPP: Private Power Producer

(Source: CEB Web Site)

2.2.3 Transmission and Distribution Loss Ratio

Power loss ratio of transmission and distribution system in past five (5) years in Sri Lanka is shown in Table 2.5.

Table 2.5 Power Loss Ratio of Transmission and Distribution System

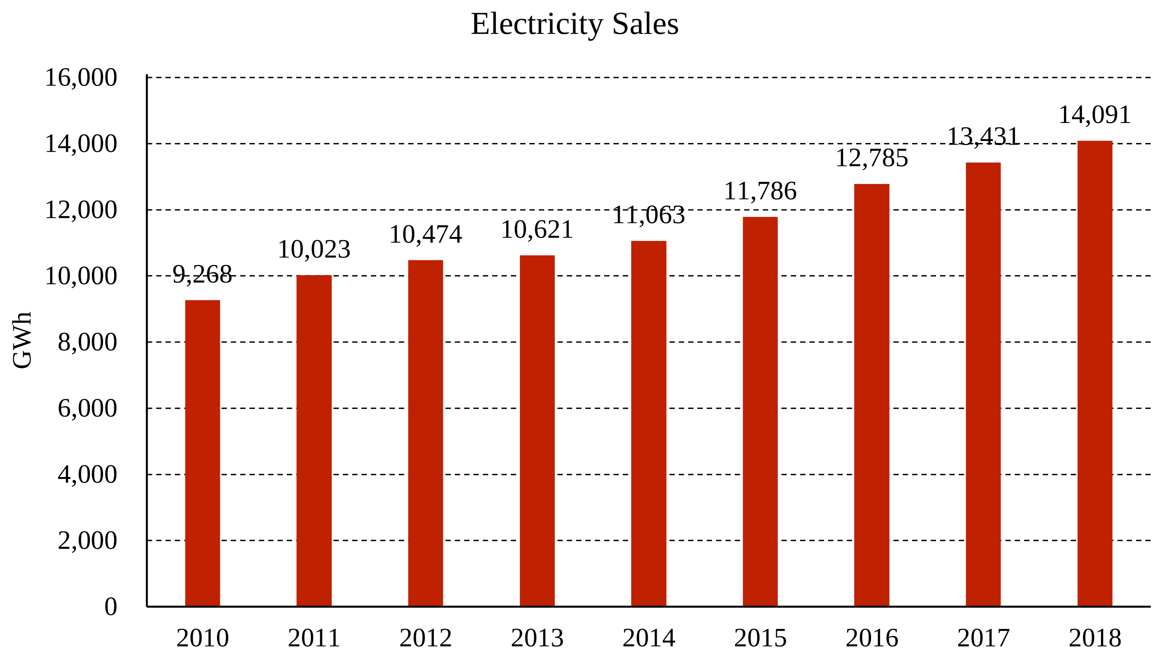
Power Loss Ratio (%)				
2014	2015	2016	2017	2018
10.91	10.40	10.28	8.45	8.34

(Source: CEB Annual Report 2018)

2.2.4 Electricity Sales

The total electricity sales (including Sales to LECO) during the year increased from 13,431GWh in the preceding year to 14,091GWh resulting in a rate of increase of 4.9%. Trends of the Electricity Sales is shown in Figure 2.1.

The average daily consumption of electricity in the year was 38.6GWh as against 36.8GWh in the previous year.

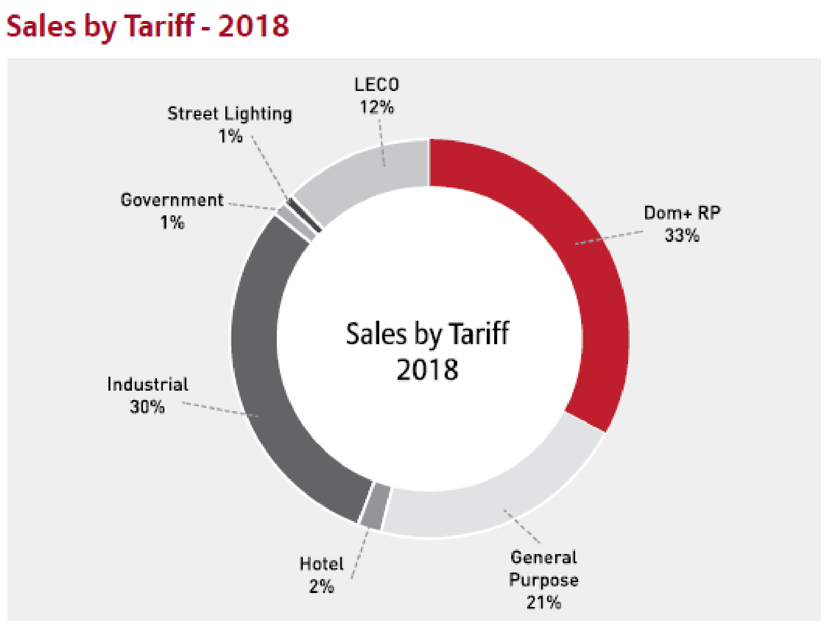


(Source: CEB Annual Report 2018)

Figure 2.1 Trends of Electricity Sales

2.2.5 Sales by Tariff

The highest energy consumption was by the consumers in the category 'Domestic and Religious Purpose' accounting for about 32.9% of the total consumption. This was followed by the industrial sector which accounted for 30.4% of the total consumption. The electricity consumption by consumers in the general purpose category was however only 20.9% of the total consumption indicating an annual growth of 6%. Figure 2.2 shown the ratio of Sales by Tariff in 2018.



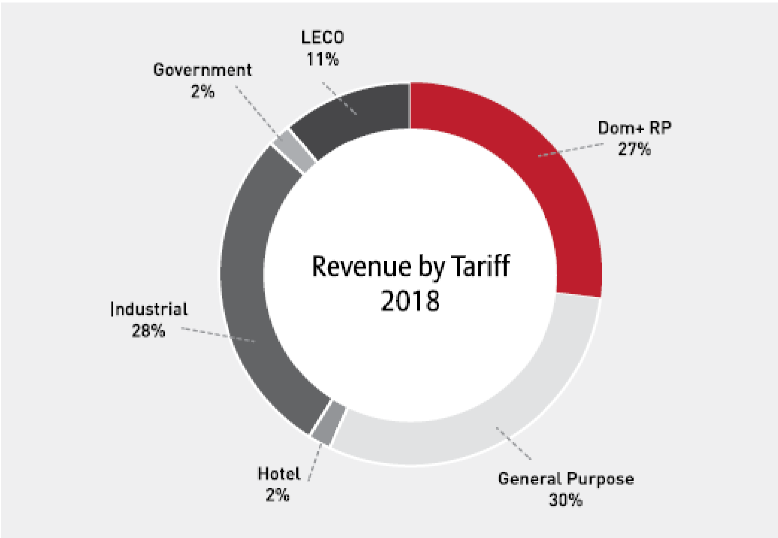
(Source: CEB Annual Report 2018)

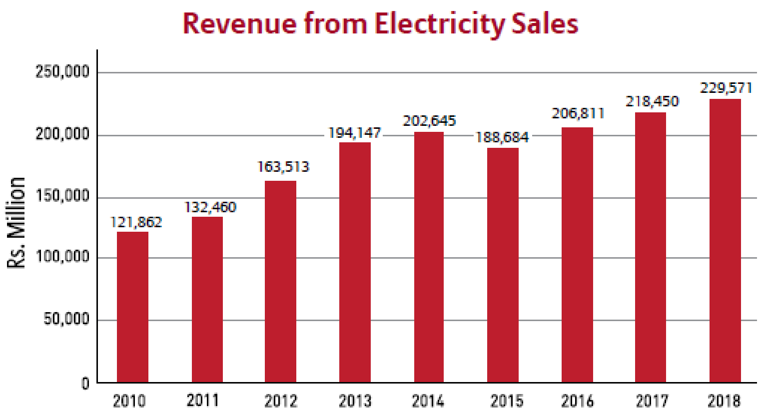
Figure 2.2 Sales by Tariff

2.2.6 Revenue

The total annual revenue from electricity sales which stood at Rs. 218,450 million (around 125 billion JPY) in 2017 increased to Rs. 229,571 million (around 131 billion JPY) during the year 2018 recording a growth of 5.1%. The highest revenue was from the General Purpose customers followed by Industrial Sector customers (27.5%). The contribution to the total revenue from the customers coming under the category 'Domestic and Religious Purpose' was 27.3%.

Figure 2.3 shows revenue from Electricity sales in CEB.





(Source: CEB Annual Report 2018)

Figure 2.3 Revenue from Electricity Sales

Chapter 3 Organization

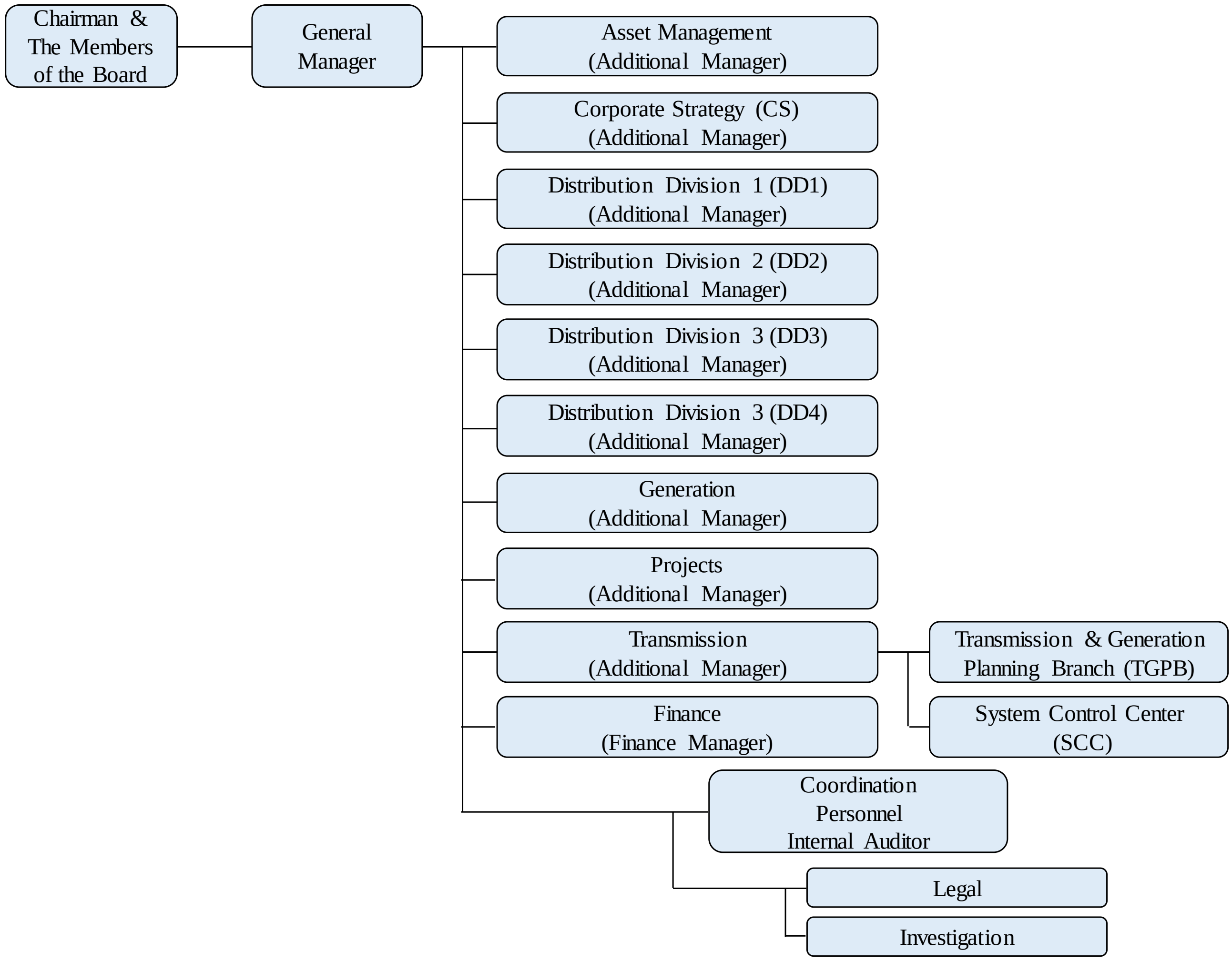
3.1 Implementation Organization in the Project

Counterpart of the Project is Ceylon Electricity Board (CEB). CEB is in charge of power generation, power transmission and power distribution and Energy (MOPE) is related organization in the Project.
Counterparts are Transmission and Generation Planning Branch (TGPB), System Control Center (SCC), Distribution Division (DD1, DD2, DD3 and DD4), Corporate Strategy (CS) and Corporate Finance (CF) in CEB, Lanka Electricity Company (LECO) and Sustainable Energy Authority (SEA).
The Public Utilities Commission of Sri Lanka (PUCSL), which is the economic, technical and safety regulator of the electricity industry in Sri Lanka and the designated regulator for petroleum and water services industries, will be invited as cooperation organization, because PUCSL has a role of approval on electricity tariff so that PUCSL is related to CEB corporate finance.

3.2 Organization of CEB

3.2.1 Outline of CEB Organization

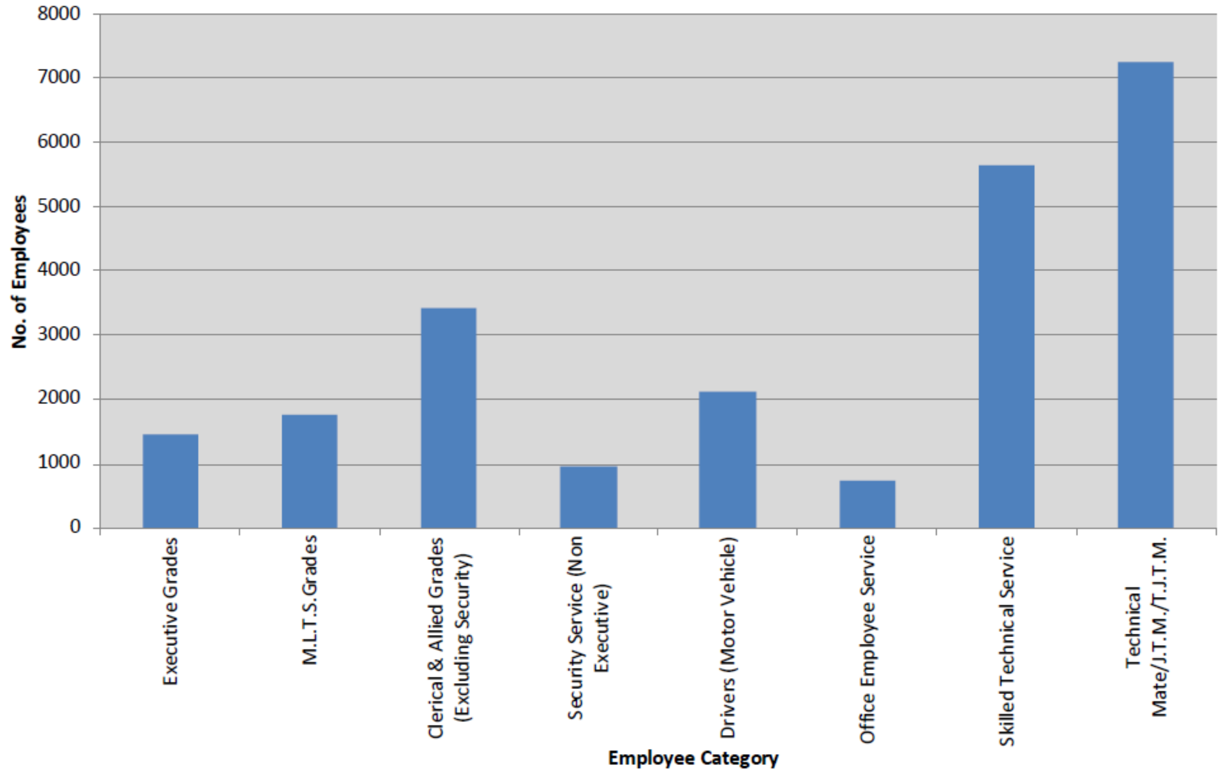
Outline of organization in CEB is shown in Figure 3.1.



(Source: CEB Annual Report 2018)

Figure 3.1 Outline of Organization in CEB

In response to the increasing demand for electricity, the consumer/employee ratio of CEB has improved over the years. This ratio in year 1990 was fifty three (53) while the figures for 2016 and 2017 have gone up to 311 and 304 respectively. By 31st of December, 2018, CEB had 23,380 number of employees and Figure 3.2 shows its distribution into different categories.



(Source: Corporate Plan 2019-2023)

Figure 3.2 Distribution of Employees by Service Category

3.2.2 Distribution Division and LECO

A major part of the electricity distribution in the country is handled by CEB amounting to 88% of the total sales volume while the rest is taken care by the Lanka Electricity Company Ltd. (LECO), a subsidiary of the CEB. The entire CEB distribution system is geographically separated for ease of administration and operations to four (4) Divisions namely; Distribution Division 1 (DD1), Distribution Division 2 (DD2), Distribution Division 3 (DD3) and Distribution Division 4 (DD4). Another main objective of forming four (4) Divisions is to achieve benchmark competition that can improve the efficiency and the quality of supply to the customers. The Provinces that comes under each Division are given in Table 3.1 and area map is shown in Figure 3.3 respectively.

A Province is sub-divided into several areas managed by Area Chief Engineers or Area Electrical Engineers depending on the number of consumers served by the Area. An area is further sub divided into several Consumer Service Centers (CSC) each headed by an Electrical Superintendent.

Table 3.1 Provinces Operated by each Distribution Division

Name of the Division	Province
Distribution Division 1 (DD1)	Colombo City, North Western, North Central and Northern Provinces
Distribution Division 2 (DD2)	Western Province North, Central and Eastern Provinces
Distribution Division 3 (DD3)	Western Province South II, Uva and Sabaragamuwa Provinces
Distribution Division 4 (DD4)	Western Province South I and Southern Provinces

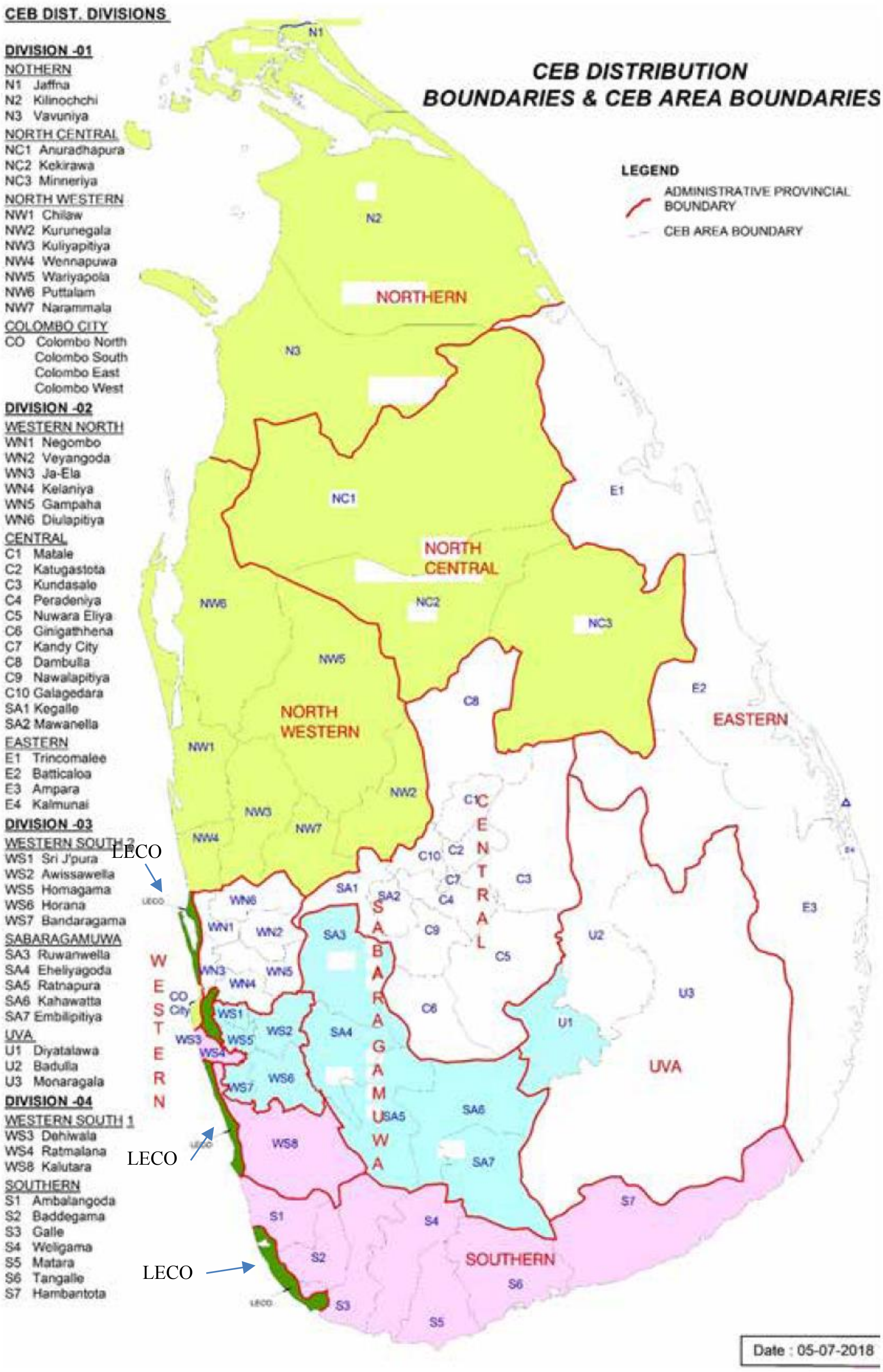
(Source: CEB Annual Report 2018)

Distribution assets of each Distribution Division are as shown in Table 3.2.

Table 3.2 Distribution Assets of Each Distribution Division

Type of asset	Distribution Division1	Distribution Division2	Distribution Division3	Distribution Division4
33kV Lines (km)	10,534	9,185	7,106	4,483
11kV Lines (km)	1,307	627	45	293
33/11kV Primary substations (Nos)	33	43	12	39
LV (400V) Lines (km)	45,465	40,105	31,615	25,623
LV Distribution Substations (Nos)	10,068	9,293	5,854	4,940

(Source: CEB Corporate Plan 2019-2023)



(Source: CEB Annual Report 2018)

Figure 3.3 Provinces Operated by each Distribution Division

Chapter 4 Power Sector Master Plan and Long Term Development Plan

4.1 Power Sector Master Plan

The Power Sector Master Plan in Sri Lanka (MP) (Target year: 2040) was formulated in FY 2017 by assistance of JICA. As above mentioned, three (3) scenarios were examined in MP, i) Scenario mainly focused on Economic Efficiency, ii) Scenario mainly focused on reduction of Environmental Burden and iii) Scenario focused on balance between Energy Safety, Economical Efficiency and Environmental Burden. MOPE and CEB have selected iii) Scenario focused on balance between Energy Safety, Economical Efficiency and Environmental Burden among three (3) scenarios

4.2 Renewable Energy Situation in the Master Plan

Since Sri Lanka has abundant potential of Renewable Energy (RE), coordination between investment plan in power sector and flexibility of power system operation is essential for smooth integration of expected large amount of installation of RE. In the coordination, it will be taken both power supply reliability and cost into consideration.

The Master Plan suggested that improvement and sophistication of operation in power distribution sector should be high priority for achievement the scenario.

Purpose of the Project is to examine appropriate treatment of introduction of Variable Renewable Energy (VRE), to find countermeasures for improvement of power supply reliability and reinforcement of transmission/ distribution line, to assist reviewing power system Grid Code and improvement of prediction/management skill on growing VRE output and to strengthen capacity of organization for management finance condition of CEB, in order to realize appropriate structure each type of power facilities with high promotion of VRE.

4.3 The National Energy Policy

The primary objective of the energy policy is to ensure energy security through supplies that are cleaner, secure, economical and reliable, to provide convenient, affordable energy services to support socially equitable development of Sri Lanka. Policy guidelines, such as the ‘General Policy Guidelines on the Electricity Industry’, are expected to be prepared and issued, based on the National Energy Policy.

Working through the conflicting demands from the security, equity and sustainability dimensions, known as the energy trilemma, Sri Lanka today is seen to be moving away from the delicate balance of these three (3) forces.

The National Energy Policy is thus founded on ten (10) pillars, rooted in the broad areas impacting the society, economy and the environment, in an effort to counter balance the forces through enhanced equity, security and sustainability, respectively.

1. Assuring Energy Security
2. Providing Access to Energy Services
3. Providing Energy Services at the Optimum Cost to the National Economy
4. Improving Energy Efficiency and Conservation
5. Enhancing Self Reliance
6. Caring for the Environment
7. Enhancing the Share of Renewable Energy
8. Strengthening Good Governance in the Energy Sector
9. Securing Land for Future Energy Infrastructure
10. Providing Opportunities for Innovation and Entrepreneurship

The ten (10) pillars are described in greater detail below;

1) Assuring Energy Security
Primary and secondary energy supplies of the country will be secured to ensure continuity, adequacy and reliability.

2) Providing Access to Energy Services
Access to reliable, convenient, affordable, equitable and quality energy services will be provided to all citizens to improve their living standards and to engage in gainful economic activities.

3) Providing Energy Services at the Optimum Cost to the National Economy
Energy services will be provided at the optimum long-term cost, to lower the burden on the national economy and to achieve competitiveness of locally produced goods and services in international markets.

4) Improving Energy Efficiency and Conservation
Efficient use of energy will be promoted in all sectors and across the energy value chain, engaging both the suppliers and users.

5) Enhancing Self Reliance
Indigenous energy resources will be developed to the optimum levels to minimize dependence on imported resources, subject to resolving technical, economic, environmental and social constraints, with the objective of minimizing the vulnerability of energy supplies to external situations.

6) Caring for the Environment
A meaningful contribution to climate change will be made by maintaining the low carbon intensity of the Sri Lankan energy sector. Adverse environmental and social impacts of energy services will be minimized to care for the global and local environment.

7) Enhancing the Share of Renewable Energy
Indigenous renewable energy resources will be developed to the optimum level to attain sustainability and a higher degree of resilience in the energy sector.

8) Strengthening Good Governance in the Energy Sector
Governance of the energy sector to be strengthened to realize accountability, fairness and transparency to achieve investor and consumer confidence. A stable policy environment will be ensured, and the regulatory framework will be further strengthened to assure good governance in the energy sector.

9) Securing Land for Future Energy Infrastructure
Strategic locations for establishing energy facilities and corridors which inter connect such facilities will be earmarked and secured in advance to ensure timely implementation of such facilities and to minimize adverse social impacts.

10) Providing Opportunities for Innovation and Entrepreneurship
Considering the limitation to the scale of markets available in Sri Lanka to breed technology intensive local businesses, the relatively large size of the energy sector will be utilized to nurture local entrepreneurship and innovation.

4.4 The Long Term Generation Expansion Plan

The Long Term Generation Expansion Plan is a rolling plan prepared every two years for a period of 20 years, in order to methodically plan power plant development activities to provide reliable, quality electricity to the entire nation at affordable prices. Approval on The Long Term Generation Expansion Plan (LTGEP) 2018-2037 was granted on June 2018.

According to the LTGEP 2018-2037, Biomass contribution is 2,897MW comprising 1,205MW Wind and 1,392MW Solar. Further 3x200MW Pumped Storage Power Plant is also planned to be implemented.

Accordingly, Generation Planning Unit initiated the process of preparing new Long Term Generation Expansion Plan 2020-2039.

CEB initiated the study on 'Integration of Renewable Based Generation into Sri Lankan Grid 2020-2030' with the objective of investigating main challenges and to determine the optimum level of renewable energy based generation to the grid.

The scope of the study covers the areas of renewable energy resource estimation, future renewable energy projection with optimized long term generation expansion planning, transmission infrastructure availability and development, system stability and operation, economics of integration.

4.5 Transmission Planning

Long Term Transmission Development Plan (LTTDP) of CEB is prepared by the Transmission Planning Unit and this is a rolling plan prepared every two (2) years for a period of ten (10) years, based on approved Long Term Generation Expansion Plan (LTGEP).

Chapter 5 Information by Capacity Assessment

In this chapter, collected data and information via capacity assessment are described. These information and data will become baseline information of the Project.
In order to clarify the relationship between PDM and contents in this Chapter, description of **[Tentative Indicator for PDM]** is added to each content since Indicators are under discussion, when the content is related to PDM.

5.1 System and Strategy related to Variable Renewable Energy

5.1.1 Corporate Strategy for VRE (VRE installation amount and timing) and Periodical Review on the Strategy in CEB

[Tentative Indicator for PDM]: Corporate Strategy of VRE (VRE installation amount and timing) is prepared by CEB periodically.

As above mentioned, the Long Term Generation Expansion Plan (LTGEP) is a rolling plan prepared every two (2) years for a period of twenty (20) years, Renewable Generation Options for Future Expansions is describes in the LTGEP. PV, Wind Power, Biomass Power and so on are introduced as Other Renewable Energy compare to Hydro Power.
Planning Studies on development of power generation are carried out to meet all the environmental and climate change obligations of Sri Lanka during twenty (20) years planning horizon. Sri Lanka, being a partner to COP21 Paris agreement on mitigation of global climate change induced impacts. According to the ratified Nationally Determined Contributions (NDC) in September 2016 by UNFCCC, among mitigation strategies, Sri Lanka expects 4% unconditional and 16% conditional reduction of greenhouse gas emissions in the electricity sector. This is incorporated in the LTGEP 2020-2039 by integrating more Other Renewable Energy (ORE) based generation and low carbon thermal generating options to meet the Sri Lanka's obligations in COP21 Paris agreement on mitigation of global climate change induced impacts.

5.1.2 Understandings of the Pros and Cons regarding Each Kind of VRE

[Tentative Indicator for PDM]: At least one (1) C/P is certified as key person who understand the pros and cons regarding each kind of VRE

Transmission Planning Department and Generation Planning Department are in charge of planning on future installation of VRE. Thus, engineers in charge of planning of VRE generally understand the pros and cons regarding each kind of VRE. Understanding level and what kind of knowledge should be necessary to build up will be discussed in the Project.

General information about development of VRE is as follows.
The 100MW wind farm project that is currently being developed by Ceylon Electricity Board at Mannar was considered as a committed project. One of the main objectives of this large wind farm is to operationally test a novel semi-dispatchable operating strategy, by which more wind resources are expected to be integrated. As the transmission infrastructure has been already developed, the remaining wind potential in Mannar is required to be developed next in phases to meet Other Renewable Energy (ORE) additions facilitated in this LTGEP to meet government policy targets.
A separate renewable integration study was carried out to identify the year by year renewable resource integration. The operational flexibility, transmission and system constraints were considered in this study. A strong renewable energy development has been facilitated through this plan with a more than fivefold increase to the expected total renewable capacity for the next twenty years as compared to the past two decades. The

cumulative ORE capacities envisaged at the end of 20 years are 1,323MW from wind, 2,210MW from solar, 654MW from mini-hydro and 144MW from biomass.
Solar PV additions take place at present under different schemes such as small-scale rooftop, small scale and large scale ground mounted systems. Incentives offered to high end domestic consumers to avoid consumption in higher blocks in the increasing block tariff domestic tariff structure had contributed to higher interest to install domestic solar rooftop systems. Installation of solar PV systems at rooftops helps the country to utilize the otherwise unproductive asset of rooftop area for a productive economic purpose. Government of Sri Lanka (GOSL) launched an accelerated solar development campaign in 2016 to promote rooftop solar installations in the country. The program objective of reaching 200MW of rooftop solar PV capacity by 2020 has been already achieved and a continuous growth in rooftop capacity is observed.
The revised base case plan of the LTGEP 2020-2039 prepared after adopting the gazette reliability criteria of PUCSL of 2.5% (minimum) and 20% (maximum) reserve margin is presented as an addendum in this draft LTGEP 2020-2039 report and is termed "revised base case plan".

5.1.3 Understandings of the Installation Procedures from Planning to Commercial Operation

[Tentative Indicator for PDM]: At least additional one (1) C/P is certified as key person who understand VRE installation procedure from the beginning, project formulation to the end and commencement of commercial operation

Renewable Energy Development Department is in charge of the procurement of VRE. There is procurement guideline on permission procedures and procurement of VRE, and some engineers in the Department generally understand the procedures. Understanding level and what kind of procedures should be improved will be discussed in the Project.
Outline of procurement procedures for installation of VRE is as below.
When developer applies a VRE project, the developer must take the procedure in line with “On-Grid Renewable Energy Development” published by SEA in May, 2011, and receive renewable energy permit issued by SEA. Any person (an individual or a company) may apply for a renewable energy project anytime in line with above official procedure, irrespective of whether the person holds any rights to the resource of land rights.

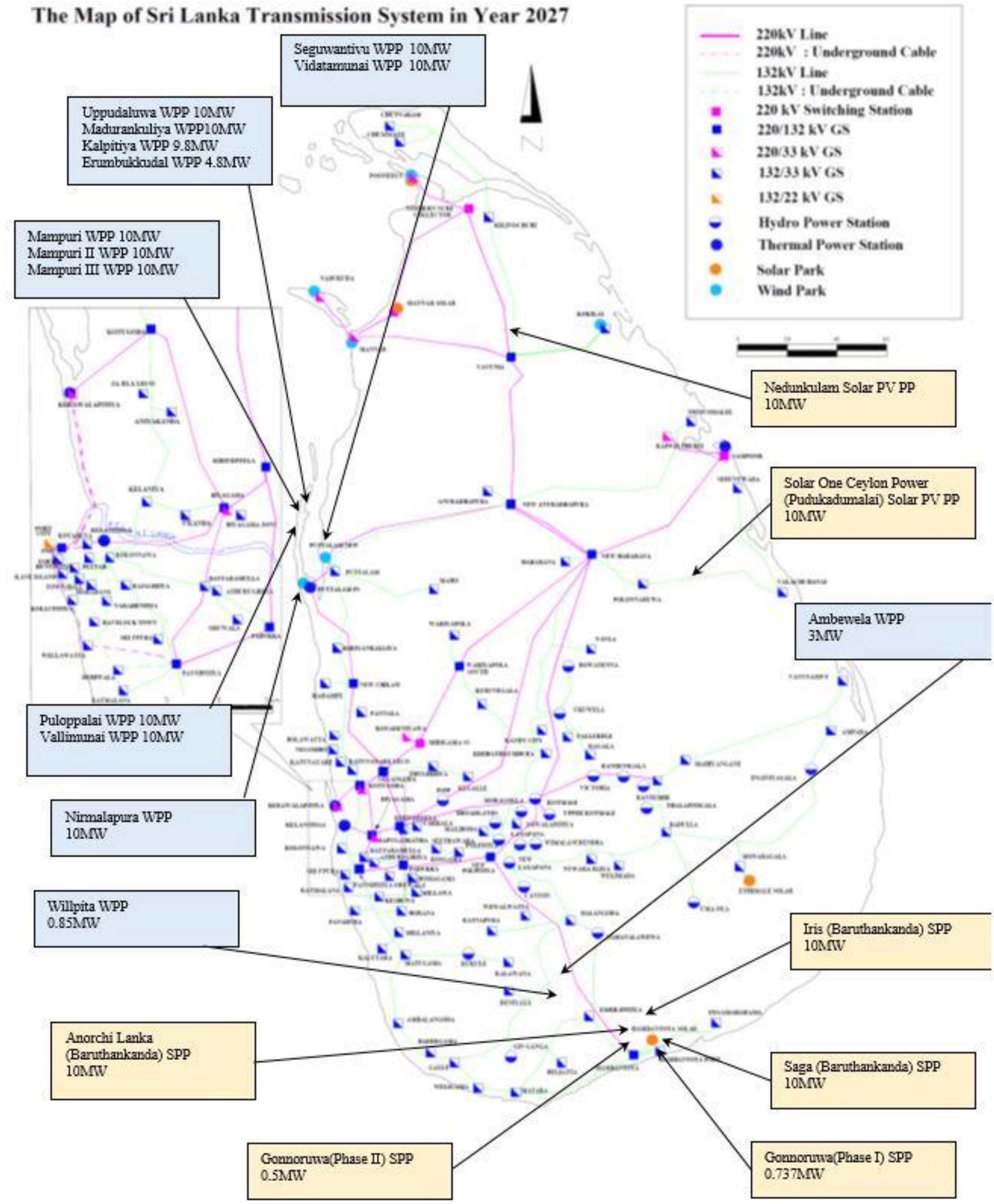
5.1.4 Formulation of the Plan for Introduction of VRE to Meet Sri Lanka's National Energy Policy

[Tentative Indicator for PDM]: At least one (1) plan to promote the introduction of VRE to meet Sri Lanka's national energy policy is formulated

Transmission Planning Department and Generation Planning Department are in charge of planning on future installation of VRE.
Current plan of VRE installation is described below.

(1) PV plant, WT plant and SPP at 2027

PV, WT plant and SPP planned by 2027 are shown in Figure 5.1. The markup balloon in Figure 5.1 indicate the existing WPP and SPP.



(Source: CEB information)

Figure 5.1 PV, WT Plant and SPP at 2027

Existing Solar Power Plant, Development Plan for Solar Power Plant as of 2020 are shown in Table 5.1 and Table 5.2.

Table 5.1 Existing Solar Power Plant (As of 2020)

	Developer Name	Solar Plant Name	Capacity (MW)	Location		
				Connected GSS	Latitude	Longitude
1	Japan Solar Plant (SEA)	Gonnoruwa Phase I SPP	0.737	Hambanthota	6°13'31.31"N	81°4'38.07"E
2	Korean Solar Plant (SEA)	Gonnoruwa Phase II SPP	0.5	Hambanthota	6°13'34.94"N	81°4'31.86"E
3	Saga Solar	Saga (Baruthankanda) SPP	10	Hambanthota	6°13'53.59"N	81°5'8.85"E
4	Iris Eco Power Lanka (Pvt) Ltd	Iris (Baruthankanda) SPP	10	Hambanthota	6°13'57.19"N	81°4'43.77"E
5	Anorchi Lanka (Private) Ltd	Anorchi Lanka (Baruthankanda) SPP	10	Hambanthota	6°13'39.72"N	81°4'50.40"E
6	Solar One Ceylon (Pvt) Ltd	Solar One Ceylon Power (Pudukadumalai) Solar PV PP	10	Valachchenai	7°58'31.22"N	81°14'9.89"E
7	Vydexa (Lanka) Power Corporation (Pvt) Ltd	Nedunkulam Solar PV PP	10	Vauniya	8°46'16.69"N	80°31'40.50"E
Total			51.237			

(Source: CEB information)

Table 5.2 Development Plan for Solar Power Plant (As of 2020)

	Developer Name	Solar Plant Name	Capacity (MW)	Location			Year of Operation	Present Status
				Connected GSS	Latitude	Longitude		
1	Not decided	Rooftop Solar Power Programs	Not decided	No data	No data	No data	-	
2	Not decided	37x1MW Solar Park	37	No data	No data	No data	2021	Under Construction
3	Not decided	90x1MW Solar Park	90	No data	No data	No data	2021	Awarded/under Construction
4	Not decided	2x10MW Solar Park	29	No data	No data	No data	-	
5	Not decided	150MW Dist. Solar Park	150	No data	No data	No data	2022	Bidding stage
6	Not decided	Utility Scale Solar Park	100 planned	No data	No data	No data	2020	Prefeasibility is being done

(Source: CEB information)

Existing Wind Power Plant, Development Plan for Wind Power Plant as of 2020 are shown in Table 5.3 and Table 5.4.

Table 5.3 Existing Wind Power Plant

	Developer Name	Wind Plant Name	Capacity (MW)	Location		
				Connected GSS	Latitude	Longitude
1	Senok Wind Power (Pvt) Ltd	Mampuri WPP	10	Puttalam	8°0'36.37"N	79°43'24.09"E
2	Seguwantivu Wind Power (Pvt) Ltd	Seguwantivu WPP	10	Puttalam	8° 3'30.43"N	79°48'12.98"E
3	Vidatamunai Wind Power (Pvt) Ltd	Vidatamunai WPP	10	Puttalam		
4	Vallibel Willwind (Pvt) Ltd	Willpita WPP	0.85	Balangoda	6°37'22.36"N	80°44'37.80"E
5	Nirmalapura Wind Power (Pvt) Ltd	Nirmalapura WPP	10	Norochcholei PP	7°57'14.73"N	79°44'27.14"E
6	Ace Wind Power (Pvt) Ltd	Ambewela WPP	3	Nuwara Eliya	6°54'4.68"N	80°48'4.12"E
7	Powergen Lanka (Pvt) Ltd	Uppudaluwa WPP	10	Norochcholei PP	7°58'49.37"N	79°46'32.87"E
8	Daily Life Renewable Energy (Pvt) Ltd	Madurankuliya WPP	10	Norochcholei PP	8°0'45.40"N	79°43'36.69"E
9	Pavan Danavi (Pvt) Ltd	Kalpitiya WPP	9.8	Norochcholei PP	8°2'55.19"N	79°43'7.84"E
10	Nala Dhanavi (Pvt) Ltd	Erumbukkudal WPP	4.8	Norochcholei PP	8°2'55.19"N	79°43'7.84"E
11	Senok Wind Energy (Pvt) Ltd	Mampuri II WPP	10	Norochcholei PP	8°0'36.37"N	79°43'24.09"E
12	Senok Wind Resource (Pvt) Ltd	Mampuri III WPP	10	Norochcholei PP	8°0'36.37"N	79°43'24.09"E
13	Joul Power (Pvt) Ltd	Puloppalai WPP	10	Kilinochchi	9°33'54.05"N	80°20'21.87"E
14	Beta Power (Pvt) Ltd	Vallimunai WPP	10	Kilinochchi	No data	No data
15	Musalpetti Wind Power (Pvt) Ltd	Musalpetti WPP	10	Puttalam	8°0'36.37"N	79°43'24.09"E
	Total		128.5			

(Source: CEB information)

Table 5.4 Development Plan for Wind Power Plant

	Developer Name	Wind Plant Name	Capacity (MW)	Location			Year of Operation	Present Status
				Connected GSS	Latitude	Longitude		
1	No data	Mannar WPP Phase 1	100	No data	No data	No data	2020	Under Construction
2	No data	Mannar WPP Phase 2	100	No data	No data	No data	2023	Procurement process yet to start
3	No data	Mannar WPP Phase 3	No data	No data	No data	No data	-	
4	No data	240MW WPP at Pooneryn	No data	No data	No data	No data	-	

(Source: CEB information)

(2) Development plan of renewable energy in Sri Lanka

Future developed capacity in Renewable Energy and development and retirement plan in Thermal Power Plant in Sri Lanka are shown in draft LTGEP 2020-2039 (2019) as below.

Table 5.5 Draft Long Term Generation Expansion Plan from 2020 to 2039

Year	Renewable Additions	Thermal Additions	Thermal Retirements	LOLP %
2020	Solar 100MW (including 35MW committed) Wind 20MW (2x10MW Chunnakam Wind) Mini Hydro 15MW* Biomass 5MW*	200MW Short Term Basis Supplementary Power Plants 100MW Short Term Basis Supplementary Power Plants 145MW Reciprocating Engine Power Plants	6x5MW Northern Power	1.427
2021	Solar 110MW (including 70MW+ 2x10MW committed) 100MW Mannar Wind Park Mini Hydro 20MW* Biomass 5MW* Uma Oya HPP 122MW Broadlands HPP 35MW	395MW Reciprocating Engine Power Plants 130MW Gas Turbine[2]	100MW ACE Embilipitiya 20MW ACE Matara 51MW Asia Power 200MW Short Term Basis Supplementary Power Plants 100MW Short Term Basis Supplementary Power Plants	1.362
2022	Solar 60MW Wind 150MW (including 60MW committed) Mini Hydro 20MW* Biomass 5MW*	4x24MW Reciprocating Engine Power Plants 100MW Reciprocating Engine Power Plants – Galle 200MW Open Cycle Operation of 1x300MW Natural Gas fired Combined Cycle Power Plant – Western Region[2]	290 MW Reciprocating Engine Power Plants	1.424
2023	Solar 60MW Wind 110MW Mini Hydro 20MW* Biomass 5MW* Moragolla HPP 31MW Seethawaka HPP 24MW	100MW Steam Turbine Operation of 1x300MW Natural Gas fired Combined Cycle Power Plant – Western Region[2] (Combined Cycle Operation) (Identified in LTGEP 2015-2034 and LTGEP 2018-2037 to be commissioned by 2019) 300MW Natural Gas fired Combined Cycle Power Plant – Western Region[2] (Identified in LTGEP 2018-2037 to be commissioned by 2021) 300MW Lakvijaya Coal Power Plant Extension 163MW Combined Cycle Power Plant (KPS–2)[4]	190MW Reciprocating Engine Power Plants 4x17MW Kelanitissa Gas Turbines 115 MW Gas Turbine[1] 4x9MW Sapugaskanda Diesel Ext.[1] 163MW Sojitz Kelanitissa Combined Cycle Plant[4]	0.449
2024	Solar 60MW Wind 90MW Mini Hydro 20MW* Biomass 5MW* Thalpitigala HPP 15MW	300MW Natural Gas fired Combined Cycle Power Plant	4x17MW Sapugaskanda Diesel[1]	0.345
2025	Solar 80MW Wind 40MW Mini Hydro 20MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant	4x15.6MW CEB Barge Power Plant[1]	0.331
2026	Solar 90MW Wind 35MW Mini Hydro 10MW* Biomass 5MW*	2x300MW New Coal fired Power Plant (Foul Point Phase I)	60MW Reciprocating Engine Power Plants 4x9MW Sapugaskanda Diesel Ext.[1]	0.077
2027	Solar 90MW Wind 50MW Mini Hydro 10MW* Biomass 5MW*	–	–	0.210

Year	Renewable Additions	Thermal Additions	Thermal Retirements	LOLP %
2028	Solar 100MW Wind 40MW Mini Hydro 10MW* Biomass 5MW* Pumped Storage HPP 200MW	–	–	0.152
2029	Solar 100MW Wind 40MW Mini Hydro 10MW* Biomass 5MW* Pumped Storage HPP 200MW	–	–	0.121
2030	Solar 100MW Wind 20MW Mini Hydro 10MW* Biomass 5MW* Pumped Storage HPP 200MW	300MW New Coal fired Power Plant (Change to Super critical will be evaluated)	–	0.019
2031	Solar 100MW Wind 60MW Mini Hydro 10MW* Biomass 5MW*	–	–	0.155
2032	Solar 110MW Wind 50MW Mini Hydro 10MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant 196MW Reciprocating Engine Power Plants	4x24MW Reciprocating Engine Power Plants 100MW Reciprocating Engine Power Plants – Galle	0.128
2033	Solar 110MW Wind 35MW Mini Hydro 10MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant – Western Region 300MW New Coal Power Plant (Change to Super critical will be evaluated)	165MW Combined Cycle Plant (KPS) 163MW Combined Cycle Plant (KPS-2) 3x8.93MW Uthuru Janani Power Plant	0.182
2034	Solar 120MW Wind 70MW Mini Hydro 10MW* Biomass 5MW*	300MW New Coal Power Plant (Change to Super critical will be evaluated)	–	0.105
2035	Solar 120MW Wind 45MW Mini Hydro 10MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant – Western Region 300MW Natural Gas fired Combined Cycle Power Plant	300MW West Coast Combined Cycle Power Plant	0.060
2036	Solar 110MW Wind 50MW Mini Hydro 10MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant	–	0.055
2037	Solar 110MW Wind 50MW Mini Hydro 10MW* Biomass 5MW*	–	–	0.241
2038	Solar 110MW Wind 70MW Mini Hydro 10MW* Biomass 5MW*	300MW New Coal Power Plant (Change to Super critical will be evaluated)	–	0.193
2039	Solar 110MW Wind 70MW Mini Hydro 5MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant	–	0.178

(Source: Long Term Generation Expansion Plan 2019)

5.1.5 Assistance by Donors in Sri Lanka Power Sector

(1) Assistance by World Bank Group

Generation Planning Unit acts as the main focal point for Carbon Partnership Facility (CPF) program between CEB and IBRD (International Bank for Reconstruction and Development) of the World Bank group for emission reduction considering the Renewable Energy development program identified in the LTGEP.

Seller Participation Agreement (SPA) was signed between two parties and according to the agreement CEB has the responsibility to develop and implement the Emission Reduction Program.

Any Private Power Producer who is willing to join the scheme will have to transfer the carbon credits to Government through CEB. Carbon revenue received in this program is intended to be used to overcome technical and financial barriers for renewable development.

The Partnership for Market Readiness (PMR) is a grant-based, capacity building trust fund that provides funding and technical assistance for the collective innovation and piloting of carbon pricing instruments (CPIs). Climate Change Secretariat under the purview of Ministry of Mahaweli Development and Environment is the implementing entity for PMR program and CEB as a major stakeholder have been involved in providing necessary input and feedback to the work carried out under PMR program.

Further, Generation Planning Unit participated in the programs organized by the Sri Lanka Sustainable Energy Authority and the Climate Change Secretariat under Ministry of Mahaweli Development and Environment with related to barrier analysis for climate change mitigation options in energy sector in order to prioritize the mitigation measures, developing energy sector project proposals for Nationally Appropriate Mitigation Action (NAMA) funding facility, developing inputs for Paris Agreement Work Program, developing a measurement, reporting and verification (MRV) system for GHG emissions.

Generation Planning Unit represents CEB at the National Expert Committee on Climate Change Mitigation under the Ministry of Mahaweli Development and Environment. This committee evaluates proposals related to reduction of GHG emissions including NAMA proposals and carries out feasibility studies for pilot projects. Acquiring of international climate finance for such pilot projects is also coordinated through this committee.

(2) Assistance by ADB

ADB assisted Preparation for the Power System Reliability Strengthening Project. CEB may receive a loan of 200 MUSD for reliability improvement in CEB transmission system and innovative technology applications in reliability improvement from ADB's ordinary capital resources and potential co-financing from Asian Infrastructure Investment Bank. Following transmission network developments will be financed by this loan.

Table 5.6 Transmission Network Project related to Assistance by ADB

● Construction of Kerawalapitiya 220kV Switching Station ● Construction of Hambantota-Matara 85km, 132kV Transmission Line ● Reconstruction of New Anuradhapura – Trincomalee 104km, 132kV Transmission Line ● Construction of Kandy City 132/11kV Grid Substation ● Construction Homagama 132/33kV Grid Substation
● Construction of Tissamaharama 132/33kV Grid Substation ● Construction of Kalawana 132/33kV Grid Substation ● Reconstruction of New Habarana-New Anuradhapura 50km, 220kV transmission line ● Construction of Wariyapola 132/33kV Grid Substation and Wariyapola-South 220/132kV Switching Station ● Construction of Negombo 132/33kV grid substation ● Construction of Ja-Ela 132/11kV grid substation ● Construction of Baddegama 132/33kV grid substation ● Construction of Mirigama 220kV Switching Station &Kotadeniyawa 220/33kV grid substation

(Source: Annual Report 2018)

Present status of completed and ongoing programs assisted by ADB is shown below.

Table 5.7 Present Status of Ongoing Programme by Assistance of ADB

- **Clean Energy & Network Efficiency Improvement Project**
  - Construction of Mannar Transmission Infrastructure -Completed
  - Construction of Kegalle GS and associated 132kV transmission infrastructure-Completed
  - Padukka and New Polpitiya SS and associated 220kV transmission infrastructure-Ongoing
- **Green Power Development & Energy Efficiency Improvement Investment Program (Tranche 1)**
  - Construction of Kerawalapitiya GS-Completed
  - Construction of Kalutara, Kesbewa and Kappalturai GS and associated 132kV transmission infrastructure-Ongoing
- **Green Power Development & Energy Efficiency Improvement Investment Program (Tranche 2)**
  - Construction of Hambantota SS and associated 220kV transmission line from New Polpitiya to Hambantota - Ongoing
  - Construction of Nadukuda Wind Collector GS and associated Manna-Nadukuda 220kV transmission line- Ongoing
  - Construction of Colombo B GS- Ongoing
- **Supporting Electricity Supply Reliability Improvement Project**
  - Construction of 100Mvar BSC at Pannipitiya GS- Ongoing
  - Construction of +100/-50MVar SVC at Biyagama GS- Ongoing
  - Construction of 105MVar Reactors at New Anuradhapura and 50Mvar Reactors at Mannar GS- Ongoing

(Source: CEB information)

(3) AFD

Present status of ongoing programs assisted by Agence Francaise de Development (AFD) is shown below.

Table 5.8 Present Status of Ongoing Programme by Assistance of AFD

Renewable Energy Absorption Transmission Development Project

Construction of Maliboda, Wewelwatta, Nawalapitiya and Ragala GSs and associated 132kV transmission infrastructure

- Construction of Maliboda 132/33kV, Grid Substation with 2x31.5MVA transformer
- Construction of Ragala 132/33kV, Grid Substation with 2x31.5MVA transformer
- Construction of Wewalwatta132/33kV, Grid Substation with 2x31.5MVA transformer
- Construction of Nawalapitiya 132/33kV, Grid Substation with 2x31.5MVA transform

(Source: CEB information)

5.1.6 Training for Engineers on VRE Installation

There is no specific Training Policy.

On the other hand, CEB analyzes some cases as below using PSS/E software.

1. Load Flow Studies
2. Dynamic Studies

5.1.7 Whole Sale Market and Balance Market

There is no Whole Sales Market and Balance Market in Sri Lanka so far.

5.1.8 Organization of System Connection Restriction Relaxation System

There is no such system in Sri Lanka.

Connect and Manage system which is conducting in Japan will be examined in the Project. This system is considered introducing in Sri Lanka for avoiding delay of development under mass development of VRE in future.

5.1.1 Limitation of Output of VRE

There is no rule for limitation of output of VRE in Sri Lanka.
This system will be discussed in the Project to keep stable operation in power system under large capacity of VER introduction in future.

5.1.9 Assistance System for Improvement of CEB Finance Status

Taxation or assistance system for improvement of CEB finance status will be discussed in the Project such as Promotion of Power Resources Development Tax or Fuel Cost Adjustment System which are applied in Japan. There is no such system in Sri Lanka.

5.2 Corporate Finance of CEB

5.2.1 Financial Status of CEB

(1) Financial Performance

[Tentative Indicator for PDM]:
Assessment on operating profit improvement and preparation of recommendation reports on CEB finance;
i) Case that the present regulatory conditions and electricity tariff level continue to exist and VRE installation is promoted
ii) Case that regulatory conditions and other relevant conditions are reviewed then VRE installation is promoted

For recent years, CEB has recorded a net loss except 2015 due to its increasing cost of sales. As more than 60% of CEB's cost structure consists of the direct generation cost, the growing demand has caused generation cost to consistently increase as indicated by the average electricity cost per unit. The situation was worsened with dry hydrology conditions during the period as CEB had to depend on high cost thermal power generation. Moreover, CEB was not able to recover the increasing cost by cost-reflective tariff revenue as the electricity tariff has not been revised since 2014 and stayed around LKR 16.20 per kWh. As a result, due to the shortage of operational cash flow and growing capital expenditure needs to maintain the electricity system, CEB had to increase new borrowings to LKR 62 billion in 2018.
In terms of financial stability, the current ratio indicates CEB had ability to meet its short-term obligations from 2014 to 2016 but it was gradually deteriorated from 2017. Its funding structure increasingly rely on debt financing as indicated by the debt to assets ratio. In 2015 and 2016, the debt service coverage ratio (DSCR) was greater than 1.0 indicating the core operation was able to generate sufficient cash flow to meet the debt service (interest payments and principal repayments). However, the ratio has dropped since 2017 indicating CEB's financial viability has been deteriorated.

Table 5.9 Financial Status of CEB (2014 - 2018)

(LKR million)

	2014	2015	2016	2017	2018
Summary Income Statement					
Revenue	202,645	188,684	206,811	218,450	229,571
Cost of Sales	(213,646)	(168,781)	(222,097)	(260,273)	(250,891)
Gross Profit/ (Loss)	(11,001)	19,903	(15,286)	(41,823)	(21,320)
Other Income & Gain	5,871	8,292	10,323	8,143	9,450
Administrative Expenses	(3,146)	(4,087)	(4,965)	(5,110)	(5,425)
Finance Income	304	434	1,048	1,194	1,466
Finance Cost	(7,030)	(5,134)	(4,311)	(8,415)	(13,036)
Profit/ (Loss) before Income Tax	(15,002)	19,408	(13,191)	(46,011)	(28,865)
Summary Balance Sheet					
Assets	764,035	776,852	804,354	831,990	870,920
Property, Plant & Equipment	681,471	694,415	704,695	724,065	747,049
Investment in Subsidiaries	785	912	912	912	912
Investment in Joint Venture	150	329	329	329	329
Investment of Insurance Reserve Fund	5,653	6,036	6,496	7,246	8,070
Other Non-current Financial Assets	2,291	3,848	8,983	8,912	10,204
Other Non-current Assets	-	896	949	961	1,242
Non-current Assets Held for Sale	1,023	1,025	1,022	-	-
Current Assests	72,662	69,391	80,968	89,565	103,114
Liabilities	369,204	347,225	390,991	464,798	533,276
Interest Bearing Loans and Borrowings	202,821	198,344	201,752	214,564	281,262
Consumer Deposits	10,458	11,484	12,753	13,557	14,311
Provision & Other Deferred Liabilities	6,572	6,116	7,262	8,622	10,038
Government Grants	-	-	211	243	228
Contract Liablities	66,292	71,696	77,628	82,564	86,335
Current Liabilities	83,061	59,585	91,385	145,248	141,102
Equity	394,831	429,627	413,363	367,192	337,644
Contributed Capital	289,038	302,228	302,695	302,695	302,695
Reserves	27,434	28,463	30,283	32,783	34,830
Retained Earnings	78,359	98,936	80,385	31,714	119
Total Equity & Liabilities	764,035	776,852	804,354	831,990	870,920
Financial Indicators					
Operational Performance					
Average selling price per unit (LKR/kWh)	18.50	16.00	16.18	16.26	16.29
Average cost per unit at selling point (LKR/kWh)	20.00	15.07	18.08	20.34	19.12
Gross profit margin	-5.4%	10.5%	-7.4%	-19.1%	-9.3%
Net Cash Flow from Operations (LKR million) *	-	21,353	18,441	22,051	(17,273)
New Bank Loans (LKR million) *	-	319	6,049	2,582	62,169
Financial Stability					
Current Ratio	0.87	1.16	0.89	0.62	0.73
Debt to Assets	0.48	0.45	0.49	0.56	0.61
Debt Service Coverage Ratio (DSCR) *	-	2.94	1.04	(0.80)	0.29

* Indicators from financial analysis in CEB Corporate Plan 2019-2023

(Source: CEB Financial Statements, Statistical Digests and Corporate Plan 2019 – 2023)

(2) Corporate Financial Planning and Monitoring

[Tentative Indicator for PDM]: CEB Corporate finance plan is updated periodically

CEB revises its financial plan on an annual basis.

Finance Division prepares Preliminary Financial Plan and CEB Master Budget subject to approval of corporate management for each year. CEB has also prepared the Corporate Plan for the 2019-2023 period and Action Plan 2020.

Corporate Plan provides financial analysis of CEB's performance (2015 - 2018) and financial projection for the 2019 – 2023 period. The financial projection shows CEB's net loss will increase under the assumption that the average electricity tariff (LKR 16.20/kWh) is not revised over the period (See Table 5.10)

Table 5.10 Financial Projection by Corporate Plan

	2019	2020	2021	2022	2023
Average Tariff (LKR/kWh)	16.20	16.20	16.20	16.20	16.20
Average Cost per Unit (LKR/kWh)	22.83	23.72	25.09	26.73	24.70
Net Profit (Loss) before Other Income (LKR million)	(99,040)	(120,062)	(149,092)	(185,334)	(157,061)
Estimated Subsidy (LKR million)	103,678	120,984	149,092	185,334	157,061

(Source: CEB Corporate Plan 2019 – 2023)

Corporate Plan and Action Plan 2020 present the following corporate goals and Key Performance Indicators (KPIs) along with each goal.

Table 5.11 CEB's Corporate Goals and KPIs

Corporate Goal	Key Performance Indicator
1. Make CEB Financially Stronger	- Gering ratio - Percentage of financial surplus or deficit over total revenue - Percentage change of financial cost - Percentage of short-term borrowing
2. Enhance low cost electricity generation	- Average generation cost per unit of electricity - Average operational cost per unit of electricity Sold - % of electricity generated from plants having a unit cost above average generation cost (energy)
3. Provide electricity to entire country at an affordable price	- Overall Electrification level - Average household electricity expenditure Ratio
4. Ensure high quality electricity supply and services to customers	- Ease of getting electricity index - System Average Interruption Duration Index (SAIDI) - System Average Interruption Frequency Index (SAIFI) - Estimated Energy Not Supplied (EENS) - Number of customer complaints against variation of power quality - Average Cycle Time per new connection - Reduction in No of customer complaints - Average response time per customer complaint
5. Maintain stronger relationship with external stakeholders	- No of CSR activities per year - Average duration of serving a request from stakeholders (other than customers)
6. Enhance employee engagement	- Employee productivity - Organizational commitment index - Overall employee satisfaction index
7. Achieve operational excellence with state of art technology	- No of e-services introduced - No. of smart services introduced - No. of fatal electrical accidents per year
8. Optimize integration of green energy	- No of Green energy projects integrated to the grid - % Increase of installed capacity from renewable sources - Percentage of green energy produced over total energy - Average emission index

(Source: CEB Corporate Plan 2019-2023)

For the monitoring and evaluation, KPIs are reported on a quarterly basis by Corporate Strategy Division and Finance Division. Also, variance analysis of budget and actual expenses is made by Finance Division monthly.

Table 5.12 Planning and Monitoring Framework of CEB

Stage	Process	Section/Department	In charge
Planning	Preparation of Preliminary Financial Plan (PFP)	Finance Division	AFM (Corporate)
	PFP provides the upper ceilings for operational & maintenance cost for each division		
	Based on the upper ceiling provided in the PFP, each Division needs to prepare their divisional financial budgets	Each Division (9 Division in CEB)	AGM/AFM of each Division
	Prepare the CEB Master Budget	Finance Division	AFM (Corporate)
Monitoring & Evaluation	Variance Analysis of Actual v.s. Budget on monthly basis	Finance Division	AFM (Corporate)
	Calculation the Key Performance Indicators (KPIs)	Corporate Strategy/Finance Division	AGM(CS)/FM/ AFM (Corporate)
	Revise the budget if necessary	Finance Division	AFM (Corporate)

(Source: CEB Information)

5.2.2 Electricity Tariff System

(1) Latest Electricity Tariff Tables

Table 5.13 shows the latest electricity tariffs of CEB which mainly consist of domestic and non-domestic tariffs. Domestic tariff applies progressive block tariffs whereby charging a more expensive kWh to customers who would consume more electricity. In addition, the optional Time-of-Use (TOU) rates were introduced in 2015. However, only around two hundred fifty (250) customers have chosen TOU so far because the basic block tariffs are relatively inexpensive. Non-domestic tariffs mainly consist of unit charge and fixed charge. In addition, TOU unit charge and demand charge are applied for customers with higher contract demand.

Table 5.13 CEB Electricity Tariff

EFFECTIVE FROM	●DOMESTIC	●ToU for DOMESTIC	●NON DOMESTIC CATEGORIES
(for each 30 - day billing period)	16-09-2014	02-05-2017	15-11-2014

DOMESTIC					Unit Charge			Fixed Charge
Consumption 0 - 60 kWh per month								
Block 1	-	0 - 30	units	@	Rs 2.50	per unit	+	Rs 30.00
Block 2	-	31 - 60	units	@	Rs 4.85	per unit	+	Rs 60.00
Consumption above 60 kWh per month								
Block 1	-	0 - 60	units	@	Rs 7.85	per unit	+	N/A
Block 2	-	61 - 90	units	@	Rs 10.00	per unit	+	Rs 90.00
Block 3	-	91 - 120	units	@	Rs 27.75	per unit	+	Rs 480.00
Block 4	-	121 - 180	units	@	Rs 32.00	per unit	+	Rs 480.00
Block 5	-	Above 180	units	@	Rs 45.00	per unit	+	Rs 540.00

Time of Use Electricity Tariff for Domestic Consumers

Time of Use (ToU)	Energy Charge (Rs)	Fixed Charge (Rs)
Day (05.30 - 18.30 hrs)	25.00	540.00
Peak (18.30 - 22.30 hrs)	54.00	
Off Peak (22.30 - 05.30 hrs)	13.00	

RELIGIOUS & CHARITABLE INSTITUTIONS

Block 1	-	0 - 30	units	@	Rs 1.90	per unit	+	Rs 30.00
Block 2	-	31 - 90	units	@	Rs 2.80	per unit	+	Rs 60.00
Block 3	-	91 - 120	units	@	Rs 6.75	per unit	+	Rs 180.00
Block 4	-	121 - 180	units	@	Rs 7.50	per unit	+	Rs 180.00
Block 5	-	Above 180	units	@	Rs 9.40	per unit	+	Rs 240.00

OTHER CUSTOMER CATEGORIES			General Purpose		Industrial		Hotel	Government
			GP1-1	GP1-2	IP1-1	IP1-2		
Rate 1 Supply at 400/230V Contract demand less than or equal 42kVA			For ≤ 300 kWh/month	For > 300 kWh/month	For ≤ 300 kWh/month	For > 300 kWh/month		
	Unit Charge (Rs/kWh)		18.30	22.85	10.80	12.20	21.50	14.65
	Fixed Charge (Rs/Month)		240.00	240.00	600.00	600.00	600.00	600.00
Rate 2 Supply at 400/230V Contract demand Above 42kVA	Unit Charge (Rs/kWh)	Day (05.30 - 18.30 hrs)	21.80		11.00		14.65	14.55
		Peak (18.30 - 22.30 hrs)	26.60		20.50		23.50	
		Off Peak (22.30 - 05.30 hrs)	15.40		6.85		9.80	
	Demand Charge (Rs/kVA)		1100.00		1100.00		1100.00	1100.00
	Fixed Charge (Rs/Month)		3000.00		3000.00		3000.00	3000.00
Rate 3 Supply at 11kV & above	Unit Charge (Rs/kWh)	Day (05.30 - 18.30 hrs)	20.70		10.25		13.70	14.35
		Peak (18.30 - 22.30 hrs)	25.50		23.50		22.50	
		Off Peak (22.30 - 05.30 hrs)	14.35		5.90		8.80	
	Demand Charge (Rs/kVA)		1000.00		1000.00		1000.00	1000.00
	Fixed Charge (Rs/Month)		3000.00		3000.00		3000.00	3000.00
Street Lighting			@ Rs 17.00 per unit					

Electric Vehicle Charging Rates at CEB Charging Stations

Time of Use (ToU)	DC Fast Charging	Level 2 AC Charging
Day (05.30 - 18.30 hrs)	50.00	30.00
Peak (18.30 - 22.30 hrs)	70.00	55.00
Off Peak (22.30 - 05.30 hrs)	30.00	20.00

(Source: CEB information)

(2) Average Electricity Revenue by Customer Category

CEB's average electricity revenue is steady over recent years as shown in the table below. This is because electricity tariff has not been revised since 2014. As compared to the total average, domestic, industrial and religious customers enjoy lower tariff level by cross-subsidizing from other customer categories.

Table 5.14 Average Electricity Revenue of CEB

Average Price Rs/ kWh	2016	2017	2018
Domestic	13.42	13.48	13.60
Non-Domestic			
Religious	7.15	7.21	7.28
General Purpose	23.90	23.74	23.78
Hotel	17.74	17.73	17.62
Industrial	14.63	14.77	14.72
Government	18.34	18.26	18.23
Bulk Supply to LECO	15.77	15.79	15.53
Total	16.18	16.26	16.29

(Source: CEB Statistical Digest)

(3) CEB Electricity Bill Collection Rates

CEB's electricity bill collection rates have been above 100% for recent five years.

Table 5.15 Electricity Bill Collection Rate of CEB

(Unit: million Rs.)

Year	2015	2016	2017	2018	2019
Electricity bill collection	189,289	224,931	238,564	230,394	261,728
Revenue	188,625	206,892	218,450	229,571	242,934
Bill collection rate	100%	109%	109%	100%	108%

(Source: CEB information)

(4) Electricity Tariff Revisions

1) Electricity tariff regulations

Electricity tariffs are regulated by Section 30 of Sri Lanka Electricity Act and its amendment in 2013. The current tariff calculation method is determined by the Tariff Methodology approved by PUCSL in November 2015. The Tariff Methodology allows electricity utilities to apply their electricity tariff to include all costs for generation, transmission and distribution such as capital expenditure, depreciation, return on assets, operational expenses, inflation, etc. Based on the regulations, tariff review is implemented for each five-year tariff period and tariff adjustments are made semi-annually upon request by CEB subject to approval by PUCSL.

2) Recent Tariff Revisions

Last tariff revisions were made in September 2014 for domestic tariff and November 2014 for non-domestic tariff. No revisions are made since then because PUCSL does not allow the tariff hike for end consumers. There is a gap between the average selling end user tariff and the cost incurred for generation and transmission of the power to selling point. In 2015 the optional TOU tariff was introduced in the CEB tariff system.

5.2.3 Debts of CEB and Subsidy from Government

(1) Information on CEB's long-term debt

(lender, loan amount and conditions (interest rates and maturity), repayment history, etc.)

Most borrowings of CEB are project loans provided by bilateral and multilateral financial institutions such as ADB, JICA, AFD, etc.; 91% of which (LKR 210 billion) are subsidiary loans through GOSL treasury. In 2019 LKR 16.9 billion debt to treasury was transferred to equity.

Table 5.16 Interest-Bearing Loans of CEB

(Unit: LKR thousands)

	2019 Repayable Within 1 Year	2019 Repayable After 1 Year	2019 Total	2018 Repayable Within 1 Year	2018 Repayable After 1 Year	2018 Total
Bank Loans (24.1)	14,126,839	75,293,052	**89,419,892**	7,478,776	59,947,397	**67,426,172**
Projects Loans (24.2)	1,076,038	230,859,974	**231,936,012**	-	221,180,100	**221,180,100**
Lease Creditors (24.3)	38,873	106,668	**145,541**	28,162	16,767	**44,929**
Loans From Samurdhi Authority (24.4	132,073	-	**132,073**	183,680	117,932	**301,612**
Bank Over Draft (30.2)	13,037,720	-	**13,037,720**	7,677,126	-	**7,677,126**
	28,411,544	**306,259,694**	**334,671,238**	**15,367,744**	**281,262,195**	**296,629,939**

(Source: CEB financial statements)

(2) History of Government's Capital Injection to CEB in Last 5 Years
(Debt-Equity Swap, etc. with amount, year/month)

In accordance with Sri Lanka Electricity Act and General Policy Guidelines on the Electricity Industry, CEB is entitled to receive government subsidy based on the Procedure for Review and Adjustment of Tariff (July 2016) if the government wants to avoid tariff increase for low income customers (Samurdhi beneficiaries). Accordingly, CEB files request for subsidy every year; for instance, CEB requested LKR 85 billion in 2019 for the subsidy. However, the government has not provided any direct subsidy to CEB in line with those regulations. As a result, CEB is not allowed to recover reasonable expenses on a regular basis.

According to the "The Gazette of the Democratic Socialist Republic of Sri Lanka" published on August 2, 2016, PUCSL shall present to the Treasury a Subside Projections Report, indicating the estimated volume of subsidies required for the Tariff Period to implement the government policies and facilitate all the elements for Treasury for approval, and then during year of the Tariff Period, the PUCSL shall update the volume of subsidies required for the following year and seek the approval of the Treasury for the subsidy volumes for the next year.

Instead of the direct subsidy mentioned above, GOSL provided LKR 48 billion by offsetting CEB's fuel expense dues to Ceylon Petroleum Corporation (CPC) in 2020. Likewise, some project cost amounting to LKR 46.8 million was paid by GOSL instead of the subsidy. According to CEB officials, these financial supports are non-transparent and unsustainable.

5.2.4 Scheme of Promotion of VRE Installation such as Tax Break, Low-Interest Loans and Subsidy

(1) Competitive Tariff Procurement of VRE

1) General

CEB has been obtaining energy from Non-Conventional Renewable Energy (NCRE) sources. As at year 2018, there were 197 numbers of NCRE plants having an installed capacity of 609MW, connected to the Sri Lankan grid. National Energy Policy of Sri Lanka1 emphasizes the Government's policy of ensuring energy security and promoting the development on indigenous resources. Promoting the development of economically viable NCRE sources is a key strategy under the national energy policy. As Sri Lanka had already exploited all its large hydro potential, the focus has been turned to develop Solar and Wind Power, the most promising renewable generating sources left for the future to realize the government policy targets. Considering the rapid development of Solar power technologies and industry in Sri Lanka, it has been decided to move away from the current Feed-in Tariff and make all future Solar plants of 10MW or lesser capacity to be developed on competitive basis to realize the maximum economic benefit to the country. With the enactment of the Sri Lanka Sustainable Energy Authority (SLSEA) Act No.35 of 2007, all renewable energy resources of the country were vested with the Republic of Sri Lanka. Act No.35 of 2007 defines the Sri Lanka Sustainable Energy Authority (SLSEA) as the custodian of the renewable energy resources.

2) Organization in Charge in CEB

Organization in charge of promotion of VRE is Renewable Energy Development & Performance Monitoring Branch.

3) Tariff

Regarding procurement of VRE competitive bidding process, the tariff payable by CEB will be a flat tariff for the entire contract period. There will not be any escalation to the applicable Tariff during the entire Contract period. The Maximum Tariff is shown as Benchmark in bidding documents by each project.

4) Environmental Considerations

The Project Proponent is required to assess the environmental impacts of the proposed Solar Power plant and obtain all relevant environmental clearances and approvals from the appropriate authorities in terms of applicable laws and regulations and the guidelines published by Central Environmental Authority.

Project Proponent is required to comply with National Environment Act No. 47 of 1980, National Environment (Protection & Quality) Regulations, No 1 of 1990, and to any amendments thereto, and also to any other applicable regulation or law. The Project Company shall comply with all Environmental Laws applicable to the Facility during the Term.

(2) Fixed Tariff Procurement of Non-Conventional Renewable Energy (NCRE)

1) General

CEB is pleased to announce the new tariff for purchase electricity from Non-Conventional Renewable Energy (NCRE) Sources according to the Cabinet Approval dated 7th March 2014. The SPPA will continue for NCRE projects with a capacity up to 10MW. The tariff will be three-tire-tariff and effective from 1st January 2012 until further notice.

i) Three-tier Tariff

All prices are in Sri Lanka Rupees per kilowatt-hour (LKR/kWh). This will consist of a fixed rate, operations and maintenance (O&M) rate and a fuel rate.

Table 5.17 Three-tier Tariff for ORE

(Unit: LKR/kWh)

Technology/ Source	Escalable Base O&M Rate (Year 1-20)	Escalable Base Fuel Rate (Year 1-20)	Non-escalable (fixed rate)		
			Tier 1: Year 1-8	Tier 2: Year 9-15	Tier 3: Year 16-20
Mini-hydro	1.83	None	15.56	5.98	3.40
Mini-hydro-local	1.88	None	15.97	6.14	3.49
Wind	1.30	None	22.05	8.48	4.82
Wind-local	1.33	None	22.60	8.69	4.94
Biomass	1.52	12.25	9.67	3.72	2.11
Biomass 16yr onwards	1.90	—	—	—	—
Agro & Industrial waste	1.52	6.13	9.65	3.71	2.11
Agro & Indus 16yr onwards	1.90	—	—	—	
Waste Heat	0.48	None	9.14	3.52	2.00
Escalation rate for year 2013	5.16%	3.44%	—	—	—

(Source: draft LTGEP 2020-2039)

Any other renewable energy technology other than those specified above would be offered a flat tariff of Rs. 23.10 / kWh (non-escalable for 20 years).

At present competitive bidding process is also being followed for the development of planned NCRE projects.

(3) Promotion of Roof Top PV

1) General

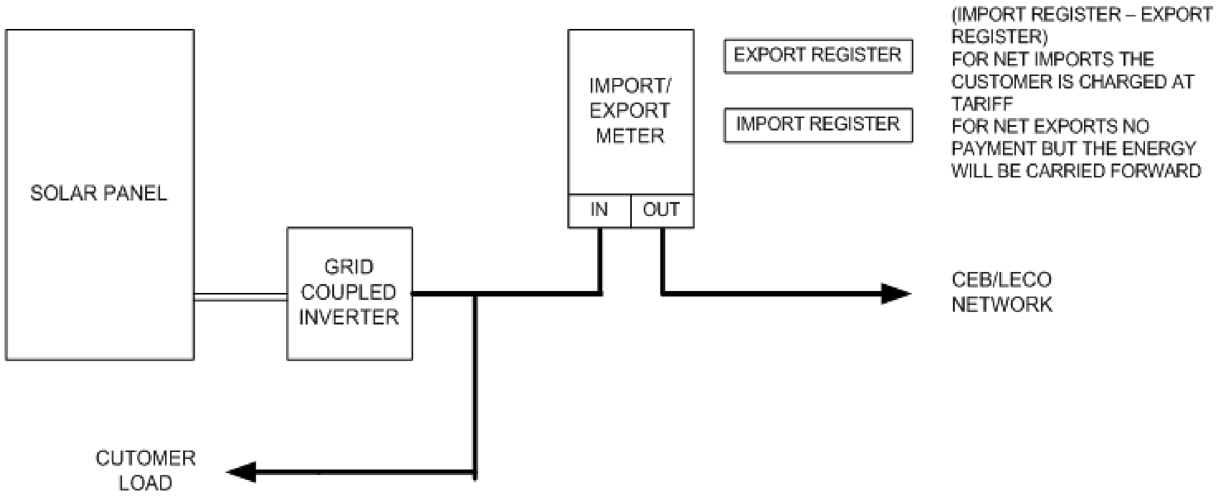
As above mentioned, the method of procurement of power plants are through competitive bidding process at present. Hence FIT (Feed in Tariff) is not available at the moment. The only exception is the Solar PV roof top programme. In 2014 pilot project was introducing to promote solar roof top projects (about 22 projects) with capital subsidy and concessionary financing funded by ADB. Presently another solar roof top project is in operation for projects up to 50kW capacity with concessionary financing (interest rate: 6%) and this is too is funded by ADB.

2) Metering

As for metering system, there are three (3) metering system for PV plant as follows.

a) Net metering

For net imports, the customer is charged at tariff and for net exports no payments will be paid and the energy will be carried forward.

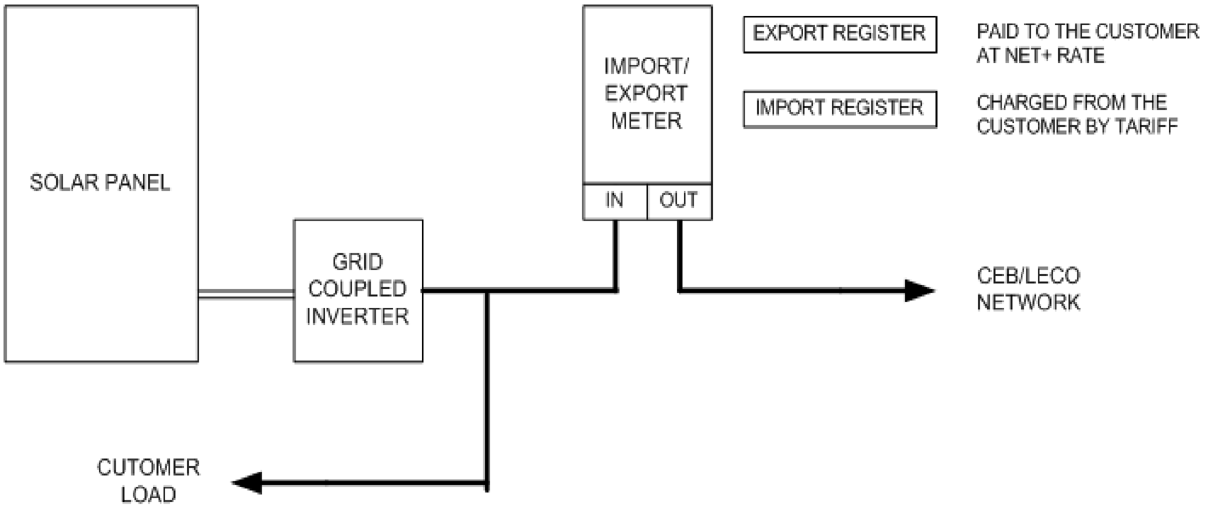


(Source: CEB information)

Figure 5.2 Net Metering

b) Net Accounting

Net imports of Net exports will be charged/paid as per the tariff. Tariff scheme is, LKR 22.00/kWh for first seven (7) years and LKR15.00/kWh for next thirteen (13) years.

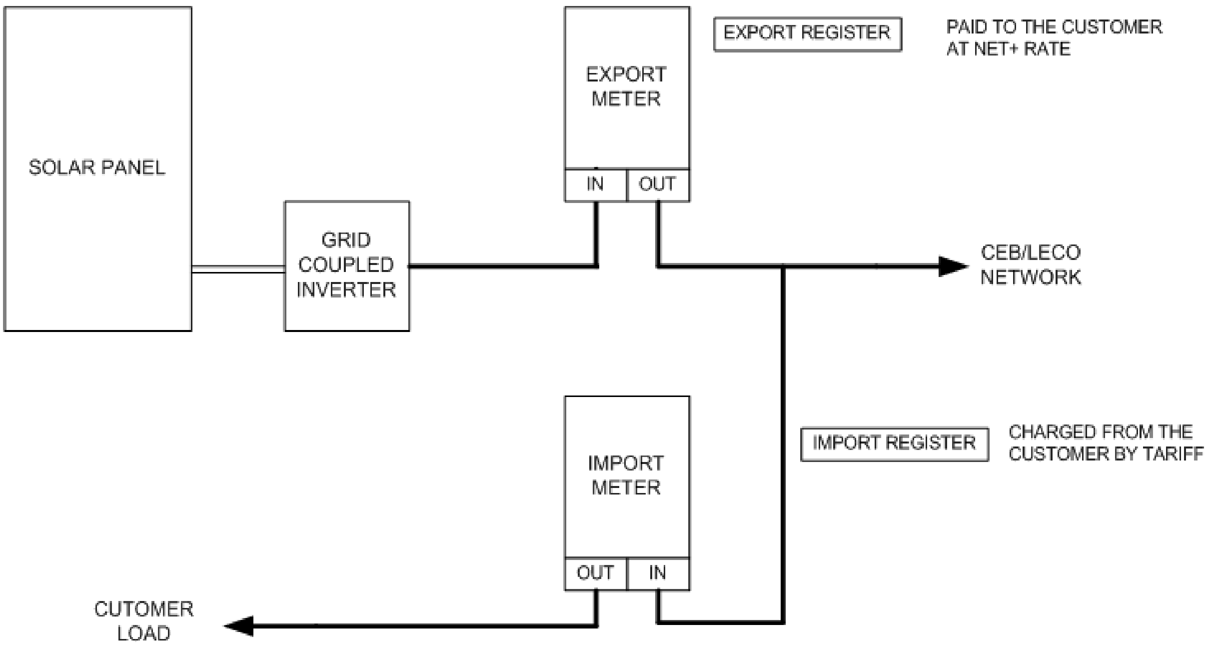


(Source: CEB information)

Figure 5.3 Net Accounting

c) Net Plus

Total energy generation from the generating source is paid at tariff. The total energy consumption by the customer (including his own generation) is charged as per the tariff. Tariff scheme is, LKR 22.00/kWh for first seven (7) years and LKR15.00/kWh for next thirteen (13) years.



(Source: CEB information)

Figure 5.4 Net Plus

(4) Implementation of standard procurement plan

[Tentative Indicator for PDM]: Standard procurement plan is implemented

The flow chart from application to receiving renewable energy permit is as follows;

1) A developer needs to submit pre-feasibility report to SEA. When a developer submits the report, the developer pay application fee to SEA, depending on amount of power proposed to be generated.
   ・When generation amount is less than 1,000kW, application fee is 100,000 LKR.
   ・For each additional 1,000kW, additional application fee is 50,000 LKR on pro rata basis.
2) Developer makes a presentation to Project Approving Committee (PAC) in SEA.
3) Developer receives "Provisional Approval" if PAC approves their project. Developer with provisional approval discusses with relevant authorities. If all relevant authorities approves the project, SEA issues "Energy Permit" to developer.

CEB request developer to submit the copy of energy permit before examination of connection to on-grid network.
The VRE power station should enter commercial operation within two years of receiving the renewable energy permit.
The bottleneck to obtain renewable energy permit is that it takes much time because there are many relevant authorities. There are cases where it takes six (6) to eighteen (18) months to obtain energy permit, even though it depends on VRE source and project scale. Relevant authorities are as follows;
・Central Environmental Authority
・Divisional Secretary
・Pradeshiya Saba (local government)
・Depart of Irrigation
・Department of Wild Life
・Urban Development Authority
・Department of Archeology
・Coast conservation & coastal management Department (for project in coastal areas)
・Civil Aviation (for wind)

5.3 Power System Operation

5.3.1 Current Situation of Power System Operation Based on Installation of VRE

(1) Analysis report on RE projects and Grid Codes

[Tentative Indicator for PDM]: The analysis report on VRE projects and Grid Codes for VRE

The study "Integration of Renewable Based Generation into Sri Lankan Grid 2020-2029" with the objective of investigating main challenges and to determine the optimum level of renewable energy based generation to the grid was completed.
It consists of three parts; long term generation expansion, Power system operational study and transmission network studies. According to the results of this study, the maximum penetration level of NCRE resources has been decided.
The analysis result for 2018-2028 is shown in Appendix 2.

(2) Analysis report on issues and impact of transmission system considering increased share of RE

[Tentative Indicator for PDM]: The analysis report on issues and impact of transmission system considering increased share of VRE

1) Supply and Demand Operation considering VRE installation

"Renewable Energy Development & Performance Monitoring Branch under Transmission Division" conducts examination and analysis for VRE installation.

CEB is periodically conducting analysis of "Integration-of-Renewable-based-Generation-Into-Sri-Lankan-Grid in decade" in order to prepare introducing large amount of VRE in future. Latest analysis version is for year 2020-2030.

As long term planning, PV is not considered as a supply power. On the other hand, Wind Turbine power is considered as some supply power. It is necessary to examine that PV and Wind Turbine power will be considered as appropriate supply power because of VRE increasing situation in near future. In addition, reserved power should be considered to keep stability of power system to connect large amount of VRE.

Currently, VRE power output to grid system is limited not to exceed the power capacity of distribution/transmission line. Thus, no outstanding impact on power system so far.

2) Operation Policy in Power System

Control Branch in CEB stipulates policy for power system operation as below. Detail of the Operation Policy is shown in Appendix 3.

a) System Operation Priority

Safety of Persons

Protection of Equipment

Availability of Supply

Quality of supply

Economies of System Operation

b) Water usage priority

Water service and drainage

Environment

Irrigation

Power

c) System Frequency

The statutory frequency limits are + or – l% of 50Hz. System Control will operate the system with the following frequency range as normal 49 .5Hz - 50.5Hz.

d) System Voltage

System Control will operate the transmission system with following voltages.

Table 5.18 Controlled Voltage in Power System

Status	Voltage		
	220kV	132kV	33kV Grid bus
As normal	+- 10% (242kV to 198kV)	+- 10% (145.2kV to 118.8kV)	+- 2% 33.66kV to 32.34kV
Under emergency	+- 10% (242kV to 198kV)	+- 10% (145.2kV to 118.8kV)	—

(Source: CEB information)

e) System Coefficient

Around 85MW/Hz

f) Spinning Reserve

Spinning Reserve Margin to be not less than 5% of gross generation. Additional High Cost generation may not be started (for short durations) only to keep this spinning reserve margin.

(3) Recommendation report on the measures for adjusting power fluctuations

[Tentative Indicator for PDM]: The recommendation report on the measures for adjusting power fluctuations

Generally, 5% of reserved power in generation plants should be keep for fluctuation of power.
Power plant which can work for adjustment against power fluctuation are shown in Table 5.19.

Table 5.19 Power Plant for Adjustment of Frequency

Name	Capacity	Ramp rate	Frequency control (Secondary, LFC)	AGC integrated	Reserve Margin (primary, secondary)
Victoria	70MW x3	100MW/min	✓	✓	✓
Kotmale	67MW x3	100MW/min	✓	✓	✓
New Laxapana	57MW x2	50MW/min	✓	✓	✓
Samnalawewa	60MW x2	100MW/min	✓	✓	✓
Upper Kotmale	75MW x2	100MW/min	✓ (Change output verbally)	—	✓
KCCP GT	110MW	100MW/min	✓ (ditto)	–	✓

(Source: CEB information)

(4) Understanding about the advanced system analysis for RE introduction

[Tentative Indicator for PDM]: 50% (Seven (7) Engineers: Power System Planning) of counterparts understand the advanced system analysis for VRE introduction

Power System Planning Department is in charge of power system analysis. There are fourteen (14) engineers in the Department.
No policy for training on advanced analysis on power system. However, CEB is conducting power flow analysis, voltage analysis, frequency analysis and N-1 analysis based on VRE installation situation by means of PSS/E. Thus, engineers in Power System Planning Department have common knowledge about these analysis.

(5) Understanding how to handle the supply and demand power operation under increasing share of VRE

[Tentative Indicator for PDM]: 50% (Seven (7) Engineers: Power System Planning) of counterparts understand how to handle the increased share of VRE

No policy for training on handling the increasing share of VRE.
CEB use both WASP and OPTGEN to derive the generation expansion plan and the related cost and energy/capacity balances are obtained from both models etc. The LOLP values from WASP are indicated in the Table 5.5 of LTGEP 2020-2039. Since the SDDP has the capability to simulate system operation, it is used to study the operational aspects of the long term plan such as minimum load operation, VRE curtailments etc.
Grid Code for Day ahead and monthly dispatch plan describes about power balancing.
Generally, system frequency is being controlled by one Hydro generator unit having capacity of 60-70 MW with the droop setting of 2% by manual intervention of the operator at the power plant.
Further, Automatic Generation Control (AGC) facility also implemented in the System Control and four power plants are integrated with AGC system. During very dry conditions when hydro generation is minimized it affects frequency controlling station as well resulting the frequency stability due to intermittency of VRE.
All other generators are supposed to be free governor mode at a droop setting of 4% and 5%. However, most of the machines don't response for frequency changes properly due to inherent issues with the plants.
Generally, the merit order dispatch during the real time operations as well as forecasting are followed. Usually, System operator planned a day ahead dispatch plan using NCP tool and dispatch the generators accordingly on the following day. Start/stop instructions are given to power plants verbally through telephone.
NCP tool does the economic dispatch in fifteen (15) minutes intervals for both hydro and thermal. The system operator need to input the VRE forecasting to that tool also. At present manual input of data is necessary based on previous day generation profiles.
During heavy wind conditions especially during off peak, system operators are facing dispatch issues of other generators because there is no way curtailing facility of VRE yet.

(6) Development of the capacity on supply and demand/power system operation considering PV and wind turbine output

[Tentative Indicator for PDM]: Nine (9) Engineers in (Power System Operation) of counterparts build the capacity of supply and demand/power system operation considering PV and wind turbine output

Power System Operation Department is in charge of supply and demand/power system operation. PV is not considered as supply power. On the other hand, wind turbine is considered as part of supply power.
There is no model for forecasting power output from VRE.
Nine (9) engineers in Power System Operation Department are working rotationally. So, there (3) shifts per day (8 hrs per shift). Three (3) engineers per shift.

CEB has Renewable Energy Desk in National System Control Center for adequate operation the power system with output of VRE. Monitoring of VRE is really necessary to determine the power demand correctly as they are embedded with the 33kV loads. Short term and long term power demand forecasting is one of the most important parameter in case of short term and long term generation forecasting. Further historical VRE generation is essential to forecast short term and long term VRE generation. Hence monitoring and recording of VRE generation is a key factor for the accurate long term generation forecast. Since long term generation forecast is used for budgetary purpose and inaccurate VRE monitoring and recording really plays very important role.
In addition to above planning aspects, there are severe impacts to real time operations. Off peak power demand drops significantly especially rainy days. If system operator don't know the VRE amount in off peak hours, it would be really difficult to manage the system frequency stability. Generally, we do the frequency control from single unit having capacity of 60-70MW.

One shift Engineer shall be deployed in the Renewable Energy Desk. He will be responsible for

- Processing of real time VRE data and make available for dispatch and network engineers to use in real time operations where necessary.
- Ensuring the recording of VRE generation data
- Forecasting of VRE generation for next three days in different time intervals
- Preparation of daily VRE generation reports

(7) Development of the capacity on formulation of optimal power source plan / power system plan considering PV and wind turbine output

[Tentative Indicator for PDM]: Nine (9) Engineers (Power System Operation) of counterparts build the capacity of formulation of optimal power source plan / power system plan considering PV and Wind Turbine output

Renewable Energy Development & Performance Monitoring Branch under Transmission Division is in charge of installation of VRE.
Currently, Four (4) engineers belong to the Branch.

(8) Development of the capacity on power system access assessment according to the revised Grid Code

[Tentative Indicator for PDM]: Four (4) Engineers (Renewable Energy Development & Performance Monitoring Branch) of counterparts build the capacity of power system access assessment according to the revised Grid Code

Renewable Energy Development & Performance Monitoring Branch under Transmission Division is in charge of reviewing the Grid Code. Four (4) engineers exist in the Branch as aforementioned.
FRT (Fault Ride Through) is considered for VRE connection to power system presently. Reviewing FRT and urgent suppression of generation power need to be discussed for large amount of VRE installation.

(9) Establish of advanced forecasting systems for PV and wind turbine output and the supply and demand operation with them

[Tentative Indicator for PDM**]:** Advanced forecasting systems for PV and wind turbine output are established, and the supply and demand operation is implemented using it

Nine (9) engineers are working related to forecasting power including output of VRE.
At present, there is no technical methodology to forecast the VRE power output. Most of VRE are considered as negative load, hence it wouldn't be bothered much. VRE which are monitored via SCADA are considered

as supply and they are predicted based on the previous day generation profiles and forecasted the weather conditions.

(10) Report on the on-site trainings for planning Pumped Storage Power Plant (PSPP)

[Tentative Indicator for PDM]: The report on the on-site trainings for planning Pumped Storage Power Plant (PSPP)

No training policy on PSPP. PSPP is not introduced at present. PSPP will be planned to operate for mitigate short term and long term fluctuations of VRE.

5.3.2 Measures for Power System Stability Based on Installation of VRE

(1) Number of engineers assigned to each work in CEB

Numbers of engineer assigned to each work is shown as below.

Table 5.20 Numbers of Engineer Assigned to Each Work

Title	Numbers of engineer
Power System Planning	14 Engineers
Power System Design	16 Engineers
Construction	16 Engineers (Excluding the Engineers in Project Division who are involving construction supervision of turnkey projects)
Power System Operation	9 Engineers
Relay Protection Planning	6 Engineers
Relay Protection Setting	6 Engineers
Maintenance of SCADA System	Substation Automation System (SAS) - 3 Engineers Gateway -2 Engineers Engineers SCADA - 2 Engineers

(Source: CEB information)

(2) Division/ Section is in charge of VRE development/ introduction in CEB and number of engineers belong to the Division/Section.

Renewable Energy Development & Performance Monitoring Branch under Transmission Division is in charge. Four (4) Engineers belong to the Division.

(3) License of power system operator.

Transmission divisions holds the transmission licensee. National System Control Center belongs to Transmission Division in CEB is in charge.

(4) Transfer policy for engineers in CEB

Transfers are carried out as per the Annual Transfer Circular issued by General Manager of CEB. Generally, Engineers are transferred once in five (5) years.

For Certain offices, the experience is adequate. But there are specific work places which requires much time than five (5) years.

(5) Understanding of the advanced power system analysis by counterparts

[Tentative Indicator for PDM]: Seven (7) engineers of counterparts understand the advanced system analysis for VRE introduction

Renewable Energy Development & Performance Monitoring Branch is in charge of advanced analysis on power system based on installation of VRE.

Switching surge analysis is carried out case by case whenever required using PSCAD, Power Factory and ETAP software by the Transmission Design Branch of CEB.
In addition, CEB generally uses some kind of Software for analysis of power system. Kinds of the Software and its license is shown below.

- PSS/E -Power Flow, Transient Analysis, Voltage Analysis, Short Circuit Current calculation
  Number of Licenses of PSS/E- 11Nos of Licenses as follows:
  - 7Nos -Transmission Planning
  - 2Nos-System Control
  - 2Nos-Control & Protection

  Ver. – PSS/E Ver. 33.5.2

(6) Recommendation of improvement of Grid Codes

[Tentative Indicator for PDM]: The improvements of Grid Codes are recommended

Power System Operation Department is in charge of examine the policy in Grid Code.
FRT (Fault Ride Through) is considered for VRE connection to power system presently. Reviewing FRT and urgent curtailment of generation power need to be discussed for large amount of VRE installation.
Currently, PV is not considered as supply power.
There is no model for forecasting power output from VRE.

(7) Countermeasure for VRE fluctuation

[Tentative Indicator for PDM]: At least one (1) countermeasure for VRE fluctuation is employed

At present, no outstanding problem occurred in voltage fluctuation of power system caused by VRE installation, because VRE output power is not so large yet.
There is no model for forecasting power output from VRE.

5.3.3 Capacity Improvement Based on Practice of System Analysis and Operation Technology Considering VRE

[Tentative Indicator for PDM]: Counterpart complies the training materials that are assisted by JICA Expert Team

(1) Training policy/ Curriculums on Power System Management/ Operation in CEB
All internal trainings are carried out by the CEB Technical Training Centre which is under the purview of DGM (Deputy General Manager) for training.
Currently, there is no specific policy on training. CEB has only internal training program for fresh Power System Operation Engineers. As for training for System Control Engineers, CEB prepared Training Guide for System Control Engineers and it describes as follows. Detailed Training Guide for System Control Engineers is shown in Appendix 4.

Table 5.21 Training Guide for System Control Engineers

Training Guide for System Control Engineers

Guideline for training

Trainee must attain comprehensive knowledge on following points during the training period.

1. General Knowledge on Sri Lankan Power System
   - Steady state frequency stability via supply demand balance
   - Hydro Complexes, Power Stations and Grid Substations (GSSs)
   - Installed Capacity of Sri Lankan Power System
   - Load Curve
   - System operation policy guidelines
   - IPPs
   - Water Management Directives
   - Irrigation releases
   - System operating priority order.
   - Water using priority order
2. Generation Dispatch
   - Security Constrained Merit Order Dispatch
   - Optimizing the run of the river plant operations
   - Characteristics of Thermal power stations
   - Characteristics of Hydro power stations
   - Characteristics of IPP Contracts
   - Spinning reserve
   - Currently applicable Single unit loading limitation
   - Day ahead dispatch planning
   - How to decide what machines should be stopped for a given duration
   - How to stagger hydro generation in the load curve to get maximum benefits during Thermal maximum scenario.
   - Managing the generator start/stop during/after the morning peak.
   - Managing the generator start/stop after night peak.
   - Dispatching of generators to accommodate transmission constraints such as line loadings, voltage control, Transformer (T/F) loading etc.
   - Water value Concept
   - Voltage Control
   - Day ahead demand forecast and factors affecting. (Weather, holidays, special events etc.)
   - Frequency controlling machines.
   - Pond balancing under various conditions, (high inflow, unavailability of certain machines in the cascade, head loss etc.).
   - Routine outages of certain machines (Gas side wash, Turbo wash etc.) and durations.
   - Alarms reported by Power stations and action to be taken (MVA limit, generator T/F temperature high, head loss etc.).
   - Communication between power station OEs, SCEs, EEs
   - 33kV feeders taking auxiliary power to some Power stations. (Victoria, Samanala wewa, Upper Kothmale etc.).
   - Power Stations with 33kV GSS

3. Transmission Network Operations

- All SCEs must be familiar with the entire 132kV, 220kV transmission Network layout with prominence to the followings.
- GSS internal arrangement with special emphasis to the followings.
- T/F paralleling and AVR operation schemes.
- Under Ground Cable network (132/220/33kV).
- Operation and Maintenance responsibilities of UG and OH cables
- Auto Re-closure operation
- Permit to Work procedure
- Voltage Control using Generator AVR, T/F Taps, Capacitors, switching off Transmission Line etc.
- Controlling line load flows using Generation, Voltage etc.
- Transmission System Operations such as BB transfer, incoming line transfer.
- Procedure of releasing 33kV feeders for maintenance
- Procedure of releasing Transmission system equipment for maintenance
- New Energization procedure

4. Total Failure restoration.

SCE shall be aware the procedure to follow during System restoration after Total System Failure.

- Control Room Documentation and Reports prepared by SCE
- Literature (Operation Manuals, Safety Manuals, Contingency plans, special Operation Memorandums etc.).
- SCADA/EMS System.
- Trainee SCE should acquire thorough knowledge on NCP tool
- Trainee SCE should acquire adequate knowledge on PSSE/SDDP Software Tools
- Under Frequency Load shedding scheme
- Special protection schemes of Coal power plants and its impact to System Stability
- Renewable Energy Capacity, impacts to system operations and monitoring
- Subordinate staff administration.
- SCC building power supply, fire alarm system, water supply, black start DG operation, Lighting Distribution panels, firefighting.
- Functions of Operation planning, Operations Audit and System Modelling units
- Maintaining the log book
- Power Station/ Grid Substation visits

(Source: CEB information)

(2) Training plan/program during FY2020-2021 for Power System Management/ Operation engineers in CEB

CEB has no specific plan on Power System management/ operation. No scheduled training programs. Sometimes there are some training programs organized by CEB itself or external parties.

(3) Training on Variable Renewable Energy (VRE) such as PV and Wind turbine in CEB.

CEB has no specific plan on Variable Renewable Energy (VRE) such as solar power, wind power in CEB.

(4) Training policy/curriculums on Optimal Power Source Plan or Power System Plan considering PV and Wind Power in CEB.

There is no specific Training Policy. Training on Power System Planning is carried out mainly focusing the PSS/E software which includes following studies:

1. Load Flow Studies
2. Dynamic Studies

(5) Training programs for Power System Management/Operation including VRE conducted by organization other than CEB

It's very rare chance to conduct this subject of training at outside of CEB.

(6) Trainings for Power System Management/ Operation including VRE conducted in overseas countries

Power System Operation and Control in Japan funded by JICA was conducted.

- 2012- E.N.K Kudahewa (WG2 member: Chief Engineer (System Operations), CEB)
- 2014- R.S. Weerathinga (Not member of this project)

(7) Training facilities for Power System Operation in CEB

There is no specific location of training center for Power System Operations. But CEB has the Training Center at Deavananda Road, Piliyandala.

As for SCADA training, CEB has Training Simulator integrated in SCADA for training of the Power System Operation Engineers.

"Power System Stability and Control, Author- Prabha Kundur" is one of technical textbook for the training on power system operation.

(8) Trainers for engineers in Power System Operation in CEB

There is no specific trainer in CEB for engineers in Power System Operation. Training is conducting by On the Job Training.

(9) Policy on designating the work to each engineer in power sector

There is no specific policy. However, the experience and knowledge of the Engineer will be taken into consideration when assigning the work to Engineers.

(10) Number of assignment engineers to Power Operation Department in CEB

Requirement number of engineers is twenty-three (23) Engineers, i.e. nine (9) day time engineers, twelve (12) shift Engineers, one (1) System studies Engineer and one (1) Chief engineers.

However, currently, number of engineers do not satisfied the requirement numbers of engineer.

(11) Evaluation system for engineers in Power System Management/ Operation from the view point of technical skill.

CEB has the evaluation system for engineers in Power System Management/ Operation. Trainees must attain comprehensive knowledge on technical points during the training period. The points is above shown in Table 5.21 in Clause 5.3.3 (1).

5.4 Operation and Maintenance in Distribution Line

5.4.1 Availability in Distribution Line

(1) Analysis report on current status of power supply in terms of reliability and quality

[Tentative Indicator for PDM]: The analysis report on current status of power supply in terms of reliability and quality

SAIFI, SAIDI are reported in an annual report, but no specific report on the analysis on current status of power supply in terms of reliability and quality in distribution line so far.

Current voltage and current three (3) phase unbalance situation in 33kV and 11kV distribution line, one of issue to improve for efficient power supply, is shown in Table 5.22. Currently, there is no clear problem.

Table 5.22 Voltage and Current Unbalance Situation in 33kV and 11kV Distribution Line

Organization	Voltage and current unbalance situation in 33kV and 11kV distribution line
DD1	[Guide line etc.] Only for 400V - PUCSL Guideline 2012 [Three (3) phase unbalance at 11kV distribution line] As three (3) phase transformers are always used. CEB is not experiencing any voltage unbalance in 11kV lines. [Three (3) phase unbalance at 33kV distribution line] As three (3) phase transformers are always used. CEB is not experiencing any voltage unbalance in 33kV lines. [Problems of three (3) phase Unbalance at 11kV distribution line owing to installation of PV/WT] As PV/WTs installations are connected to 11kV lines through three phase transformers (installed within PV/WTs generation facility), CEB is not experiencing any voltage / current unbalance in 11kV lines. [Problems of three (3) phase Unbalance at 33kV distribution line owing to installation of PV/WT] As PV/WTs installations are connected to 33kV lines through three phase transformers (installed within PV/WTs generation facility), CEB is not experiencing any voltage / current unbalance in 33kV lines.
DD2	[Guide line etc.] No Three (3) phase unbalance has occurred. [Three (3) phase unbalance at 11kV distribution line] No Three (3) phase unbalance has occurred. [Three (3) phase unbalance at 33kV distribution line] No Three phase unbalance has occurred. [Problems of three (3) phase Unbalance at 11kV distribution line owing to installation of PV/WT] Not Applicable. [Problems of three (3) phase Unbalance at 33kV distribution line owing to installation of PV/WT] Not Applicable.
DD3	[Guide line etc.] For LV connection (400V), Distribution Code of Sri Lanka issued by Public Utility Commission guideline 2012. [Three (3) phase unbalance at 11kV distribution line] Not Applicable. [Three (3) phase unbalance at 33kV distribution line] As we are using three phase transformers, such voltage unbalance in 33kV level not recorded so far. [Problems of three (3) phase Unbalance at 11kV distribution line owing to installation of PV/WT] Not Applicable. [Problems of three (3) phase Unbalance at 33kV distribution line owing to installation of PV/WT] As we are using three phase transformers, such voltage unbalance in 33kV level not recorded so far.
DD4	[Guide line etc.] No Three phase unbalance has occurred. [Three (3) phase unbalance at 11kV distribution line] No Three (3) phase unbalance has occurred. [Three (3) phase unbalance at 33kV distribution line] No Three (3) phase unbalance has occurred. [Problems of three (3) phase Unbalance at 11kV distribution line owing to installation of PV/WT] Not Applicable. [Problems of three (3) phase Unbalance at 33kV distribution line owing to installation of PV/WT] Not Applicable.
LECO	Not Applicable

(Source: CEB and LECO information)

(2) Recommendation report on the countermeasures to improve reliability and quality of power supply

[Tentative Indicator for PDM]: The recommendation report on the countermeasures to improve reliability and quality of power supply

Main measures to prevent from power failures in distribution line is shown in Table 5.23. Although general measures have been taken, there are no signs of analyzing the cause of failure and leading to actual improvement.
C/P and JICA Expert Team will discuss to seek more appropriate and effective way to avoid power failures in distribution line.

Table 5.23 Main Measures to Prevent from Power Failures in Distribution Lines

Organization	Main measures to prevent from power failures
DD1	-Inspection of distribution line and clear the vegetation disturbing the line clearance -Coordination of protective devices -Maintenance of line hardware -Adopting polymer insulators in salt-damaged areas -Good workmanship -Line rehabilitation -Grid maintenance once a year -Getting load reading in trans former (TF) and identify overload conditions, based on that send new planning proposals, system augmentation (new feeder arrangement , new transformer) -Analyzed network lodging by planning software and identify overload condition and 33kv feeder arrange in advance -Training the relevant staffs
DD2	-Inspection of distribution line and clear the vegetation disturbing the line clearance -Coordination of protective devices -Maintenance of line hardware -Good workmanship -Line rehabilitation -Grid maintenance once a year -Getting load reading in TF and identify overload conditions, and based on that send new planning proposals system augmentation (new feeder arrangement , new transformer) -Analyzed network lodging by planning software and identify overload condition and 33kv feeder arrange in advance -Training the relevant staffs -Converting bare conductors to Arial Bundled Conductors -Use of proper connectors, jumpers with correct tools
DD3	-Inspection of distribution line and clear the vegetation disturbing the line clearance -coordination of protective devices - Maintenance of line hardware -Good workmanship -Line rehabilitation -Grid maintenance once a year -Getting load reading in TF and identify overload conditions, based on that send new planning proposals, system augmentation (new feeder arrangement , new transformer) -Analyzed network lodging by planning software and identify overload condition and 33kv feeder arrange in advance -Training the relevant staffs

Organization	Main measures to prevent from power failures
DD4	-Inspection of distribution line and clear the vegetation disturbing the line clearance -Coordination of protective devices and annual testing of protection devices -Maintenance of line hardware -Good workmanship -Line rehabilitation -Grid maintenance once a year -Getting load reading in TF and identify overload conditions, based on that send new planning proposals, system augmentation (new feeder arrangement , new transformer) -Analyzed network loading by panning software and identify overload condition and 33kV feeder arrange in advance -Training the relevant staff
LECO	-Routine maintenance of distribution lines and wayleave clearing -Introduce protective devices -Preventive maintenance activities of distribution assets -Improve the line clearances with line accessories by introducing insulating covers like pole top covers.

(Source: CEB and LECO information)

(3) Effectiveness of the recommendations from the pilot projects to improve reliability and quality of distribution network

[Tentative Indicator for PDM]: The effectiveness of the recommendations from the pilot projects to improve reliability and quality of distribution network

In this Project, C/P and JICA Expert Team will conduct pilot project in distribution line by installation of equipment to improve reliability for power supply.
At the beginning of the Project, C/P and JICA Expert Team discuss candidate site of pilot project.

5.4.2 Measures for Reduction of Faults in Distribution Line

(1) Review report on current O&M practice for distribution network

[Tentative Indicator for PDM]: The review report on current O&M practice of distribution network

Subjects of trainings regarding distribution line, such as system planning, system design, power system operation, power failure detection, operation and maintenance, renewable energy connection etc., in each organization are shown in Table 5.24. Although general training is conducted mainly for younger workers, almost no specialized training has been carried out for blackout failure countermeasures.

Table 5.24 Subjects of Trainings regarding Distribution Line

Organization	Type of Training
DD1	[Type of Training (i)] Distribution System Planning [Type of Training (ii)] Sri Lankan Power System and Future [Type of Training (iii)] Solar PV Generation [Type of Training (iv)] Power Quality [Type of Training (v)] Aerial Bundled Conductors and accessories
DD2	[Type of Training (i)] Distribution System Planning [Type of Training (ii)] Use of Syner GI Software for Distribution Planning [Type of Training (iii)] Sri Lankan Power System and Future [Type of Training (iv)] Distribution Line Construction [Type of Training (v)] Distribution Transformer Maintenance [Type of Training (vi)] Aerial Bundled Conductors and accessories
DD3	[Type of Training (i)] Distribution System Planning [Type of Training (ii)] Sri Lankan Power System and Future [Type of Training (iii)] Solar PV Generation [Type of Training (iv)] Power Quality [Type of Training (v)] Aerial Bundled Conductors and accessories
DD4	[Type of Training (i)] Distribution System Planning [Type of Training (ii)] Operation and Maintenance
LECO	[Type of Training (i)] Operation and Maintenance of 11kV O/H and UG Lines List of training modules conducted by the Training Center is attached as Table 5.25.

(Source: CEB and LECO information)

Table 5.25 List of Training Modules Conducted by the Training Center in LECO

No.	Module Name
Module 1	Basic Management
Module 2	Industrial Relations
Module 3	Supervisory Skills
Module 4	Problem Solving and Decision Making
Module 5	Project Management
Module 6	Strategic Management
Module 7	Public Relation and communication
Module 8	Finance for non-financial executives
Module 9	Budgeting (annual budget preparation)
Module 10	Fundamentals of Business Accounting
Module 11	Management Auditing
Module 12	Technical Knowledge (core business of LECO) for Clerks
Module 13	Branch Office Procedure Related to Customer
Module 14	Administrative Activities of the Branch Office
Module 15	Basic Computer Knowledge
Module 16	MS Office Package - Word
Module 17	MS Office Package - Excel
Module 18	"Pronto" Software Package
Module 19	Billing Software

No.	Module Name
Module 20	Personnel and Payroll
Module 21	Company Orientation for New Recruits
Module 22	Communication Skills (Secretaries, Receptions and Steno/Typists)
Module 23	Quality Management System and Good House Keeping
Module 24	Procurement Procedure and Stock Control
Module 25	Electricity Act and Regulations
Module 26	General Safety
Module 27	LV line Construction
Module 28	HV Line Construction
Module 29	Equipment Installation
Module 30	Construction Process
Module 31	Testing and Commissioning
Module 32	Sub-Station and Switching Station commissioning
Module 33	Maintenance of HV Power Lines, LV Power Lines and Meter Connection
Module 34	Equipment Maintenance
Module 35	11kV Line Failure
Module 36	LV Line and Service Cable Failure
Module 37	Safety of LECO
Module 38	Tools and Equipment Used in Construction, Maintenance and Breakdown Process
Module 39	Practice and Usage of tools and Equipment for Special Purpose Tools
Module 40	Hydraulic Tools and Tools for Line Construction
Module 41	LV Line Design and Planning
Module 42	HV Line Design and Planning
Module 43	Sub-Station Design and Planning; Switching Station commissioning
Module 44	Loss reduction and Control in the LECO Distribution System
Module 45	Special Construction
Module 46	Energy Meter
Module 47	Technician Training Programme for Grade iii Technicians
Module 48	Technician Training Programme for Grade ii Technicians
Module 49	Technician Training Programme for Grade I Technicians
Module 50	Technician Training Programme for Grade I (special) Technicians
Module 51	Induction Training Programme for Newly Requited Technicians
Module 52	Induction Training Programme for Newly Requited Technical Officers
Module 53	Induction Training Programme for Newly Requited Engineers

(Source: LECO information)

(2) Development of the capacity of power outage reduction measures by installation of facilities

[Tentative Indicator for PDM]: At least six (6) of counterparts build the capacity of power outage measures using facilities

Knowledge on reduction of power outage in distribution line did not enough penetrate into engineers of each DD1, DD2, DD3, DD4 and LECO. Recloser and Fault Indicator are introduced into distribution line in Sri Lanka so far.

Therefore, C/P and JICA Expert Team join to conduct pilot project by introducing and trial using the facilities for reduction of power outages in distribution line under the Project.

5.4.3 VRE Connection to Distribution Line

[Tentative Indicator for PDM]: Review report on the power fluctuation on distribution system

(1) Regulation/Guideline for PV/WT installation

CEB has Regulation/Guideline for PV/WT installation is follows,

>CEB guide for grid interconnection of embedded generators, December 2000 (Part 1 & Part 2)

>Grid connection requirement for large scale roof top solar power plants - addendum to the CEB guide for grid interconnection of embedded generators, December 2000. (Annexure 3)

(2) Power/Voltage Fluctuation

Current situation of power/voltage fluctuation in distribution line is shown in Table 5.26. Not satisfactory data is collected on the fluctuation situation of power/voltage in distribution line.

Table 5.26 Current Situation of Power/Voltage Fluctuation in Distribution Line

Organization	Power/voltage fluctuation situation
DD1	No data exists. Active/Reactive power and voltage transition data are presently not available, since Grid Power Station (GSS) don't install VTs at each 33 kV feeders at GSS. The only possible option is providing current flow data from the log books. If not those data may collected by installing separate meters / data loggers on above selected 33kV feeders
DD2	Some active power can be provided. 10.0MW Valacchena – Feeder 05 (Eastern Province) 3.0MW- Veyangoda – Feeder 08 (Western Province North) 1.0MW- Pallekele – Feeder 06 (Central Province)
DD3	Currently, no recorded data is available. If Active/Reactive power and Voltage transition data is required, data can be obtained.
DD4	Active/Reactive power and Voltage data are presently not available. Only current flow data from the log books maintained by Control Room Operators is available.
LECO	Not Applicable

(Source: CEB and LECO information)

(3) Maximum installed capacity of PV/WT in 33kV distribution lines

Maximum installation capacity of PV and/or Wind Turbine (WT) power generations connected to 33kV distribution line under current situation is shown in Table 5.27.

No PV and WT power generation connect to 11kV distribution line.

Table 5.27 Maximum Installed Capacity of PV/WT in 33kV Distribution Lines

Organization	Installed capacity of PV/WT in 33kV distribution lines
DD1	In the present network of CEB-DD1, the maximum capacity of the PV & WT power generation connected to 33 kV distribution line is 10MW. However, allowed capacity will depend on the loading of the existing 33kV feeder and the location (length) of the generation source along the feeder.
DD2	No information
DD3	Single point available maximum feeding is 2MW. It is Solar PV installation. However collectively maximum Solar PV feeding in 33kV line is 4,081kW (without rooftop solar, less than 42kVA). This allowed capacity will depend on the loading of the existing 33kV feeder and the location (length) of the generation source along the feeder.

Organization	Installed capacity of PV/WT in 33kV distribution lines
DD4	10MW
LECO	Not Applicable

(Source: CEB and LECO information)

(4) Development of the capacity of measuring and analyzing power/ voltage fluctuations in distribution lines caused by photovoltaic/ wind turbine output

[Tentative Indicator for PDM]: At least six (6) of counterparts build the capacity of measuring and analyzing power/voltage fluctuations caused by photovoltaic/ wind turbine output

At present, both no measuring and no analysis on fluctuation of frequency/ voltage are conducted in CEB. VRE did not make any effect on the frequency/ voltage in distribution lines because of their small amount of installation so far.

Therefore, engineers in charge of the analysis generally do not experience what kind of problem will occur by VRE installation.

Under above situation, Distribution Divisions are considering problems of excess over allowable voltage level owing to PV installation and Table 5.28 shows the problems.

Table 5.28 Problems of Excess of Allowable Voltage Level

Organization	Problems of excess of allowable voltage level
DD1	-All PV / WT installation connected to 33kV lines are operating at Voltage Control Mode. Hence, possible voltage excess are mitigated introducing voltage limitation to each PV / WT generation, where necessary. -However, with this situation, CEB-DD1 has to limit integration / capacities of PV / WT generation for certain 33kV feeders, till the voltage improvements are implemented on the network. i) Polonnaruwa Feeder 04 ii) Valachchenei Feeder 05
DD2	No problem exist so far. Voltage Limit Not exceeded due to PV/WT installation.
DD3	Medium Voltage level connected Solar PV connecting in “Voltage control mode”. Therefore, no any recorded instance for voltage limit violation due to solar PV. However, in future CEB-DD3 may have such issues.
DD4	PV is installed in voltage control mode. Therefore not exceeded.
LECO	Not Applicable

(Source: CEB and LECO information)

Also, Distribution Divisions are considering problems of excess over allowable capacity owing to PV installation and Table 5.29 shows the problems. Practically, no outstanding problems have occurred so far.

Table 5.29 Problems of Excess of Allowable Capacity

Organization	Problems of excess of allowable capacity
DD1	-The maximum current of 33 kV feeders does not exceed the facility capacity as PV / WTs. They run below allowable voltage limit. -However, capacity excess expected to occur in case of introducing new PV /WTs generation to certain 33 kV lines, such as i) Polonnaruwa Feeder 04 ii) Valachchenei Feeder 05 iii) Puttalam Feeder 01 iv) Norochcholai Feeder 02
DD2	No outstanding problem have occurred. Voltage Limit Not exceeded due to PV/WT installation
DD3	Not recorded such cases in DD3 so far. However, CEB-DD3 study the connection feasibility based on voltages before giving any connection clearance.
DD4	Not Applicable
LECO	Not Applicable

(Source: CEB and LECO information)

(5) Study report on the pilot sites to confirm the response ability for load fluctuation by installing batteries in distribution substation or feeder

[Tentative Indicator for PDM]: Study report on the pilot sites to confirm the response ability for load fluctuation by installing batteries in distribution substation or feeder

Currently, there is no storage battery connected to distribution feeder.

5.4.4 Capacity Development of Distribution Line Engineers

(1) Type of Training

Type of training on distribution line is described in 5.4.2 (1).

(2) Evaluation on Engineering Trainees after their Training

Each organization, DD1, DD2, DD3, DD4 and LECO, have evaluation methods on engineering trainees respectively as shown in Table 5.30.

Table 5.30 Subjects of Trainings regarding Distribution Line

Organization	Evaluation method of Training
DD1	[Evaluation on training] Yes [Evaluation method] Through the evaluation sheet given at the end of each training sessions.
DD2	[Evaluation on training] -CEB has CEB training centers. Most of programs are conducted to lower level technical staffs. A few training programs are available for engineers (in distribution) time to time. -All the new engineers are given introduction trainings (class room & field) 2 or 3 months about the Generation, Transmission & Distribution. -Several no of trainings are arranged by Training branch and divisional wise annually. [Frequent training Programs] -Syner GI Software is arranged for all Distribution Planning engineers -Distribution Transformer Maintenance (trainer CEB engineers) -Aerial Bundled Conductors and accessories (trainer CEB engineers) [One time overseas training Programs arranged during past years] (few engineers are participated) -Training on Ifix Software -Training on IConiX Software -Auto Recloser Training at NOJA Power Company, Australia, etc. [Evaluation method] -By the evaluation sheet given at the end of each training sessions. -After Engineers completed 3 years working period, interviews are carried out to evaluate their knowledge by panel of Senior CEB engineers.
DD3	[Evaluation on training] Yes [Evaluation method] -Through the evaluation sheet given at the end of each training sessions.
DD4	[Evaluation on training] Yes [Evaluation method] -By Feedback forms
LECO	[Evaluation on training] Yes [Evaluation method] -By Feedback forms

(Source: CEB and LECO information)

(3) Policy/standards/guidelines for Load Fluctuation Suppression by installation of storage batteries, etc.
There is no Policy/standards/guidelines for Load Fluctuation Suppression in all DDs and LECO.

(4) Regulations/guidelines for phase balance of voltage
"Distribution Code of Sri Lanka, 2012 introduced by PUCSL" is the guideline for phase balance of voltage.

(5) Regulations/guidelines for introducing PV and/or Wind Turbine (WT) generations
"CEB Guide for Grid Interconnection of Embedded Generators, 2000-Part I and II" is the guideline for introducing PV and/or Wind Turbine (WT) generations.

(6) Regulations/guidelines for introducing Storage Batteries.
There is no Policy/guidelines for introducing Storage Batteries.

(7) Officers, engineers and staffs who engaged to work on Load Fluctuation Suppression

There is no such specific engineer or staff for engaging the work on Load Fluctuation Suppression.

(8) Division/Section is in charge of Load Fluctuation Suppression

There is no such specific Division/Section currently.

(9) Evaluation systems for engineers in Load Fluctuation Suppression from the view point of technical skill

There is no such evaluation system currently.

(10) Trainers for engineers for Load Fluctuation Suppression

There is no specific trainer for Load Fluctuation Suppression.

(11) Training policy/curriculums on SAIFI/SAIDI

System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) are set as one of main index in CEB including each DD. Everyday work for Distribution line improvement in availability will make both SAIFI and SAIDI value reducing. "Distribution Code of Sri Lanka, 2012" is one of relevant Code in which described with SAIFI and SAIFI.

(12) Policy/standards/guidelines on Power Supply Reliability such as prioritization criteria for supplying loads, areas, etc.

"Distribution Code 2012 of PUCSL" is the Guidelines on Power Supply Reliability in distribution line. Prioritization criteria for supplying loads, areas, etc. in power supply reliability via distribution line is shown in Table 5.31.

Table 5.31 Guidelines on Power Supply Reliability and Prioritization Criteria for Supplying Loads, Areas

Organization	Guideline and prioritization area
DD1 DD2 DD3 DD4 LECO	[Guideline] Distribution Code 2012 of PUCSL [prioritization criteria] -Urban and Metropolitan areas: N-1 (Medium Voltage) -Rural area: N-0 (Medium Voltage) -Urban, Metropolitan and Rural area: N-0 (Low Voltage)

(Source: CEB and LECO information)

(13) Installed facilities to reduce power outage duration such as Recloser, Fault Indicator (FI) and Ground Fault Detector etc.

DD1, DD2, DD3, DD4 and LECO have installed the facilities for reduction of power outage as shown in Table 5.32 Most of the facilities are installed in 33kV distribution line.

Table 5.32 Installed Facilities for Reduction of Power Outage

Organization	Installed facilities
DD1	Reclosers
DD2	Auto Reclosers, Fault Indicators
DD3	Reclosers, Fault Indicators
DD4	Auto Reclosers
LECO	Auto Reclosers

(Source: CEB and LECO information)

(14) Outage Reduction improvement in distribution line

1) Section is in charge of Outage Reduction improvement

Division/Section in charge of Outage Reduction improvement and number of related engineers belong to the Division/Section are shown in Table 5.33.

Table 5.33 Installed Facilities for Reduction of Power Outage

Organization	Division/Section	Number of engineers
DD1	DGM(P&D), CE(P&D) of each provinces	10
DD2	DGM(P&D), CE(P&D) of each provinces	13
DD3	DGM(P&D), CE(P&D) of each provinces	12
DD4	DGM(P&D), CE(P&D) of each provinces	10
LECO	System Operation Department	2

(Source: CEB and LECO information)

2) Numbers of engineers who understood about the facilities for reduction of power outage duration

Most of engineers in related division in each organization have knowledge and know-how about the facilities for reduction of power outage duration described in 5.4.4 (13) and number of engineers who have enough knowledge about the facilities is shown in Table 5.34.

Table 5.34 Number of Engineers who have Knowledge about the Facilities

Organization	Number of engineers
DD1	About 10 engineers (all planning engineers in the division)
DD2	About 13 engineers (all planning engineers in the division)
DD3	About 12 engineers per division
DD4	All planning engineers in the division (about 10 engineers) and maintenance engineers
LECO	10 engineers

(Source: CEB and LECO information)

3) Training Policy/Curriculums on Outage Reduction Countermeasures

There was no policy/curriculums on the Outage Reduction Countermeasures. And in 2020-2021 year, also there is no plan to hold a training on the Outage Reduction Countermeasures.

Furthermore, no specific trainer and no specific textbook on Outage Reduction exists among these organizations.

4) Number of Days/Weeks Conducted a Training for Freshman/New Comer Engineers on Outage Reduction

There is few chance to hold a training for freshman/ new comer engineers on Outage Reduction. Basically, they should be trained on this matter by on the job training. Outline of the training is shown in Table 5.35.

Table 5.35 Holding a Training for Freshman/New Comer Engineers on Outage Reduction

Organization	Training for Freshman/New Comer Engineers on Outage Reduction
DD1	[Training Period] One (1) day [Outline of Training] No specific contents
DD2	[Training Period] One (1) day [Outline of Training] Planning concepts, use of alternative feeding arrangements and Auto reclosers
DD3	[Training Period] One (1) day [Outline of Training] No specific contents
DD4	[Training Period] Not specifically for outage reduction [Outline of Training] N/A
LECO	[Training Period] Not specifically for outage reduction [Outline of Training] N/A

(Source: CEB and LECO information)

5) External trainings including overseas training on Outage Reduction

There is no such external training including overseas training on Outage Reduction in distribution lines.

6) Evaluation system for engineers in Outage Reduction from the view point of technical skill

All DDs and LECO have no evaluation system for engineers in Outage Reduction from the view point of technical skill.

(15) Policy/standards/guidelines on Procurement

"National Procurement Manual and Guideline issued by National Procurement Commission" is used as guideline for procurement.

5.5 Capacity Building

5.5.1 Training for CEB Staffs

(1) Yearly training program results for engineers of CEB

CEB conducts technical and non-technical training for executive engineers as Workshop and Capacity Development (CD) Training at the training center. These training in 2018 and 2019 are shown in Table 5.36 and Table 5.37 respectively.

Table 5.36 Workshop and Capacity Development (CDP) Training at the Training Center in 2018

No.	Course Name	Category of Executives	Technical Training/Other	No of Programmes	Partici pants
1	Workshop on “Labour Law” for Executives	Senior executives	Other	3	192
2	Workshop on “Effective use of IT” for Junior Executives	Junior Executives	Other	2	49
3	Workshop on “Contract Management” for Engineers in CEB	Engineers	Other	2	232
4	Workshop on “Procurement Management” for CEB Executive	Senior executives	Other	1	100
5	Workshop on “Power Quality and Applicable Standard for Connecting Solar PV Plant to the Grid” for Engineers	Engineers	Technical	3	205
6	Workshop on “Bidding Document Preparation” for Engineers & Accountants	Engineers & Accountants	Other	1	119
7	Workshop on “Public Private Partnership for CEB Engineers	Engineers	Other	1	49
8	Workshop on “Power System Protection”	Engineers	Technical	1	125
9	Workshop on “Earthling” for Engineers	Engineers	Technical	2	182
10	Workshop on “Financial Management” for Engineers	Engineers	Other	1	70

(Source: CEB information)

Table 5.37 Workshop and Capacity Development (CDP) Training at the Training Center in 2019

No.	Course Name	Category of Executives	Technical Training/Other	No of Programmes	Partici pants
1	Workshop on “Labour Law” for Senior Executives in CEB	Senior executives	Other	2	156
2	Workshop on Present Status and Future of Electricity Sector & Planning Perspectives	Engineers	Technical	2	176
3	Workshop on “Power System Protection”	Engineers	Technical	1	116
4	CPD Training Progaramme on “Induction to Sri Lanka Power System Tariff Setting & Regulatory Structure for CEB Engineers	Engineers	Technical	2	257
5	Workshop on “Procurement Management” for CEB Executive	Senior executives	Other	1	64
6	Induction Training Programme for Junior Executives	Junior Executives	Other	1	58
7	CPD Training Progaramme for “Financial Management"	Engineers	Other	1	122
8	CPD Training Progaramme for “Distribution Planning” for Engineers	Engineers	Technical	1	126
10	CPD Training Progaramme for “Transmission Maintenance”	Engineers	Technical	1	128
11	CPD Training Progaramme for “Transmission Construction ”	Engineers	Technical	1	75
12	CPD Course on “Disciplinary Procedures” for Senior Executives	Senior executives	Other	1	125
13	CPD Training Programme for Procumbent & Contract Management for Accountants	Accountants	Other	1	107
14	MS Excel Training on Advanced Analysis For Business and Technical Users for Accountants	Accountants & Acct.Assistant s	Other	1	107

(Source: CEB information)

Technical training programmes other than above training including training for linesman conducted in 2018 and 2019 are shown in Table 5.38 and Table 5.39 respectively.

Table 5.38 Training Programmes in 2018

No.	Training Programme	Duration	Attendance
1	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2018.01.02 - 01.19	50
2	Training programme for Linesman Grade I	2018.01.08 - 02.02	30
3	Training programme for Trainee Jounior Technical Mates Stage III	2018.01.08 - 01.26	44
4	Training programme for Consumer Coordinator	2018.01.08 - 01.12	29
5	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.01.15 - 02.02	60
6	Training programme for Junior Technical Mates	2018.01.15 - 04.06	35
7	Training programme for Trainee Junior Technical Mates Stage III	2018.01.29 - 02.16	60
8	Training programme for Trainee Semi Skilled Consumer Coordinator (Central Province)	2018.01.08 - 01.17	60
9	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2018.01.29 - 02.16	49
10	Training programme for Technical Mates	2018.02.12 - 03.09	45
11	Training programme for Trainee Semi Skilled Consumer Coordinator (North Western Province)	2018.02.14 - 03.02	54
12	Training programme for Trainee Semi Skill Consumer Coordinator (Kinchigune TC)	2018.02.19 - 03.09	44
13	Training programme for Trainee Jounior Technical Mates Stage III	2018.02.19 - 03.09	45
14	Training programme for Semi Skilled Billmen	2018.03.05 - 03.09	51
15	Training programme for Artificer	2018.03.05 - 03.16	43
16	Training programme for Trainee Junior Technical Mates Stage III (N6)	2018.03.12 - 03.29	45
17	Training programme for Control Room Operator Grade II	2018.03.12 - 04.06	22
18	Training programme for Junior Technical Mates (N6 to N5)	2018.03.12 - 04.06	35
19	Training programme for Artificer	2018.03.19 - 03.29	48
20	Training programme for Consumer Coordinator Grade I	2018.04.02 - 04.06	57
21	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.04.23 - 05.11	58
22	Training programme for Trainee Junior Technical Mates Stage II	2018.04.23 - 05.11	30
23	Training programme for Control Room Operator Grade I	2018.04.23 - 05.18	8
24	Training programme for Junior Technical Mates	2018.04.23 -07.13	44
25	Training programme for Artificer	2018.05.01 -05.12	41
26	Training programme for Technical Mates	2018.05.14 - 06.08	30
27	Training programme for Mechanical Fitter Grade II	2018.05.14 - 06.08	2
28	Training programme for Electrical Fitter Grade II	2018.05.14 - 06.08	30
29	Training programme for Trainee Junior Technical Mates Stage II	2018.05.28 - 06.14	43
30	Training programme for Semi Skilled Consumer Coordinator	2018.05.21 -05.25	57
31	Training programme for Linesmen Grade II	2018.05.14 - 06.08	41
32	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.06.11 - 06.29	58
33	Training programme for Junior Technical Mates	2018.06.18 - 07.03	46

No.	Training Programme	Duration	Attendance
34	Training programme for Trainee Junior Technical Mates Stage III	2018.06.18 - 07.06	43
35	Training programme for Artificer	2018.06.18 - 06.29	42
36	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.07.09 - 07.26	64
37	Training programme for Linesman Grade I	2018.07.09 - 08.03	39
38	Training programme for Technical Mates	2018.07.16 - 08.11	33
39	Training programme for Trainee Junior Technical Mates Stage III (N6)	2018.07.09 - 07.26	57
40	Training programme for Artificer	2018.07.30 - 08.10	39
41	Training programme for Billmen Grade I	2018.07.30 - 08.03	28
42	Training programme for Linesman Grade I	2018.08.06 - 08.31	26
43	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.08.13 - 08.31	65
44	Training programme for Artificer	2018.08.13 - 08.24	38
45	Training programme for Mechanical Fitter Grade I	2018.08.13 - 09.07	9
46	Training programme for Electrical Fitter Grade I	2018.08.13 - 09.07	2
47	Training programme for Junior Technical Mates	2018.08.27 - 09.21	53
48	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.09.03 - 09.21	49
49	Training programme for Trainee Junior Technical Mates Stage III	2018.09.10 - 09.28	40
50	Training programme for Trainee Junior Technical Mates Stage II	2018.09.03 - 09.21	25
51	Training programme for Junior Technical Mates Stage III	2018.09.25 - 10.19	49
52	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.09.10 - 09.28	68
53	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.09.25 - 10.12	46
54	Training programme for Linesmen Grade II	2018.09.25 - 10.19	64
55	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2018.10.01 - 10.19	45
56	Training programme for Trainee Junior Technical Mates Stage III	2018.10.22 - 11.16	56
57	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.10.15 - 11.02	45
58	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2018.10.22 - 11.16	46
59	Training programme for Linesman Grade I	2018.10.22 - 11.17	25
60	Training programme for Technical Mates	2018.10.29 - 11.30	36
61	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.11.05 - 11.23	51
62	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2018.11.19 - 12.14	53
63	Training programme for Trainee Junior Technical Mates Stage III	2018.11.19 - 12.14	48
64	Training programme for Trainee Semi Skill Consumer Coordinator (Kalawana TC)	2018.11.26 - 12.14	51
65	Training programme for Junior Technical Mates	2018.11.26 - 12.21	57
66	Training programme on Lath Machine Operating	2018.12.03 - 12.07	5
67	Training programme on Energy Meters	2018.12.10 - 12.11	16

(Source: CEB information)

Table 5.39 Training Programmes in 2019

No.	Training Programme	Duration	Attendance
1	Training programme for Linesmen Grade II	2019.01.07 - 02.01	56
2	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2019.01.07 - 01.25	47
3	Training programme for Trainee Junior Technical Mates Stage III	2019.01.07 - 02.01	50
4	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2019.01.07 - 02.01	42
5	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2019.01.28 - 02.22	44
6	Training programme for Artificer	2019.01.21 - 02.01	39
7	Training programme for Linesmen Grade II	2019.02.05 - 03.02	47
8	Training programme for Artificer	2019.02.05 - 02.16	29
9	Training programme for Trainee Junior Technical Mates Stage III (Tamil Medium)	2019.02.05 - 03.02	46
10	Training programme for Trainee Semi Skilled Consumer Coordinator (Northern Province)	2019.02.05 - 02.22	89
11	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.02.11 - 03.01	50
12	Training programme for Control Room Operator Grade II	2019.02.20 - 03.16	31
13	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2019.02.25 - 03.22	44
14	Modular Training Programme	2019.02.11 - 02.15	6
15	Training programme for Trainee Junior Technical Mates Stage III (Tamil Medium)	2019.03.05 - 03.29	41
16	Training programme for Junior Technical Mates (N5)	2019.01.14 - 04.05	55
17	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.03.25 - 04.12	44
18	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.03.25 - 04.12	45
19	Modular Training Lath Machine	2019.03.11 - 03.15	8
20	Training programme for Technical Mates	2019.04.22 - 05.17	52
21	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.04.22 - 05.17	36
22	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.04.22 - 05.10	38
23	Training programme for Trainee Junior Technical Mates Stage III	2019.04.22 - 05.17	55
24	Training programme for Junior Technical Mates	2019.04.22 - 07.12	51
25	Modular Training (Energy Meters)	2019.04.23 - 04.25	13
26	Training programme for Artificer	2019.05.06 - 05.17	36
27	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.05.13 - 05.31	39
28	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.05.20 - 06.14	39
29	Training programme for Trainee Junior Technical Mates Stage III	2019.05.20 - 06.14	42
30	Training programme for Technical Mates	2019.05.27 - 06.21	49
31	Training programme for Linesman Grade I	2019.06.03 - 06.28	33
32	Training programme for Junior Technical Mates	2019.06.17 - 07.12	51
33	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.06.17 - 07.12	34
34	Training programme for Trainee Junior Technical Mates Stage III	2019.06.24 - 07.19	58
35	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.06.03 - 06.21	49

No.	Training Programme	Duration	Attendance
36	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.06.24 - 07.12	39
37	Modular Training	2019.06.24 - 06.28	4
38	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.07.15 - 08.02	40
39	Training programme for Trainee Junior Technical Mates Stage III	2019.07.22 - 08.16	37
40	Training programme for Mechanical Fitter Grade II	2019.07.22 - 08.16	27
41	Training programme for Electrical Fitter Grade II	2019.07.22 - 08.16	24
42	Training programme for Trainee Junior Technical Mates Stage II	2019.07.15 - 08.13	34
43	Training programme for Linesmen Grade II	2019.07.08 - 08.02	29
44	Training programme for Linesmen Grade II	2019.08.05 - 08.30	50
45	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.08.05 - 08.23	47
46	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.08.19 - 09.12	34
47	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.08.26 - 09.12	43
48	Training programme for Junior Technical Mates	2019.08.26 - 09.20	43
49	Training programme for Trainee Junior Technical Mates Stage III	2019.09.02 - 09.27	51
50	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.09.16 - 10.11	43
51	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.09.16 - 10.04	51
52	Training programme for Artificer	2019.09.16 - 09.27	44
53	Training programme for Junior Technical Mates (N5)	2019.09.30 - 12.20	57
54	Training programme for Semi Skilled Technical Service	2019.09.30 - 10.25	34
55	Training programme for Mechanical Fitter Grade I	2019.09.30 - 10.25	19
56	Training programme for Electrical Fitter Grade I	2019.09.30 - 10.25	26
57	Training programme for Semi Skilled Consumer Coordinator	2019.10.07 - 10.11	38
58	Training programme for Trainee Junior Technical Mates Stage III	2019.09.30 - 10.25	53
59	Training programme for Trainee Junior Technical Mates Stage II	2019.10.14 - 11.08	40
60	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2019.10.21 - 11.14	37
61	Modular Training Programme (Auto Mobile)	2019.10.14 - 10.18	2
62	Training programme for Trainee Junior Technical Mates Stage III	2019.10.28 - 11.22	42
63	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.11.18 - 12.13	41
64	Training programme for Linesmen Grade II	2019.11.18 - 12.13	37
65	Modular Training Programme for Modular (ABC Power Line)	2019.11.08 - 11.09	10
66	Modular Training Programme for Modular (PLC Circuit)	2019.11.05 - 11.07	15
67	Training programme for Technical Mates (N4)	2019.11.25 - 12.20	48
68	Training programme for Junior Technical Mates (N5)	2019.11.25 - 12.20	56
69	Training programme for Trainee Semi Skilled Consumer Coordinator	2019.11.25 - 12.13	38

(Source: CEB information)

(2) Location of CEB Training Center & list of main facilities in the Training Center for practical technical training, such as Circuit Breaker, Protection Relay Panel, Electric Pole for training, etc. with simple specification and number of main facilities.

CEB has a training center located Deavananda Road, Piliyandala.
Main facilities at the training center are shown in Table 5.40.

Table 5.40 Training Facilities at CEB Training Center

Infrastructure facilities

No.	Facility	Quantity	Remarks
1	Auditoriums	3 nos	
2	Lecture halls (class rooms)	8 nos	
3	Computer labs	1 nos	
4	Workshops	6 nos	Wiring ,meter, control, lathe, machine and linesman
5	Cafeteria	1 nos	
6	Hostel	2 nos	Executive & non-executive

Model Lines & other

No.	Facility	Quantity	Remarks
1	LT ABC model line	1 nos	
2	33kV MV line model	1 nos	
3	HT ABC model line	1 nos	Under construction
4	Protection Lab	1 nos	Operated by Tr. Protection branch
5	model gantry	1 nos	

(Source: CEB information)

Chapter 6 Baseline of Project Indicator for Overall Goal

Objectively Verifiable Indicators in the Project on Overall Goal is set up three (3) items as below.

6.1 SAIFI, SAIDI and LOLP

(1) SAIFI (System Average Interruption Frequency Index)

[Tentative Indicator for PDM]: SAIFI at urban, rural areas, etc. [times/capital/year]:
at 2026
11 in DD1, DD2, DD3, DD4 and LECO (to be discussed during the Project)

System Average Interruption Frequency Index (SAIFI) is one of main index to show how many times blackout occurred per one year, per one consumer.
Present value of SAIFI in Sri Lanka in 2017 is shown in Table 6.1.

Table 6.1 SAIFI in Sri Lanka

Organization	SAIFI [Number]
DD1	15.1 (2018)
DD2	43.8 (2018)
DD3	56.8 (2018)
DD4	36.2 (2018)
LECO	109 (2017)

(Source CEB information)

(2) SAIDI (System Average Interruption Duration Index)

[Tentative Indicator for PDM]: SAIDI at urban, rural areas, etc. [minutes/capital/year]:
at 2026
1,320 in DD1, DD2, DD3, DD4 and LECO (to be discussed during the Project)

System Average Interruption Duration Index (SAIDI) is main index to show how long duration blackout occurred per one year, per one consumer.
Present value of SAIDI in Sri Lanka in 2017 is shown in Table 6.2.

Table 6.2 SAIDI in Sri Lanka

Organization	SAIDI [Minutes]
DD1	4,532 (2018)
DD2	4,468 (2018)
DD3	4,885 (2018)
DD4	5,911 (2018)
LECO	4,196 (2017)

(Source CEB information)

(3) LOLP (Loss of Load Probability)

[Tentative Indicator for PDM]: LOLP in 2026: 1.5% or less

LOLP is power system index to show probability on shortage of supplied power from power generations to necessary power. The target of LOLP is 1.5% or less.

According to LTTDP 2018-2027, past LOLP values in Sri Lanka were 1.245% at 2018, 0.220 (expected) at 2019. According to LTGEP 2020-2039, planned value of LOLP at 2026 is 0.077%.

Reserve Margin is considered as the input for the optimization software while the maximum LOLP is another constraint. The Reserve Margin criterion has been subjected to debate and revised plan for LTGEP 2020-2039 has been prepared on Reserve Margin criteria of 2.5-20% as per the requirement of the regulatory commission. Both these constraints are stipulated in the Grid Code based upon which the LTGEP is prepared. Theoretically, there exists a relationship between the reserve margin and the LOLP which varies with time depending system characteristics. Appropriate values for RM and LOLP based on system characteristics and reliability requirements could be further explored.
In the WASP tool, annual LOLP is calculated based on monthly LOLP values. WASP calculates the monthly LOLP values for different hydro conditions and then computes a weighted average LOLP for each month. Then the simple averages of monthly values give the annual LOLP value and it is obtained as an output of the optimization/simulation software.

6.2 Fluctuation of Voltage and Frequency in Power System

[Tentative Indicator for PDM]: the same level as before large amount installation of PV and wind Power

In this indicator, it is targeted that fluctuation level after installation of large amount of VRE will be controlled the same level as present status.

At present, as for voltage control, all power transformers are kept in Automatic Voltage Regulator (AVR) in Auto mode to do the automatic control of 33kV voltage and 132kV voltage where having 220/132kV Auto Transformers.
Capacitor banks are connected to 33kV bus and they are supposed to be connected to the system automatically based on the power factor of the bus. However, in that case system don't get the adequate reactive power from capacitors. Hence system operators need manual switching of the capacitors.
At present, CEB don't have any SVC and Reactors are planned to be connected to 220kV bus in the near future.
Please refer to 5.4.3 (2) about current situation of voltage fluctuation in distribution line.

6.3 Error of the Prediction System of PV and Wind Turbine Output

[Tentative Indicator for PDM]: Error of the prediction system of PV and wind turbine output in 2026 within 20% (Average)

At present, no prediction system for VRE output established.
System Operator predict coming output of VRE by means of their experiences.

It is important to get weather information for prediction of VRE output. Department of Meteorology is in charge of collection of weather information and forecast. CEB and Department of Meteorology are government organizations and NSCC is engaging with Department of Meteorology to obtain the information about the activation of monsoons. However, the weather data necessary for developing the weather forecasting system used in this project will be charged.

(End of report)

スリランカ国

電力マスタープラン実現に向けた
能力向上プロジェクト

キャパシティアセスメントレポート

2020 年 10 月

中部電力株式会社

日本工営株式会社

スリランカ国電力マスタープラン実現に向けた能力向上プロジェクト
キャパシティアセスメントレポート

目　次

添付資料

(1) Project Design Matrix (PDM)
(2) Integration of Renewable Based Generation into Sri Lankan Grid 2020-2030
(3) Operation Policy in Power System
(4) Training Guide for System Control Engineers

図及び表

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<表>

略語表

Word	Original
ADB	Asian Development Bank
AGC	Automatic Generation Control
ASEAN	Association of South East Asian Nations
CA	Capacity Assessment
CD	Capacity Development
CEB	Ceylon Electricity Board
CF	Corporate Finance
C/P	Counterpart
CPC	Ceylon Petroleum Corporation
CPI	Consumer Price Index
CPIs	Carbon Pricing Instruments
CS	Corporate Strategy
CSC	Consumer Service Center
DD	Distribution Division
DG	Diesel Generator
EE	Electrical Engineer
FIT	Feed in Tariff
FRT	Fault Ride Through
GHG	Greenhouse Gas
GM	General Manager
GMS	Greater Mekong Sub-region
GOSL	Government of Sri Lanka
GSS	Grid Substation
IFC	International Finance Corporation
IPP	Independent Power Producer
JEPIC	Japan Electric Power Information Center
JICA	Japan International Cooperation Agency
KPI	Key Performance Indicators
LECO	Lanka Electricity Company
LOLP	Loss of Load Probability
LTGEP	Long Term Generation Expansion Plan
LTTDP	Long Term Transmission Development Plan
MOPE	Ministry of Power and Energy
MP	Master Plan
NAMA	Nationally Appropriate Mitigation Action
NCRE	Non-Conventional Renewable Energy
NDC	Nationally Determined Contribution
NSCC	National System Control Center
OH	Overhead

Word	Original
OJT	On the Job Training
ORE	Other Renewable Energy
PAA	Project Approving Agency
PAC	Project Approving Committee
PDM	Project Design Matrix
PIR	Price Increase Rate
PMR	The Partnership for Market Readiness
PPP	Private Power Producer
PSPP	Pumped Storage Power Plant
PUCSL	Public Utility Commission of Sri Lanka
RE	Renewable Energy
RM	Reserve Margin
SAIFI	System Average Interruption Frequency Index
SAIDI	System Average Interruption Duration Index
SAS	Substation Automation System
SCADA	Supervisory Control and Data Acquisition System
SCC	System Control Center
SEA	Sustainable Energy Authority
SPA	Seller Participation Agreement
SPP	Solar Power Plant
SVC	Static Var Compensator
TF	Transformer
TGPB	Transmission and Generation Planning Branch
TOU	Time-of-Use
UG	Underground
VRE	Variable Renewable Energy
WG	Working Group
WPP	Wind Power Plant

NIPPON KOEI
中部電力

第1章　序論

1.1　背景

1.1.1　プロジェクトの背景

2017 年度に国際協力機構（以下「JICA」）が協力して策定した「電力マスタープラン」（以下「MP」）では、①経済性を重視するシナリオ、②環境への負荷軽減を重視するシナリオ及び③エネルギー安全保障・経済性・環境のバランスを重視したシナリオの３つが検討され、電力・エネルギー・ビジネス開発省（Ministry of Power, Energy and Business Development、以下「MOPEBD」）及びセイロン電力庁（Ceylon Electricity Board、以下「CEB」）は③を優先シナリオとして選定した。風力及び太陽光等の再生可能エネルギー（以下「再エネ」）のポテンシャルに恵まれているスリランカ国では、供給信頼度やコストに配慮しつつ、今後大量に開発される見込みの再エネを電力系統に円滑に統合するための計画的な設備投資及び系統運用の柔軟性確保に向けた対応が必要となっている。MP では、このシナリオを実現するための優先課題として、配電損失率や供給信頼度の改善のための配電部門の運用高度化等が提案されている。

スリランカ国電力マスタープラン実現に向けた能力向上プロジェクト（以下「本事業」）は、最適な電源構成を実現し再エネの導入を促進するため、変動性再エネへの対応策検討、送配電網増強や供給信頼度向上のための対応策検討、グリッドコード改定や出力の予測・管理技術向上を支援するとともに、財務管理能力に関する CEB 等の組織的能力を強化することを目的としている。

1.1.2　プロジェクトの概要

本事業の概要を以下に示す。

本事業では、①再生可能エネルギーに係る企業戦略及び計画策定能力の強化、②再生可能エネルギー導入量増加に伴う送電系統運用及び開発能力の強化ならびに③配電運用能力の強化の３つの主要な成果（テーマ）を設定しており、それぞれのテーマで、カウンターパートと JICA 専門家から成るワーキンググループ（以下「WG」）を構成して活動を行う。

(1) 上位目標

再生可能エネルギーの導入量増加に対し、送配電系統の安定度及び信頼度が維持･改善される。

(2) プロジェクト目標

長期電源開発計画における再エネ導入量増加に向けた送配電網運用上の信頼度維持･改善のためスリランカ電力セクター関係機関の組織能力が強化される。

(3) 成果

成果１：再生可能エネルギーに係る企業戦略及び計画策定能力が強化される。

成果２：再生可能エネルギー導入量増加に伴う送電系統運用及び能力が強化される。

成果３：配電運用能力が強化される。

(4) 活動

＜成果１に係る活動＞

1-1　再生可能エネルギーに係る企業戦略及び計画

1-1-1 将来のビジネスシナリオを考慮して、再生可能エネルギー導入に伴うCEB企業財務へ与える影響を評価する。

1-1-2 投資ニーズに対応するために、更新された企業財務計画について助言する。

1-1-3 再生可能エネルギーの調達計画・手順について助言する。

＜成果２に係る活動＞

2-1　再生可能エネルギーの技術評価

2-1-1 再生可能エネルギーのプロジェクト（既存及び将来計画）とグリッドコードにおける技術要件をレビューする。

2-1-2 再生可能エネルギー導入量増加に伴う送電系統への影響及び課題を分析する。

2-1-3　高度系統解析のための研修を実施する。

2-2　再生可能エネルギー導入量増加に伴う対策

2-2-1　再生可能エネルギー導入量増加に伴う対策に係る研修を実施する。

2-2-2　出力変動調整のための対策を比較評価する。

2-2-3　系統運用センター（System Control Center、以下「SCC」）に設置予定の再生可能エネルギーデスクの必要要件を整理する。

2-2-4　将来の再生可能エネルギー導入量増加に伴う出力変動への対応力を確認し、出力予測システムの構築を支援する。

2-2-5　揚水発電のための現場研修を実施する。

＜成果３に係る活動＞

3-1　停電削減対策

3-1-1　CEBの配電部及びLECO（Lanka Electricity Company）の停電状況とその原因を分析する。

3-1-2　信頼度向上のための課題解決活動を支援する。

3-1-3　パイロットサイトで事故点探査装置等の導入により、停電対策（復旧時間の改善）のための効果の確認を行なう。

3-1-4　活動3-1-3のパイロットプロジェクトの費用対効果を評価する。

3-2　負荷変動抑制

3-2-1　再生可能エネルギー導入量増加に伴う配電網の出力及び電圧変動を測定し分析する。

3-2-2　パイロットサイトの配電変電所に蓄電池を導入し、負荷変動への対応力を確認する。

(5) JICA 専門家

14 名の専門家を派遣

No.	氏　名	担　当
1	平野　晶	業務主任者／電力戦略
2	吉田　俊貴	副業務主任者／電力戦略
3	谷畑　治	電力制度・政策
4	三井　真一	再生可能エネルギー
5	蒔田　勇作	経済財務
6	Suresh Chand Verma	需給運用
7	高見澤　悠	電力系統（計画、運用）
8	安常　秀信	電力系統（解析）
9	松川　宗夫	気象予測／電力需要予測
10	高津　賢一郎	蓄電池等エネルギー需給管理
11	式町　浩二	配電技術
12	西川　幸司(～2020 年 9 月 30 日) 神谷　幸洋(2020 年 10 月 1 日～)	配電（計画、設計、工事）／業務調整
13	和田　正樹	水力土木（計画、設計、工事）
14	新宮　弘久	地質

1.2　キャパシティアセスメントの概要

1.2.1　キャパシティディベロプメント

本事業では、CEBの組織的能力を強化することを目的としている。目的達成のためのキャパシティディベロプメント（以下「CD」）として、関連するテーマの研修のほか、系統運用及び配電システムの現場での実習（On the Job Training, 以下、OJT）、カウンターパート（以下「C/P」）が直面している課題解決に自ら取り組む活動ならびに本邦研修等を適宜組み合わせ、JICA専門家の技術的サポートを加えて効果的・効率的に実施することにより、再生可能エネルギー導入量増加に伴う電力系統及び配電技術を理解・習得することを目指す。本事業はプロジェクト目標の達成を目指して実施されるが、その成果は、プロジェクト目標を実現することができる政策制度環境及び実施主体の能力をスリランカ実施機関（C/P）及び関係機関が獲得することにある。

本事業では、実施された一連のCDの目標達成度をプロジェクト終了前に評価するとともに、本事業の成果をCEBの内部に定着させ自立発展的に上位目標を達成するための方策について検討し、その結果をCDレポートとして取りまとめることとしている。

1.2.2　プロジェクトデザインマトリックス

本事業の達成目標を明確にするため、プロジェクトデザインマトリックス（以下「PDM」）を策定する。PDMでは、本事業で達成すべき最終目標、目的、アウトプットを明確に定める。CDの最終目標及びアウトプットの目標は事業開始時に設定するため、CDの初期状態すなわちベースラインを把握する必要がある。

PDMに設定された各項目の達成状況は、本事業実施中に定期的にモニタリングされる。モニタリングでは、本事業の初期状態すなわちベースラインからの目標達成に向けた進捗状況をPDMの項目に従って確認し、確実な目標達成に向けた方策等を検討する。モニタリングを的確に行うため、目標値は可能な限り定量的な値とすることが肝要である。本事業のPDMを添付書類1に示す。

1.2.3　キャパシティアセスメントの位置づけ

CDのベースラインを把握し、到達すべき目標値を設定するため、本事業開始時にキャパシティアセスメントを行う。キャパシティアセスメントでは、主に再生可能エネルギー導入量増加に伴う電力系統及び配電技術係る個人・組織・制度レベルでの、プロジェクト開始時点のC/Pの能力を確認する。キャパシティアセスメント（以下「CA」）では、C/Pが達成すべき目標及び目標の達成度を測る手法も念頭に置いて実施する。また、組織のアセスメントにおいては、CEBの財務状況、電気料金の現状課題の分析、財務健全性測定手法等を考慮する。

1.3 キャパシティアセスメントの実施方法

1.3.1 COVID19 影響下における対応

本事業は2020年3月から開始する計画であったが、COVID-19の影響により事業当初から現地渡航ができない状況となっている。かかる状況の中、日本から遠隔による業務実施を模索し、2020年5月より日本からの遠隔で業務を開始した。キャパシティアセスメントについても、業務開始に合わせ、2020年5月から7月にかけて日本から遠隔で実施した。

1.3.2 キャパシティアセスメントの実施方法

キャパシティアセスメントは遠隔でのアンケート及びインタビューにより実施した。

2020年5月に本事業の質問票をCEBに送付したのに合わせ、JIC専門家の各WGより、アセスメントシート（CAアンケート）をCEBに送付した。2020年6月にアセスメントシートの回答を受け、追加確認すべき内容は日本とスリランカを結ぶTV会議によるインタビューにより聞き取りを行った。

今回はC/Pへの直接のインタビューや現地の視察ができない中でのアセスメントとなり、ベースラインの確認や目標値の設定に関する一部の内容については、現地への渡航が開始されてから再度確認すべき点もあることに留意されたい。

キャパシティアセスメントの概要図を図1.1に示す。

- **Organizations to be assessed**

CEB　　Related organization　　MOPE　SEA　LECO　PUCSL

- **Method of Assessment**

Questionnaire, Assessment Sheet and interview　（Remote work from Japan）

- **Outline of Assessment Items**

【General & WG1】

SAIFI	LOLP
SAIDI	Error of Power Prediction
CEB finance condition	Understanding on VRE Technical Matter
CEB Profit	Understanding VRE installation procedure
Corporate Strategy on VRE	

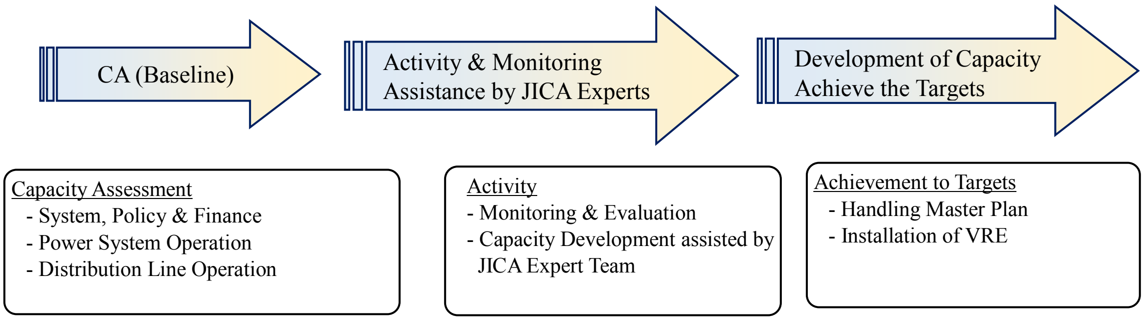
【WG2】

Grid Codes on Electric power System	Adjustment of Power Fluctuation
RE connection to Power System	Training Materials
Power System Analysis	Power Supply/Demand Operation
Handling increased RE	Building Power System Planning

【WG3】

Reliability and Quality in Distribution Line	Installation Battery to Distribution line
O & M in Distribution Line	Understanding of Power Outage Measures
Condition of Power Fluctuation	Understanding of Power Fluctuation

- **Capacity Assessment (CA) and Capacity Development (CD)**



(出所: JICA Expert Team)

図 1.1　キャパシティアセスメントの概要

第2章　スリランカ国の基本情報

2.1　基本情報

2.1.1　人口

スリランカの人口は2,103万人(2016年時点)である。

2.1.2　GDP

スリランカの2018年度の名目GDPは889億米ドル、一人当たりのGDPは4,102米ドルである。また、GDP経済成長率は3.2%である。東南アジア各国との比較を表2.1に示す。

スリランカ経済は，紛争の終結による復興需要や経済活動の活性化等によって，2012年に過去最高となる9.1%の経済成長を達成した。2016年4.5%，2017年3.4%，2018年3.2%と経済成長を維持している。

表2.1　各国のGDP比較

国名	一人当たりのGDP	GDP経済成長率	備考
スリランカ	4,102米ドル	3.2%	2018年値
インドネシア	3,927米ドル	5.2%	2018年値
タイ	7,187米ドル	4.1%	2018年値
フィリピン	3,104米ドル	6.2%	2018年値
インド	2,015米ドル	6.8%	2018年値
日本	39,304米ドル	0.3%	2018年値

（出所: 外務省HP、IMF統計）

2.1.3　CPI (Consumer Price Index)

スリランカの消費者物価指数（CPI）及び東南アジア各国との比較を表2.2に示す。

表2.2　各国のCPI比較

国名	消費者物価指数 または物価上昇率（%）	備考
スリランカ	2.1	2018年値（2013年基準）
インドネシア	3.1	2018年値　物価上昇率
タイ	1.9	2018年値（2015年基準）
フィリピン	5.2	2018年値　物価上昇率
インド	4.6	2019年値　物価上昇率
日本	2.0	2019年値（2015年基準）

（出所: 外務省HP、総務省HP）

2.2　電力関係情報

2.2.1　最大電力

スリランカの過去 5 年間の最大電力を表 2.3 に示す。

表 2.3　スリランカの最大電力の推移

最大電力（MW）				
2014	2015	2016	2017	2018
2,152	2,283	2,453	2,523	2,616

(出所: CEB Annual Report 2018)

2.2.2　発電種別発生電力量

スリランカにおける 2019 年の発電種別発生電力量を表 2.4 に示す。

表 2.4　スリランカの発電種別発生電力量

種別	発生電力量(GWh)（2019 年実績）					
	火力発電（Oil）	火力発電 (Coal)	水力発電	風力発電	太陽光発電 ﾊﾞｲｵﾏｽ発電	ﾙｰﾌﾄｯﾌﾟ PV
CEB	2,137	5,361	3,783	0	―	―
PPP	2,875	―	1,011	348	220	141

PPP: Private Power Producer

(出所: CEB Web Site)

2.2.3　送配電ロス率

スリランカにおける送配電ロス率の過去 5 年間の推移を表 2.5 に示す。

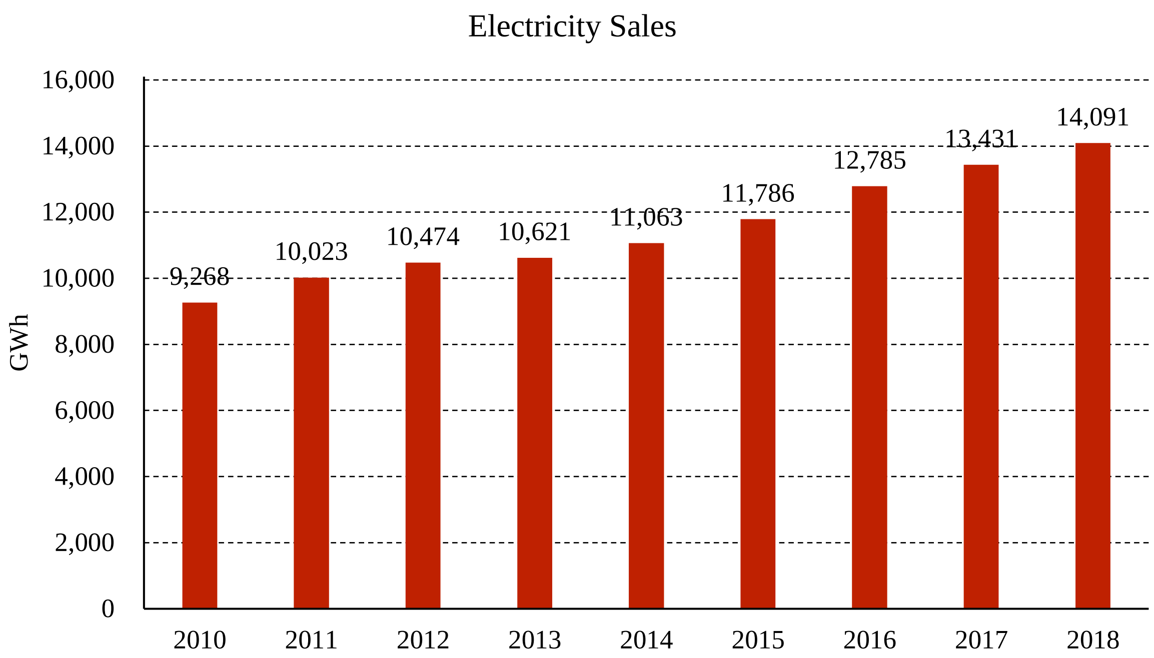
表 2.5　スリランカの送配電ロス率の推移

送配電ロス率（%）				
2014	2015	2016	2017	2018
10.91	10.40	10.28	8.45	8.34

(出所: CEB Annual Report 2018)

2.2.4　販売電力量

LECO を含んだ販売電力量は、2017 年の 13,431GWh から 2018 年には 14,091GWh に増加し、その増加率は 4.9%となっている。販売電力量の推移を図 2.1 に示す。一日当たりの消費電力量は、前年の 36.8GWh から 38.6GWh に増加している。

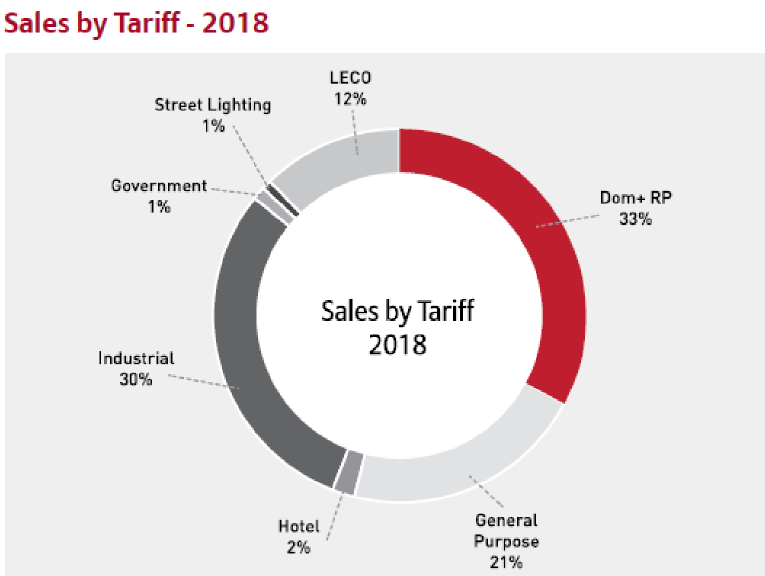


(出所: CEB Annual Report 2018)

図 2.1　販売電力量の推移

2.2.5　電気料金種別販売量

電気料金種別のうち最も販売電力量が多い種別は Domestic and Religious Purpose であり、全体に占めるその販売電力量比率は 32.9% である。次に Industrial Sector が続きその比率は 30.4% である。General Purpose は 20.9%を占めており、その年伸び率は 6%である。図 2.2 に電気料金種別の販売電力量比率を示す。

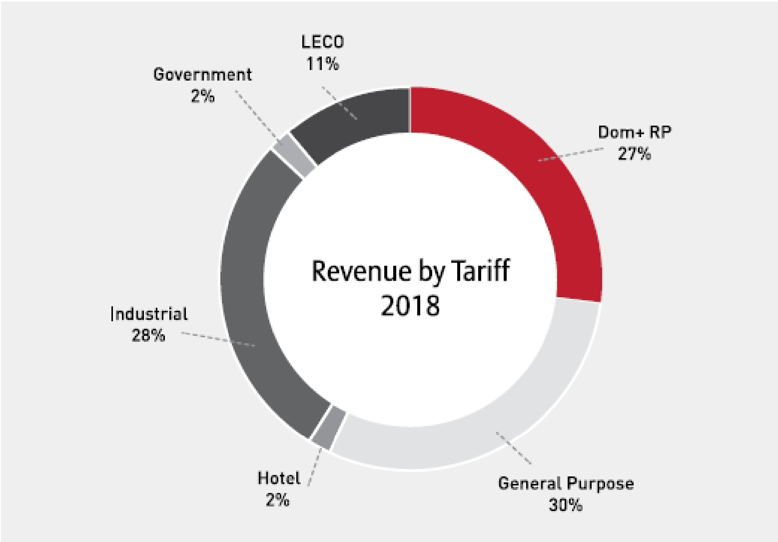


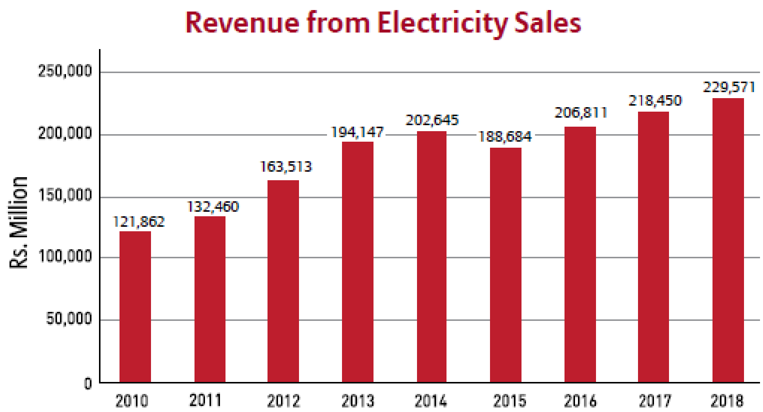
(出所: CEB Annual Report 2018)

図 2.2　電気料金種別の販売電力量比率

2.2.6　電気料金収入

電力販売収入は、2017 年に 2,184.5 億ルピー（約 1,250 億円）、2018 年に 2,295.7 億ルピー（約 1,310 億円）であり、その伸び率は 5.1%である。最も料金収入が多いのは General Purpose カテゴリーであり、Industrial Sector が 27.5%でそれに続いている。Domestic and Religious Purpose カテゴリーの全体に占める料金収入比率は 27.3%である。図 2.3 に電気料金種別の収入を示す。





(出所: CEB Annual Report 2018)

図 2.3　電気料金種別の収入

第3章　事業実施体制

3.1　事業実施体制

発電・送電・配電を担うCEBを実施機関とし、電力・エネルギー政策を管轄するMOPEを監督省庁とする。

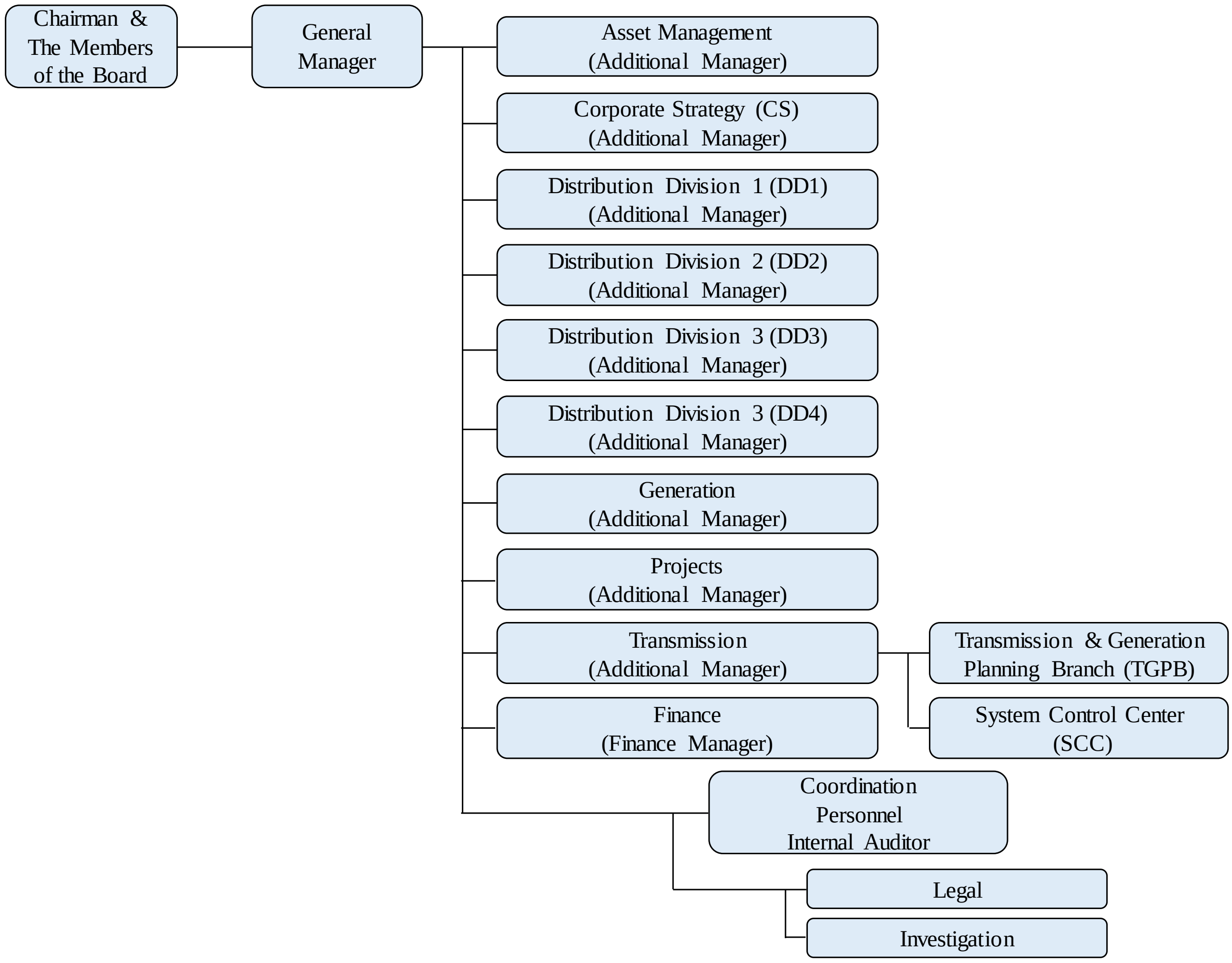
カウンターパートは、CEBの送電計画部門（Transmission and Generation Planning Branch、以下「TGPB」）、系統運用センター（System Control Center、以下「SCC」）、配電部（Distribution Division、以下「DD」）１～４、企業戦略部（Corporate Strategy、以下「CS」）、企業財務部（Corporate Finance、以下「CF」）、LECO（Lanka Electricity Company）、SEA（Sustainable Energy Authority）とする。

規制機関であるPUCSL（Public Utilities Commission of Sri Lanka）は、事業免許発行、電気料金承認等の役割を担っており、再生可能エネルギー導入に伴うCEB企業財務に影響することから協力機関とした。

3.2　CEB 組織体制

3.2.1　CEB 組織　概要

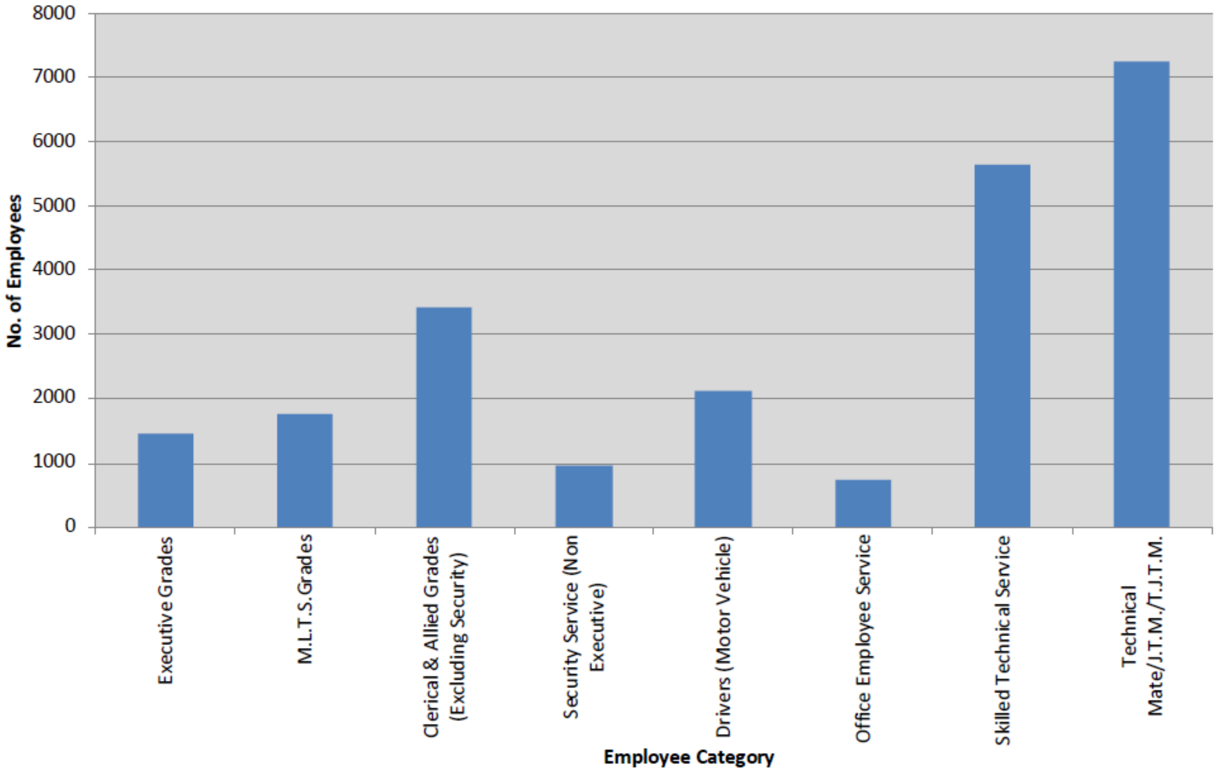
実施機関であるCEBの組織概要図を図3.1に示す。



(出所: CEB Annual Report 2018)

図 3.1　CEB 組織概要図

近年の電力需要の高まりとともに、職員一人当たりの消費電力量も増えている。その比率は、1990年に53であったものが、2016年、2017年にはそれぞれ311及び304となっている。2018年12月31日時点でのCEB職員数は23,380人である。図3.2に各部門の職員数のグラフを示す。



(出所: Corporate Plan 2019-2023)

図 3.2　部門別 CEB 職員数

3.2.2　配電部門及び LECO

スリランカの配電供給はCEBとCEBの出資会社であるLECOによりまかなわれており、CEBが配電供給全体の88%を占めている。CEBの配電部門は、地域で４つのDivision、すなわち、Distribution Division 1 (DD1)、Distribution Division 2 (DD2)、Distribution Division 3 (DD3)及びDistribution Division 4 (DD4)に分けられて配電の運用・管理を行っている。加えて、配電部門のDivision化は、Divisionによる競争を促し、効率化ならびに顧客満足度を向上させる狙いがある。

各Divisionが管轄するProvinceの一覧を表3.1に示す。また、各Division及びLECOの管轄地域図を図3.3に示す。

Provinceはさらに複数のエリアに分割され、各エリアには、顧客数に応じて、Area Chief EngineersまたはArea Electrical Engineersを責任者として置き、運営・管理を行っている。さらに、各エリアには数か所Consumer Service Centers (CSC)を置いてサービスを行っている。

表 3.1　各 Distribution Division の管轄する Province

Name of the Division	Province
Distribution Division 1 (DD1)	Colombo City, North Western, North Central and Northern Provinces
Distribution Division 2 (DD2)	Western Province North, Central and Eastern Provinces
Distribution Division 3 (DD3)	Western Province South II, Uva and Sabaragamuwa Provinces
Distribution Division 4 (DD4)	Western Province South I and Southern Provinces

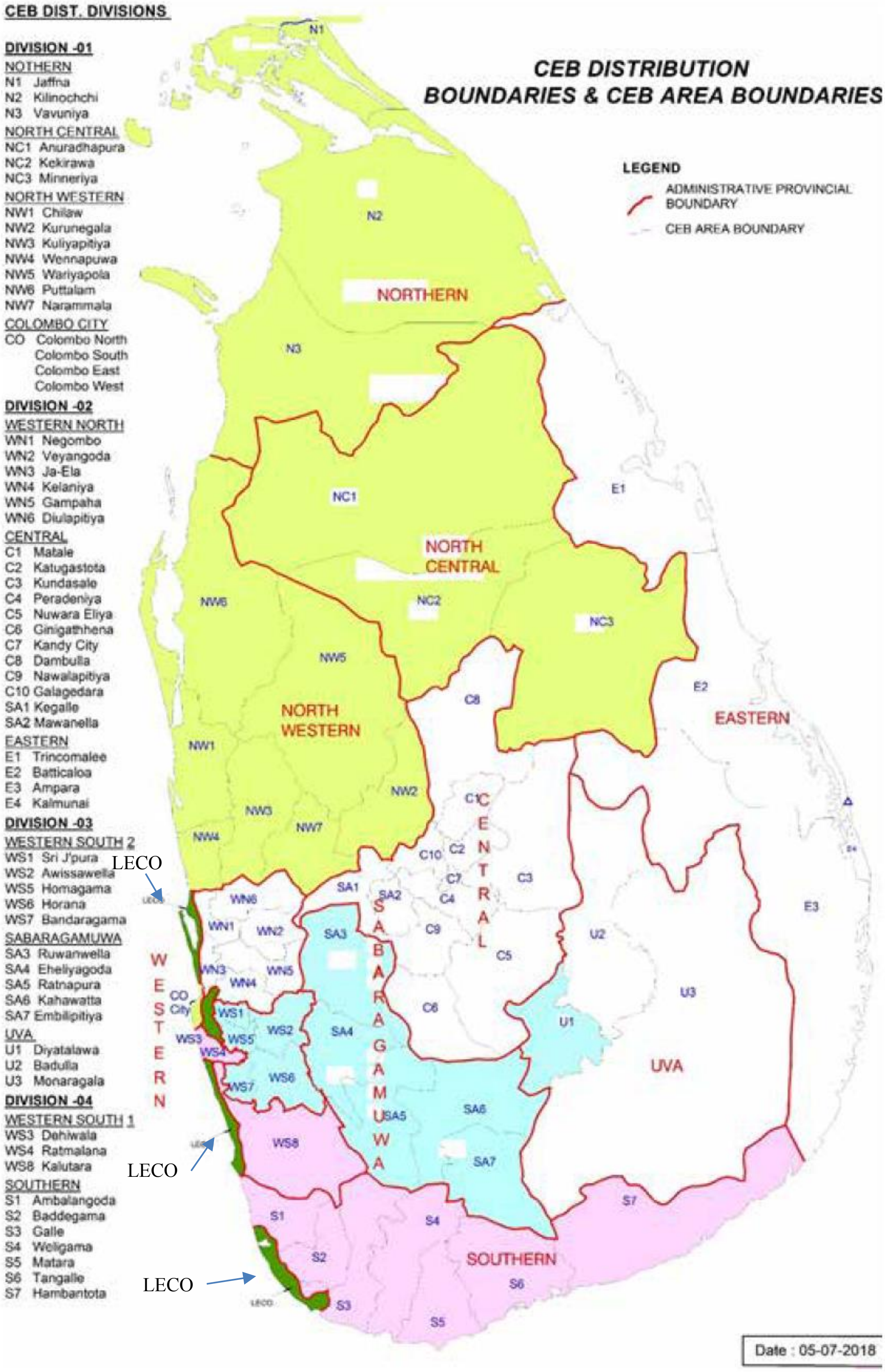
(出所: CEB Annual Report 2018)

各Distribution Divisionが管轄する資産を表3.2に示す。

表 3.2　各 Distribution Division が管轄する資産

資産の種類	Distribution Division1	Distribution Division2	Distribution Division3	Distribution Division4
33kV Lines (km)	10,534	9,185	7,106	4,483
11kV Lines	1,307	627	45	293
33/11kV Primary substations (Nos)	33	43	12	39
LV (400V) Lines (km)	45,465	40,105	31,615	25,623
LV Distribution Substations (Nos)	10,068	9,293	5,854	4,940

(出所: CEB Corporate Plan 2019-2023)



(出所: CEB Annual Report 2018)

図 3.3　各 Distribution Division 及び LECO の管轄エリア

第4章　電力マスタープラン及び長期開発計画

4.1　電力マスタープランの策定状況

スリランカ国における「電力マスタープラン（目標年：2040 年）（MP）」は、JICA の支援により 2017 年度に策定されている。MP では、先述のとおり、①経済性を重視するシナリオ、②環境への負荷軽減を重視するシナリオ、③エネルギー安全保障・経済性・環境のバランスを重視したシナリオの３つが検討され、電力・エネルギー・ビジネス開発省及びセイロン電力庁は、③エネルギー安全保障・経済性・環境のバランスを重視したシナリオを優先案として選定した。

4.2　電力マスタープランにおける再生可能エネルギーの位置づけ

風力及び太陽光等再生可能エネルギー（以下「再エネ」）のポテンシャルに恵まれているスリランカ国では、供給信頼度やコストに配慮しつつ、今後大量に開発される見込みの再エネを系統の安定度を維持したまま連系するための計画的な設備投資及び系統運用の柔軟性確保に向けた対応が必要である。

MP では、電源の多様化とともに、ピーク負荷や変動性再エネに追従可能な電源（揚水発電等）、潜在的な国産ガス及び輸入化石燃料を利用した高効率火力発電の導入、配電損失率や供給信頼度の改善のための配電部門の運用高度化等を、上記シナリオを実現するための優先課題として提案している。

本事業は、最適な電源構成を実現し再生可能エネルギーの導入を促進するため、変動性再エネへの対応策検討、送配電網増強や供給信頼度向上のための対応策検討、グリッドコード改定や出力の予測・管理技術向上を支援するとともに、財務管理能力に関する CEB 等の組織的能力を強化することを目的としている。

4.3　国家エネルギー政策

国家エネルギー政策によると、エネルギー政策の主な目的は、スリランカの社会的に平等な開発を支援する便利で手頃なエネルギーサービスを提供するために、よりクリーンで安全、経済的、信頼できる供給を通じてエネルギーの安全を確保することとされている。General Policy Guidelines on the Electricity Industryなどの政策ガイドラインは、国家エネルギー政策に基づいて策定されることとなっている。

スリランカは、エネルギーの安全、公平、持続可能性の、いわゆるエネルギートリレンマの相反する活動に取り組んでいるが、これら3つの関係は、現在必ずしもうまくバランスしていない。

国家エネルギー政策は、社会、経済、環境に影響を与える幅広い分野に根差した10のテーマに基づいており、それぞれ公平性、安全性、持続可能性の強化を通じてそのバランスを図ろうとしている。

1) エネルギー安全保障の確保
2) エネルギーサービスへのアクセスの提供
3) 経済に最適なコストによるエネルギーサービスの提供
4) エネルギー効率と節約の向上
5) 自立の促進
6) 環境への配慮
7) 再生可能エネルギーのシェア向上
8) エネルギーセクターにおけるガバナンス強化
9) 将来のエネルギーインフラのために用地確保
10) イノベーションと事業促進の機会提供

10のテーマの概要は以下のとおり述べられている。

1） エネルギー安全保障の確保

国の一次・二次エネルギー供給により、継続性、適切性及び信頼性を確保する。

2） エネルギーサービスへのアクセスの提供

信頼でき、便利で、手頃な価格で、公平で質の高いエネルギーサービスへのアクセスは、経済活動に従事しようとするすべての市民に提供されるとともに市民の生活水準を向上させる。

3） 経済に最適なコストによるエネルギーサービスの提供

エネルギーサービスは、最適な長期コストで提供され、国内経済への負担を軽減し、国際市場での現地生産の商品やサービスの競争力を実現する。

4） エネルギー効率と節約の向上

エネルギーの効率的な使用は、サプライヤーとユーザー両者に裨益し、すべてのセクター及びエネルギーバリューチェーン全体で促進される。

5） 自立の促進

技術的、経済的、環境的、社会的制約を解決しつつ、輸入資源への依存を最小限に抑えるために、自国エネルギー資源を最適なレベルまで開発する。同時に、外部要因によるエネルギー供給の脆弱性を最小限にすることを目的とする。

6） 環境への配慮

スリランカのエネルギー部門の低炭素運営を維持することにより、気候変動抑制に貢献する。環境と社会への影響を最小限に抑え、地球環境と地域環境に配慮する。

7） 再生可能エネルギーのシェア向上

サステナビリティとレジリエンスを達成しつつ、自国の再生可能エネルギー資源を最適なレベルまで開発する。

8） エネルギーセクターにおけるガバナンス強化

投資家と消費者の信頼を得るための説明責任、公平性、透明性を実現するためにエネルギー部門のガバナンスを強化する。安定した政策環境が確保され、規制の枠組みが強化されて、エネルギー部門のより良いガバナンスが確保される。

9） 将来のエネルギーインフラのための用地確保

エネルギー設備とインフラを効果的に接続するため、かつ社会への影響を最小限に抑えるために、適切な用地を事前に確保し、タイムリーな設備投入を確実に行う。

10）イノベーションと事業促進の機会提供

高い技術を持ったビジネスを育成するために、スリランカの市場規模の制約も踏まえ、比較的大規模なエネルギーセクターを活用してスリランカでの起業家精神とイノベーションを育成する。

4.4 長期発電拡充計画

CEB は長期発電拡充計画（Long Term Generation Expansion Plan、以下「LTGEP」）を作成している。LTGEP には今後 20 年間の拡充計画が記載されており、2 年ごとに見直しされている。現在 2020 年度から 2039 年度までの LTGEP を作成中である。LTGEP の主要な目的は、調達の透明化及び最小費用化を進めることにある。

LTGEP には、既存発電設備、発電拡充計画策定方針、需要想定、計画プロジェクトの投資及び建設計画、最小費用での拡充計画案が示されている。

第5章　キャパシティアセスメントによる収集情報

本章ではキャパシティアセスメントにより把握したデータもしくは現状の状況を記載する。本章のデータが本事業のベースラインのデータとなる。

なお、プロジェクトデザインマトリックスに掲載している項目を明確にするため、PDM に掲載されている項目に、【PDM 指標案】として付している。

5.1　再生可能エネルギーにかかる政策制度

5.1.1　CEB における VRE 投入戦略及びその定期的見直し

【PDM 指標案】：CEB による VRE 投入量及び投入時期の戦略策定ならびに定期的見直し

長期発電拡充計画（LTGEP）では、20年間の計画を2年ごとに見直しされている。再生可能エネルギー（RE）発電の計画もLTGEPに記載されている。REについては、太陽光発電、風力発電、バイオマス発電などが、水力発電に対して、他の再生可能エネルギー（Other Renewable Energy：ORE）として整理されている。

環境及び気候変動抑制の義務を満たすために、20年の計画期間のすべての発電所開発に関する計画調査が実施される。スリランカはCOP21パリ協定に参画しており、2016年9月にUNFCCCによって承認されたNationally Determined Contributions（NDC）では、スリランカは、気候変動緩和方針として電力部門の温室効果ガス排出量を無条件で4%、さらに条件付きで16%削減すると想定している。これは、LTGEP 2020-2039に組み込まれ、ORE発電と低炭素発電を合わせて、COP21パリ協定におけるスリランカの義務を果たすこととしている。

5.1.2　VRE 種別における長所及び短所の理解

【PDM指標案】: VRE種別ごとの長所及び短所に精通したキーパーソンが1名以上在籍する。

VREの将来の設置計画策定は、Transmission Planning Department and Generation Planning Departmentが担当している。VREの建設計画を担当するエンジニアは、一般に、VREに関する長所と短所を理解している。VREに関するエンジニアの理解度と知識については、本プロジェクトでさらに確認を進める。

VREの開発に関する情報は以下の通り。

100MW Mannar風力発電プロジェクトがCEBにより開発が進められ、2020年12月運開の見通しである。送電線は建設が完了している。大きな容量を持つMannar風力発電所の目的の一つには、今後さらに風力発電を増設しつつ、風力発電所の新たな制御運用をテストすることも含まれている。政府の政策目標を達成するには、Mannar発電所の増設を計画通り進めることにより、LTGEPに記載されているOREの計画容量の開発を達成する必要がある。

毎年の開発計画ごとに、運用の柔軟性、送電及び系統システムの制約を踏まえたREの系統連系分析が実施されている。LTGEPでは、再生可能エネルギー開発促進が記載されており、過去20年間と比較して、今後20年間で5倍以上の再生可能エネルギー開発が計画されている。LTGEPの20年間に計画されているOREの合計容量は、風力発電1,323 MW、太陽光発電2,210MW、小水力発電654MW、バイオマス発電144MWである。

現状、太陽光発電は、ルーフトップ、小規模及び大規模 PV プラントなどのスキームで設置されている。高い電気料金での電力消費を避けるためにハイエンドの消費者に提供されるインセンティブは、ルーフトップ PV システム設置への関心を高めている。ルーフトップ PV は、屋上スペースをスリランカの経済活動に活用することができる。スリランカ政府は、ルーフトップ PV 導入を促進するために、2016年から太陽光発電開発キャンペーンを始めている。2020 年までにルーフトップ PV 容量を 200MW に到達させる目標はすでに達成されており、継続的な開発が期待されている。PUCSL による 2.5%（最小）及び 20%（最大）の予備率基準を採用して LTGEP 2020-2039 のドラフト版が策定され、現在その後一部

見直しがされている。

5.1.3 VRE 設置計画から運用開始までの手続きの理解

【PDM指標案】: VRE設置計画から運用開始までの手続きに精通したキーパーソンが追加で1名以上承認される。

VRE の調達は再生可能エネルギー開発部が担当している。 許可手続きと VRE の調達に関する調達ガイドラインがあり、部門の一部のエンジニアがその手続きを理解している。理解度と改善すべき手順について本プロジェクト内でさらに議論される。

VRE 導入のための調達手続きの概要は以下のとおり。

再エネ開発プロジェクトを申し込む際は、SEA から発行されている On-Grid Renewable Energy Development（2011 年 5 月版が最新）に沿って手続きし、SEA からプロジェクト開発許可を得る必要がある。どの民間企業、外国企業も等しく申し込むことができ、企業や国籍によって手順の違いはない。

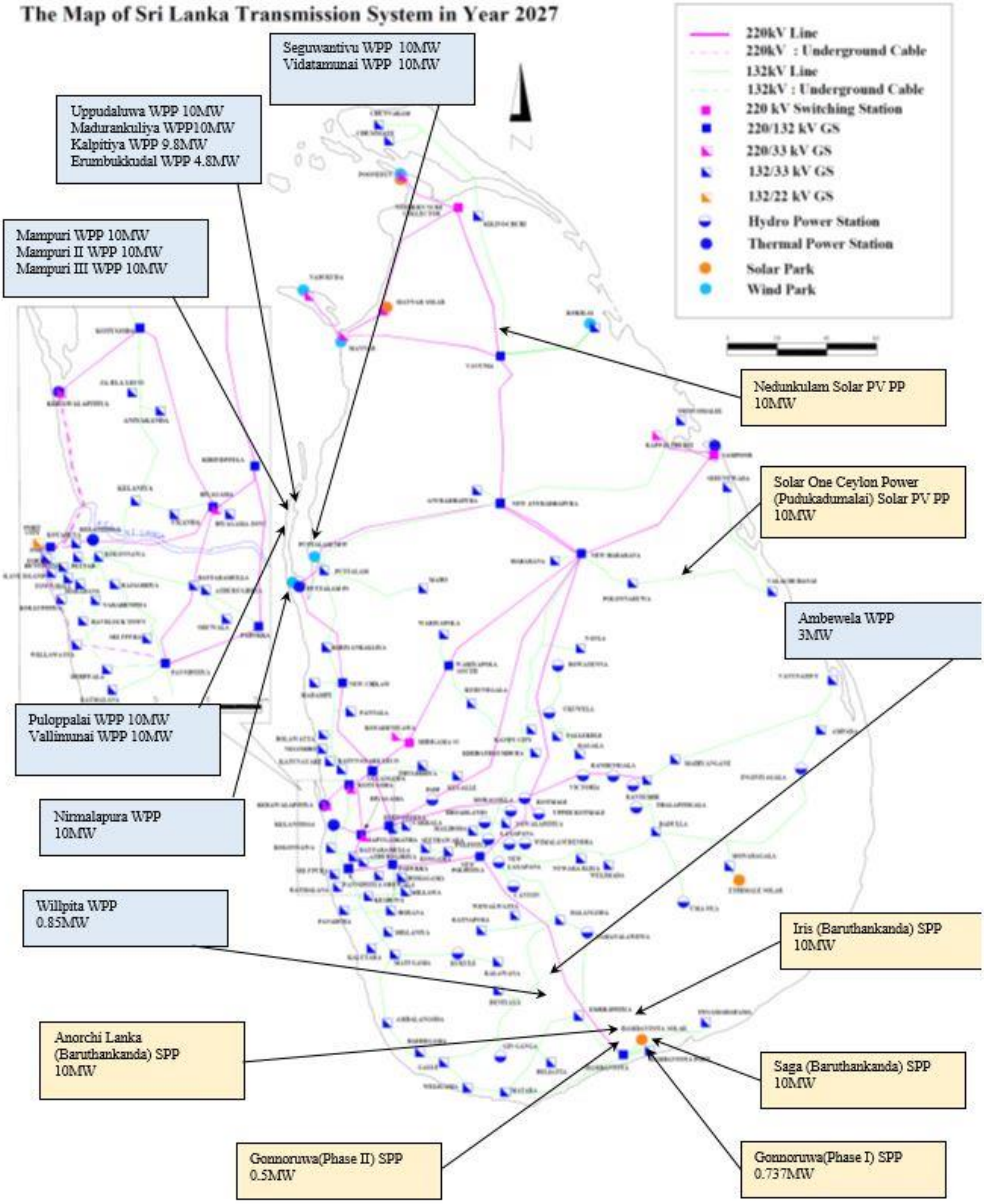
5.1.4 スリランカエネルギー方針に基づく VRE 導入計画立案

【PDM指標案】: スリランカエネルギー方針に基づき1件以上のVRE導入計画が立案される。

現状の VRE 導入計画は以下の通りである。

(1) 2027 年断面の PV、WT 及び SPP 導入計画

2027 年断面の PV、WT 及び SPP 導入計画を図 5.1 に示す。



(出所: CEB information)

図 5.1　2027 年断面の PV、WT プラント及び SPP の導入計画

2020 年時点の、既存 PV 発電所及び PV 発電所開発計画は表 5.1 及び表 5.2 のとおり。

表 5.1 既存 PV 発電所（2020 年時点）

	Developer Name	Solar Plant Name	Capacity (MW)	Location		
				Connected GSS	Latitude	Longitude
1	Japan Solar Plant (SEA)	Gonnoruwa Phase I SPP	0.737	Hambanthota	6°13'31.31"N	81°4'38.07"E
2	Korean Solar Plant (SEA)	Gonnoruwa Phase II SPP	0.5	Hambanthota	6°13'34.94"N	81°4'31.86"E
3	Saga Solar	Saga (Baruthankanda) SPP	10	Hambanthota	6°13'53.59"N	81°5'8.85"E
4	Iris Eco Power Lanka (Pvt) Ltd	Iris (Baruthankanda) SPP	10	Hambanthota	6°13'57.19"N	81°4'43.77"E
5	Anorchi Lanka (Private) Ltd	Anorchi Lanka (Baruthankanda) SPP	10	Hambanthota	6°13'39.72"N	81°4'50.40"E
6	Solar One Ceylon (Pvt) Ltd	Solar One Ceylon Power (Pudukadumalai) Solar PV PP	10	Valachchenai	7°58'31.22"N	81°14'9.89"E
7	Vydexa (Lanka) Power Corporation (Pvt) Ltd	Nedunkulam Solar PV PP	10	Vauniya	8°46'16.69"N	80°31'40.50"E
Total			51.237			

(出所: CEB information)

表 5.2 PV 発電所計画（2020 年時点）

	Developer Name	Solar Plant Name	Capacity (MW)	Location			Year of Operation	Present Status
				Connected GSS	Latitude	Longitude		
1	Not decided	Rooftop Solar Power Programs	Not decided	No data	No data	No data	-	
2	Not decided	37x1MW Solar Park	37	No data	No data	No data	2021	Under Construction
3	Not decided	90x1MW Solar Park	90	No data	No data	No data	2021	Awarded/under Construction
4	Not decided	2x10MW Solar Park	29	No data	No data	No data	-	
5	Not decided	150MW Dist. Solar Park	150	No data	No data	No data	2022	Bidding stage
6	Not decided	Utility Scale Solar Park	100 planned	No data	No data	No data	2020	Prefeasibility is being done

(出所: CEB information)

2020 年時点の、既存風力発電所及び風力発電所開発計画を表 5.3 及び表 5.4 に示す。

表 5.3　既存風力発電所（2020 年時点）

	Developer Name	Wind Plant Name	Capacity (MW)	Location		
				Connected GSS	Latitude	Longitude
1	Senok Wind Power (Pvt) Ltd	Mampuri WPP	10	Puttalam	8°0'36.37"N	79°43'24.09"E
2	Seguwantivu Wind Power (Pvt) Ltd	Seguwantivu WPP	10	Puttalam	8° 3'30.43"N	79°48'12.98"E
3	Vidatamunai Wind Power (Pvt) Ltd	Vidatamunai WPP	10	Puttalam		
4	Vallibel Willwind (Pvt) Ltd	Willpita WPP	0.85	Balangoda	6°37'22.36"N	80°44'37.80"E
5	Nirmalapura Wind Power (Pvt) Ltd	Nirmalapura WPP	10	Norochcholei PP	7°57'14.73"N	79°44'27.14"E
6	Ace Wind Power (Pvt) Ltd	Ambewela WPP	3	Nuwara Eliya	6°54'4.68"N	80°48'4.12"E
7	Powergen Lanka (Pvt) Ltd	Uppudaluwa WPP	10	Norochcholei PP	7°58'49.37"N	79°46'32.87"E
8	Daily Life Renewable Energy (Pvt) Ltd	Madurankuliya WPP	10	Norochcholei PP	8°0'45.40"N	79°43'36.69"E
9	Pavan Danavi (Pvt) Ltd	Kalpitiya WPP	9.8	Norochcholei PP	8°2'55.19"N	79°43'7.84"E
10	Nala Dhanavi (Pvt) Ltd	Erumbukkudal WPP	4.8	Norochcholei PP	8°2'55.19"N	79°43'7.84"E
11	Senok Wind Energy (Pvt) Ltd	Mampuri II WPP	10	Norochcholei PP	8°0'36.37"N	79°43'24.09"E
12	Senok Wind Resource (Pvt) Ltd	Mampuri III WPP	10	Norochcholei PP	8°0'36.37"N	79°43'24.09"E
13	Joul Power (Pvt) Ltd	Puloppalai WPP	10	Kilinochchi	9°33'54.05"N	80°20'21.87"E
14	Beta Power (Pvt) Ltd	Vallimunai WPP	10	Kilinochchi	No data	No data
15	Musalpetti Wind Power (Pvt) Ltd	Musalpetti WPP	10	Puttalam	8°0'36.37"N	79°43'24.09"E
	Total		128.5			

(出所: CEB information)

表 5.4　風力発電所計画（2020 年時点）

	Developer Name	Wind Plant Name	Capacity (MW)	Location			Year of Operation	Present Status
				Connected GSS	Latitude	Longitude		
1	No data	Mannar WPP Phase 1	100	No data	No data	No data	2020	Under Construction
2	No data	Mannar WPP Phase 2	100	No data	No data	No data	2023	Procurement process yet to start
3	No data	Mannar WPP Phase 3	No data	No data	No data	No data	-	
4	No data	240MW WPP at Pooneryn	No data	No data	No data	No data	-	

(出所: CEB information)

(2) VRE 開発計画

LTGEP2020-2039（2019）に示されている、RE 発電開発計画容量、火力発電所の開発及び廃止計画を以下に示す。

表 5.5　ドラフト Long Term Generation Expansion Plan (2020-2039)

Year	Renewable Additions	Thermal Additions	Thermal Retirements	LOLP %
2020	Solar 100MW (including 35MW committed) Wind 20MW (2x10MW Chunnakam Wind) Mini Hydro 15MW* Biomass 5MW*	200MW Short Term Basis Supplementary Power Plants 100MW Short Term Basis Supplementary Power Plants 145MW Reciprocating Engine Power Plants	6x5MW Northern Power	1.427
2021	Solar 110MW (including 70MW+ 2x10MW committed) 100MW Mannar Wind Park Mini Hydro 20MW* Biomass 5MW* Uma Oya HPP 122MW Broadlands HPP 35MW	395MW Reciprocating Engine Power Plants 130MW Gas Turbine[2]	100MW ACE Embilipitiya 20MW ACE Matara 51MW Asia Power 200MW Short Term Basis Supplementary Power Plants 100MW Short Term Basis Supplementary Power Plants	1.362
2022	Solar 60MW Wind 150MW (including 60MW committed) Mini Hydro 20MW* Biomass 5MW*	4x24MW Reciprocating Engine Power Plants 100MW Reciprocating Engine Power Plants – Galle 200MW Open Cycle Operation of 1x300MW Natural Gas fired Combined Cycle Power Plant – Western Region[2]	290 MW Reciprocating Engine Power Plants	1.424
2023	Solar 60MW Wind 110MW Mini Hydro 20MW* Biomass 5MW* Moragolla HPP 31MW Seethawaka HPP 24MW	100MW Steam Turbine Operation of 1x300MW Natural Gas fired Combined Cycle Power Plant – Western Region[2] (Combined Cycle Operation) (Identified in LTGEP 2015-2034 and LTGEP 2018-2037 to be commissioned by 2019) 300MW Natural Gas fired Combined Cycle Power Plant – Western Region[2] (Identified in LTGEP 2018-2037 to be commissioned by 2021) 300MW Lakvijaya Coal Power Plant Extension 163MW Combined Cycle Power Plant (KPS–2)[4]	190MW Reciprocating Engine Power Plants 4x17MW Kelanitissa Gas Turbines 115 MW Gas Turbine[1] 4x9MW Sapugaskanda Diesel Ext.[1] 163MW Sojitz Kelanitissa Combined Cycle Plant[4]	0.449
2024	Solar 60MW Wind 90MW Mini Hydro 20MW* Biomass 5MW* Thalpitigala HPP 15MW	300MW Natural Gas fired Combined Cycle Power Plant	4x17MW Sapugaskanda Diesel[1]	0.345
2025	Solar 80MW Wind 40MW Mini Hydro 20MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant	4x15.6MW CEB Barge Power Plant[1]	0.331
2026	Solar 90MW Wind 35MW Mini Hydro 10MW* Biomass 5MW*	2x300MW New Coal fired Power Plant (Foul Point Phase I)	60MW Reciprocating Engine Power Plants 4x9MW Sapugaskanda Diesel Ext.[1]	0.077
2027	Solar 90MW Wind 50MW Mini Hydro 10MW* Biomass 5MW*	–	–	0.210
2028	Solar 100MW Wind 40MW Mini Hydro 10MW* Biomass 5MW* Pumped Storage HPP 200MW	–	–	0.152

Year	Renewable Additions	Thermal Additions	Thermal Retirements	LOLP %
2029	Solar 100MW Wind 40MW Mini Hydro 10MW* Biomass 5MW* Pumped Storage HPP 200MW	–	–	0.121
2030	Solar 100MW Wind 20MW Mini Hydro 10MW* Biomass 5MW* Pumped Storage HPP 200MW	300MW New Coal fired Power Plant (Change to Super critical will be evaluated)	–	0.019
2031	Solar 100MW Wind 60MW Mini Hydro 10MW* Biomass 5MW*	–	–	0.155
2032	Solar 110MW Wind 50MW Mini Hydro 10MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant 196MW Reciprocating Engine Power Plants	4x24MW Reciprocating Engine Power Plants 100MW Reciprocating Engine Power Plants – Galle	0.128
2033	Solar 110MW Wind 35MW Mini Hydro 10MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant – Western Region 300MW New Coal Power Plant (Change to Super critical will be evaluated)	165MW Combined Cycle Plant (KPS) 163MW Combined Cycle Plant (KPS-2) 3x8.93MW Uthuru Janani Power Plant	0.182
2034	Solar 120MW Wind 70MW Mini Hydro 10MW* Biomass 5MW*	300MW New Coal Power Plant (Change to Super critical will be evaluated)	–	0.105
2035	Solar 120MW Wind 45MW Mini Hydro 10MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant – Western Region 300MW Natural Gas fired Combined Cycle Power Plant	300MW West Coast Combined Cycle Power Plant	0.060
2036	Solar 110MW Wind 50MW Mini Hydro 10MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant	–	0.055
2037	Solar 110MW Wind 50MW Mini Hydro 10MW* Biomass 5MW*	–	–	0.241
2038	Solar 110MW Wind 70MW Mini Hydro 10MW* Biomass 5MW*	300MW New Coal Power Plant (Change to Super critical will be evaluated)	–	0.193
2039	Solar 110MW Wind 70MW Mini Hydro 5MW* Biomass 5MW*	300MW Natural Gas fired Combined Cycle Power Plant	–	0.178

(出所: Long Term Generation Expansion Plan 2019)

5.1.5 他ドナーによる電力分野の支援

(1) 世界銀行グループによる支援

CEBと世界銀行グループの国際復興開発銀行（IBRD）はカーボン排出削減のためのカーボンパートナーシップファシリティ（CPF）プログラムを進めており、LTGEPでRE開発計画が組み込まれている。CPFプログラムは発電計画ユニットが担当している。

Seller Participation Agreement（SPA）が2者間で締結され、CEBは排出削減プログラムの開発及び実施の責任を負っている。このスキームに参加する意思があるプライベートの電力事業者は、CEBを通じて炭素クレジットを政府に譲渡することになる。当プログラムで受け取った炭素収入はVREの技術的及び財政的支援に活用される。

Partnership for Market Readiness（PMR）は、炭素価格取引のイノベーションと試行運用のための資金と技術支援を無償で提供するプログラムである。Ministry of Mahaweli Development and Environmentの管轄

下にあるClimate Change SecretariatがPMRプログラムの実施主体であり、CEBが主となって、PMRプログラムに必要なインプットとフィードバックを提供している。

さらに、Generation Planning Unitは、気候変動緩和措置を優先するために、SEAとMinistry of Mahaweli Development and Environment下のClimate Change Secretariatにより活動しているプログラムに参加し、エネルギー部門の気候変動緩和対策としての国際気候変動緩和活動（NAMA）資金提供施設を用いたエネルギー部門プロジェクトの提案、パリ協定プログラムへの対応策立案、温室効果ガス排出量の測定・報告・検証（MRV）対応を実施している。

Generation Planning UnitはCEBを代表して、Ministry of Mahaweli Development and Environment配下の気候変動緩和専門家委員会に参加している。この委員会は、NAMAからの提案を含むGHG排出削減に関連する提案を評価し、パイロットプロジェクトの実現可能性を調査している。これらパイロットプロジェクトのための、気候に関する国際的な資金獲得も、この委員会で調整される。

(2) ADB による支援

ADBは、電力系統信頼性強化プロジェクトを支援している。 CEBに向けては、CEB送変電システムの信頼性向上と革新技術開発のために、ADBによる資本支援ならびにアジアインフラ投資銀行（AIIB）からの協調融資を合わせて2億米ドルの融資枠が用意されている。

以下に示す送変電ネットワーク増強プログラムは、この融資によって賄われている。

表 5.6　ADB が支援する送変電プロジェクト

● Construction of Kerawalapitiya 220kV Switching Station ● Construction of Hambantota-Matara 85km, 132kV Transmission Line ● Reconstruction of New Anuradhapura – Trincomalee 104km, 132kV Transmission Line ● Construction of Kandy City 132/11kV Grid Substation ● Construction Homagama 132/33kV Grid Substation
● Construction of Tissamaharama 132/33kV Grid Substation ● Construction of Kalawana 132/33kV Grid Substation ● Reconstruction of New Habarana-New Anuradhapura 50km, 220kV transmission line ● Construction of Wariyapola 132/33kV Grid Substation and Wariyapola-South 220/132kV Switching Station ● Construction of Negombo 132/33 kV grid substation ● Construction of Ja-Ela 132/11 kV grid substation ● Construction of Baddegama 132/33 kV grid substation ● Construction of Mirigama 220kV Switching Station &Kotadeniyawa 220/33kV grid substation

(出所: Annual Report 2018)

現在進行中のADB支援プロジェクトは以下の通り。

表 5.7　現在進行中の ADB 支援プロジェクト

- **Clean Energy & Network Efficiency Improvement Project**
  - Construction of Mannar Transmission Infrastructure -Completed
  - Construction of Kegalle GS and associated 132kV transmission infrastructure-Completed
  - Padukka and New Polpitiya SS and associated 220kV transmission infrastructure-Ongoing
- **Green Power Development & Energy Efficiency Improvement Investment Program (Tranche 1)**
  - Construction of Kerawalapitiya GS-Completed
  - Construction of Kalutara, Kesbewa and Kappalturai GS and associated 132kV transmission infrastructure-Ongoing
- **Green Power Development & Energy Efficiency Improvement Investment Program (Tranche 2)**
  - Construction of Hambantota SS and associated 220kV transmission line from New Polpitiya to Hambantota - Ongoing
  - Construction of Nadukuda Wind Collector GS and associated Manna-Nadukuda 220kV transmission line- Ongoing
  - Construction of Colombo B GS- Ongoing
- **Supporting Electricity Supply Reliability Improvement Project**
  - Construction of 100Mvar BSC at Pannipitiya GS- Ongoing
  - Construction of +100/-50Mvar SVC at Biyagama GS- Ongoing
  - Construction of 105MVar Reactors at New Anuradhapura and 50Mvar Reactors at Mannar GS-Ongoing

(出所: CEB information)

(3) AFD

現在進行中のAFD支援プロジェクトは以下の通り。

表 5.8　現在進行中の AFD 支援プロジェクト

Renewable Energy Absorption Transmission Development Project

Construction of Maliboda, Wewelwatta, Nawalapitiya and Ragala GSs and associated 132kV transmission infrastructure

- Construction of Maliboda 132/33kV, Grid Substation with 2x31.5MVA transformer,
- Construction of Ragala 132/33kV, Grid Substation with 2x31.5MVA transformer,
- Construction of Wewalwatta132/33kV, Grid Substation with 2x31.5MVA transformer
- Construction of Nawalapitiya 132/33kV, Grid Substation with 2x31.5MVA transform

(出所: CEB information)

5.1.6　VRE に関するエンジニアの研修

VRE に特化した研修プログラムは策定されていない。

一方で、CEB では PSS/E ソフトを用いて、下記の解析業務を行っている。

1) 電力潮流解析
2) 動的系統解析

5.1.7 電力卸売市場及び調整市場の状況

現状、スリランカには電力卸売市場はない。

5.1.8 系統接続制限緩和制度整備

現状、スリランカに系統接続制限緩和制度はない。本プロジェクトでは、日本で用いられている Connect and Manage のスリランカへの適用を議論する。将来の VRE 大量導入において系統制限による開発遅延を防ぐために導入を模索する。

5.1.9 発電抑制ルール整備

現状、VRE の出力抑制の必要も生じていないことから、出力抑制のルールはない。

将来の VRE 大量導入の対処策として、九州電力管内で行われている VRE 発電出力抑制制度のスリランカへの適用準備について、本プロジェクトで議論する。また、北海道電力管内で行われている、PV、WTG 導入時の出力変動制約、蓄電池導入制度のスリランカへの適用準備についても議論する。

5.1.10 CEB 財務体質支援補助制度の整備

現状、スリランカに電力事業者の財務体質を改善するための特別な制度はない。CEB の財政状態改善のための税制度や支援については、日本で採用されている電源開発促進税や燃料費調整制度などを踏まえて、本プロジェクトで議論する。

5.2 CEB 財務

5.2.1 CEB の財務状況

(1) 財務実績

【PDM 指標案】: 営業利益改善に向けたアセスメントが実施され提言報告書が作成される。

（ケース 1）現状制度継続及び電気料金維持の場合に VRE 投入促進した場合

（ケース 2）現状制度継続及び電気料金見直しと共に VRE 投入促進した場合

近年の売上原価上昇により、2015 年を除いて CEB は赤字を計上し続けている。CEB の総コストの 60%以上を発電費用が占めるため、電力需要の上昇により kWh 当たりの供給コストが増加し続ける結果となっている。費用の高い火力発電に依存しているため、特にこの期間中は、干ばつの影響により CEB の収支は悪化してきた。

さらに、2014 年から電力料金の改定が行われておらず、平均料金収入が LKR 16.20/kWh 程度に留まるため、上昇するコストをカバーする収入が得られていない。その結果、営業キャッシュフローの不足と電力システムの維持拡大に必要な資本支出の増加により、2018 年には新規借入金を LKR 622 億まで増加しなければならなかった。

財務的な健全性・安定性という意味では、2014 年～2016 年の CEB のカレント・レシオは 1.0 程度であり短期的な資金繰りの問題は見られなかったが、2017 年以降徐々に悪化している。負債比率（debt-to-assets ratio）に示される通り、CEB の資本構成は借入金に頼る傾向が強まっている。2015 年～2016 年には、デットサービスカバレッジレシオ（DSCR）は 1.0 以上となっており、中核事業が借入金の元利払いに充てるだけの十分なキャッシュフローを生み出すことができているが、2017 年以降 DSCR は急速に低下し、CEB 財務の安全性が悪化していることが示されている。

表 5.9　CEB の財務状況（2014 – 2018）

(LKR million)

	2014	2015	2016	2017	2018
Summary Income Statement					
Revenue	202,645	188,684	206,811	218,450	229,571
Cost of Sales	(213,646)	(168,781)	(222,097)	(260,273)	(250,891)
Gross Profit/ (Loss)	(11,001)	19,903	(15,286)	(41,823)	(21,320)
Other Income & Gain	5,871	8,292	10,323	8,143	9,450
Administrative Expenses	(3,146)	(4,087)	(4,965)	(5,110)	(5,425)
Finance Income	304	434	1,048	1,194	1,466
Finance Cost	(7,030)	(5,134)	(4,311)	(8,415)	(13,036)
Profit/ (Loss) before Income Tax	(15,002)	19,408	(13,191)	(46,011)	(28,865)
Summary Balance Sheet					
Assets	764,035	776,852	804,354	831,990	870,920
Property, Plant & Equipment	681,471	694,415	704,695	724,065	747,049
Investment in Subsidiaries	785	912	912	912	912
Investment in Joint Venture	150	329	329	329	329
Investment of Insurance Reserve Fund	5,653	6,036	6,496	7,246	8,070
Other Non-current Financial Assets	2,291	3,848	8,983	8,912	10,204
Other Non-current Assets	-	896	949	961	1,242
Non-current Assets Held for Sale	1,023	1,025	1,022	-	-
Current Assests	72,662	69,391	80,968	89,565	103,114
Liabilities	369,204	347,225	390,991	464,798	533,276
Interest Bearing Loans and Borrowings	202,821	198,344	201,752	214,564	281,262
Consumer Deposits	10,458	11,484	12,753	13,557	14,311
Provision & Other Deferred Liabilities	6,572	6,116	7,262	8,622	10,038
Government Grants	-	-	211	243	228
Contract Liablities	66,292	71,696	77,628	82,564	86,335
Current Liabilities	83,061	59,585	91,385	145,248	141,102
Equity	394,831	429,627	413,363	367,192	337,644
Contributed Capital	289,038	302,228	302,695	302,695	302,695
Reserves	27,434	28,463	30,283	32,783	34,830
Retained Earnings	78,359	98,936	80,385	31,714	119
Total Equity & Liabilities	764,035	776,852	804,354	831,990	870,920
Financial Indicators					
Operational Performance					
Average selling price per unit (LKR/kWh)	18.50	16.00	16.18	16.26	16.29
Average cost per unit at selling point (LKR/kWh)	20.00	15.07	18.08	20.34	19.12
Gross profit margin	-5.4%	10.5%	-7.4%	-19.1%	-9.3%
Net Cash Flow from Operations (LKR million) *	-	21,353	18,441	22,051	(17,273)
New Bank Loans (LKR million) *	-	319	6,049	2,582	62,169
Financial Stability					
Current Ratio	0.87	1.16	0.89	0.62	0.73
Debt to Assets	0.48	0.45	0.49	0.56	0.61
Debt Service Coverage Ratio (DSCR) *	-	2.94	1.04	(0.80)	0.29

* Indicators from financial analysis in CEB Corporate Plan 2019-2023

(出所: CEB 財務諸表、Statistical Digests and Corporate Plan 2019 – 2023)

(2) 企業財務計画とモニタリング

【PDM 指標案】: CEB 財務計画が定期的に見直しされる

CEB は毎年財務計画の見直しを行っている。CEB の財務部（Finance Division）は毎年 Preliminary Financial Plan と CEB 予算案を作成し経営幹部の承認を得る。また、CEB は Corporate Plan（2019～2023）とアクションプラン 2020 を作成している。

Corporate Plan は 2015～2018 年の財務分析と 2019～2023 年の財務予測を含んでいる。財務予測では、

平均電力料金（LKR 16.20/kWh）が期間中に改定されないという前提に基づき、CEB の純損失が増加していくことが示されている（表 5.10 参照）。

表 5.10　Corporate Plan による財務予測

Year	2019	2020	2021	2022	2023
Average Tariff (LKR/kWh)	16.20	16.20	16.20	16.20	16.20
Average Cost per Unit (LKR/kWh)	22.83	23.72	25.09	26.73	24.70
Net Profit (Loss) before Other Income (LKR million)	(99,040)	(120,062)	(149,092)	(185,334)	(157,061)
Estimated Subsidy (LKR million)	103,678	120,984	149,092	185,334	157,061

(出所: CEB Corporate Plan 2019 – 2023)

Corporate Plan 及びアクションプラン 2020 は下表の通り企業目標と重要業績指標（KPIs）を提示している。

表 5.11　CEB の企業目標と KPIs

Corporate Goal	Key Performance Indicator
1. Make CEB Financially Stronger	- Gering ratio - Percentage of financial surplus or deficit over total revenue - Percentage change of financial cost - Percentage of short-term borrowing
2. Enhance low cost electricity generation	- Average generation cost per unit of electricity - Average operational cost per unit of electricity Sold - % of electricity generated from plants having a unit cost above average generation cost (energy)
3. Provide electricity to entire country at an affordable price	- Overall Electrification level - Average household electricity expenditure Ratio
4. Ensure high quality electricity supply and services to customers	- Ease of getting electricity index - System Average Interruption Duration Index (SAIDI) - System Average Interruption Frequency Index (SAIFI) - Estimated Energy Not Supplied (EENS) - Number of customer complaints against variation of power quality - Average Cycle Time per new connection - Reduction in No of customer complaints - Average response time per customer complaint
5. Maintain stronger relationship with external stakeholders	- No of CSR activities per year - Average duration of serving a request from stakeholders (other than customers)
6. Enhance employee engagement	- Employee productivity - Organizational commitment index - Overall employee satisfaction index
7. Achieve operational excellence with state of art technology	- No of e-services introduced - No. of smart services introduced - No. of fatal electrical accidents per year
8. Optimize integration of green energy	- No of Green energy projects integrated to the grid - % Increase of installed capacity from renewable sources - Percentage of green energy produced over total energy - Average emission index

(出所: CEB Corporate Plan 2019-2023)

モニタリング・評価の段階では、CEB の企業戦略部（Corporate Strategy Division）と財務部が四半期毎に KPIs を報告している。また、財務部が企業予算と実績の差異分析を毎月行っている。

表 5.12　CEB の計画・モニタリングのフレームワーク

Stage	Process	Section/Department	In charge
Planning	Preparation of Preliminary Financial Plan (PFP)	Finance Division	AFM (Corporate)
	PFP provides the upper ceilings for operational & maintenance cost for each division		
	Based on the upper ceiling provided in the PFP, each Division needs to prepare their divisional financial budgets	Each Division (9 Division in CEB)	AGM/AFM of each Division
	Prepare the CEB Master Budget	Finance Division	AFM (Corporate)
Monitoring & Evaluation	Variance Analysis of Actual v.s. Budget on monthly basis	Finance Division	AFM (Corporate)
	Calculation the Key Performance Indicators (KPIs)	Corporate Strategy/Finance Division	AGM(CS)/FM/ AFM (Corporate)
	Revise the budget if necessary	Finance Division	AFM (Corporate)

(出所: CEB Information)

5.2.2　電気料金制度

(1)　電気料金体系

表 5.13 に CEB 電気料金を示す。電気料金は大きく家庭用と事業用に大別される。家庭用料金は電力使用量に応じて料金が漸増するブロック制料金が適用されている。加えて、2015 年より顧客は時間帯別（TOU）料金を選択することも可能となったが、ブロック制料金の方が安価であるために、TOU 料金を選択した顧客はわずか 250 家庭程度である。事業用料金は主に固定基本料金と従量制料金で構成されているほか、高い契約容量の顧客に対しては TOU 料金が適用されている。

表 5.13　CEB の電気料金

EFFECTIVE FROM	●DOMESTIC 16-09-2014	●ToU for DOMESTIC 02-05-2017	●NON DOMESTIC CATEGORIES 15-11-2014
(for each 30 - day billing period)			

					Unit Charge			Fixed Charge
DOMESTIC								
Consumption 0 - 60 kWh per month								
Block 1	-	0 - 30	units	@	Rs 2.50	per unit	+	Rs 30.00
Block 2	-	31 - 60	units	@	Rs 4.85	per unit	+	Rs 60.00
Consumption above 60 kWh per month								
Block 1	-	0 - 60	units	@	Rs 7.85	per unit	+	N/A
Block 2	-	61 - 90	units	@	Rs 10.00	per unit	+	Rs 90.00
Block 3	-	91 - 120	units	@	Rs 27.75	per unit	+	Rs 480.00
Block 4	-	121 - 180	units	@	Rs 32.00	per unit	+	Rs 480.00
Block 5	-	Above 180	units	@	Rs 45.00	per unit	+	Rs 540.00

Time of Use Electricity Tariff for Domestic Consumers

Time of Use (ToU)	Energy Charge (Rs)	Fixed Charge (Rs)
Day (05.30 - 18.30 hrs)	25.00	540.00
Peak (18.30 - 22.30 hrs)	54.00	
Off Peak (22.30 - 05.30 hrs)	13.00	

RELIGIOUS & CHARITABLE INSTITUTIONS

Block 1	-	0 - 30	units	@	Rs 1.90	per unit	+	Rs 30.00
Block 2	-	31 - 90	units	@	Rs 2.80	per unit	+	Rs 60.00
Block 3	-	91 - 120	units	@	Rs 6.75	per unit	+	Rs 180.00
Block 4	-	121 - 180	units	@	Rs 7.50	per unit	+	Rs 180.00
Block 5	-	Above 180	units	@	Rs 9.40	per unit	+	Rs 240.00

OTHER CUSTOMER CATEGORIES			General Purpose		Industrial		Hotel	Government
			GP1-1	GP1-2	IP1-1	IP1-2		
Rate 1 Supply at 400/230V Contract demand less than or equal 42kVA			For ≤ 300 kWh/month	For > 300 kWh/month	For ≤ 300 kWh/month	For > 300 kWh/month		
	Unit Charge (Rs/kWh)		18.30	22.85	10.80	12.20	21.50	14.65
	Fixed Charge (Rs/Month)		240.00	240.00	600.00	600.00	600.00	600.00
Rate 2 Supply at 400/230V Contract demand Above 42kVA	Unit Charge (Rs/kWh)	Day (05.30 - 18.30 hrs)	21.80		11.00		14.65	14.55
		Peak (18.30 - 22.30 hrs)	26.60		20.50		23.50	
		Off Peak (22.30 - 05.30 hrs)	15.40		6.85		9.80	
	Demand Charge (Rs/kVA)		1100.00		1100.00		1100.00	1100.00
	Fixed Charge (Rs/Month)		3000.00		3000.00		3000.00	3000.00
Rate 3 Supply at 11kV & above	Unit Charge (Rs/kWh)	Day (05.30 - 18.30 hrs)	20.70		10.25		13.70	14.35
		Peak (18.30 - 22.30 hrs)	25.50		23.50		22.50	
		Off Peak (22.30 - 05.30 hrs)	14.35		5.90		8.80	
	Demand Charge (Rs/kVA)		1000.00		1000.00		1000.00	1000.00
	Fixed Charge (Rs/Month)		3000.00		3000.00		3000.00	3000.00
Street Lighting			@ Rs 17.00 per unit					

Electric Vehicle Charging Rates at CEB Charging Stations

Time of Use (ToU)	DC Fast Charging	Level 2 AC Charging
Day (05.30 - 18.30 hrs)	50.00	30.00
Peak (18.30 - 22.30 hrs)	70.00	55.00
Off Peak (22.30 - 05.30 hrs)	30.00	20.00

(出所: CEB information)

(2) 顧客種別の平均電力収入

下表に示すとおり、CEB の平均電力収入は近年変化がない。これは 2014 年以降電気料金が改定されていないためである。全体平均と比較して、家庭用、工業用及び宗教施設の顧客は、他の顧客種別からのクロスサブシディにより安価な電気料金を享受している。

表 5.14 CEB の平均電力収入

Average Price Rs/ kWh	2016	2017	2018
Domestic	13.42	13.48	13.60
Non-Domestic			
Religious	7.15	7.21	7.28
General Purpose	23.90	23.74	23.78
Hotel	17.74	17.73	17.62
Industrial	14.63	14.77	14.72
Government	18.34	18.26	18.23
Bulk Supply to LECO	15.77	15.79	15.53
Total	16.18	16.26	16.29

(出所: CEB Statistical Digest)

(3) 電気力料金回収率

CEB の電気料金回収率は最近 5 年間に亘り 100%以上となっている。

表 5.15 CEB の電気料金回収率

Year	2015	2016	2017	2018	2019
Electricity bill collection	189,289	224,931	238,564	230,394	261,728
Revenue	188,625	206,892	218,450	229,571	242,934
Bill collection rate	100%	109%	109%	100%	108%

(出所: CEB information)

(4) 電気料金改定

1) 電気料金制度

電気料金はスリランカ電力法 30 条及びその 2013 年改正法により規制されている。現在の電気料金計算方法は PUCSL が 2015 年 11 月に制定した Tariff Methodology で定められており、電気事業者は、資本費用、減価償却、適切な収益、各種運営費、物価上昇等、発電・送電・配電に必要となるすべての費用を賄う電力料金を設定することが許されている。CEB の要請と PUCSL の承認に基づき、基本料金改定は 5 年ごとに行われ、料金調整は半年ごとに実施されることになっている。

2) 最近の電気料金改定

電気料金改定は、2014 年 9 月に家庭用料金、2014 年 11 月に法人用料金に対して行われたものが最後となっており、PUCSL がエンドユーザーへの料金値上げを承認しないためにそれ以降の料金改定は実施されていない。その結果、CEB の平均電気料金収入と、発送電に係る平均コストは逆鞘の関係になっている。2015 年には選択制の TOU 料金が導入されている。

5.2.3 CEB の負債及び政府からの補助金

(1) CEB 長期負債

CEB の借入金の多くは ADB、JICA、AFD 等の二国間または多国籍のドナーによるプロジェクト借款である。そのうち 91%（LKR 2,104 億）は政府国庫を経由した転貸である。2019 年には、LKR 169 億の負債が政府により資本金に変換された。

表 5.16　CEB の有利子負債

(Unit: LKR thousands)

	2019 Repayable Within 1 Year	2019 Repayable After 1 Year	2019 Total	2018 Repayable Within 1 Year	2018 Repayable After 1 Year	2018 Total
Bank Loans (24.1)	14,126,839	75,293,052	**89,419,892**	7,478,776	59,947,397	**67,426,172**
Projects Loans (24.2)	1,076,038	230,859,974	**231,936,012**	-	221,180,100	**221,180,100**
Lease Creditors (24.3)	38,873	106,668	**145,541**	28,162	16,767	**44,929**
Loans From Samurdhi Authority (24.4	132,073	-	**132,073**	183,680	117,932	**301,612**
Bank Over Draft (30.2)	13,037,720	-	**13,037,720**	7,677,126	-	**7,677,126**
	28,411,544	**306,259,694**	**334,671,238**	**15,367,744**	**281,262,195**	**296,629,939**

(出所: CEB financial statements)

(2)　政府補助金の状況

スリランカ電力法と電力事業に関する基本政策ガイドラインに則り、政府が低所得層に対する料金値上げを回避するために、CEB は Procedure for Review and Adjustment of Tariff（2016 年 7 月）に基づき政府補助金を受領することが認められている。これに従い、CEB は政府補助金の申請を毎年行っているが、上記に従った補助金は交付されておらず、CEB の費用負担を賄うことでできていない。

また、Sri Lanka 国官報（2016 年 8 月 2 日）によると、必要な電気料金の施行の前に、PUCSL は必要な補助金予測のポートをとりまとめる。さらに PUCSL は電気料金の施行期間中において、も補助金について改定を行うと定められている

制度上認められた補助金交付の代わりに、政府は CEB のセイロン石油公社（CPC）に対する燃料費債務を相殺する形で 2020 年に LKR 480 億を支給した。同様に、政府によりプロジェクト費用 LKR 46.8 百万が支払われている。CEB によれば、これらの財政支援は透明性が低く持続可能なものではないとされている。

5.2.4　VRE 投入促進のための制度（補助金、低利率ローンなど）

(1)　価格入札によるVREの調達

1)　概要

CEBは、非従来型の再生可能エネルギー（NCRE）を活用している。2018年現在、197のNCREプラントで総容量609MWの設備が系統に接続されている。スリランカの国家エネルギー政策では、エネルギー安全保障の確保、現地資源開発促進という政府の政策が強調されている。経済的で実行可能なNCREの開発を促進することは、国家エネルギー政策に基づいた重要な戦略に位置づけられる。

スリランカは主要な水力ポテンシャルを開発済みであるため、政府の政策を実現するために、再生可能エネルギーである太陽光と風力発電の開発に焦点があてられている。スリランカでは、太陽光発電技術と産業の急速な発展を考慮して、これまでの固定価格買取制度から、10MW以下の太陽光発電についても価格入札に基づいて開発する方針を打ち出している。同時に、この価格入札による開発は国に利益をもたらすことが期待される。

2007年のスリランカ持続可能エネルギー局（SLSEA）法第35号の制定により、国のすべての再生可能エネルギー資源はスリランカ共和国に付与されている。同法では、スリランカ持続可能エネルギー局（SLSEA）を再生可能エネルギー資源の管理者としている。

2)　CEBの担当部署

再生可能エネルギー開発・運用監視課（Renewable Energy Development & Performance Monitoring Branch）がVRE導入促進の担当部署となっている。

3)　Tariff

VRE 価格入札調達においては PPA が締結され、CEB が支払う料金は契約期間全体で均一な料金としている。また、契約期間全体を通じて料金がエスカレーションすることはない。公示案件ごとに、価格上限ベンチマークとして、最大買取価格が示される。

4) 環境配慮

プロジェクト事業者は、提案する太陽光発電所の環境への影響を評価し、該当する法律や規制及び環境局より公開されたガイドラインに対して、関連するクリアランス及び承認を取得する必要がある。プロジェクト事業者は、1980年の国家環境法第47号、1990年の国家環境（保護及び品質）規制、その他の適用される規制または法律を遵守する必要がある。また、プロジェクト事業者は、プロジェクト期間中すべての環境法を遵守するものとされている。

(2) 固定価格による非従来型再生可能エネルギー開発

1) 一般

2014年3月7日の内閣決定に基づき、CEBは非従来型の再生可能エネルギー由来電力の購入を進めている。当該スキームでは、小規模事業者が10MW以下のプロジェクトを実施し、CEBは表5.17に示す料金表に基づいた3段階価格での買い取りを行う。当該料金は2012年1月1日に決定されたものであり、次回改定まで採用される。

2) 3段階料金制度

すべての料金はスリランカルピー建てとし、固定価格（Fixed Rate）、運用メンテナンスコスト（Operations and Maintenance Rate）及び燃料費（Fuel Rate）から成っている。

表 5.17　NCRE 電力買取の 3 段階料金

(Unit: LKR/kWh)

Technology/ Source	Escalable Base O&M Rate (Year 1-20)	Escalable Base Fuel Rate (Year 1-20)	Non-escalable (fixed rate)		
			Tier 1: Year 1-8	Tier 2: Year 9-15	Tier 3: Year 16-20
Mini-hydro	1.83	None	15.56	5.98	3.40
Mini-hydro-local	1.88	None	15.97	6.14	3.49
Wind	1.30	None	22.05	8.48	4.82
Wind-local	1.33	None	22.60	8.69	4.94
Biomass	1.52	12.25	9.67	3.72	2.11
Biomass 16yr onwards	1.90	—	—	—	—
Agro & Industrial waste	1.52	6.13	9.65	3.71	2.11
Agro & Indus 16yr onwards	1.90	—	—	—	
Waste Heat	0.48	None	9.14	3.52	2.00
Escalation rate for year 2013	5.16%	3.44%	—	—	—

(出所: draft LTGEP 2020-2039)

上記以外の再生可能エネルギー起源の電力に対してはRs. 23.10 / kWh（20年間エスカレーションなし）の買い取り価格が提示される。

現在、競争価格でのNCRE開発スキームも進められている。

(3)　ルーフトップ PV の導入促進

1)　概要

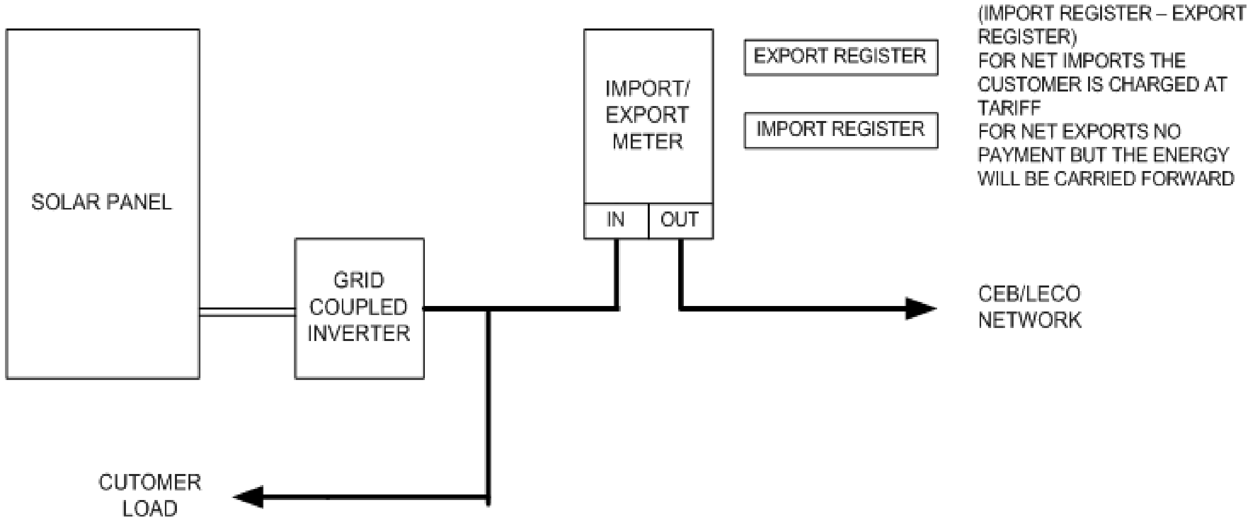
前述のとおり、発電設備の調達は現在競争入札で実施されている。現時点でルーフトップ PV を除き FIT スキームは無い。スリランカでは、ルーフトップ PV の導入促進に向け、ADB の支援により、2014 年に 22 件のルーフトップ PV パイロットプロジェクトが開始された。パイロットプロジェクトでは、ADB による補助金や優遇ローンの支援が行われた。現在、これとは別に、50kW 以下のルーフトップ PV に対する ADB 支援による優遇レートの融資（利率 6%）スキームが進められている。

2)　電力計量

PVシステムの計量方法として以下の３つの方式があり、PV設置者が3種類の計量方式から選択できる。

a)　Net metering

PV 出力は顧客構内で消費する。電力消費と PV 出力とで相殺された顧客の電力購入分は電気料金を支払うが、系統への余剰電力がある場合でも買い取り料金の支払いはない。

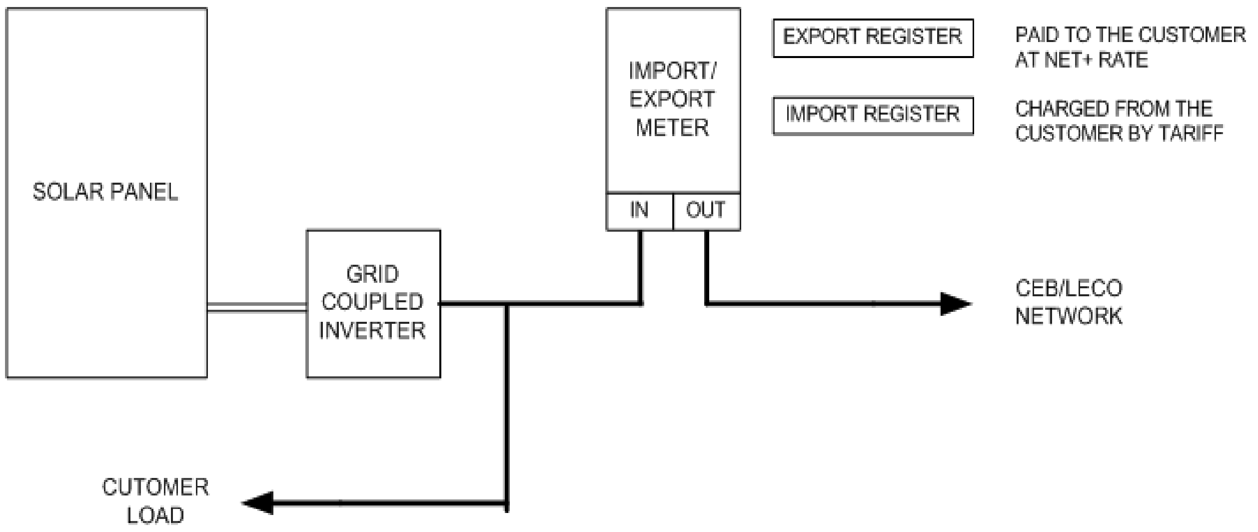


(出所: CEB information)

図 5.2　Net Metering

b)　Net Accounting

顧客の電力消費と PV 出力の差が電力消費の場合は電力料金を支払い、系統への余剰電力となる場合は電力買い取り料金が顧客に支払われる。電力買い取りスキームは、20 年契約で、最初の 7 年間が LKR 22.00/kWh、その後 13 年は LKR15.00/kWh である。

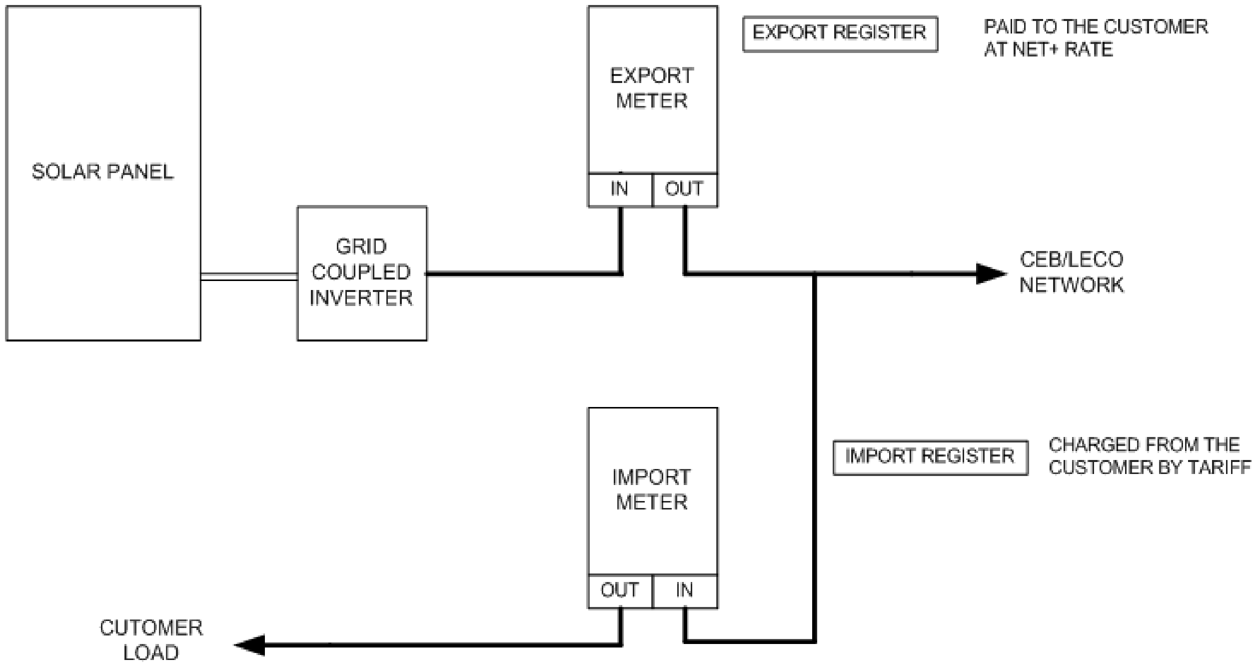


(出所: CEB information)

図 5.3　Net Accounting

c)　Net Plus

PV 総出力に対して電力買い取り料金が支払われる。一方、顧客消費電力量に対して、顧客が電気料金を支払う。電力買い取りスキームは、20 年契約で、最初の 7 年間が LKR 22.00/kWh、その後 13 年は LKR15.00/kWh である。



(出所: CEB information)

図 5.4　Net Plus

(4)　標準調達計画の確立

【PDM 指標案】：標準手順による調達が実施される

申込から開発許可を得るまでの流れは以下のとおりである。

1) 開発事業者は Pre-feasibility report を SEA に提出するとともに、発電設備容量に応じた申請料（1,000 kW 以下：100,000 LKR、1,000kW 超過：1,000 kW ごとに 50,000 LKR を上乗せ）を納付する。

2) SEA の Project Approving Committee (PAC)にプレゼンする。

3) SEA の PAC が認めれば、開発事業者は仮の許可を取得する。仮の許可証を持って他関係機関に訪問し、これら機関からも許可を得た後、SEA から正式な開発許可を得る。

なお、CEB は系統連系検討前に開発事業者に対して許可書(写)の提出を求める。また、再エネ開発許可を得てから 2 年以内に運転を開始しなければならない。

プロジェクト開発許可取得のボトルネックとして、許可取得まで時間がかかることが挙げられる。プロジェクトの内容にもよるが、7～9 機関を訪問し許可を得なければならないため、開発許可を得るまでに 6 ヵ月～18 ヵ月必要となる。関係機関は次のとおり。

・Central Environmental Authority
・Divisional Secretary
・Pradeshiya Saba (local government)
・Depart of Irrigation
・Department of Wild Life
・Urban Development Authority
・Department of Archeology
・Coast conservation & coastal management Department (for project in coastal areas)
・Civil Aviation (for wind)

5.3　系統運用技術

5.3.1　VRE を踏まえた系統運用の現状

(1)　再生可能エネルギー及び運用方針の分析報告書

【PDM 指標案】: 再生可能エネルギー及び運用方針の分析報告書

今後の最適なVRE導入を決定するための解析として、「Integration of Renewable Based Generation into Sri Lankan Grid 2020-2030」が実施され完了している。その解析は、長期電源開発、電力系統運用解析及び送変電運用解析の3部構成となっており、その解析結果により、最大の新たな再エネ導入が決定される。

添付資料 2 に 2018-2028 年の分析実施結果を示す。

(2)　再生可能エネルギー増加による電力系統の課題及び影響の分析

【PDM 指標案】再生可能エネルギー増加による電力系統の課題及び影響の分析報告書

1)　VRE 導入検討

VRE の導入の担当部署は送電部門（Transmission Division）内の再生可能エネルギー開発・運用監視課（Renewable Energy Development & Performance Monitoring Branch）である。

CEB は将来的に大量の VRE を導入する準備を整えるために、スリランカにおける 10 年間の再生可能エネルギーの導入検討を定期的に行っている。最新のものは 2020～2030 年の分析である。

長期需給計画において、PV は供給力として見込んでいない。一方、風力は若干ではあるが供給力として見込んでいる。VRE が増加するなか、供給力としての見込み量について考え方を整理する必要がある。また、VRE は負荷変動速度が速いため、この変化速度に対応した供給予備力の確保が課題である。

現状、VRE 出力が小さいため、配電/送電線の送電容量を超えておらず、電力システムへの顕著な影響は表れていない。

2)　電力系統運用方針

CEBのControl Branchが系統運用方針を制定している。概要は以下のとおりである。より詳細な方針は添付資料3を参照されたい。

a)　運用優先度

公衆保安
電力機器の保護
電力供給信頼度確保
電力品質確保
経済運用

b)　水力運用優先度

水供給と下水
環境保持
灌漑
電力

c)　系統周波数

法定上、周波数の変動は50Hz±1%以内に収めることとされている。系統運用者は49.5Hzから50.5Hzの範囲で制御することとしている。

d)　系統電圧

系統電圧は下表のとおり制御することとしている。

表 5.18　系統電圧制御範囲

	系統電圧		
	220kV	132kV	33kV Grid bus
通常時	±10% (242kV to 198kV)	±10% (145.2kV to 118.8kV)	±2% 33.66kV to 32.34kV
異常時	±10% (242kV to 198kV)	±10% (145.2kV to 118.8kV)	—

(出所: CEB information)

e)　系統定数

系統定数は約 85 MW/Hzである。

f)　供給予備率

供給予備率は発電量の5%以下とならないように運用されている。なお、発電予備率を確保するためだけに発電コストの高い発電所を運転することはしない。

(3)　VRE 接続に起因する電圧・周波数動揺への対策提言

【PDM 指標案】: VRE 接続に起因する電圧・周波数動揺への対策提言

需要変動に対しては、並列した発電機を対象に 5%の予備力を持って対応している。周波数調整に対応できる発電機は以下の表 5.19 のとおり。

表 5.19　周波数調整に対応できる発電機

Name	Capacity	Ramp rate	Frequency control (Secondary, LFC)	AGC integrated	Reserve Margin (primary, secondary)
Victoria	70MW x3	100MW/min	✓	✓	✓
Kotmale	67MW x3	100MW/min	✓	✓	✓
New Laxapana	57MW x2	50MW/min	✓	✓	✓
Samnalawewa	60MW x2	100MW/min	✓	✓	✓
Upper Kotmale	75MW x2	100MW/min	✓ (Change output verbally)	—	✓
KCCP GT	110MW	100MW/min	✓ (ditto)	–	✓

（出所：CEB Information）

(4)　再生可能エネルギー導入時の先進解析技術の理解

【PDM 指標案】: 50%（Power System Planning のエンジニア 7 名）が再生可能エネルギー導入時の先進解析技術を理解する

電力計画部門（Power System Planning Department）が電力系統分析を担当している。 部門には 14 人のエンジニアが在籍している。

電力システムの高度な分析に関する教育方針は作成されていないが、CEB は、PSS/E を使用し、VRE の設置状況に基づいた電力潮流分析、電圧分析、周波数分析、N-1 分析を行っている。Power System Planning Department のエンジニアは、これらの分析について一般的な知識を持っている。

(5)　再生可能エネルギー増加に対応した需給運用

【PDM 指標案】: 50%（Power System Planning のエンジニア 7 名）が再生可能エネルギー増加に対応した運用を理解する

VRE の増加を踏まえた需給運用の教育方針は策定されていない。

CEB では、WASP と OPTGEN の両方を使用して LTGEP を策定し、関連するコストとエネルギー/容量のバランスを両方のモデルなどから導出している。WASP から求めた LOLP 値は、LTGEP 2020-2039 の表 5.5 に示されている。SDDP にはシステム操作をシミュレートする機能があるため、最小負荷運用、VRE 抑制などの長期計画での運用面をシミュレーションするために使用されている。

電力需給バランスを踏まえた、前日及び毎月の電力供給計画については、グリッドコードに記載されている。

通常、電力系統の周波数制御は出力 60～70MW の水力発電機 1 機で調整を行い、ドループ制御（ガバナ制御の一つ：発電機の出力が増加すると、速度調節の目標値を下げる）方式により、発電所員がマニュアルで 2%の設定として調整している。

さらに、給電指令所から発電機の自動出力制御（AGC: Automatic Generation Control）を行うことができ、4 つの発電所が制御対象となっている。水力発電所により調整を行っているため、水力発電所の出力が最小となる渇水期においては、周波数調整に影響を及ぼすだけでなく、VRE の出力変動により系統安定性にも影響を与えることになる。

上記以外の発電所は、4%から 5%のドループ設定でガバナーフリーにより運転されているとみられる。しかし、ほとんどの発電所は周波数の変化に適切に応答できる仕様とはなっていない。実際の運用では、一般的に、経済性、運用性の高い給電運用と予測が行われている。系統運用者は、給電計画用のツールである NCP を使用して前日に給電計画を立て、当日、その計画に沿って発電機を運転する。発電機の運転停止指令は電話にて口頭で伝えられている。

NCP ツールは、水力発電と火力発電の両者について、15 分間隔で経済的な発電計画を立てることができる。 系統運用者は、NCP に VRE 出力予測を入力する必要がある。現状は、前日の情報に基づいて、データを手動入力している。強風で特にオフピーク時には、VRE 出力を抑制する方法がないため、系統運用者は系統を安定させるための発電機の運転制御に苦労している。

(6)　PV 及び風力発電出力を考慮した需要供給運用技術の向上

【PDM 指標案】: 9 名の Power System Operation Department のエンジニアの PV 及び風力発電出力を考慮した需要供給運用技術の向上

長期需給運用計画において、PV は供給力として見込んでいない。一方、風力は若干ではあるが供給力として見込んでいる。VRE が増加するなか、供給力としての見込み量について本プロジェクト内で考え方を整理する必要がある。なお、現状 VRE の出力予測モデルはない。

CEB は、VRE の電力システムへの連系を適切に運用するために、National System Control

Center（NSCC）の下に再生可能エネルギーデスク（Renewable Energy Desk）を設けている。VRE は 33kV 配電線に連系される。系統運用を適切に行うためには、VRE の発電量を予測する必要があるとともに、VRE 発電量の監視は重要である。

また、短期及び長期の VRE 発電量を予測するには、過去の VRE 運用実績データが不可欠であり、VRE 出力の記録は、正確な長期発電予測を行うための重要な情報である。長期的な発電量予測は設備計画に使用されるため、正確な VRE の監視と記録は非常に重要である。

計画面に加えて、リアルタイムの系統運用に深刻な影響がある。オフピーク時の電力需要は、特に雨天時に大幅に減少する。系統運用者がオフピーク時の VRE 出力を把握していないと、電力系統の周波数の安定運用が困難となる。通常、周波数制御は出力 60～70 MW の発電機単一ユニットによって行っている。

再生可能エネルギーデスクには、1 名のエンジニアが交替で配置される。業務は以下の通り。

- ネットワークエンジニアがリアルタイム制御で必要となった場合に使用できるようにリアルタイムで VRE データを整理する
- VRE 出力データの記録
- 複数の時間間隔パターンによる今後 3 日間の VRE 出力予測作成
- 毎日の VRE 出力レポートの作成

(7) PV 及び風力発電出力を考慮した最適電源開発計画技術の向上

【PDM 指標案】: 9 名の Power System Operation Department のエンジニアの PV 及び風力発電出力を考慮した最適電源開発計画技術の向上

VRE の導入担当部署は、送電部門（Transmission Division）内の再生可能エネルギー開発・運用監視課（Renewable Energy Development & Performance Monitoring Branch）である。現状エンジニアは 4 名である。

(8) 見直した系統運用方針に基づく VRE 系統アクセスアセスメント技能の向上

【PDM 指標案】: 4 名の再生可能エネルギー開発・運用監視課（Renewable Energy Development & Performance Monitoring Branch）のエンジニアの見直した系統運用方針に基づく VRE 系統アクセスアセスメント技能の向上

系統連系要件（Grid Code）への適合確認は、送電部門（Transmission Division）内の再生可能エネルギー開発・運用監視課（Renewable Energy Development & Performance Monitoring Branch）が担当している。当部署には 4 名の技術者が在席している。

VRE を電力系統に接続するための条件として、既に FRT（Fault Ride Through: 電力系統の擾乱発生時における VRE 運転継続要件）が系統連系要件に規定されている。VRE 大量導入における、FRT 要件の見直しや VRE の緊急出力抑制について検討する必要がある。

(9) 先進的 PV 及び風力発電出力予測システムの開発及び同システムを使用した需要供給運用の実施

【PDM 指標案】: 先進的 PV 及び風力発電出力予測システムの開発及び同システムを使用した需要供給運用の実施

現状、VRE の予測モデルはなし。系統運用は、9 名のエンジニアで実施している。

VRE 出力のほとんどは、マイナスの負荷（需要の減少）として管理されており、現状、系統への目立った影響はない。一方、SCADA を介して監視される VRE は供給力と見なされており、前日の発電状況及び気象予報から当日の出力が予測される。

(10) 揚水発電所現場研修報告

【PDM 指標案】: 揚水発電所現場研修の報告

揚水発電に限らず、教育方針はない。揚水発電がないため、運用技術はない。

5.3.2　VRE 導入を踏まえた系統安定化対策

(1)　CEB 各業務へのエンジニア配置

各業務へのエンジニア配置人数は表 5.20 のとおり。

表 5.20　各業務へのエンジニア配置数

業務	エンジニア数
Power System Planning	14 Engineers
Power System Design	16 Engineers
Construction	16 Engineers (Excluding the Engineers in Project Division who are involving construction supervision of turnkey projects)
Power System Operation	9 Engineers
Relay Protection Planning	6 Engineers
Relay Protection Setting	6 Engineers
Maintenance of SCADA System	Substation Automation System (SAS) - 3 Engineers Gateway -2 Engineers Engineers SCADA - 2 Engineers

(出所: CEB information)

(2)　VRE 開発・導入対応部署

送電部門内の、再生可能エネルギー開発・運用監視課（Renewable Energy Development & Performance Monitoring Branch）がVREの開発・導入を担当している。在籍しているエンジニアは4名である。

(3)　系統運用者のライセンス

送電部門は送電ライセンスを受けている。系統運用業務は、送電部門内の NSCC（National System Control Center）が担当している。

(4)　CEB での異動基準

職員の異動は、CEBのGeneral Manager発令により、毎年実施されている。各エンジニアはおおよそ5年に1回の頻度で異動している。ほとんどの職場では、5年間で業務を習得できるが、一部の職場では業務の習得に5年以上かかるところもある

(5)　CEB エンジニアによる先進的系統分析技術の理解

【PDM 指標案】: 7 名のエンジニアが先進的系統分析技術を理解する

再生可能エネルギー開発・運用監視課（Renewable Energy Development & Performance Monitoring Branch）は、VRE 導入に基づく電力システムの分析を担当している。スイッチングサージ解析は、送電計画課（Transmission Design Branch）が PSCAD、Power Factory 及び ETAP ソフトウェアを用いて、ケースバイケースで状況に応じて実行される。

さらに、CEB は電力系統の分析にもソフトウェアを使用している。ソフトウェアの種類とそのライセ

ンスは以下のとおり。

-PSS / E Ver. 33.5.2　電力潮流、過渡解析、電圧解析、短絡電流計算

PSS / E には 11 のライセンスがあり、そのライセンス保有数内訳は以下のとおり。

> 7 ライセンス　送電計画

> 2 ライセンス　システム制御

> 2 ライセンス　制御保護

(6) 系統運用方針の改善提言

【PDM 指標案】: 系統運用方針の改善が提言される。

現状の系統連系要件においても、FRT（Fault Ride Through）要件の記載あり。VRE 大量導入に伴い、FRT 要件の見直しや発電抑制などについての検討が必要である。

現状、PV は供給力として見込んでおらず、風力は若干ではあるが供給力として見込んでいる。VRE が増加するなか、供給力としての見込み量について考え方を整理する必要がある。なお、VRE の出力予測モデルはなし。

(7) VRE 起因による電圧・周波数変動への対策

【PDM 指標案】: VRE 起因による電圧・周波数変動への対策が 1 つ以上適用される。

現状、VRE の導入量が少ないため周波数及び系統電圧に大きな問題は生じていない。

5.3.3　VER を考慮した系統技術・運用技術の演習に基づく能力向上

【PDM 指標案】: JICA 専門家支援により、カウンターパートがトレーニング用教材を導入する。

(1) 系統管理・運用に関するトレーニング方針/カリキュラム

CEB 内の技術トレーニングは、DGM（Deputy General Manager）が掌握する CEB テクニカルトレーニングセンターで実施される。

現状、トレーニング全体に関する特定の方針は策定されていない。CEB には、新規電力システム運用エンジニア向けのトレーニングプログラムのみがある。CEB では、システム制御技術者向けトレーニングガイドを作成し、以下のように記載されている。

システム制御エンジニア向けのトレーニング項目詳細は、添付資料 4 に示す。

表 5.21　系統運用技術者向けトレーニングガイドの概要

Training Guide for System Control Engineers

Guideline for training

Trainee must attain comprehensive knowledge on following points during the training period.

1. General Knowledge on Sri Lankan Power System
    - Steady state frequency stability via supply demand balance
    - Hydro Complexes, Power Stations and Grid Substations (GSSs)
    - Installed Capacity of Sri Lankan Power System
    - Load Curve
    - System operation policy guidelines
    - IPPs
    - Water Management Directives
    - Irrigation releases
    - System operating priority order.
    - Water using priority order
2. Generation Dispatch
    - Security Constrained Merit Order Dispatch
    - Optimizing the run of the river plant operations
    - Characteristics of Thermal power stations
    - Characteristics of Hydro power stations
    - Characteristics of IPP Contracts
    - Spinning reserve
    - Currently applicable Single unit loading limitation
    - Day ahead dispatch planning
    - How to decide what machines should be stopped for a given duration
    - How to stagger hydro generation in the load curve to get maximum benefits during Thermal maximum scenario.
    - Managing the generator start/stop during/after the morning peak.
    - Managing the generator start/stop after night peak.
    - Dispatching of generators to accommodate transmission constraints such as line loadings, voltage control, Transformer (T/F) loading etc.
    - Water value Concept
    - Voltage Control
    - Day ahead demand forecast and factors affecting. (Weather, holidays, special events etc.)
    - Frequency controlling machines.
    - Pond balancing under various conditions, (high inflow, unavailability of certain machines in the cascade, head loss etc.).
    - Routine outages of certain machines (Gas side wash, Turbo wash etc.) and durations.
    - Alarms reported by Power stations and action to be taken (MVA limit, generator T/F temperature high, head loss etc.).
    - Communication between power station OEs, SCEs, EEs

- 33kV feeders taking auxiliary power to some Power stations. (Victoria, Samanala wewa, Upper Kothmale etc.).
- Power Stations with 33kV GSS

3. Transmission Network Operations

- All SCEs must be familiar with the entire 132kV, 220kV transmission Network layout with prominence to the followings.
- GSS internal arrangement with special emphasis to the followings.
- T/F paralleling and AVR operation schemes.
- Under Ground Cable network (132/220/33kV).
- Operation and Maintenance responsibilities of UG and OH cables
- Auto Re-closure operation
- Permit to Work procedure
- Voltage Control using Generator AVR, T/F Taps, Capacitors, switching off Transmission Line etc.
- Controlling line load flows using Generation, Voltage etc.
- Transmission System Operations such as BB transfer, incoming line transfer.
- Procedure of releasing 33kV feeders for maintenance
- Procedure of releasing Transmission system equipment for maintenance
- New Energization procedure

4. Total Failure restoration.

SCE shall be aware the procedure to follow during System restoration after Total System Failure.

- Control Room Documentation and Reports prepared by SCE
- Literature (Operation Manuals, Safety Manuals, Contingency plans, special Operation Memorandums etc.).
- SCADA/EMS System.
- Trainee SCE should acquire thorough knowledge on NCP tool
- Trainee SCE should acquire adequate knowledge on PSSE/SDDP Software Tools
- Under Frequency Load shedding scheme
- Special protection schemes of Coal power plants and its impact to System Stability
- Renewable Energy Capacity, impacts to system operations and monitoring
- Subordinate staff administration.
- SCC building power supply, fire alarm system, water supply, black start DG operation, Lighting Distribution panels, firefighting.
- Functions of Operation planning, Operations Audit and System Modelling units
- Maintaining the log book
- Power Station/ Grid Substation visits

(出所: CEB information)

(2) 2020/2021 年の系統システム運用に関するトレーニング計画

CEB では、系統システムに特化したトレーニング計画は策定していない。しかし、不定期に CEB 内部及び外部の講師による研修を開催している。

(3) VRE（太陽光発電、風力発電など）に関する CEB でのトレーニング

CEB では、VRE（太陽光発電、風力発電など）に特化したトレーニング計画を策定していない。

(4) VRE 導入を踏まえた電源計画または最適電源計画に関するトレーニング

CEB では、VRE 導入を踏まえた電源計画に特化したトレーニング計画を策定していない。しかし、PSS/E ソフトを用いて、下記の解析研修が行われている。

1) 潮流解析
2) 動的電力系統解析

(5) VRE 導入を踏まえた系統運用に関する CEB 外部でのトレーニング計画

系統運用に関したトレーニングを CEB 外部で受講する機会はほとんどない。

(6) VRE 導入を踏まえた系統運用に関する国外でのトレーニング計画

過去に、JICA が開催した電力系統運用制御研修の受講実績あり。
2012 年：E.N.K Kudahewa (WG2 member: Chief Engineer (System Operations), CEB)
2014 年：R.S. Weerathinga (Not member of this project)

(7) 系統運用トレーニングのための施設

系統運用のためのトレーニング施設はない。
SCADA トレーニングに関して、CEB が所有する SCADA にトレーニングシミュレーション機能がついており、シミュレーション機能によるエンジニアのトレーニングを実施している。
系統運用技術のテキストブックとして、"Power System Stability and Control, Author- Prabha Kundur" をエンジニアのトレーニングに使用している。

(8) 系統運用技術における CEB 内の講師

系統運用技術に特化した講師はいない。トレーニングは基本的に OJT（On the Job Training）により実施されている。

(9) エンジニアに対する業務付与の方針

エンジニアの業務配置や付与の方針は無い。しかし、各エンジニアの経験や知識は配置や担当業務付与に考慮される。

(10) 系統運用部署への配置エンジニア数

定員数は23名であり、その内訳は、チーフエンジニア1名、日勤者9名、交替勤務者12名、系統分析担当者1名である。

(11) 系統運用エンジニアの技術面での評価システム

CEB では系統運用エンジニアの評価システムがある。5.3.3 (1) の表 5.21 に示した習得項目に関する知見ならびに技術スキルを決められた期間中にマスターする必要がある。

5.4　配電線運用保守

5.4.1　配電線信頼度の現状

(1)　電力供給信頼度及び品質に関する分析報告

【PDM 指標案】：電力信頼度及び品質に関する分析報告

これまで、現状、供給信頼度や電力品質について、SAIFI、SAIDI に関しては年次報告書に記載されるが、配電線の設備や電力供給の状況の観点から分析された報告書は作成されていない。

現状の 33kV、11kV 配電線における電圧及び電流の三相アンバランス状況を表 5.22 に示す。アンバランスは効率的な電力供給のために解消すべき事象であるが、現状は問題化していない。

表 5.22　33kV・11kV 配電線における電圧及び電流の三相アンバランス状況

Organization	Voltage and current unbalance situation in 33kV and 11kV distribution line
DD1	[Guide line etc.] Only for 400V - PUCSL Guideline 2012 [Three (3) phase unbalance at 11kV distribution line] As three (3) phase transformers are always used. CEB is not experiencing any voltage unbalance in 11kV lines. [Three (3) phase unbalance at 33kV distribution line] As three (3) phase transformers are always used. CEB is not experiencing any voltage unbalance in 33kV lines. [Problems of three (3) phase Unbalance at 11kV distribution line owing to installation of PV/WT] As PV/WTs installations are connected to 11kV lines through three phase transformers (installed within PV/WTs generation facility), CEB is not experiencing any voltage / current unbalance in 11kV lines. [Problems of three (3) phase Unbalance at 33kV distribution line owing to installation of PV/WT] As PV/WTs installations are connected to 33kV lines through three phase transformers (installed within PV/WTs generation facility), CEB is not experiencing any voltage / current unbalance in 33kV lines.
DD2	[Guide line etc.] No Three (3) phase unbalance has occurred. [Three (3) phase unbalance at 11kV distribution line] No Three (3) phase unbalance has occurred. [Three (3) phase unbalance at 33kV distribution line] No Three phase unbalance has occurred. [Problems of three (3) phase Unbalance at 11kV distribution line owing to installation of PV/WT] Not Applicable. [Problems of three (3) phase Unbalance at 33kV distribution line owing to installation of PV/WT] Not Applicable.
DD3	[Guide line etc.] For LV connection (400V), Distribution Code of Sri Lanka issued by Public Utility Commission guideline 2012. [Three (3) phase unbalance at 11kV distribution line] Not Applicable. [Three (3) phase unbalance at 33kV distribution line] As we are using three phase transformers, such voltage unbalance in 33kV level not recorded so far. [Problems of three (3) phase Unbalance at 11kV distribution line owing to installation of PV/WT] Not Applicable. [Problems of three (3) phase Unbalance at 33kV distribution line owing to installation of PV/WT] As we are using three phase transformers, such voltage unbalance in 33kV level not recorded so far.
DD4	[Guide line etc.] No Three (3) phase unbalance has occurred.

Organization	Voltage and current unbalance situation in 33kV and 11kV distribution line
	[Three (3) phase unbalance at 11kV distribution line] No Three (3) phase unbalance has occurred. [Three (3) phase unbalance at 33kV distribution line] No Three (3) phase unbalance has occurred. [Problems of three (3) phase Unbalance at 11kV distribution line owing to installation of PV/WT] Not Applicable. [Problems of three (3) phase Unbalance at 33kV distribution line owing to installation of PV/WT] Not Applicable.
LECO	Not Applicable

(出所: CEB and LECO information)

(2) 電力供給信頼度及び品質に関する改善提言報告

【PDM 指標案】: 電力供給信頼度及び品質に関する改善提言

現状の配電線における主な停電故障防止対策を表 5.23 に示す。一般的な対策は講じているものの、故障原因を分析して実際の改善に繋げる動きは見られない。

カウンターパートと JICA 専門家はより適切な対策について、本プロジェクト内で議論を通して見出していく計画である。

表 5.23 配電線における主な停電故障防止対策

Organization	Main measures to prevent from power failures
DD1	-Inspection of distribution line and clear the vegetation disturbing the line clearance -Coordination of protective devices -Maintenance of line hardware -Adopting polymer insulators in salt-damaged areas -Good workmanship -Line rehabilitation -Grid maintenance once a year -Getting load reading in trans former (TF) and identify overload conditions, based on that send new planning proposals, system augmentation (new feeder arrangement , new transformer) -Analyzed network lodging by planning software and identify overload condition and 33kv feeder arrange in advance -Training the relevant staffs
DD2	-Inspection of distribution line and clear the vegetation disturbing the line clearance -Coordination of protective devices -Maintenance of line hardware -Good workmanship -Line rehabilitation -Grid maintenance once a year -Getting load reading in TF and identify overload conditions, and based on that send new planning proposals system augmentation (new feeder arrangement , new transformer) -Analyzed network lodging by planning software and identify overload condition and 33kv feeder arrange in advance -Training the relevant staffs -Converting bare conductors to Arial Bundled Conductors -Use of proper connectors, jumpers with correct tools
DD3	-Inspection of distribution line and clear the vegetation disturbing the line clearance -coordination of protective devices - Maintenance of line hardware -Good workmanship

Organization	Main measures to prevent from power failures
	-Line rehabilitation -Grid maintenance once a year -Getting load reading in TF and identify overload conditions, based on that send new planning proposals, system augmentation (new feeder arrangement , new transformer) -Analyzed network lodging by planning software and identify overload condition and 33kv feeder arrange in advance -Training the relevant staffs
DD4	-Inspection of distribution line and clear the vegetation disturbing the line clearance -Coordination of protective devices and annual testing of protection devices -Maintenance of line hardware -Good workmanship -Line rehabilitation -Grid maintenance once a year -Getting load reading in TF and identify overload conditions, based on that send new planning proposals, system augmentation (new feeder arrangement , new transformer) -Analyzed network loading by panning software and identify overload condition and 33kV feeder arrange in advance -Training the relevant staff
LECO	-Routine maintenance of　distribution lines and wayleave clearing -Introduce protective devices -Preventive maintenance activities of distribution assets -Improve the line clearances with line accessories by introducing insulating covers like pole top covers.

(出所: CEB and LECO information)

(3)　パイロットプロジェクトにおける電力供給信頼度及び品質向上効果

【PDM 指標案】：パイロットプロジェクトにおける電力供給信頼度及び品質向上効果の報告

本プロジェクトでは、カウンターパートと JICA 専門家は配電線における、信頼度向上機器の導入パイロットプロジェクトを進める。プロジェクトの開始から、パイロットプロジェクトのサイト選定をカウンターパートと JICA 専門家により進める。

5.4.2　配電線故障対策の状況

(1)　配電線運用保守トレーニングの見直し

【PDM 指標案】：配電線運用保守トレーニングの見直しの報告

各配電部門における、配電系統計画、配電系統設計、配電線運用、故障点探査、運用保守、VRE 接続などのトレーニングの実施状況を表 5.24 に示す。若手を中心とした一般的なトレーニングは実施されているが、停電故障対策に特化したトレーニングはほとんど実施されていない。

表 5.24　各配電部門で実施している配電線関係トレーニング

Organization	Type of Training
DD1	[Type of Training (i)]　Distribution System Planning [Type of Training (ii)]　Sri Lankan Power System and Future [Type of Training (iii)]　Solar PV Generation [Type of Training (iv)]　Power Quality [Type of Training (v)]　Aerial Bundled Conductors and accessories
DD2	[Type of Training (i)]　Distribution System Planning [Type of Training (ii)]　Use of Syner GI Software for Distribution Planning [Type of Training (iii)]　Sri Lankan Power System and Future [Type of Training (iv)]　Distribution Line Construction [Type of Training (v)]　Distribution Transformer Maintenance [Type of Training (vi)]　Aerial Bundled Conductors and accessories
DD3	[Type of Training (i)]　Distribution System Planning [Type of Training (ii)]　Sri Lankan Power System and Future [Type of Training (iii)]　Solar PV Generation [Type of Training (iv)]　Power Quality [Type of Training (v)]　Aerial Bundled Conductors and accessories
DD4	[Type of Training (i)]　Distribution System Planning [Type of Training (ii)]　Operation and Maintenance
LECO	[Type of Training (i)]　Operation and Maintenance of 11kV O/H and UG Lines List of training modules conducted by the Training Center is attached as 表 5.25.

(出所: CEB and LECO information)

表 5.25　LECO で実施している配電線関係トレーニング

No.	Module Name
Module 1	Basic Management
Module 2	Industrial Relations
Module 3	Supervisory Skills
Module 4	Problem Solving and Decision Making
Module 5	Project Management
Module 6	Strategic Management
Module 7	Public Relation and communication
Module 8	Finance for non-financial executives
Module 9	Budgeting (annual budget preparation)
Module 10	Fundamentals of Business Accounting
Module 11	Management Auditing
Module 12	Technical Knowledge (core business of LECO) for Clerks
Module 13	Branch Office Procedure Related to Customer
Module 14	Administrative Activities of the Branch Office
Module 15	Basic Computer Knowledge
Module 16	MS Office Package - Word

No.	Module Name
Module 17	MS Office Package - Excel
Module 18	"Pronto" Software Package
Module 19	Billing Software
Module 20	Personnel and Payroll
Module 21	Company Orientation for New Recruits
Module 22	Communication Skills (Secretaries, Receptions and Steno/Typists)
Module 23	Quality Management System and Good House Keeping
Module 24	Procurement Procedure and Stock Control
Module 25	Electricity Act and Regulations
Module 26	General Safety
Module 27	LV line Construction
Module 28	HV Line Construction
Module 29	Equipment Installation
Module 30	Construction Process
Module 31	Testing and Commissioning
Module 32	Sub-Station and Switching　Station commissioning
Module 33	Maintenance of HV Power Lines, LV Power Lines and Meter Connection
Module 34	Equipment Maintenance
Module 35	11kV Line Failure
Module 36	LV Line and Service Cable Failure
Module 37	Safety of LECO
Module 38	Tools and Equipment Used in Construction, Maintenance and Breakdown Process
Module 39	Practice and Usage of tools and Equipment for Special Purpose Tools
Module 40	Hydraulic Tools and Tools for Line Construction
Module 41	LV Line Design and Planning
Module 42	HV Line Design and Planning
Module 43	Sub-Station Design and Planning; Switching　Station commissioning
Module 44	Loss reduction and Control in the LECO Distribution System
Module 45	Special Construction
Module 46	Energy Meter
Module 47	Technician Training Programme for Grade iii Technicians
Module 48	Technician Training Programme for Grade ii Technicians
Module 49	Technician Training Programme for Grade I Technicians
Module 50	Technician Training Programme for Grade I (special) Technicians
Module 51	Induction Training Programme for Newly Requited Technicians
Module 52	Induction Training Programme for Newly Requited Technical Officers
Module 53	Induction Training Programme for Newly Requited Engineers

(出所: LECO information)

(2) 配電線機器導入による故障削減技術の向上

【PDM 指標案】: WG のリーダーならびに DD1、2、3、4 及び LECO のそれぞれ 1 名以上の計 6 名以上の技術者が配電線機器導入による故障削減技術を向上

DD1、DD2、DD3、DD4 及び LECO における、配電線故障削減のための設備や知識は、現状十分とは言えない。現状、停電、故障削減のための機器として、再閉路開閉器と故障区間表示器が使用されている。

そのため、JICA 専門家チームは、本プロジェクトのパイロットプロジェクトにおいて、新たな配電線故障削減対策機器の導入を試行する計画である。

5.4.3 配電線電圧変動改善

【PDM 指標案】: 配電線電圧変動改善報告

(1) 太陽光発電及び風力発電連系ガイドライン

CEB は太陽光発電、風力発電の配電線連系ガイドラインを以下で定めている。

>CEB guide for grid interconnection of embedded generators, (Part 1 & Part 2) 2000 年 12 月

>Grid connection requirement for large scale roof top solar power plants - addendum to the CEB guide for grid interconnection of embedded generators, (Annexure 3). 2000 年 12 月

(2) 電力及び電圧変動

配電線における、現状の電圧及び周波数変動値は以下のとおりである。大きな影響とはなっていないため、十分なデータが採集されてはいない。

表 5.26 電圧及び周波数変動状況

Organization	Power/voltage fluctuation situation
DD1	No data exists. Active/Reactive power and voltage transition data are presently not available, since Grid Power Station (GSS) don't install VTs at each 33 kV feeders at GSS. The only possible option is providing current flow data from the log books. If not those data may collected by installing separate meters / data loggers on above selected 33kV feeders
DD2	Some active power can be provided. 10.0MW Valacchena – Feeder 05 (Eastern Province) 3.0MW- Veyangoda – Feeder 08 (Western Province North) 1.0MW- Pallekele – Feeder 06 (Central Province)
DD3	Currently, no recorded data is available. If Active/Reactive power and Voltage transition data is required, data can be obtained.
DD4	Active/Reactive power and Voltage data are presently not available. Only current flow data from the log books maintained by Control Room Operators is available.
LECO	Not Applicable

(出所: CEB and LECO information)

(3) 33kV 配電線の PV 及び WT 最大連系容量

33kV 配電線への PV 及び WT 発電の最大連系容量について、現状の状況を表 5.27 に示す。
現在、11kV 配電線には VRE 電源は接続されていない。

表 5.27 33kV 配電線への PV 及び WT 発電の最大連系容量

Organization	Installed capacity of PV/WT in 33kV distribution lines
DD1	In the present network of CEB-DD1, the maximum capacity of the PV & WT power generation connected to 33 kV distribution line is 10MW. However, allowed capacity will depend on the loading of the existing 33kV feeder and the location (length) of the generation source along the feeder.
DD2	No information
DD3	Single point available maximum feeding is 2MW. It is Solar PV installation. However collectively maximum Solar PV feeding in 33kV line is 4,081kW (without rooftop solar, less than 42kVA). This allowed capacity will depend on the loading of the existing 33kV feeder and the location (length) of the generation source along the feeder.
DD4	10MW
LECO	Not Applicable

(出所: CEB and LECO information)

(4) PV 及び風力発電出力による電圧変動解析技術の向上

【PDM 指標案】: WG のリーダーならびに DD1、2、3、4 及び LECO のそれぞれ 1 名以上の計 6 名以上技術者が PV 及び風力発電出力による電圧変動解析技術を向上

現在、配電線の電圧及び周波数変動に対する対策はとられていない。これは、VRE 出力がいまだ少なく、配電線の電圧、周波数に影響を及ぼすほどの出力に至っていないからである。
従って、配電線解析エンジニアは、VRE が今後導入されるにあたりどのような問題が発生するのかがまだ経験していない。
かかる状況の中、各 Distribution Division で、配電線への PV 連系により、今後配電線の電圧が許容電圧を超過した際に発生する問題を抽出した。その内容を表 5.28 に示す。

表 5.28 配電線の電圧が規定値を超過した際に発生する問題

Organization	Problems of excess of allowable voltage level
DD1	-All PV / WT installation connected to 33kV lines are operating at Voltage Control Mode. Hence, possible voltage excess are mitigated introducing voltage limitation to each PV / WT generation, where necessary. -However, with this situation, CEB-DD1 has to limit integration / capacities of PV / WT generation for certain 33kV feeders, till the voltage improvements are implemented on the network. i) Polonnaruwa Feeder 04 ii) Valachchenei Feeder 05
DD2	No problem exist so far. Voltage Limit Not exceeded due to PV/WT installation.

Organization	Problems of excess of allowable voltage level
DD3	Medium Voltage level connected Solar PV connecting in "Voltage control mode". Therefore, no any recorded instance for voltage limit violation due to solar PV. However, in future CEB-DD3 may have such issues.
DD4	PV is installed in voltage control mode. Therefore not exceeded.
LECO	Not Applicable

(出所: CEB and LECO information)

上記と同様に、各 Distribution Division で、配電線への PV 連系により、送電電力が配電線の容量を超過した際に発生する問題を抽出した。その内容を表 5.29 に示す。

表 5.29　送電電力が配電線の容量を超過した際に発生する問題

Organization	Problems of excess of allowable capacity
DD1	-The maximum current of 33 kV feeders does not exceed the facility capacity as PV / WTs. They run below allowable voltage limit. -However, capacity excess expected to occur in case of introducing new PV /WTs generation to certain 33 kV lines, such as i) Polonnaruwa Feeder 04 ii) Valachchenei Feeder 05 iii) Puttalam Feeder 01 iv) Norochcholai Feeder 02
DD2	No outstanding problem have occurred. Voltage Limit Not exceeded due to PV/WT installation
DD3	Not recorded such cases in DD3 so far. However, CEB-DD3 study the connection feasibility based on voltages before giving any connection clearance.
DD4	Not Applicable
LECO	Not Applicable

(出所: CEB and LECO information)

(5)　電圧変動対策としてのパイロット配電線へのバッテリー導入における効果報告

【PDM 指標案】：電圧変動対策としてのパイロット配電線へのバッテリー導入における効果報告

配電線への負荷変動調整用バッテリー導入実績は無い。

5.4.4　配電線技術者育成

(1) トレーニングの種類

配電線技術トレーニングの種類については 5.4.2 (1)の記載を参照されたい。

(2)　トレーニング後の受講者の評価

DD1、DD2、DD3、DD4 及び LECO は表 5.30 のとおりトレーニング受講者の評価を行っている。

表 5.30　トレーニング受講者の評価

Organization	Evaluation method of Training
DD1	[Evaluation on training] Yes [Evaluation method] Through the evaluation sheet given at the end of each training sessions.
DD2	[Evaluation on training] -CEB has CEB training centers. Most of programs are conducted to lower level technical staffs. A few training programs are available for engineers (in distribution) time to time. -All the new engineers are given introduction trainings (class room & field) 2 or 3 months about the Generation, Transmission & Distribution. -Several no of trainings are arranged by Training branch and divisional wise annually. [Frequent training Programs] -Syner GI Software is arranged for all Distribution Planning engineers -Distribution Transformer Maintenance (trainer CEB engineers) -Aerial Bundled Conductors and accessories (trainer CEB engineers) [One time overseas training Programs arranged during past years] (few engineers are participated) -Training on Ifix Software -Training on IConiX Software -Auto Recloser Training at NOJA Power Company, Australia, etc. [Evaluation method] -By the evaluation sheet given at the end of each training sessions. -After Engineers completed 3 years working period, interviews are carried out to evaluate their knowledge by panel of Senior CEB engineers.
DD3	[Evaluation on training] Yes [Evaluation method] -Through the evaluation sheet given at the end of each training sessions.
DD4	[Evaluation on training] Yes [Evaluation method] -By Feedback forms
LECO	[Evaluation on training] Yes [Evaluation method] -By Feedback forms

(出所: CEB and LECO information)

(3)　バッテリー導入等による負荷変動防止の方針・ガイドライン

各 DD 及び LECO ともに、バッテリー導入等による負荷変動防止のための方針・ガイドラインは策定されていない。

(4)　三相電圧平衡のためのガイドライン

「Distribution Code of Sri Lanka」（2012 年、PUCSL）に、配電線三相平衡のガイドラインが記されている。

(5) 配電線への PV、WT 発電導入のためのガイドライン

「CEB Guide for Grid Interconnection of Embedded Generators」（2000 年　Part I 及び Part II）が PV 及び WT 発電導入のためのガイドラインとなっている。

(6) 負荷調整用バッテリーの導入ガイドライン

負荷調整用バッテリーの導入ガイドラインは策定されていない。

(7) 負荷変動抑制のためのエンジニア、スタッフの配置

負荷変動抑制業務に特化したエンジニア、スタッフは配置されていない。

(8) 負荷変動抑制のための部署

負荷変動抑制業務に特化した部署は設置されていない。

(9) 負荷変動抑制業務に携わるエンジニアの技術評価

当該の評価システムはない。

(10) 負荷変動抑制担当エンジニアの講師

当該の講師はいない。

(11) SAIFI/SAIDI に関するトレーニングまたはカリキュラム

各 DD では SAIFI（System Average Interruption Frequency Index）及び SAIDI（System Average Interruption Duration Index）を主要なインデックスとして位置付けている。基本的に、配電線部門の日常業務はすべて SAIFI 及び SAIDI の改善につながっている。配電線関連の指針である「Distribution Code of Sri Lanka（2012 年）」に SAIFI 及び SAIFI が言及されている。

(12) 優先供給負荷やエリアの基準などの供給信頼度に関する方針・ガイドライン

「Distribution Code（2012 年 PUCSL）」が優先供給負荷やエリアの基準などの供給信頼度に関するガイドラインとされている。配電線負荷供給基準の概要は表 5.31 のとおり。

表 5.31　配電線負荷供給基準

Organization	Guideline and prioritization area
DD1 DD2 DD3 DD4 LECO	[Guideline] Distribution Code 2012 of PUCSL [prioritization criteria] -Urban and Metropolitan areas: N-1 (Medium Voltage) -Rural area: N-0 (Medium Voltage) -Urban, Metropolitan and Rural area: N-0 (Low Voltage)

(出所: CEB and LECO information)

(13) 再閉路開閉器や故障区間表示器などの配電線故障削減機器

DD1、DD2、DD3、DD4 及び LECO で使用している配電線故障削減機器は表 5.32 のとおり。これらの機器のほとんどは 33kV 配電線に設置されている。

表 5.32　配電線故障削減機器

Organization	Installed facilities
DD1	Reclosers
DD2	Auto Reclosers, Fault Indicators
DD3	Reclosers, Fault Indicators
DD4	Auto Reclosers
LECO	Auto Reclosers

(Source: CEB and LECO information)

(14) 配電線故障削減対策

1)　故障削減対策担当部署

配電線故障削減対策担当部署及び担当エンジニア数を表5.33に示す。

表 5.33　配電線故障削減対策担当部署及び担当エンジニア数

Organization	Division/Section	Number of engineers
DD1	DGM(P&D), CE(P&D) of each provinces	10
DD2	DGM(P&D), CE(P&D) of each provinces	13
DD3	DGM(P&D), CE(P&D) of each provinces	12
DD4	DGM(P&D), CE(P&D) of each provinces	10
LECO	System Operation Department	2

(出所: CEB and LECO information)

2)　エンジニアによる配電線故障削減機器の理解

5.4.4 (13) に述べたとおり、多くの 33kV 配電線に故障削減を目的として機器が設置されていることから、エンジニアの多くがそれらの機器に関する知識を有している。当該機器の知識を持っているエンジニア数を確認した結果を表 5.34 に示す。

表 5.34　配電線故障削減機器の知識を持っているエンジニア数

Organization	Number of engineers
DD1	About 10 engineers (all planning engineers in the division)
DD2	About 13 engineers (all planning engineers in the division)
DD3	About 12 engineers per division
DD4	All planning engineers in the division (about 10 engineers) and maintenance engineers
LECO	10 engineers

(出所: CEB and LECO information)

3)　配電線故障削減対策に関するトレーニング方針・カリキュラム

配電線故障削減対策に関するトレーニング方針・カリキュラムはない。2020-2021 年度のトレーニング計画の中にも、配電線故障削減対策の枠は設定されていない。

加えて、配電線故障削減対策技術を専任で指導する講師はおらず、関係するテキストブックもない。

4) 新人エンジニアに向けた故障削減トレーニング期間

新人エンジニアに特化した配電線故障削減の技術トレーニングはほとんど実施されていない。新人エンジニアは OJT によりとレーニングを受けている。新人技術者に向けた配電線故障削減トレーニングの概要を表 5.35 に示す。

表 5.35 新人技術者に向けた配電線故障削減トレーニングの概要

Organization	Training for Freshman/New Comer Engineers on Outage Reduction
DD1	[Training Period] One (1) day [Outline of Training] No specific contents
DD2	[Training Period] One (1) day [Outline of Training] Planning concepts, use of alternative feeding arrangements and Auto reclosers
DD3	[Training Period] One (1) day [Outline of Training] No specific contents
DD4	[Training Period] Not specifically for outage reduction [Outline of Training] N/A
LECO	[Training Period] Not specifically for outage reduction [Outline of Training] N/A

(出所: CEB and LECO information)

5) 社外での配電性故障削減技術トレーニング

配電線故障削減技術の社外でのトレーニングの機会はない。

6) 配電線故障削減技術の観点によるエンジニアの評価

DD1、DD2、DD3、DD4 及び LECO とも、配電線故障削減技術の観点によるエンジニア評価のシステムはない。

(15) 調達ガイドライン

配電部門の調達ガイドラインとして、「National Procurement Manual and Guideline」（National Procurement Commission）が用いられている。

5.5　人材育成

5.5.1　CEB 職員のトレーニング

(1)　過去（2018 年、2019 年）の CEB エンジニア研修実績

2018 年及び 2019 年に、CEB トレーニングセンターにて、Executive Engineer に対して実施した技術及び技術以外の Workshop と Capacity Development (CDP)を表 5.36 及び

表 5.37 に示す。

表 5.36　トレーニングセンターで実施した Workshop 及び Capacity Development（2018 年）

No.	Course Name	Category of Executives	Technical Training/Other	No of Programmes	Participants
1	Workshop on “Labour Law” for Executives	Senior executives	Other	3	192
2	Workshop on “Effective use of IT” for Junior Executives	Junior Executives	Other	2	49
3	Workshop on “Contract Management” for Engineers in CEB	Engineers	Other	2	232
4	Workshop on “Procurement Management” for CEB Executive	Senior executives	Other	1	100
5	Workshop on “Power Quality and Applicable Standard for Connecting Solar PV Plant to the Grid” for Engineers	Engineers	Technical	3	205
6	Workshop on “Bidding Document Preparation” for Engineers & Accountants	Engineers & Accountants	Other	1	119
7	Workshop on “Public Private Partnership for CEB Engineers	Engineers	Other	1	49
8	Workshop on “Power System Protection”	Engineers	Technical	1	125
9	Workshop on “Earthling” for Engineers	Engineers	Technical	2	182
10	Workshop on “Financial Management” for Engineers	Engineers	Other	1	70

(出所: CEB information)

表 5.37　トレーニングセンターで実施した Workshop 及び Capacity Development（2019 年）

No.	Course Name	Category of Executives	Technical Training/Other	No of Programmes	Participants
1	Workshop on “Labour Law” for Senior Executives in CEB	Senior executives	Other	2	156
2	Workshop on Present Status and Future of Electricity Sector & Planning Perspectives	Engineers	Technical	2	176
3	Workshop on “Power System Protection”	Engineers	Technical	1	116
4	CPD Training Progaramme on “Induction to Sri Lanka Power System Tariff Setting & Regulatory Structure for CEB Engineers	Engineers	Technical	2	257
5	Workshop on “Procurement Management” for CEB Executive	Senior executives	Other	1	64
6	Induction Training Programme for Junior Executives	Junior Executives	Other	1	58
7	CPD Training Progaramme for “Financial Management"	Engineers	Other	1	122
8	CPD Training Progaramme for “Distribution Planning” for Engineers	Engineers	Technical	1	126
10	CPD Training Progaramme for “Transmission Maintenance”	Engineers	Technical	1	128
11	CPD Training Progaramme for “Transmission Construction ”	Engineers	Technical	1	75
12	CPD Course on “Disciplinary Procedures” for Senior Executives	Senior executives	Other	1	125
13	CPD　Training Programme for Procumbent & Contract Management for Accountants	Accountants	Other	1	107
14	MS Excel Training on Advanced Analysis For Business and Technical Users for Accountants	Accountants & Acct.Assistants	Other	1	107

(出所: CEB information)

上表以外にも、配電線作業者向けのトレーニングが実施されている。それらのうち 2018 年及び 2019 年に開催されたトレーニングを表 5.38 及び表 5.39 に示す。

表 5.38　トレーニングプログラム（2018 年）

No.	Training Programme	Duration	Attendance
1	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2018.01.02 - 01.19	50
2	Training programme for Linesman Grade I	2018.01.08 - 02.02	30
3	Training programme for Trainee Jounior Technical Mates Stage III	2018.01.08 - 01.26	44
4	Training programme for Consumer Coordinator	2018.01.08 - 01.12	29
5	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.01.15 - 02.02	60
6	Training programme for Junior Technical Mates	2018.01.15 - 04.06	35
7	Training programme for Trainee Junior Technical Mates Stage III	2018.01.29 - 02.16	60
8	Training programme for Trainee Semi Skilled Consumer Coordinator (Central Province)	2018.01.08 - 01.17	60
9	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2018.01.29 - 02.16	49
10	Training programme for Technical Mates	2018.02.12 - 03.09	45
11	Training programme for Trainee Semi Skilled Consumer Coordinator (North Western Province)	2018.02.14 - 03.02	54
12	Training programme for Trainee Semi Skill Consumer Coordinator (Kinchigune TC)	2018.02.19 - 03.09	44
13	Training programme for Trainee Jounior Technical Mates Stage III	2018.02.19 - 03.09	45
14	Training programme for Semi Skilled Billmen	2018.03.05 - 03.09	51
15	Training programme for Artificer	2018.03.05 - 03.16	43
16	Training programme for Trainee Junior Technical Mates Stage III (N6)	2018.03.12 - 03.29	45
17	Training programme for Control Room Operator Grade II	2018.03.12 - 04.06	22
18	Training programme for Junior Technical Mates (N6 to N5)	2018.03.12 - 04.06	35
19	Training programme for Artificer	2018.03.19 - 03.29	48
20	Training programme for Consumer Coordinator Grade I	2018.04.02 - 04.06	57
21	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.04.23 - 05.11	58
22	Training programme for Trainee Junior Technical Mates Stage II	2018.04.23 - 05.11	30
23	Training programme for Control Room Operator Grade I	2018.04.23 - 05.18	8
24	Training programme for Junior Technical Mates	2018.04.23 -07.13	44
25	Training programme for Artificer	2018.05.01 -05.12	41
26	Training programme for Technical Mates	2018.05.14 - 06.08	30
27	Training programme for Mechanical Fitter Grade II	2018.05.14 - 06.08	2
28	Training programme for Electrical Fitter Grade II	2018.05.14 - 06.08	30
29	Training programme for Trainee Junior Technical Mates Stage II	2018.05.28 - 06.14	43
30	Training programme for Semi Skilled Consumer Coordinator	2018.05.21 -05.25	57
31	Training programme for Linesmen Grade II	2018.05.14 - 06.08	41
32	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.06.11 - 06.29	58
33	Training programme for Junior Technical Mates	2018.06.18 - 07.03	46
34	Training programme for Trainee Junior Technical Mates Stage III	2018.06.18 - 07.06	43

No.	Training Programme	Duration	Attendance
35	Training programme for Artificer	2018.06.18 - 06.29	42
36	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.07.09 - 07.26	64
37	Training programme for Linesman Grade I	2018.07.09 - 08.03	39
38	Training programme for Technical Mates	2018.07.16 - 08.11	33
39	Training programme for Trainee Junior Technical Mates Stage III (N6)	2018.07.09 - 07.26	57
40	Training programme for Artificer	2018.07.30 - 08.10	39
41	Training programme for Billmen Grade I	2018.07.30 - 08.03	28
42	Training programme for Linesman Grade I	2018.08.06 - 08.31	26
43	Training programme for Trainee Semi Skilled Consumer Coordinator	2018.08.13 - 08.31	65
44	Training programme for Artificer	2018.08.13 - 08.24	38
45	Training programme for Mechanical Fitter Grade I	2018.08.13 - 09.07	9
46	Training programme for Electrical Fitter Grade I	2018.08.13 - 09.07	2
47	Training programme for Junior Technical Mates	2018.08.27 - 09.21	53
48	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.09.03 - 09.21	49
49	Training programme for Trainee Junior Technical Mates Stage III	2018.09.10 - 09.28	40
50	Training programme for Trainee Junior Technical Mates Stage II	2018.09.03 - 09.21	25
51	Training programme for Junior Technical Mates Stage III	2018.09.25 - 10.19	49
52	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.09.10 - 09.28	68
53	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.09.25 - 10.12	46
54	Training programme for Linesmen Grade II	2018.09.25 - 10.19	64
55	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2018.10.01 - 10.19	45
56	Training programme for Trainee Junior Technical Mates Stage III	2018.10.22 - 11.16	56
57	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.10.15 - 11.02	45
58	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2018.10.22 - 11.16	46
59	Training programme for Linesman Grade I	2018.10.22 - 11.17	25
60	Training programme for Technical Mates	2018.10.29 - 11.30	36
61	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2018.11.05 - 11.23	51
62	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2018.11.19 - 12.14	53
63	Training programme for Trainee Junior Technical Mates Stage III	2018.11.19 - 12.14	48
64	Training programme for Trainee Semi Skill Consumer Coordinator (Kalawana TC)	2018.11.26 - 12.14	51
65	Training programme for Junior Technical Mates	2018.11.26 - 12.21	57
66	Training programme on Lath Machine Operating	2018.12.03 - 12.07	5
67	Training programme on Energy Meters	2018.12.10 - 12.11	16

(出所: CEB information)

表 5.39　トレーニングプログラム（2019 年）

No.	Training Programme	Duration	Attendance
1	Training programme for Linesmen Grade II	2019.01.07 - 02.01	56
2	Training programme for Trainee Semi Skilled Consumer Coordinator (Kalawana TC)	2019.01.07 - 01.25	47
3	Training programme for Trainee Junior Technical Mates Stage III	2019.01.07 - 02.01	50
4	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2019.01.07 - 02.01	42
5	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2019.01.28 - 02.22	44
6	Training programme for Artificer	2019.01.21 - 02.01	39
7	Training programme for Linesmen Grade II	2019.02.05 - 03.02	47
8	Training programme for Artificer	2019.02.05 - 02.16	29
9	Training programme for Trainee Junior Technical Mates Stage III (Tamil Medium)	2019.02.05 - 03.02	46
10	Training programme for Trainee Semi Skilled Consumer Coordinator (Northern Province)	2019.02.05 - 02.22	89
11	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.02.11 - 03.01	50
12	Training programme for Control Room Operator Grade II	2019.02.20 - 03.16	31
13	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2019.02.25 - 03.22	44
14	Modular Training Programme	2019.02.11 - 02.15	6
15	Training programme for Trainee Junior Technical Mates Stage III (Tamil Medium)	2019.03.05 - 03.29	41
16	Training programme for Junior Technical Mates (N5)	2019.01.14 - 04.05	55
17	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.03.25 - 04.12	44
18	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.03.25 - 04.12	45
19	Modular Training Lath Machine	2019.03.11 - 03.15	8
20	Training programme for Technical Mates	2019.04.22 - 05.17	52
21	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.04.22 - 05.17	36
22	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.04.22 - 05.10	38
23	Training programme for Trainee Junior Technical Mates Stage III	2019.04.22 - 05.17	55
24	Training programme for Junior Technical Mates	2019.04.22 - 07.12	51
25	Modular Training (Energy Meters)	2019.04.23 - 04.25	13
26	Training programme for Artificer	2019.05.06 - 05.17	36
27	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.05.13 - 05.31	39
28	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.05.20 - 06.14	39
29	Training programme for Trainee Junior Technical Mates Stage III	2019.05.20 - 06.14	42
30	Training programme for Technical Mates	2019.05.27 - 06.21	49
31	Training programme for Linesman Grade I	2019.06.03 - 06.28	33
32	Training programme for Junior Technical Mates	2019.06.17 - 07.12	51
33	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.06.17 - 07.12	34
34	Training programme for Trainee Junior Technical Mates Stage III	2019.06.24 - 07.19	58

No.	Training Programme	Duration	Attendance
35	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.06.03 - 06.21	49
36	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.06.24 - 07.12	39
37	Modular Training	2019.06.24 - 06.28	4
38	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.07.15 - 08.02	40
39	Training programme for Trainee Junior Technical Mates Stage III	2019.07.22 - 08.16	37
40	Training programme for Mechanical Fitter Grade II	2019.07.22 - 08.16	27
41	Training programme for Electrical Fitter Grade II	2019.07.22 - 08.16	24
42	Training programme for Trainee Junior Technical Mates Stage II	2019.07.15 - 08.13	34
43	Training programme for Linesmen Grade II	2019.07.08 - 08.02	29
44	Training programme for Linesmen Grade II	2019.08.05 - 08.30	50
45	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.08.05 - 08.23	47
46	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.08.19 - 09.12	34
47	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.08.26 - 09.12	43
48	Training programme for Junior Technical Mates	2019.08.26 - 09.20	43
49	Training programme for Trainee Junior Technical Mates Stage III	2019.09.02 - 09.27	51
50	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.09.16 - 10.11	43
51	Training programme for Trainee Semi Skilled Consumer Coordinator (Kinchigune TC)	2019.09.16 - 10.04	51
52	Training programme for Artificer	2019.09.16 - 09.27	44
53	Training programme for Junior Technical Mates (N5)	2019.09.30 - 12.20	57
54	Training programme for Semi Skilled Technical Service	2019.09.30 - 10.25	34
55	Training programme for Mechanical Fitter Grade I	2019.09.30 - 10.25	19
56	Training programme for Electrical Fitter Grade I	2019.09.30 - 10.25	26
57	Training programme for Semi Skilled Consumer Coordinator	2019.10.07 - 10.11	38
58	Training programme for Trainee Junior Technical Mates Stage III	2019.09.30 - 10.25	53
59	Training programme for Trainee Junior Technical Mates Stage II	2019.10.14 - 11.08	40
60	Training programme for Trainee Junior Technical Mates Stage II (Kinchigune TC)	2019.10.21 - 11.14	37
61	Modular Training Programme (Auto Mobile)	2019.10.14 - 10.18	2
62	Training programme for Trainee Junior Technical Mates Stage III	2019.10.28 - 11.22	42
63	Training programme for Trainee Junior Technical Mates Stage II (Kalawana TC)	2019.11.18 - 12.13	41
64	Training programme for Linesmen Grade II	2019.11.18 - 12.13	37
65	Modular Training Programme for Modular (ABC Power Line)	2019.11.08 - 11.09	10
66	Modular Training Programme for Modular (PLC Circuit)	2019.11.05 - 11.07	15
67	Training programme for Technical Mates (N4)	2019.11.25 - 12.20	48
68	Training programme for Junior Technical Mates (N5)	2019.11.25 - 12.20	56
69	Training programme for Trainee Semi Skilled Consumer Coordinator	2019.11.25 - 12.13	38

(出所: CEB information)

(2) CEB トレーニングセンターの場所及び研修設備（遮断器、保護リレー盤、電柱など）の概要

CEB はトレーニングセンターを持っている。地点は Deavananda Road, Piliyandala である。
トレーニングセンターの主な設備は表 5.40 のとおりである。

表 5.40 CEB トレーニングセンターの主な設備

Infrastructure facilities

No.	Facility	Quantity	Remarks
1	Auditoriums	3 nos	
2	Lecture halls (class rooms)	8 nos	
3	Computer labs	1 nos	
4	Workshops	6 nos	Wiring ,meter, control, lathe, machine and linesman
5	Cafeteria	1 nos	
6	Hostel	2 nos	Executive & non-executive

Model Lines & other

No.	Facility	Quantity	Remarks
1	LT ABC model line	1 nos	
2	33kV MV line model	1 nos	
3	HT ABC model line	1 nos	Under construction
4	Protection Lab	1 nos	Operated by Tr. Protection branch
5	model gantry	1 nos	

(出所: CEB information)

第6章　プロジェクト指標のベースライン

本事業の総括的な目標指標として、以下の 3 項目が挙げられている。

6.1　SAIFI、SAIDI 及び LOLP

(1) 年平均停電回数（SAIFI）

【PDM 指標案】: 2026 年時点の SAIFI
11（DD1、DD2、DD3、DD4、LECO）※プロジェクト内で再度議論する。

SAIFI は、需要家 1 件当たり 1 年間に発生した故障回数を示す指標である。スリランカの各地域での 2017, 2018 年の SAIFI の値は表 6.1 のとおり。

表 6.1　SAIFI

Organization	SAIFI [Number]
DD1	15.1 (2018)
DD2	43.8 (2018)
DD3	56.8 (2018)
DD4	36.2 (2018)
LECO	109 (2017)

(出所 CEB information）

(2) 年平均停電時間（SAIDI）

【PDM 指標案】: 2026 年時点の SAIDI
1,320（DD1、DD2、DD3、DD4、LECO）※プロジェクト内で再度議論する。

SAIDI は、需要家 1 件当たりで 1 年間に発生した故障の合計時間を示す指標である。スリランカの各地域での 2017, 2018 年の SAIDI の値は表 6.2 のとおりである。

表 6.2　SAIDI

Organization	SAIDI [Minutes]
DD1	4,532 (2018)
DD2	4,468 (2018)
DD3	4,885 (2018)
DD4	5,911 (2018)
LECO	4,196 (2017)

(出所 CEB information）

(3) 電力不足確率（LOLP）

【PDM 指標案】: 2026 年時点の LOLP 1.5%以下

LOLP は、供給力が需要を下回って不足が生じる確率を示す指標であり、1.5%以下を目標としている。
2018 年度の LTTDP（長期送電線開発計画）によると、スリランカにおける LOLP の値は、2018 年が 1.245%、2019 年が 0.220（計画値）である。2020 年度の LTGEP によると、2026 年の LOLP 計画値は 0.077%である。
電源予備率は最適化ソフトウェアの入力項目とされるが、LOLP 最大値は別の制約事項である。

電源予備率については、規制委員会の基準を踏まえて議論された結果、LTGEP 2020-2039 では 2.5～20%の予備率基準が採用されている。これらの数値はともに、LTGEP が基準とするグリッドコードに基づいて規定されている。理論的には、システムの特性に応じて時間とともに変化する予備率と LOLP の間に関係性がある。システム特性と信頼性からの要件を踏まえた予備率と LOLP の適切な値をさらに検討することが望まれる。

WASP ツールでは、年次 LOLP は月次 LOLP 値より計算される。WASP では、さまざまな水力条件の月間 LOLP 値を計算し、各月の加重平均 LOLP を計算する。次に、月次値の単純平均により年間 LOLP 値が得られ、最適化/シミュレーションソフトウェアの出力として取得される。

6.2 電圧及び周波数変動

【PDM 指標案】: 電圧及び周波数の変動値が大量の PV 及び風力発電を導入前後で同レベル

本指標では、現状の電圧及び周波数変動値が、今後多くの PV 及び風力発電の導入後も、同じレベルを維持していることを目標とする。

電圧制御に関しては、すべての変圧器では自動電圧調整器（AVR）が使用され、220 / 132kV 変圧器がある変電所にて 33kV 電圧と 132kV 電圧の自動調整制御を行う。

コンデンサバンクは 33kV 母線に接続され、母線の力率を測定して自動的に入り切りされる。ただし、その場合、コンデンサから十分な無効電力を得られないため、システムオペレータはコンデンサを手動で切り替えている。

CEB は、SVC のような電圧調整機器（静止機器であり無効電力供給により電圧を調整）はないが、将来的に 220kV 系統に導入されることが望まれる。

現状の配電線負荷及び電圧変動の状況については、5.4.3 (2)を参照のこと。

6.3 PV 及び風力発電出力予測システム誤差

【PDM 指標案】: PV 及び風力発電出力予測システム誤差：2026 年時点で 20%以内(平均)

現状、PV 及び風力発電の出力予測システムは確立されていない。PV 及び風力発電の出力予測は人間系による予測に依っている。

VRE 出力を予測するには、気象情報を取得することが必要となる。気象局（Department of Meteorology）は気象情報収集と予報を担務している。CEB と気象局は互いに政府機関であり、NSCC は気象局と協力して気象情報を入手している。ただし、本プロジェクトで用いる気象予測システムを構築するために必要な気象データは有償である。

Participant list for 1st Joint Coordination Committee
on
"The Project for Capacity Development on the Power Sector Master Plan Implementation Program in Democratic Socialist Republic of Sri Lanka"

Date: July 8, 2020

○Counterparts (Sri Lanka)

	Name	Position Organization	Contact E-mail address
1	Mrs. Wasantha Perera	Secretary, Ministry of Power and Energy	
2	Mr. D. D. K. Karunaratha	General Manager, Ceylon Electricity Board	
3	Dr. M. N. S. Perera	Additional General Manager (Transmission), Ceylon Electricity Board	
4	Mrs. N. W. Kumudunie Herath	Additional General Manager (Distribution Division 1), Ceylon Electricity Board	
5	Mr. M. A. D. N. Gratian	Additional General Manager (Distribution Division 2), Ceylon Electricity Board	
6	Mr. R. K. Piyadasa	Additional General Manager (Distribution Division 3), Ceylon Electricity Board	
7	Mr.G. A. D. R. P. Senevirathne	Additional General Manager (Distribution Division 4), Ceylon Electricity Board	
8	Dr. D. C. R Abeysekara	Additional General Manager (Corporate Strategy), Ceylon Electricity Board	
9	Mr. T. K. Liyanage	Finance Manager, Ceylon Electricity Board	
10	Mr. M. L. Weerasinghe	Deputy General Manager (Transmission & Generation Planning), Ceylon Electricity Board	
11	Dr. H. M. Wijekoon	Chief Engineer (Transmission Planning) Ceylon Electricity Board	
12	Dr. Narendra De Silva	General Manager, Lanka Electricity Company Pvt. (Ltd).	

	Name	Position Organization	Contact E-mail address
13	Nominee from PUCSL	, Public Utilities Commission of Sri Lanka	
14	Nominee from SLSEA	, Sri Lanka Sustainable Energy Authority	
15	Dr. H. M. Wijekoon	Chief Engineer (Transmission Planning), Ceylon Electricity Board	
16	Mr. A.W. M. R. B. Wijekoon	Electrical Engineer (Generation Planning), Ceylon Electricity Board	

〇JICA(Japan International Cooperation Agency)

	Name	Position Organization	Contact E-mail address
1	Mr. TAKASHIMA Kiyofumi	Senior Representative, Japan International Cooperation Agency, Sri Lanka Office	
2	Ms. ICHIKAWA Sayuri	Representative, Japan International Cooperation Agency, Sri Lanka Office	
3	Dr. KOBAYAKAWA Toru	Senior Director, Japan International Cooperation Agency	
4	Mr. YUZURIO Susumu	Senior Director, Japan International Cooperation Agency	
5	Ms. SHIBATA Kuri	Program Officer, Japan International Cooperation Agency	

○JICA Expert Team (Chubu Electric Power Co., Inc. and Nippon Koei Co., Ltd.)

	Name	Position Organization	Contact E-mail address
1	Mr. HIRANO Akira (Team Leader / Electric Power Strategy)	Senior Manager, Chubu Electric Power Co., Inc.	
2	Mr. YOSHIDA Toshitaka (Deputy Team Leader / Electric Power Strategy)	Assistant Manager, Chubu Electric Power Co., Inc.	
3	Mr. TANIHATA Osamu (System and Policy of Electric Power)	Senior Manager, Chubu Electric Power Co., Inc.	
4	Mr. MITSUI Shinichi (Renewable Energy)	Assistant Manager, Chubu Electric Power Co., Inc.	
5	Mr. MAKITA Yusaku (Finance)	Chubu Electric Power Co., Inc. (Group Leader/ Senior Economist, Koei Research & Consulting Inc.)	
6	Dr. Suresh Chand Verma (Supply and Demand Management)	Senior Manager, Chubu Electric Power Co., Inc.	
7	Mr. TAKAMIZAWA Yu (Power System (Planning/Operation))	Chubu Electric Power Co., Inc. (Assistant Manager, Chubu Electric Power Grid Co., Inc.)	
8	Mr. YASUTSUNE Hidenobu (Power System (System Analysis))	Manager, Chubu Electric Power Co., Inc.	
9	Mr. TAKATSU Kenichiro (Energy Management (Battery))	Assistant Manager, Chubu Electric Power Co., Inc.	
10	Dr. SHIKIMACHI Koji (Distribution Technology)	Manager, Chubu Electric Power Co., Inc.	
11	Mr. NISHIKAWA Koji (Distribution (Planning/Design/Construction) / Coordinator)	Manager, Chubu Electric Power Co., Inc.	
12	Mr. WADA Masaki (Hydraulic Civil Engineering (Planning/Design/Construction))	Deputy Chief Engineer, Nippon Koei Co., Ltd.	

Democratic Socialist Republic of Sri Lanka

The Project for Capacity Development on the Power Sector Master Plan Implementation Program

1st JCC

July 8, 2020

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Contents

00 Countermeasures against COVID-19

Basic Policy and practical Measures against COVID-19

CHUBU Electric Power
NIPPON KOEI

Basic Policy

- Even if field work in Sri Lanka is not possible due to the COVID-19, this Project will be implemented by remote work from Japan with the support of C/Ps.
- From the 4th field survey in October, it is assumed that the visit to Sri Lanka will be resumed, but it depends on when it gets resolved.
- Always we have a flexible way of thinking, respond flexibly, and not delay the Project

Measures on tangible factors

- Usage of video conference (Zoom)
- Conference facilities Introduction to C/P (In procurement Process)
- Screen sharing of presentation materials during video conference
- Adopted Live Chat with text during video conference
- Project Data Room opened (assuming JICA GIGA POD)

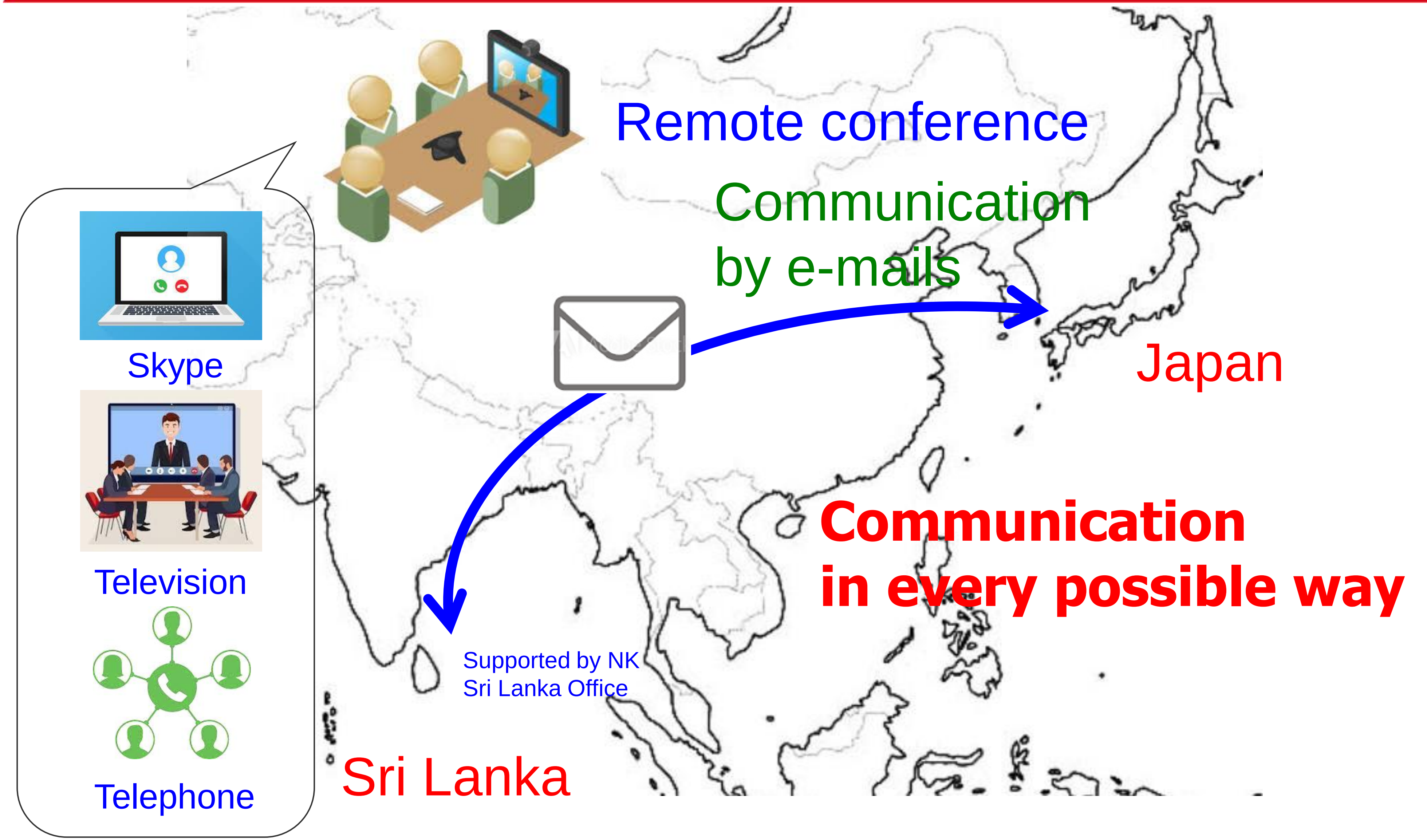
CHUBU Electric Power
NIPPON KOEI

Measures on intangible factors

<For example>

- Add a purpose and explanation to the questionnaire for the C/Ps’ better understanding
- Explain how to utilize the data/info. so that accurate & required data/info will be provided from C/Ps.
- Materials with abundant explanations makes oral explanations unnecessary.
- On-demand material introduced
- Examples of renewable energy installation in Japan and advanced countries creates image of target. And gap between the present and the target will be clearly realized.

How to proceed the Project

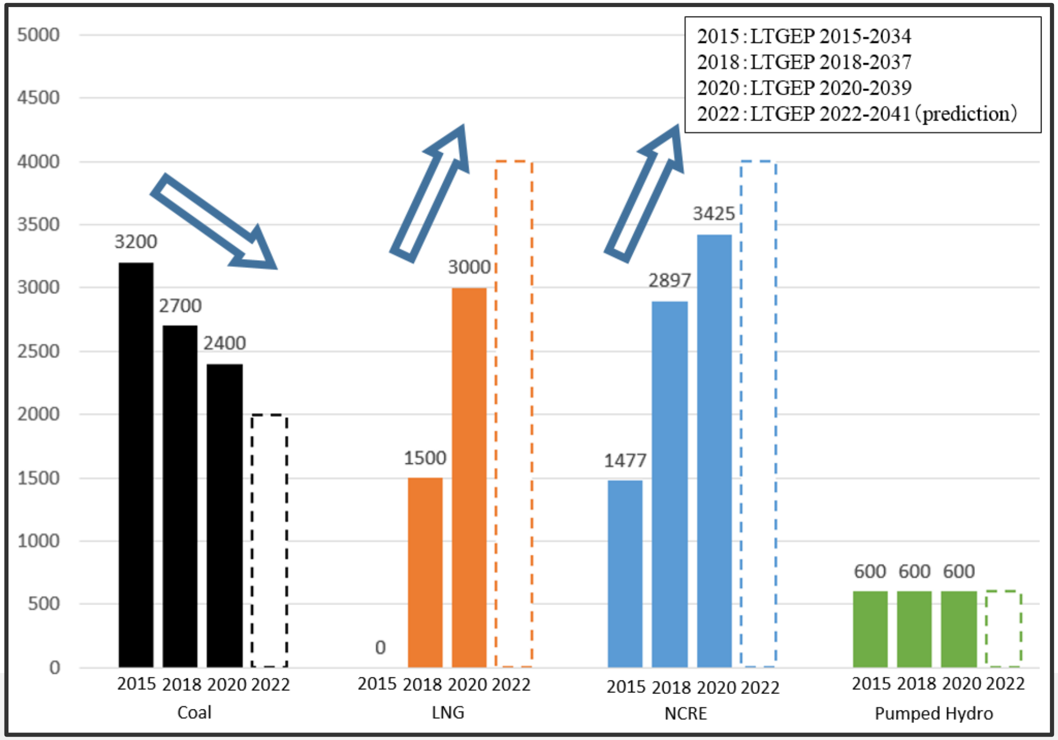


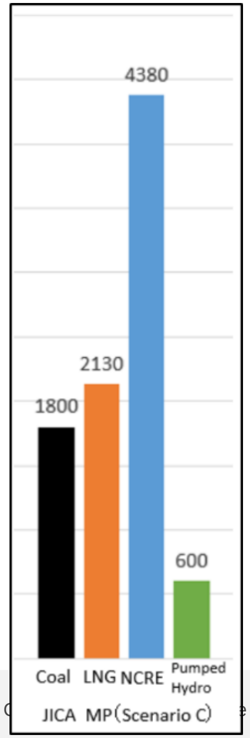
01 Background

Promotion of Shift to Renewable Energy Power Sources

- CEB updates LTGEP (Long Term Generation Expansion Plan) every two years. Past editions of LTGEP are balanced generation development plan considering 3E (Energy security, Economy, Environment). Among them, recent two editions insist enormous increase of VRE (Variable Renewable Energy) in particular in line with eco-conscious government policy and reduction of CO2/ emission (or diversification of power resources).
- This emphasis on VRE is expected to continue in the future revisions of LTGEP
- The introduction of VRE is promoted, but development of pumped storage power plant (PSPP) is postponed

→To review of power development plan and transmission development plan as well is necessary





Necessary Items to promote the Introduction of VRE

- System and policy development
- Corporate strategy planning based on the improvement of CEB financial status
- Promotion of understanding about VRE (facilities, step of project implementation)
- Facility formation (Generation and power system) considering the promotion of VRE introduction
- Effective system operation with an increased VRE ratio (improved power generation forecast and increased balancing power)
- Confirmation of fluctuation suppression caused by VRE (via pilot project)

02 Objectives

Objectives of the Project

Project Purpose

Institutional Capacity for improving transmission and distribution operational reliability is enhanced to get prepared for increased share of RE planned in the LTGEP

Outputs of the Project

1. Capacity of corporate strategy and planning for VRE is enhanced (WG1)
2. Capacity of system development and operation for transmission network in response to increased share of VRE is enhanced (WG2)
3. Capacity of distribution network operation is improved (WG3)

03 Counterparts

Counterparts

- Main Counterpart
  - Ceylon Electricity Board (CEB)

- Related Organizations
  - Ministry of Power and Energy (MOPE)
  - Sustainable Energy Authority (SEA)
  - Lanka Electricity Company (LECO)
  - Public Utility Commission of Sri Lanka (PUCSL)

04 Joint Coordination Committee (JCC) & Working Group (WG)

Role of JCC and WG

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JCC: Project Management Side

- Evaluates the study result submitted by WGs and leads the Project
- Supervises the study progress with key persons periodically
- Builds the step-by-step consensus of the study, especially between regulator and business operator
- Makes a decision and shows the direction of the Project
- <Case of the other project (Mozambique)>

  JCC's output was approved by the cabinet and then became the national plan.
  In Sri Lanka, JCC would be utilized effectively to give the authorization to the national important decisions

WG: Project Implementation Side

- Is a subordinate organization of JCC.
- Is organized for each study field for smooth implementation of the Project
- Proceeds the Project and its result is reported to JCC
- Receives technical transfer through the OJT through the collaboration work

Entry Sheet of JCC Members as of 8 July

Name	Title / Organization	Role
Mrs. Wasantha Perera	Secretary, Secretary, Ministry of Power and Energy (MOPE)	Chairman of the JCC
Mr. D. D. K. Karunaratha	General Manager, Ceylon Electricity Board (CEB)	Project Director
Dr. M. N. S. Perera	AGM, Transmission, CEB	Member
Mrs. N. W. Kumudunie Herath	AGM, Distribution Division 1, CEB	ditto
Mr. M. A. D. N. Gratian	AGM, Distribution Division 2, CEB	ditto
Mr. R. K. Piyadasa	AGM, Distribution Division 3, CEB	ditto
Mr. G. A. D. R. P. Senevirathne	AGM, Distribution Division 4, CEB	ditto
Dr. D. C. R Abeysekara	AGM, Corporate Strategy, CEB	ditto
Mr. T. K. Liyanage	Manager, Finance, CEB	ditto
Mr. M. L. Weerasinghe	DGM, Transmission & Generation Planning, CEB	ditto
Dr. H. M. Wijekoon	Chief Engineer, Transmission Planning, CEB	ditto
Dr. Narendra De Silva	General Manager, Lanka Electricity Company (LECO)	ditto
Mr./Ms. ????	Public Utility Commission of Sri Lanka (PUCSL)	ditto
Mr./Ms. ?????	Sri Lanka Sustainable Energy Authority (SEA)	ditto
Mr./Ms. ?????		ditto

- Addition and Change of Member are always acceptable

Entry Sheet of WG1 & WG2 Members as of 8 July

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Category		Counterparts (Leader in bold letters)	JICA Expert Team (Leader in bold letters)
WG1 Corporate Strategy, System and Policy	Management	**Mr. A. M. A. Alwis** Ms. K.V. S. M. Kudaligama	**Mr. HIRANO Akira** Mr. YOSHIDA Toshitaka Mr. TANIHATA Osamu
	Members	11 Ladies and Gentlemen	Mr. MITSUI Shinichi Mr. Yusaku MAKITA
WG2 Planning and Operation of Power System	Management	**Mr. D. S. R. Alahakoon** Mr. V. B. Wijekoon	**Dr. Suresh Chand Verma** Mr. YASUTSUNE Hidenobu Mr. TAKAMIZAWA Yu
	Members	12 Ladies and Gentlemen	Mr. MATSUKAWA Muneo Mr. TAKATSU Kenichiro
WG3 Improvement of Distribution System Reliability	Management	* Refer to the next slide for WG3	**Dr. SHIKIMACHI Koji** Mr. NISHIKAWA Koji
	Members		

Mr. WADA Masaki, Mr. SHINGU Hirohisa will join appropriate WG as needed

- Addition and Change of Member are always acceptable
- Members from other institutes are welcome.

Entry Sheet of WG3 Members as of 15 May

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Organization		WG3-1: Power outage measures (**Leader in bold letters**)	WG3-2: Load fluctuation control (**Leader in bold letters**)
WG Management		**Mr. N.H.C Janaka**	**Ms. M. Ganes**
DD1	Management	Ms. H.I.S. Jayasundara	Ms. U.G.J.K. Gamlath
	Members	2 Ladies	Lady and Gentleman
DD2	Management	Ms. K.G.N.A.Kumari	Mr. R.M.J.Rathnayake
	Members	2 Ladies	Lady and Gentleman
DD3	Management	Mr. K.A.N. Jayantha	Mr. J.M.S Kumara
	Members	2 Gentlemen	Lady and Gentleman
DD4	Management	Mr. P. H. L. J. Ranasinghe	Mr. D.D.K.G Sandasiri
	Members	2 Ladies	Lady and Gentleman
LECO	Management	Mr. Sampath Dissanayake	Mr. Janaka Sanjeewa
	Members	Lady and Gentleman	2 Gentlemen
JICA Experts Team		**Dr. Koji SHIKIMACHI**, Mr. Koji NISHIKAWA	

- Addition and Change of Member are always acceptable
- Two Leaders are assigned from C/P to deal with pilot project respectively

JICA Expert Team (1/3)

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Name		Assignment
Mr. HIRANO Akira E-mail:		Team Leader/ Electric Power Strategy
Mr. YOSHIDA Toshitaka E-mail:		Deputy Team Leader/ Electric Power Strategy
Mr. TANIHATA Osamu E-mail:		System and Policy of Electric Power
Mr. MITSUI Shinichi E-mail:		Renewable Energy
Mr. MAKITA Yusaku E-mail:		Economics and Finance

JICA Expert Team (2/3)

Name		Assignment
Dr. Suresh Chand Verma E-mail:		Demand and Supply Management
Mr. TAKAMIZAWA Yu E-mail:		Power System (Planning/Operation)
Mr. YASUTSUNE Hidenobu E-mail:		Power System (System Analysis)
Mr. MATSUKAWA Muneo E-mail:		Meteorological Forecast / Demand Forecast
Mr. TAKATSU Kenichiro E-mail:		Energy Management (Battery)

JICA Expert Team (3/3)

Name		Assignment
Dr. SHIKIMACHI Koji E-mail:		Distribution Technology
Mr. NISHIKAWA Koji E-mail:		Distribution (Planning/ Design/ Construction) / Coordinator
Mr. WADA Masaki E-mail:		Hydraulic Civil Engineering (Planning/ Design/ Construction)
Mr. SHINGU Hirohisa E-mail:		Geology

05 Schedule of the Project

Schedule of the Project

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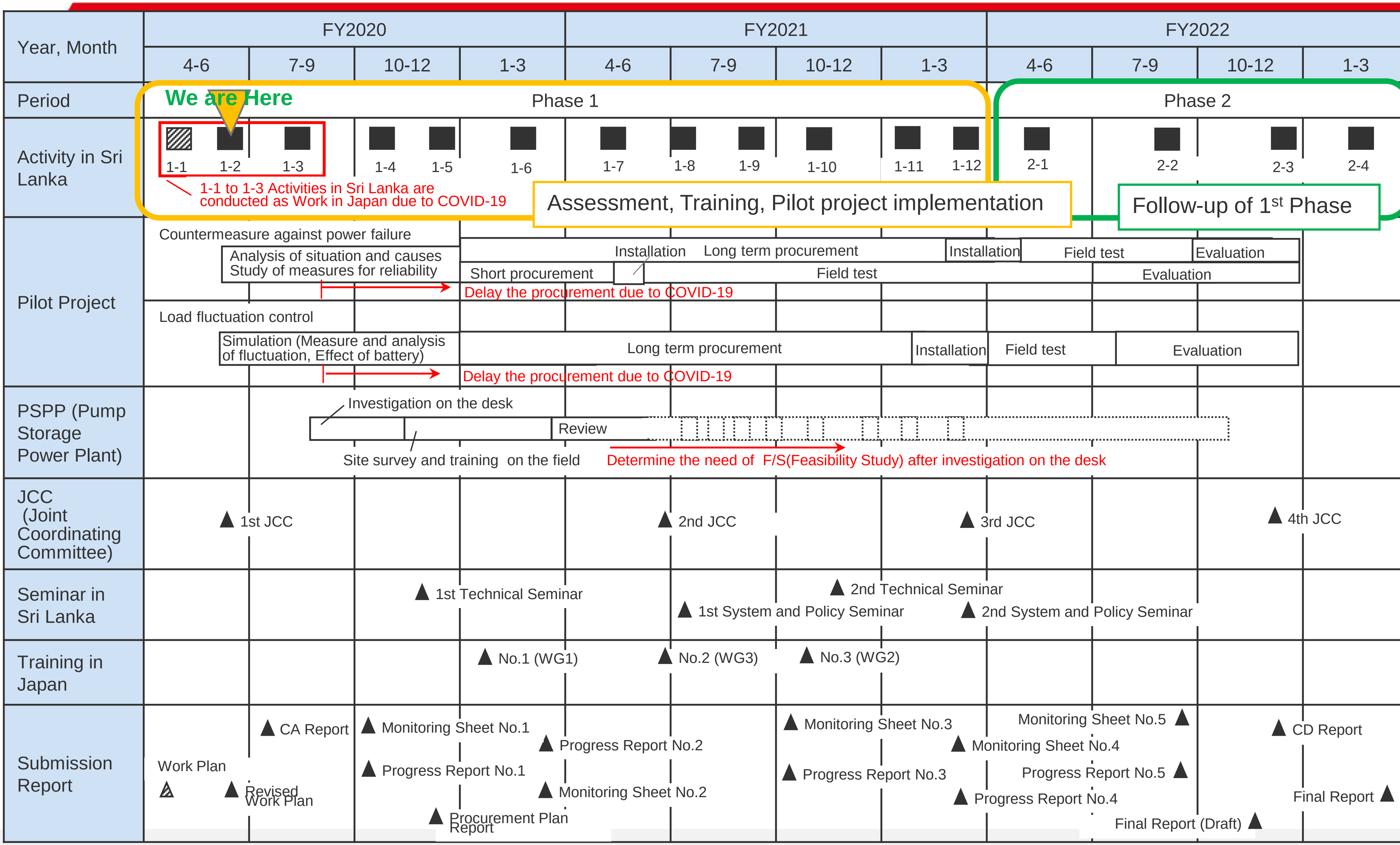
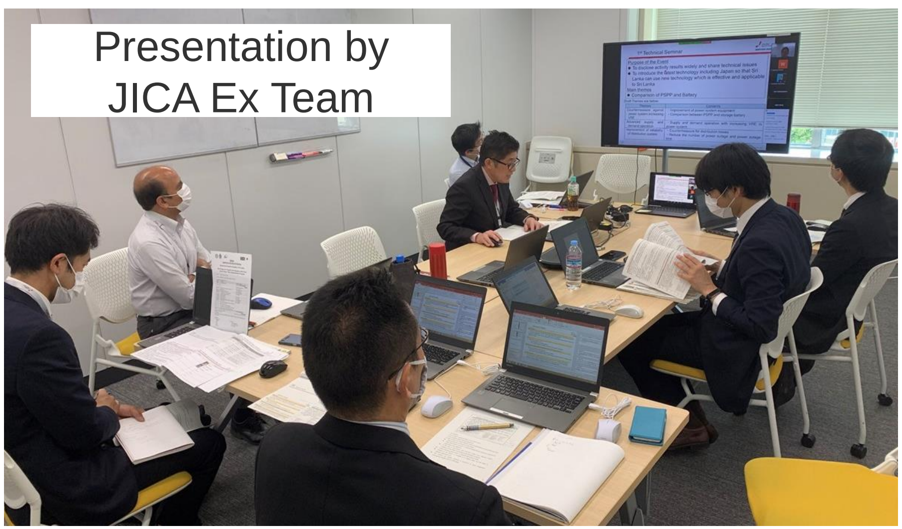


06 Progress of the Project

06-1 First Field Activity (Remote)

1^{st} Field Activity

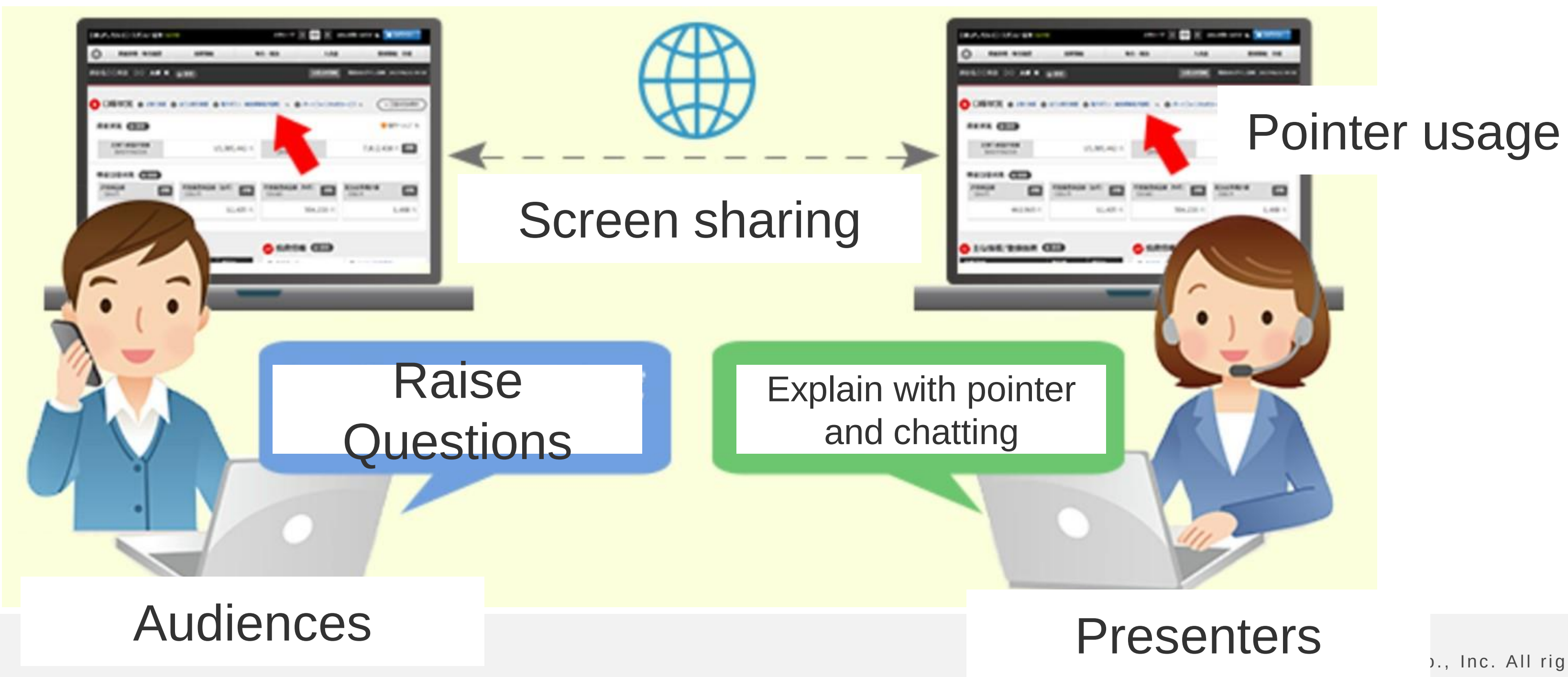
- 1^{st} field activity was remotely conducted from 11 to 22 May.
- Kick-off meeting was held on 12 May
  - ➢ WP was explained then policy and methodology were basically agreed.
  - ➢ Comments from each WG were reflected in the original WP and revised WP was submitted to C/P
- It is expected that remote survey will last up to around 3rd field activity. To facilitate field activity remotely, Conference facilities Introduction to C/P was agreed and is in the procurement process.


Presentation by JICA Ex Team


Presentation by C/P

WG Set-up

- Member assignment was completed for 3WGs respectively on 15 May in the first activity.
- Name, face photos, organization, contact info, etc. for all leaders and members have been prepared in the list
- List of WG leaders, sub-leaders, member's face photos, affiliations, contacts has been prepared
- In the 1st field activity, WG 1, 2 and 3 held 3 times meetings via Zoom respectively. Main items confirmed/discussed are below:
  - How to proceed the project
  - Role assignment between C/Ps and JICA Expert Team toward the project goal
  - VRE installation trends and operational technology related to VRE bulk introduction in VRE advanced countries including Japan
  - Capacity Assessment（Written questionnaire/interview）



Basic Information Gathering

- To have C/P provide accurate information, JICA Expert Team explains Questionnaire itself, importance of target information / data, and how to use. We continue collecting them via close support by CEB.
- JICA Expert Team created a CA questionnaire to confirm the baseline and continue collecting them via close support by CEB as well.
- PDM target temporarily set based on the baseline condition. (Details will be described later)

①Received useful info. from C/P

2-2System and Policy

No.	Question, Requested Data, Information and Documents and Answer, Descriptions	Department and Person in charge of Action (Name, Dep, e-mail)	Purpose of Material	Note	Open/Close
2-2-1	**Feed in Tariff (FIT)** 【Document/Data】 FIT Scheme in Sri Lanka (i) Contents (ii)Relative organization and procedure up to approval (iii) Calculation method of FIT cost (iv) Reimbursement of FIT Cost (Please let us know who the final bearer is.) (v)Comparison between the predicted volume in 2012, commencement year, and the actual volume now of VRE installation Please describe supplementary information in below, if any. 【Supplementary information】	CEB A.M. A. Alwis Leader of Management Deputy General Manager (Renewable Energy Development), A.W. S. Peiris DLM Chief Engineer (Renewable Energy Development),	To grasp the present system correctly and propose improved plans	The method of procurement of power plants are through competitive bidding process at present. Hence FIT is not available at the moment. The only exception is the Solar PV roof top program. (Follow-up Request, 1st June) Even though some projects are under bidding stage, you have rules on this. Please kindly provide documents or some useful URL, which explain them.	

②Examined and requested follow-up questions

Better understanding of the condition

06-2 2nd Field Activity (Remote)

Activities in the 2nd Field Work (Remote) (June 29 to July 10)

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<u>Main Activities</u>

- JCC (Explanation of WP and Work Progress)
- WG Activities
  - Information offer of Japan and VRE advanced countries
  - Data/info. collection based on questionnaire
  - Capacity Assessment interview, etc.
- Technical Transfer
  - WG1: Focus on information offer
  - WG2: Supply and demand operation considering VRE forecast
  - WG3-1: Power failure mechanism
  - WG3-2: Effect sample of battery introduction
- Presentation from C/P (Present status and problems (e.g., VRE metering, Integrate VRE output into power system operation, proper use of supply and demand planning software (NCP, SDDP※))

SDDP: “Stochastic Dual Dynamic Programming”, hydrothermal dispatch model

Schedule of the 2nd Field Work

Meeting time is determined considering 3 and half hour time difference between Sri Lanka and Japan.

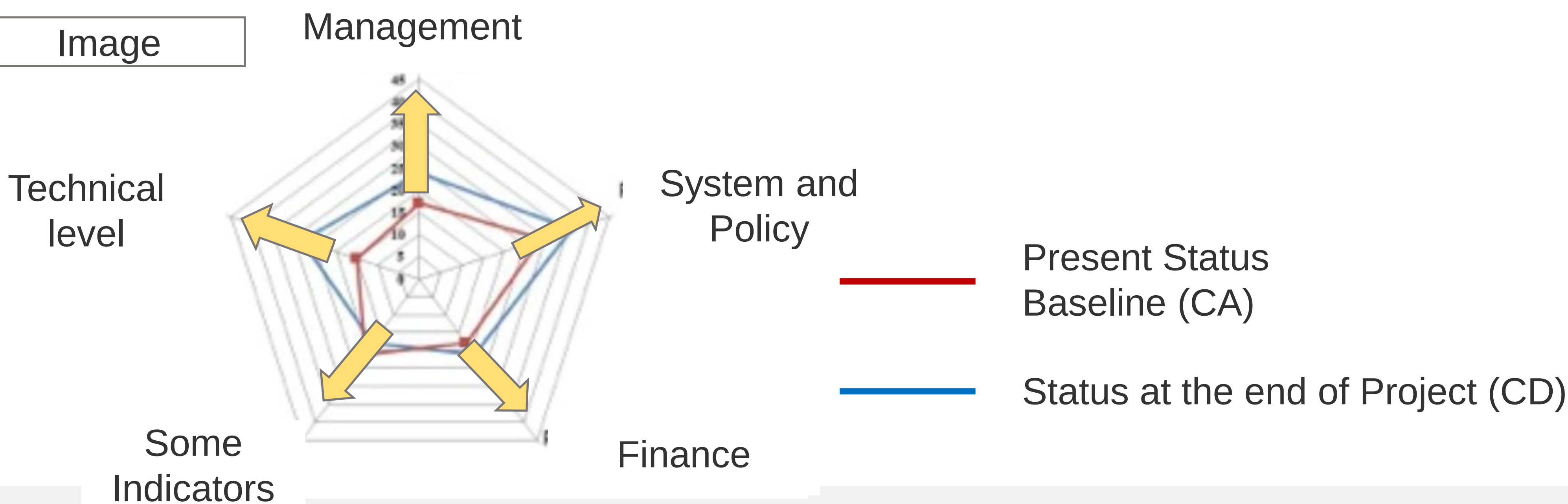
Items	Time & Date (UTC+5:30, Sri Lanka time)	Note
WG1 Activities	9:00～12:00, June 29 9:00～12:00, July 2 13:00～16:00, July 3	➢ Case studies of VRE developed countries ➢ VRE facilities and its O&M ➢ Auxiliary measures for System and Policy ➢ Capacity Assessment and Data/Info. Collection
WG2 Activities	13:00～16:00, June 29 13:00～16:00, July 1 9:00～12:00, July 6	➢ Confirmation of Questionnaire ➢ Supply and demand operation considering VRE forecast ➢ Site selection for the forecast model building of VRE ➢ Capacity Assessment
WG3-1 Activities	9:00～10:30, July 1 9:00～10:30, July 3 13:00～14:30, July 6	➢ Collect outage and failure data and information ➢ Summarize and categorize the outage and failure ➢ Share and transfer technical knowledge on failure cause
WG3-2 Activities	10:30～12:00, July 1 10:30～12:00, July 3 14:30～16:00, July 6	➢ Collect VRE data and information ➢ Summarize and categorize the VRE ➢ Share and transfer technical knowledge on battery effect
WG1/2/3	13:00～16:00, July 2	Slots for any WG that needs time
Confirmation Meeting for JCC	10:00～11:00, July 7	
1st JCC	10:00～12:30, July 8	
Wrap-up	13:00～14:00, July 9	
MM Signing	July 10	

07 Capacity Assessment (CA)

Capacity Assessment (CA)

- To clarify the current status is essential to set the achievable goal with reasonable efforts.
- To confirm the current conditions by Capacity Assessment (CA) and the conditions are set as the Baseline.
- Improved condition is evaluated at milestones and the end of the Project for grasping the degrees of improvement from the Baseline.

Image



Main Points Checked by CA

- Financial condition in CEB
- Reviewing situation of planning on CEB finance
- Current Corporate Strategy for VRE introduction in CEB
- Power system analysis situation considering VRE installation
- Power system planning situation considering VRE installation
- Current roles of System Control Center
- Training for capacity development
- Current value of SAIFI/SAIDI
- Introduction situation of equipment for improving reliability in D/L

No.	Contents of Assessment	Answer *Please fill in cells below with y
4-3	Have you installed any facilities to reduce power outage duration such as Re-closer, Fault Indicator (FI) and Ground Fault Detector etc.? If yes, please let us know all of the names and main specifications of the facilities.	Yes / No [If ye Re-cl

No.	Contents of Assessment	Answer *Please fill in cells below with your answer.
	Is there any training programs for **Power System Management/Operation including VRE** conducted by organization other than CEB in Sri Lanka? If yes, please provide detailed information such as when, where, who conducted, who participated, what is the main subject of training, etc…	[Training by organization other than CEB] Yes / No [Information about external training]

Gathering Info. by CA Sheet & Interview

08 Project Design Matrix (PDM)

Effective Utilization of PDM

- PDM is prepared with concrete contents based on R/D
- PDM clarifies the overall goal in the Project, each element to achieve the goal and its evaluation method
- At the end of the Project, conditions of the Project are confirmed and compared with baseline conditions, then finally compiled as final result, i.e. Capacity Development (CD).
- Progress is managed on a regular basis, and the status is regularly reported to JCC.
- The contents are flexibly reviewed if necessary through constant verification.

Narrative Summary	Objectively Verifiable Indicators	Means of Verification
Overall Goal		
Stability and reliability of transmission and distribution networks are maintained/improved even with increased share of VRE (Variable Renewable Energy).	(1) Fluctuations of voltage and frequency of networks: the same level as before large amount installation of PV and wind power	CEB's technical data
	(2) SAIFI at urban, rural areas, etc.: xx in 2026	CEB's technical data
	SAIDI at urban, rural areas, etc.: xx in 2026	CEB's technical data
	LOLP: xx in 2026	CEB's technical data
	(3) Error of the prediction system of PV and wind turbine output in 2026: within +-20%	CEB's technical data
Project Purpose		
Institutional Capacity for	(1) Corporate finance plan is updated	CEB management report

Activities	Inputs: The Japanese Side	Inputs: The Sri Lanka Side
Activities of WG1 1-1 Corporate Strategy and Planning for VRE 1-1-1 To assess the impact of the introduction of VRE on CEB corporate finance taking into consideration of the future business scenarios. 1-1-2 To advice on the planning and procurement for VRE purchases. 1-1-3 To advice on the planning and procurement for VRE purchases. Activities of WG2 2-1 VRE Technical Evaluation 2-1-1 To review VRE projects(existing and future plan) and Grid Codes for VRE. 2-1-2 To analyze issues and impact of transmission system considering increased share of VRE (e.g. update of system enhancement) 2-1-3 To conduct trainings on advances system analysis.	(1) Dispatch of Japanese experts - Team Leader/ Electric Power Strategy - Deputy Team Leader/ Electric Power Strategy - System and Policy of Electric Power - Renewable Energy/ Power Source Develop Planning - Finance - Supply and Demand Management - Power System (Planning/ Operation) - Power System (System Analysis) - Metrological Forecast/ Demand Forecast - Energy Management (Battery) - Distribution Technology - Distribution (Planning/ Design/ Construction)/ Coordinator - Hydraulic Civil Engineering (Planning/ Design/ Construction) - Geology	(1) Assignment of counterparts - Project Director (P/D) - Project Manager (P/M) - Engineers in charge - Others (2) Facilities and equipment - Project office space - Office equipment - Others (3) Recurrent costs - counterparts' wage and allowances - counterparts' domestic travel expense

Structure of PDM
(Overall Goal, Project Purpose, Outputs, Activities)

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- PDM widely describes long term target, project purposes, project outputs, detailed activities for achieving the goals etc.

<Overall Goal>
Higher and longer-term development effectiveness brought by the achievement of the Project

<Project Purpose>
It should be achieved by the completion of the Project

<Outputs>
Specific matters that should be realized by the Project in order to achieve the Project Purpose

<Activities>
Concrete activities of the project implemented by making effective use of inputs so that outputs would be realized

Narrative Summary	Objectively Verifiable Indicators	Means of verification	Important Assumptions
Overall Goal			
Project Purpose			
Outputs 1. 2. 3.			
Activities 1-1 1-2 … 2-1 … 3-1 …	Input Japanese side	Sri Lanka side	
			Pre-conditions

Structure of PDM
(Indicators, Means of verification)

- Indicators are better to be set and evaluated quantitatively.
- Achievable Goal with reasonable efforts will be basically finalized by **31st July 2020** (one month after CA finished), based on the results of CA & discussion
- Indicator will be reviewed consecutively by discussion between C/P and JICA Team

<u>Objectively Verifiable Indicators</u> are to check the achievement of "Overall Goal", "Project Purpose" and "Outputs".

- What? (Data)
- of Whom? (Target group)
- of Where? (Target area, place)
- How much? (Quantity)
- How well? (Quality)
- by When? (Year)

<u>Means of Verification</u> is data source to verify indicators.

- selecting reliable data source
- selecting sustainable data source

Narrative Summary	Objectively Verifiable Indicators	Means of verification	Important Assumptions
Overall			
Project Purpose			
Outputs 1. 2. 3.			
ctivities 1-1 1-2 … 2-1 … 3-1 …	Input Japanese side	Sri Lanka side	
			Pre-conditions

Draft Objectively Verifiable Indicators for Project Purpose

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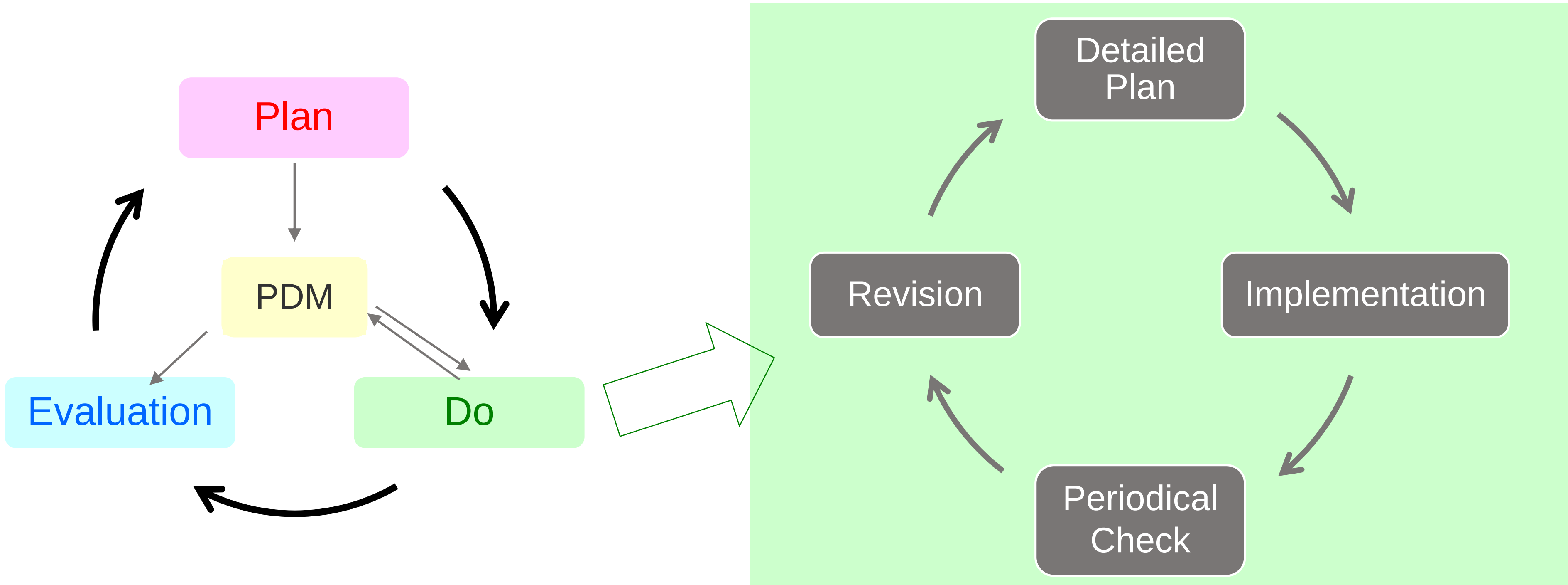
- Each Indicator will be confirmed on achievement level via Monitoring Sheets every six months. (Explained in detail later)
- Status will be reported in JCC

Indicator	Current Status	Target at the end of the Project
Revision frequency of Finance Plan	Annually	Corporate finance plan is updated periodically.
Development of Procurement Plan	N/A	Standard procurement plan is implemented.
The number of engineers who are able to conduct advanced power system analysis	Under confirming	The number of staff who can undertake advanced power system analysis is increased.
Grid Code development related to VRE installation	No guideline on battery installation requirement	The improvements of Grid Codes are recommended.
Reliability improvement countermeasures (Pilot Project)	N/A	At least one countermeasure for VRE fluctuation is employed.
SAIFI [interruptions/customer/year]	Latest Values in DD1, DD2, DD3, DD4 and LECO	SAIFI at the pilot sites where the facilities against power outage are installed: xx in 2026
SAIDI [minutes/year]	Latest Values in DD1, DD2, DD3, DD4 and LECO	SAIDI at the pilot sites where the facilities against power outage are installed: xx in 2026
System and policy installation on promotion of VRE	N/A	At least one plan to promote the introduction of VRE to meet Sri Lanka's national energy policy is formulated.
Output prediction system of VRE	N/A	Advanced forecasting systems for PV and wind turbine output are established, and the supply and demand operation is implemented using it.

09 Project Monitoring

Monitoring Sheet for Checking the Progress & Results

- To check periodically the difference between plan and actual result, the degree of achievement, risks etc.
- To improve continuously the quality in the Project, and finally achieve the project goals



- “Monitoring” does not aim at the implementation of the Project on schedule.
- It is quite important to flexibly change the plan of the Project to achieve the goals.

Monitoring Sheet Structure

- Clarifies and shares the achievements, problems, and improvement points of this term.
- If there is a matter to be improved, discussion is conducted to find the solution.
- Respond flexibly to changes in the situation, review Indicators, and review the direction of the goals, if necessary.
- C/P and JICA Expert Team will state the matters to be implemented in the next term and mutually confirm them.

Indicators	Activity	Issues and resolution	Next Target in 6 months	Next Action in 6 months		Progress to final target (%)
				C/P	JICA Ex Team	
AAA						
BBB						
CCC						

The format shall allow the C/P and JICA Expert Team to proceed activities toward the goals <u>with a sense of unity</u>.

10 How to proceed this Project

WG1: Outline of Activities and PDM

Outline of WG1 Activities (Corporate Strategy, System and Policy)

- Examination of system and policy for mass introduction of VRE
- Comprehension improvement of VRE facilities and its O&M
- Development of plans and installation procedures of VRE
- Examination of CEB corporate strategy to promote the VRE introduction (via quantitative evaluation by corporate financial analysis)

PDM (Project Design Matrix) of WG1

Indicators for Outputs	(1) The assessment and recommendation reports on CEB finance are prepared. (2) Operating profit improvement is assessed. (3) Corporate strategy of VRE (VRE installation amount and timing) is prepared by CEB periodically. (4) At least one C/P is certified as key person who understand the pros and cons regarding each kind of VRE. (5) At least one C/P is certified as key person who understand VRE installation procedure from the beginning, project formulation to the end and commencement of commercial operation.

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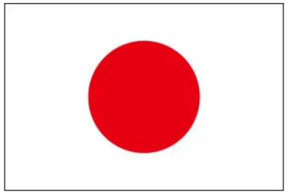
1. Watching VRE development and System & Policy in Japan and in advanced countries
2. Setting the target in Sri Lanka for promotion of VRE installation
3. Checking a gap on System & Policy between the current status and the target
4. Examining the obstacles & cost effectiveness to achieve the target



Input

History of the system & policy

Current conditions and problems

Current system & policy

- Prioritizing the “System and policy” for development
- Analysis on effectiveness (Financial analysis for CEB etc.)

Increasing benefits of Sri Lanka and CEB by introduction of advanced & cost-effective systems and policies

WG1: Corporate Financial Analysis for VRE Policy Improvement

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- In the face of the anticipated higher share of VRE sources in future, the corporate financial analysis will be carried out to provide guidance through quantitative impact assessment for the policy discussion among the government policy makers and stakeholders.
- JICA Expert Team in cooperation with CEB will do the analysis through three steps, i.e. (i) analysis of the status quo and recent financial results, (ii) financial projection with higher share of VRE sources under the existing policy measures, and (iii) financial projection with introduction of proposed VRE policy improvement.

1. Status Quo Analysis
- Analysis of recent financial status
- Shows current challenges

2. Projection under Existing Policies
- Scenario under current VRE regulatory setup
- Shows unsustainable power system operation

3. Projection under Proposed Policies
- Scenario under proposed improvement of VRE policies and regulations
- Shows sustainable power system operation and VRE development in future

Proposed VRE Policies
- Government subsidy for excess electricity purchase
- VRE levy charge to customers to fund FIT payments
- New tariff system adopting fuel cost adjustment, etc.…

WG2: Outline of Activities and PDM

Outline of WG2 Activities (Planning and Operation of Power System)

(1) Impact of a large scale integration of VRE on the power system, and countermeasure for power system operation and supply and demand management

(2) Technical transfer of advanced power system analysis

(3) Development of VRE output prediction model

(4) Comparison of PSPP (Pumped Storage Power Plant) and batteries in terms of supply and demand

(5) WG2 Training in Japan

- Power System Planning and Operation, Management of the Power Supply and Demand (Energy Storage)

PDM (Project Design Matrix) of WG2

Indicators for Project Purpose	(1) Recommendation for the improvements of Grid Codes (2) Increase in the number of staff who can undertake advanced power system analysis. (3) Deploying of at least one countermeasure for VRE fluctuation. (4) Preparation of prediction system of PV and wind turbine output, and implementation of the supply and demand operation using it.

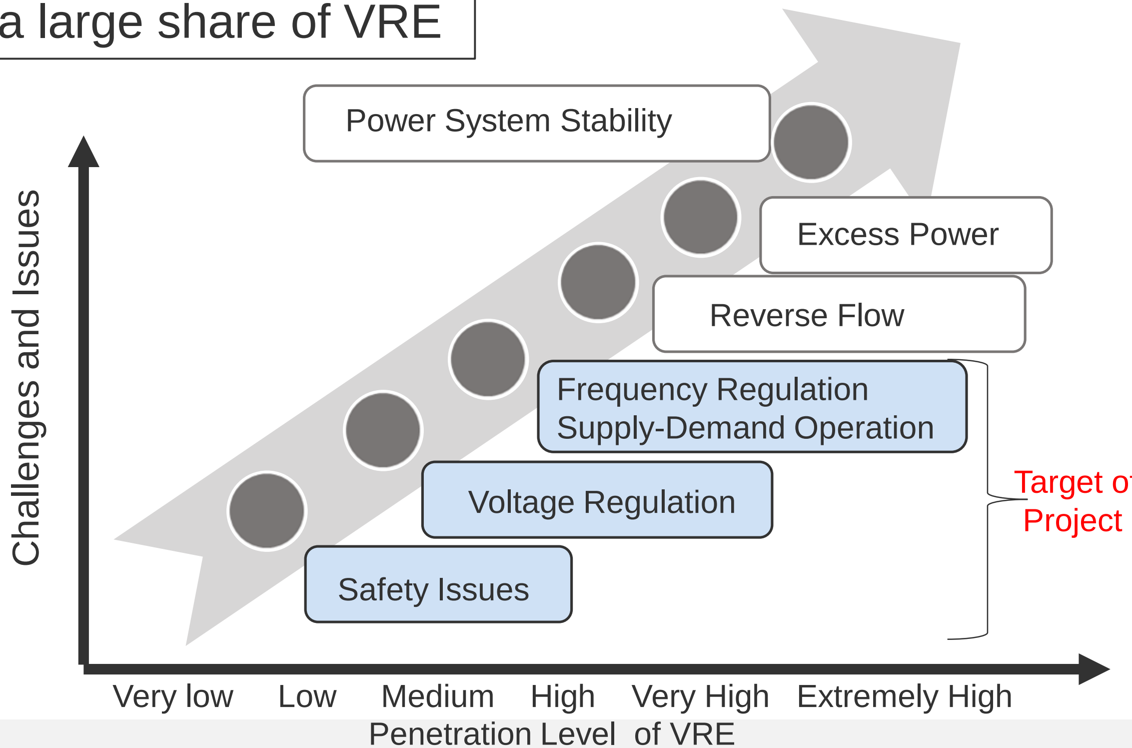
WG2: Power System Operation with a Large Amount of VRE

- Main mission of power system operation ⇨ To keep the lights on!!
- To achieve this mission, major challenges are how to maintain stable, high quality and economic system operation in view of the following factors;

(1) Integration of a large share of Variable Renewable Energy Sources (VRE) like PV and Wind.
(2) Introducing new Technologies (VRE Forecasting Technology, Batteries, Grid stabilization, etc.)

Main challenge to address integration of a large share of VRE

(1) VRE output and demand forecasting techniques
(2) Maintain voltage & frequency within specified limits
(3) Optimal dispatch solution techniques
(4) Upgradation of grid stabilization technology with VRE
(5) Updating of simulation technologies & tools



WG2: Overview of Forecast for VRE Output

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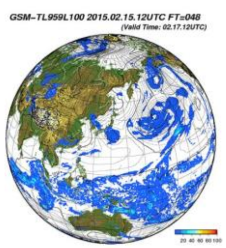
- Weather forecast for VRE can be calculated based on the weather models of the Meteorological Agency and the Meteorological Organizations of each country.
- The output of PV and wind power can be predicted from weather forecast results and specifications of facilities.

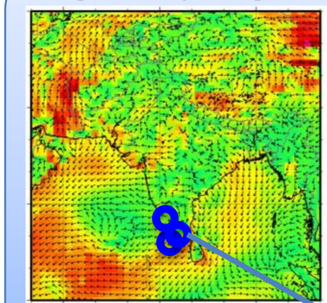
Output from Weather model



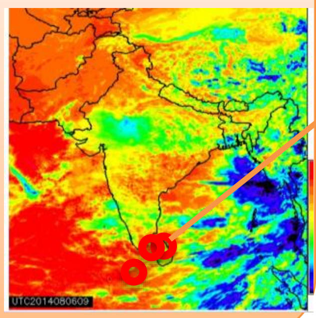
Statistical model

Forecast for VRE at power plant

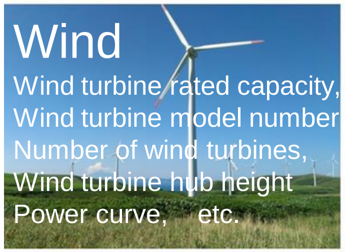
[Wind speed]

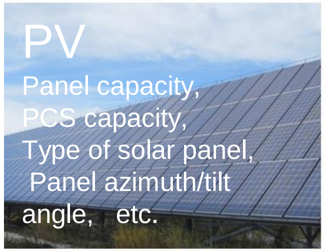


[Solar irradiation]



Facility information





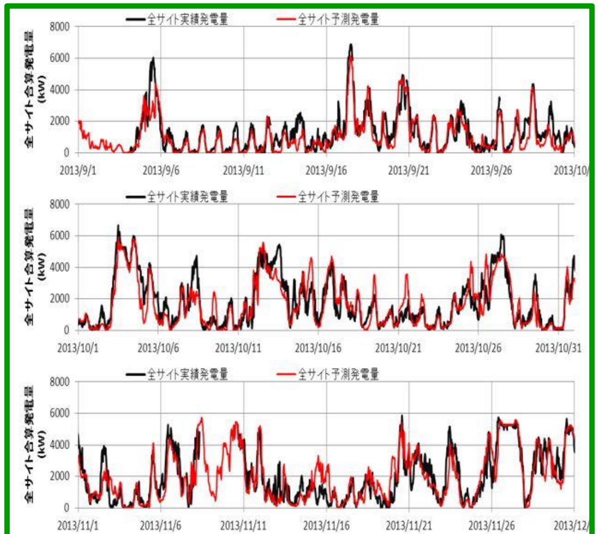
Wind speed at wind power plant

Wind power generation at the plant

Solar irradiation at PV power plant

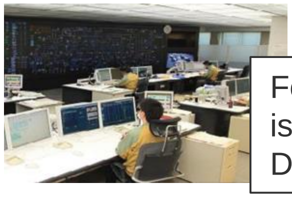
PV power generation at the plant

Statistical model



X_axis: timeline [year/month/day]
Y_axis: total amount of all power output(wind + PV) [kW]
legend: historical result; forecast for power generation output

※Specification should be considered in detail at the time of design



Forecast system of PV output is installed at Central Load Dispatching Center in CEPCO.

WG3: Outline of PDM and Activities (WG3-1)

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PDM(Project Design Matrix) of WG 3

Indicators for Project Purpose	(1) SAIFI at the pilot sites where the facilities against power outage are installed: xx in 2023 (2) SAIDI at the pilot sites where the facilities against power outage are installed: xx in 2023 (3) Standard procurement plan is implemented

Outline of WG 3 -1 (Power Outage Measures)

- Analysis for Outage Situations and Causes of CEB's DD1-4 and LECO
- Suggestion for Supply Reliability Improvement
- Introduction of Reliability Improvement Facilities and Estimation of their Effects in Pilot Projects

(Tentative)	FY2020	FY2021	FY2022
Power outage measures	Analysis, Study; Long term procurement; Short procurement	Long term procurement; Installation; Field test	Installation; Field test; Evaluation; Field test; Evaluation

How to proceed

1. Survey and cause analysis on failure outage status per MV line
2. Planning of measures and Selection of pilot sites and measure facilities
3. Procurement and installation of the facilities
4. Evaluation of quantitative effects by estimating the power outage amount [kWh] before and after the countermeasures
5. Estimation of cost effectiveness of measure facilities in the pilot projects and evaluation of contribution to CEB finance aiming to the mass introduction based on target supply reliability in the future

Fault indicator

Ground fault detector

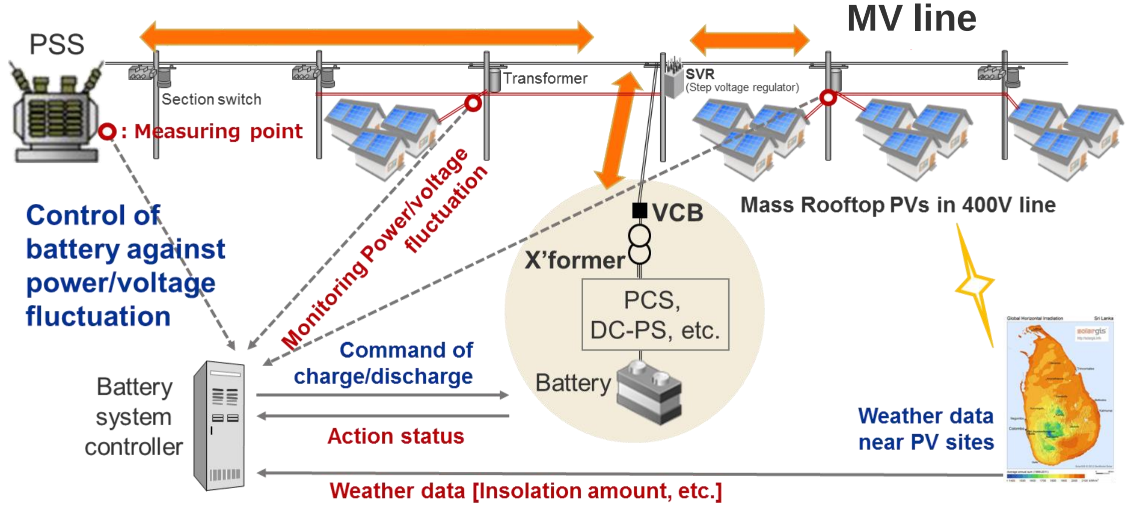
WG3: Outline of Activities (WG3-2)

Outline of WG 3 -2 (Load Fluctuation Suppression)
● Measurement and Analysis of Power/Voltage Fluctuation in Distribution Network due to Large Increase of Renewable Energy ● Estimation of Load Fluctuation Control by Introducing Storage Batteries

(Tentative)	FY2020	FY2021	FY2022
Load fluctuation suppression	Simulation, Planning → Procurement	Procurement → Installation	Field test, Evaluation

How to proceed

1. Data collection and study on the distribution system with mass introduction of PV and wind turbine (WT) generation
2. Consideration of site, battery system specifications, Procurement and Installation
3. Acquiring of weather data near the site Forecast of PV/WT generation amount [Cooperation with WG2]
4. Estimation of controlling function for output power/voltage by charging/discharging battery



Introduction of Storage Battery System in a Pilot Project

11 Seminar

Purpose of the Event

- To disclose activity results widely and share technical issues
- To introduce the latest technology including Japan so that Sri Lanka can use new technology which is effective and applicable to Sri Lanka

Main themes

- Comparison of PSPP and Battery

Draft Themes are below:

Themes	Contents
Countermeasure against power system increasing VRE	・Improvement of power system equipment ・Comparison between PSPP and storage battery
Advanced supply and demand operation	・Supply and demand operation with increasing VRE in power system
Improvement of reliability of distribution system	・Countermeasure for distribution losses ・Reduce the number of power outage and power outage time

Examination of Pros and cons of PSPP and Battery, Determining the Direction

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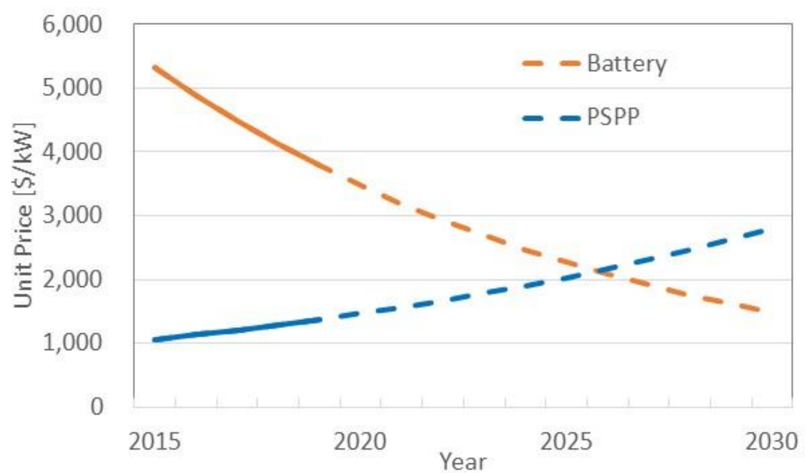
There are some options as balancing power.

- Careful consideration of advantages and disadvantages for prospective options rather than PSPP is very important
- After thorough discussions with the C/P and JICA, final conclusions would be made regarding what should be the best balancing power source and reported at the 1st Technical Seminar.

Item	Merit	Demerit
PSPP	➢ Large scale development ➢ Low running cost ➢ Long-term usage	➢ Long development term (5 years for construction, 5 years and over for land negotiation) ➢ Require the resettlement ➢ Staged development is impossible. ➢ Initial investment is large and financing (loan) is difficult. ➢ Development sites is limited ➢ Operation is restricted by river law ➢ Loss is bigger than storage battery: about 30%
Battery	➢ Short development term Total within 2 years(6 months for design, 1 year for construction) ➢ Staged develop is possible ➢ Low loss (5-15%) ➢ Significant price decline (Expected to fall by 40% in the next 5 years) (Figure 3-4) ➢ Charge and discharge can be switched without stopping	➢ Unit price of storage batteries is still high, but the rate of decline is large. ➢ The standard life of the storage battery is about 10 years.



- ✓ Battery innovation is remarkable, price drop is remarkable as well
- ✓ Reversal of construction costs would be real within 10 years

2nd Technical Seminar

- The same purpose of the Event as 1st technical seminar
- Main topics of report/discussion
  - Achievement of this Project (presented by C/P mainly)
  - Pilot Project implementation results (cost-effectiveness, further improvement points, etc.)

Draft Themes are below:

Theme	Contents
1) Safety measures for hydro power plant	The public conservation, the River Law and operation rules
2) Implementation status of the pilot project	Introduction of the planning and expected result of the introduced pilot project
3) Virtual Power Plant	Introduction of the contents and result of the virtual power plant in Japan (Toyota VPP Project)
4) Status of the world offshore wind power	Increasing the capacity of generator unit Project of the zero subsidiary cost Construction type of landing (monopole/ jacket) and floating

1st System and Policy Seminar

Purpose of the Event

- To push forward smooth introduction of large amounts of renewable energy by having Decision Maker understand the contents fully

Main themes

- Measures to promote the introduction of VRE in advanced foreign countries including Japan

Draft Themes are below:

Theme	Contents
1) History and Issues of Electric power sector business in Japan	・Electric Power Development Strategy, Diversification of Power Sources, Strategic Energy Plan
2) System and Policy for VRE installation in Japan	・Background and History ・Schemes applied in Japan (Subsidy, RPS, FIT) and their outcome
3) Human Resource Development of Electric Power Utilities	・Training System ・OJT, Group Training, Self-development

2nd System and Policy Seminar

- The same purpose of the Event as 1st System and Policy Seminar
- Main topics of report/discussion
  - ➢ System and policy that can be applied in Sri Lanka (Achievement of this Project) (presented by C/P mainly)

Draft Themes are below:

Theme	Contents
1) Japan's System and Policy for VRE Installation Adoptable in Sri Lanka	・Japan's System and Policy for VRE Installation which are adoptable in Sri Lanka ・Japanese version of Connect & Manage (Effective usage of existing transmission facilities) ・Cost Allocation for inter-regional trunk system among electric power utilities
2) Scheme to secure Adjustment Power	・Capacity Market ・Supply-demand Adjustment Market (ΔkW Market) ・Demand Response (Upside, Downside) ・Reinforcement of interconnection

jica

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Electric Power

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Participant list for 2nd Joint Coordination Committee
on
"The Project for Capacity Development on the Power Sector Master Plan Implementation Program in Democratic Socialist Republic of Sri Lanka"

Date: July 30, 2021

〇Counterparts (Sri Lanka)

	Name	Position Organization	Contact E-mail address
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2	Mrs. N. W. K. Herath	General Manager, CEB	
3	Mr. Sugath Dharmakeerthi	Additional Secretary (Thermal Power, Transmission and Distribution)	
4	Mr. G. J. Aluthge	Additional General Manager (Transmission), CEB	
5	Mrs. T. A. K. Jayasekera	Additional General Manager (Distribution Division 2), CEB	
6	Mr. J. Nanthakumar	Additional General Manager (Distribution Division 3), CEB	
7	Mr. J. Meegoda	Additional General Manager (Distribution Division 1), CEB	
8	Mr. T. K. Liyanage	Finance Manager,	
9	Mr. M. L. Weerasinghe	Deputy General Manager (Transmission & Generation Planning), CEB	
10	Dr. H. M. Wijekoon	Project Director, Colombo Port City Development Project, CEB (Former Chief Engineer (Transmission Planning), CEB)	
11	Mr. V.B. Wijekoon	Chief Engineer (Generation Planning), CEB	
12	Mr. K. Ramjee	Chief Engineer (Transmission Planning), CEB	
13	Mr. N.H. Janaka Chamil	Chief Engineer (P&D - DD4), CEB	

	Name	Position Organization	Contact E-mail address
14	Mr. K. Siriwardana	Director, Tariff and Economic Affairs, Public Utility Commission of Sri Lanka	
15	Dr. N. De Silva	General Manager, Lanka Electricity Company Pvt. (Ltd).	
16	Mr. T.L.B. Attanayake	Electrical Engineer (Transmission Planning), CEB	
17	Mr. G.B Alahendra	Electrical Engineer (Transmission Planning), CEB	
18	Mr. A.W.M.R.B. Wijekoon	Electrical Engineer (Generation Planning), CEB	
19	Mrs. H.D.K.Herath	Electrical Engineer (Transmission Planning), CEB	
20	Mrs. W.G.Pawithra	Electrical Engineer (Transmission Planning), CEB	

〇JICA(Japan International Cooperation Agency)

	Name	Position Organization	Contact E-mail address
1	YUZURIO Susumu	Senior Director, Team 1, Energy and Mining Group, Infrastructure Management Department	
2	SHIBATA Kuri	Infrastructure Management Officer, Team 1, Energy and Mining Group, Infrastructure Management Department	
3	DEN Takashi	South Asia Division 3 (Sri Lanka/ Maldives), South Asia Department	
4	HIRABAYASHI Yurie	Representative, Sri Lanka Office	
5	Cabral, SL	National Staff, Sri Lanka Office	

〇JICA Expert Team (Chubu Electric Power Co., Inc. and Nippon Koei Co., Ltd.)

	Name	Position Organization	Contact E-mail address
1	Mr. HIRANO Akira (Team Leader / Electric Power Strategy)	Senior Manager, Chubu Electric Power Co., Inc.	
2	Mr. YOSHIDA Toshitaka (Deputy Team Leader / Electric Power Strategy)	Manager, Chubu Electric Power Co., Inc.	
3	Mr. TANIHATA Osamu (System and Policy of Electric Power)	Senior Manager, Chubu Electric Power Co., Inc.	
4	Mr. MAKITA Yusaku (Finance)	Chubu Electric Power Co., Inc. (Group Leader/ Senior Economist, Koei Research & Consulting Inc.)	
5	Dr. Suresh Chand Verma (Supply and Demand Management)	Senior Manager, Chubu Electric Power Co., Inc.	
6	Mr. TAKAMIZAWA Yu (Power System (Planning/Operation))	Manager, Chubu Electric Power Co., Inc.	
7	Mr. YASUTSUNE Hidenobu (Power System (System Analysis))	Manager, Chubu Electric Power Co., Inc.	
8	Mr. MATSUKAWA Muneo (Meteorological Forecast / Demand Forecast)	Chubu Electric Power Co., Inc. (Executive Engineer, Japan Weather Association)	
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10	Mr. WADA Masaki (Hydraulic Civil Engineering (Planning/Design/Construction))	Deputy Chief Engineer, Nippon Koei Co., Ltd.	
11	Mr. SHINGU Hirohisa (Geology)	Nippon Koei Co., Ltd. (General Manage, Onsight Co., Ltd)	
12	Dr. SHIKIMACHI Koji (Distribution Technology)	Manager, Chubu Electric Power Co., Inc.	
13	Mr. KAMIYA Yukihiro (Distribution (Planning/Design/Construction) / Coordinator)	Manager, Chubu Electric Power Co., Inc.	

CEYLON ELECTRICITY BOARD

Draft Long Term Generation Expansion Plan 2022-2041 & Renewable Energy Development

2nd Joint Coordination Committee (JCC)

The Project for Capacity Development on the Power Sector Master Plan Implementation Program

Transmission and Generation Planning Branch
Ceylon Electricity Board
Sri Lanka

Policy Directions (Issued as per the section 5 of the Sri Lanka Electricity Act)

General Policy Guidelines in Respect of the Electricity Industry (Issued on April 2019)

Fuel Diversity and Security

- Strategic firm capacity mix to strengthen the economy and energy security.
- Installing firm capacity to have 2/3 of the demand for power
- **30% LNG, 30% High Efficient Coal, 25% Large Storage Hydro,15% other firm**

Generation

- Adequate Generation for Growing demand.
- Cost of Electricity to be maintained as low as possible
- Appropriate technologies for different demand characteristics

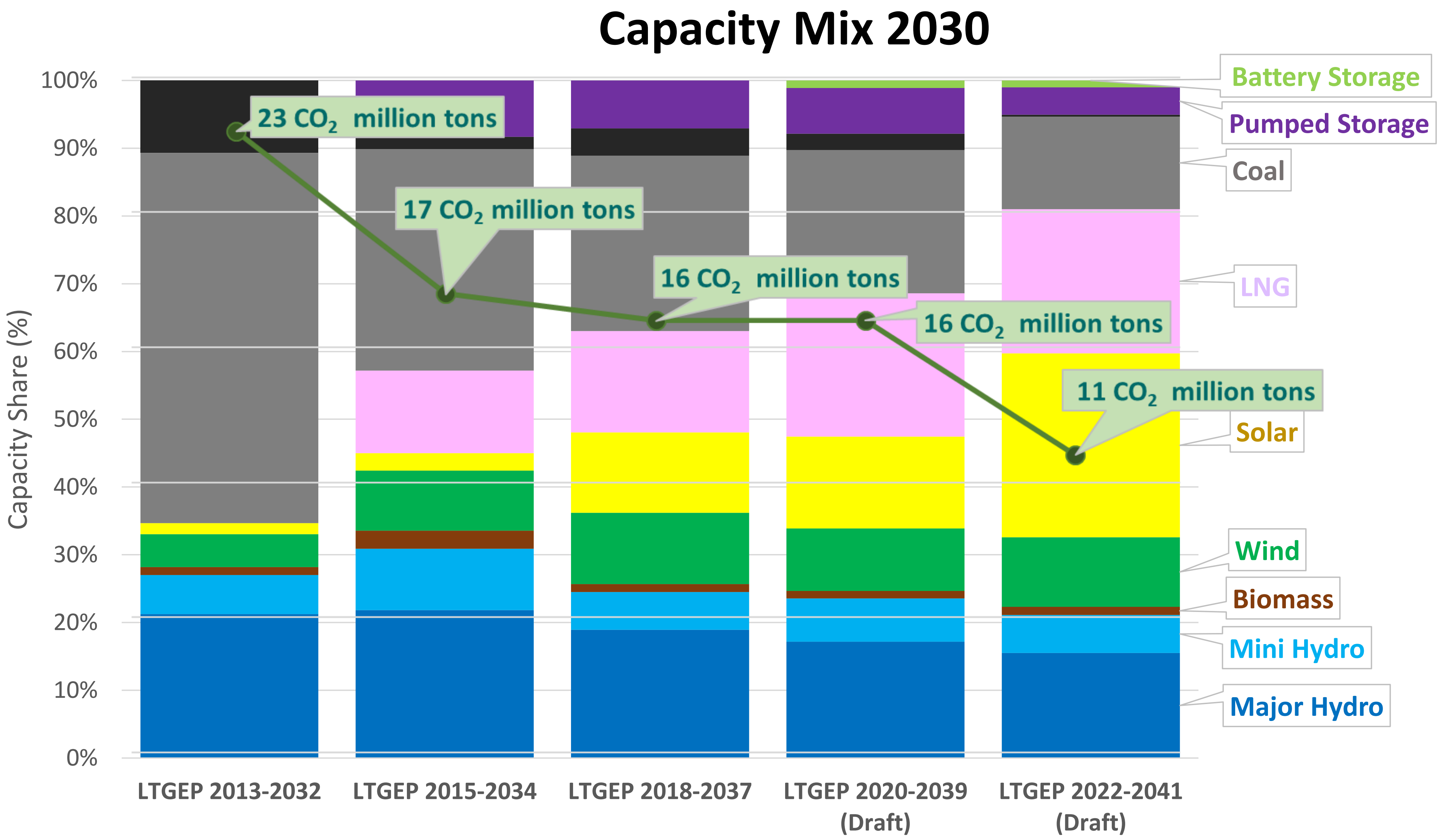
Financing

- Private sector participation is welcome in generation projects, but major source of fund for all transmission and generation development will be from international, bilateral donor agencies.
- Embedded generation will be encouraged through private sector.

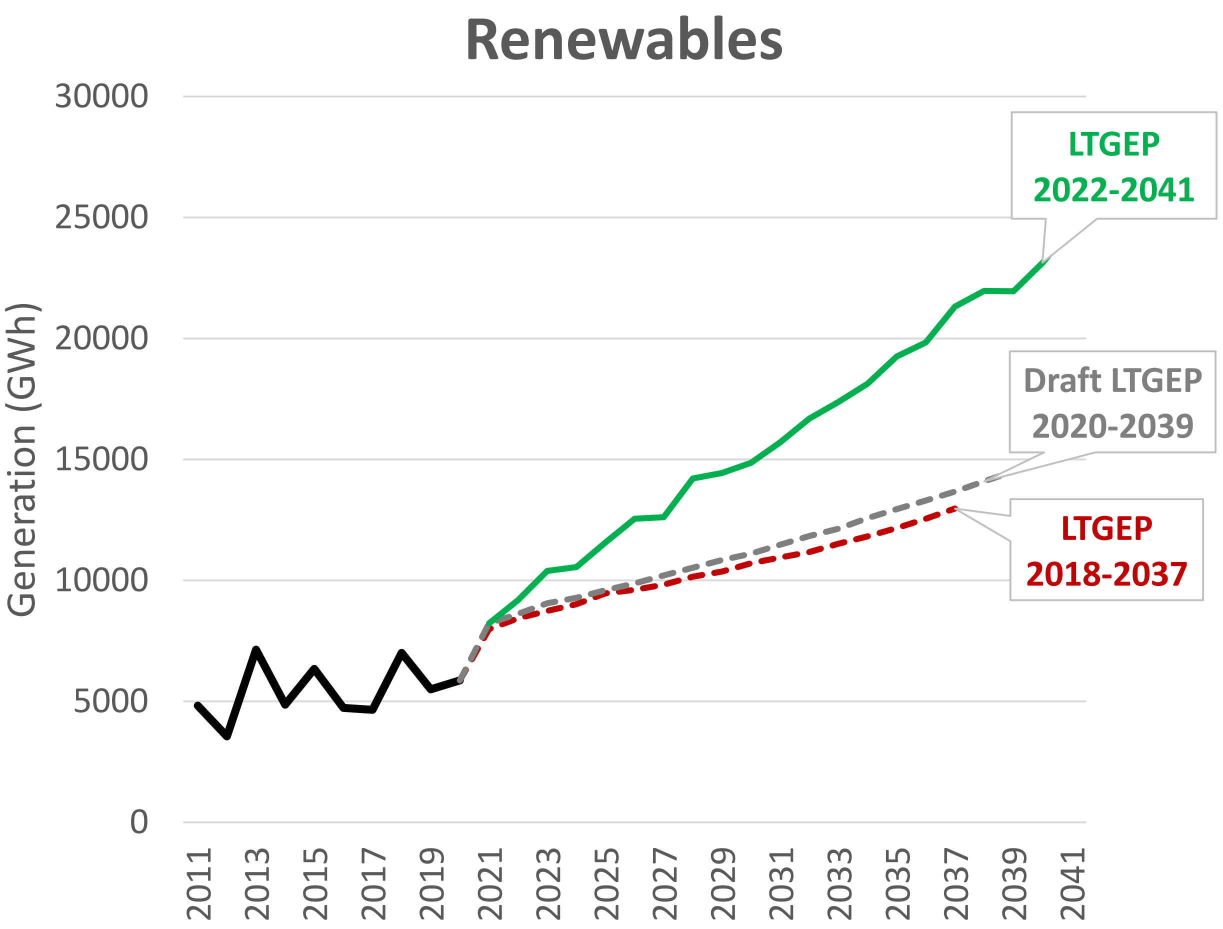
Environment

- Prioritizing renewable energy development based on resource potential, economics, maturity, technology, quality of supply.
- **1/3 of the power demand by non conventional sources by 2030**
- Subjected to favourable weather conditions, country mush progress with a **Vision to achieve 50% from RE**

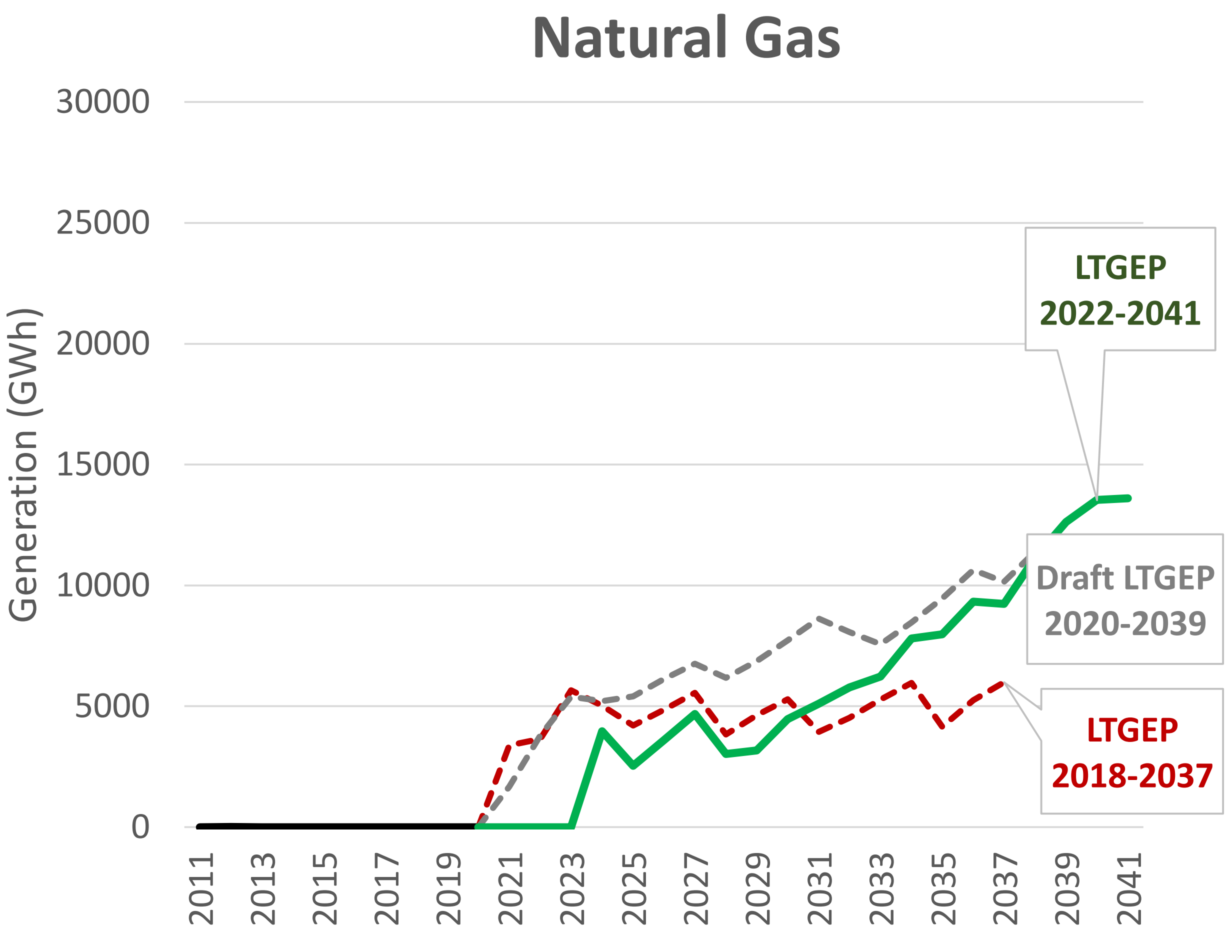
Long Term Generation Expansion Plans



Key Changes

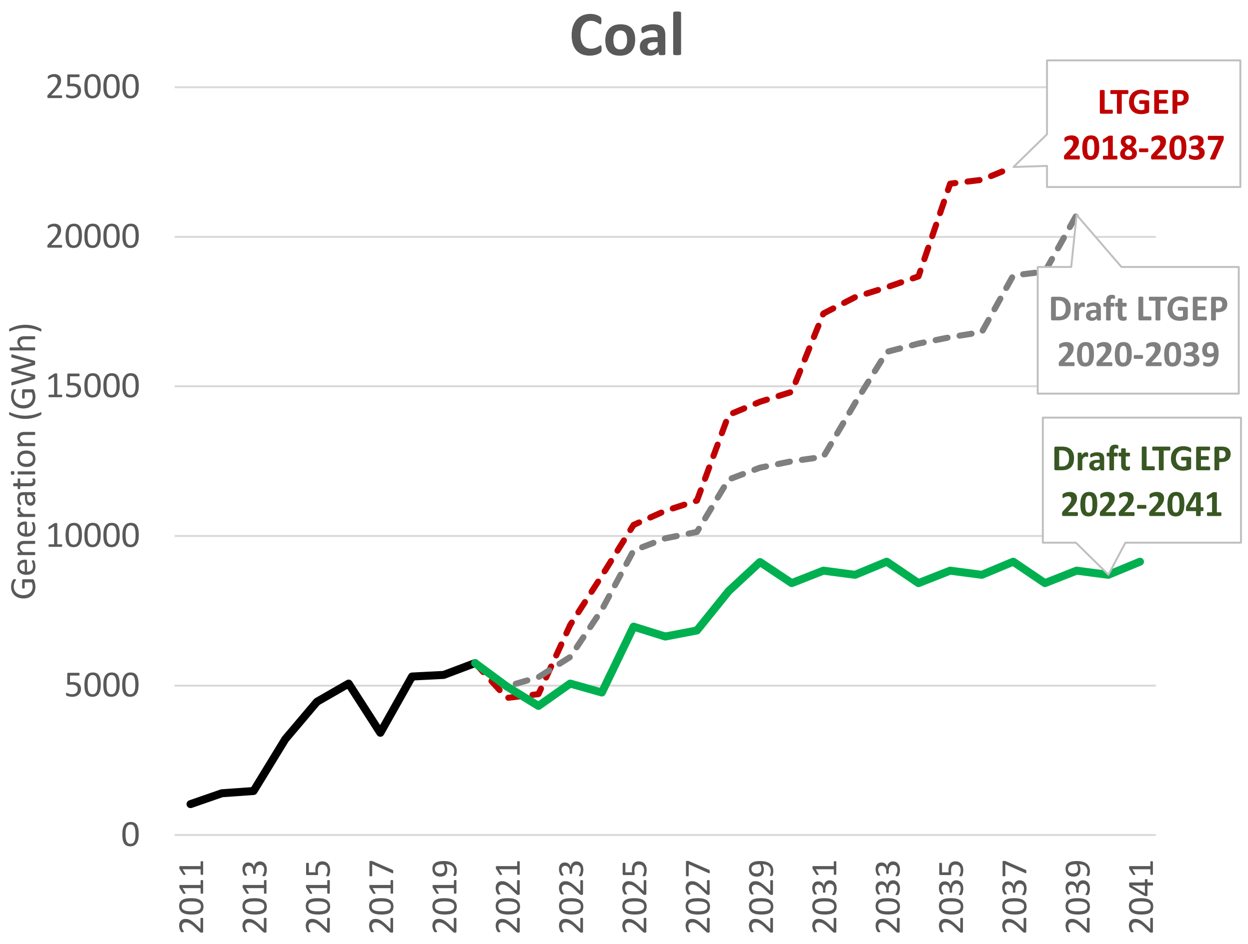


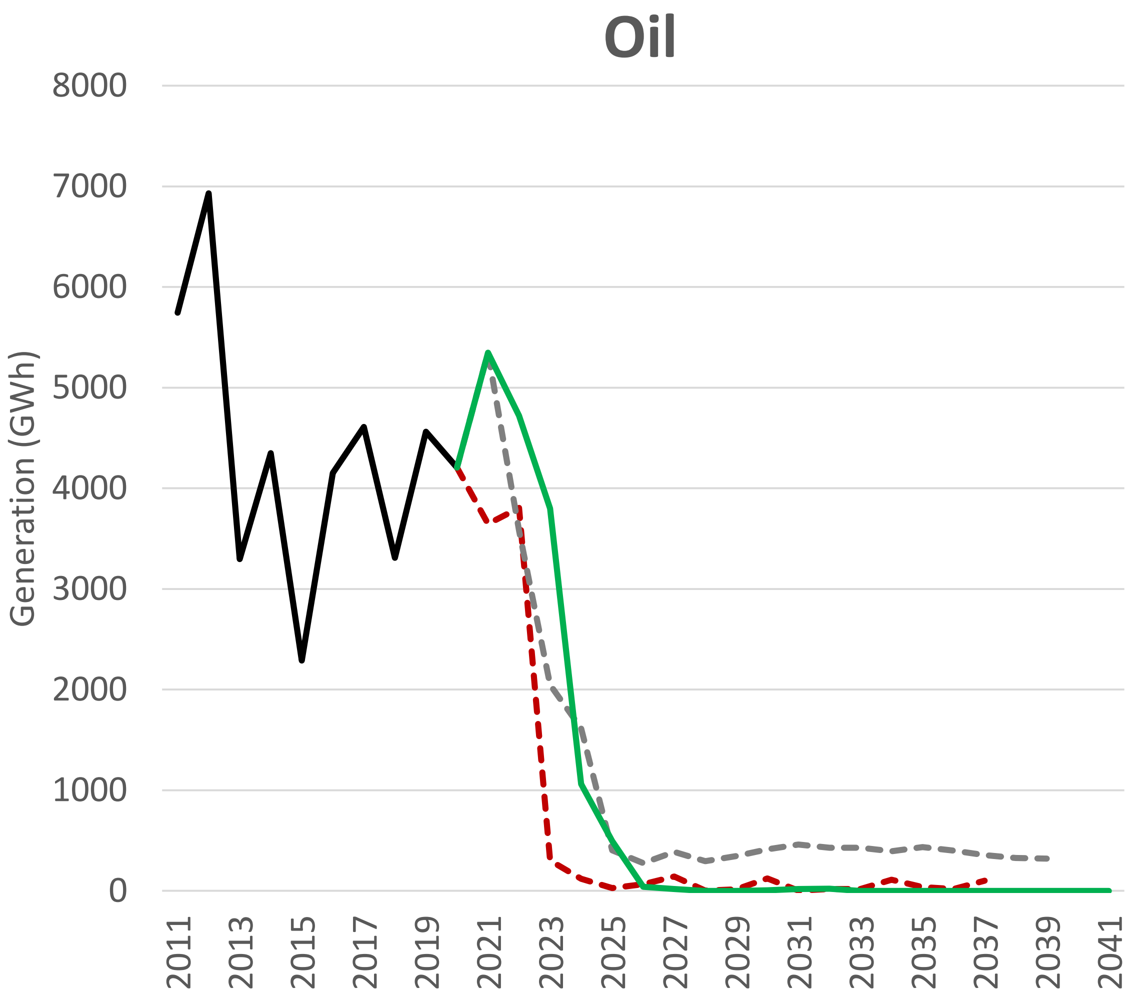
Renewables
Generation (GWh)
30000
25000
20000
15000
10000
5000
0
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
LTGEP 2022-2041
Draft LTGEP 2020-2039
LTGEP 2018-2037



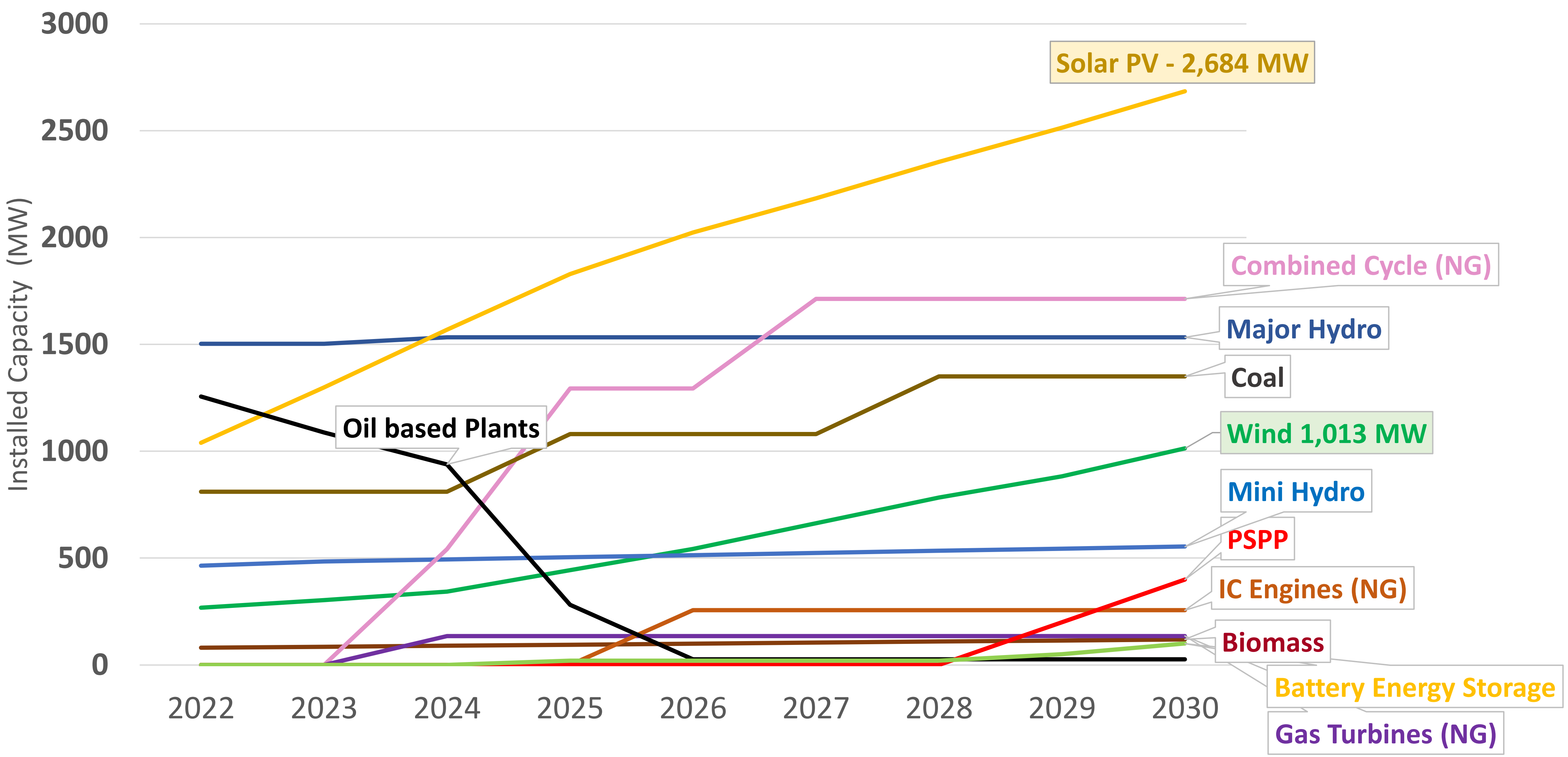
Natural Gas
Generation (GWh)
30000
25000
20000
15000
10000
5000
0
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
LTGEP 2022-2041
Draft LTGEP 2020-2039
LTGEP 2018-2037

Key Changes


Coal
25000
20000
15000
10000
5000
0
Generation (GWh)
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
LTGEP 2018-2037
Draft LTGEP 2020-2039
Draft LTGEP 2022-2041

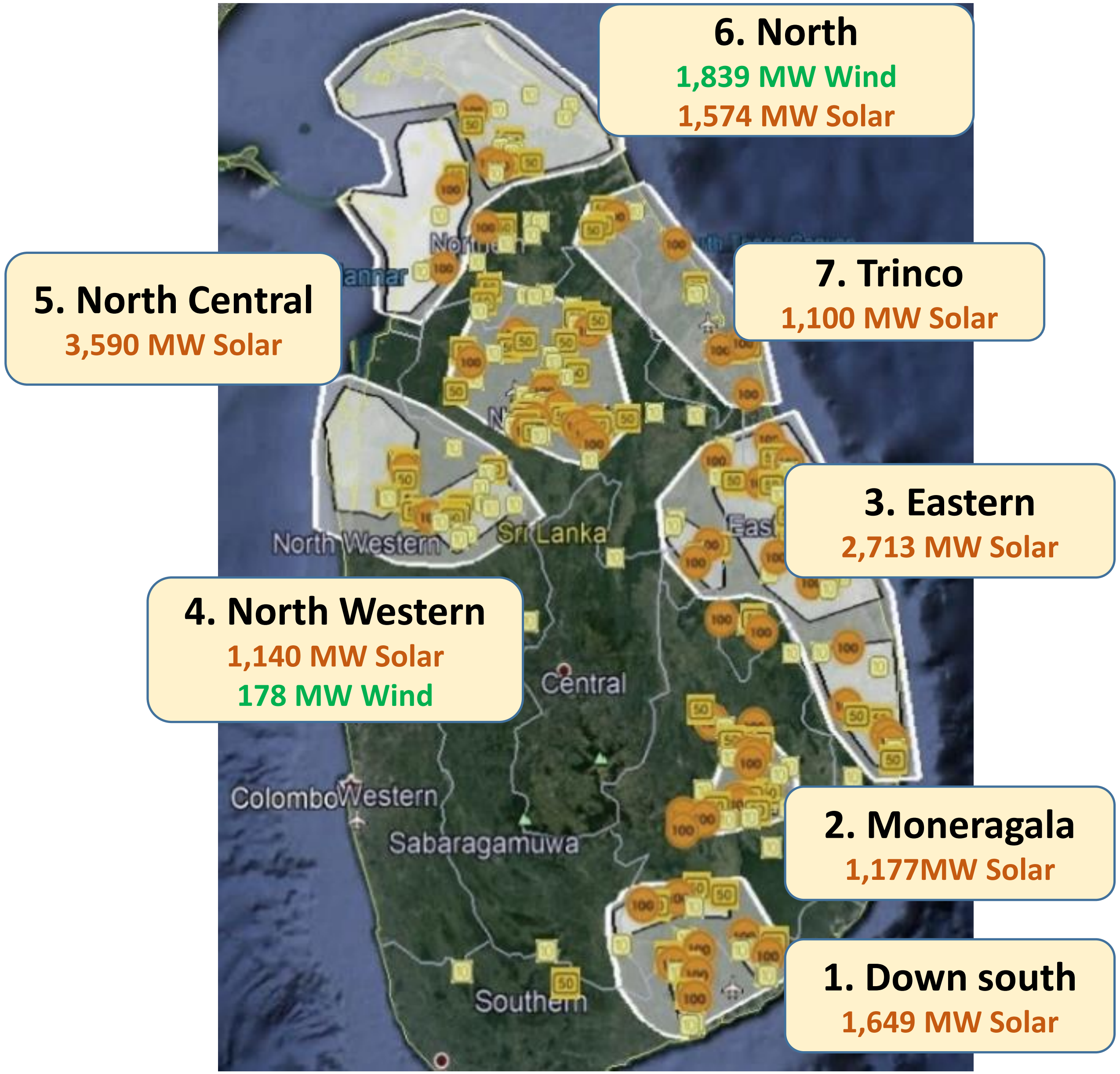

Oil
8000
7000
6000
5000
4000
3000
2000
1000
0
Generation (GWh)
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041

2020-2030



Solar PV - 2,684 MW
Combined Cycle (NG)
Major Hydro
Coal
Wind 1,013 MW
Mini Hydro
PSPP
IC Engines (NG)
Biomass
Battery Energy Storage
Gas Turbines (NG)
Oil based Plants
Installed Capacity (MW)
3000
2500
2000
1500
1000
500
0
2022
2023
2024
2025
2026
2027
2028
2029
2030

Renewable Energy Zones



Zone 1 - Down south

- Hambantota Subzone
- Thissamaharama Subzone
- Embilipitiya Sub Zone

Zone 2 - Monaragala

Zone 3 - Eastern

- Ampara Subzone
- Batticaloa Subzone
- Polonnaruwa subzone

Zone 4 - North Western

- Puttalam Subzone
- Kurunegala Subzone

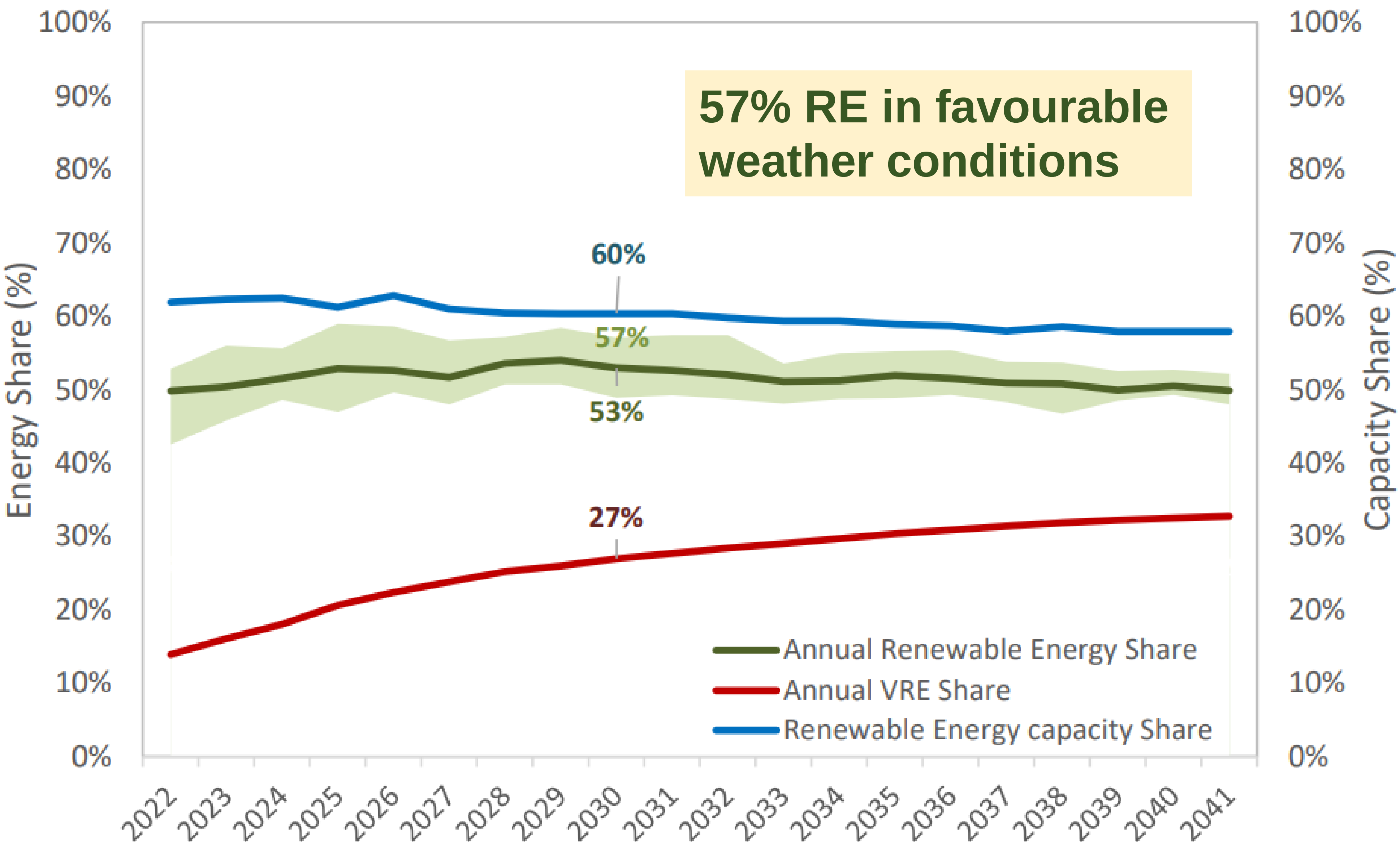
Zone 5 - North Central

Zone 6 - North

- Mannar Subzone
- Jaffna-Killinochchi Subzone

Zone 7 - Trinco

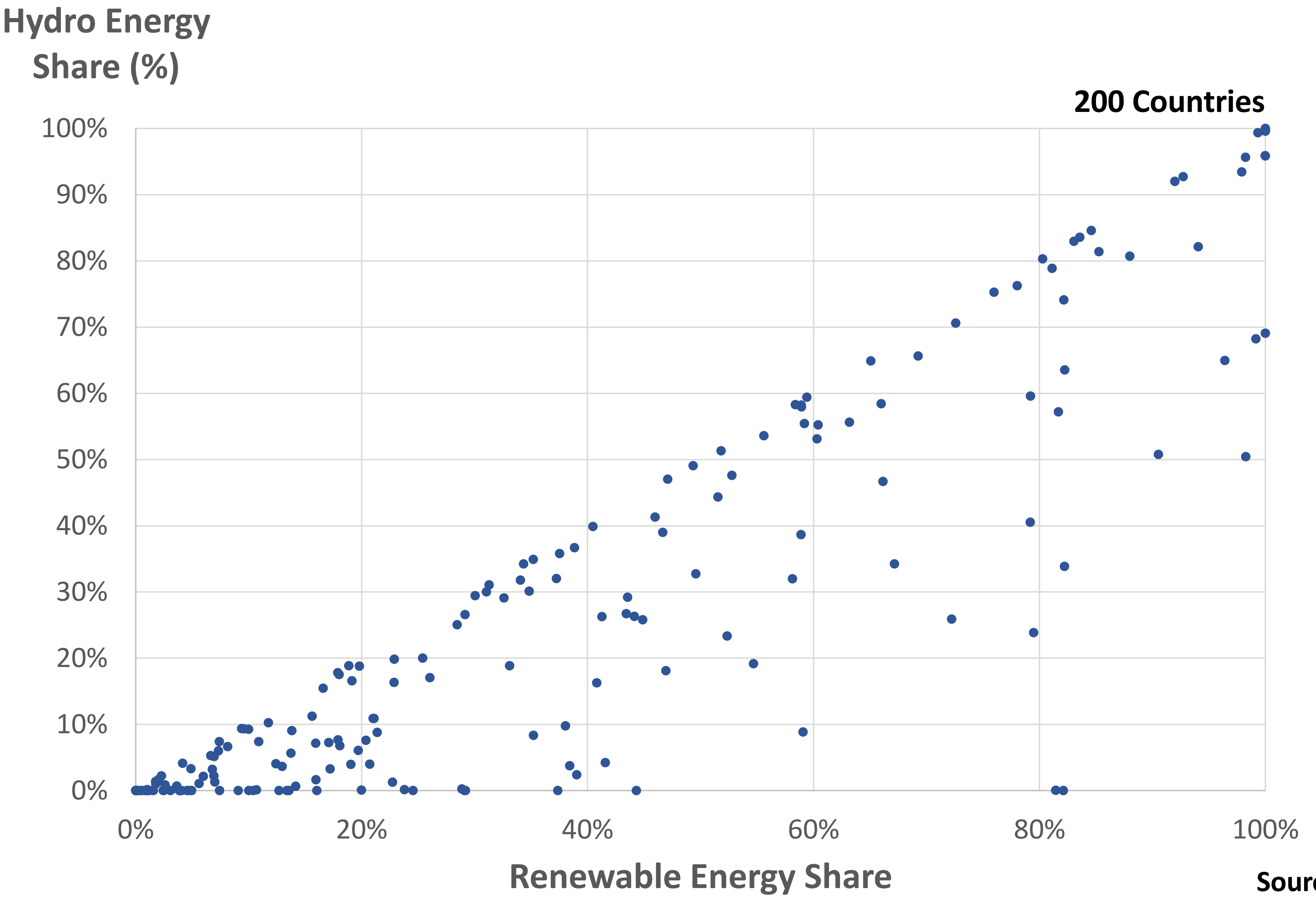
Renewable Energy Contribution



Future Low Carbon Pathway

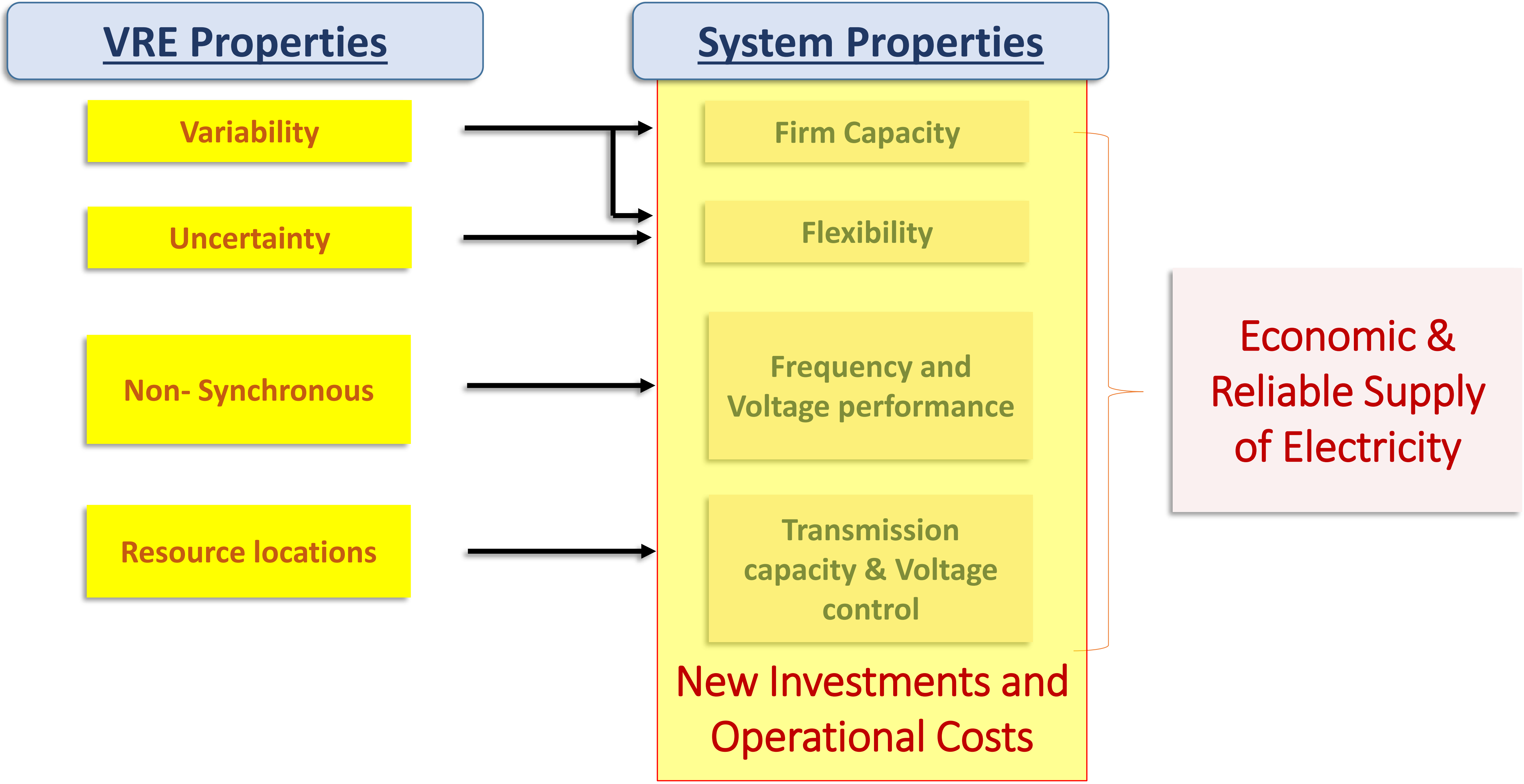
- **Electricity Demand to grow at 5.2% for the next 20 years on average**
- **Embracing Low Carbon Development Pathway facilitating the Clean Energy Transition**
- **Complying all the Environmental and Climate Obligations of Sri Lanka**
- **3,500 MW of New Indigenous Renewable Energy Additions by 2030**
- **Special Emphasis on Power System Flexibility**
- **700 MW of Grid Scale Energy Storage Development for Renewable Energy Integration**

Renewable Energy Share by Country

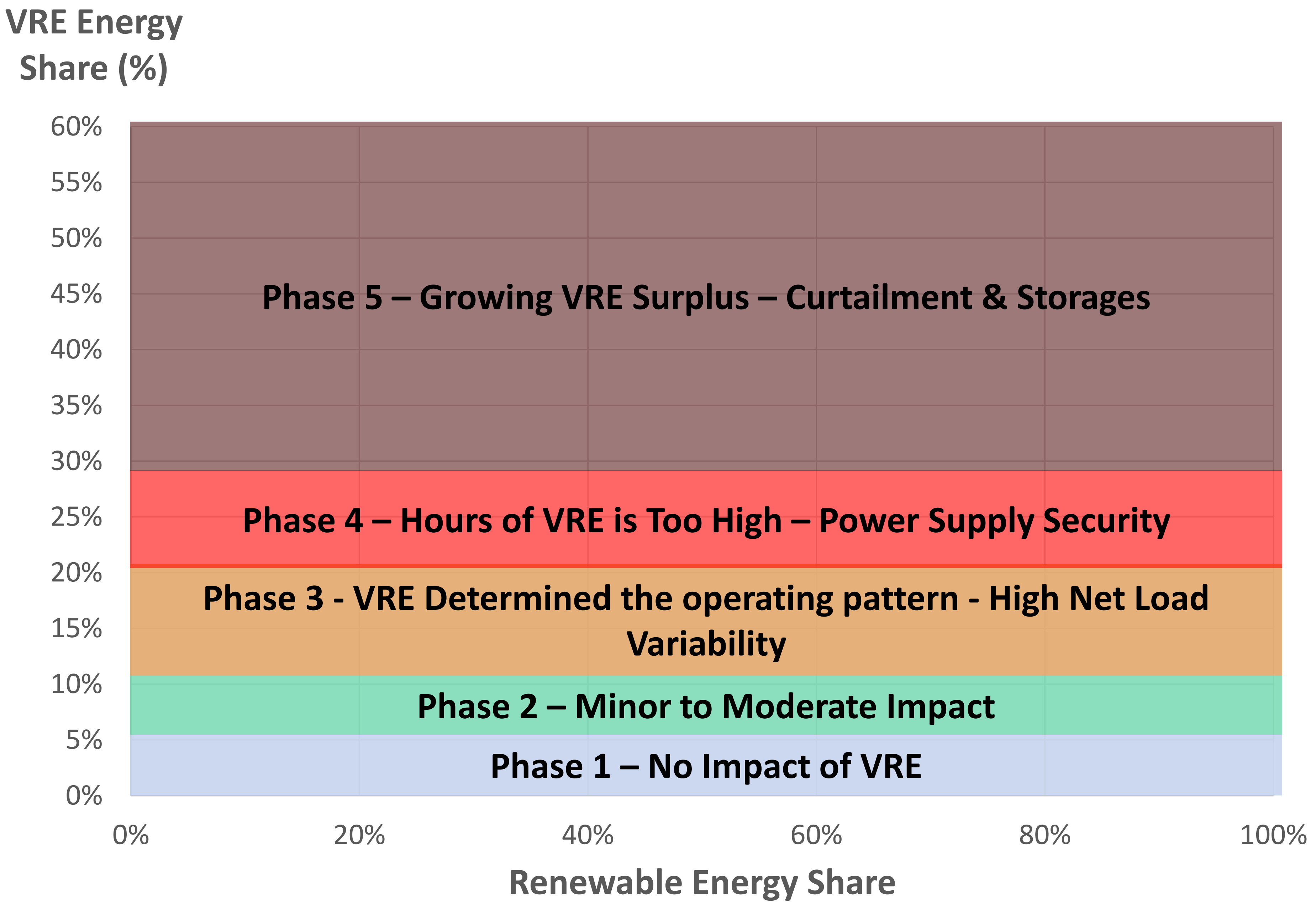


Source: International Energy Agency

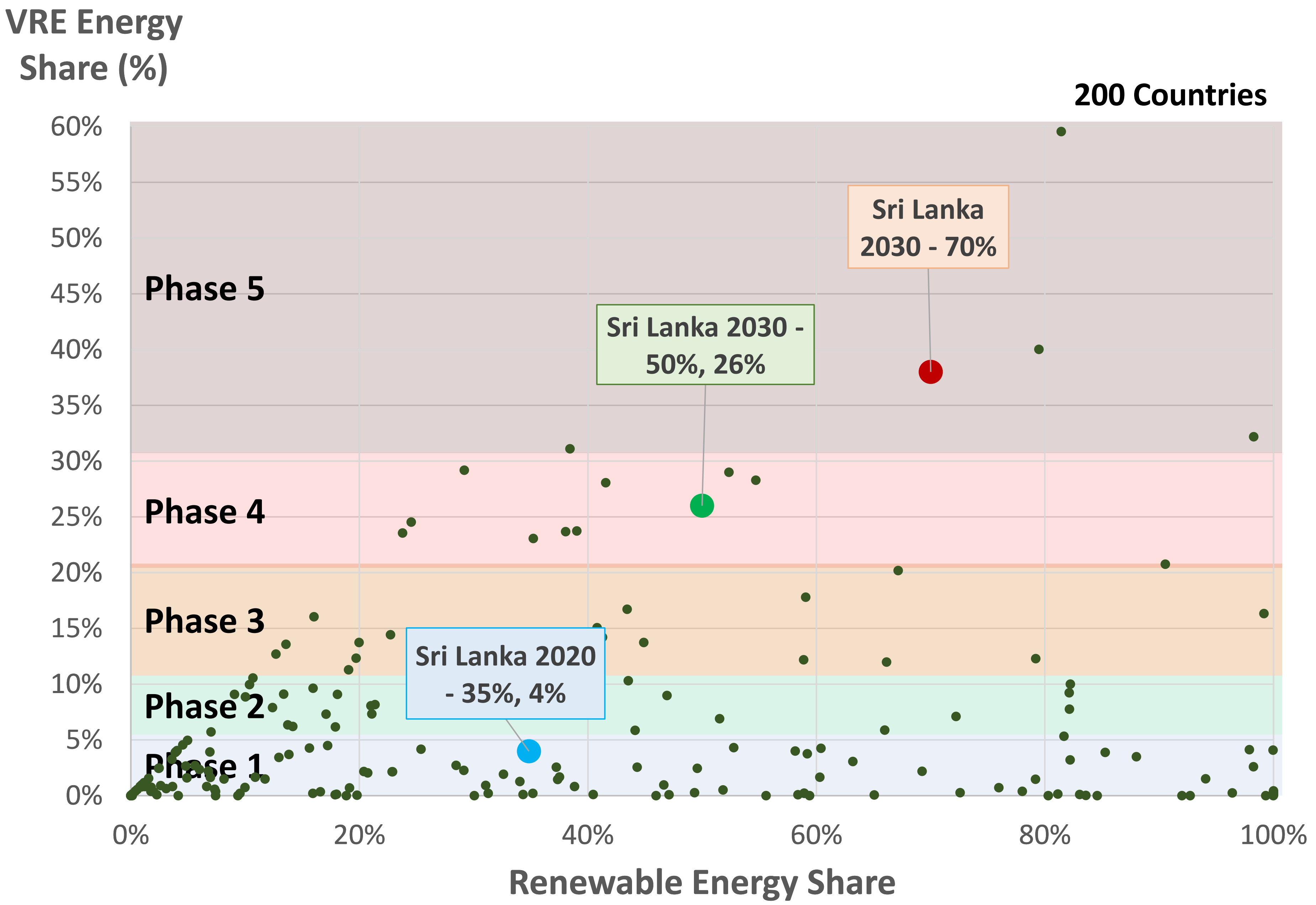
Challenges of Variable Renewable Energy



VRE Integration Challenges



Sri Lanka



VRE Energy Share (%)
200 Countries
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Phase 5
Phase 4
Phase 3
Phase 2
Phase 1
Sri Lanka 2030 - 70%
Sri Lanka 2030 - 50%, 26%
Sri Lanka 2020 - 35%, 4%
0%
20%
40%
60%
80%
100%
Renewable Energy Share

Successful VRE Development Program

Key Building Blocks

Policy and strategies

- National Energy Policy
- RE Targets,
- NDCs,
- LEDs

Grid Integration

- Identifying and prioritizing Integration measures

Prioritizing resource areas

- Resource Assessment,
- Identify zones
- Transmission Development options

Enabling Environment

- Fiscal
- Financing
- Contractual
- Regulatory
- Operational

Competitive Procurement

- Lower the costs,
- Streamline the process

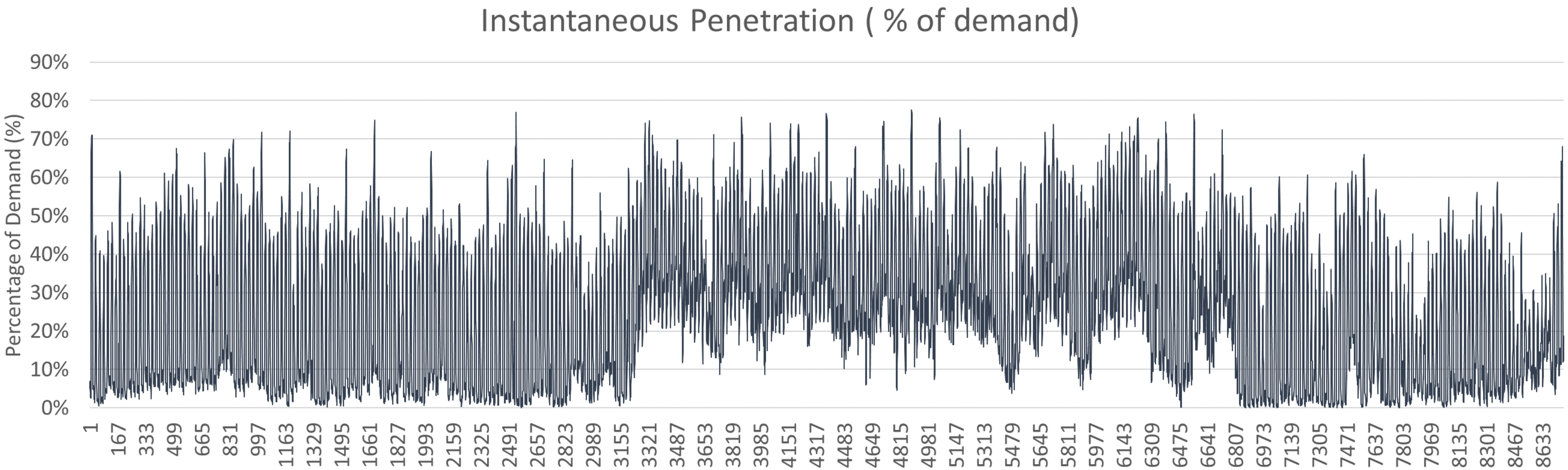
Financing

- Public
- Private

- Planning
- Implementation
- Stakeholders involvement

Challenges for a Smaller System

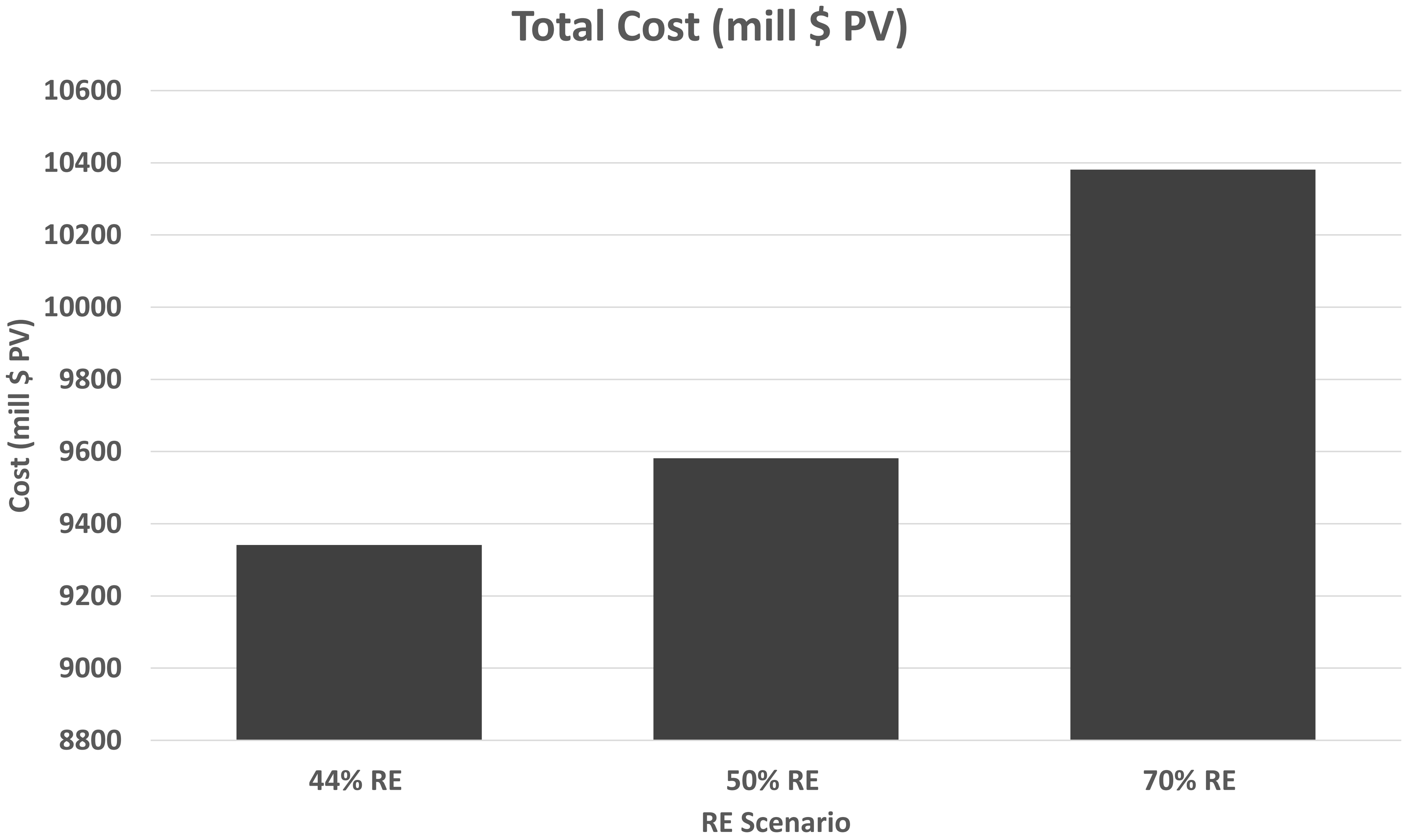
50 % Renewable Energy Share by 2030



Year 2030 – (Hours)

Preliminary Analysis

20 Year Cost of Policy Scenarios (million USD PV)



Key Takeaways

Draft LTGEP 2022-2041 facilitates the,

- Resource Development Process
- Transmission Development Process
- Development of Flexible Generation
- Initiating Energy Storage Projects
- Development of Codes and Regulation

Key Takeaways

- Overcoming Implementation Challenges
- Overcoming Financing Challenges
- Adopting Best Practices
- Maintain the Supply Security and Affordability Strategically
- Initiating Technology Pilots (Energy Storage, Demand Response ..)
- Development of Codes and Regulation

Thank you

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Democratic Socialist Republic of Sri Lanka

The Project for Capacity Development on the Power Sector Master Plan Implementation Program

2nd Joint Coordination Committee (JCC)

July 30, 2021

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Contents

01 Objectives

Objectives of the Project

Project Purpose

Institutional Capacity for improving transmission and distribution operational reliability is enhanced to get prepared for increased share of RE planned in the LTGEP

Outputs of the Project

1. Capacity of corporate strategy and planning for VRE is enhanced (WG1)
2. Capacity of system development and operation for transmission network in response to increased share of VRE is enhanced (WG2)
3. Capacity of distribution network operation is improved (WG3)

02 Schedule of the Project

Schedule of the Project

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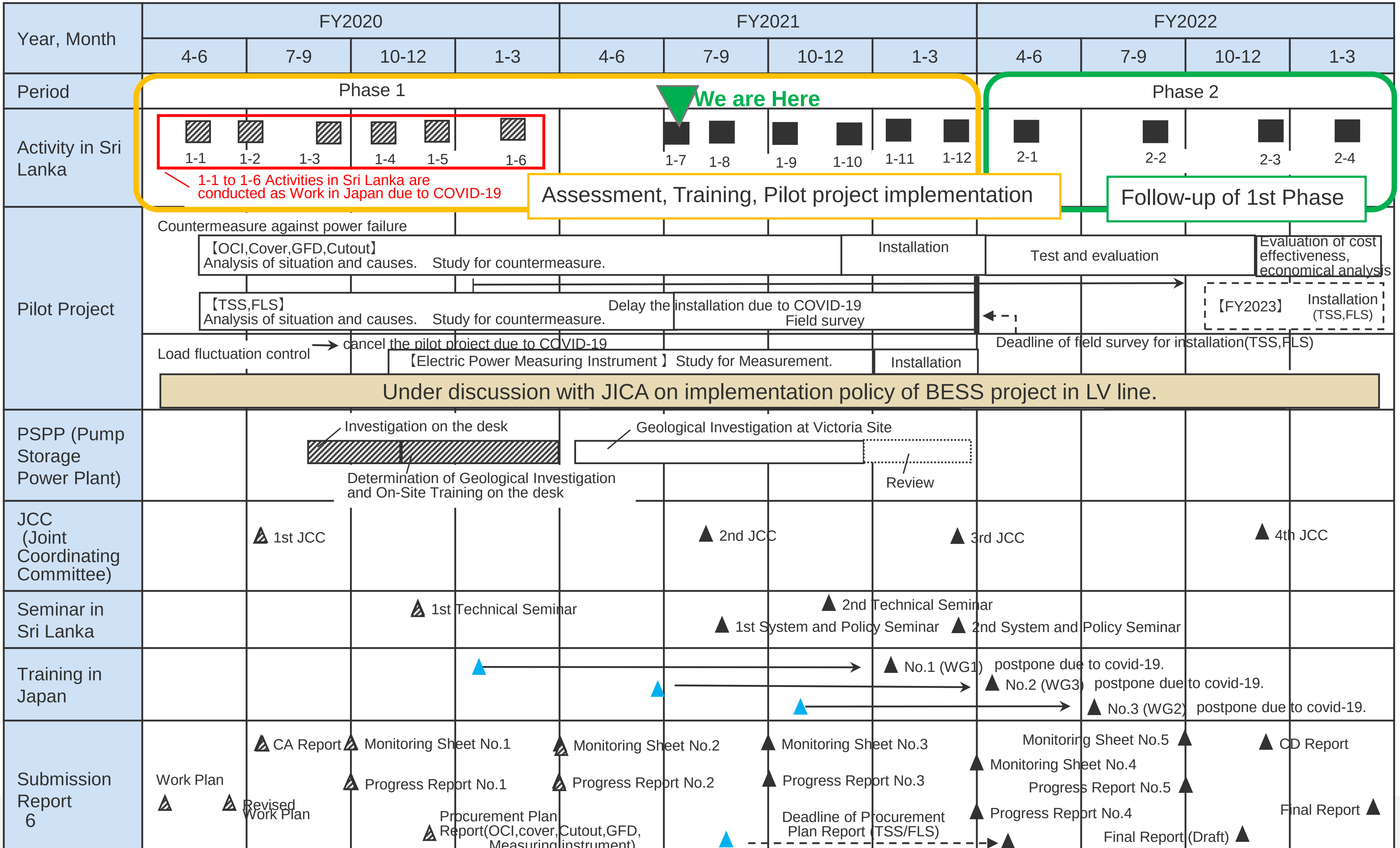

6

03 WG1 (Corporate Strategy, System and Policy)

03-1 Progress of the Project

Past Activities

- In order to clarify the issues of the current system in Sri Lanka, the case studies of developed countries including Japan were explained in advance.
- By explaining the current situation from the C/P, ownership has been promoted.
- Each theme will be discussed in this survey for the 1st system and policy seminar

	2020			2021	
	2Q	3Q	4Q	1Q	2Q
① System and Policy	Organization of the WG Explanation of efforts in developed countries Information gathering in Sri Lankan system and policy		Target selection Organization of the examination structure	Examination of system review Proposal of auxiliary measures	Discussion with CEB management / PUCSL
② Streamlining of VRE Development Approval	Organization of the WG Explanation of VRE outline / O&M		Assign of SEA member	Introduction of Japanese case Information gathering in Sri Lankan system	
③ Financial Analysis	Organization of the WG Explanation of examination method Information gathering in CEB financial system and status	Financial analysis under the CEB's current system			Discussion with CEB management / PUCSL

Past Activities (Detail) ① System and Policy

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Input Stage

JICA Expert

- Promotion of Understanding
- Active involvement

✓ FIT Tariff Scheme
✓ Electricity Tariff Scheme
✓ Pros & Cons of VRE

Info. Input of developed countries

✓ VRE introduction promotion
✓ Effective power system utilization (improvement of operating rate)
✓ Power System stabilization
✓ Power market development

CEB

Selection Stage

- Selection of items to study
- Review of existing system / establishment of new system

✓ FIT Tariff Review
✓ Competitive Bidding applied Range expansion

Examination of auxiliary measures

✓ FCA (Fuel Cost Adjustment)
✓ Independence of FIT Scheme from Electricity Tariff

Study Stage

✓ Study based on precondition
✓ Discussion of study results

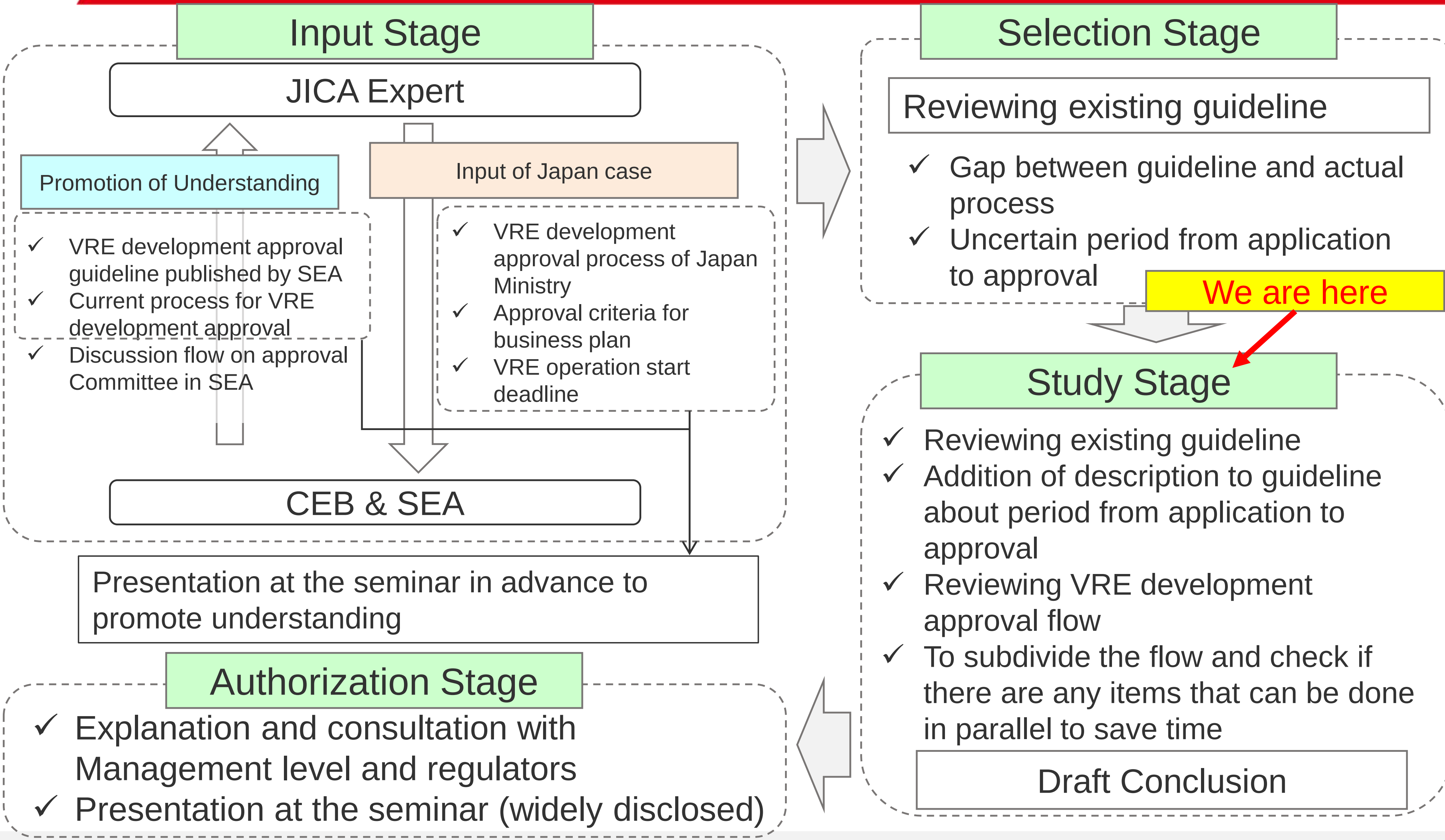
Draft Conclusion

We are here

Authorization Stage

✓ Explanation and consultation with Management level and regulators
✓ Presentation at the seminar (widely disclosed)

Past Activities (Detail)
② Streamlining of VRE Development Approval



Past Activities (Detail) ③ Financial Analysis

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Review of Recent Financial Status of CEB

- ✓ Despite steady growth in electricity demand, CEB consistently records operational deficit mainly due to the electricity tariff kept low (Rs. 16.2 – 16.6/kWh) since 2014.
- ✓ CEB's operation is not able to finance its debt service for the project loans borrowed from the government

Financial Projection of CEB (to be discussed in policy and systems seminar)

Projection under Existing Policies

We are here

- Scenario under current tariff level and VRE regulatory setup
- Results show current financial challenges of CEB: CEB will have negative net worth in around 5 years in future

Projection under Proposed Policies

- Scenario under proposed improvement of VRE policies and regulations
- e.g. revision of FIT tariff, Fuel Cost Adjustment, overall electricity tariff level, etc.

Current Status Confirmation by PDM

	Indicators	Major Activities so far	Issues	Progress ratio
1-1	The assessment and recommendation reports on CEB finance are prepared.	✓ Financial status analysis	No outstanding issue	40%
1-2	Operating profit improvement is assessed. / Case that the present regulatory conditions and electricity tariff level continue to exist and VRE installation is promoted / Case that regulatory conditions and other relevant conditions are reviewed then VRE installation is promoted	✓ Effective options as future conditions are examined ✓ Financial status analysis for both cases	Coexistence of both finance improvement and promotion of VRE	50%
1-3	Corporate strategy of VRE (VRE installation amount and timing) is prepared by CEB periodically.	✓ VRE increasing trend analysis (past and future) ✓ Conformation of CEB strategy and its consistency with national policy		20%
1-4	At least one (1) C/P is certified as key person who understand the pros and cons regarding each kind of VRE	✓ Explanation of Features and O&M for each type of VRE	No outstanding Issues	Evaluation at the end of the project
1-5	At least one (1) C/P is certified as key person who understand VRE development procedure which helps developer to make a plan from the beginning, project formulation to the end and commencement of commercial operation	✓ Procedure analysis ✓ Potential problem finding	Maximum 24 months is required to acquire the VRE development permission	Evaluation at the end of the project

Now under confirmation based on the Draft LTGEP 2022-2041

03-2 Progress of the Technical Transfer

Information Input from a wide range of perspectives

- Info. input of system and policy cases and technical cases in developed foreign countries including Japan
  → To deepen knowledge and broaden thinking of C/P
- Info. input from similar countries in level
  →To be able to grasp the cases that can be adopted immediately.

	Subjects	Categories
1	Feed in Tariff Scheme in Japan	A
2	Output Limitation in Variable Renewable Energy	A
3	Auxiliary measure, Fuel Cost Adjustment System	B
4	Power Development Promotion Tax	B
5	Renewable energy introduction promotion system in major countries	C
6	Outline of VRE system and O&M of PV	D
7	Capacity Market and Balancing Market	A
8	Connect and Manage	A
9	Obligation of battery installation with VRE in Hokkaido Japan	A
10	Renewable Energy Policies of Similar Countries in Southeast Asia	C

Category

A: Main measures of VRE introduction and promotion adopted in developed countries
B: Sub measures of VRE introduction and promotion adopted in developed countries
C: Main measures of VRE introduction and promotion adopted in similar developing countries
D: Outline of VRE / O&M
E: Financial Analysis
F: Others

Information Input from a wide range of perspectives Cont'd

	Subjects	Categories
11	Fading out of inefficient Coal Thermal Power Plant	F
12	Priority Dispatch	B
13	Global warming tax	B
14	Promoting Act of Maritime Renewable Energy Resources	D
15	Amendment of Act on "Special Measures concerning Electricity Procurement from RE"	A
16	O&M of Offshore Wind Power	D
17	VRE Cost Estimation in CEB and Global Average Cost	B
18	Financial Analysis Approach for the bulk of VRE installation	E
19	Process of Financial Projection	E

Category

A: Main measures of VRE introduction and promotion adopted in developed countries
B: Sub measures of VRE introduction and promotion adopted in developed countries
C: Main measures of VRE introduction and promotion adopted in similar developing countries
D: Outline of VRE / O&M
E: Financial Analysis
F: Others

By inputting the latest information from a wide range of perspectives, discussion basis were formed such as what is the most optimal policy and system for Sri Lanka.

Presentation from C/P on Issues of Current Condition

- By analyzing and presenting the problems of the current condition by the C/P itself, the problems were sorted out and the core of the problems was clarified for C/P
- Understanding of C/P was promoted
- Making presentation created a sense of ownership and grew it.

	Subjects
1	The detail of the three metering systems for roof-top PV (Net Metering, Net Accounting, Net Plus)
2	Integration of renewable based generation into Sri Lanka grid 2018-2028
3	Tariff scheme and structure
4	Pros & Cons of VRE from the focus on impact on finance in CEB
5	FAC (Fuel Adjustment Charge)
6	Prospective scheme for Sri Lanka Tariff
7	Project approving process in SEA

Selection of the Study Items

- From various options, consider which item can critically improve the current situation then select
- Decide what to consider specifically in one selected item

Study of Major Field

- Sound and sustainable electricity business management
- Market Development
- Effective Usage of Existing Power System
- Auxiliary measures

Decide Specific items

- FIT Tariff revision
- FIT Tariff applied range revision

- Subsidy Scheme
- FCA
- Independence of FIT scheme from Electricity Tariff

Examine a wide range of items and select priority items
→ Expansion of vision, improvement of logical thinking ability for prioritization

Examination and Seminar presentation

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- Providing information for examination and CEB opinions to the JICA Expert Team
- The current status and issues of system and policy are summarized and presented at the seminar

Collaboration Work

- Data and examination condition
- CEB's opinions

Provisional analysis considering cases in other countries including Japan

Active involvement
(Opinions and comments at the meeting)

Repeated examination

Collaborative Holding

1st System and Policy Seminar

✓ The establishment of ownership in the project for C/P

✓ Promotion of understanding through seminar presentations

03-3 Way to Move Forward

Realization of the studied schemes

<u>Activity ①</u> After the 1st System and Policy Seminar

Aiming to Realization of;

1) FIT Tariff Revision
2) Expansion of Competitive Bidding range
3) Electricity Tariff level improvement

**In parallel with above, subsidy scheme from Government to CEB is desirable in operation.*

<Roles of the Project Team>

CEB: Preparation of the Road Map
Discussion with related institutions
Confirmation of issues and necessity procedures

JICA Experts: Supporting CEB
-Making advices based on experiences in Japan
-Supporting discussion with relevant institutions

Moving forward to next schemes in Sri Lanka

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During Phase II, for future power sector reform in Sri Lanka, other system or scheme will be discussed among the Project Team what system/scheme is fit and necessary for Sri Lanka.

Activity ② After the 1st System and Policy Seminar and during Phase II

Study on next systems and schemes to be fit for Sri Lanka
>Discussion feasibility and adaptability of the systems and schemes;

- Establishment of market system in power sector, such as;
  - -Wholesale market => *For participation of lot of power producers*
  - -Capacity Market => *For appropriate installation of Power Plant in future*
  - -Balancing Market => *To keep power supply/demand balance*
- Connect and Manage in power system
  - -Flexible operation of reserve margin in transmission line capacity
  - -Non-firm type renewable energy connection, etc.

  >Power system can be efficiently used and it will lead to further development of renewable power

Schedule (System and Policy)

Year / Month		2021			2022	2022- (Phase II)
		4-6	7-9	10-12	1-3	4-3
Activity at Sri Lanka		Work at Sri Lanka	▲ 1st System and Policy Seminar		2nd System and Policy Seminar ▲	
Preparation for the Seminar		Preparation for 1st Seminar		Preparation for 2nd Seminar		
Activity ①	CEB		Road Map Preparation Discussion with relevant institutions	Study of issues, procedures		To discuss what action C/P & Expts can take, depending on the study. - Proposal to Gov. - Action to realize
	Expts		Supporting C/P			
Activity ②	CEB				Acquiring information through Activity①	Discussion which system fits for Sri Lanka's system
	Expts					

Overall Schedule (System and Policy)

Year	2021/22 Apr. … Mar.	2022/23 Apr. … Mar.		Future in another 5 or 10 years
This Project	Phase I	Phase II		
Activity①	Preparation of Road map for activity 1 Discussion with related institutions & study	Procedure for system revision		
Activity②		To study what system and policy is necessary and fit for Sri Lanka		
Action by CEB			To act for realize the necessary system/scheme	Realizing new system/scheme
Sri Lanka Power Sector	Growth of the Power System in Sri Lanka			

04 WG2 (Planning and Operation of Power System)

04-1 Progress of the Project

WG2: Activities Record

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	Phase Ⅰ					
	2020			2021		
	Apr. - Jun.	Jul. - Sep.	Oct. – Dec.	Jan. – Mar.	Apr. – Jun.	Jul.
			▲1st Technical Seminar			
1. Supply and Demand Operation	Introduction of impact of large amount of VRE introduction and operation case studies		Proposal of optimal capacity calculation of PSPP and Storage Battery Review of Grid Code			
2. Countermeasure for power system stability(PSPP and Battery Storage)	Introduction of case study of PSPP and Batteries		Introduction of Battery's detailed characteristics Cost merit between PSPP and Batteries			
3. VRE Forecast	Review of existing VRE location and facility information		Data Collection of Weather and Facility	Development of the VRE Forecast Model		Forecasting VRE output distribution
4. Geological Investigation (Victoria site)		Review of PSPP development plan	Consideration of reconnaissance On Site Training on the Desk▲	Proceeding of subcontracting	Geological Investigation	On Site Training (Inception Stage)▲

※PSPP: Pumped Storage Power Plant, VRE: Variable Renewable Energy

WG2: Activities Stage of Supply and Demand Operation

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Input Stage

JICA Expert

Input the case studies from other countries

- ✓ Grid Code and actual Operation of Generators
- ✓ Sri Lanka Solar PV Program (Net Metering Schemes)

- ✓ Actual Operation of Generators in Power System where a large amount of VRE is introduced
- ✓ Day Ahead Planning and Operation of Supply and Demand Balance
- ✓ Explained rules and practices regarding VRE Control in Japan

Promotion of the Understanding & Sharing information about Actual Operation

CEB

Selection Stage

Revise the Grid Code

We are here

- ✓ Review the current Grid Code
- ✓ VRE's curtailment rule and method
- ✓ Considering Fault Ride Through (FRT)

Supply and Demand operation using VRE forecast

- ✓ Considering the supply capacity of the forecasting VRE output
- ✓ Supply and Demand operation using the forecasting VRE output

Study Stage

- ✓ FRT according to the introduction capacity of the VRE
- ✓ Revision of Grid Code
- ✓ Supply and Demand balancing operation considering forecast error of VRE output

Actual Stage

- ✓ Practical planning and operation using the forecasted VRE output
- ✓ Propose the Revised the Grid Code

WG2: Activities Stage of Countermeasure for power system stability(PSPP and Battery Storage)

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Input Stage

JICA Expert

- ✓ Planning of the battery introduction.
- ✓ The role of PSPP in supply and demand operation
- ✓ Preliminary Studies on Grid Connected Battery Storage.

Input the case studies from other countries

- ✓ Battery system for mitigate the VRE output fluctuation
- ✓ PSPP Capacity Consideration
- ✓ Virtual synchronous generator (synthetic inertia) using battery
- ✓ Detailed characteristics of battery storage
- ✓ Demonstration of test results of battery storage system

Promotion of the Understanding, Ownership & Sharing information about future plans

CEB

Selection Stage

Detailed battery storage characteristics

- ✓ Battery Types(Li-ion, NAS, Redox-Flow, Lead Acid)
- ✓ Installation and O&M cost of each kind of battery

Comparison of PSPP and battery storage

- ✓ Comparison of operational advantages and disadvantages
- ✓ Comparison of construction and operating costs

Target for the power system stability

- ✓ Each characteristics of PSPP and battery storage to mitigate the power system fluctuation

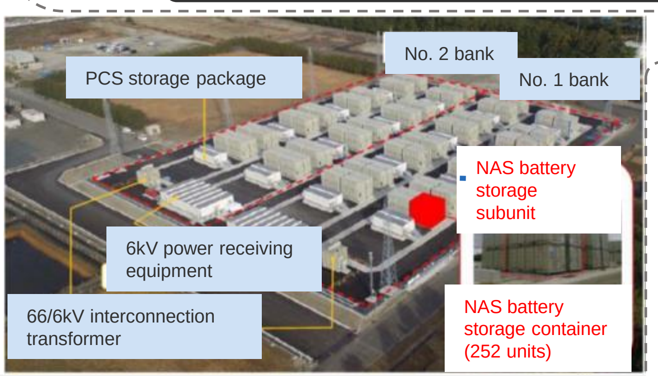
We are here

Study Stage

- ✓ Considering the operation of PSPP and battery storage for power system stability
- ✓ Calculation of the battery storage capacity according to the VRE's introducing capacity
- ✓ Combined use of PSPP and storage battery

Authorization Stage

- ✓ Propose battery storage capacity according to the VRE introduced capacity
- ✓ Operation of the PSPP and battery storage to mitigate the VRE output fluctuation



Practical examples of using NAS battery in Japan （Buzen Substation）

WG2: Activities Stage of VRE Forecast

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Input Stage

JICA Expert

- ✓ VRE potential of each area (existing and planning sites of VRE plants)
- ✓ Weather data and Facility Information
- ✓ Installed capacity of the Roof top PV at each area

Promotion of the Understanding & Sharing information about Actual Facilities

Input the case studies from other countries

- ✓ Topology of the weather forecasting
- ✓ Essential information for VRE forecast model development
- ✓ Accuracy of the VRE forecast
- ✓ CEPCO's PV Forecast System

CEB

Selection Stage

Select the Target Point for VRE forecasting model development

- ✓ Selection of the points for developing VRE forecast model of the Roof-top PV, major Solar Power Plants, and Wind Power Plants
- ✓ Confirmation of the providing data of weather and Facilities in and around these points

Data Distribution of VRE forecast

- ✓ Distribution protocol
- ✓ Frequency of distributing VRE forecast in a day and its timing
- ✓ Development of the receiving server

We are here

Study Stage

- ✓ Developing the VRE forecasting model
- ✓ Forecasting & distribution VRE Data (From July 2021)
- ✓ Verification of the VRE data
- ✓ Estimating VRE's output for whole area using developed forecasting model of VRE

Implementation Stage

- ✓ Implement the VRE forecasting model, if needed
- ✓ Actual planning and operation of the Supply and Demand with VRE forecast

WG2: Activities Stage of Geological Investigation

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Input Stage

JICA Expert

- ✓ The situation of the Maha3 and Victoria Lake PSPP development
- ✓ Provide the 1:10,000 geological map

Input the case studies about general issues of PSPP development

- ✓ Current situation of the Geological Investigation at Maha3 and Victoria Site
- ✓ Task and schedule for geological investigation
- ✓ Issues for PSPP development

Promotion of the Understanding & Sharing information about the development plan

CEB

Selection Stage

Select the Target of the Geological Investigation

- ✓ Issues of the Maha3 Pre-Feasibility Study
- ✓ Recognition of the PSPP planning
- ✓ Decide the site Maha3 or Victoria Site

Contents of the Geological Investigation

- ✓ Investigation area with special emphasis to identify the protection area at Victoria Site
- ✓ Core dolling points
- ✓ Schedule of the Investigation

We are here

Study Stage

- ✓ Geological Investigation at the Victoria Site(From June 2021)
- ✓ Decide the detailed core dolling points
- ✓ On-site training at Inception Stage and Final Stage

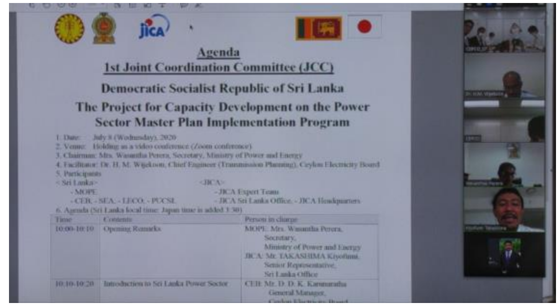
Authorization Stage

- ✓ Verifying the results of the Geological Investigation
- ✓ Comparing the issues of Maha3 and Victoria Site
- ✓ Considering the Full-Swing Geological Investigation at Victoria site

04-2 Progress of the Technical Transfer

WG2: Technical Transfer of 1st Technical Seminar

- Date: 15th December, 2020
- Virtual Meeting between Japan and Sri Lanka



	Subjects	Presenter
1	Outline of the project and issues for introducing large amount of VRE	CEB: Dr. Wijekoon
2	Countermeasure for power system with increasing VRE	
2-1	Issues for PSPP development	JICA Expert: Mr. WADA
2-2	Comparison of the cost merit between PSPP and battery storage	JICA Expert: Mr. TAKATSU
2-3	Development plan for combined PSPP and battery storage	CEB: Mr. Asith Kaushalya
3	Advanced supply and demand operation	
3-1	Development of VRE output forecast model and evaluation of its accuracy	JICA Expert: Mr. MATSUKAWA
3-2	Supply and demand operation with increasing VRE in power system	JICA Expert: Mr. TAKAMIZAWA
3-3	Technical issues and measures for supply and demand operation of power system with increasing VRE	CEB: Mr. Eranga Kudahewa
3-4	Determination of development sites for VRE output forecast model	CEB: Mr. Randika Wijekoon

WG2: Technical Transfer of Supply and Demand Operation

	Subjects	Field work activities
1	Actual operation of generators in power system where a large amount of VRE is introduced	1st field work
2	Day ahead planning and operation of supply and demand balance	2nd field work
3	Impact by photovoltaic output on power system	2nd field work
4	PSPP capacity consideration in Sri Lanka and Japan	3rd field work
5	Re-confirmation of simulation premises of PSPP installation	3rd field work
6	The purpose of the PSPP utilization for power system	4th field work
7	Supply and demand operation with increasing VRE in power system	5th field work
8	Grid code review (Confirmation of premises)	6th field work
9	Explained rules and practices regarding VRE Control in Japan	Additional 6th field work
10	Introduction about the Grid Code in Japan	7th field work

WG2: Supply-demand Balancing Operation Considering VRE Output Forecast (1st Technical Seminar)

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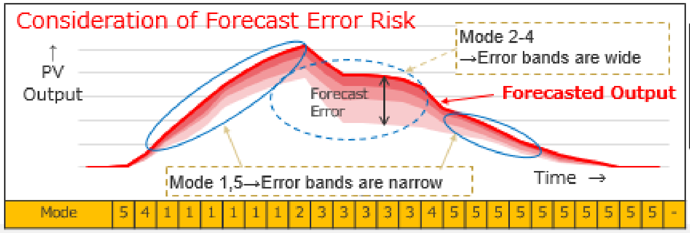
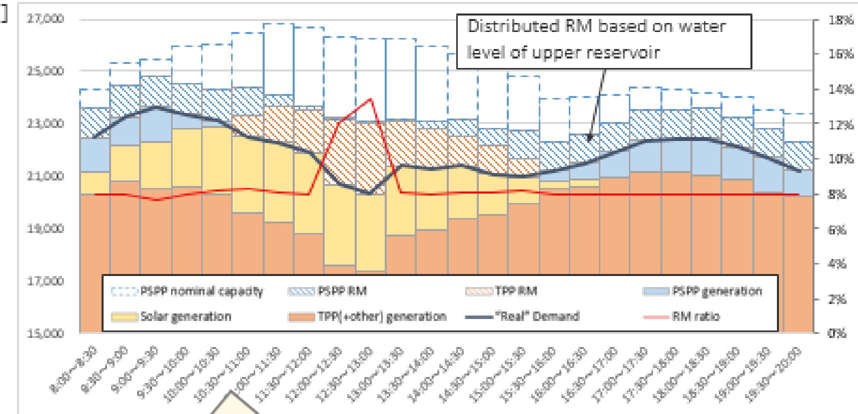
Considering forecast error of VRE output

Mode	1	2	3	4	5
Clearness Index	1~0.71	0.71~0.62	0.62~0.43	0.43~0.21	0.21~0
Weather	Clear Sunny	Sunny	Little cloudy	Cloudy	Rainy

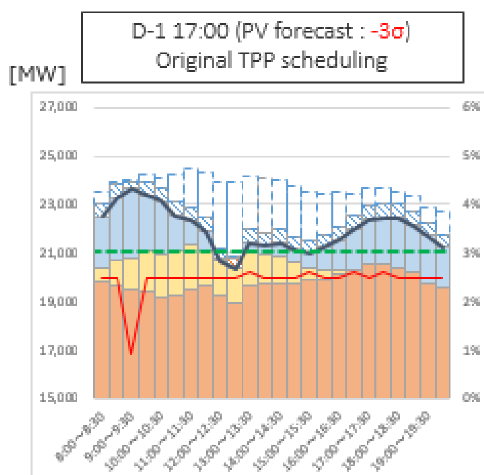


Forecast Error
-1σ (68.3%)
-2σ (95.4%)
-3σ (99.7%)

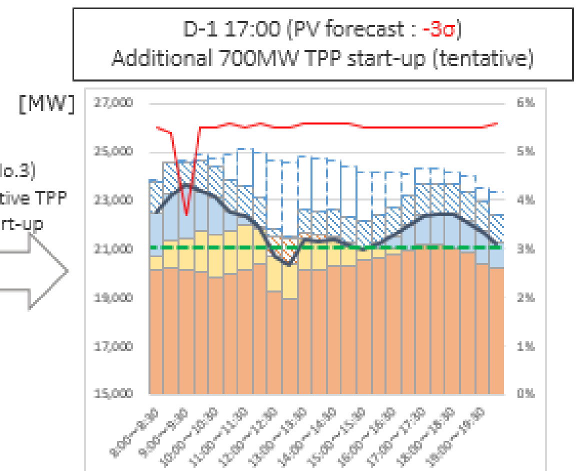
PSPP RM distributed based on reservoir level



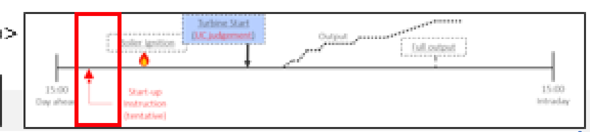
Risk Managed Operation



(No.3) Tentative TPP start-up



<Schedule of TPPs tentative Start-up>



RM: Reserve Margin
TPP: Thermal Power Plant
D-1: The day before

WG2: Power System Stability Considering Rate of Change of Frequency (RoCoF)

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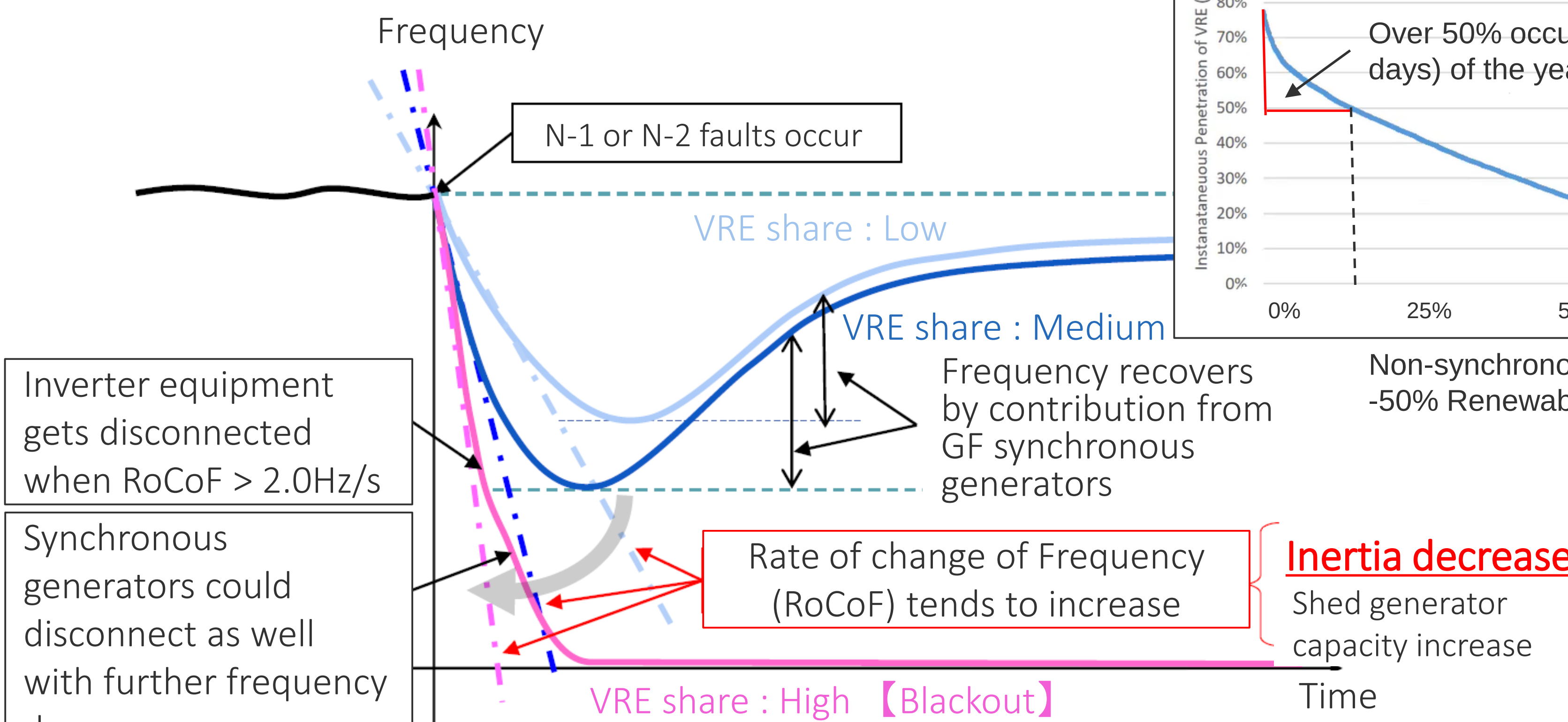
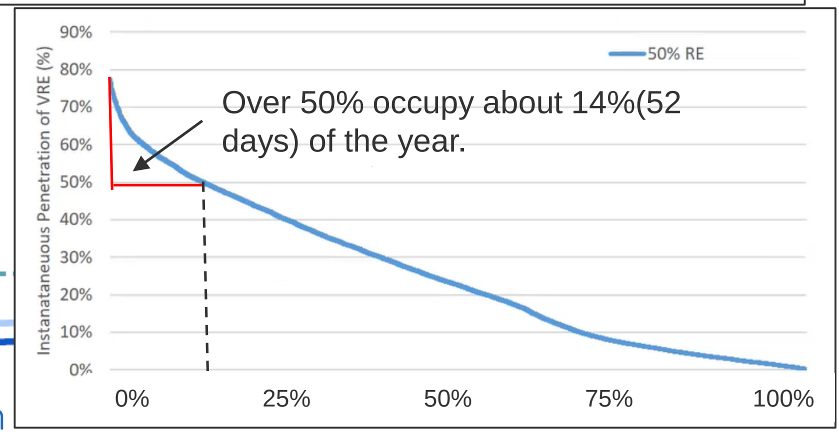
- In Japan, RoCoF limit is defined as 2Hz/s due to ramp rate limits in FRT(Fault Ride Through).
- When conventional generators in power system decreases , RoCoF tends to increase.
- There is **a need to have certain minimum percentage of conventional generators** in power system **to maintain RoCoF vis-a-vis system inertia & thereby power system stability**.



Source: OCCTO HP



Non-synchronous Penetration Level
-50% Renewable 2030 in Sri Lanka

WG2: Technical Transfer of power system stability(PSPP and Battery Storage)

	Subjects	Field Work Activities
1	Battery storage for countermeasure against demand fluctuation	1st field work
2	Battery system for mitigate the VRE output fluctuation (Demonstration test with island as field of power system	2nd field work
3	The cost merit of battery installation.	3rd field work
4	Comparison of the cost merit between PSPP and storage battery	3rd and 5th field work
5	Consideration for development of PSPP (for comparison with battery)	3rd field work
6	Adjustable speed PSPP for countermeasure of a large amount of VRE introduction	4th field work
7	Virtual synchronous generator (synthetic inertia) using battery	4th field work
8	PSPP utilization for countermeasure of a large amount of VRE introduction	4th field work
9	Issues for PSPP development	5th field work
10	Detailed characteristics of storage battery such as life cycle chart, charging/ discharging characteristics with cut off values, operating and storage, etc.	6th field work
11	Capital and Operation Costs of Storage Battery	7th field work

WG2: Technical Transfer of power system stability(PSPP and Battery Storage)

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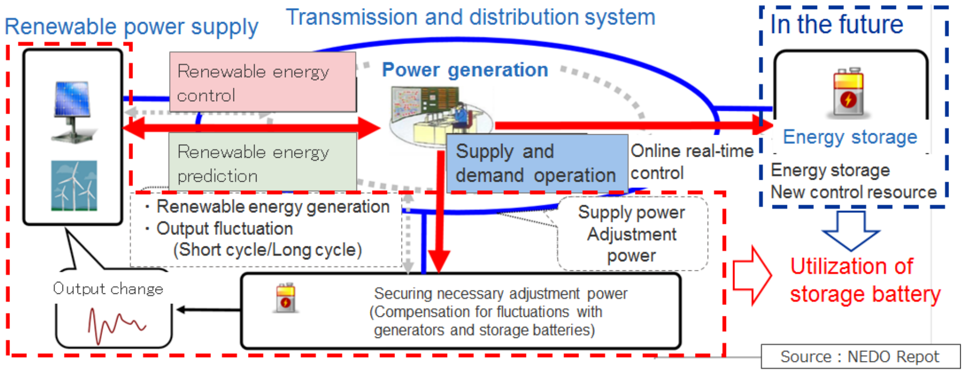
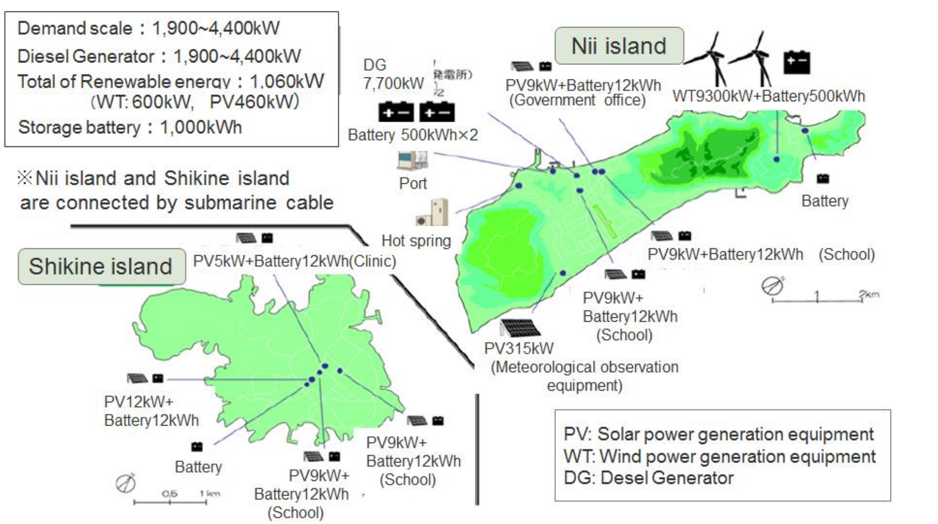
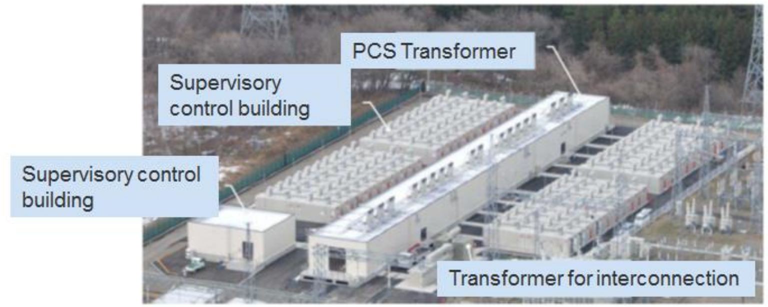
Battery system to mitigate the VRE output fluctuation (2nd field work)



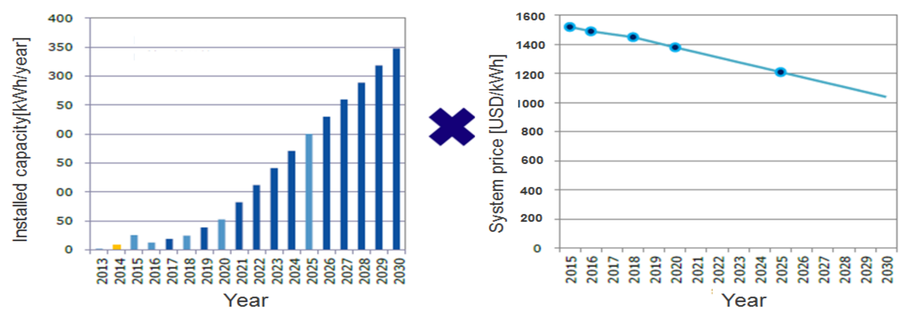


Source : NEDO Repot

Practical examples in Japan (Li battery)



Installation area	6,000m² (100m×60m)
Demonstration period	2013-2017
Storage battery type	Li battery
Output capacity	Output:20MW Capacity:20MWh
Purpose	Measures against frequency fluctuations
Total construction cost	92MUSD



※Includes O&M costs and amortization costs.

WG2: Technical Transfer of VRE Forecast

	Subjects	Field Work Activities
1	Forecast accuracy depending on the existence of the weather data, VRE facility data and VRE output data, and the expected VRE forecast accuracy	3rd field work
2	Confirmation of candidate sites for forecasting VRE	3rd field work
3	Determination of the development sites for VRE forecast model	4th and 5th field work
4	Delivery method and timing of the forecast data for the weather data such as wind velocity, irradiation, etc. and VRE output	4th field work
5	PV Forecasting in Chubu Electric Power Co., Inc.	4th field work
6	Development of VRE output forecast model and evaluation of its accuracy	5th field work
7	Topology of the VRE forecasting model which convert from Global Weather Model to VRE forecast output	5th field work
8	Conversion tool which can convert weather data such as wind velocity and solar irradiation to VRE forecast output	5th field work
9	Using the facility information of Saga Solar Power to develop the Roof-top PV forecasting model at area 3 which is the southern western area in Sri Lanka	6th field work
10	The method of estimation of each area's VRE outputs from the point VRE output	6th field work
11	The necessary data for the estimation such as total capacities of VREs in targeting areas	6th field work
12	Explanation about the validation of VRE forecast output as a future plan	Additional 6th field work

WG2: Technical Transfer of VRE Forecast

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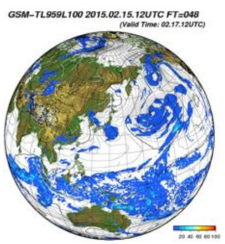
◆ Overview of Forecast for VRE Output

- Weather forecast for VRE can be calculated based on the weather models of the Japan Meteorological Agency and the Meteorological Organizations of each country.
- The output of PV and wind power can be predicted from weather forecast results and specifications of facilities.
- Forecast weather and VRE output data distribution was started from July 1st 2021.

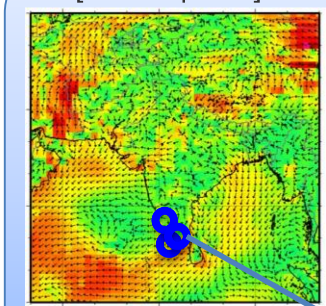
Output from Weather model



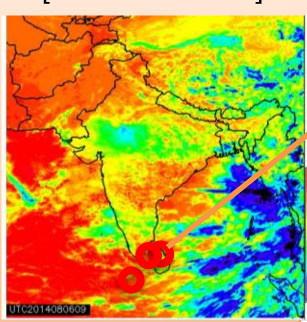
Statistical model

Forecast for VRE at power plant

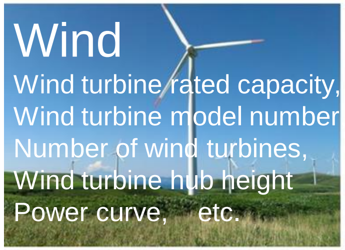
[Wind speed]

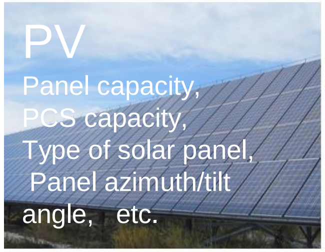


[Solar irradiation]



Facility information





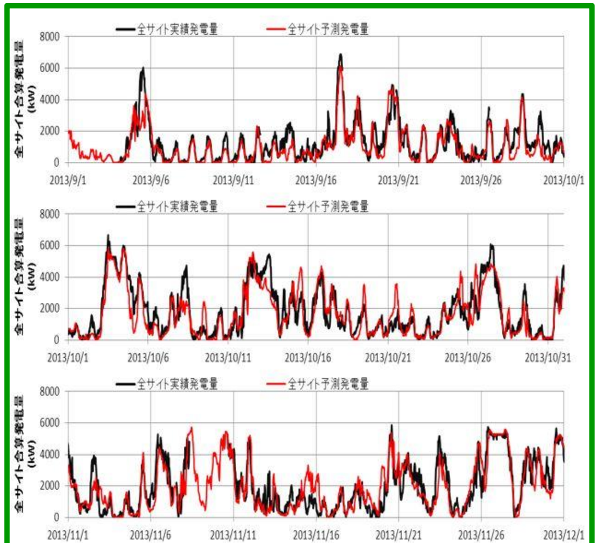
Wind speed at wind power plant

Solar irradiation at PV power plant

Wind power generation at the plant

PV power generation at the plant

Statistical model



X_axis: timeline [year/month/day]
Y_axis: total amount of all power output(wind + PV) [kW]
legend: historical result / forecast for power generation output

※Specification should be considered in detail at the time of design

Forecast system of PV output is installed at Central Load Dispatching Center in CEPCO.

WG2: Technical Transfer of Geological Investigation

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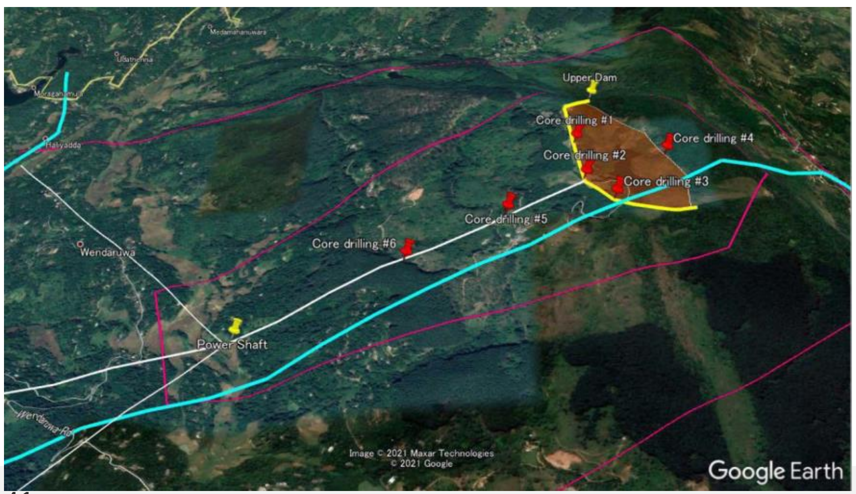
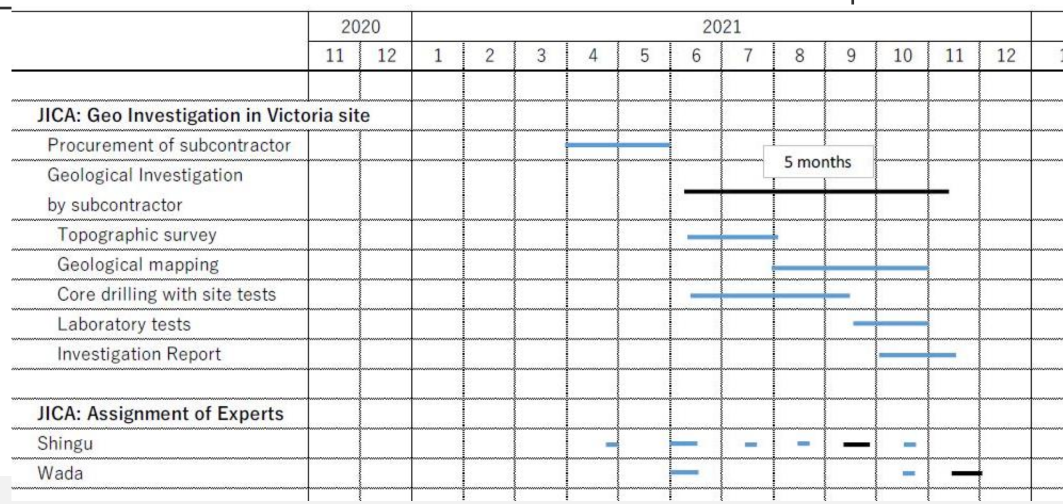
	Subjects	Field Work Activities
1	Providing the data for On-site training for Pumped Storage Power Plant (PSPP) development	3rd field work
2	On-site training about PSPP (October, 2020)	4th field work
3	Current situation of the geological investigation at Maha 3 and Victoria site such as issues and progress to date	5th field work
4	Task and schedule for geological investigation and confirmation of the protection area at Victoria site	5th field work
5	Issues for PSPP development	5th field work
6	Scope and period about the geological investigation at Victoria site	6th field work
7	On-site Training about Geological Investigation (Inception Stage, July 2021)	7th field work





04-3 Way to Move Forward

WG2: Activities for Achieve the Target

1. Supply and demand operation

✓Propose the revised Grid Code considering the large amount of VRE introduction that includes the FRT, VRE curtailment, etc.

✓Propose practical planning and operation using the forecasted VRE output.

✓Assist in formulating the next LTGEP(2022-2041) while considering the VRE, PSPP, and Battery Storage.

2. Countermeasure for power system stability(PSPP and Battery Storage)

✓Propose optimal capacity of PSPP and Storage Battery in accordance with the VRE introduced capacity

✓ Propose Storage Battery introduction plan considering the existing PSPP construction plan

✓ Propose operation of the PSPP and Battery Storage to mitigate VRE output fluctuation

WG2: Activities for Achieve the Target

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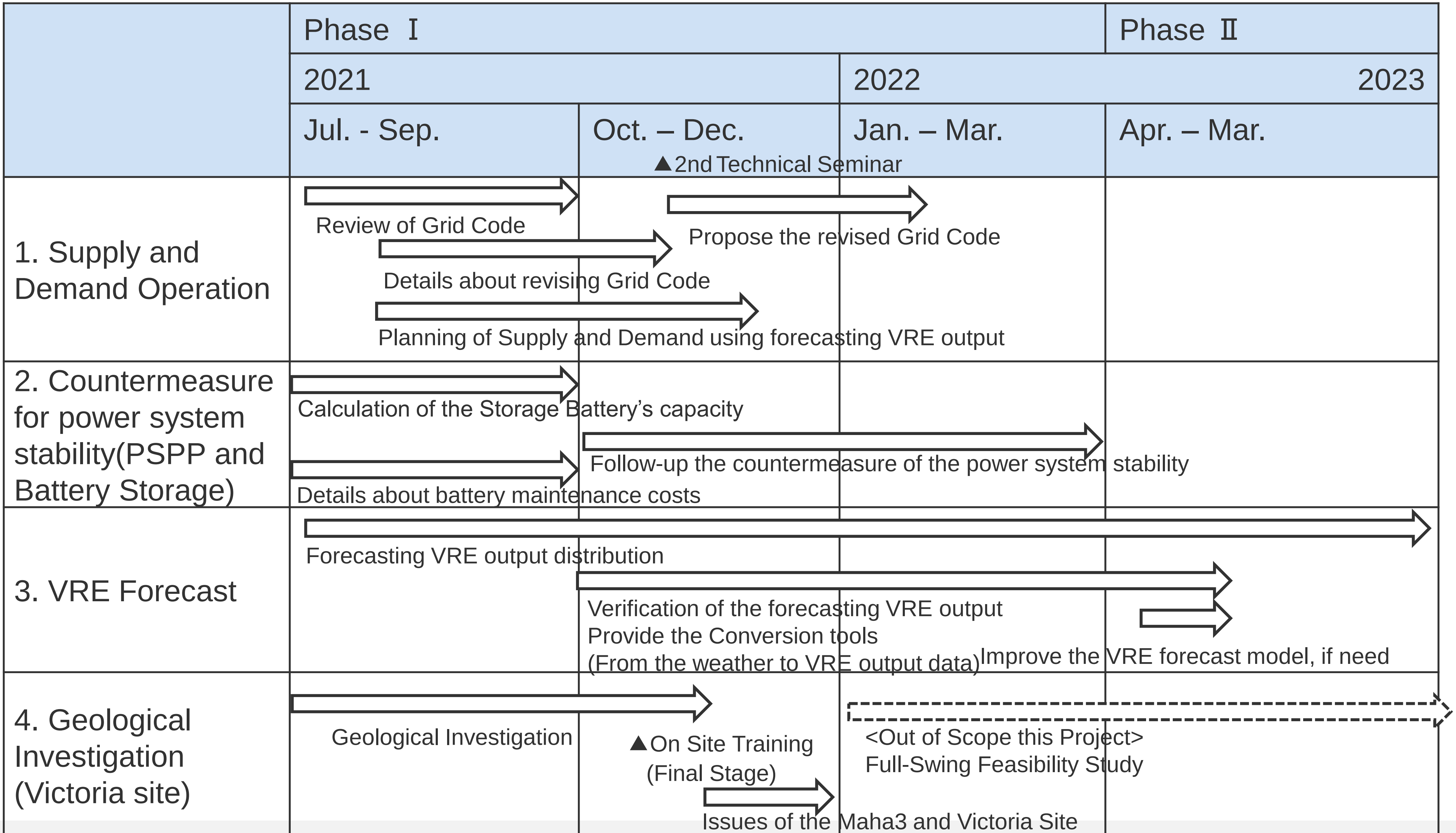
3. VRE forecast
✓Develop the VRE forecasting model and distribute the forecasted VRE output.
✓Verification of the accuracy of the forecasted VRE output.
✓Estimation of the whole VRE's output using developed each of VRE forecasting model.
✓Provide the conversion tool that can convert the weather data to VRE output.

4. Geological investigation(Victoria site)
✓Geological investigation at the Victoria site.
✓Verification of the geological investigation result.
✓On-site training of inception stage and final stage.
✓Comparison of the issues of the Maha 3 and Victoria site.

5. Training on advanced power system analysis
✓Confirmation of the current situation of the advanced power system analysis.
✓Experience of using the CEPCO's analog simulator during training session in Japan.
✓Practical training of advanced power system analysis by providing the issues.

WG2: Future Schedule



05 WG3 (Improvement of Distribution System Reliability)

05-1 Progress of the Project

WG3-1 & 3-2: Activity Record from APR 2020 to JUN 2021

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	2020			2021	
Month Field(remote) work	Apr. - Jun. #1	Jul. - Sep. #2 #3	Oct. – Dec. #4 #5	Jan. – Mar. #6	Apr. – Jun.
WG3-1 Power outage measures	Preparation for WG activities	Sharing power failure information and survey on failure outage status Analysis and planning of failure outage measures	Selection and planning of pilot sites and facility measures Procurement preparation	Reconsideration of some site conditions and additional survey Estimation of effect on site by facility measures	
WG3-2 Load fluctuation suppression	Preparation for WG activities	Sharing distribution technologies for VRE and survey on load fluctuation status Selection of candidate feeders for a pilot project	Measurement at a pilot candidate site and analysis Discussion on alternatives and procurement preparation	Selection of measurement sites and study of load fluctuation by VRE	

WG3: Outline of PDM and Activities (WG3-1)

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PDM(Project Design Matrix) of WG 3

Indicators for Project Purpose	(1) SAIFI at the pilot sites where the facilities against power outage are installed: xx in 2023 (2) SAIDI at the pilot sites where the facilities against power outage are installed: xx in 2023 (3) Standard procurement plan is implemented

Outline of WG 3 -1 (Power Outage Measures)

- Analysis for Outage Situations and Causes of CEB's DD1-4 and LECO
- Suggestion for Supply Reliability Improvement
- Introduction of Reliability Improvement Facilities and Estimation of their Effects in Pilot Projects

(Tentative)	FY2020	FY2021	FY2022
Power outage measures	Analysis, Study	After site survey: Long term procurement; Delay: Short procurement, Installation, Field test; Installation	Field test, Evaluation; Evaluation

How to proceed (Results in red)

1. Survey and cause analysis on failure outage status per MV line
2. Planning of measures and Selection of pilot sites and measure facilities
3. Procurement and installation of the facilities
4. Evaluation of quantitative effects by estimating the power outage amount [kWh] before and after the countermeasures
5. Estimation of cost effectiveness of measure facilities in the pilot projects and evaluation of contribution to CEB finance aiming to the mass introduction based on target supply reliability in the future

Over Current Indicator

Ground Fault Detector

WG3 Pilot Project Site

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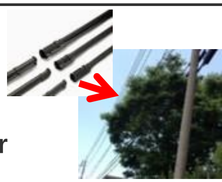
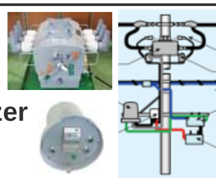
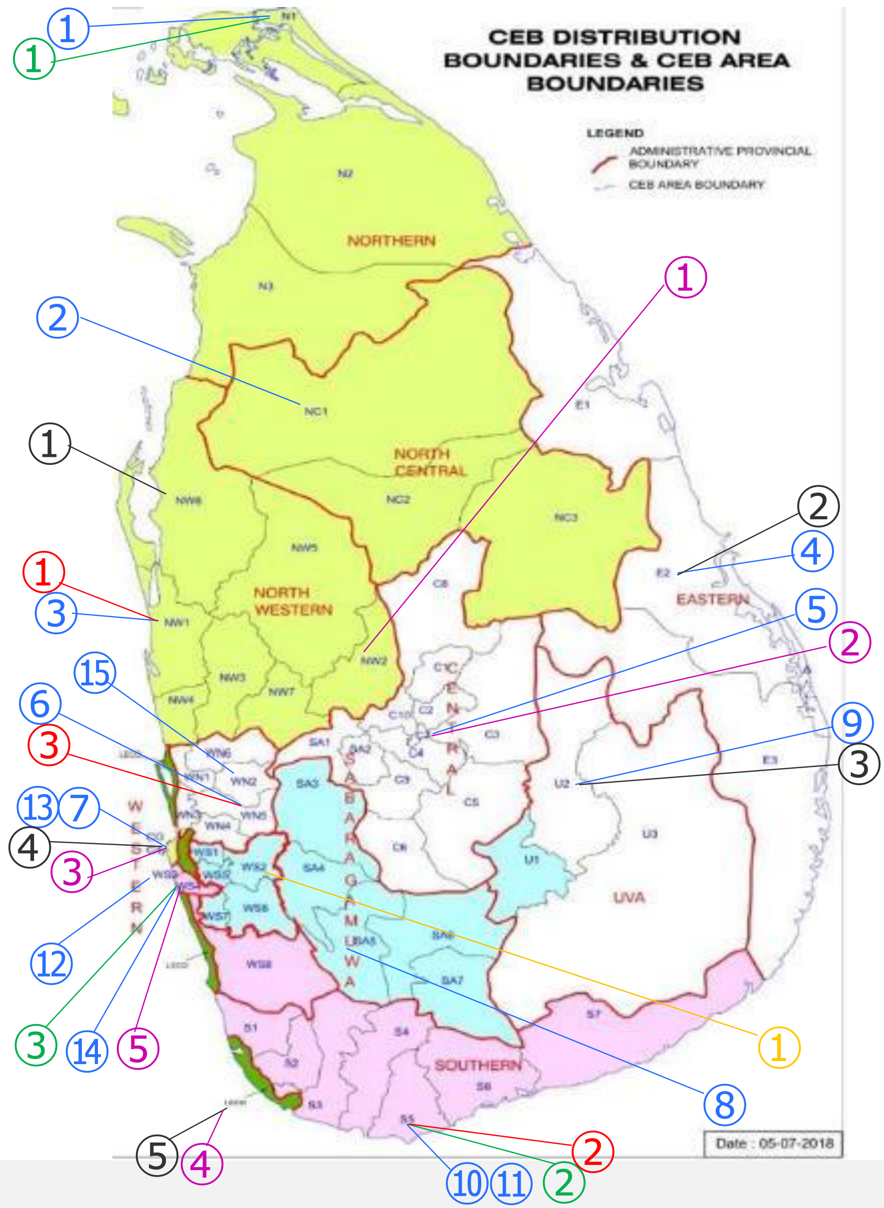
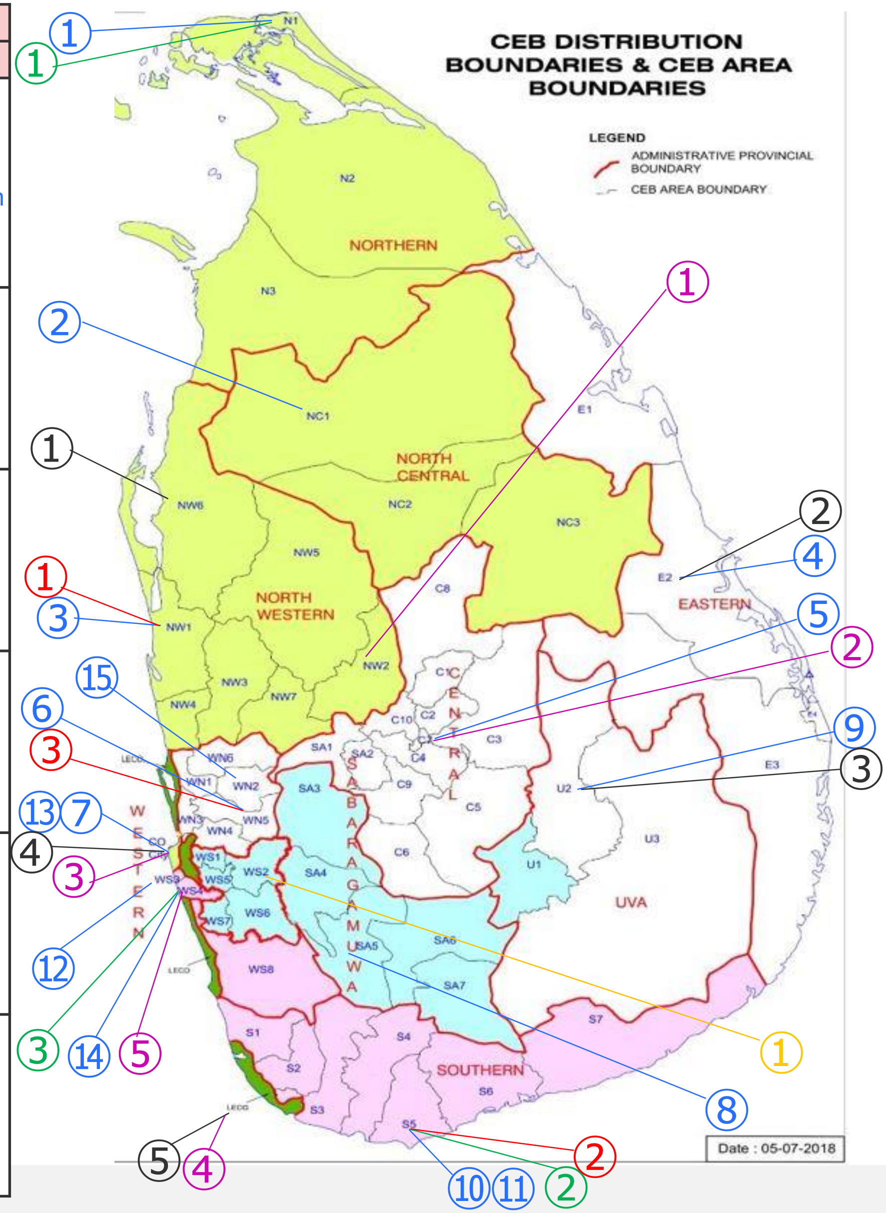
Equipment		Installation Policy (Applicable Voltage)	Indicator	Pilot Project Site
Over Current Indicator [OCI]		Top 3 Feeders with many "short-circuit failure power outage time" (11kV and 33kV)	SAIDI	① ～ ⑮
Abrasion Resistant Cover for Conductor		Top 1 Feeder with the most "Number of failures due to contact with trees" (11 kV)	SAIFI	① ～ ③
Ground Fault Detector [GFD]		Introduced to Provincial offices(or substation), which want to reduce the most "ground fault outage time" (11kV and 33kV)	SAIDI	① ～ ⑤
Enclosed Cutout Fuse		Feeder with many "Number of failures due to contact with other objects and deterioration of fuse" (11 kV)	SAIFI	① ～ ③
Time Sequential Sectionalizer [TSS]		The feeder, which wants to reduce the most "failure power outage time" (11kV and 33kV)	SAIDI	①
Fault Location System [FLS]		The feeder, which wants to reduce the most "failure power outage time" (11kV and 33kV)	SAIDI	① ～ ⑤

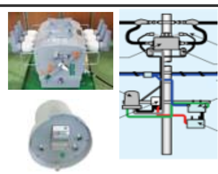


List of Pilot Project Site

Equipment	Pilot Project Site				
	DD1	DD2	DD3	DD4	LECO
Over Current Indicator [OCI]	①Habarana F7 ②Madampe F5 ③Chunna-kam F10	④Valaich-chenai F6 ⑤Kiribath−kumbura F9 ⑥Sapugas-kanda F9	⑦Pannipitiya F2 ⑧Ratnapura F2 ⑨Badulla F8	⑩Deniyaya F4 ⑪.Matara F2 ⑫Panadura F7	⑬Boralesgamuwa F-Pepiliyana ⑭Kalutara F-Nagas Junction ⑮Beligaha F-Boossa
Abrasion Resistant Cover for Conductor	①PoojaNagaraya	—	—	②Matara F1	③ Kaluwamodara F-Moragalla
Ground Fault Detector [GFD]	①Norochcholai F2	②Valaich−chenai F6	③Mahiyanganaya F3	④Rathmalana F2	⑤Hikkaduwa F-Wewalamilla
Enclosed Cutout Fuse	①Kompyan III of Kompayan	—	—	②Matara F4	⑤Peliyagoda F-Sedawatta
Time Sequential Sectionalizer [TSS]	—	—	①Seethawaka F1	—	—
Fault Location System [FLS]	①Pannala F2	②Kiribath-kumbura F9	③Kosgama F1	④New Gall F1	⑤Molligoda F-Pirivena road



WG3 Procurement Status of Countermeasure Equipment

Equipment		Field Survey	Quantity	Production period (including delivery) ※Further period needed due to COVID-19	status
Over Current Indicator [OCI]		—	6 pieces per organization (total 30 pieces)	6 months In FEB, 2022	Advertised on Newspaper on July 4th, 2021
Abrasion Resistant Cover for Conductor		—	Approx. 165 pieces per organization (total 500 pieces)	4 months In DEC, 2021	
Ground Fault Detector [GFD]		—	1 set per organization (total 5 sets)	12 months In AUG, 2022	
Enclosed Cutout Fuse		—	18 pieces per organization (total 54 pieces)	6 months In DEC, 2021	
Time Sequential Sectionalizer [TSS]		Required	1 set (only DD3)	13 months	Due to COVID-19, field survey hasn't been conducted yet.
Fault Location System [FLS]		Required	1 set per organization (total 5 sets)	13 months	

WG3: Progress of Activities (WG3-2)

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Outline of WG 3 -2 (Load Fluctuation Suppression)

- Measurement and Analysis of Power/Voltage Fluctuation in Distribution Network due to Large Increase of Renewable Energy ⇨ 33 kV Valachchenai F5 with 12 MW SPP (reverse power flow)
- Estimation of Load Fluctuation Control by Introducing Storage Batteries
  ⇨ Estimation of only necessary capacity of a storage battery system

How to proceed (Results in red)

1. Data collection and study on the distribution system with mass introduction of PV and wind turbine (WT) generation
2. Consideration of site, battery system specifications, Procurement and Installation
3. Acquiring of weather data near the site
   Forecast of PV/WT generation amount
   [Cooperation with WG2]
4. Estimation of controlling function for output power/voltage by charging/discharging battery

Surveyed problems based on the VRE data collection.

DD LECO	Substation	Feeder No.	Voltage kV	Active power flow Forward MW	Active power flow Backward MW	Reactive power flow Forward MW	Reactive power flow Backward MW	Power factor	Current umbalance R %	Current umbalance Y %	Current umbalance B %	Voltage Max. kV	Voltage Min. kV	Voltage umbalance R %	Voltage umbalance Y %	Voltage umbalance B %	Harmonic injection Max. %	Harmonic injection at degree n %	Freqency Hz	Loss %	Protection coordination	Short circuit current (A)
DD1	Valachchena New	F05	33	No obvious problem	Problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	Norochcholei Wind	F2	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	Walikanda	Walikanda	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
DD2	Sapugaskanda	F0	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	Veyangoda	F8	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
DD3	Panadura	F1	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	Pannipitiya	F4	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	Horana	F4	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	Horana	F6	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
DD4	Hambantota	F2	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	Hambantota	F4	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	Panadura	F07	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	Panadura	F08	33	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem

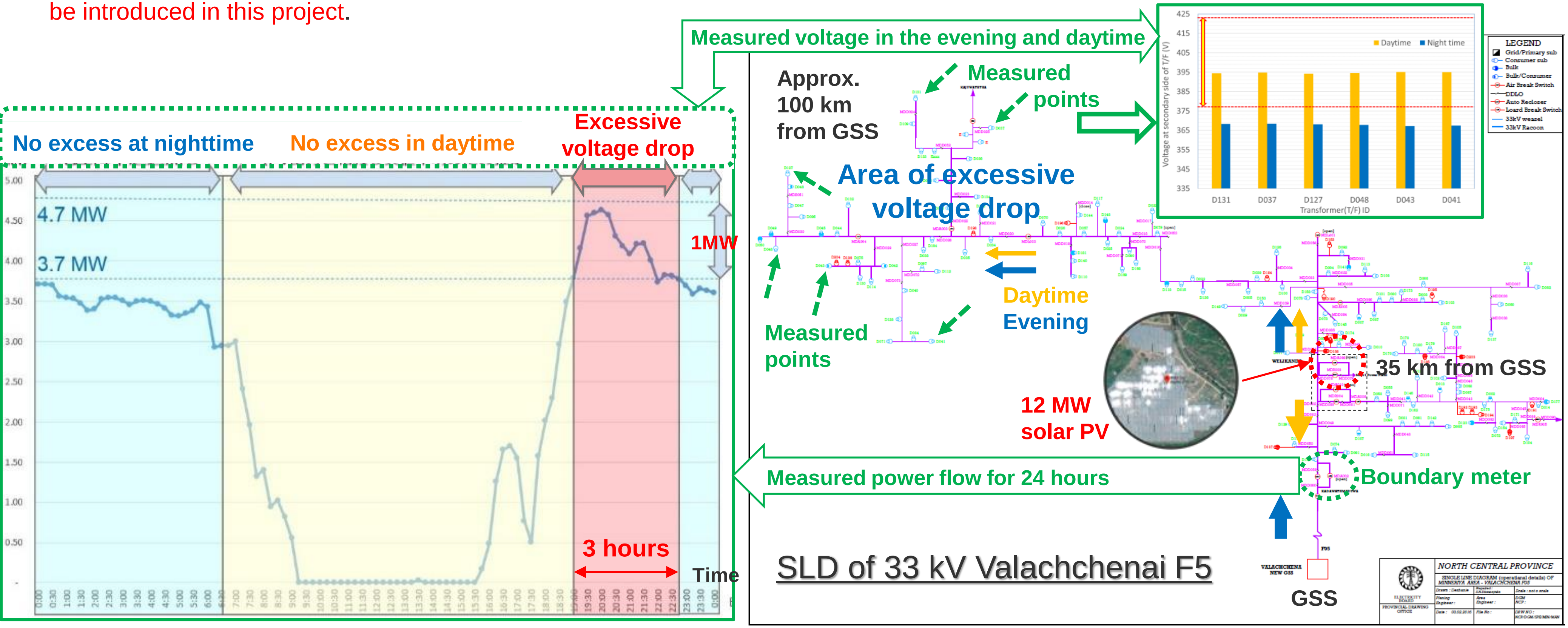
No obvious problems by VRE in MV lines except for one so far

WG3: Progress of Activities (WG3-2, Continued)

-Consideration of site and storage battery system specifications -

- Problem: Not reverse power flow but excessive voltage drop at peak in the evening
- Estimated to require 1MW-3h class battery energy storage system (BESS) for countermeasures
- Because the estimation of the BESS (1MW - 3h), “approx. 400 million yen + construction cost exceeds the budget,” BESS in LV Line cannot be introduced in this project.

Agreed at the 5th Field Work Activities (Minutes of Meeting)



It was necessary to understand and analyze the load fluctuation status of distribution lines due to the mass introduction of VRE, but the on-site data required for evaluation was not accumulated. In addition, it was not easy to measure in the field, and it is necessary to improve the measurement technical capability.
Therefore, the introduction of measuring instruments and the improvement of measuring technology will be promoted.

05-2 Progress of the Technical Transfer

WG3-1: Technical Transfer (Power Outage Measures)

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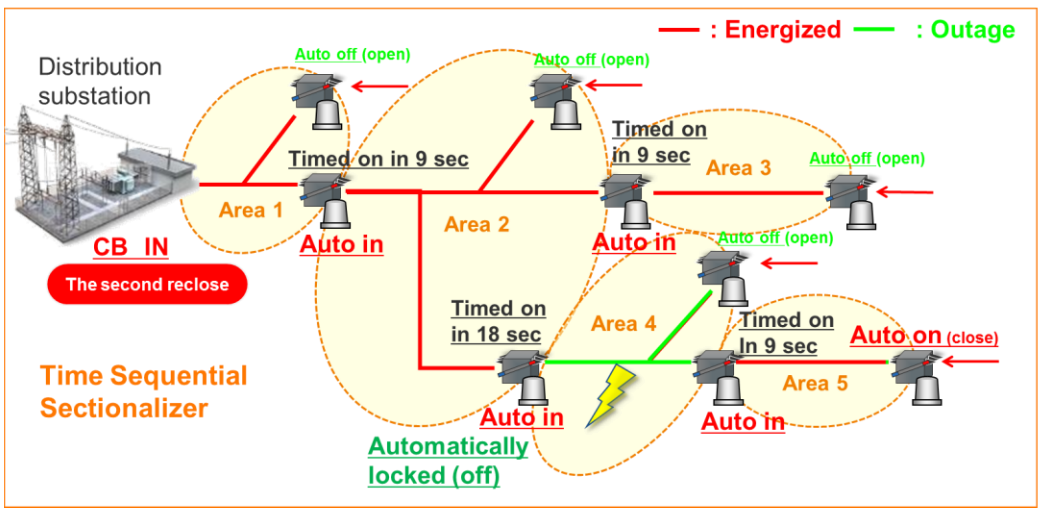
C/Ps were assigned areas in charge, and support are provided so that C/Ps can independently calculate the effect of introducing power outage countermeasure equipment based on failure data.

No.	Subjects	Date
1	Classification of measures to improve supply reliability	1st July, 2020
2	Countermeasures by fault classification	1st July, 2020
3	Automatic fault section detection system with time sequential sectionalizer	1st July, 2020
4	Distribution facilities for power outage countermeasures	1st July, 2020
5	Calculation of effect of reducing power outage frequency	1st July, 2020
6	Analysis of power outages by cause of failure and damaged equipment	3rd July, 2020
7	Failure cause and failure mechanism	3rd July, 2020
8	Countermeasure based on failure mechanism	6th July, 2020
9	Equipment procurement plan	8th September, 2020
10	Over current indicator, Abrasion resistance cover for conductor, Ground fault detector, Enclosed cutout fuse, Fault locating system and Time sequential sectionalizer as countermeasure facilities	8th, 10th and 15th September, 2020
11	How to determine target MV feeders and locate target installation points of countermeasure facilities	26th, 27th October, 2020

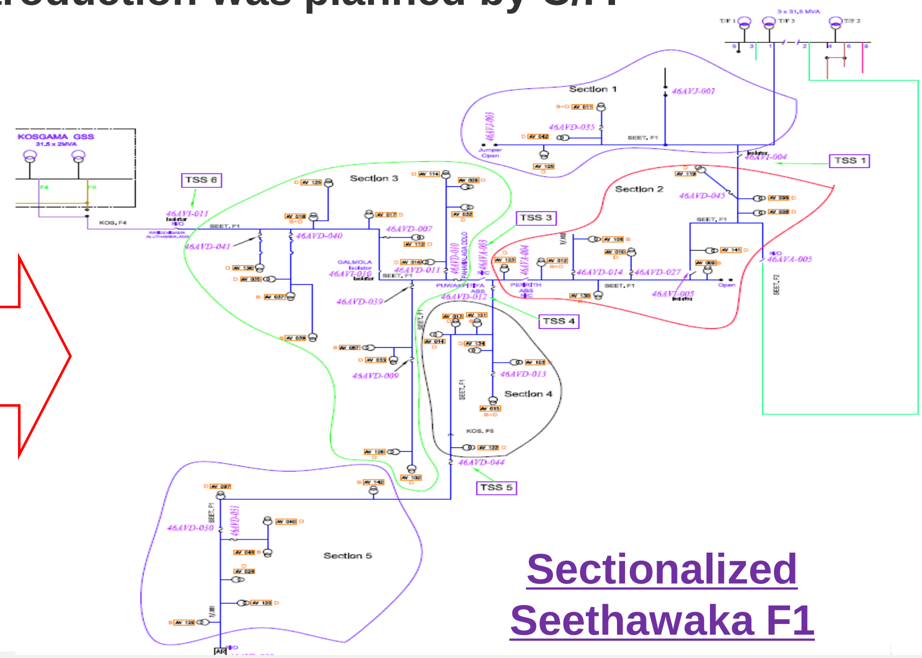
WG3-1: Technical Transfer (continued)

No.	Subjects	Date
12	Clarification of the specifications of power outage countermeasure facilities	26th, 27th October, 2020 4th November, 2020
13	Estimation of equipment introduction effect,	15th December, 2021 10th February, 2021
14	Calculation method of SAIDI and SAIFI,	10th February, 2021
15	Details of failure record required for effect calculation,	12th February, 2021

Based on the transferred technical knowledge, TSS introduction was planned by C/P.



One of the contents shown in the technical seminar

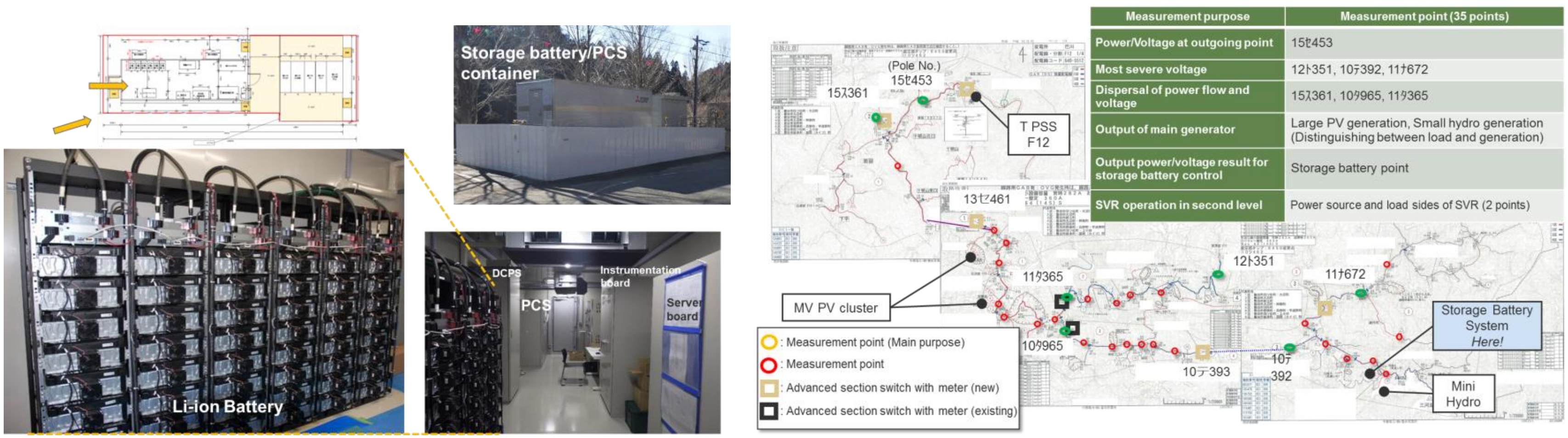


WG3-2: Technical Transfer (Load Fluctuation Suppression)

No.	Subjects	Date
1	Classification of grid interconnection in Japan,	1st July, 2020
2	Guideline regarding power quality securement for grid interconnection requirement in Japan,	1st July, 2020
3	Grid interconnection code in Japan,	1st July, 2020
4	Technical matters on VRE (DER) interconnection,	3rd July, 2020
5	Rooftop PV connection to 400V line,	3rd July, 2020
6	VRE connection to MV line,	3rd July, 2020
7	Priority of VRE matters for a pilot project,	3rd July, 2020
8	Countermeasures against VRE matters,	6th July, 2020
9	How to procure and construct for a pilot project,	6th July, 2020
10	How to acquire output power/voltage data (How to measure and communicate),	6th July, 2020
11	VRE information and matters in candidate feeders,	8th September, 2020
12	Load fluctuation suppression in VRE matters,	8th September, 2020
13	Confirmation of interconnection procedure of storage battery system in Sri Lanka,	8th September, 2020

WG3-2: Technical Transfer (Continued)

No.	Subjects	Date
14	Storage battery system installation in Toyota city virtual power plant project,	15th September, 2020
15	Utilization of storage battery system in distribution grid,	27th October, 2020
16	Analyzed result of the measured and collected data in Valachchenai F5,	8th December, 2020
17	Necessary capacity to improve voltage drop in Valachchenai F5,	8th December, 2020
18	Measurement and communication to acquire output power/voltage data,	10th and 15th December, 2020
19	Consideration of importance of technical measurement capability due to mass VRE,	10th, February, 2021
20	Typical matter -Voltage excess matter in LV line-,	12th February, 2021
21	Candidate countermeasures against power/voltage fluctuation in MV or LV lines,	15th February, 2021



Storage battery system installation in Toyota city virtual power plant project

05-3 Way to Move Forward

WG3-1：Project Term Change for TSS and FLS.

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Current Status

As for TSS and FLS, the specifications could not be determined due to the delay in the field survey due to COVID-19, so there is no time to carry out the pilot project in this project.

Revised Plan

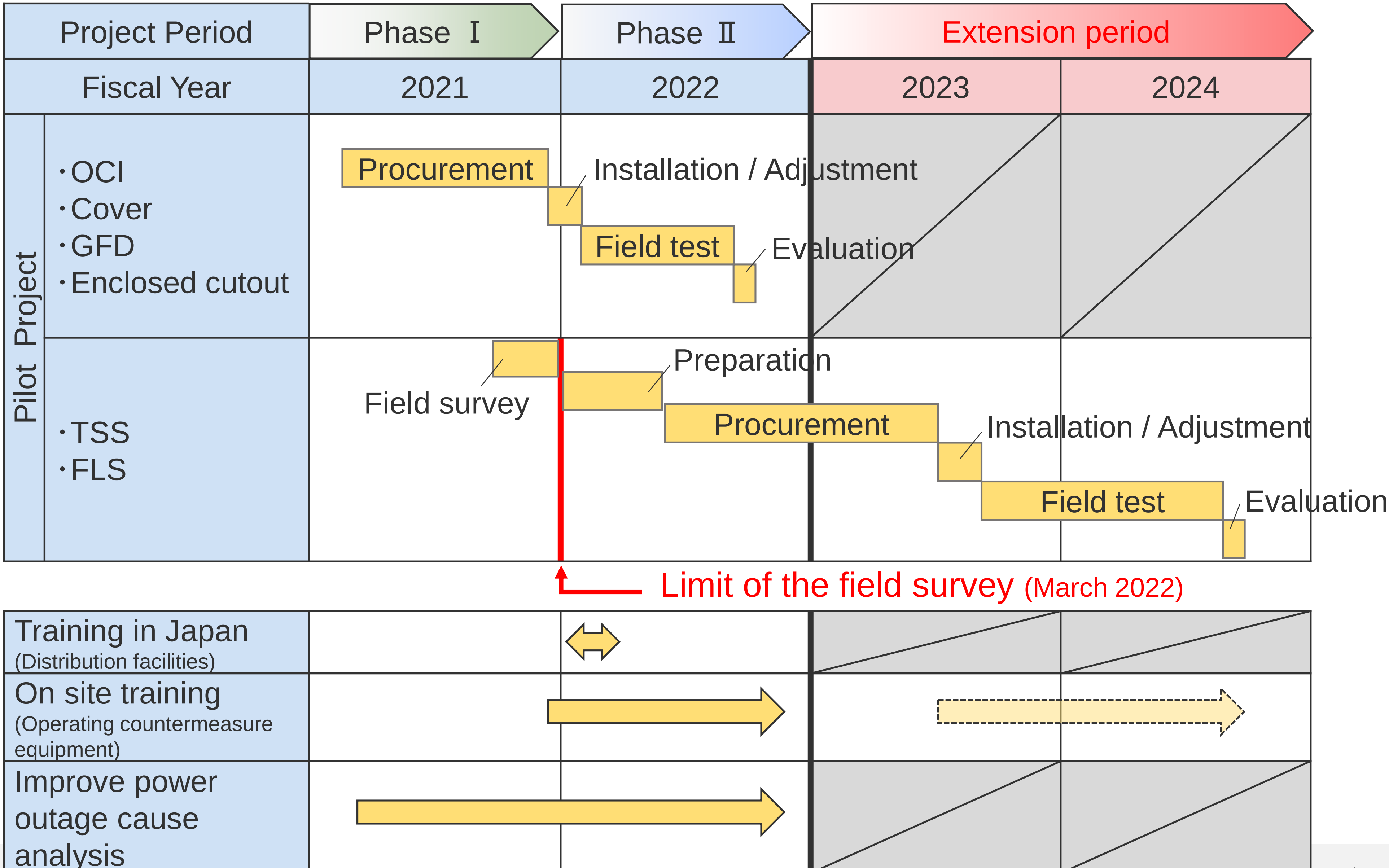
Extension of project period of WG3-1

✓Condition

1. Extension period：Up to 2 years. (Maximum March, 2025)
2. The limit of the field survey：March, 2022.

- Procurement (include Installation)：15 months
- Field Test：12months
- Evaluation：1 month

WG3-1：Future Schedule



WG3-2: Importance of Technical Capability in Measurement

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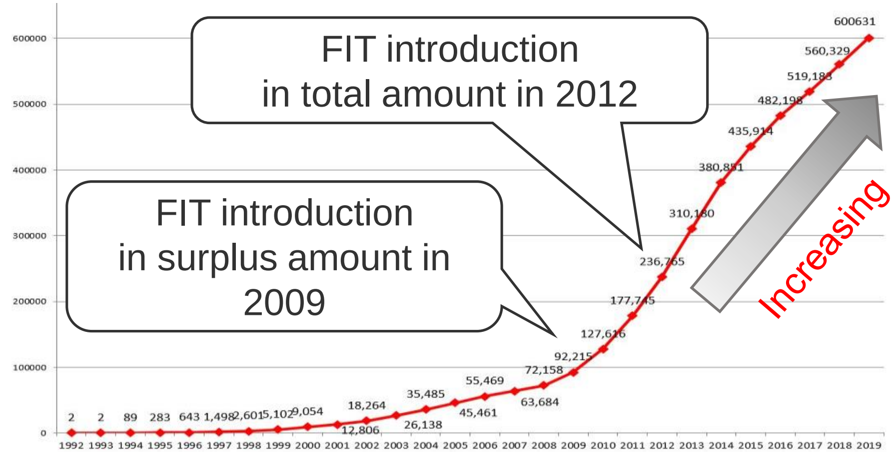
According to the increase of SPP interconnection, the inquiries about limitation of SPP output and the measuring works against the inquiries would be increased.
However, the inquiry number could be decreased by enhancing capabilities for measurement and review.

Measure and review to optimize outgoing voltage at grid substation, MV/LV transformer, AVR set value in SPP, etc.

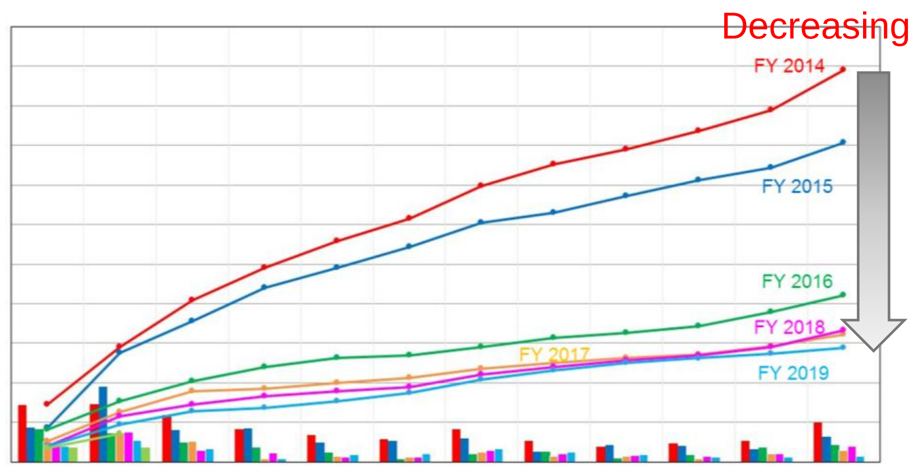
Furthermore,

Due to widespread of saving energy, creative energy such as RE, DER and BSS, customers will take more and more interest in electricity.

Due to application of smart meter, advanced distribution facility with sensor, detailed voltage which has not been seen sensitively will be exposed.



Increasing trend of SPP facility interconnected in CEPCO



Decreasing trend of inquiry number about solar PV generation

Measurement works get more and more "diversified" and "sophisticated."
Therefore, it is necessary to enhance technical measurement capability.

WG 3-2: Changed Activity Plan

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	Project Contents (Draft to discussion)
Original	Introduce a storage battery system as a measure to suppress load fluctuations associated with the mass introduction of VRE, and confirm the effect of suppressing load fluctuations.
Alternative	Improve measurement and analysis technical capabilities of distribution system data (output power/voltage), in order to understand the impact of mass introduction of VRE quantitatively in distribution systems. • Selection of target feeders and measurement/record • Confirmation of load fluctuation matters by analyzing measured data • Proposal and estimation of countermeasures

Under discussion with JICA on implementation policy of BESS project in LV line.

WG 3-2: Activity Plan from Now on

Project Period	Phase Ⅰ			Phase Ⅱ
Fiscal Year	FY 2021			FY 2022
Month	Jul. - Sep.	Oct. – Dec.	Jan. – Mar.	Apr. – Mar.
WG3-2 Load fluctuation suppression	Procurement of electric power measuring instrument*			
	Additional study in Valachchenai F5		Measurement and analysis of power/voltage fluctuation by SPP in Valachchenai F5 and the selected sites	
		Consideration and comparison of power/voltage fluctuation suppression methods		
		Under discussion with JICA on implementation policy of BESS project in LV line.		

*Electric Power Measuring Instrument	Quantity	Expected delivery	Status
Clamp on power logger 	5 sets	End of DEC, 2021	Advertised on Newspaper on July 4th, 2021
Power quality analyzer 	1 set		

06 System and Policy Seminar

1st System and Policy Seminar (Aug. 2021)

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Purpose of the Seminar

- In order to achieve Sri Lanka's renewable energy introduction target and continuity and efficiency of electricity business, the issues of the current system are identified and the potential necessary policy and system in the future are shared.

Features of this seminar

1. Presentation in collaboration with CEB members of the main C/P and JICA Expert Team
2. Online seminar using Zoom

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Contents of the Seminar

1. Keynote Speech by TBA, MoP
2. Presentation of current financial status analysis by CEB
   - ✓ Causes for concern on present tariff and FIT tariff
3. Introduction of current status analysis and countermeasure systems by JICA expert team
   - ✓ Tariff methodology
   - ✓ CEB financial analysis
   - ✓ Compatibility of sound financial status of CEB and promotion of VRE installation
   - ✓ Fuel Cost Adjustment System
   - ✓ Independence of FIT scheme from Electricity Tariff
   - ✓ Renewable Energy introduction promotion system in Asian countries
4. Streamlining of VRE development approval process

07 Training in Japan

Schedule of the Training in Japan (Tentative)

Training is basically conducted through OJT (WG Activities) and Seminars (Technical Seminar, System and Policy Seminar), on the contrary, contents that are more effective if they are conducted in Japan are organized in Japan.

	Schedule	**Participants**
Electric Power Technology, System and Policy (WG1)	January 2022	12 executives (MOPE (2), PUCSL (1), SEA (1), CEB (8))
Distribution facilities (WG3)	April 2022	To be discussed
Power system planning and operation, Management of the power supply and demand (WG2)	July 2022	To be discussed

Electric Power Technology, System and Policy of WG1(Tentative: Jan. 2022)

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Purpose: To help improve the current system in Sri Lanka, deepen the understanding the systems, policies, and structure for promoting the mass introduction of Variable Renewable Energy economically and rationally for executive officers

Date			Activities		Accommodation
1	Mon.		Move	Arrival in Nagoya	
2	Tue.	AM		Briefing	Nagoya
		PM	Lecture	Outlines of Electric Industry in Japan and Chubu Electric Power Company	
3	Wed.	AM	Visit	Research and Development Center (Toyota VPP project)	Nagoya
		PM	Visit	Chubu Seiki Co., Inc. (Smart meter, HEMS)	
4	Thu.	AM	Lecture	Power Conditioning System, Power System Operation, Cross Regional Operation, Smart Grid, Negawat Transaction	Nagoya
		PM	Visit	Central Load Dispatching Center in CEPCO	
5	Fri.	AM	Lecture	Electricity tariff, Smart Meter, Demand Side Management, Energy Saving Technology	Nagoya
		PM	Visit	Human Resource Developing Center and Customer Service Center in CEPCO	

Electric Power Technology, System and Policy of WG1(Tentative)

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Date			Activities		Accommodation
6	Sat.			Day-off	Nagoya
7	Sun.	AM		Day-off	Shizuoka
		PM	Move	From Nagoya to Shizuoka by bullet train (Shinkansen-train)	
8	Mon.	AM	Visit	Higashi-Shimizu Frequency Converter Substation	Tokyo
		PM	Visit	275/77kV Suruga substation and underground transmission line	
			Move	From Shizuoka to Tokyo by bullet train (Shinkansen-train)	
9	Tue.	AM	Visit	Organization for Cross-regional Coordination of Transmission Operators (OCCTO)	Tokyo
		PM	Visit	JICA headquarters	
			Discussion	Wrap-up meeting	
10	Wed.		Move	Departure to Sri Lanka	—

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Participant list for 3rd Joint Coordination Committee
on
"The Project for Capacity Development on the Power Sector Master Plan Implementation Program in Democratic Socialist Republic of Sri Lanka"

Date: July 05, 2022

〇Counterparts (Sri Lanka)

	Name	Position Organization	Contact E-mail address
1	Mr. M P D U K Mapa Pathirana	Secretary, Ministry of Power and Energy	
2	Mr. Sugath Dharmakeerthi	Additional Secretary (Power Generation, Transmission and Distribution), Ministry of Power and Energy	
3	Ms. K. V. S. M. Kudaligama	Chief Engineer (Tariff), CEB	
4	Ms. M Ganes	Chief Engineer (Planning Development) DD4, CEB	
5	Ms. U. G. J. K. Gamlath	Chief Engineer (Planning & Development) DD1, CEB	
6	Mr. P. M. Piyasena	Chief Engineer (Planning & Development) Sabaragamuwa DD3, CEB	
7	Mr. P. H. L. J. Ranasinghe	CE (Construction) SP DD4, CEB	
8	Mr. N. H. C. Janaka	Chief Engineer (Construction) –SP2 DD4 CEB	
9	Mr. K. Ramjee	Chief Engineer (Transmission Planning), CEB	
10	Mr. T. L. B. Attanayaka	Electrical Engineer (Transmission Planning), CEB	
11	Mr. G.B. Alahendra	Electrical Engineer (Transmission Planning), CEB	
12	Ms. H. D. K. Herath	Electrical Engineer (Transmission Planning), CEB	
13	Mr. K. P. J. P. Premathilake	Electrical Engineer (Development) DD3, CEB	
14	Ms. W. G. Pawithra	Electrical Engineer (Transmission Planning), CEB	

	Name	Position Organization	Contact E-mail address
15	Mr. K. Siriwardana	Director, Tariff and Economic Affairs, Public Utility Commission of Sri Lanka	
16	Mr. Raveen Patthamperuma	Regulatory Engineer, LECO	
17	Mr. Sampath Dissanayake	Control Engineer, LECO	

〇JICA(Japan International Cooperation Agency)

	Name	Position Organization	Contact E-mail address
1	Akira SATO	Senior Director, Team 1, Energy and Mining Group, Infrastructure Management Department	
2	Kuri SHIBATA	Infrastructure Management Officer, Team 1, Energy and Mining Group, Infrastructure Management Department	
3	Kiyofumi TAKASHIMA	Senior Representative, Sri Lanka Office	
4	Tsuyoshi MIZUNO	Representative, Sri Lanka Office	
5	Cabral, SL	National Staff, Sri Lanka Office	

〇JICA Expert Team (Chubu Electric Power Co., Inc. and Nippon Koei Co., Ltd.)

	Name	Position Organization	Contact E-mail address
1	Mr. Akira HIRANO (Team Leader / Electric Power Strategy)	Senior Manager, Chubu Electric Power Co., Inc.	
2	Mr. Toshitaka YOSHIDA (Deputy Team Leader / Electric Power Strategy)	Manager, Chubu Electric Power Co., Inc.	
3	Mr. Osamu TANIHATA (System and Policy of Electric Power)	Senior Manager, Chubu Electric Power Co., Inc.	
4	Mr. Yusaku MAKITA (Finance)	Chubu Electric Power Co., Inc. (Group Leader/ Senior Economist, Koei Research & Consulting Inc.)	
5	Dr. Suresh Chand Verma (Supply and Demand Management)	Senior Manager, Chubu Electric Power Co., Inc.	
6	Mr. Yu TAKAMIZAWA (Power System (Planning/Operation))	Manager, Chubu Electric Power Co., Inc.	
7	Mr. Shinichirou YAMAGA (Power System (System Analysis))	Assistant Manager, Chubu Electric Power Co., Inc.	
8	Mr. Muneo MATSUKAWA (Meteorological Forecast / Demand Forecast)	Chubu Electric Power Co., Inc. (Executive Engineer, Japan Weather Association)	
9	Mr. Yasushi Momose	Nippon Koei Co., Ltd	
10	Mr. SHINGU Hirohisa (Geology)	Nippon Koei Co., Ltd.	
11	Dr. Koji SHIKIMACHI (Distribution Technology)	Manager, Chubu Electric Power Co., Inc.	
12	Mr. Yukihiro KAMIYA (Distribution (Planning/Design/Construction) / Coordinator)	Manager, Chubu Electric Power Co., Inc.	

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Democratic Socialist Republic of Sri Lanka

The Project for Capacity Development on the Power Sector Master Plan Implementation Program

3rd Joint Coordination Committee (JCC)

July 05, 2022

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Contents

01 Objectives

Objectives of the Project

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Project Purpose

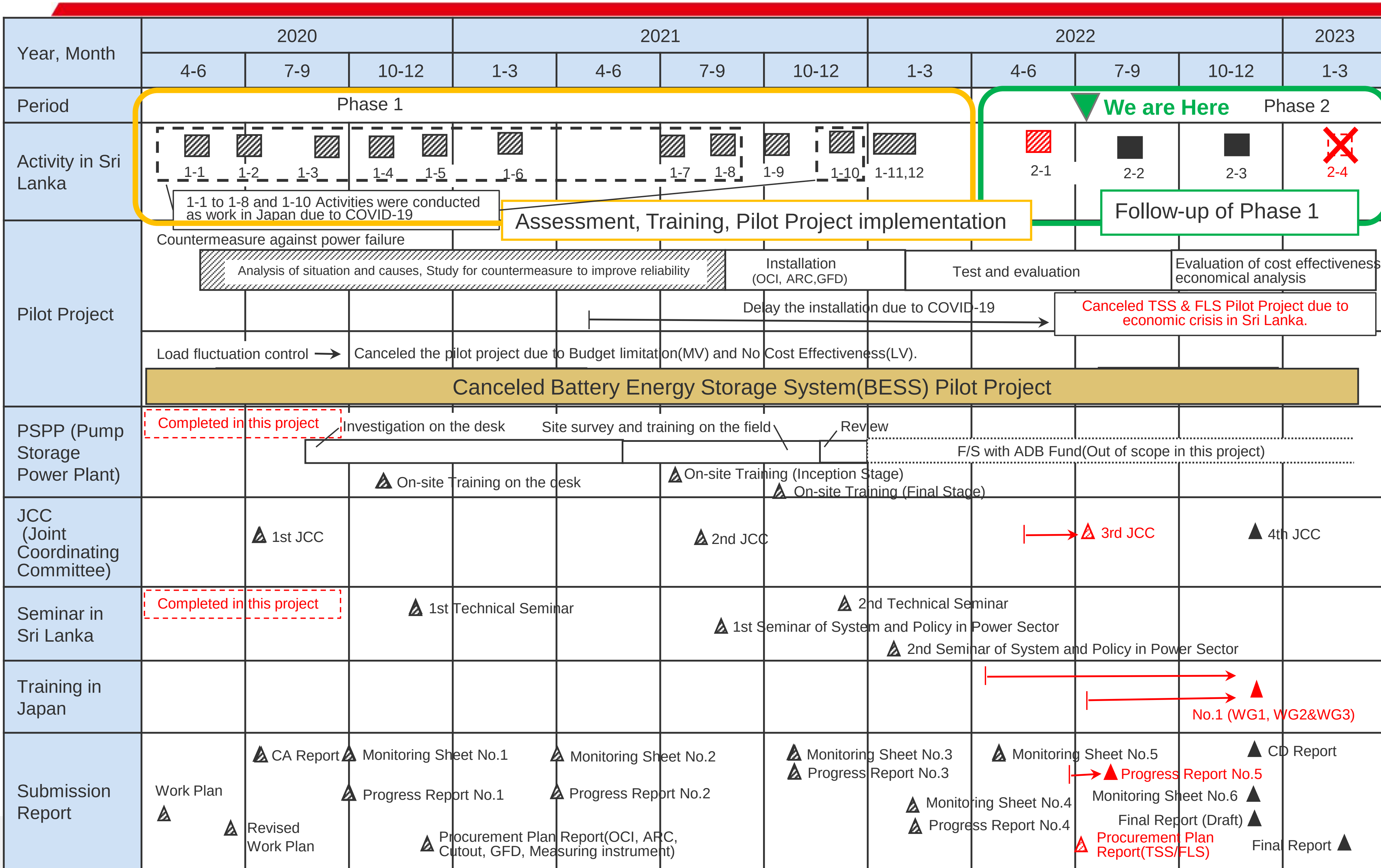
Institutional Capacity for improving transmission and distribution operational reliability is enhanced to get prepared for increased share of RE planned in the LTGEP

Outputs of the Project

1. Capacity of corporate strategy and planning for VRE is enhanced (WG1)
2. Capacity of system development and operation for transmission network in response to increased share of VRE is enhanced (WG2)
3. Capacity of distribution network operation is improved (WG3)

02 Schedule of the Project

Schedule of the Project



03 WG1 (Corporate Strategy, System and Policy)

03-1 Progress of the Project

Past Activities

- The revision of FIT Tariff was examined focusing on Roof-Top PV for CEB financial improvement. A draft proposal was planned to submit it to CEB to get the approval from management board in April 2022, however the serious economic condition makes it delayed.
- The existing guidelines for renewable energy development permission procedures have never been revised since enacted in 2011, and we assist to improve the procedures. At present, it has been revised in January 2022 and is being tried.
- C/P and JICA Expert Team analyzed the CEB financial outlook with the case of existing system maintained and the case of FIT Tariff revised. It turned out that the FIT Tariff revision alone has a limited effect.

	2020	2021				2022		
	1-12	1-3	4-6	7-9	10-12	1-3	4-6	7-9
Seminar				1st S&P Seminar	△	△	2nd S&P Seminar	
① System and Policy	Info. input Preparation for discussion		Target Selection. FIT Tariff rev study		Result discussion with PUCSL and SEA Basic study of Power Market	Draft doc. submission Balancing Market study by collaborate work	Approved by CEB management Submitted to Expert committee	
② Streamlining of VRE Development Approval			Grasp the current process of VRE development approval		Consider the measure against time-consuming process for the new guideline	● New guideline was issued	Comments and possible issues for the new guideline and online system	Evaluate new guideline and online system and consider further measures
③ Financial Analysis	Analysis on CEB financial status, tariff system, etc.		Financial projection in current system and policy setting under draft LTGEP 2020-2039		Financial projection with revised rooftop PV FIT under draft LTGEP 2022-2041		Discussion on outline of Recommendation Report and report drafting	

Past Activities (Detail) ① System and Policy

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Input Stage

JICA Expert

- Promotion of Understanding
- Active involvement

✓ FIT Tariff Scheme
✓ Electricity Tariff Scheme
✓ Pros & Cons of VRE

Info. Input of developed countries

✓ VRE introduction promotion
✓ Effective power system utilization (improvement of operating rate)
✓ Power System stabilization
✓ Power market development

CEB

Selection Stage

- Selection of items to study
- Review of existing system / establishment of new system

✓ FIT Tariff Review
✓ Competitive Bidding applied Range expansion

Examination of auxiliary measures

✓ FCA (Fuel Cost Adjustment)
✓ Independence of FIT Scheme from Electricity Tariff

Study Stage

FIT Tariff Revision for Roof top PV

✓ Study on appropriate profit of owners
✓ Increasing trend analysis of Roof top PV
✓ Installation cost reduction analysis of Roof Top PV
✓ Feasibility analysis of competitive bidding introduction for Roof Top PV

✓ FIT Tariff setting by capacity
✓ Proposal of annual automatic tariff review system

When the economic condition recovers

Authorization Stage

✓ Submission to CEB Management Board of Draft Proposal of FIT Tariff Revision
✓ Approval of CEB Management
✓ Submission to Expert Committee by CEB
✓ Evaluation by PUCSL
✓ Approval of Cabinet
✓ Enforcement of new FIT Tariff

We are here

① System and Policy　Major Achievements in the recent 1 year

The following details have been clarified regarding the revision of Roof Top PV FIT Tariff:

✓ While the electricity charge is the Universal Charge and is constant, FIT Tariff is larger than that and it causes negative profit always. Therefore it is needed to review for the sound electricity business.

✓ PV construction costs around the world and in neighboring India are declining rapidly. And the problem is that it has never been reviewed since the introduction of the Roof Top PV FIT Tariff in 2016.

✓ Wide range of players from households to Mega Solar that utilizes their factory roofs have uniform Tariff, which is unfair.

✓ The FIT Tariff revision is a global trend, and the regulator PUCSL does not seem to have strong objections about the revision.

✓ FIT Tariff revisions other than Roof Top PV have already started by the Expert Committee, and Roof top PV can be started also by adding as one item.

Draft Roof Top FIT Tariff Revision was proposed to CEB already in March, 2022

Understanding of CEB on electric power market has been promoted as follows:

✓ The fact that there are many types of electric power markets was recognized by CEB.

✓ With no trading market at all, we examined what market would be most needed in the future.

✓ In preparation for the future when VRE will increase rapidly, we could deepen knowledge by conducting a collaborative survey by CEB and JICA Expert Team regarding Balancing Market which would become the most important.

Past Activities (Detail)
② Streamlining of VRE Development Approval

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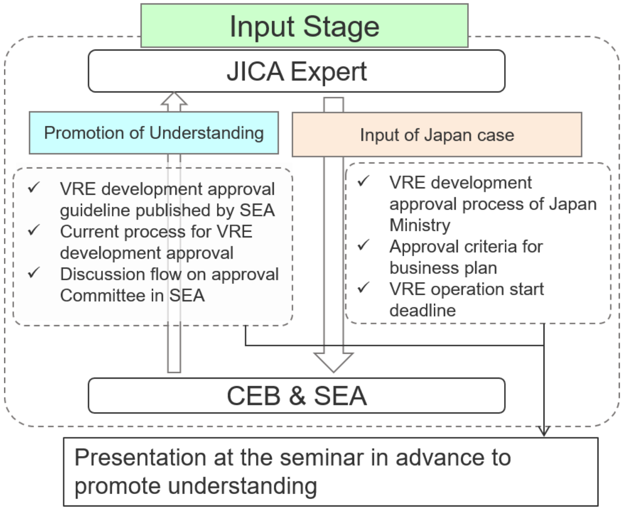

Selection Stage

Reviewing existing guideline

- ✓ Gap between guideline and actual process
- ✓ Uncertain period from application to approval

Study Stage

- ✓ Reviewing existing guideline
- ✓ Addition of description to guideline about period from application to approval
- ✓ Reviewing VRE development approval flow
- ✓ To subdivide the flow and check if there are any items that can be done in parallel to save time

Draft Conclusion

Authorization Stage

- ✓ Explanation and consultation with Management level and regulators
- ✓ Presentation at the seminar (widely disclosed)

Published

We are here

Evaluation Stage

- ✓ Evaluate the new attempts by duration, burden and so on comparing the previous ways
- ✓ Find out a further revise for the new process.
- ✓ Approach certain departments such as Wildlife and Forest for reducing the approval process

① Streamlining of VRE Development Approval

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Grasping the time-consuming process on the approval process

- ✓ Developer burden process: Line up every line agencies to submit application
- ✓ Comings and goings process: Applications go and come among certain agencies to be approved
- ✓ Land property: Taking much time for approvals makes the contract expiry on the land
- ✓ Variable demarcated area: Forest / wild life department area is vulnerable to nature and unpredictable. This sometimes causes the projects stopped
- ✓ No time limitation for line agency approval: This makes the approvals stagnated

Suggestion

- ☐ Share the approval process and required period in the case of Japan
- ☐ Measure against the time-consuming process
  - ✓ <u>Developer burden process: Eliminate the process or supported by SEA</u>
  - ✓ <u>Comings and goings process: Eliminate the process of supported by SEA</u>
  - ✓ <u>Land property: Put an emphasis on land identification. Feasibility study is much important before the contract on land property</u>
  - ✓ Variable demarcated area: Find out ways not to be affected by demarcated area (still discussing)
  - ✓ <u>No time limitation for line agency approval: Define each duration of the process.</u> Make a guideline whole process can be seen (still discussing)

Achievement

- ◆ Committee was established for accelerating the approval process
- ◆ Revise the approval process and new guidelines is published

Past Activities (Detail)
③ Financial Analysis

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Review of Recent Financial Status of CEB

✓ CEB consistently records operational deficit mainly due to the electricity tariff kept low and not cost-reflective since 2014 resulting in the unsustainable debt position.

Financial Projection of CEB

Projection under existing policies (current tariff level and FIT system)

- The results show that the current financial challenges of CEB widens and may cause CEB fall into the negative net worth within a few years.

Projection with the proposed revision of rooftop solar PV FIT

- The cost reduction effect from the revision of rooftop PV FIT accounts for around 0.2-0.3 LKR/kWh.
- As the rooftop PV FIT tariff revision may not show significant effects to the overall financial status, the financial effects of electricity tariff revision and the government capital contribution were also estimated.

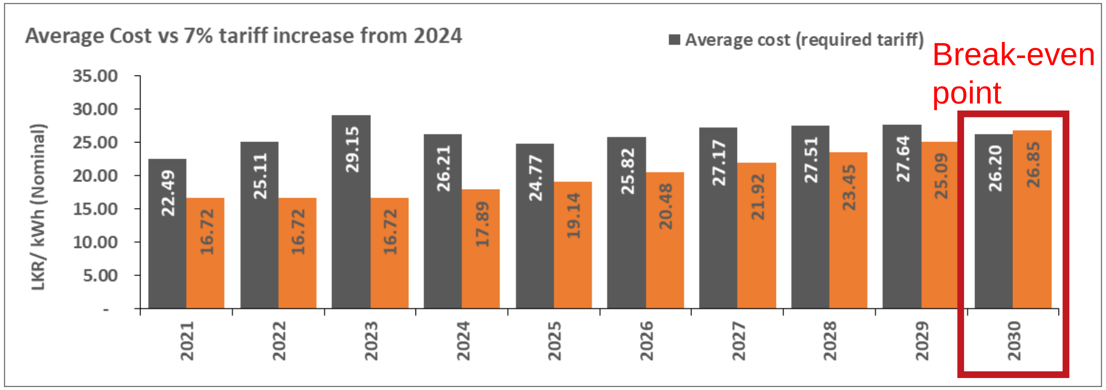
Financial projection results and its implications

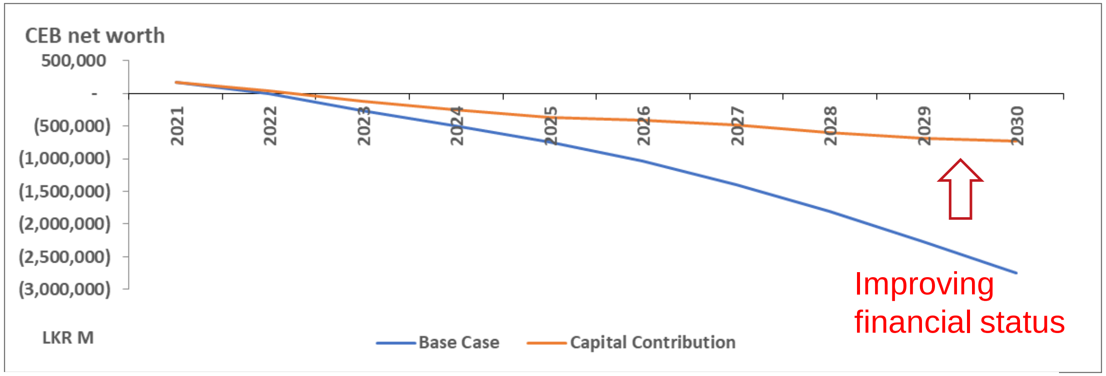
- Cost reduction effect of the rooftop PV FIT revision is as limited as around 0.2-0.3 LKR/kWh since its share accounts for a few percent of total generation.
- Although the rooftop PV FIT revision might have a significant impact in the long term, it is necessary to take additional measures to improve the CEB financial status, for instance:

✓ **Electricity tariff revision**: The case with 7% electricity tariff increase from 2024 would reach the break-even point in 2030 and significantly improve CEB's financial status.

✓ **Capital contribution**: In case that 50% of CAPEX is funded by the capital contribution from the government, its financial position would be improved significantly.

✓ **Other measures**: Debt-Equity Swap, donor support/ subsidy for CAPEX needs, etc.





→ Further analysis will be conducted in the "Recommendation Report" preparation in the 2nd stage activities

03-2 Progress of the Technical Transfer

Study of FIT tariff revision for rooftop PV

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Technical Transfer items

- Understanding changes and issues in environment surrounding the introduction of Rooftop PV
- Understanding how to calculate FIT tariff for Rooftop PV
- Rooftop PV FIT tariff revision proposal preparation support

Understanding the necessity and issues of reviewing the FIT system of Rooftop PV

- Renewable energy 70% introduction target
- Global reduction in Solar PV equipment installation costs
- Enjoying the excessive profits of Rooftop PV operators
- Increased CEB financial burden

Understanding how to calculate FIT tariff for Rooftop PV

- Collection of calculation conditions (introduction costs, loan conditions, expected rate of return, etc.)
- Understanding how to calculate generation costs
- Examination of FIT tariff
- Understanding how to make rational periodical reviews

Rooftop PV FIT tariff revision proposal preparation support

C/Ps recognized changes and issues in the business environment and improved the ability to review the appropriate system by oneself

Technical Transfer on Power Market

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<In Phase 1>
Understanding the overview of the power market and products in other countries by learning about power market (Wholesale, Balancing market) in Japan and European country.

Knowledge Transfer

Power Market in Japan
（ Wholesale, Balancing market）

Power Market in European country
（Balancing Market in EU & UK）

Connect & Manage
（Example in Japan, restriction of VRE output)

Outcome

Understanding of Power Market in advanced/developing country;

- Kinds of market in other countries and its outline
- Trend of the market development
- Products of Balancing Market corresponding to VRE development

Improvement of basic knowledge on the establishment of Power Market in Sri Lanka

CEB Financial Planning

Technical Transfer Items
- ➢ Analysis on current financial status
- ➢ Financial projection model for CEB business analysis and planning

Challenges faced by CEB to implement LTGEP 2022-2041

Rapidly increasing share of VRE generation (solar PV and wind)

Shift to investment in NG-fired TPPs (CEB and IPPs)

Growing financial burden of CEB for investment in transmission and grid support (BESS, PSPP, etc.)

Low electricity tariff that is very hard to revise to be cost-reflective

Capacity Development of CEB Staff in Corporate Financial Planning

2021/2022 Activities

- Understanding of current status through CEB financial analysis
- Financial projection based on LTGEP 2022-2041 and the proposed solar PV FIT

03-3 Way to Move Forward

Realization of the studied schemes

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Activity①：Realization of the FIT Tariff Revision for rooftop PV
Activities for completion and realization of the Recommendation Report on finance

<Roles of the Project Team>

When the economic condition recovers,

CEB: Getting approval from CEB management board

Submission and discussion of FIT tariff revision report to Expert Committee

Government approval procedure for FIT revision

discussion with JICA Experts and related institutions regarding the Recommendation Report

JICA Experts: Supporting CEB

-Making advices based on experiences in Japan

-Supporting discussion with relevant institutions

-Support for drafting the Recommendation Report using the financial projection model

Moving forward to next schemes in Sri Lanka

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Activity② : Learning on the power market systems of advanced/developing countries. Discussing issues and solutions on future power market and policy in Sri Lanka between C/P and JICA Expert Team.

Step 1 (to Aug. 2022) **<u>Survey & learning on Power Market of neighboring developing countries and on Balancing Market of advanced countries in Europe.</u>**

<Roles of C/P>

Desk survey of the Power Market in the Philippines as a case study of developing country.

Desk survey of the Balancing Market in the Ireland as a case study of advanced country.

<Roles of JICA Expert Team>

Desk survey of the Balancing Market in UK additionally and of the Balancing Market in Germany as a case study of advanced country.

Support of C/P surveys in terms of providing information sources, etc.

=> <u>Making presentation each other's findings at a joint meeting</u>, to understand the Power Markets in other countries.

Step2(Sep. to Dec. 2022) **<u>In terms of establishment of Power Market in Sri Lanka, identifying issues and discussing solutions to them between C/P and JICA Expert Team.</u>**

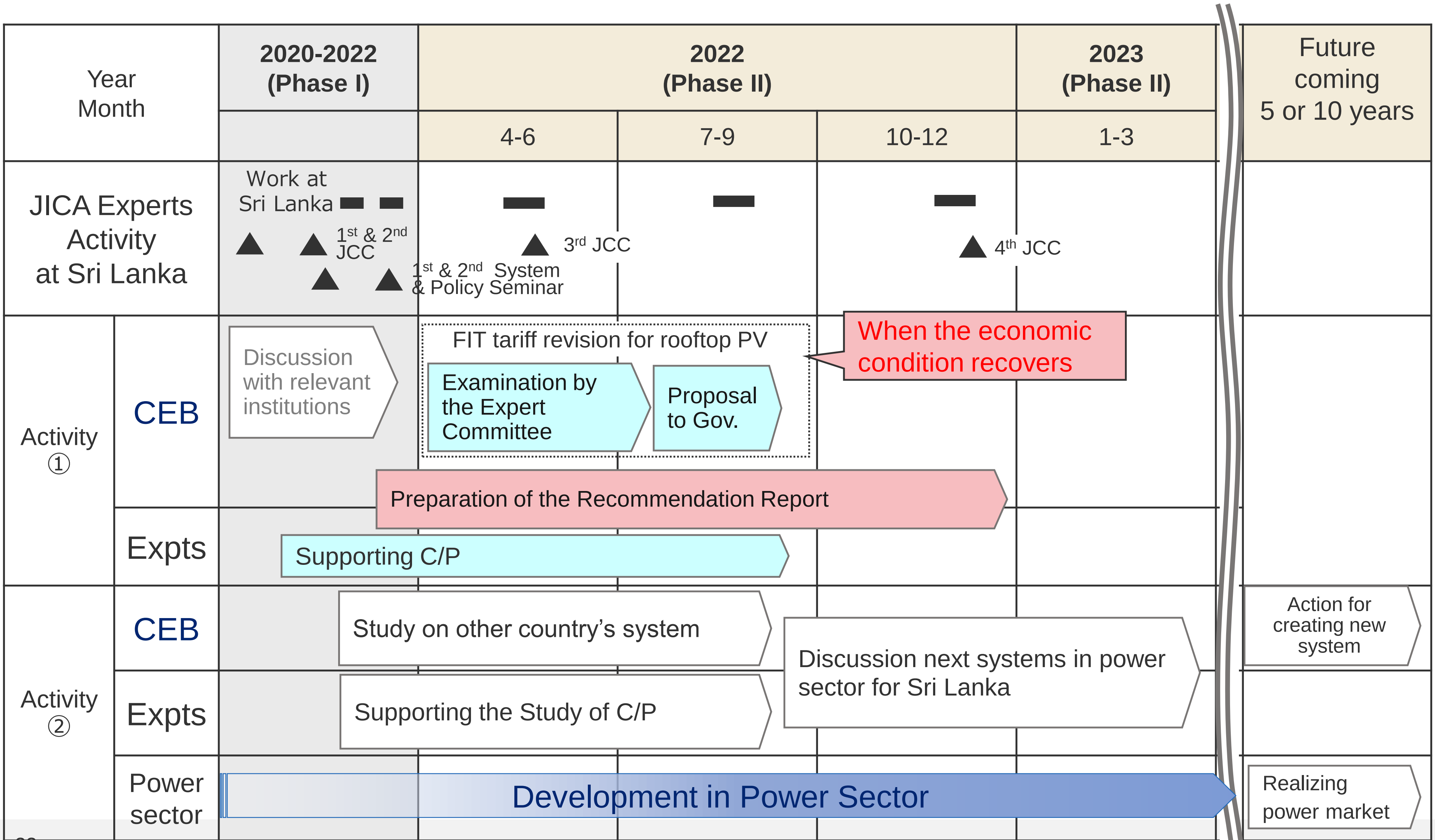
<Roles of C/P>

Organizing the issues and measures required in Sri Lanka for establishment of Power Market in the future.

<Roles of JICA Expert Team>

Supporting C/P activity

Schedule (System and Policy)



04 WG2 (Planning and Operation of Power System)

04-1 Progress of the Project

WG2: Past Activities

	Phase I						Phase 2
	2020	2021				2022	
	4 - 12	1- 3	4– 6	7– 9	10– 12	1- 3	4・5
Seminar: Completed for WG2	▲1st Technical Seminar				▲2nd Technical Seminar		
1. Supply and Demand Operation	Introduction of impact of large amount of VRE introduction and operation case studies	Proposal of supply and demand operation with PSPP and Storage Battery combination Review of Grid Code		Discussion about revising of Grid Code with VRE introduction			
2. Countermeasure for power system stability(PSPP and Battery Storage)	Introduction of case study of PSPP and Batteries Cost merit between PSPP and Batteries				Introduction of Battery's detailed characteristics Discussion about optimal capacity of battery storage considering VRE		
3. VRE Forecast	Review of existing VRE location and facility information Data Collection of Weather, Facility and output power Development of the VRE Forecast Model			Development of VRE conversion tool Forecast VRE output distribution			
Completed in this project 4. Geological Investigation (Victoria site)	Review of PSPP development plan Consideration of reconnaissance ▲On Site Training on the Desk	Proceeding of subcontracting		Geological Investigation ▲On Site Training (Inception Stage)	▲On Site Training (Final Stage)		

※PSPP: Pumped Storage Power Plant, VRE: Variable Renewable Energy

WG2: Activities Stage of Supply and Demand Operation

Input Stage

JICA Expert

- ✓ Grid Code and actual Operation of Generators
- ✓ Sri Lanka Solar PV Program (Net Metering Schemes)

Promotion of the Understanding & Sharing information about Actual Operation

CEB

Input the case studies from other countries

- ✓ Actual Operation of Generators in Power System where a large amount of VRE is introduced
- ✓ Day Ahead Planning and Operation of Supply and Demand Balance
- ✓ Explained rules and practices regarding VRE Control in Japan

Selection Stage

Revise the Grid Code

- ✓ Review the current Grid Code
- ✓ VRE's curtailment rule and method
- ✓ Considering Fault Ride Through (FRT)

Supply and Demand operation using VRE forecast

- ✓ Considering the supply capacity of the forecasting VRE output
- ✓ Supply and Demand operation using the forecasting VRE output

We are here

Study Stage

- ✓ Revision of Grid Code based on the PSS/E analysis
  - ☐ FRT (Fault Ride Through) Requirement
  - ☐ RoCoF (Rate of Change of Frequency) Requirement
  - ☐ Power Factor Requirement
  - ☐ VRE Control Extent(Voltage level, Capacity)
- ✓ Supply and Demand balancing operation considering forecast error of VRE output

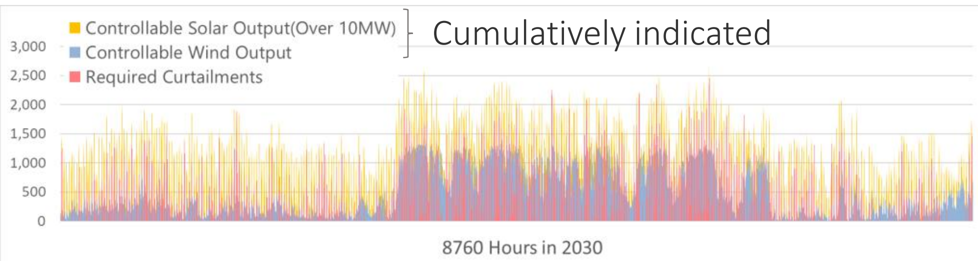
Actual Stage

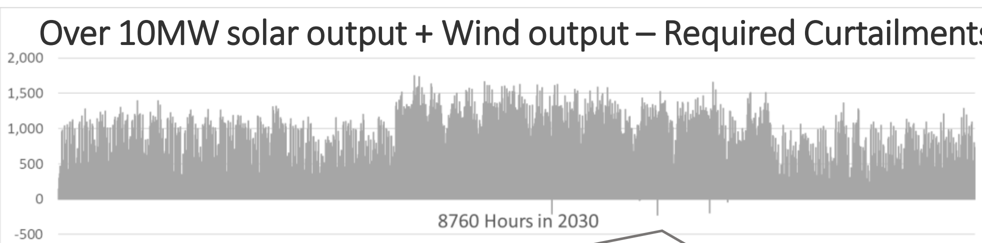
- ✓ Practical planning and operation using the forecasted VRE output
- ✓ Propose the Revised Grid Code

① Supply and Demand Operation

- CEB calculated VRE curtailment based on hydro averaged scenario without batteries and its results showed that the maximum required VRE curtailment would be around 2,500MW in 2030.
- To achieve stable power supply, it is necessary to control VRE output and define its extent (e.g. over certain capacity) in Grid Code.
- If controllable solar is defined as that over 10MW, there would be insufficient curtailable output, however, JICA Expert Team considers step by step installation of grid code would be better considering cost impact for small VRE power plant and possibility of installing storage battery.

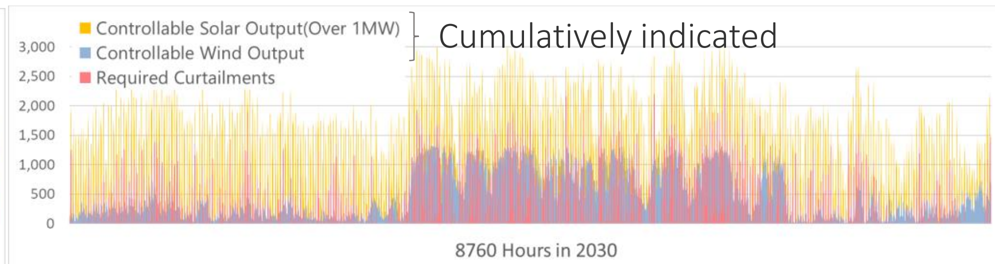
<Controllable Solar : over 10 MW case>

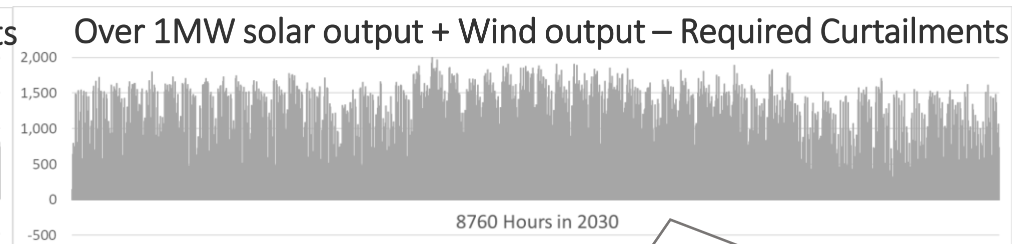




Insufficient controllable VRE output
(Negative numbers: minimum -300MW)

<Controllable Solar : over 1 MW case>





Curtailment volume can be covered.
(No negative number)

WG2: Activities Stage of Countermeasure for power system stability(PSPP and Battery Storage)

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Input Stage

JICA Expert

- ✓ Planning of the Battery introduction.
- ✓ The role of PSPP in supply and demand operation
- ✓ Preliminary Studies on Grid Connected Battery Storage.

Promotion of the Understanding, Ownership & Sharing information about future plans

Input the case studies from other countries

- ✓ Battery system to mitigate the VRE output fluctuation
- ✓ PSPP Capacity Consideration
- ✓ Virtual synchronous generator (synthetic inertia) using battery
- ✓ Detailed characteristics of battery storage
- ✓ Demonstration of test results of Battery Storage system

CEB

Selection Stage

Detailed battery storage characteristics

- ✓ Battery Types(Li-ion, Sodium Sulfur, Redox-Flow, Lead Acid)
- ✓ Installation and O&M cost of each kind of battery

Comparison of PSPP and battery storage

- ✓ Comparison of operational advantages and disadvantages
- ✓ Comparison of construction and operating costs

Target for the power system stability

- ✓ Each characteristics of PSPP and Battery Storage to mitigate the power system fluctuation

Study Stage

- ✓ Calculation of the Battery Storage capacity according to the VRE's introduction capacity
- ✓ Considering the operation of PSPP and Battery Storage for power system stability
- ✓ Combined use of PSPP and Battery Storage

Authorization Stage

- ✓ Propose battery storage capacity according to the VRE introduction capacity
- ✓ Operation of the PSPP and Battery Storage to mitigate the VRE output fluctuation

We are here

② Countermeasure for power system stability (PSPP and Battery Storage)

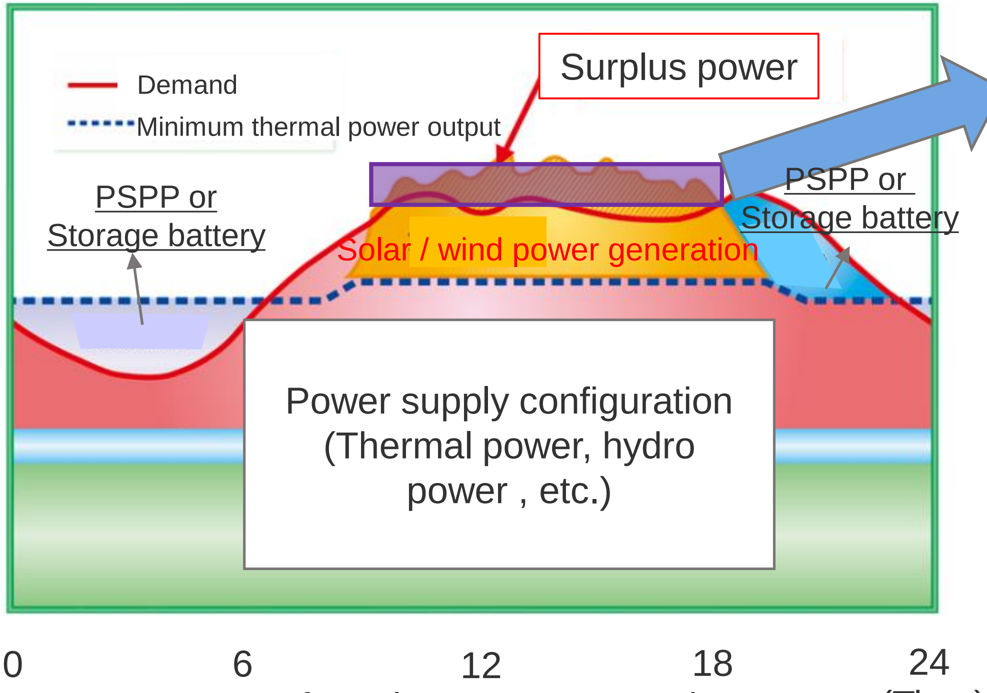
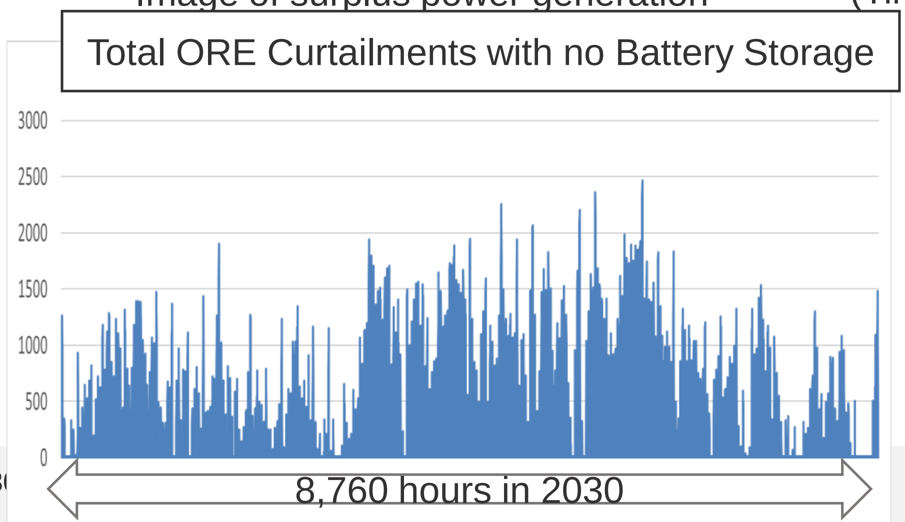


Image of surplus power generation



With the target of achieving 70% renewable energy in 2030, calculation of surplus power and capacity requirement of the Battery Storage needs to be introduced.

① The surplus power and renewable energy introduction amount were calculated by SDDP simulations under the condition of Battery Storage introduction amount of some patterns. (Including utilization of PSPP)

② Utilizing the results of SDDP simulations, JICA Expert Team calculated the effect of reducing thermal fuel and CO_2, and considered the capacity of Battery Storage to be introduced.

WG2: Activities Stage of VRE Forecast

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Input Stage

JICA Expert

- ✓ VRE potential of each area (existing and planning sites of VRE plants)
- ✓ Weather data and Facility Information
- ✓ Installed capacity of the Roof top PV at each area

Promotion of the Understanding & Sharing information about Actual Facilities

Input the case studies from other countries

- ✓ Topology of the weather forecasting
- ✓ Essential information for VRE forecast model development
- ✓ Accuracy of the VRE forecast
- ✓ CEPCO's PV Forecast System

CEB

Selection Stage

Select the Target Point for VRE forecasting model development

- ✓ Selection of the points for developing VRE forecast model of the Roof-top PV, major Solar Power Plants, and Wind Power Plants
- ✓ Confirmation of the providing data of weather and Facilities in and around these points

Data Distribution of VRE forecast

- ✓ Distribution protocol
- ✓ Frequency of distributing VRE forecast in a day and its timing
- ✓ Development of the receiving server

Study Stage

- ✓ Developing the VRE forecasting model
- ✓ Forecasting & distribution VRE Data (From July 2021)
- ✓ Developed VRE conversion tool
- ✓ Verification of VRE forecast data accuracy
- ✓ Estimating VRE's output for whole area by using developed forecasting model of VRE

We are here

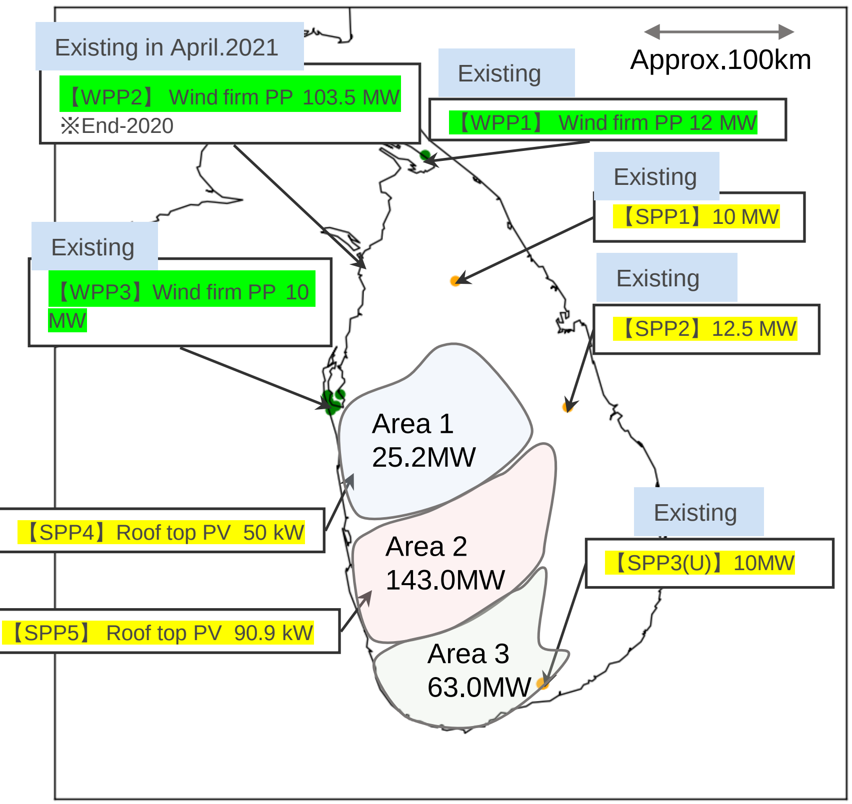
Implementation Stage

- ✓ Improvement the VRE forecasting model, if needed
- ✓ Actual planning and operation of the Supply and Demand with VRE forecast

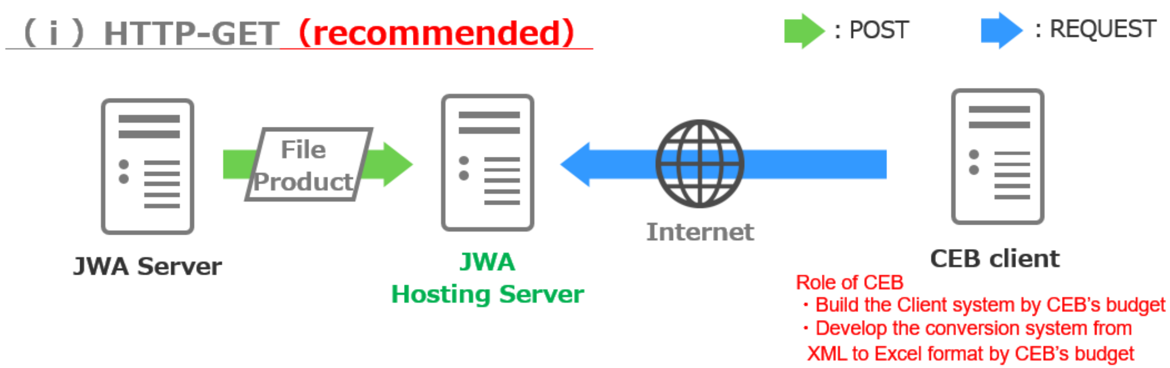
③ VRE Forecast

- Developed the VRE forecast model and submission of the VRE forecasting output
- Improved the SPP4 forecast model for the revised rated capacity.
- Provided the conversion tool of VRE output from weather data
- Forecast error compared with actual data and forecasting VRE output

✓Sites of VRE forecasting model development



✓Submission of the forecast weather data (Wind speed, wind velocity, irradiation) and forecast VRE output data



WG2: Activities Stage of Geological Investigation

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Input Stage

JICA Expert

- ✓ The situation of the Maha3 and Victoria Lake PSPP development
- ✓ Provide the 1:10,000 geological map

Promotion of the Understanding & Sharing information about the development plan

Input the case studies about general issues of PSPP development

- ✓ Current situation of the Geological Investigation at Maha3 and Victoria Site
- ✓ Task and schedule for geological investigation
- ✓ Issues for PSPP development

CEB

Selection Stage

Select the Target of the Geological Investigation

- ✓ Issues of the Maha3 Pre-Feasibility Study
- ✓ Recognition of the PSPP planning
- ✓ Decide the site Maha3 or Victoria Site

Contents of the Geological Investigation

- ✓ Investigation area with special emphasis to identify the protection area at Victoria Site
- ✓ Core dolling points
- ✓ Schedule of the Investigation

Study Stage

- ✓ Geological Investigation at the Victoria Site (From June 2021)
- ✓ Decide the detailed core drilling points
- ✓ On-site training at Inception Stage and Final Stage

Authorization Stage

- ✓ Verifying the results of the Geological Investigation
- ✓ Comparing the issues of Maha3 and Victoria Site
- ✓ Considering the Full-Swing Geological Investigation at Victoria site with ADB fund

Completed in this project

④ Geological Investigation

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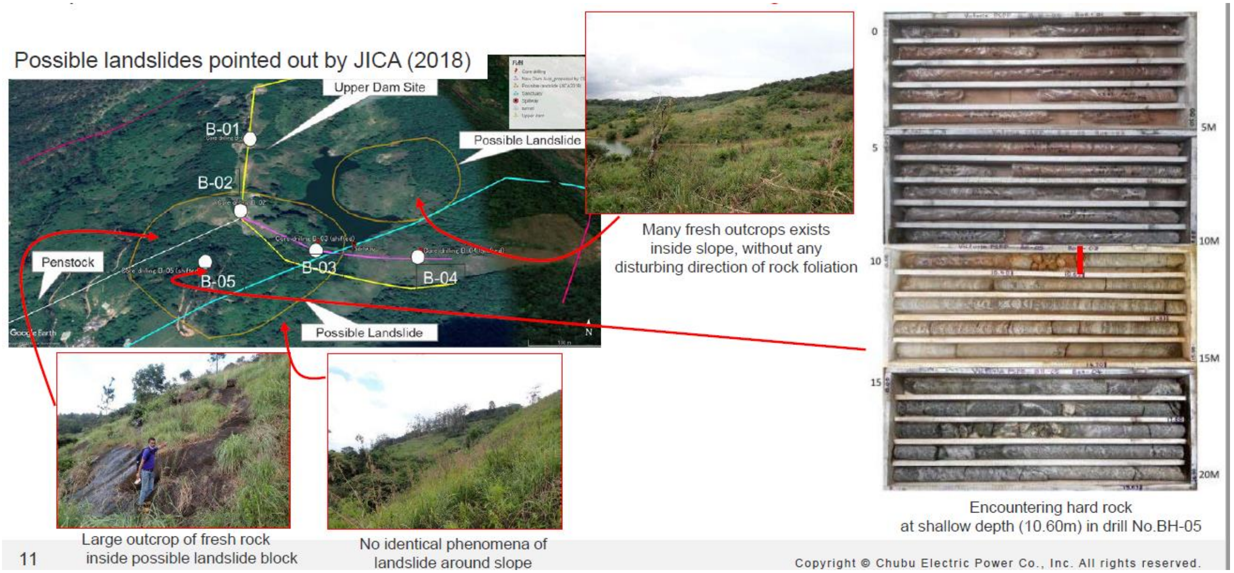
- Completed geological investigation at Victoria site in December 2021.
- For upper area of Victoria PSPP site, the fatal geological risk does not seem to exist based on investigation results in this stage (2021).
- 2nd Technical Seminar: Evaluation of the results at the Victoria site
  Consideration how to proceed with the development for the PSPP
- Conducted on-site training (Final Stage):Victoria site on October 26, 2021
  On-line on October 28, 2021

✓Sample of core drilling



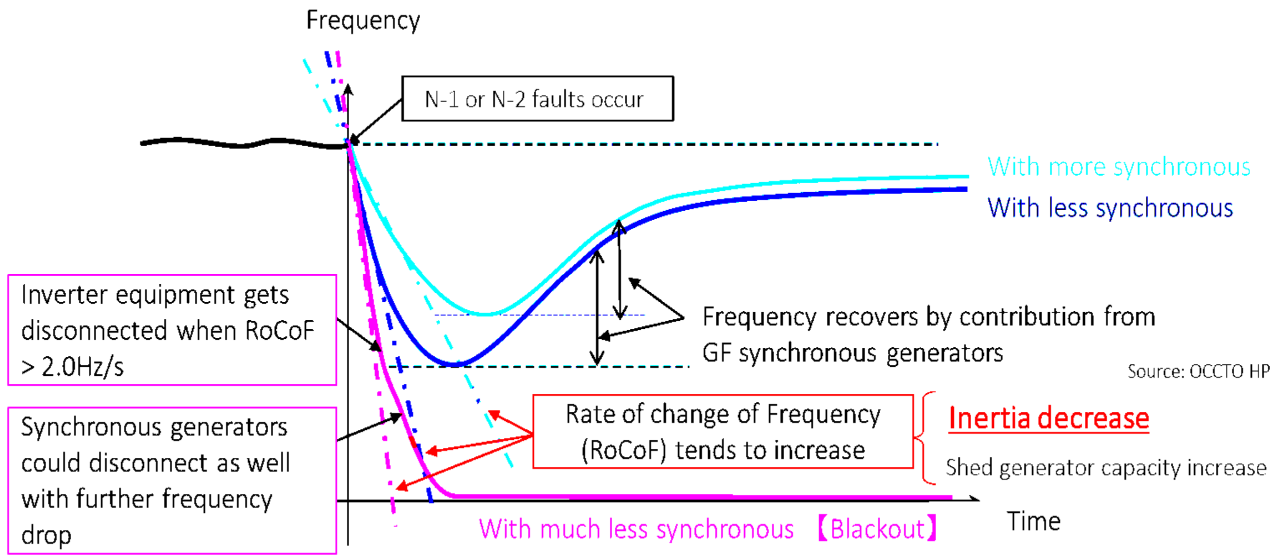
✓On-site training at Victoria site

04-2 Progress of the Technical Transfer

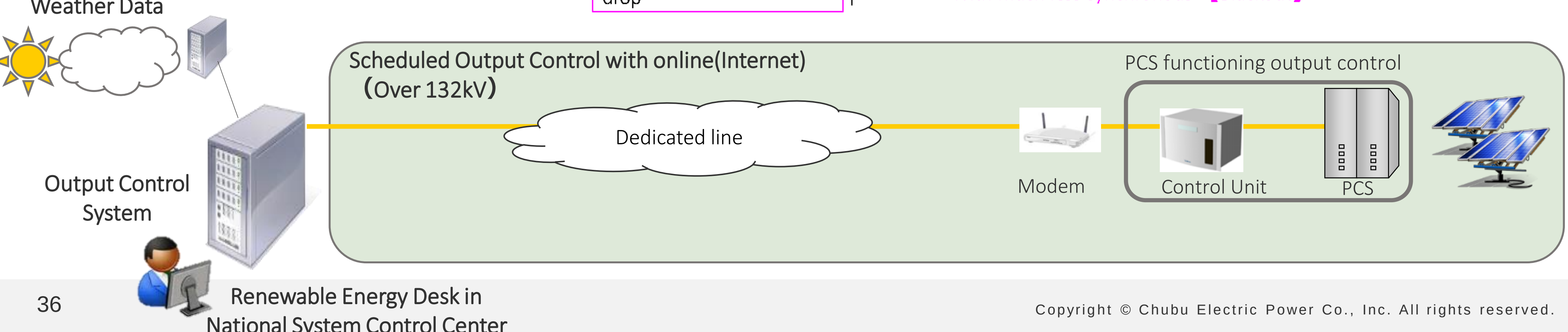
WG2: Supply-demand balancing operation considering large amount of VRE introduction

- Proposed RoCoF regulation considering VRE in Grid Code
- Introduced VRE curtailment function in PCS

✓Necessity of RoCoF for large amount of VRE introduction



✓Curtailment method of utility scale PV



WG2: Technical Transfer of power system stability(PSPP and Battery Storage)

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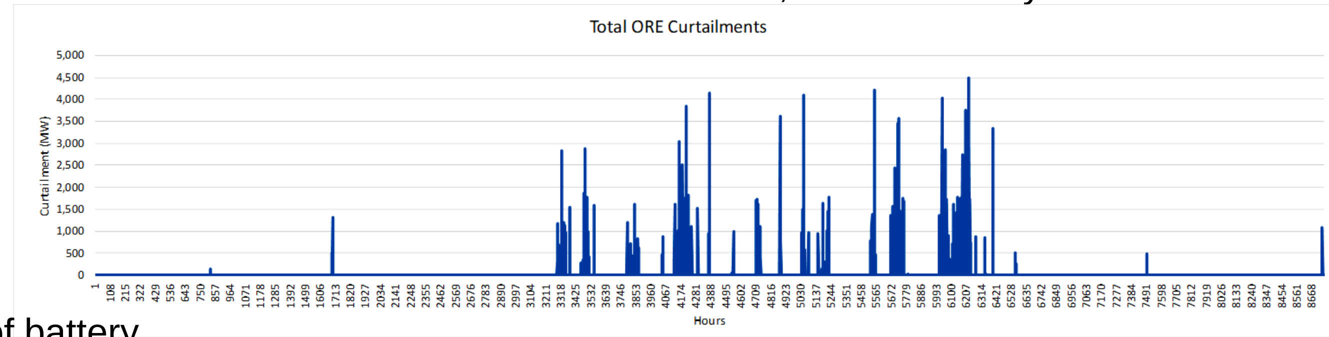
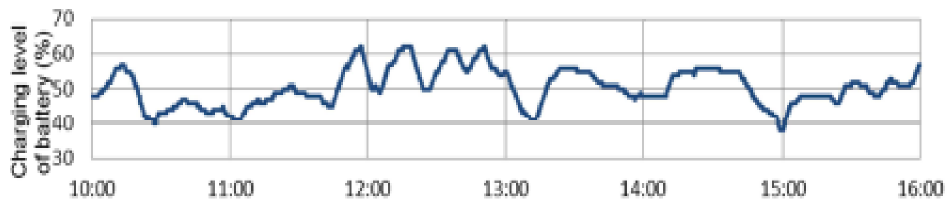
- Detailed characteristics of each type of Battery Storage.
- Battery Storage capacity required to achieve 70% RE by 2030.

✓Curtailment simulation with 2,500MW battery introduction



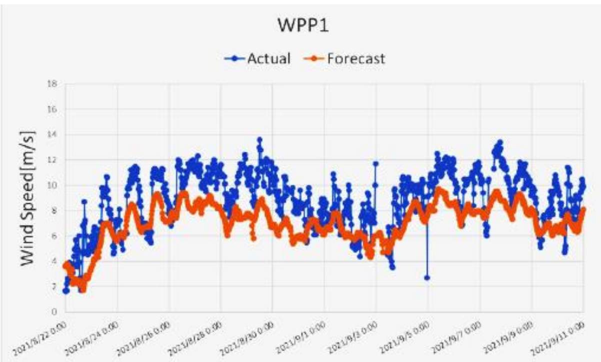
✓Detailed characteristics of each type of battery

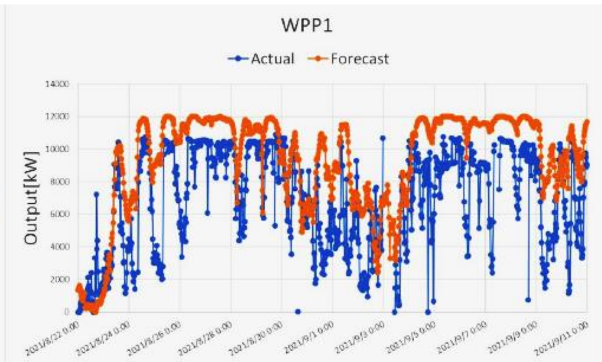
Type	Charging/ Discharging Characteristics
Sodium Sulfur	• When using as a measure against surplus power, use in the range of 0 to 100%. • If it is used for frequency measures for short cycle measures, it is recommended to use it in the range of 20 to 80%.
Li-ion	• When using as a measure against surplus power, use in the range of 0 to 100%. • If it is used for frequency measures for short cycle measures, it is recommended to use it in the range of 30 to 70%. 
Redox Flow	• When using as a measure against surplus power, use in the range of 0 to 100%. • If it is used for frequency measures for short cycle measures, it is recommended to use it in the range of 50 to 95%.

WG2: Technical Transfer of VRE Forecast

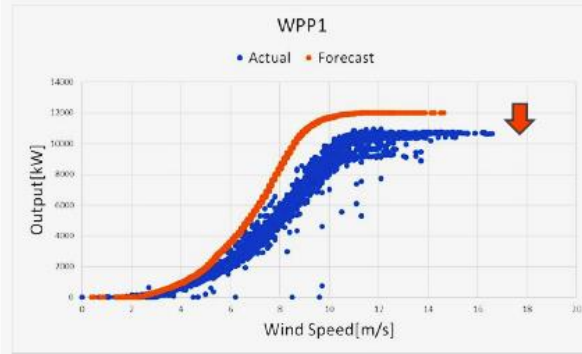
- Provided the VRE conversion tool from weather data to VRE output
- Evaluation of VRE forecast error technique and verification method of actual data and VRE forecast
- Improved method of the VRE forecast model

✓Verification of forecast data and actual data



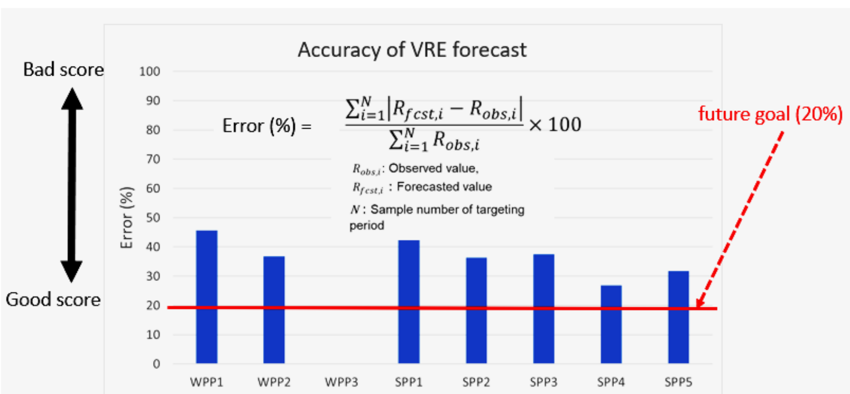


✓Improved method of the VRE forecast model

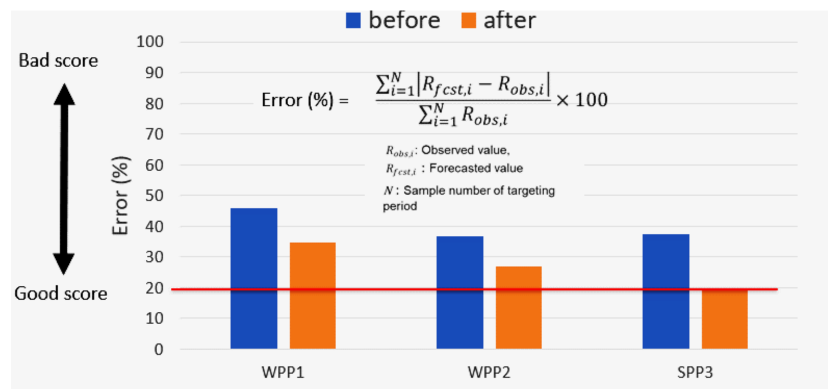


Applied image.

✓Comparison of the accuracy of the forecasting VRE output



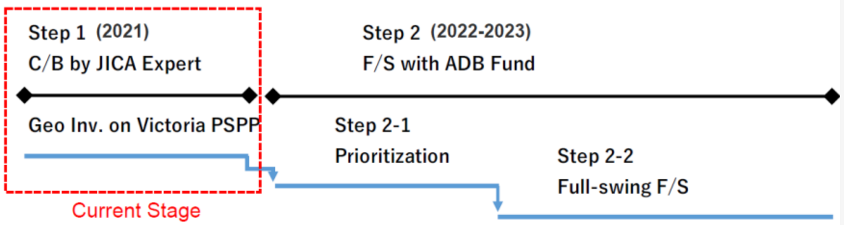
improving



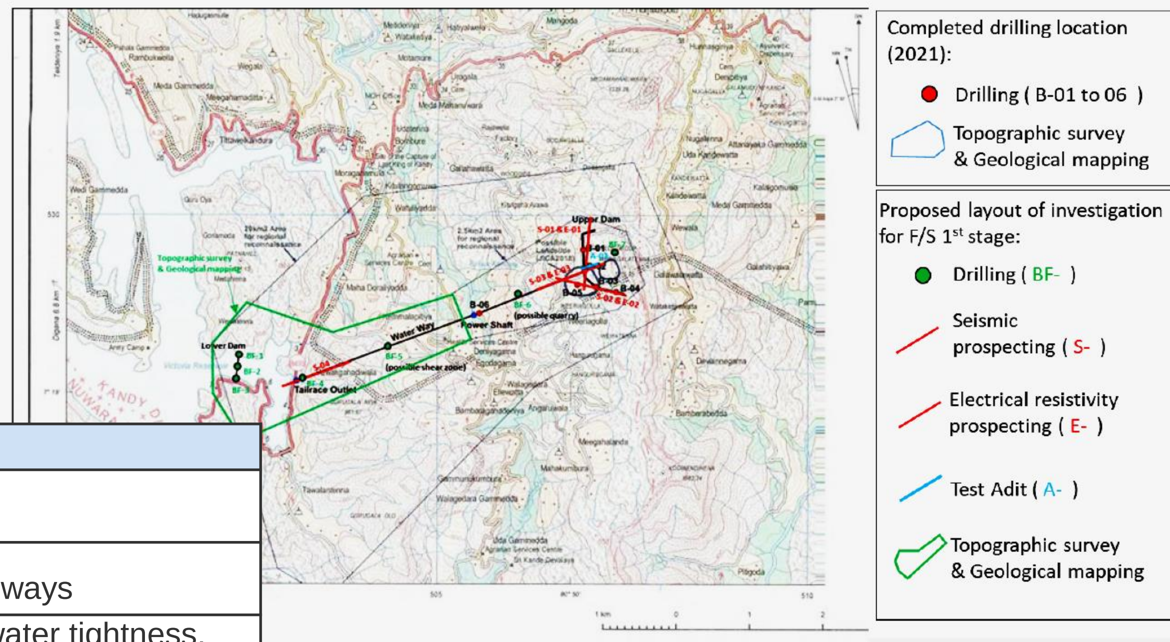
WG2: Technical Transfer of Geological Investigation

- Through geological investigation and on-site training, the following points relating to the geological investigation of PSPP (Pumped Storage Power Plant) were shared.
  - ✓ How to schedule the Geological Investigation at Victoria Site
  - ✓ What are main check points of Geological Investigation for PSPP development

✓Schedule of the Geological Investigation at Victoria Site



Proposed layout of geological investigation for Victoria Lake site in Next F/S 1st stage



✓Check points of Geological Investigation for PSPP development

Structures	Check Points
Underground power house	1. Rock condition
Lower water way	1. Landslide risks 2. Rock condition along water ways
Lower storage dam and reservoir	1. Safety of dam foundation, water tightness, landslide and water seepage risks.
Upper storage dam	1. Safety of dam foundation 2. Water tightness
Reservoir	1. Landslide risks 2. Water seepage risks
Upper water way	1. Landslide risks of portals 2. Rock condition along water ways

04-3 Way to Move Forward

WG2: Activities to Achieve the Target

1. Supply and demand operation

✓ Simulation of power system with 70% RE using PSS/E to ensure stable operation under various contingencies

✓ Propose the revised Grid Code considering the target of 50% RE that includes the FRT, VRE curtailment, etc.
For 70% RE target, propose the additional Grid Code requirements based on 50% RE.

✓ Practical planning and operation by using the forecasted VRE output. (in future using Renewable Energy Desk)

✓ Formulating LTGEP(2022-2041) considering the target of 70% RE by 2030.

2. Countermeasure for power system stability (PSPP and Battery Storage)

✓ Propose suitable capacity of Battery Storage in combination with PSPP to achieve 70% RE by 2030

✓ Propose Battery Storage introduction plan considering the existing PSPP construction plan

✓ Propose PSPP and Battery Storage operation to mitigate VRE output fluctuation

WG2: Activities to Achieve the Target

3. VRE forecast
✓Verification of the accuracy of the forecasted VRE output.
✓Improve the VRE forecast model using actual data.
✓Review the improved VRE forecast model to achieve the target accuracy.
✓Estimation of the whole VRE's output using each of developed VRE forecasting model.

4. Geological investigation (Victoria site) Completed in this project
✓Out of the Scope: Full-Swing Feasibility Study at Victoria site with ADB fund

5. Training in Japan
✓Experience of using the CEPCO's analog simulator for power system during training session in Japan.

WG2: Future Schedule

	Phase Ⅱ			
	2022			2023
	6	7 – 9	10 – 12	1 – 3
1. Supply and Demand Operation	Simulation of power system considering RE70%	Propose the revised Grid Code Planning of Supply and Demand using forecast VRE output	Review the power system operation	
2. Countermeasure for power system stability (PSPP and Battery Storage)	Calculation of Battery Storage capacity	Follow-up the countermeasure of the power system stability		
3. VRE Forecast	Forecasting VRE output distribution Verification of the forecasting VRE output	Improve the VRE forecast model Forecasting VRE output distribution by improved VRE forecast model	Review the forecasting VRE output	
4. Geological Investigation (Victoria site)	Completed in this project <Out of Scope in this Project> Full-Swing Feasibility Study			

05 WG3 (Improvement of Distribution System Reliability)

05-1 Progress of the Project (WG3-1)

Past Activities

	2020	2021				2022
Month	4-12	1-3	4-6	7-9	10-12	1-3
WG3-1 Power outage measures		Estimation of effect on site by facility measures		Effect estimation at pilot sites	Determination of target SAIFI/SAIDI in the pilot sites	
			Procurement of ARC/OCI/GFD			ARC installation and OJT
				Record Power Outage Report in detail		

WG3: Outline of PDM and Activities (WG3-1)

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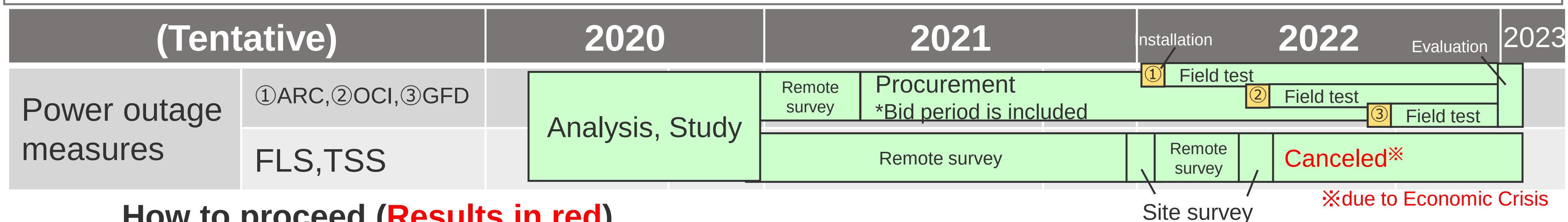
PDM(Project Design Matrix) of WG 3

Indicators for Project Purpose	(1) SAIFI at the pilot sites where the facilities against power outage are installed: ** in 2023 (2) SAIDI at the pilot sites where the facilities against power outage are installed: ** in 2023

**: shown in the next pages

Outline of WG 3 -1 (Power Outage Measures)

- Analysis for Outage Situations and Causes of CEB's DD1-4 and LECO
- Suggestion for Supply Reliability Improvement
- Introduction of Reliability Improvement Facilities and Estimation of their Effects in Pilot Projects



How to proceed (Results in red)

1. Survey and cause analysis on failure outage status per MV line
2. Planning of measures and Selection of pilot sites and measure facilities
3. Procurement and installation of the facilities
4. Evaluation of quantitative effects by estimating the power outage amount [kWh] before and after the countermeasures
5. Estimation of cost effectiveness of measure facilities in the pilot projects and evaluation of contribution to CEB finance aiming to the mass introduction based on target supply reliability in the future

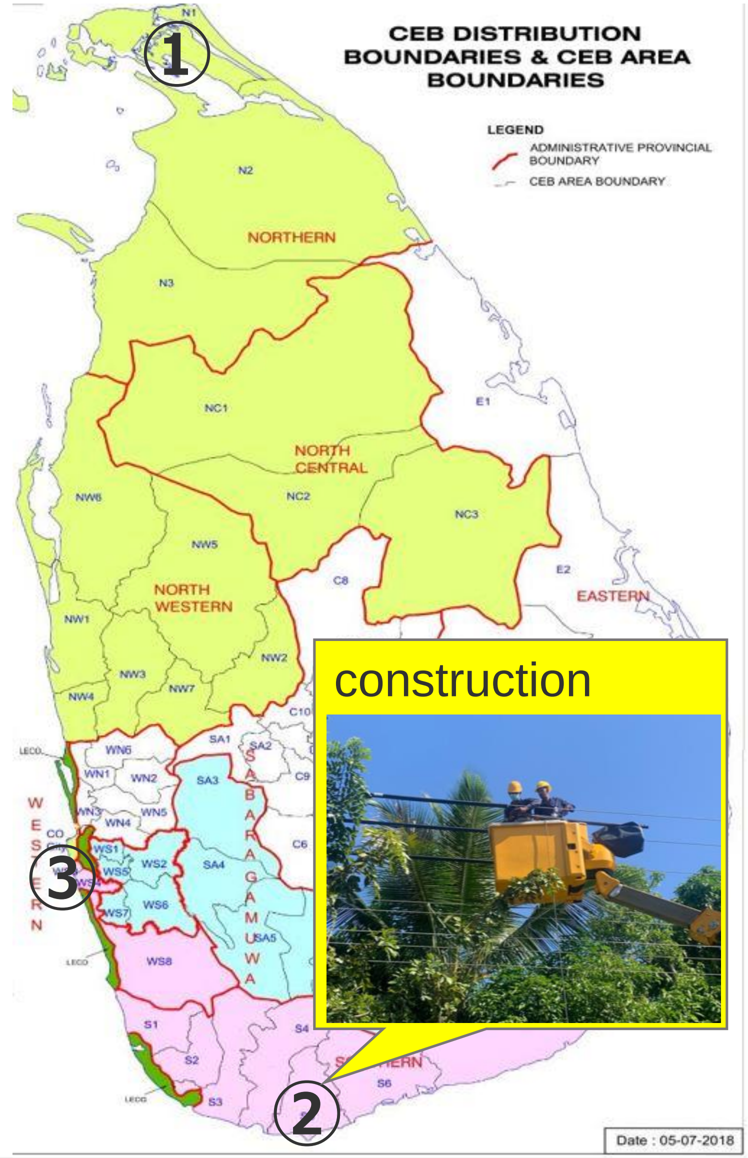
ARC Pilot Project Site

Pilot Project Status

All Installed

Equipment	**Pilot Project Site**		
	DD1	**DD4**	**LECO**
Abrasion Resistant Cover for Conductor	①PoojaNagaraya	②Matara F1	③ Kaluwamodara F-Moragalla

ARC		DD1	DD4	LECO
Pilot feeder	Unit	Pooja Nagaraya	Matara F1	Kaluwamodara Moragalla Feeder
SAIFI ’19	[min]	10	2.4	56.2
SAIFI ’23	[min]	**3.8**	**1.3**	**37.5**
Effect	[min]	-6.2	-1.1	-18.7
Effect	%	-62	-45.9	-33.3
SAIDI ’19	[min]	1,192	110	1,450
SAIDI ’23	[min]	**397**	**53**	**967**
Effect	[min]	-795	-57	-483
Effect	%	-66.7	-51.8	-33.4



OCI Pilot Project Site

Pilot Project Status

Delivered (June.2022)
Installation (~July.2022)

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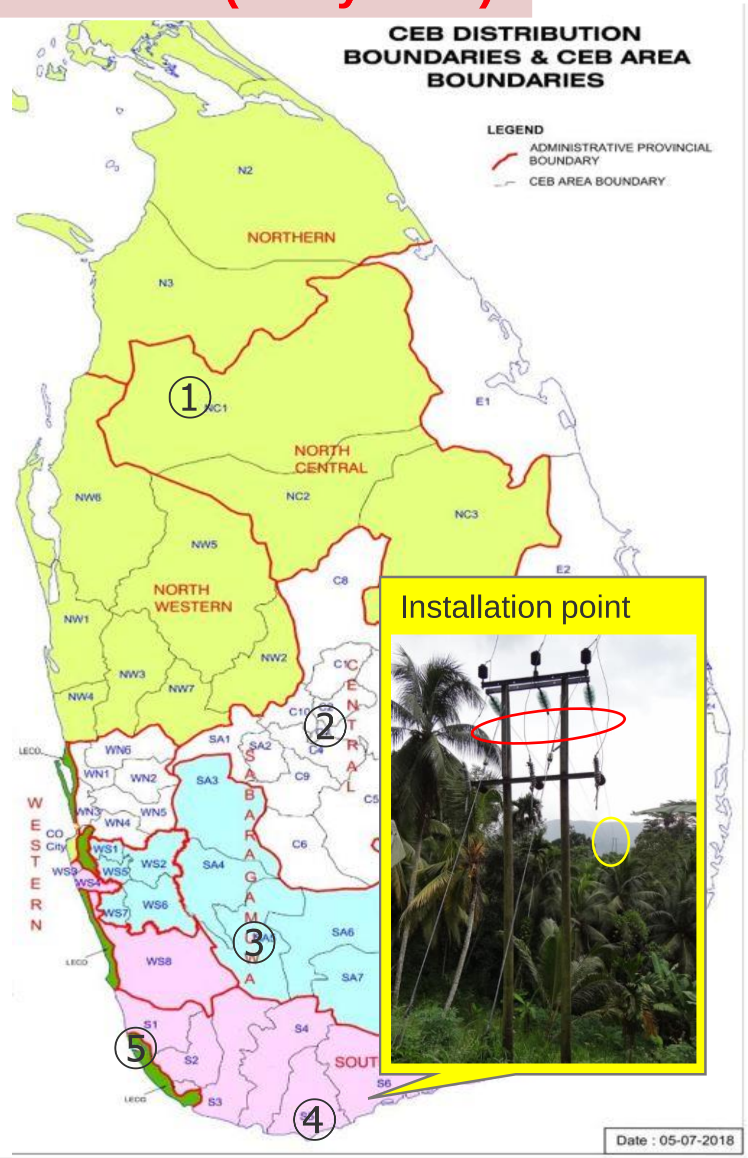
Equipment	Pilot Project Site				
	DD1	DD2	DD3	DD4	LECO
Over Current Indicator [OCI]	① Habarana F7	② Kiribath -kumbura F9	③ Ratnapura F2	④ Deniyaya F4	⑤ Beligaha F-Boossa

OCI		DD1	DD2	DD3	DD4	LECO
Pilot feeder	Unit	Habarana F7	Kiribathkumbura	Ratnapura F2	Deniyaya F4	Beligaha BoosaFeeder
SAIDI ’19	[min]	4,620	1,021	637.6	6,052	3,734
SAIDI ’23	[min]	4,126	955	355.9	5,054	3,437
Effect	[min]	-494	-66	-282	-998	-297
Effect	%	-10.7	-6.5	-44.2	-16.5	-7.9



GFD Pilot Project Site

Pilot Project Status

Under manufacturing (~Sept.2022)

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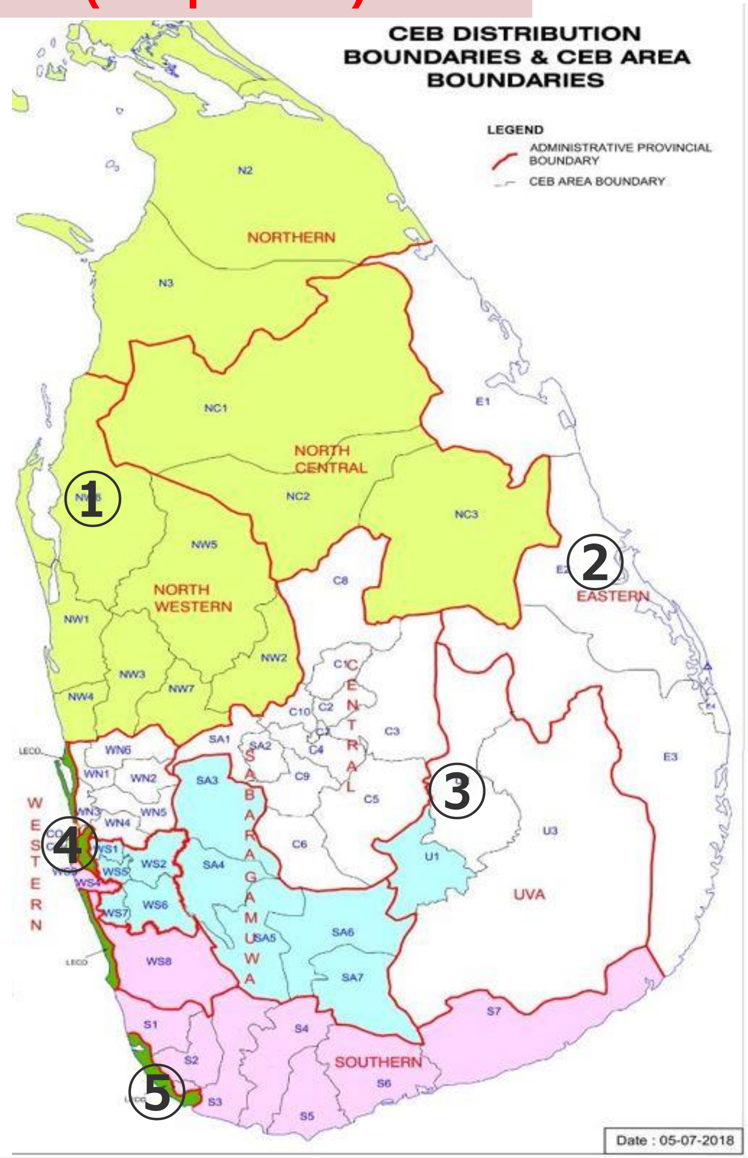
Equipment	Pilot Project Site				
	DD1	DD2	DD3	DD4	LECO
Ground Fault Detector [GFD]	①Norochcholai F2	②Valaich−chenai F6	③Mahiyanganaya F3	④Rathmalana F2	⑤Hikkaduwa F-Wewalamilla

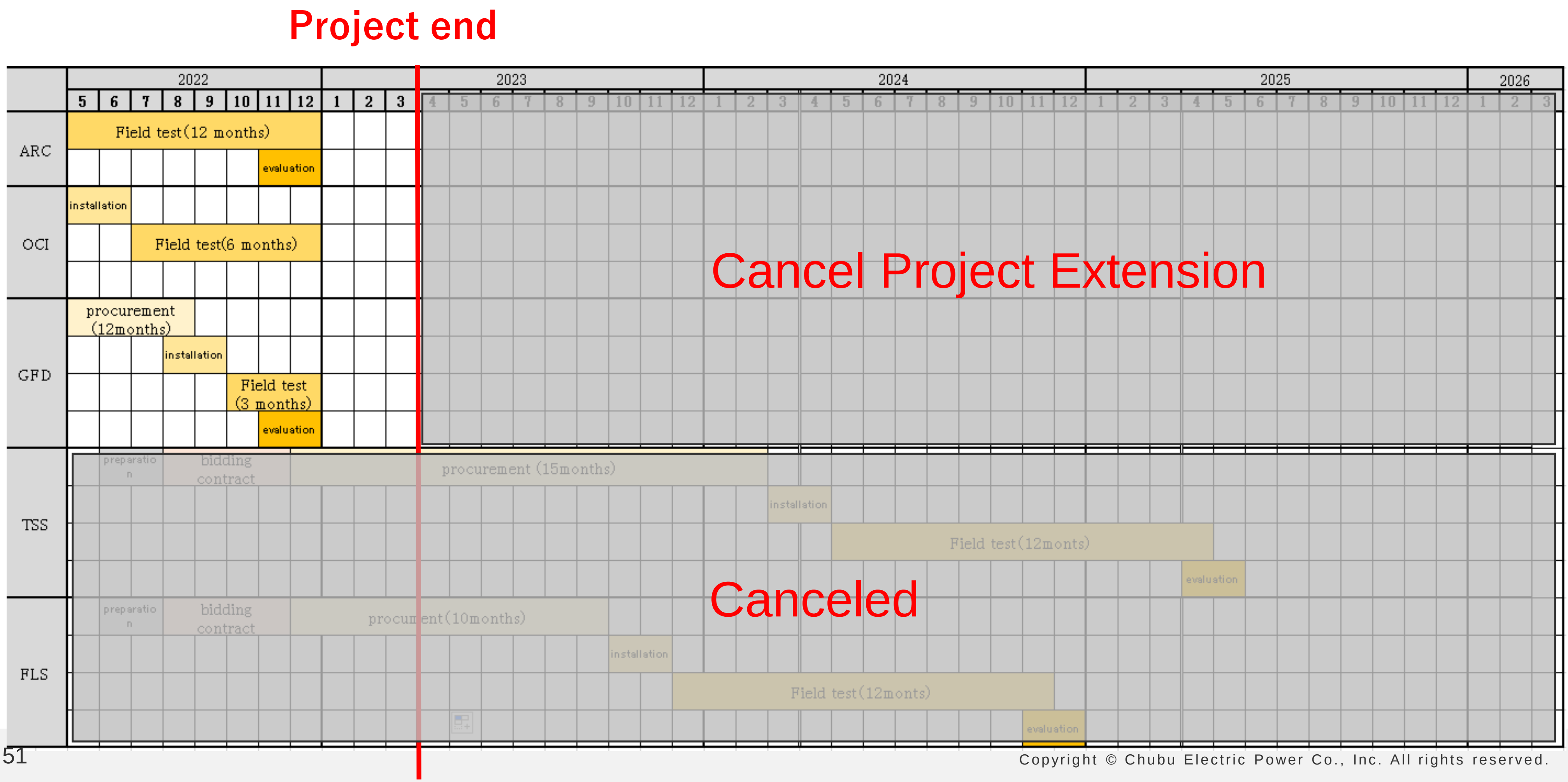
GFD	Unit	DD1	DD2	DD3	DD4	LECO
Pilot feeder	Unit	Norochcholai F2	Balaichchenai F6	Mahiyanganaya F3	Rathmalana F2	Hikkaduwa Wewalamlla feeder
SAIDI ’19	[min]	490	552.1	68.37	417	4,565
SAIDI ’23	[min]	**277**	**386.5**	**36.47**	**216**	**3,241**
Effect	[min]	-123	-166	-31.9	-201	-1324
Effect	%	-43.5	-30.0	-46.7	-48.3	-29.1



Schedule of Pilot Project.

Field survey for FLS and TSS was conducted in January and June 2022.

→Due to Economic Crisis in Sri Lanka, CEB and LECO decided to cancel the Pilot Project of TSS and FLS.



05-2 Progress of the Technical Transfer (WG3-1)

WG3-1: Technical Transfer

1. Improved effects were estimated by C/Ps.

- C/P can estimate the effect of countermeasure facilities

DD1:ARC: Pooja Nagaraya

BEFORE (2019)

Number of power failures per year

cause	OC	EF	Both	Total
2019	2	9	4	15

Number of tree/etc contact

Tree/etc Contact
10

Total number of power failure = 15 per year

SAIFI
10

AFTER (ESTIMATION)

1. ARC is effective to 10 of 15 failures (66.6%)
2. No more tree contact

Total number of power failure
- 15 – 10 = 5 per year

Total number of power failure = 5 per year

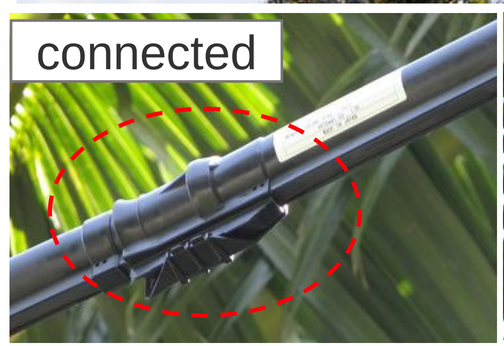
Difference 66.6%

PDM - SAIFI
3.82

ARC will improve SAIFI from 10 to 3.8 in this Pilot Site.

2. OJT at the ARC installation site.

- How to install ARC in a place where work vehicles cannot enter.
- Advised on a more effective mounting range of ARC.



05-3 Way to Move Forward (WG3-1)

WG3-1

- Maintain a database on pilot sites and continuously monitor the outage data after deploying the relevant countermeasure devices to ascertain the effectiveness. Ex: SAIFI and SAIDI improvements
- Maintain the cause of fault under the each outage event so as to ease the troubleshooting.
- Effective deployment of countermeasure devices and maintain them appropriately.
- Cooperate with JICA for GFD pilot installations.
- Improve the distribution control center setup as did in WPS2.

WG3-1 : Future Schedule

Evaluation

Project Period		Phase Ⅱ			
Year		2022			2023
		4-6	7-9	10-12	1-3
Pilot Project	・OCI	Field Test	Field Test	Field Test / Evaluation	Evaluation
	・Cover	Procurement	Installation /Training; Field Test	Field Test / Evaluation	Evaluation
	・GFD	Procurement	Procurement	Training /Field Test / Evaluation	Evaluation
	・TSS ・FLS	Field survey	Canceled due to Economic Crisis in Sri Lanka.		
Training in Japan (Distribution facilities)				⟷	
On site training (Operating countermeasure equipment)		→	→	→	→
Improve power outage cause analysis		→	→	→	

05-1 Progress of the Project (WG3-2)

Past Activities

	2020	2021				2022
Month	4-12	1-3	4-6	7-9	10-12	1-3
WG3-2 Load fluctuation suppression		Selection of measurement sites and study of load fluctuation by VRE	Selection of measurement sites and study of load fluctuation by VRE			
			Procurement of EPMI			
				Study and estimation on BESS installation in LV line		
					Study of modeling and estimation	
						Site survey for VRE conditions and data collection in the target LV line

WG3: Progress of Activities (WG3-2)

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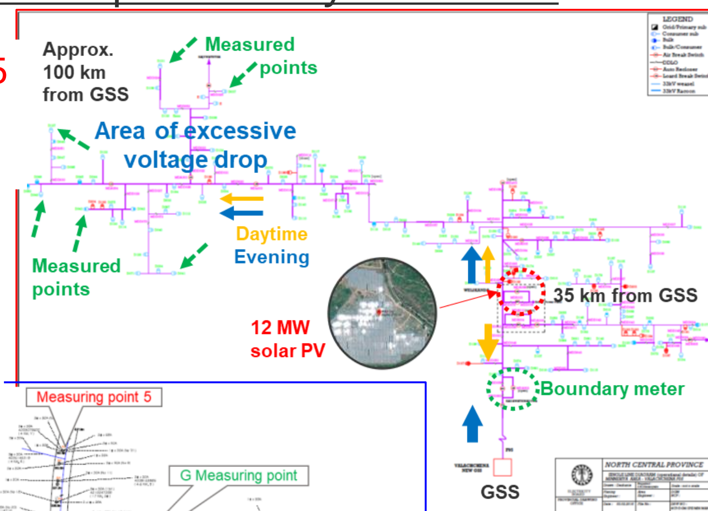
Outline of WG 3 -2 (Load Fluctuation Suppression)	
● Measurement and Analysis of Power/Voltage Fluctuation in MV Network due to Large Capacity of VRE ➡	33 kV Valachchenai F5 with 12 MW SPP (Reverse power flow)
● [Revised] Estimation of Power/Voltage Fluctuation in LV Network due to Large Number of VRE ➡	LV feeder of Transformer TL-007 in Ethulkotte (Modeling and estimation)

How to proceed [Revised]
(Results in red, Ongoing in blue)

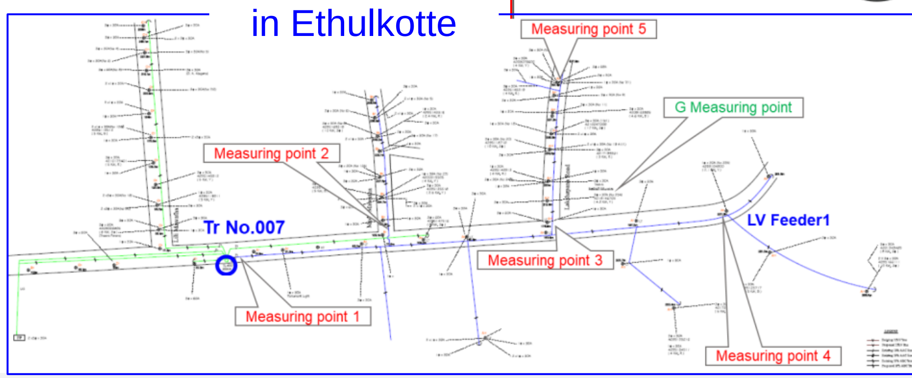
1. Data collection and study on the distribution system with mass introduction of PV and wind turbine (WT) generation
2. Consideration of site, battery system specifications.
3. Selection of target feeder to measure and analysis
4. Confirmation of load fluctuation matters by analyzing measured data
5. Proposal and estimation of countermeasures

Target MV and LV feeders with problems by mass VRE

33 kV Feeder No.5 of Valachchenai GSS



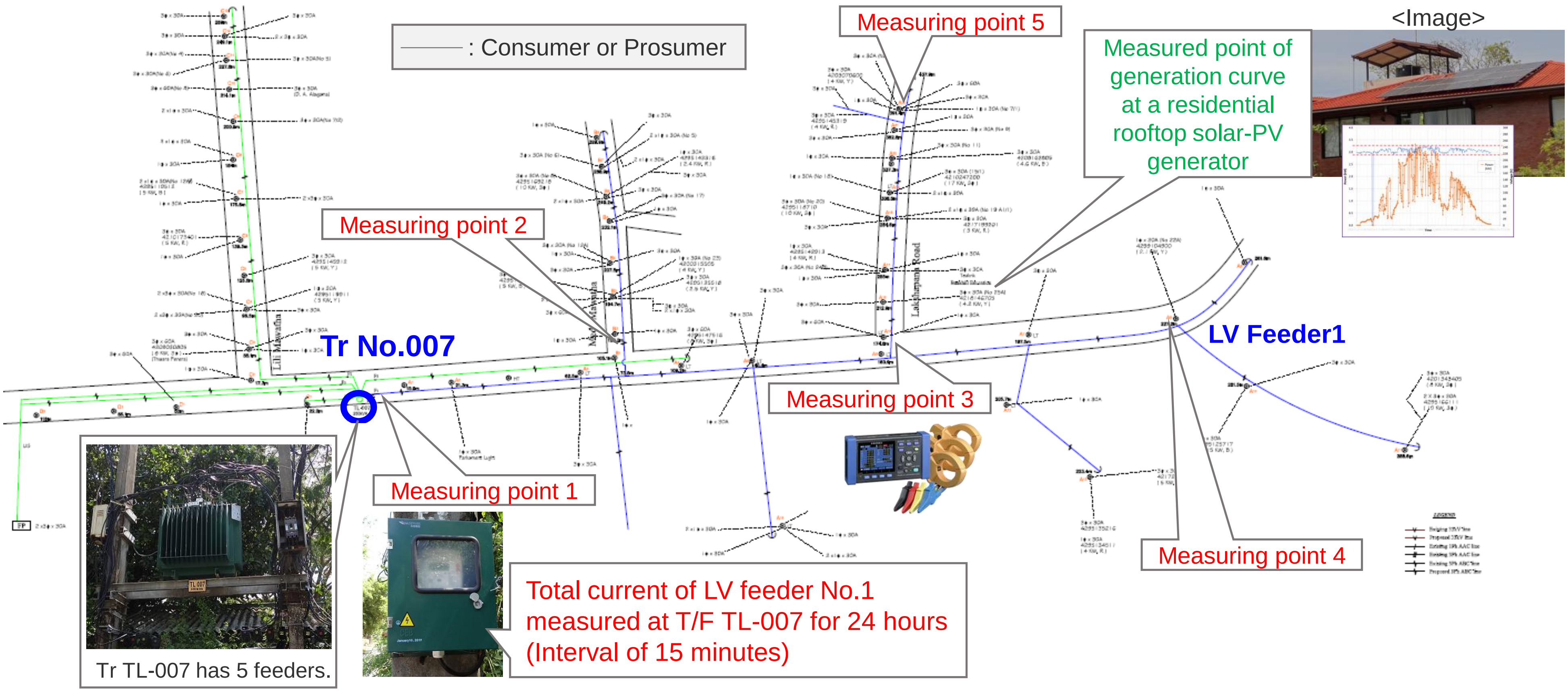
LV Feeder No.1 of TL-007 Transformer in Ethulkotte



WG3: Progress of Activities (WG3-2, Continued)

- Measure and analyze the voltage fluctuation in **<u>No.1 LV feeder of TL-007 transformer in Ethulkotte</u>** to estimate cost effectiveness comparison between BESS and conventional countermeasures.
  - Most of necessary data and information were obtained for modeling and analyze.
  - Measurement data are being prepared to estimate load fluctuation.

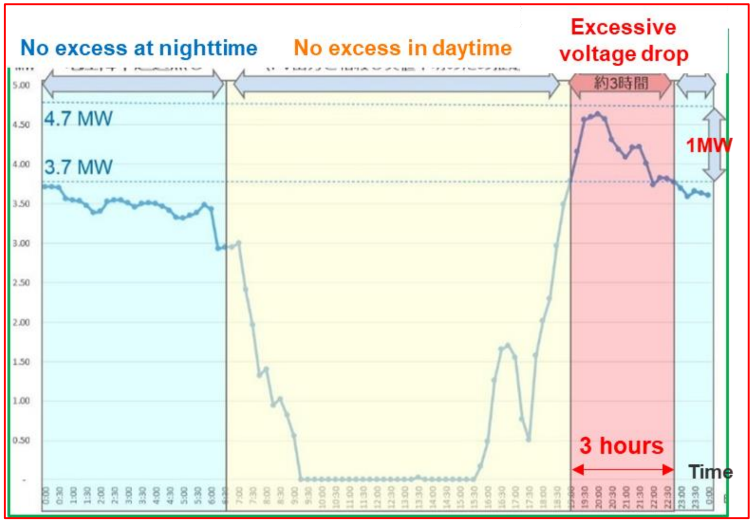
<u>Lots of DER (residential rooftop solar PV generators) are interconnected to the LV feeder No.1.</u>



05-2 Progress of the Technical Transfer (WG3-2)

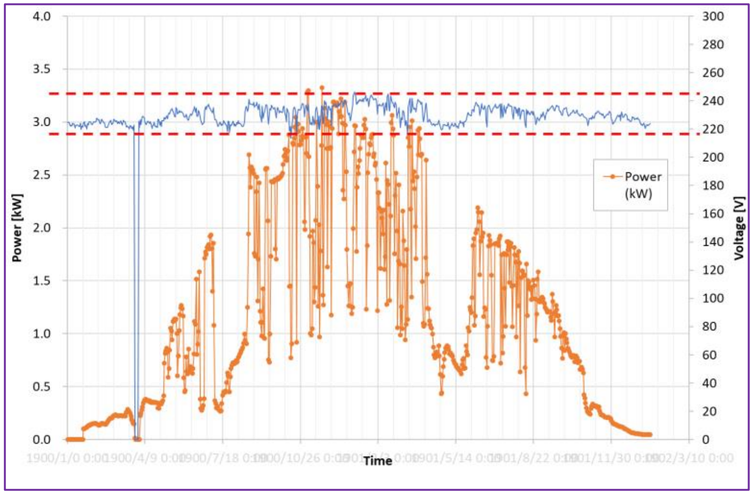
WG3: Technical Transfer (WG3-2)

- ✓ The experiences in Japan in terms of power/voltage fluctuation by VRE in both MV and LV networks.
- ✓ In terms of MV network, measurement and analysis on 33 kV Valachchenai F5 and estimation of necessary BESS (may need 1 MW-3 hours class). this pilot project was dropped due to budget constraints of the high capacity requirement of the battery storage. Accordingly, It was decided to have measurement on LV feeders



Power flow at the boundary meter point between DD1 and DD2 in 33 kV Seethawaka Feeder 5 having 12 MW class solar-PV generator

- ✓ In terms of LV network, measurement and analysis on No.1 LV feeder of TL-007 transformer in Ethulkotte and cost effectiveness comparison between BESS and conventional countermeasures.



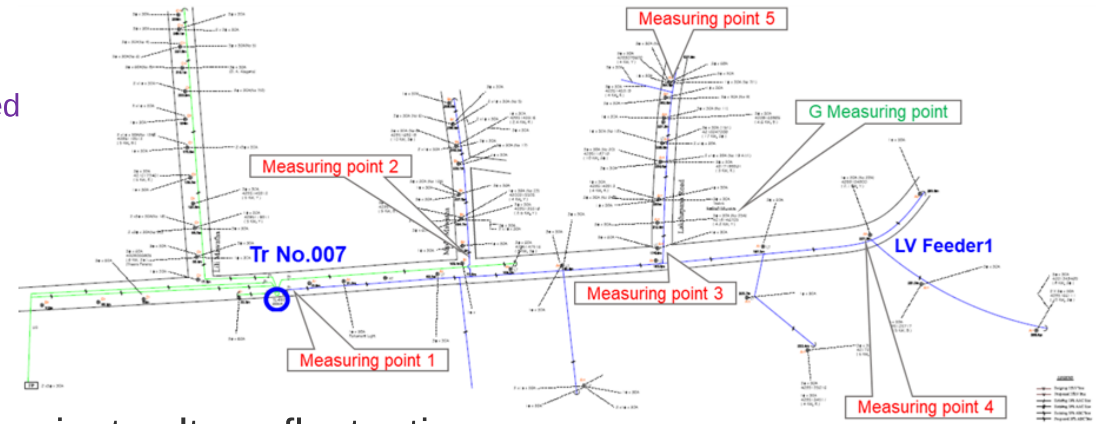
Generation curve and voltage fluctuation of an residential rooftop solar-PV at an prosumer in the No.1 LV feeder of TL-007 transformer in Ethulkotte

- ➢ **C/Ps will share their experienced and obtained measuring and analyzing capabilities to the other C/Ps to measure and analyze power/voltage fluctuation.**

05-3 Way to Move Forward (WG3-2)

WG 3-2: Activities to Achieve the Targets

- Collected the connected load and generation capacities along the feeder and their monthly consumption.
- Measure power/voltage fluctuation at rooftop solar-PV generators of residential prosumers.
  - Generation curves in sunny, cloudy(obtained) and rainy days
- Measure power/voltage fluctuation at the outgoing point(obtained), two major branching points, two end points.
  - Load-generation combined fluctuations for 24 hours at both weekday and weekend obtained



- Check the connection phase of 1ϕ consumers to estimate phase unbalance more exactly (Obtained).
- Consider suppression way such as BESS and conventional countermeasures against voltage fluctuations
- Estimate and compare their suppression effects against voltage fluctuation by the prepared model.
- **Share the results and knowledge one another**

WG 3-2: Schedule from Now on

Year	2022			2023
Month	4-6	7-9	10-12	1-3
WG3-2 Load fluctuation suppression	Survey to obtain necessary information (including connection phase) for modeling Measure power/voltage fluctuation (load-generation combined) at major points Measure actual generation curves at residential rooftop solar-PV generators Consider suppression way against fluctuations Estimate and compare suppression effects Share the result and knowledge			

06 Training in Japan

Schedule of the Training in Japan (Tentative)

Training is basically conducted through OJT (WG Activities) and Seminars (Technical Seminar, System and Policy Seminar), on the contrary, contents that are more effective if they are conducted in Japan are organized in Japan.

- Condition of training in Japan: No restriction and influence of COVID-19 on flights, immigration, site visit, etc.
- The trainings for WG1, WG2 and WG3 will be conducted at once.

No.	Themes	Tentative schedule	Prospective trainees
1	Electric Power Technology, System and Policy (WG1)	December,2022※	12 executives※ (MOPE (2), PUCSL (1), SEA (1), CEB (8))
3	Power system planning and operation, Management of the power supply and demand (WG2)		CEB's Engineer; 6 members
2	Distribution facilities (WG3)		10 members※

※Under consideration

Training Items in Japan(Tentative: December 2022)

CHUBU Electric Power
NIPPON KOEI

Purpose

- To learn the technologies of power supply systems
- To understand equipment of power transmission, substation and distribution by the introduction of Japanese technologies
- To understand the outline of human resource development and training system in Japan

Date	WG1（12 persons※）		WG2 (6 persons)		WG3-1/WG3-2 total 10 persons※	
	Contents	Accommodation	Contents	Accommodation	Contents	Accommodation
Day1 Tue.	Arrival in Narita Move to Sendai	Sendai	Same as WG1	Sendai	Same as WG1	Sendai
Day2 Wed.	Briefing Lecture: Outline of CEPCO Visit: Nishi-Sendai Battery Substation(Li-ion) Move to Tokyo	Tokyo	Same as WG1	Tokyo	Same as WG1	Tokyo
Day3 Thu.	Visit & Lecture: Japan Weather Association	Tokyo	Same as WG1 Move to Shizuoka	Shizuoka	Same as WG1 Move to Shizuoka	Shizuoka
Day4 Fri.	Visit: Toshiba factory (battery) Visit: Biomass power station	Tokyo	Visit: Meidensha factory (PV) Visit: Higashi-Shimizu FC substation Move to Nagoya	Nagoya	Same as WG2	Nagoya
Day5 Sat	Holiday	Tokyo	Holiday	Nagoya	Holiday	Nagoya
Day6 Sun.	Move to Nagoya	Nagoya	Holiday	Nagoya	Holiday	Nagoya

※Under consideration

(Continued on next page)

Training Items in Japan(Tentative)

Date	WG1（12 persons※）		WG2 (6 persons)		WG3-1/WG3-2 total 10 persons※	
	Contents	Accommodation	Contents	Accommodation	Contents	Accommodation
Day7 Mon.	Visit: Human Resource Developing Center	Nagoya	Same as WG1	Nagoya	Same as WG1	Nagoya
Day8 Tue.	Visit: Customer Service Center Visit: Chubuseiki factory (Smart meter)	Nagoya	Visit: Research & Development Center Visit: Toenec Safety Creation Center	Nagoya	AM: Same to WG1 PM: Same to WG2	Nagoya
Day9 Wed.	Visit: NGK Insulators (NAS battery) JICA Chubu Wrap-up meeting	Nagoya	Visit: Analog Simulator facility Visit: Meijo-substation (Underground substation)	Nagoya	Visit: R&D Center Visit: Aichi Electric Factory (TSS, SVR, BES, etc.)	Nagoya
Day10 Thu.	Move to Narita Departure to Sri Lanka	—	Visit: Okuyahagi Pumped Storage Hydropower Station Visit: Customer Service Center	Nagoya	Visit: Nippon Kouatsu Electric factory (GFD, OCI, etc.) Same to WG2	Nagoya
Day11 Fri.			Visit: NGK Insulators (NAS battery) JICA Chubu Wrap-up meeting	Nagoya	Same as WG2	Nagoya
Day12 Sat.			Move to Narita Departure to Sri Lanka	—	Same as WG2	—

※Under consideration

CHUBU
Electric Power

NIPPON KOEI

Minutes of Meeting

of

The 3rd Joint Coordination Committee

on

The Project for Capacity Development on the Power Sector Master Plan Implementation Program in Sri Lanka

JICA Expert Team of "The Project for Capacity Development on the Power Sector Master Plan Implementation Program in Sri Lanka (hereinafter referred to as "the Project")" organized by the Japan International Cooperation Agency (hereinafter referred to as "JICA"), headed by Mr. Akira HIRANO, has conducted the 3rd Joint Coordination Committee (hereinafter referred to as "JCC") on July 05, 2022.

During JCC, JICA Expert Team had a series of discussions and exchanged views with Ceylon Electricity Board (hereinafter referred to as "CEB") and with the institutions concerned, with respect to the technical and operational issues in the Project and measures to be taken by both sides for smooth implementation of the Project.

As a result of the discussions, both sides agreed on the matters referred to the document attached hereto.

July 05, 2022

平野 昭

Mr. Akira HIRANO
Project Team Leader
JICA Expert Team

高嶋 清史

Mr. TAKASHIMA Kiyofumi
Senior Representative
JICA Sri Lanka

Mr. M. P. D. U. K. Mapa Pathirana
Secretary
Ministry of Power

Attachment

1. **Opening Remarks from Mr. Sugath Dharmakeerthi, Additional Secretary(Power Generation, Transmission and Distribution), Ministry of Power and Energy**
   - ✓Sincere thanks to JICA for support. Project is final stage of implementation. Each WG (Working Group) will submit report successfully. Objective is consistent with national policy of government 70% RE (Renewable Energy) by 2030.
   - ✓Battery energy storage system project in WG3 is unable to implement under tough situation unfortunately, but battery is essential component for RE development.

2. **Opening Remarks from Mr. TAKASHIMA Kiyofumi, Senior Representative, JICA Sri Lanka**
   - ✓We are facing severe financial crisis, Energy shortage. Internal conflict, Tsunami hit in 2004. But Sri Lanka has overcome one by one and achieved economic prosperity.
   - ✓Under current situation, RE development is needless to say important and we must carry out technical cooperation successfully. We had discussion regarding Technical and economic, institutional, political matter, and it is meaningless if we do not move to actual implementation. Today's Meeting is good opportunity to deepen understanding for project achievement and to think together how to realize and achieve RE development in the future.

3. **Presentation of Progress of the Project for WG1 Activities**

Presenter: Mr. Akira HIRANO, WG1 Team Leader, JICA Expert Team

(J I C A) : To CEB WG1 member, could you explain your plan how to get an approval of FIT(Feed In Tariff) revision?

(C E B) : From 07.03.2022 onwards Central Bank of Sri Lanka allowed the USD a free float in the financial market and then onwards we are experiencing following drastic changes related to investment parameters,

1. Devaluation of LKR against US Doller (almost 80% devaluation within last 12 months)
2. Yearly Inflation percentage reaching almost 40%, which was around 6% until December 2021.
3. Interest rates, both AWPLR (average weighted primary lending rate) and risk free Treasury Bill rates as well as government bonds reaching all time high values of 16.38%, around 21%-23% for 90days bills and 13% for 12year bonds respectively.

All above figures indicate that it is not the best time to try to calculate a tariff for 20year period, when the investment parameters are changing rapidly in a very volatile local economic situation. Even though the USD denominated cost items (solar panels, inverters etc.) remain almost unchanged, other factors have changed very rapidly and still the situation is not that much stable.

While we appreciate your efforts in introducing the calculation sheet for revision of the R/Top (Roof Top) FIT formula, if we try to apply the current parameters, the tariff would be even more than the existing rate. One of the main reasons of introducing the change of R/Top FIT scheme was that the price prevalent (Rs. 22/kWh and Rs. 15.50/kWh) was excessive considering the cost/investment parameters prevailed about 6 months before. But now the changes in the local economic situation is very much volatile. Further, CEB has not yet been allowed an increase in the electricity sales tariff either.

Therefore, it is better to wait for some time to let the economic situation to settle down at least to some extent before CEB try to introduce revision of the FIT for R/Top Solar.

(Answered by Mr. Perera after the JCC)

4. **Presentation of Progress of the Project for WG2 Activities**

Presenter: Dr. Suresh Chand Verma, WG2 Team Leader, JICA Expert Team

✓No Question or Comment.

5. **Presentation of Progress of the Project for WG3-1 Activities**

Presenter: Mr. Yukihiro KAMIYA, WG3 Deputy Team Leader, JICA Expert Team
Mr. P.H.L.J.Ranasinghe, WG3-1 sub-Leader of management, CEB

✓No Question or Comment.

6. **Presentation of Progress of the Project for WG3-2 Activities**

Presenter: Dr. Koji SHIKIMACHI, WG3 Team Leader, JICA Expert Team
Ms. M. Ganes, WG3-2 Team Leader, CEB
Mr. K.P.J.P. Premathilake, WG3-2 member, CEB

✓No Question or Comment.

7. **Cancellation of FLS(Fault Locating System) and TSS(Time Sequential Sectionalizer) Pilot Project**

Due to the Economic Crisis in Sri Lanka, CEB and LECO decided to cancel the FLS and TSS Pilot Project. JCC members agreed the cancellation of the equipment procurement for FLS and TSS accordingly. The project will terminate by March 2023 as originally scheduled.

8. **Modification of PDM(Project Design Matrix)**

・Based on the cancellation of FLS and TSS Pilot Project, the PDM was revised.
The revised items are shown below. (The revised or added sections are underlined in Annex-4.)

✓ Practical values of SAIDI(System Average Interruption Duration Index) and SAIFI(System Average Interruption Frequency Index) in 2026 will be set after evaluation of investment cost effectiveness based on the Pilot Project of OCI(Over Current Indicator), ARC(Abrasion Resistance Cover) and GFD(Ground Fault Detector) only. TSS and FLS are excluded from the Pilot Project.

✓Expected effectiveness of TSS/FLS Pilot Projects is being estimated within this project.

✓Pilot Projects of TSS and FLS are eliminated from the Activity 3-1-3.

・In addition, the following items are revised and added according to past Activity. (The revised or added sections are underlined in Annex-4.)

✓The response ability for load fluctuation is being confirmed within this project by modeling. (refer to Minutes of Meeting of 5th Activity)

✓ Electric Power Measuring Instruments was procured alternatively, to enhance capability of measuring and analyzing load fluctuation by VRE(Variable Renewable Energy).(refer to Minutes of Meeting of 5th Activity)

✓The target values (SAIDI and SAIFI) of Pilot Project are added.(refer to Minutes of Meeting of

10th Activity)

✓Pilot Projects of BESS is eliminated from the Activity 3-2-2.

9. Training in Japan

Presenter: Mr. Toshitaka YOSHIDA

✓CEB and JICA Expert Team tentatively agreed that the training in Japan will be conducted as below concerning the COVID-19 influence in the World Wide.

✓The training in Japan for WG1, WG2 and WG3 will be conducted at once.

	Themes	Tentative Schedule	Prospective Trainees
WG1	Electric Power Technology, System and Policy	December, 2022	Twelve (12) executives (MOPE (2), PUCSL (1), SEA (1), CEB (8))
WG2	Power system planning and operation, Management of the power supply and demand		CEB's Engineer; Six (6) members
WG3	Distribution facilities		CEB/LECO's Engineer; Ten (10) members

✓CEB and JICA Expert Team agreed the conditions for conducting trainings in Japan.

- No restriction and influence of COVID-19 on flights, immigration, and site visit.

✓JICA HQs agreed to accept the number of trainees in the table above.

10. Closing from Mr. Akira HIRANO, Team Leader, JICA Expert Team

Now is the tough condition to proceed the project as scheduled however piling up what we can do is very important, which finally leads to the big success. We believe this condition will not continue forever. To prepare for the timing when this condition will finish is meaningful. We should proceed this phase 2 so that we will be able to make the rapid start at that time. Unlike 1st phase which JICA experts led, in 2nd phase, you will be the main players and we will support you. I hope you will have a big achievement through this activity.

11. Electronic signature

The parties acknowledge and agree that this Minutes of Meetings may be executed by electronic signature, which is considered as an original signature for all purposes and has the same force and effect as an original signature. "Electronic signature" includes faxed versions of an original signature or electronically scanned and transmitted versions (e.g., via pdf) of an original signature.

Annex- 1: Agenda of the 3rd JCC
Annex- 2: Progress Report
Annex- 3: Participants List
Annex- 4: Revised PDM
Annex- 5: Minutes of Meeting of the Second Joint Coordination Committee

(End)

Participant list for 4th Joint Coordination Committee
on
"The Project for Capacity Development on the Power Sector Master Plan Implementation Program in Democratic Socialist Republic of Sri Lanka"

Date: November 22, 2022

〇Counterparts (Sri Lanka)

	Name	Position Organization	Contact E-mail address
1	Mr. M P D U K Mapa Pathirana	Secretary, Ministry of Power and Energy	
2	Mr. Sugath Dharmakeerthi	Additional Secretary (Power Generation, Transmission and Distribution), Ministry of Power and Energy	
3	Mr. P. W. Hendahewa	Additional General Manager (Transmission Non-Wired Operations), CEB	
4	Mr. Eng. H. S. Somathilaka	Additional General Manager (Projects), CEB	
5	Mr. M. L. Weerasinghe	Deputy General Manager (Trans. & Gen. Planning), CEB	
5	Mr. K. K. P. Perera	Deputy General Manager (Renewable Energy Development), CEB	
6	Ms. Sandhya Diddeniya	Project Director (NTDNDEIP), CEB	
7	Mr. V. B. Wjjekoon	Chief Engineer (Generation Planning), CEB	
8	Ms. K. V. S. M. Kudaligama	Chief Engineer (Tariff), CEB	
9	Ms. M Ganes	Chief Engineer (Planning Development) DD4, CEB	
10	Ms. U. G. J. K. Gamlath	Chief Engineer (Planning & Development) DD1, CEB	
11	Mr. P. S. Fonseka	Chief Engineer (Generation Development Studies), CEB	
12	Mr. R. M. J. Rathnayake	Chief Engineer (Planning & Development) WPN, DD2, CEB	
13	Mr. Lasith Ranasinghe	Chief Engineer (Southern Province), DD4, CEB	

	Name	Position Organization	Contact E-mail address
14	Mr. D.M.D. Ranawaka	CE (Planning and Development) -WPSII, CEB	
15	Ms. Anusha Selvarasa	Electrical Engineer (Northern Province), DD1, CEB	
16	Mr. K. M. C. P. Kulasekara	Electrical Engineer (System Studies), CEB	
17	Mr. G.B. Alahendra	Electrical Engineer (Transmission Planning), CEB	
18	Mr. M. D. R. K. Karunarathne	Electrical Engineer (Plant Scheduling), CEB	
19	Mr. K.A.M.N. Pathirathna	Electrical Engineer (Generation Planning), CEB	
20	Ms. W. G. Pawithra	Electrical Engineer (Transmission Planning), CEB	
21	Mr. K. P. J. P. Premathilake	Electrical Engineer (Development) DD3, CEB	
22	Ms. H. G. N. Sandamali	Electrical Engineer (Planning) WPSII, DD3, CEB	
23	Ms. H. D. K. Herath	Electrical Engineer (Transmission Planning), CEB	
24	Mr. B. P. L. De Silva	Electrical Engineer, CEB	
25	Mr. Tharindu De Silva	System Development Engineer, LECO	
26	Mr. J. M. Athula	Director General, SLSEA	
27	Ms. Poornima Kalhari	Assistant Director, SLSEA	
28	Mr. K. Siriwardana	Director, Tariff and Economic Affairs, Public Utility Commission of Sri Lanka	
29	Mr. Hasanka Kamburugamuwa	Deputy Director - Economic Studies, Public Utility Commission of Sri Lanka	
30	Mr. Sameera Adikaram	Deputy Director - Security of Supply, Public Utility Commission of Sri Lanka	

○JICA(Japan International Cooperation Agency)

	Name	Position Organization	Contact E-mail address
1	Mr. Akira SATO	Director, Team 1, Energy and Mining Group, Infrastructure Management Department	
2	Ms. Kuri SHIBATA	Infrastructure Management Officer, Team 1, Energy and Mining Group, Infrastructure Management Department	
3	Ms. Yuka KITAMATSU	South Asia Department	
4	Mr. Tadayuki OGAWA	Senior Advisor	
5	Ms. Yuri IDE	Senior Representative, Sri Lanka Office	
6	Mr. Tsuyoshi MIZUNO	Representative, Sri Lanka Office	

○JICA Expert Team (Chubu Electric Power Co., Inc. and Nippon Koei Co., Ltd.)

	Name	Position Organization	Contact E-mail address
1	Mr. Akira HIRANO (Team Leader / Electric Power Strategy)	Senior Manager, Chubu Electric Power Co., Inc.	
2	Mr. Toshitaka YOSHIDA (Deputy Team Leader / Electric Power Strategy)	Manager, Chubu Electric Power Co., Inc.	
3	Mr. Osamu TANIHATA (System and Policy of Electric Power)	Senior Manager, Chubu Electric Power Co., Inc.	
4	Dr. Suresh Chand Verma (Supply and Demand Management)	Senior Manager, Chubu Electric Power Co., Inc.	
5	Dr. Koji SHIKIMACHI (Distribution Technology)	Manager, Chubu Electric Power Co., Inc.	
7	Mr. Yukihiro KAMIYA (Distribution (Planning/Design/Construction) / Coordinator)	Manager, Chubu Electric Power Co., Inc.	
8	Mr. Shinichirou YAMAGA (Power System (System Analysis))	Assistant Manager, Chubu Electric Power Co., Inc.	
9	Mr. Ryunosuke MIZUNO	Assistant Manager, Chubu Electric Power Co., Inc.	
11	Mr. Shogo TAKADA	Assistance Manager, Chubu Electric Power Co., Inc.	
12	Mr. Masaki WADA	Deputy Chief Engineer, Nippon Koei Co., Ltd.	
13	Mr. Yasushi MOMOSE	Nippon Koei Co., Ltd	
14	Mr. Yusaku MAKITA (Finance)	Chubu Electric Power Co., Inc. (Group Leader/ Senior Economist, Koei Research & Consulting Inc.)	
15	Mr. Muneo MATSUKAWA (Meteorological Forecast / Demand Forecast)	Chubu Electric Power Co., Inc. (Executive Engineer, Japan Weather Association)	
16	Mr. Atsushi TAKAMASU	Japan Weather Association	

Long Term Generation Expansion Plan

2023-2042

Generation Planning Unit
Transmission & Generation Planning Branch
Ceylon Electricity Board

Background

2021 July

Conditionally approved !!!

2021 July-September

Key Highlights of Sri Lanka's Nationally Determined Contributions and Vision for a Low Carbon Future

Sri Lanka is highly vulnerable to the adverse impacts of climate change. The country focuses on building the resilience of **Agriculture, Fisheries, Livestock, Health, Water, Biodiversity, Coastal and Marine, Tourism, Urban Planning and Human Settlement** sectors

Sri Lanka's per capita greenhouse gas emission in 2010 was **1.02** tons and its global cumulative contribution in 2019 was **0.03%.**

Despite this low carbon footprint and highly vulnerable status, Sri Lanka commits to increase **32%** forest cover by 2030 and reduce greenhouse gas emissions by **14.5%** for the period of 2021-2030 from **Power (electricity generation), Transport, Industry, Waste, Forestry, and Agriculture**

In order to realize this ambitious target, Sri Lanka further commits;

- To achieve **70%** renewable energy **in electricity generation** by 2030
- To achieve **Carbon Neutrality** by 2050 in electricity generation
- **No** capacity addition of **Coal** power plants

Sri Lanka has already launched following major initiatives;

- Adopting 'Colombo Declaration on Sustainable Nitrogen Management' with an ambition to halve nitrogen waste by 2030
- Banning agro-chemicals and chemical fertilizer
- Promoting organic fertilizer and farming
- Banning single-use plastics
- Promoting E-mobility
- Promoting circular economy

Sri Lanka expects to achieve its **Carbon Neutrality** by 2050

2021 October

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இலங்கைப் பொதுப் பயன்பாடுகள் ஆணைக்குழு
PUBLIC UTILITIES COMMISSION OF SRI LANKA

ඔබේ අංකය / உமது இல. / Your No. }
අපේ අංකය / எமது இல. / Our No. } PUC/LIC/AP21/01
දිනය / திகதி / Date } 5th October 2021

- To achieve 70% renewable energy in electricity generation by 2030
- To achieve Carbon Neutrality by 2050 in electricity generation
- No capacity addition of Coal power plants

The Commission requires you to submit the Least Cost Long Term Generation Expansion Plan prepared in compliance with the government policy on or before 30th June 2022.

Thank you,
Yours Sincerely,

Public Utilities Commission of Sri Lanka

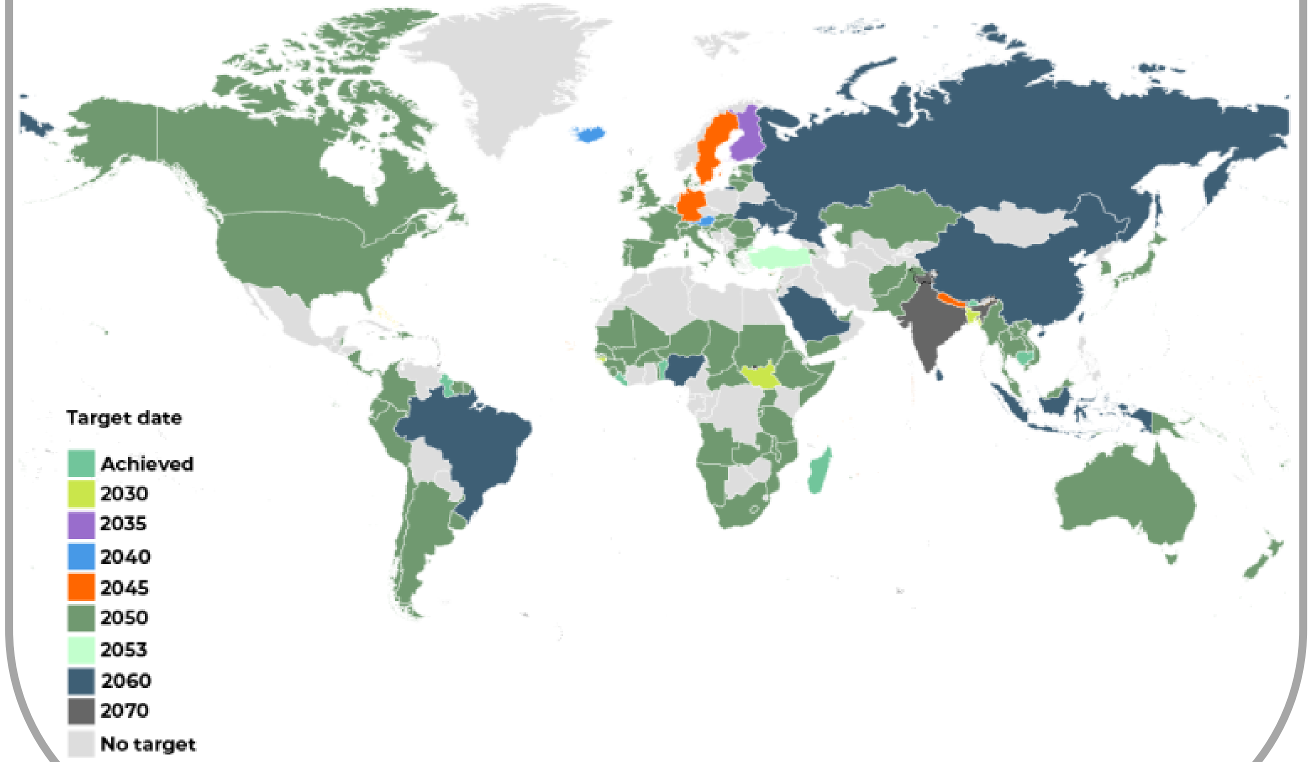
Janaka Ratnayake
Chairman

Global International Commitments

CLIMATE CRISIS

Net zero pledges

More than **137 countries have committed to net zero**. India and Nigeria were the latest nations to make the pledge at COP26, with India expecting to reach the target by 2070.



CLIMATE

Pledge to quit coal

At COP26, more than 40 countries have pledged to shift away from coal

Afghanistan	Cook Islands	Iraq	Mozambique	Slovenia
Albania	Costa Rica	Ireland	Myanmar	Solomon Islands
Algeria	Côte d'Ivoire	Israel	Namibia	Somalia
Andorra	Croatia	Italy	Nauru	South Africa
Angola	Cuba	Jamaica	Nepal	South Sudan
Antigua & Barbuda	Cyprus	Japan	Netherlands	Spain
Argentina	Czech Republic	Jordan	New Zealand	Sri Lanka
Armenia	Denmark	Kazakhstan	Nicaragua	Sudan
Australia	Djibouti	Kenya	Niger	Suriname
Austria	Dominica	Kiribati	Nigeria	Eswatini
Azerbaijan	Dominican Republic	North Korea	Niue	Sweden
Bahamas	Ecuador	South Korea	Norway	Switzerland
Bahrain	Egypt	Kuwait	Oman	Syria
Bangladesh	El Salvador	Kyrgyzstan	Pakistan	Tajikistan
Barbados	Equatorial Guinea	Laos	Palau	Tanzania
Belarus	Eritrea	Latvia	Palestine	Thailand
Belgium	Estonia	Lebanon	Panama	Timor-Leste
Belize	Ethiopia	Lesotho	Papua New Guinea	Togo
Benin	European Union	Liberia	Paraguay	Tonga
Bhutan	Fiji	Libya	Peru	Trinidad & Tobago
Bolivia	Finland	Liechtenstein	Philippines	Tunisia
Bosnia & Herzegovina	France	Lithuania	Poland	Turkey
Botswana	Gabon	Luxembourg	Portugal	Turkmenistan
Brazil	Gambia	North Macedonia	Qatar	Tuvalu
Brunei	Georgia	Madagascar	Romania	Uganda
Bulgaria	Germany	Malawi	Russia	Ukraine
Burkina Faso	Ghana	Malaysia	Rwanda	United Arab Emirates
Burundi	Greece	Maldives	St. Kitts & Nevis	United Kingdom
Cambodia	Grenada	Mali	St. Lucia	United States
Cameroon	Guatemala	Malta	St. Vincent & Grenadines	Uruguay
Canada	Guinea	Marshall Islands	Samoa	Uzbekistan
Cape Verde	Guinea-Bissau	Mauritania	San Marino	Vanuatu
CAR	Guyana	Mauritius	São Tomé & Príncipe	Venezuela
Chad	Haiti	Mexico	Saudi Arabia	Vietnam
Chile	Honduras	Micronesia	Senegal	Yemen
China	Hungary	Moldova	Serbia	Zambia
Colombia	Iceland	Monaco	Seychelles	Zimbabwe
Comoros	India	Mongolia	Sierra Leone	
DRC	Indonesia	Montenegro	Singapore	
Congo	Iran	Morocco	Slovakia	

Policy Directives

Ministry of Power

GENERAL POLICY GUIDELINES FOR THE ELECTRICITY INDUSTRY

General Policy Guidelines formulated in terms of Section 5(1) of the Sri Lanka Electricity Act No. 20 of 2009 was approved by the Cabinet of Ministers as required by Section 5(3) of the Said Act at its meeting held on 01.11.2021.

⇩

9. The GOSL has set the targets of achieving 70% of electricity generation in the country using renewable energy sources by 2030 and carbon neutrality in power generation by 2050, and has decided to cease building of new coal-fired power plants. The Cabinet of Ministers has approved these two policy elements that shall form the basis of Sri Lanka's future electricity capacity expansion planning.[1]. Further, new addition of firm capacity will be from clean energy sources such as regasified liquefied natural gas (RLNG).

<u>Repelling of clauses from 2019 General Policy Guideline that reflect.</u>

Removal of firm capacity requirement of 2/3rd of demand of power.

+

Removal of firm capacity mix ratios defined from coal, Natural gas, locally refined oil and Hydro

+

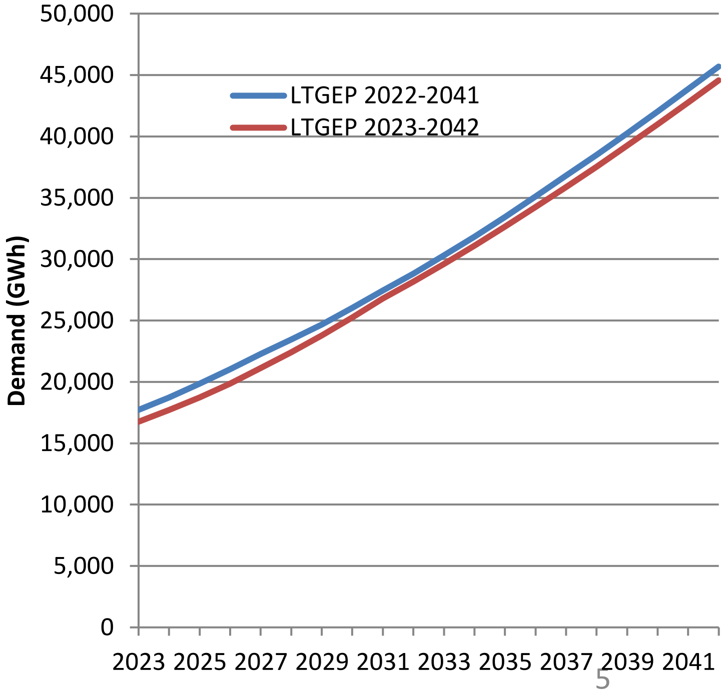
Removal of 1/3rd of demand of power from NCRE sources.

Demand Forecast 2023-2047

Year	Demand	System Loss	Generation	Peak
	GWh	%	GWh	MW
2023	16,741	7.95	**18,186**	**3,021**
2024	17,705	7.89	**19,222**	**3,149**
2025	18,725	7.83	**20,317**	**3,283**
2026	19,854	7.77	**21,526**	**3,432**
2027	21,124	7.70	**22,886**	**3,651**
2028	22,419	7.63	**24,272**	**3,890**
2029	23,794	7.57	**25,741**	**4,127**
2030	25,253	7.50	**27,300**	**4,378**
2031	26,801	7.45	**28,958**	**4,645**
2032	28,165	7.40	**30,415**	**4,880**
2033	29,601	7.35	**31,949**	**5,127**
2034	31,099	7.30	**33,548**	**5,385**
2035	32,646	7.25	**35,198**	**5,652**
2036	34,241	7.25	**36,917**	**5,929**
2037	35,879	7.25	**38,684**	**6,214**
2038	37,547	7.25	**40,482**	**6,504**
2039	39,253	7.25	**42,321**	**6,801**
2040	41,002	7.25	**44,207**	**7,106**
2041	42,777	7.25	**46,120**	**7,415**
2042	44,584	7.25	**48,070**	**7,730**
2043	46,431	7.25	**50,061**	**8,051**
2044	48,321	7.25	**52,098**	**8,380**
2045	50,259	7.25	**54,188**	**8,718**
2046	52,248	7.25	**56,332**	**9,064**
2047	54,315	7.25	**58,560**	**9,426**

Night Peak

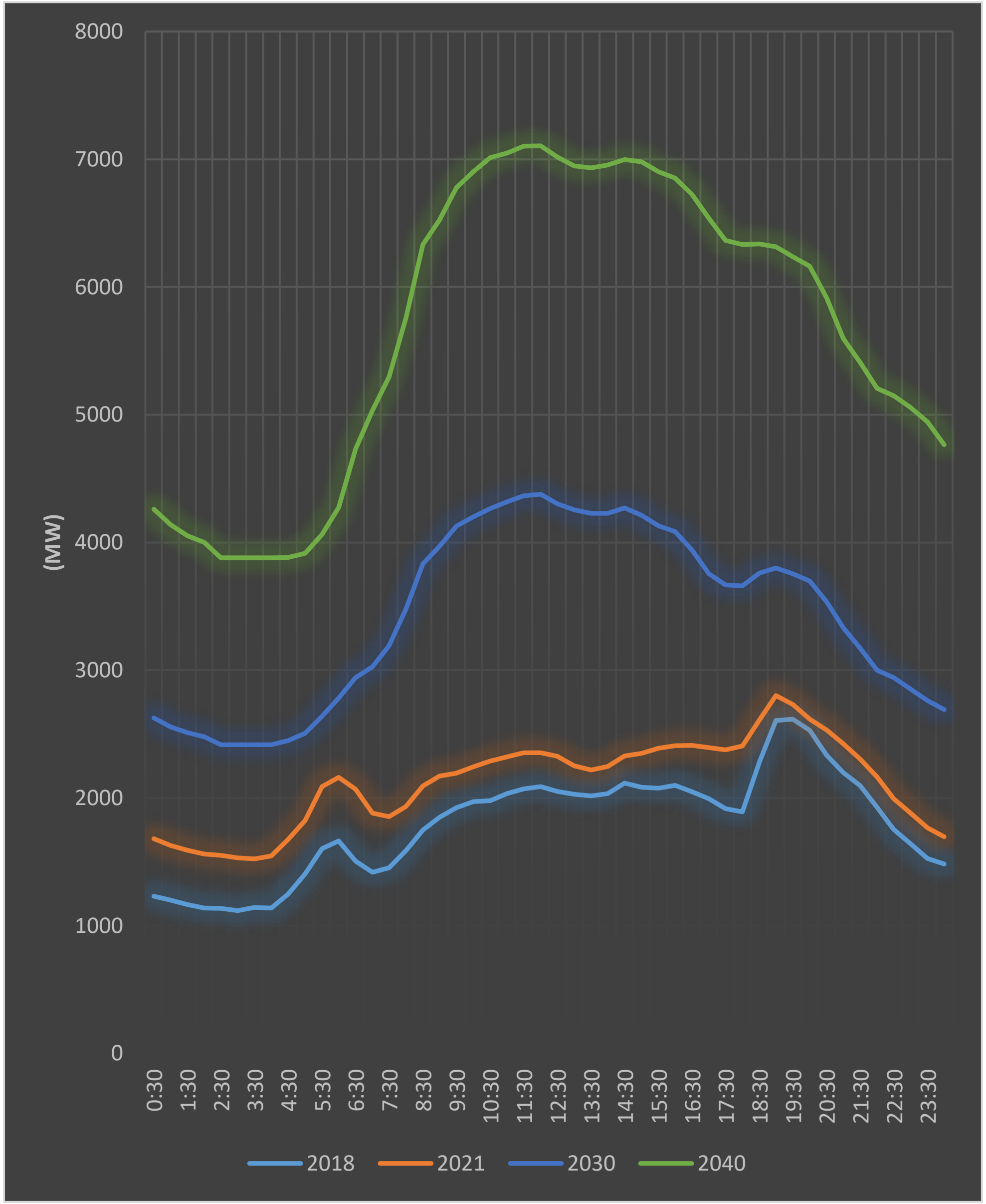
Day Peak



Typical Day Load Curve Pattern

- Day Peak Growth Faster than Night Peak Growth.

- Day peak would surpass the Night peak in year 2026



Consideration in Different timeframes

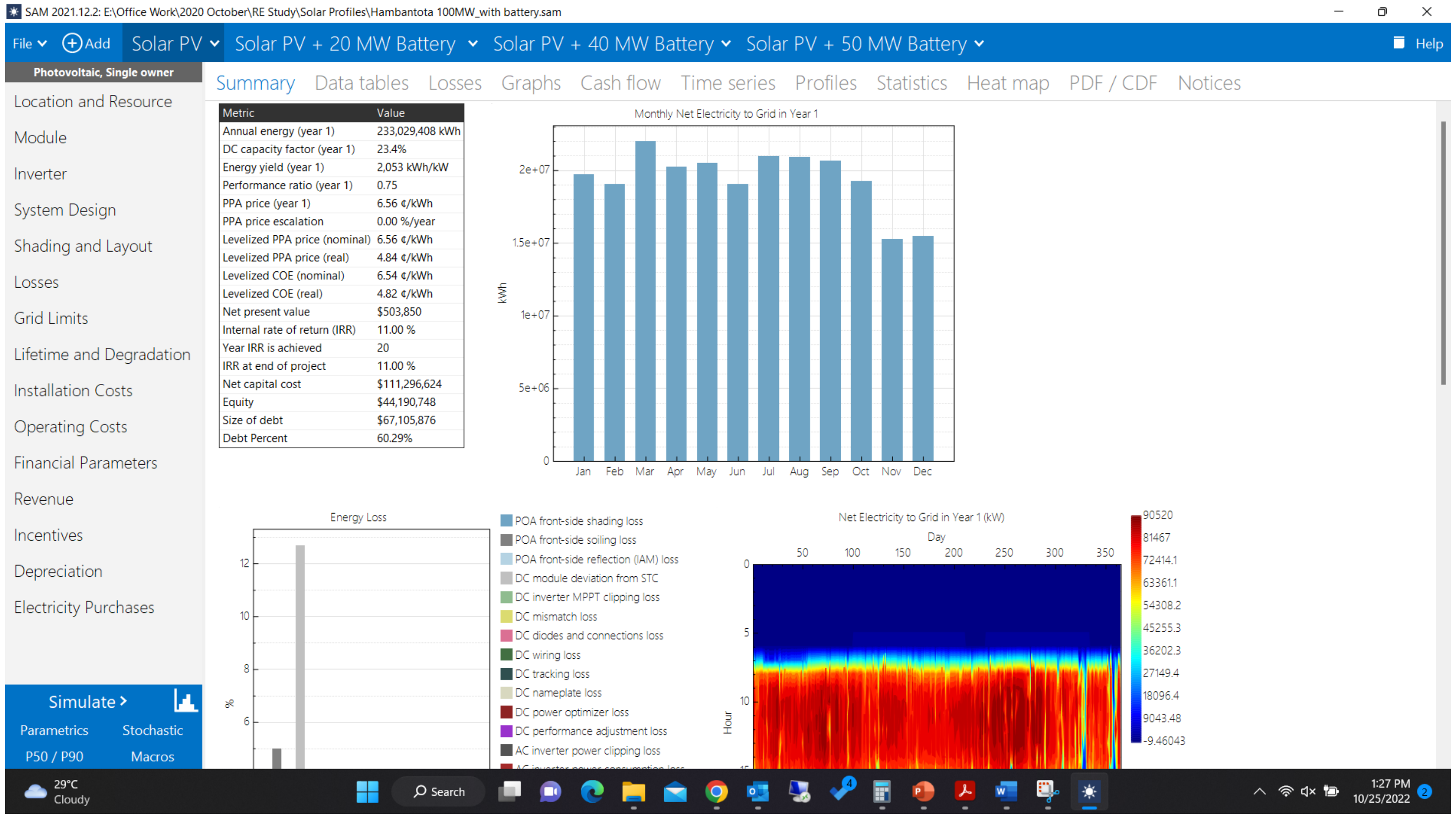
Ultra Short Term	Very Short Term	Short Term	Medium Term	Long Term	Very Long Term
Sub second to second	Second to Minutes	Minutes to Hours	Hours to Days	Days to Months	Months to years
Dynamic Stability (Inertia, Grid Strength)	Primary and Secondary Frequency Control (AGC)	Automatic Generation Control, Economic Dispatch, regulating reserves	Hourly Dispatch, Unit commitment for day ahead	Unit Commitment, Scheduling, Monthly Capacity Adequacy	Hydro Thermal Coordination, Capacity adequacy, System Reliability

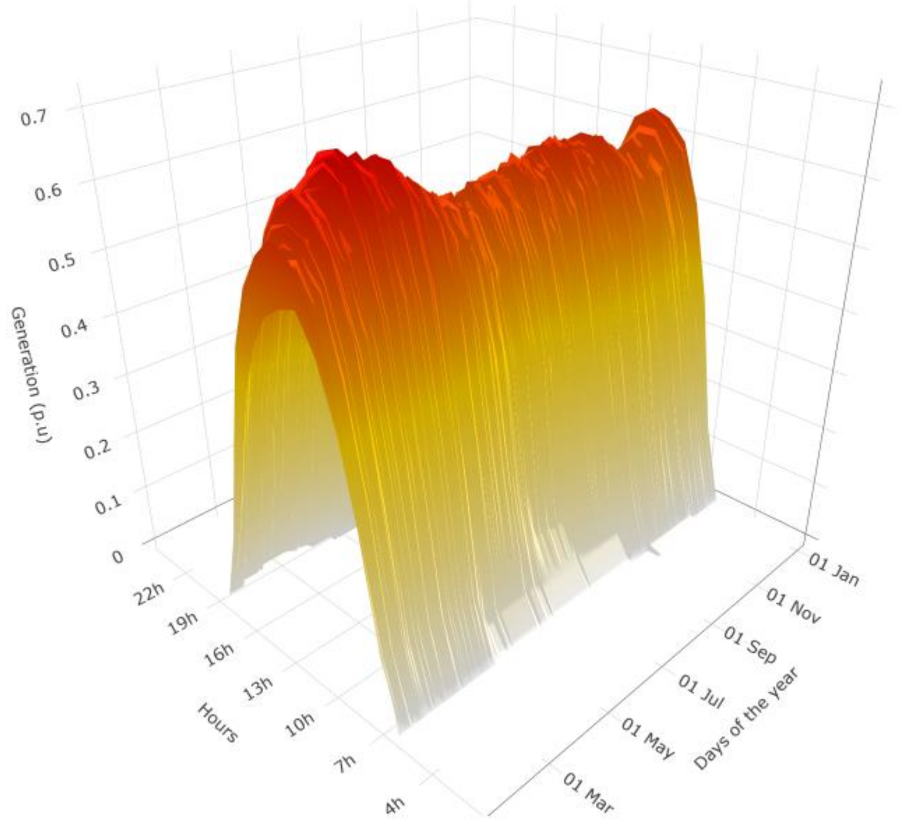
Resource Modelling - Solar Parks

NREL System Advisor Model (SAM)

NATIONAL RENEWABLE ENERGY LABORATORY

- Ground Mounted (Single Axis Tracking) / Floating Solar
- Hybrid Parks with Storage
- Dispatchable with Curtailment Policies





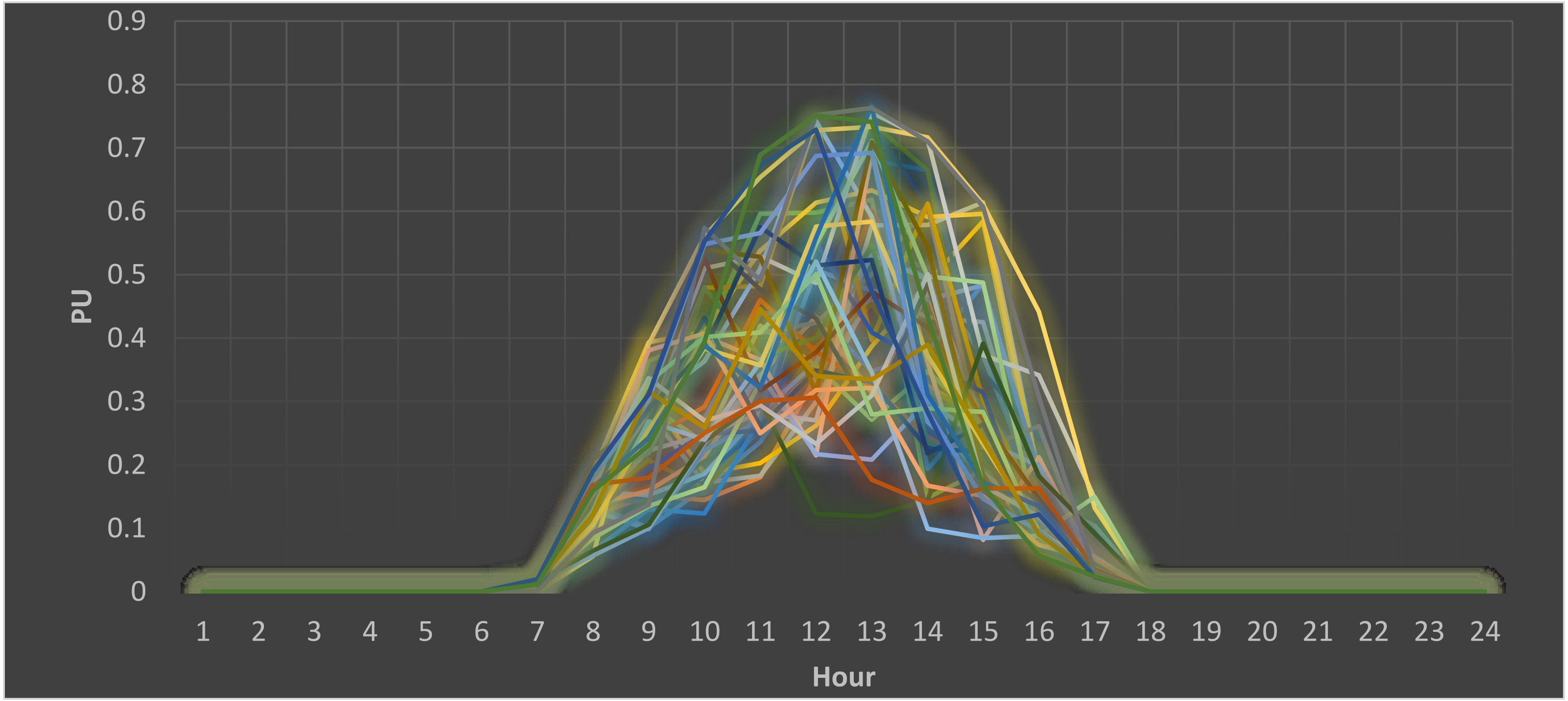
Resource Modelling - Distributed Solar

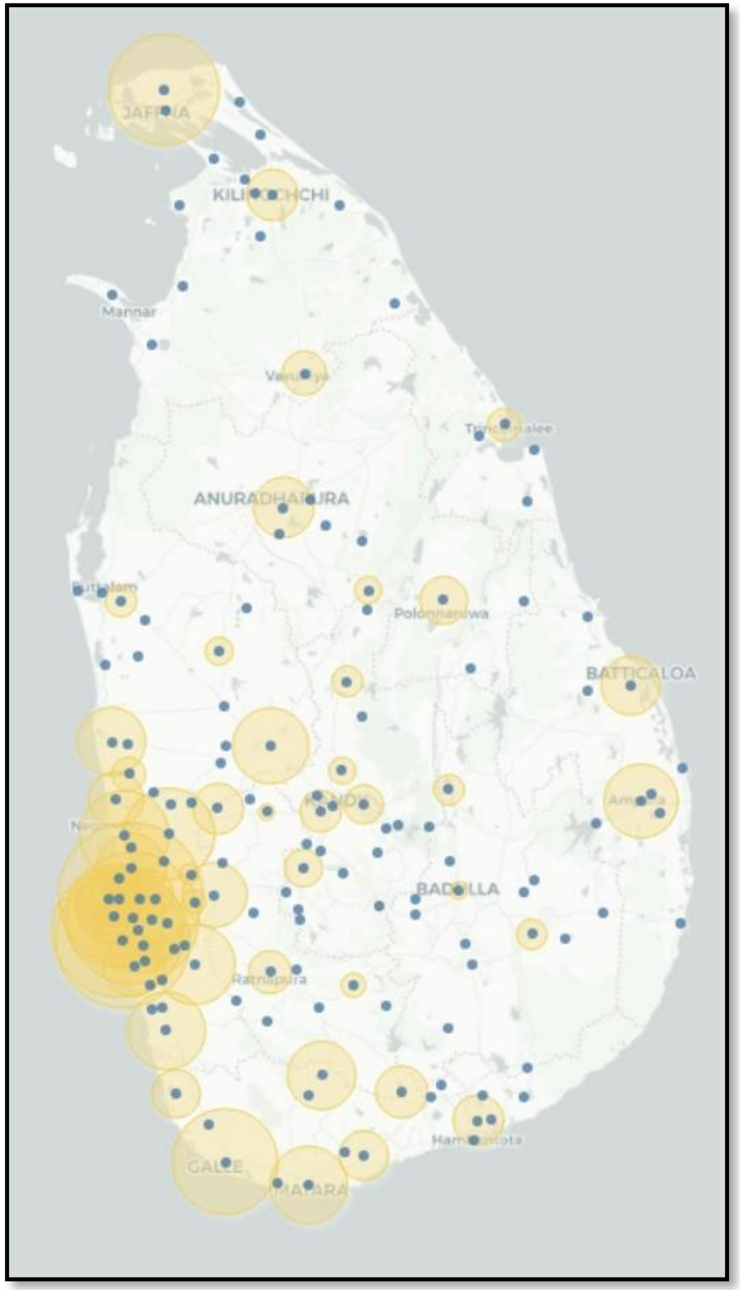
Location	Annual PF
Dehiwala	17.80%
Colombo	17.74%
Katunayaka	17.91%
Bolawatta	17.97%
Madampe	18.08%
Puttalam	18.07%
Panadura	17.49%
Pannipitiya	17.44%
Biyagama	17.39%
Aniyakanda	17.49%
Ambalangoda	18.01%
Kosgoda	17.82%

Location	Annual PF
Horana	16.98%
Veyangoda	16.90%
Pannala	18.03%
Chunnakam	18.50%
Mathugama	17.19%
Kirindiwela	17.35%
Galle	18.23%
Seethawaka	16.98%
Thulhiriya	17.33%
Maho	17.72%
Ratnapura	16.43%
Kegalle	17.21%

Location	Annual PF
Kurunegala	17.48%
Anuradhapura	17.86%
Vavuniya	17.72%
Kilinochchi	17.79%
Matara	18.49%
Deniyaya	16.46%
Nawalapitiya	15.87%
Kiribathkumbura	16.87%
Pallekele	16.89%
Ukuwela	16.52%
Naula	17.22%
Beliatta	18.24%

Location	Annual PF
Balangoda	17.36%
Nuwaraeliya	15.46%
Habarana	17.58%
Embilipitiya	17.80%
Mahiyanganaya	16.75%
Badulla	16.50%
Polonnaruwa	17.60%
Hambanthota	18.95%
Trincomalee	17.93%
Monaragala	17.38%
Ampara	17.69%
Vavunathivu	17.90%

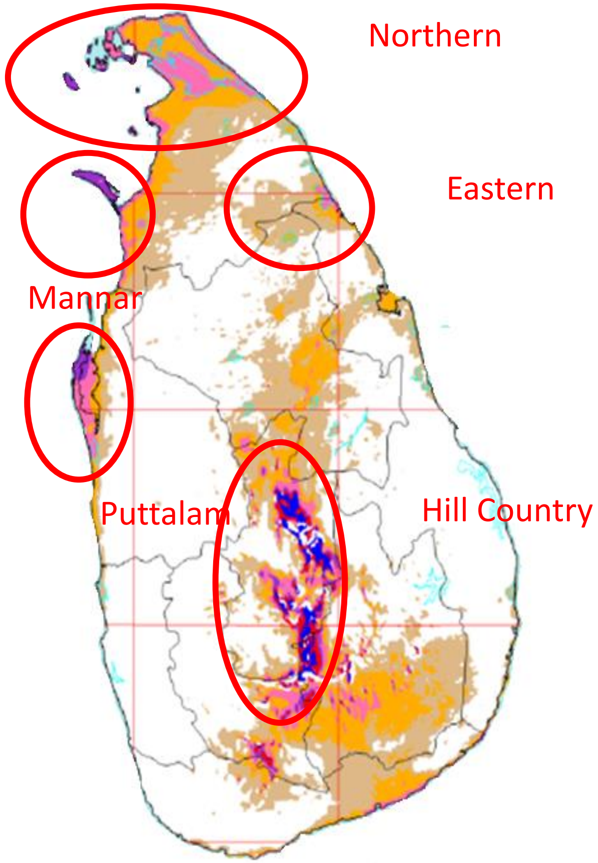




Resource Modelling - Wind

Five wind regimes were identified and wind plants were modelled based on actual site measurements for wind Production estimation

Wind Regime	Annual Plant Factor
Mannar	40.7%
Puttalam	31.4%
Hill country	19.1%
Northern	34.1%
Eastern	27.3%



Highlights of the Base Case Plan

Increased Level of VRE Integration

~ 500 MW Annual Solar PV Capacity Additions

~ 150 MW Annual Wind Capacity Additions

Large Scale Energy Storage Deployment

- **1,400** MW Pumped Storage development by 2032

- **1,125 MW** Battery Energy Storage development by 2030 / **4,670 MW** Battery Energy Storage development by 2042

70% RE TARGET

More Flexible Thermal Generation

- 1,130 MW Gas Turbine Power Plants

- 850 MW IC Engine Power Plants

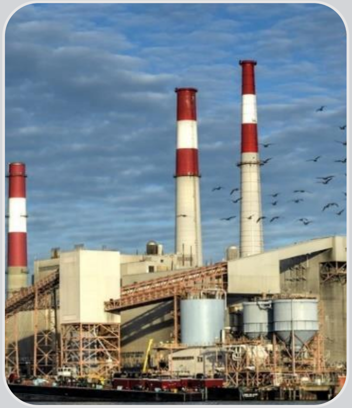
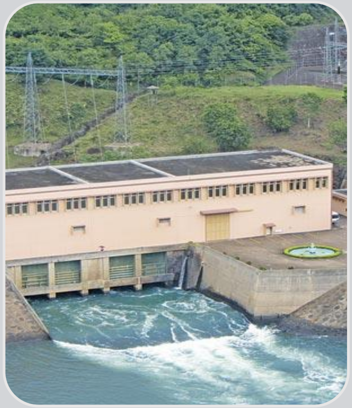
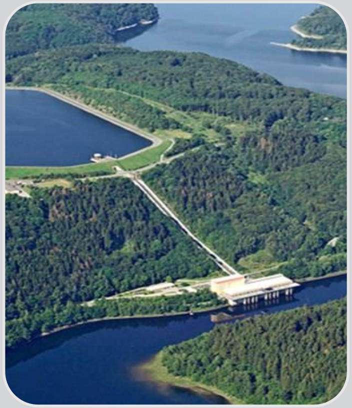
High Initial Investment

- Average annual generation and storage capacity investment of 1.25 USD Billion up to 2030

- Average annual generation and storage capacity investment of 1.43 USD Billion up to 2042

**This investment requirement contains only the investments needed on generation capacity and storage additions.*

Future Capacity Mix at Key Years

	Baseload , Intermediate Thermal	Flexible Thermal Power	Major Hydro	Other Renewable Energy	Grid Scale Battery Storage	Pumped Hydro Storage
	Coal Steam NG Combined Cycle Oil Combined Cycle Other Thermal	Gas Turbine Gas Engine		Solar Wind Mini Hydro Biomass		
2023	1,430 + 731	-	1,541	2,029	-	-
2025	2,104 + 24	330	1,571	3,302	120	-
2030	2,104 + 24	430	1,571	7,212	1,125	700

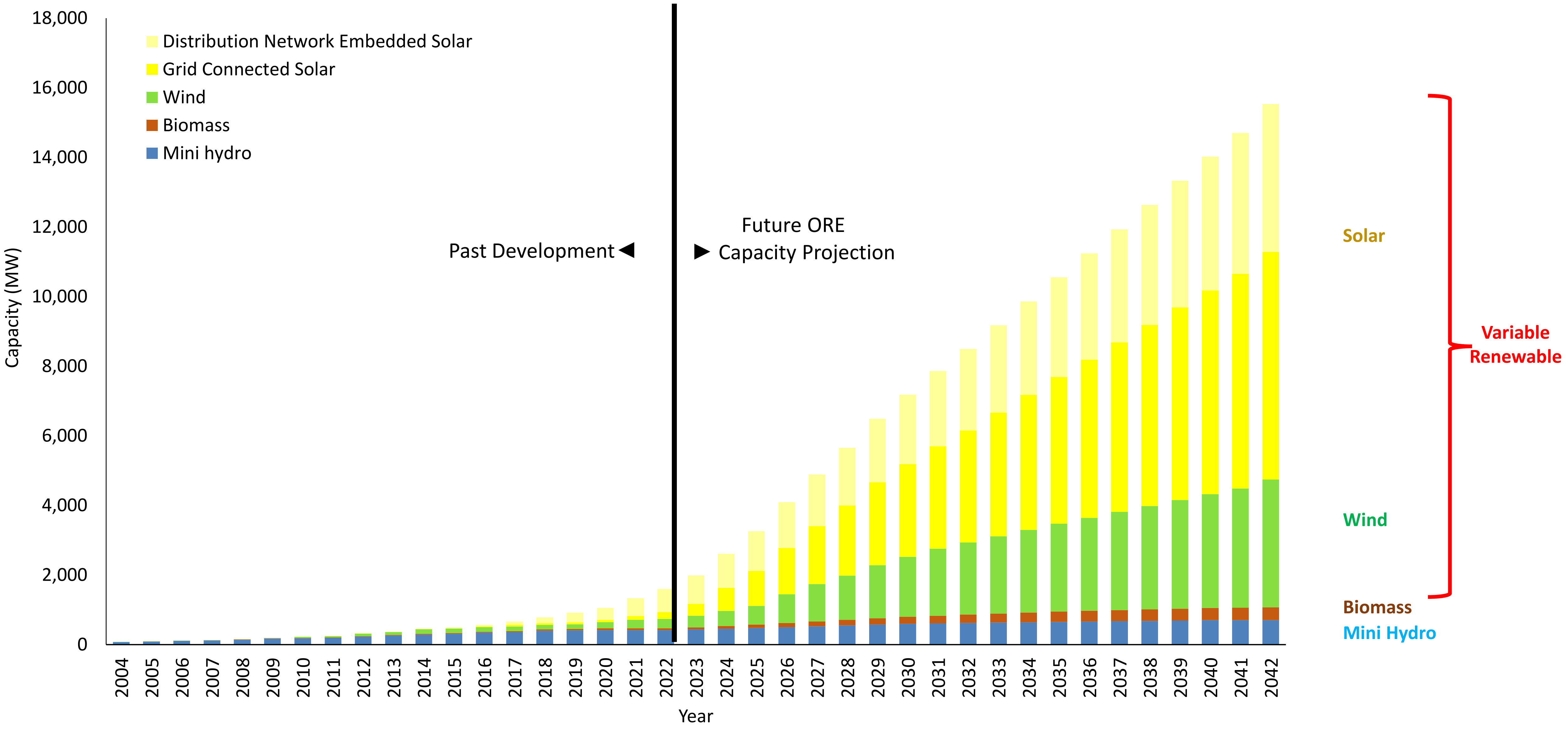
Base Case Plan Additions & Retirements

Year	Gross Capacity Addition (MW)										
	Gas Turbines	IC Engines	Coal	Combined Cycle	Major Hydro	Battery Storage	Pumped Hydro	Short Term	ORE	Existing Plant Retirements	Battery Storage Retirements
2022					155				309		
2023				240 (GT)				320	407		
2024	130			350 (ST+GT)	31	20		(200)	623	(130)	
2025				110 (ST)		100			650	(255)	
2026		200				180		(120)	835		
2027	100					200			795		
2028						350			775	(10)	
2029						150	350		835		
2030						125	350		711	(31)	
2031						125	350		692	(12)	
2032						125	350		660	(385)	
2033						150			694	(14)	
2034	100					200			737	(347)	(20)
2035	100	250				245			705	(25)	(100)
2036	200					380			730	(40)	(180)
2037	200					400			775	(85)	(200)
2038		200				550			785	(85)	(250)
2039	200					350			820	(120)	(150)
2040		200				340			793	(413)	(125)
2041	100			400		340			958	(278)	(125)
2042						340			958	(264)	(125)
Total	**1,130**	**850**	**0**	**1,100**	**31**	**4,670**	**1,400**	**0**	**14,938**	**(2,494)**	**(1,150)**

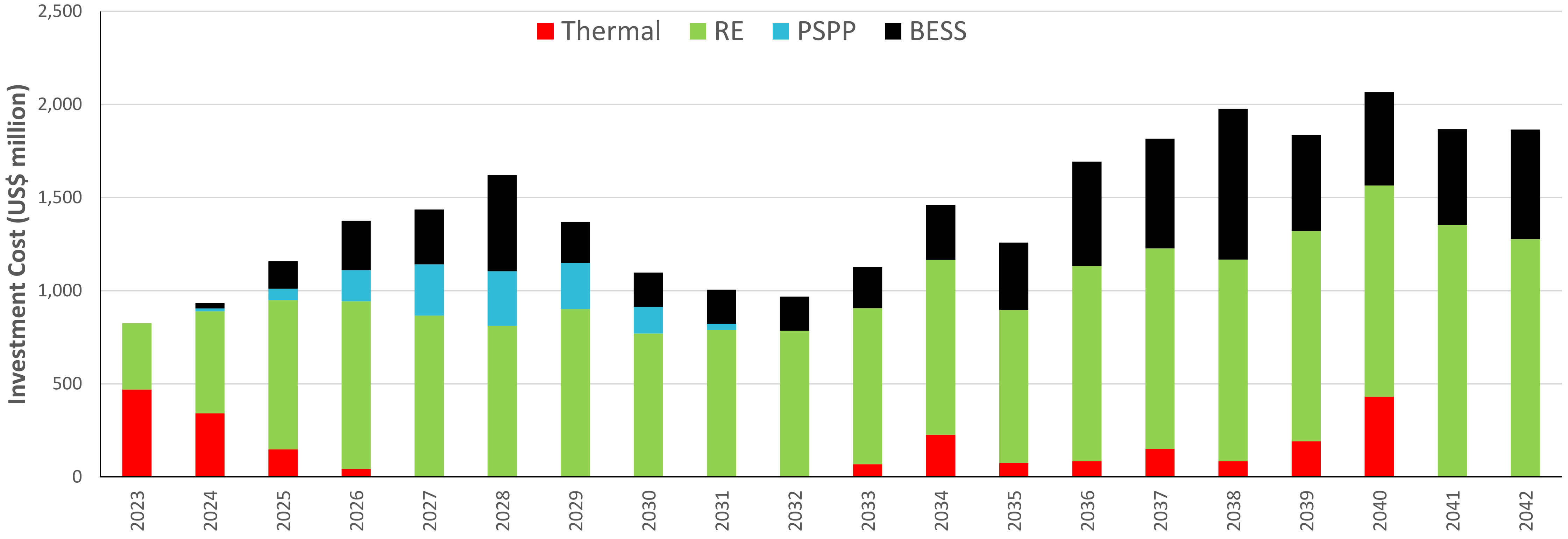
Renewable Energy Development Annual Additions (in MW)

Type	Major Hydro	Mini Hydro	Biomass	Wind	Distribution Network Embedded Solar	Grid Connected Partially Facilitated Solar	Grid Connected Fully Facilitated Solar (park)	Total Solar
Present Cumulative Capacity (2021)	1383	415	50	248	515	100	-	615
2022	155	20	10	-	160	94	-	254
2023	-	20	20	25	160	147	-	307
2024	31	20	20	60	160	223	100	483
2025	-	25	20	200	165	80	260	505
2026	-	25	20	290	170	70	260	500
2027	-	25	20	250	170	50	280	500
2028	-	25	20	200	170	40	310	520
2029	-	25	20	250	170	20	350	540
2030	-	10	20	200	170	30	250	450
2031	-	10	20	200	170	30	250	450
2032	-	10	20	150	170	30	250	450
2033	-	10	20	150	170	30	300	500
2034	-	10	20	150	180	30	300	510
2035	-	10	10	150	180	30	300	510
2036	-	10	10	150	190	30	300	520
2037	-	10	10	150	190	30	300	520
2038	-	10	10	150	200	30	300	530
2039	-	10	10	150	200	30	300	530
2040	-	-	10	150	200	20	300	520
2041	-	-	10	150	200	20	300	520
2042	-	-	10	150	200	20	300	520

Renewable Energy Development – Past & Future (Excluding Major Hydro)

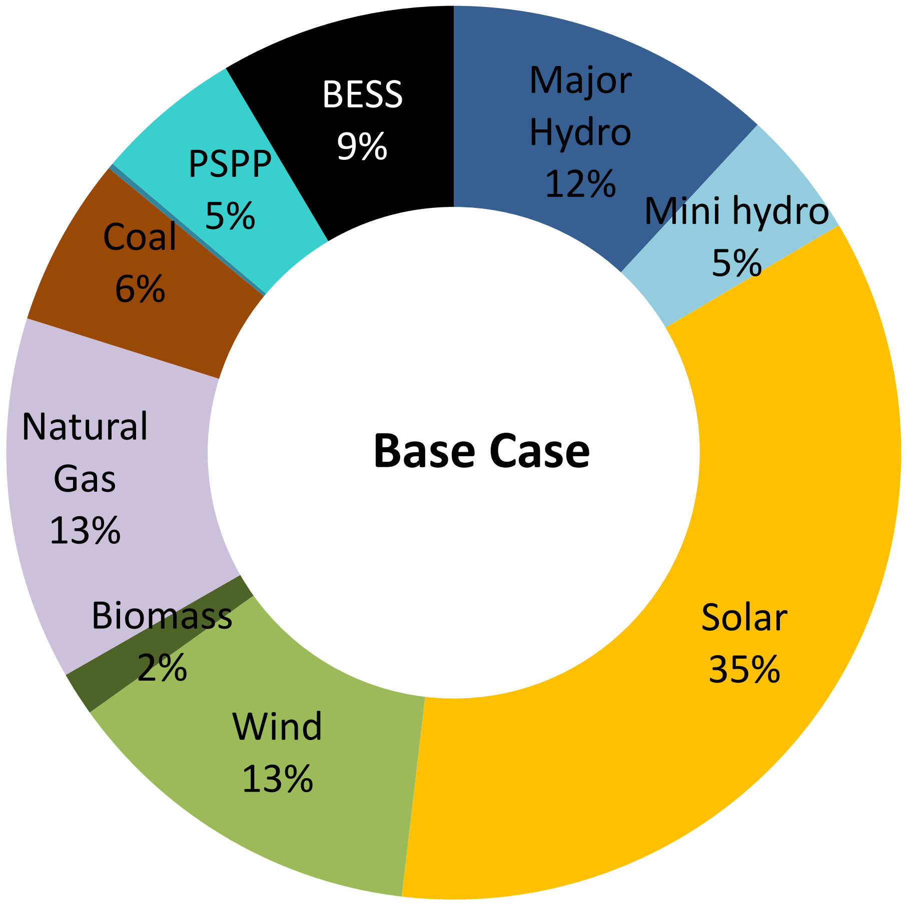


Base Case Plan – Annual Investment Requirement

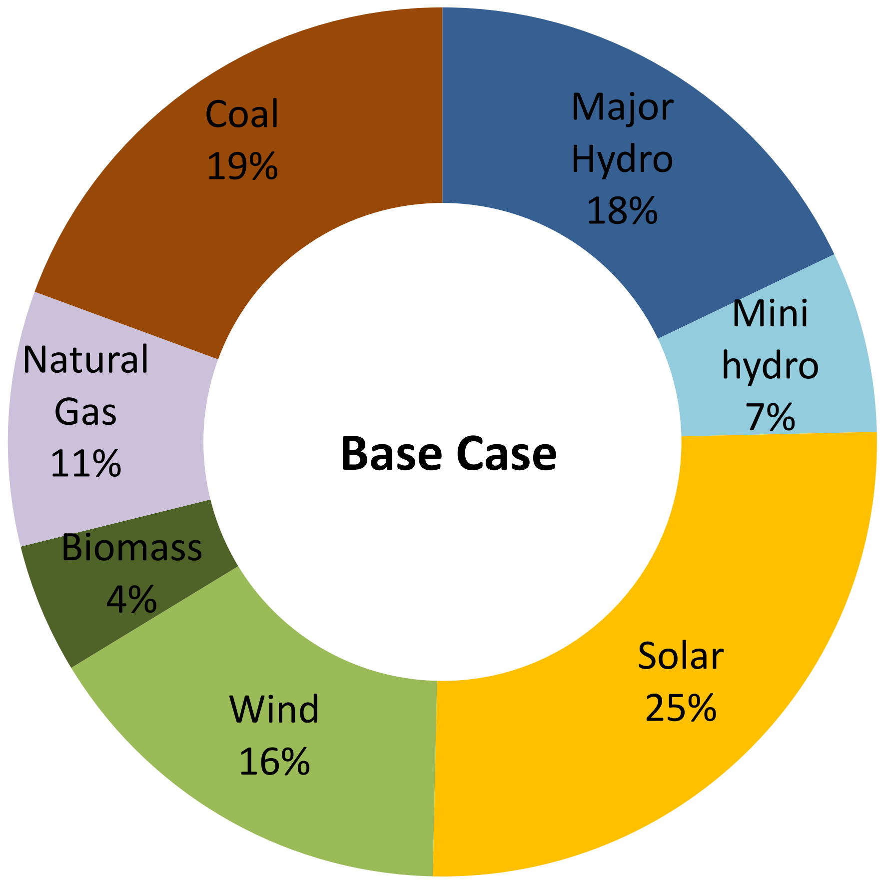


	Thermal	Renewables	Storage	Total
Average annual investment requirement for 2023-2030	**USD 125 million**	**USD 744 million**	**USD 358 million**	**USD 1,226 million**
Average annual investment requirement for 2031-2042	**USD 109 million**	**USD 1,022 million**	**USD 446 million**	**USD 1,578 million**
Average annual investment requirement for total horizon	**USD 116 million**	**USD 911 million**	**USD 411 million**	**USD 1,438 million**

Capacity Mix and Energy Mix (2030)

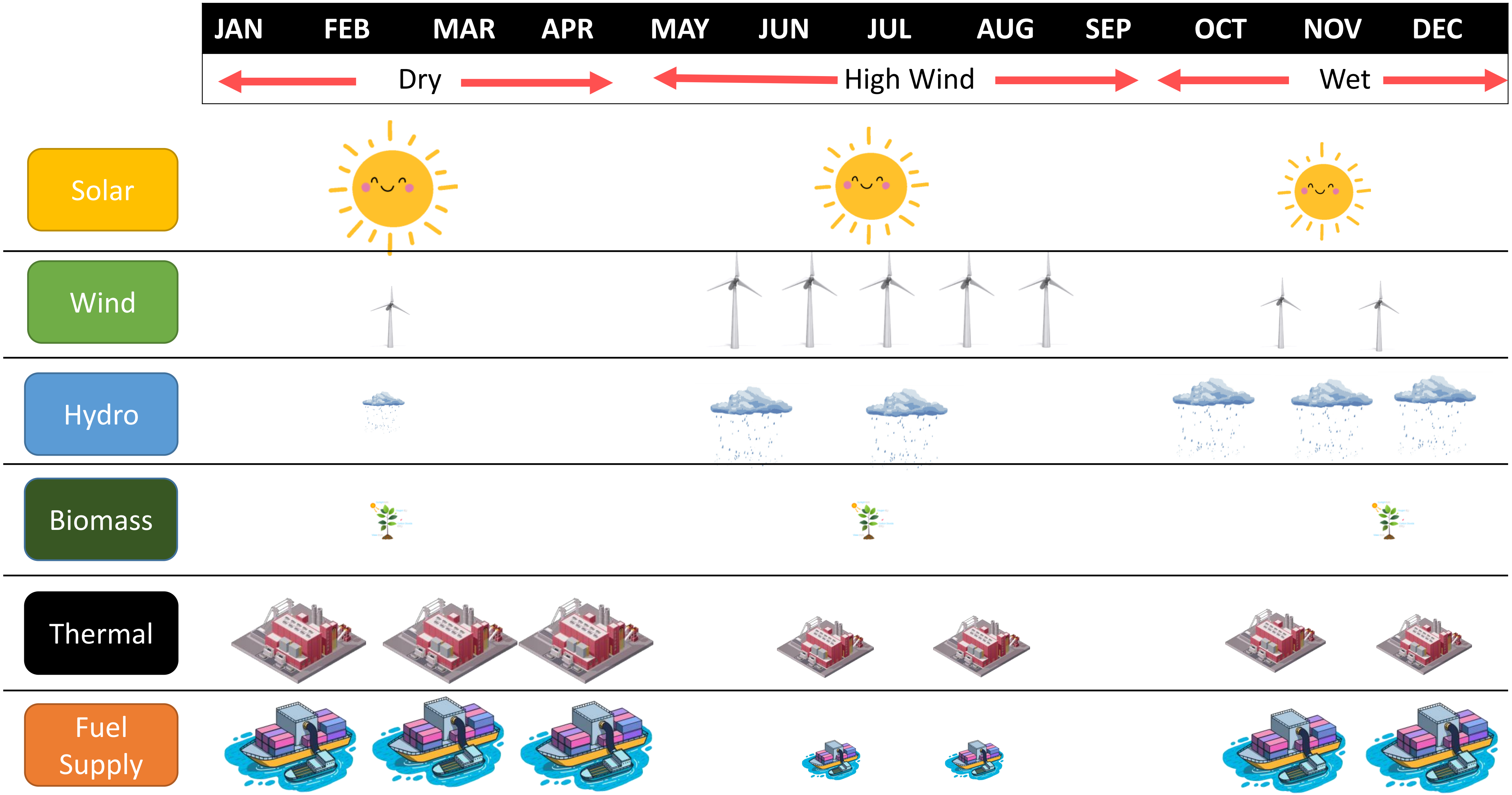


Capacity Mix

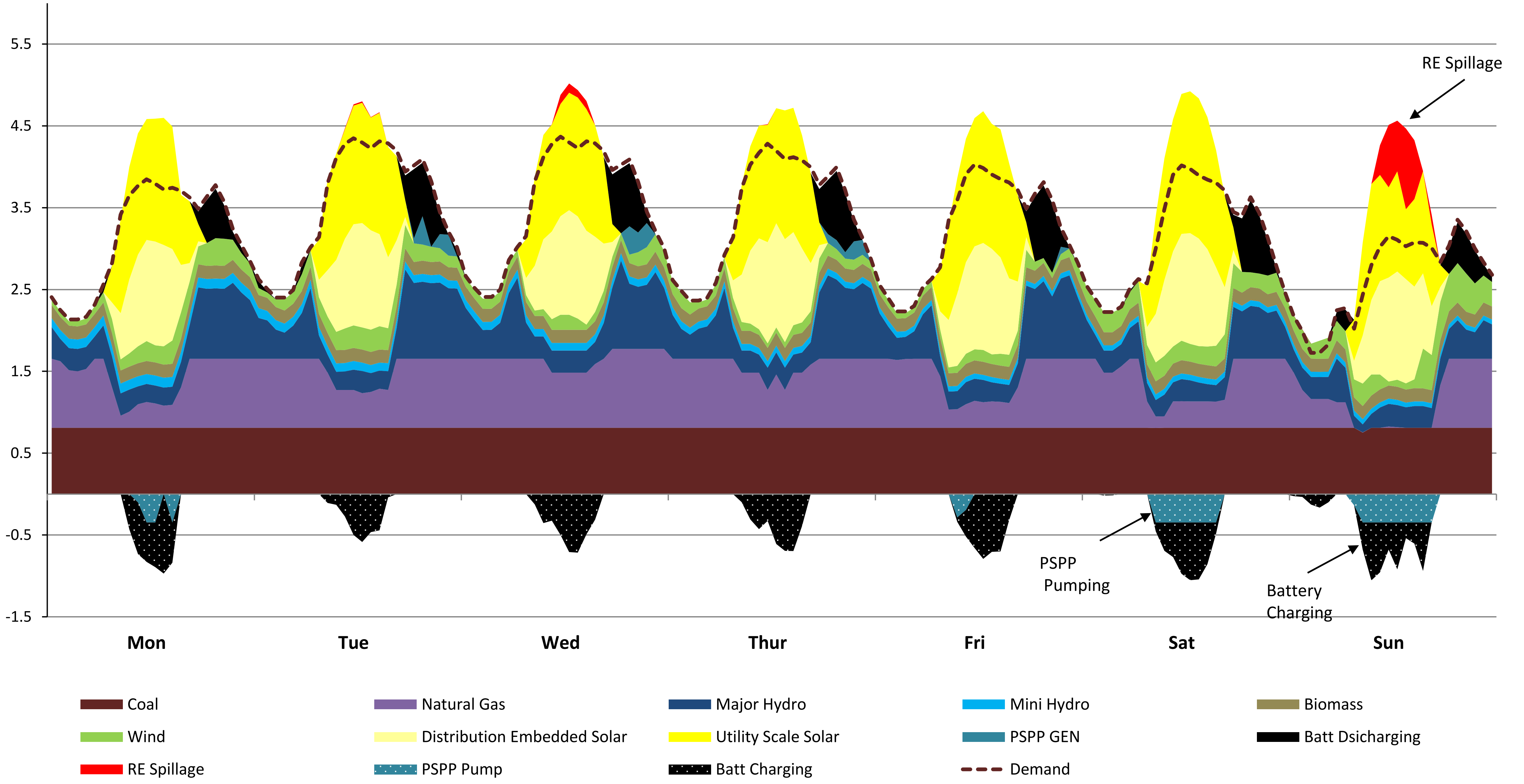


Energy Mix

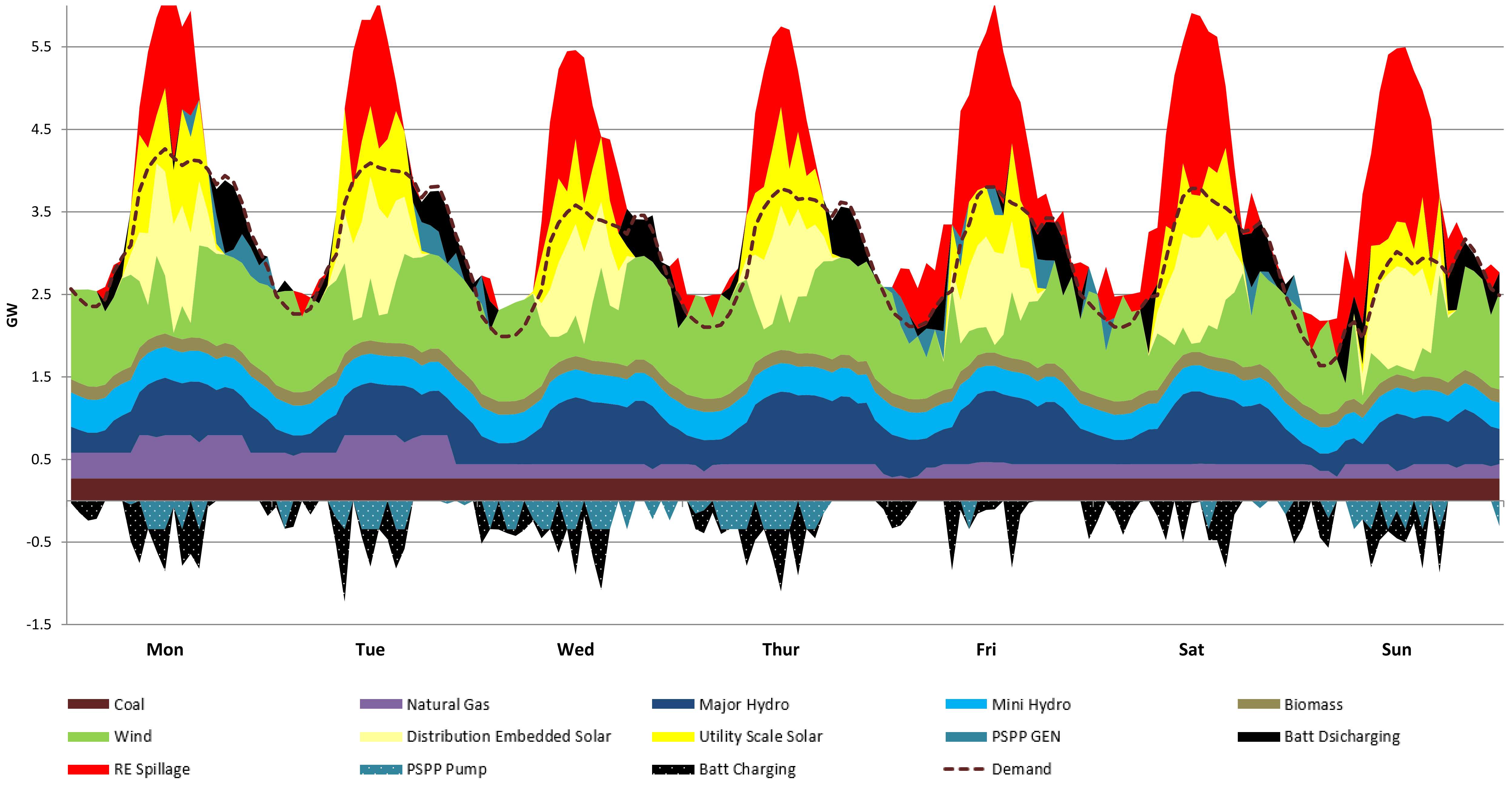
Seasonality with Source of Generation



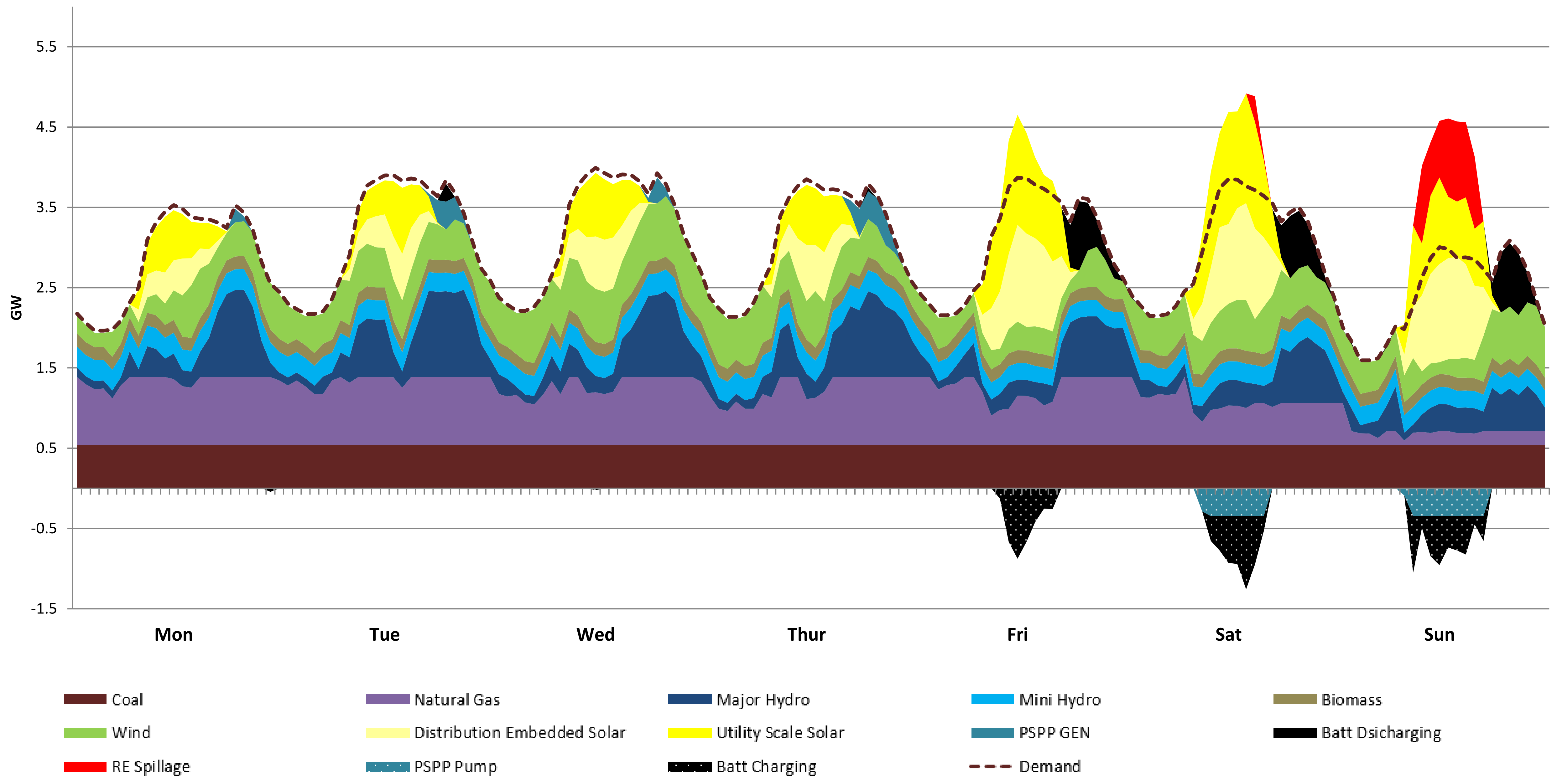
Typical Weekly Load Curve (Mon-Sun) - Dry Season 2030



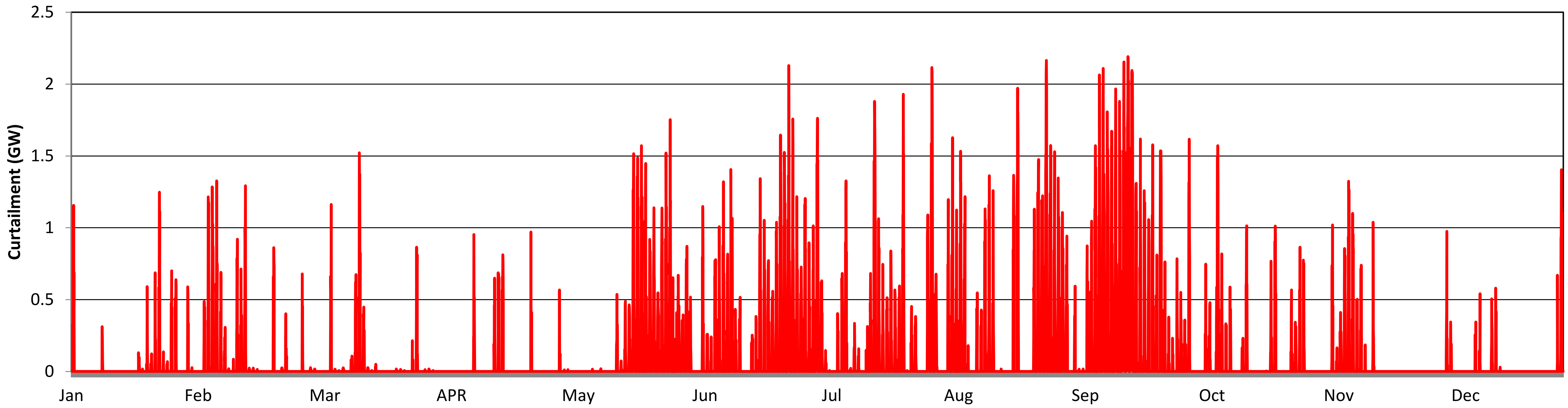
Typical Weekly Load Curve (Mon-Sun) - High Wind Season 2030



Typical Weekly Load Curve (Mon-Sun) - Wet Season 2030

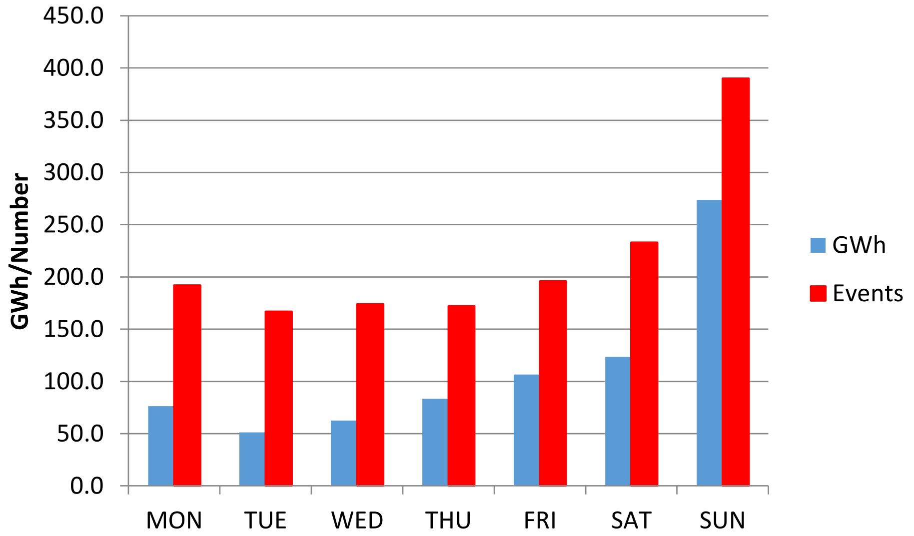


Renewable Curtailment for Year 2030

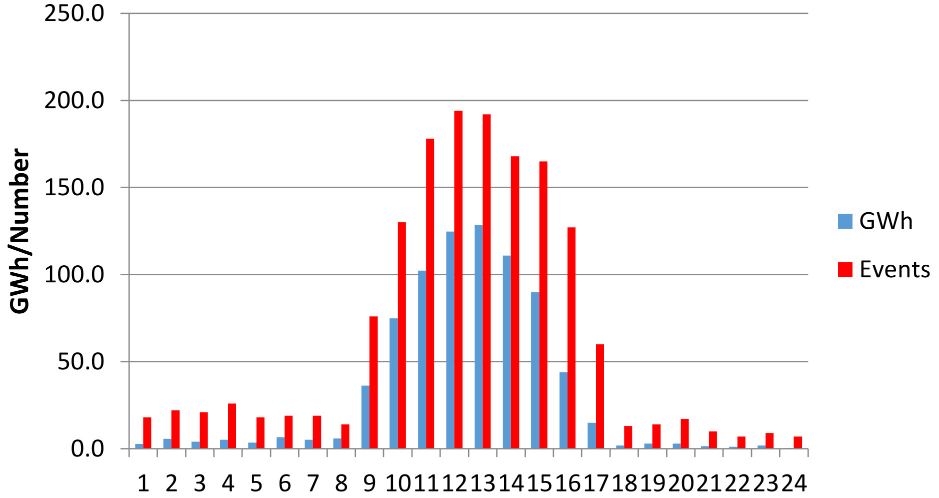


777 GWh

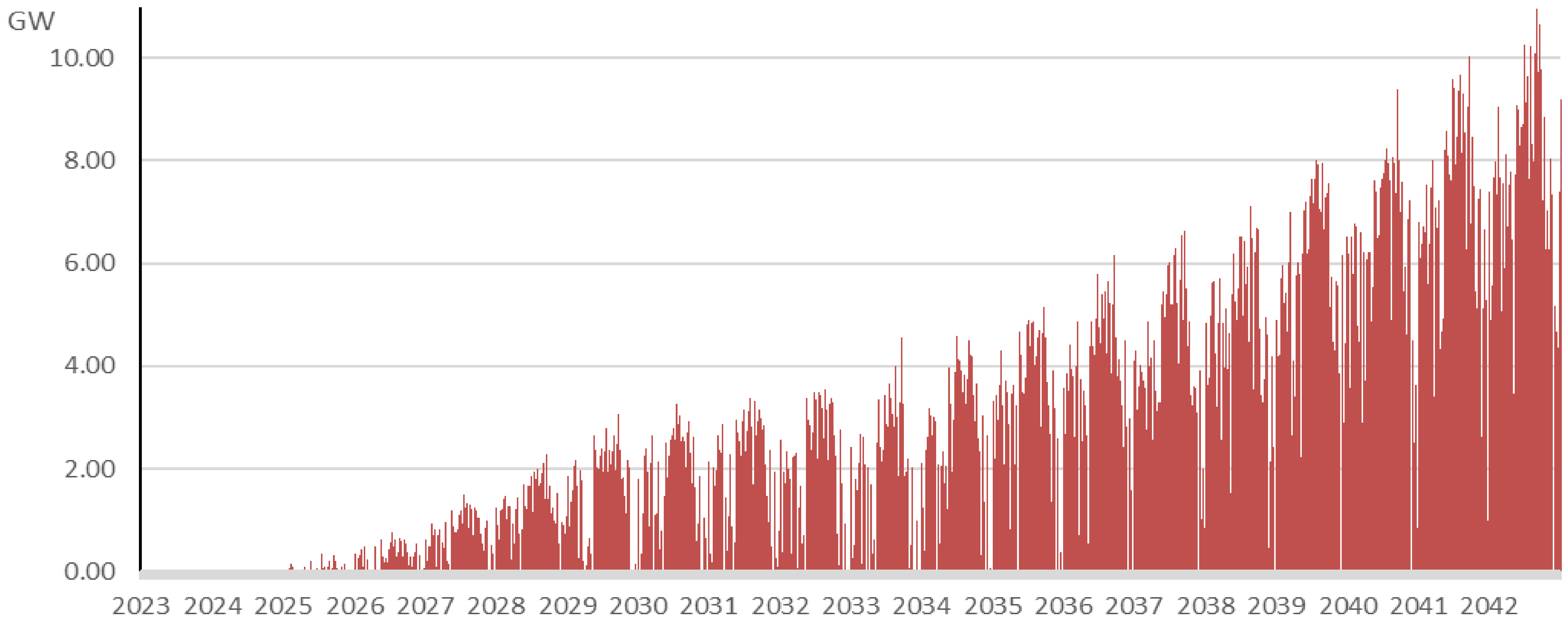
Distribution of RE Curtailments among days of the week



Distribution of RE Curtailments among hours of the day



Renewable Energy Curtailments (2023-2042)



777 GWh

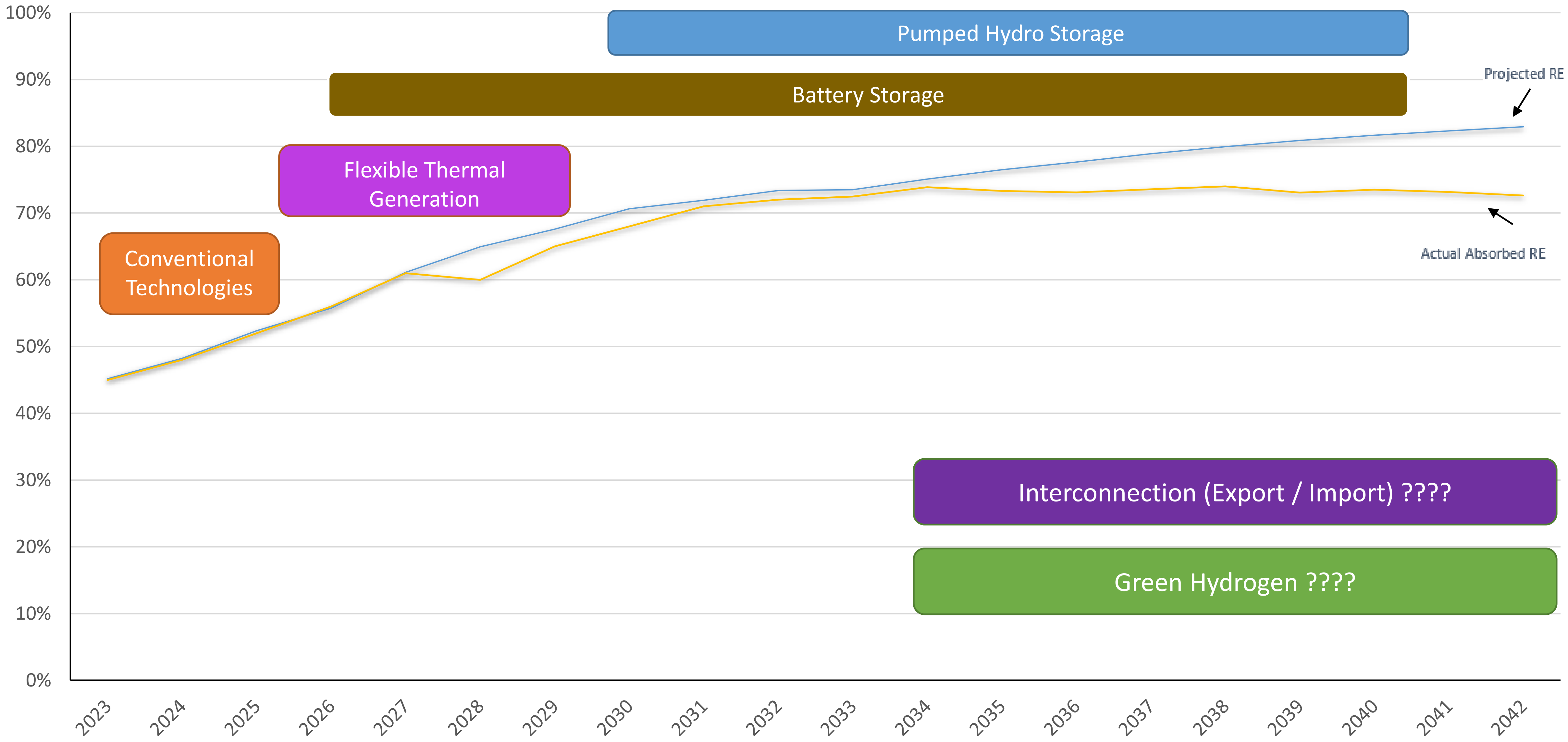
3,119 GWh

Key Scenarios - Results

		Policy Constrained Scenarios				Policy Unconstrained Scenarios		
		1. 70% RE by 2030 + No Coal (New Policy)	**2.** 70% RE by 2030 Increasing RE Share beyond 2030 + No Coal	**3.** 70% RE by 2030 HVDC Interconnection + No Coal	**4.** 70% RE by 2030 Nuclear 2040 + No Coal	**5.** 50% RE by 2030 With Coal Option Open Until 2030	**6.** 60% RE by 2030 With Coal Option Open Until 2030	**7.** 60% RE by 2030 + No Coal
Plant Additions 2023-2042 (MW)	Major Hydro	31	Need Additional Interventions	31	31	31	31	31
	ORE	13,795		13,795	13,795	10,097	11,608	11,065
	NG CCY	1,100		1,100	1,100	1,110	1,100	1,100
	NG GT/ ICE	1,930		1,580	1,880	4,030	3,820	4,130
	Coal	-		-	-	540	270	-
	Nuclear	-		-	600	-	-	-
	HVDC	-		500	-	-	-	-
	Battery	3,365		3,365	3,365	350	400	400
	PSPP	1,400		1,400	1,400	700	1,050	1,050
Present Value US$ Million	Investment	10,119	↑	10,400	10,220	7,589	7,946	7,498
	Operational	8,753	↓	8,483	8,766	10,203	9,561	10,357
	Total	18,872	↑	18,883	18,986	17,792	17,507	17,855

*Scenarios were developed considering fuel costs used for planning studies and imposing limits on instantaneous asynchronous penetration.

Renewable Share Growth and Interventions to achieve Carbon Neutrality



THANK YOU !!!

Democratic Socialist Republic of Sri Lanka

The Project for Capacity Development on the Power Sector Master Plan Implementation Program

4th Joint Coordination Committee (JCC)

November 22, 2022

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Contents of JCC

1. Project Purpose and Output
2. Schedule of the Project
3. Activity & Outcome of WG1
   (Corporate Strategy, System and Policy)
   3-1 Activity/Outcome & Action Plan
   3-2 Results of Capacity Development
   3-3 Comments on action to achieve higher goals
4. Activity & Outcome of WG2
   (Planning and Operation of Power System)
   Same as WG1 presentation
5. Activity & Outcome of WG3-1
   (Improvement of Distribution System Reliability)
   Same as WG1 presentation
6. Activity & Outcome of WG3-2
   Same as WG1 presentation
7. Training in Japan

01 Project Purpose and Output

1 Project Purpose and Output

"Project Purpose" and "Output" was defined initially.

Project Purpose

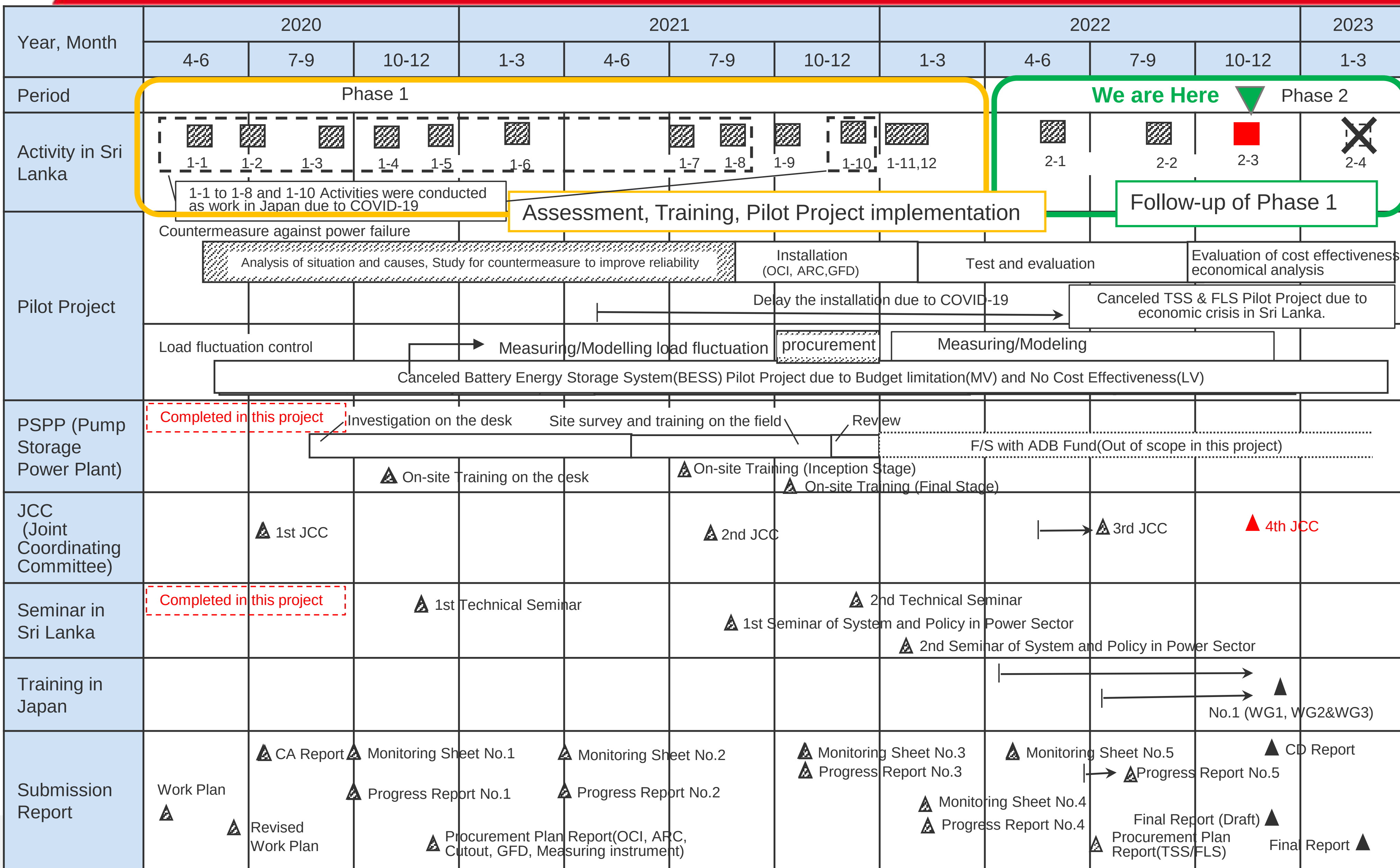
Institutional Capacity for improving transmission and distribution operational reliability is enhanced to get prepared for increased share of RE planned in the LTGEP

Outputs of the Project

1. Capacity of corporate strategy and planning for VRE is enhanced (WG1)
2. Capacity of system development and operation for transmission network in response to increased share of VRE is enhanced (WG2)
3. Capacity of distribution network operation is improved (WG3)

02 Schedule of the Project

2 Schedule of the Project



03 Activity & Outcome of WG1 (Corporate Strategy, System and Policy)

03-1 Activity / Outcome & Action Plan

3-1 Activity / Outcome (WG1)

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Issues for expansion of RE

Issues

- Future introduction of Balancing Market
- Reflection of the latest RE costs on the FIT Tariff
- Reflection of fluctuations in fuel costs on electricity tariff
- Increase in power generation costs due to raising fuel costs
- Introduction of policies to achieve 70% in renewable energy ratio
- Insufficient government subsidies
- Lower electricity tariff against to power generation cost
- Shortening the application period for permission of RE development
- Acquisition of knowledge in other countries for expansion of RE
- Improvement of finance situation

3-1 Activity / Outcome (WG1)

Targeting the Theme for Activity

Study with JICA Experts

Policies in other countries for expansion of RE

- Output limitation in VRE
- Priority Dispatch
- Connect & Manage in JPN

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Balancing Market in other countries &Japan

- Capacity market in JPN
- Whole sale market in JPN
- Balancing market in JPN

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FIT Tariff scheme in Japan

- FIT scheme in JPN
- Fuel cost adjustment in JPN
- Estimation of purchase price and IRR in JPN

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Issues

Shortening the period of permission for RE development

- Approval Process for VRE Project Development
- FIT Approval Process on JPN Ministry
- Approval Process for on-grid VRE Project Development in JPN

・
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Financial Improvement in CEB

- Financial analysis on current situation
- Financial projection progress
- Financial analysis meeting

・
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Focused on four themes

①Review of Rooftop PV FIT Tariff

②Study on Introduction of Balancing Market

③ Shortening the application period for permission of RE development

④Examination for improvement of finance situation

3-1 Activity / Outcome (WG1)
①-1 Optimization of FIT Tariff for Rooftop PV

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Situation

- ✓ Rooftop PV is an important renewable energy source.
  Sustained development is required.
- ✓ PV installation costs are falling globally.
  (Especially in large-scale)
- ✓ Rooftop PV FIT tariff have not been revised since 2016.

RE 70% is Target
in Sri Lank by 2030

Study & Activity

- ✓ Collecting information on Roof Top PV installation costs and finance data (interest rate, repayment period, IRR) in Sri Lanka
- ✓ Discussion on conditions for New adequate FIT Tariff
- ✓ Explanation of revision outline to PUCSL and getting the understanding
- ✓ Calculation of FIT tariff by classifying PV installed capacity
- ✓ Proposal preparation for the application of FIT Tariff revision
- ✓ Understanding of CEB management on the necessity of FIT tariff revision

3-1 Activity / Outcome (WG1)
①-2 Optimization of FIT Tariff for Rooftop PV

Outcome

✓ FIT tariff revision proposal(draft) was prepared.
- Reflecting lower PV installation costs in Sri Lanka
- Proposal of FIT tariff according to rooftop PV cap. (10kW, 100kW are set as thresholds)

✓ The understanding of the CEB management was obtained regarding the need to revise FIT tariff
- The background and tariff calculation method were explained to AGM (Transmission - Non Wired Operation)

✓ Clarification of revision procedures
- Clarified the procedures and period required for the FIT tariff revision by setting millstones

Explanation of FIT tariff revision to AGM(Tr.-NWO)

02 Milestones

		Procedure	Period (Month)	Note
CEB	1	Recalculation of FIT Tariff to reflect economic conditions	1.0	● It is possible for CEB to change the preconditions of the Draft Proposal (submitted by JICA Expert)
	2	Internal Approval of CEB	0.5	● Already explained to Hendahewa AGM ● Information sharing in advance if there is a related Dep
EC	3	Setting offer of Expert Committee (EC) for Roof top PV	0.5	● CEB→MoP
	4	Deliberation in the Expert Committee for Roof top PV	1.0	● Answering questions (requires solid understanding of calculation methods)
SM	5	Deliberation in the State Ministry of Solar, Wind and Hydro power generation project	1.0	● Answering questions (requires solid understanding of calculation methods)
MoP	6	Deliberation in the Ministry of Power (Third opinion from CEB, PUCSL)	2.0	● Answering questions (requires solid understanding of calculation methods)
Cabinet	7	Deliberation in the Cabinet	1.0	
	8	Cabinet Approval		● Careful explanation to developers after the revision

Around 7 months

Due to the economic crisis, business conditions changed totally. New Tariff was granted by Cabinet on Oct. 25

When the economic situation recovers in the future, CEB will be able to carry out the revision procedures for the future.

(Ref.) Roof Top PV FIT Tariff Revision

Two tier previous tariff rate
Rs. 22 (1st 7years) & Rs. 15.50 (following 13 years)

Business environment Change

Interest rate changed, Higher inflation rate, Labor cost increase, Rs. currency depreciation (Fixed exchange rate →Floating exchange rate), etc.

Government led Tariff revision.
20 years flat rate Rs. 37.00 for less than 500kW, Rs. 34.50 for above 500 kW
Cabinet Approval on Oct.25, 2022

3-1 Action Plan (WG1)
①-3 Optimization of FIT Tariff for Rooftop PV

Activity	Time period
1. To have regular meetings with the existing customers/service providers to check if the current PV tariff is sufficient	Every six months interval
2. To study what type of a PV tariff revision is required for the new clients to cover their investment cost due to exchange rate and bank interest rate volatilities.	Every six months interval
3. To study new PV tariff structures apart from the existing Net Metering, Net Accounting and Net Plus tariff schemes in order get a higher energy yield from Rooftop PV sector by not making it an excess financial burden to CEB	Every six months interval
4. CEB is looking to introduce a new tariff for Rooftop PV with battery backup storage which can export energy to CEB grid even at night peak times.	By End June 2023

3-1 Activity & Outcome (WG1)
②-1 Introduction of Balancing Market (BM)

Situation

- There is no Wholesale market, Capacity market, or Balancing market.
- Never been considered for introduction of each market
- Importance is recognized however basic knowledge of securing of Balancing power thanks to the exclusive market development has not been accumulated.

Study & Activity

- Market research on BM in the VRE developed countries
- Market research on BM in the similar developing countries and island countries

RE Installation ratio	Products outline
Power System Configuration	Timeline to the settlement
Power System Operators	Requirement of participants, etc.

- Sorting out issues to be solved for the BM introduction

Collaboration Work

Expert team

3-1 Activity & Outcome (WG1)
②-2 Introduction of Balancing Market (BM)

Outcome

- Acquiring a wide range of information in developed countries, developing countries, countries with similar environments, etc.

Type	Target Countries
Developed countries	Japan, Germany, UK
Developing countries	The Philippines
Island countries	Ireland

Lecture style

JICA Ex.: Japan, Germany, UK

Co-Work

JICA Ex.: Outline study of Ireland

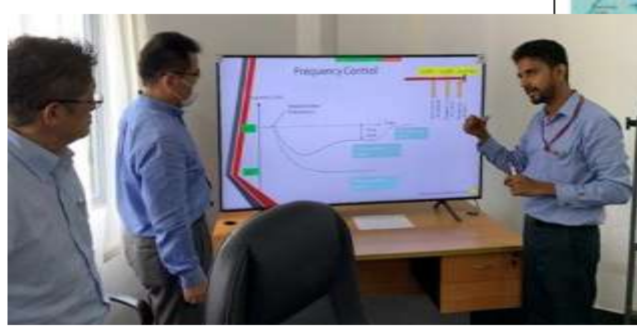
C/P: Detail study of Ireland

Independence

C/P: The Philippines

- Accumulation of BM know-how (CM, Wholesale Market as well)

- Discovery of issues to be resolved in order to introduce the BM



3-1 Action Plan (WG1)
②-3 Introduction of Balancing Market (BM)

1. CEB is closely monitoring the market based electricity structure in Europe the behavior in the regional countries and checking the ways it can be implemented in Sri Lanka.
2. Sri Lanka currently has fixed/ 3 tier pricing mechanism and CEB is checking the feasibility on demand management/shifting of demand based on the same.
3. There should be more players in order to create a competitive balancing market, hence CEB is in the process of attracting new players through competitive bidding and Feed in Tariff methodologies.
4. With the latest changes to the Electricity Act, CEB can look forward to multiple methods of procurement of electricity in order to increase more generation into the system.

3-1 Activity & Outcome (WG1)
③-1 Improvement of VRE Approval Process

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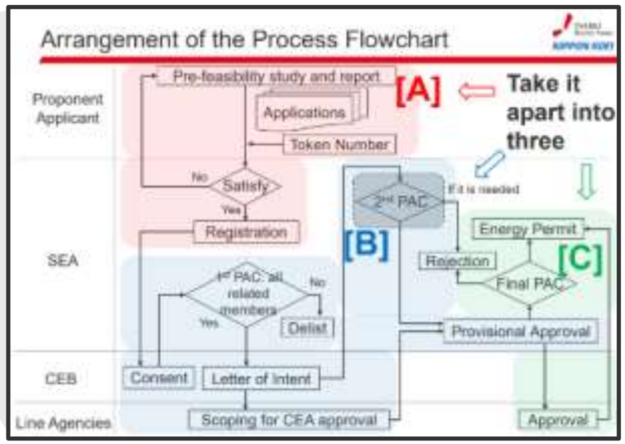
Situation

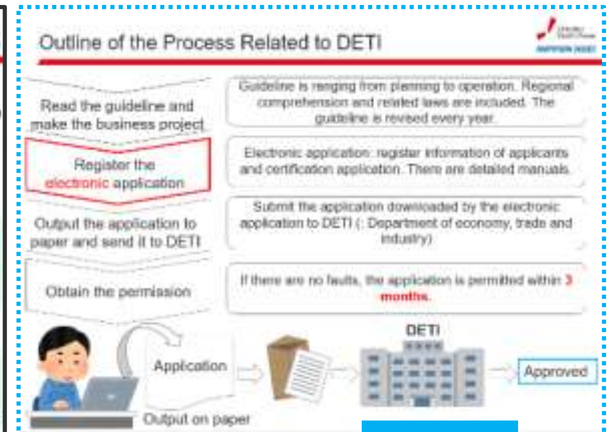
- The guideline has not been modified since 2011
- The approval process has difficulties in accelerating VRE projects

	Application	PA Issued	EP Issued
2011 ~ 2021	268 days	414 days	

Study & Activity

- Clarify the procedure
- Grasp issues
  - ☐ Developer burden process
  - ☐ Comings and goings process
  - ☐ Land property
  - ☐ Variable demarcated area
  - ☐ No time limitation for line agency approval
- Find out measure against the issues
  - ✓ Make a SEA relation
  - ✓ Put an emphasis on land identification
  - ✓ Eliminate the unneeded process





Input

- Operation & Maintenance for PV
- Operation & Maintenance for Wind Solar
- Approval process for VRE in Japan
- Japanese law related to developing VRE

3-1 Activity & Outcome (WG1)
③-2 Improvement of VRE Approval Process

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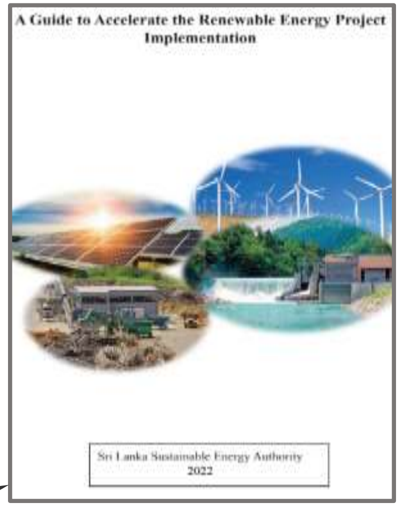
Outcome

New Guideline
Published in Jan. 2022



- Intervention of SEA
- Support in Ministerial level
- Make non-progressive projects take steps to develop

Online System
Under construction
Possibly released around the end of 2022

- Management whole procedure in one system
- Put procedures into approval simultaneously
- Accurate mapping system
- Paperless
- Electrical Approval
- Process control automatically

Application > PA Issued > EP Issued

2011 ~ 2021	268 days	414 days
2022 ~	**48 days**	N/A

3-1 Action Plan (WG1)
③-3 Improvement of VRE Approval Process

Vision	**An energy secure Sri Lanka**
Goal	**Renewable energy 70% by 2030**

Situation	• New guideline was published
	  ➢ Require more SEA relation
	• Online system is about to be introduced
	  ➢ Effectively handle approval procedure without loss
	• VRE applications will be submitted rapidly because of FIT revision

Issues	• Internal
	  ✓ SEA burden to cope with applications
	• External
	  ✓ Grid concurrence is difficult to obtain
	  ✓ Land acquisition would be denied at the end of the process

Cause	• Difficult to predict possible applications and secure staff timely • Lack of human resources coping with applications • Online system might not apply to unpredictable situation and cause error • Lack of grid capacity and applicants cannot see the capacity • Demarcated area would possibly be changed
Measures	• Secure and arrange staff and educate them to cope with applications • Share ideas with related institutions to find out possible VRE area • Share precise and possible maps with environmental agencies

3-1 Action Plan (WG1)
③-4 Improvement of VRE Approval Process

ACTION PLAN	Future				
	1 year (2023)	3 years (2025)	5 years (2027)	7 years (2029)	8 years (2030)
Transfer previous applications to online system					RE 70% ☆
Discuss related institutions about land and grid information to share them publicly or take in online					
Evaluate guideline and improve for the better periodically			Revision	Revision	
Evaluate online system and improve for the better periodically			Revision	Revision	
Make statistics to find out issues of procedure based on data obtained by online system					
Predict the possible applications in the future and secure and educate SEA staff to cope with approval process					

3-1 Activity & Outcome (WG1)
④-1 Improvement of CEB finance

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Situation

- ✓ As the electricity tariff had not been revised since 2014, CEB consistently recorded operational deficit over years resulting in the partial insolvency of treasury loans.
- ✓ New LTGEP would require more investment in transmission system for network stability and expansion due to its ambitious renewable energy expansion target.

Study & Activity

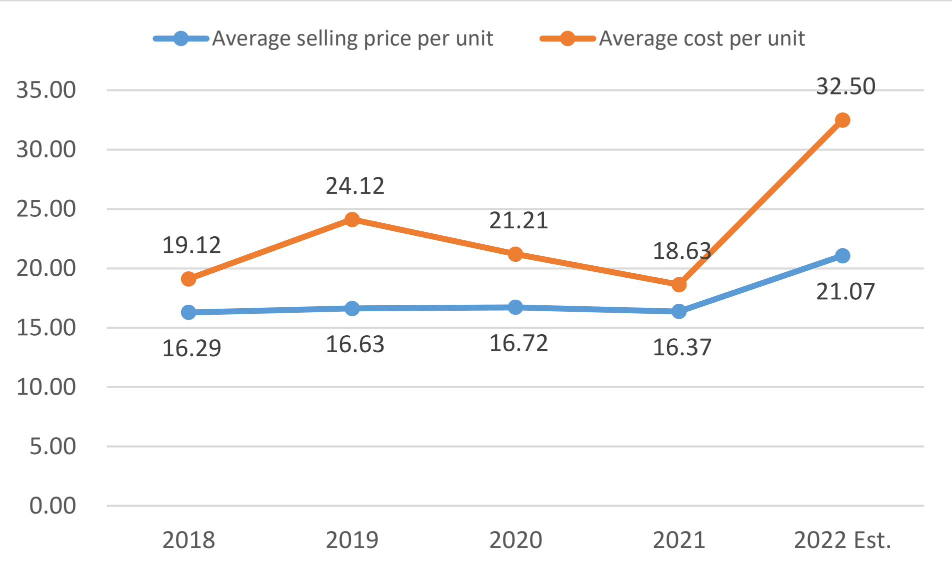
- ✓ Study and analysis of the recent status of CEB finance
- ✓ WG1 members' presentations on the financial issues
- ✓ Review of latest draft LTGEP and CEB budget, etc.
- ✓ Preparation and lecturing of the financial projection model
- ✓ Preparation and discussions of Recommendation Report

Lecturing and discussion on the financial projection model

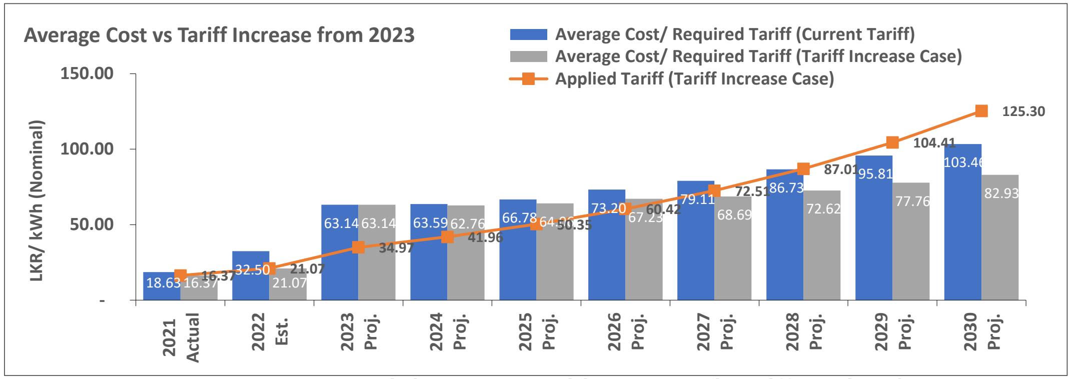
3-1 Activity & Outcome (WG1)
④-2 Improvement of CEB finance

Outcome

- ✓ Most recently in 2022, Sri Lanka is facing the severe economic crisis and the balance-of-payment problem which results in skyrocketing fuel and commodity prices, which has drastically worsened CEB's financial conditions.
- ✓ The PUCSL Approved the long-waited tariff revision in August 2022 with 75% increase, which is a step forward for CEB to improve its financial conditions
- ✓ However, further periodical tariff increase is deemed necessary along with other government support such as subsidy, capital injection, FIT revision, etc.
- ✓ Recommendation Report has included those CEB conditions and improvement options.



Average electricity selling price and cost



Average electricity cost and increased tariff projection (Recommendation Report)

3-1 Action Plan (WG1)
④-3 Improvement of CEB finance

<table>
<tr><td>Problem</td><td colspan="2">

- The draft LTGEP 2023-2042 is prepared based on 70% RE target by 2030.
- Requires massive investments in RE generation technologies and Tr./Dis. Network.
- Requires flexible generation technologies such as LNG power plants.
- Requires grid support technologies such as PS hydro and BESSS.
- Financial burden to CEB.
- Analysis of Fin status is complex and requires a Mode.

</td></tr>
<tr><td>Solution</td><td colspan="2">

- Preparation of a Financial model to;
  - Propose CEB’s mid- to long-term financial improvement options for the 2021-2030.
  - Recommend financial improvement options to CEB Mgt./MOPE/PUCSL etc.

</td></tr>
<tr><td rowspan="3">Action Plan</td><td>

- Nominate expert/s from Tr. & GP Branch, Finance Division and CS&RA Branch etc. for updating their individual stake in the Model.

</td><td>

- By December 2022

</td></tr>
<tr><td>

- Revised the model

</td><td>

- Annually after Board approval of LTGEP and finalizing of Annual accounts.

</td></tr>
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- Present the results to CEB Mgt.

</td><td>

- Annually after revision of the model.

</td></tr>
</table>

03-2 Results of Capacity Development

Results of Capacity Development (WG1)

- Results of self-evaluation of improvement of understanding of System & Policy by the Project (WG1)

WG1 members self-evaluated about capacity improvement in the Project. Each WG1 member conducted the self-evaluation in October 2022, and the evaluation (rating of five degrees) was compared between before and end of the Project.

Self-evaluation was summarized on CEB members and SLSEA members each.

Rating five (5) degrees means;

5 (81% to 100%)	: Excellent/ I have knowledge than study/ Wholly Achieved/ Quite Useful or Effective
4 (61% to 80%)	: Very Good/ Well Understood/ Well Achieved/ Very Useful or Effective
3 (41% to 60%)	: Good/ Understood/ Achieved/ Useful or Effective
2 (21% to 40%)	: Not Good/ A little understood/ Little Achieved/ A Little Useful or Effective
1 (0% to 20%)	: Bad/ Not understood/ Not Achieved/ Not Useful Effective
N/A	: Not Applicable

Results of Capacity Development (WG1 / CEB members)

(1)Results of self-evaluation by CEB members in WG1

WG1 members in CEB self-evaluated on the contents below;

(a) Understanding of study contents on main fifteen (15) themes.

(b) Understanding of FIT Tariff Revision for rooftop PV

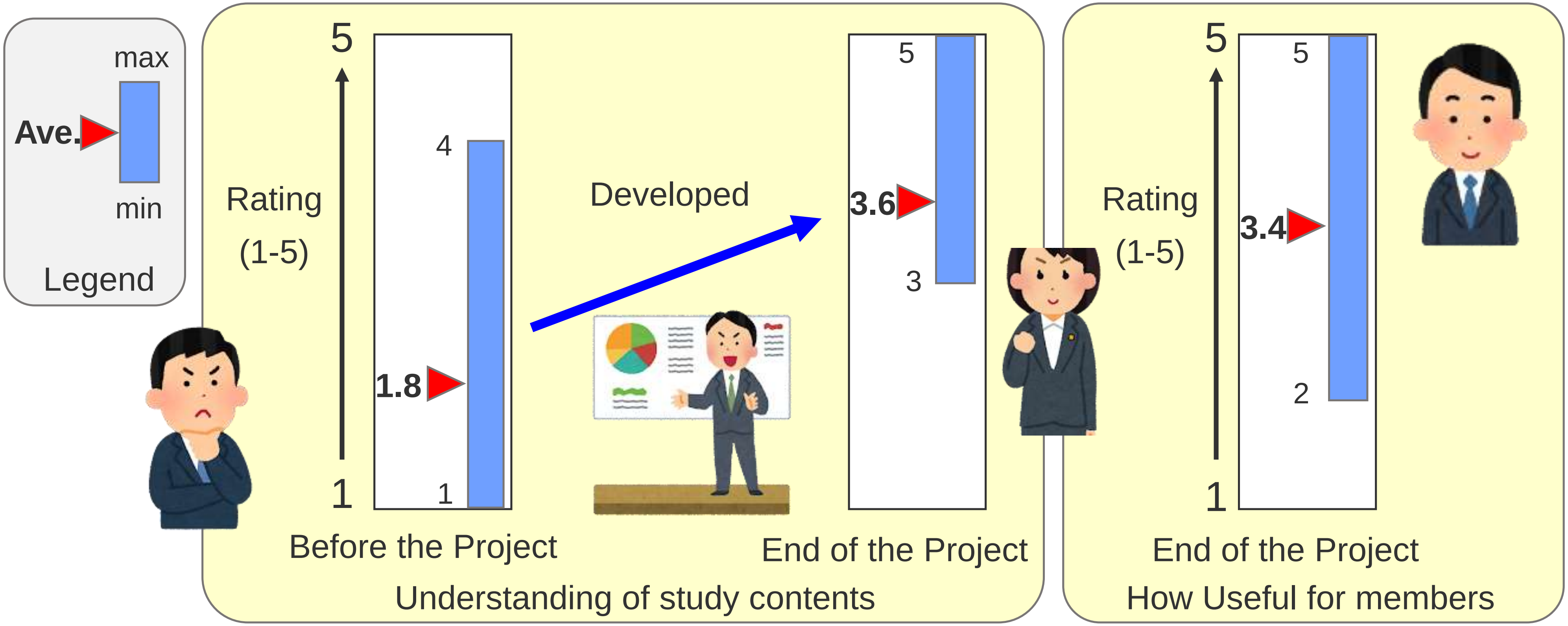
(c) Understanding of Financial Analysis and Recommendation Report

(d) Feedback opinion about the Project

Results of Capacity Development (WG1 / CEB members)

(a) Understanding of **study contents on main fifteen (15) themes**.

Average rating of self-evaluation by WG1 members on understanding study contents about System & Policy except FIT Tariff revision and Finance analysis is shown below.



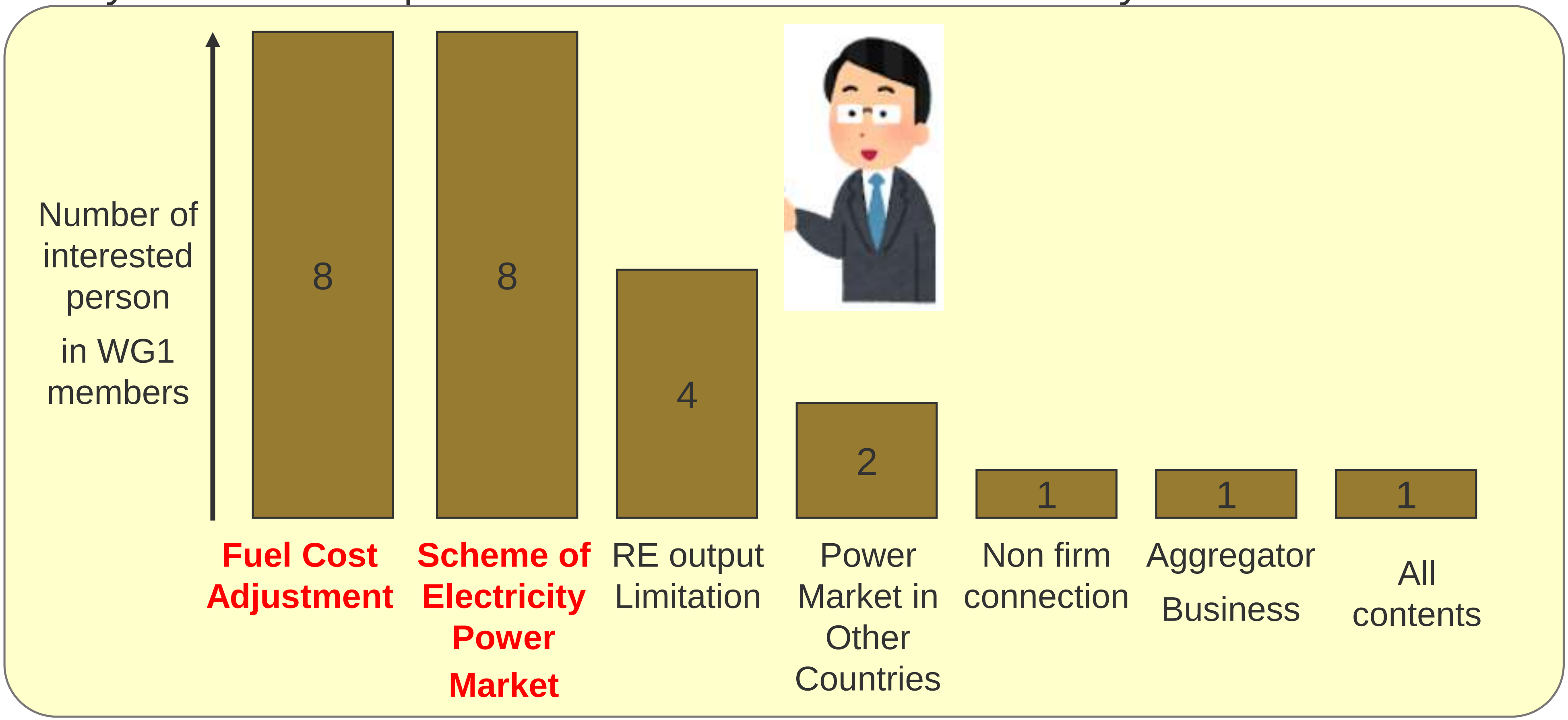
(Source: JICA Expert Team Prepared)

Fig. 3-3-1 Results of self-evaluation on understanding contents on System & Policy in the Project

Results of Capacity Development (WG1 / CEB members)

(a) Understanding of study contents on main fifteen (15) themes.

Three most **interested contents** were selected by each WG1 member among study contents except FIT Tariff revision and Finance analysis.



(Source: JICA Expert Team Prepared)

Fig.3-3-2 Interested Contents in the Project

Results of Capacity Development (WG1 / CEB members)

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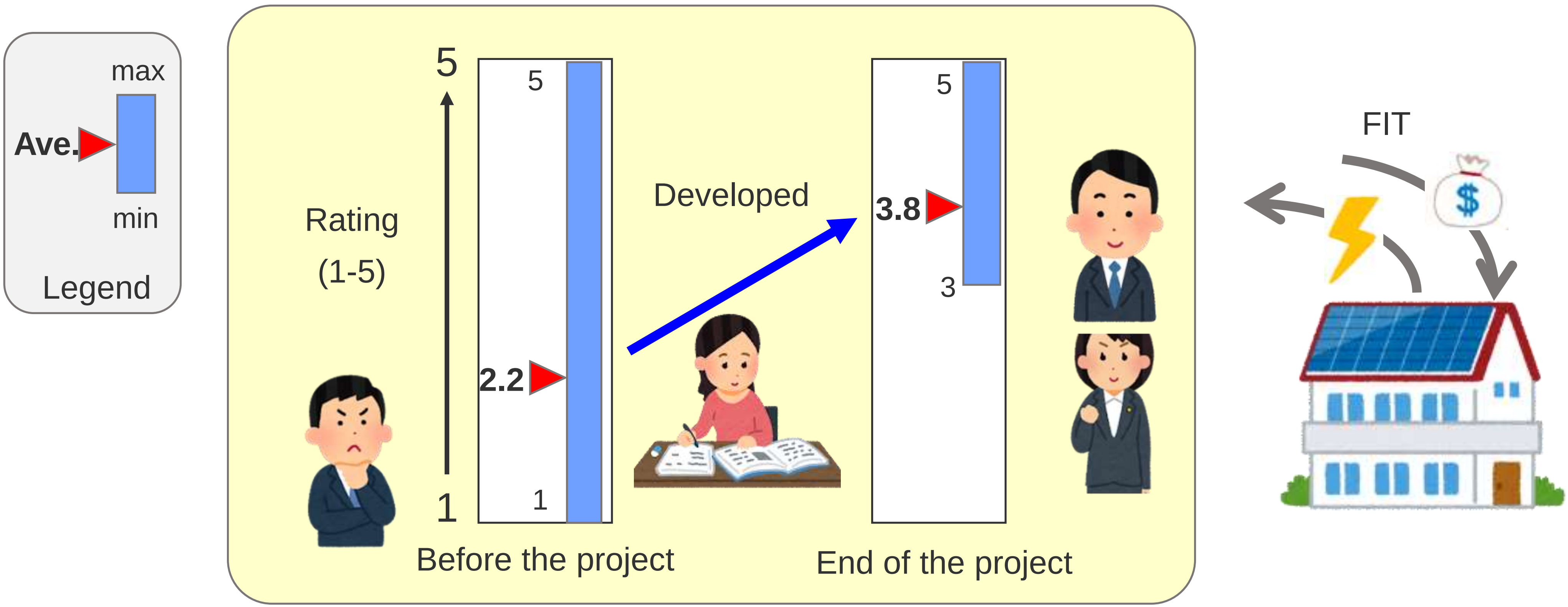
(b) Understanding of **FIT Tariff Revision** for rooftop PV.

Average rating of self-evaluation by WG1 members on understanding of FIT Tariff Revision is shown below.



(Source: JICA Expert Team Prepared)

Fig. 3-3-3 Results of self-evaluation on improvement of understanding of FIT Tariff Revision

Results of Capacity Development (WG1 / CEB members)

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(b) Understanding of FIT Tariff Revision for rooftop PV.

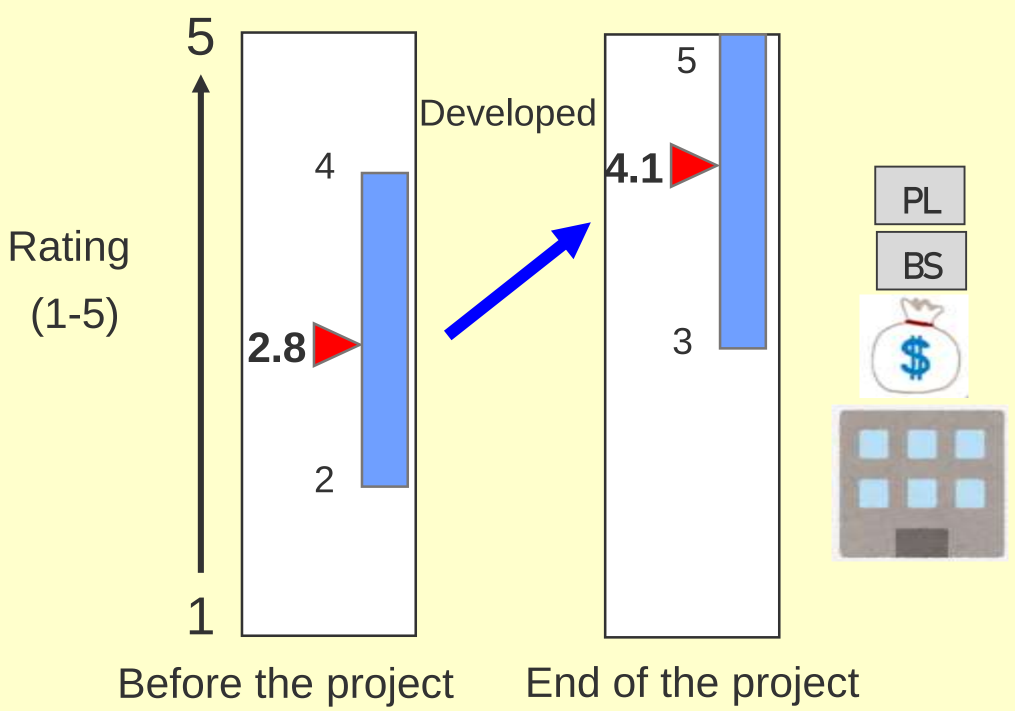
Example of comments after study about FIT Tariff Revision are as follows.

- FIT mechanism in Japan were very useful information. It is important to have an attractive FIT structure to compensate the high capital costs.
- The computation of FIT was really impressive.
- The scheme like FIP will be more favorable to promote small scale renewable developments.
- It is a good example to identify the correct methodology of implementing FIT schemes.
- Attractive FIT structure is important in order to promote and motivate the customers to install Solar PVs.
- Periodic review of the tariff is important to sustain the solar generation as well as for the viability of CEB.

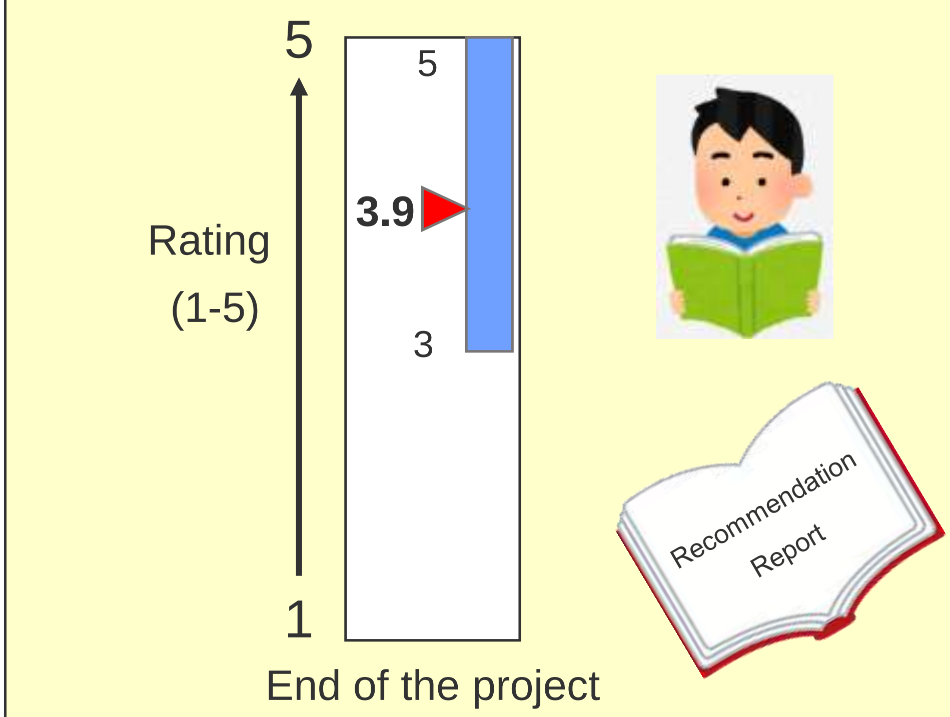
Results of Capacity Development (WG1 / CEB members)

(c) Understanding of **Financial Analysis** and **Recommendation Report**

Average rating of self-evaluation by WG1 members on understanding of **Financial Status of CEB** and **Recommendation Report** is shown below.



Understanding of Financial Status of CEB



Understanding of Recommendation Report

(Source: JICA Expert Team Prepared)

Fig. 3-3-4 Results of self-evaluation on improvement of understanding of Finance matters

Results of Capacity Development (WG1 / CEB members)

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(c) Understanding of **Financial Analysis** and **Recommendation Report**

Example of comments after study of **Financial status of CEB** are as follows.

- It is important to set a cost reflective tariff considering the macro economic factors and the actual generation cost.
- Cost reflective tariff settings will definitely pave the way to mitigate the revenue shortages against the expenditure.
- Cost reflective tariff systems should be introduced with immediate effect to overcome the financial burden.
- Overall cost optimization to integrate Renewable Energy is important.
- The timely tariff revisions are required to accommodate the increasing costs.
- Frequent analysis, periodical financial planning & budgeting and monitoring of actual vs budgeted income and expenditure, has enabled strategic decisions and implementing strict controls over both OPEX and CAPEX cost reductions.

Results of Capacity Development (WG1 / CEB members)

(c) Understanding of **Financial Analysis** and **Recommendation Report**

Example of comments after studying **Recommendation Report** are as follows.

- The Report will be used to justify the future tariff revisions.
- It is important to take swift & appropriate actions within an identified timeline to reach the expected goals.
- Recommendations will be helpful to promote Renewable in the journey of achieving the target by 2030.
- It will be more transparent if scientific equations can be introduced to decide the annual increase/decrease amount with all relevant parameters like fuel cost, exchange rate, inflation level, O&M cost, transportation cost, system loss, etc.
- Costs should be incorporated with the final equation of selling price calculation and reasonable cost reflective tariff can be obtained so that both CEB and consumers are benefited.
- The Recommendation Report will be of use when requesting for tariff revisions and for discussions with the PUCSL in the future.

Results of Capacity Development (WG1 / CEB members)

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(d) **Feedback** opinion about the Project

Feedback by WG1 members after the Project are as follows.

- The capacity development would have definitely fulfilled by Expert Team.
- I'm glad to be participating in this project and it really enhances my knowledge in different aspects. I'm expecting to apply that knowledge for the development of the power system and enhance the quality of the energy sector.
- Recommendation Report provides a simplified summary of CEB current financial status and its future financial status.
- I was able to enhance my knowledge on pricing and tariff structures.
- It was a great opportunity to understand and enhance knowledge on Renewable Energy sector in different countries.

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(2) Results of self-evaluation by SLSEA members in WG1

WG1 members in SLSEA self-evaluated on the contents below;

(a) Revision of the Guideline of the approval process

(b) Introduction of the online system

(c) Amendment of the Electricity Law to remove competitive bidding

Results of Capacity Development (WG1 / SEA members)

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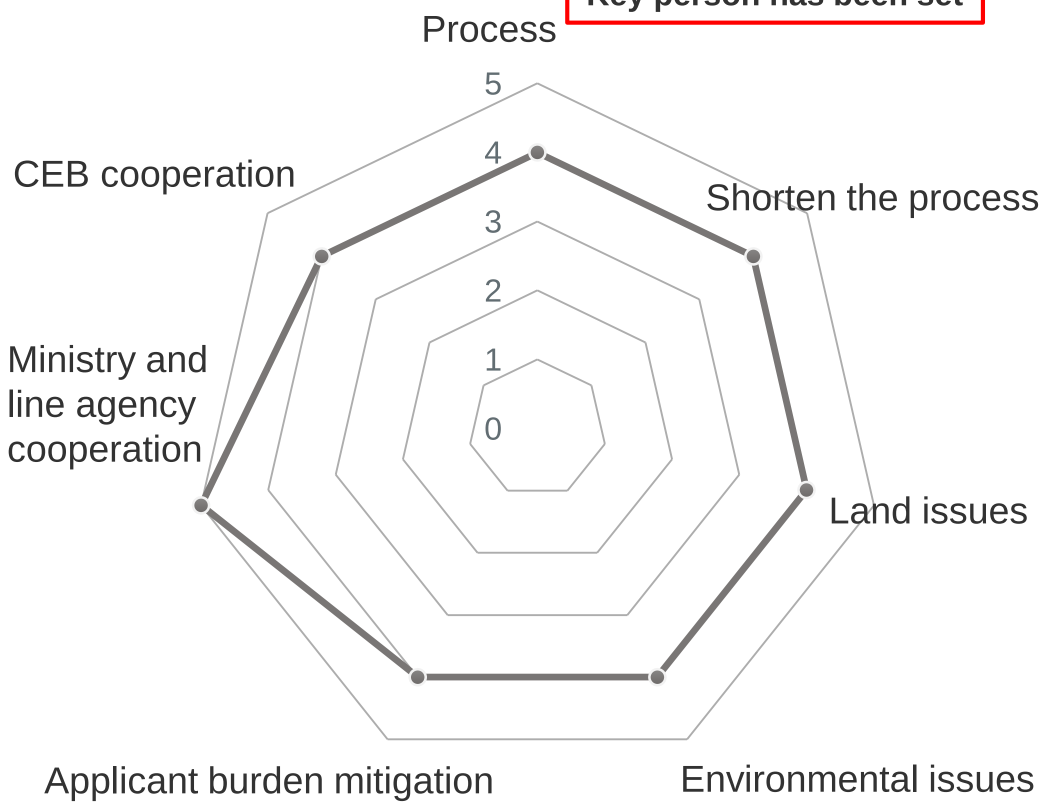
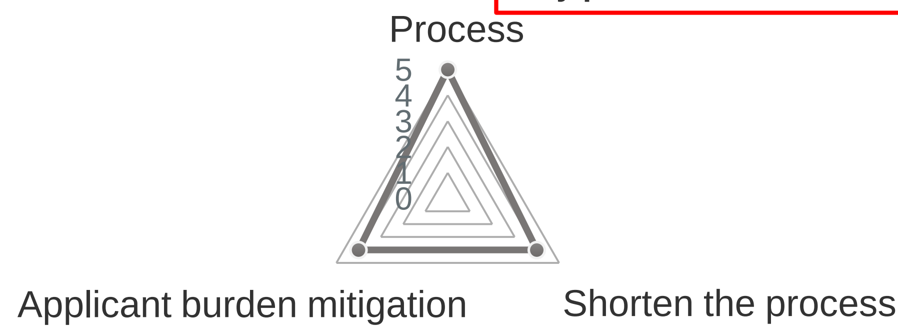
(a) Improvement by New Guideline

Key person has been set

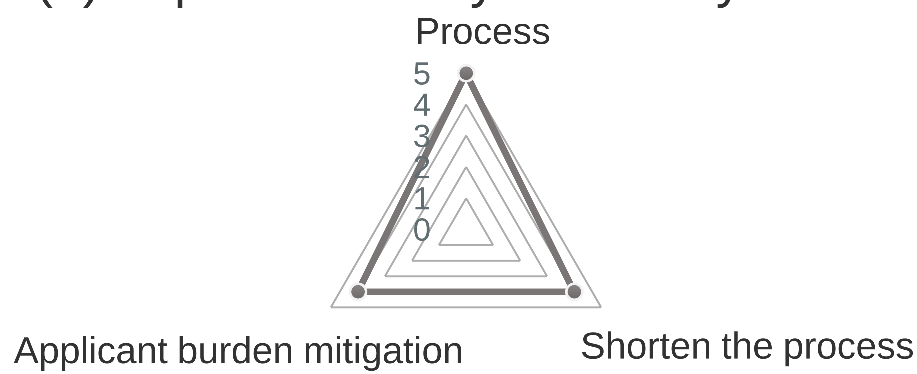


(c) Improvement by Law Amendment

Key person has been set



(b) Improvement by Online System



Input of Japanese system and policy for VRE: 5

(Source: JICA Expert Team Prepared)

03-3 Comments on action to achieve higher goals

Comments on efforts to achieve higher goals (WG1)
① Action for Rooftop PV FIT tariff revision

- **Periodical review of FIT tariff**
  The FIT tariff should be reviewed annually to reflect lower installation cost and changes in financing conditions.

PV Installation cost

IRR

Repayment period

Interest rate

Financial conditions

Protection of business operators

Promotion of development

Generation cost competitiveness

- **Automatic assumption of PV installation costs**

Japan case

- The installation unit cost (Yen/kW) is assumed from past cost distribution.
- When assuming the 2020 introduction cost (50% value), the 37% value of the cost distribution two yeas ago can be used.

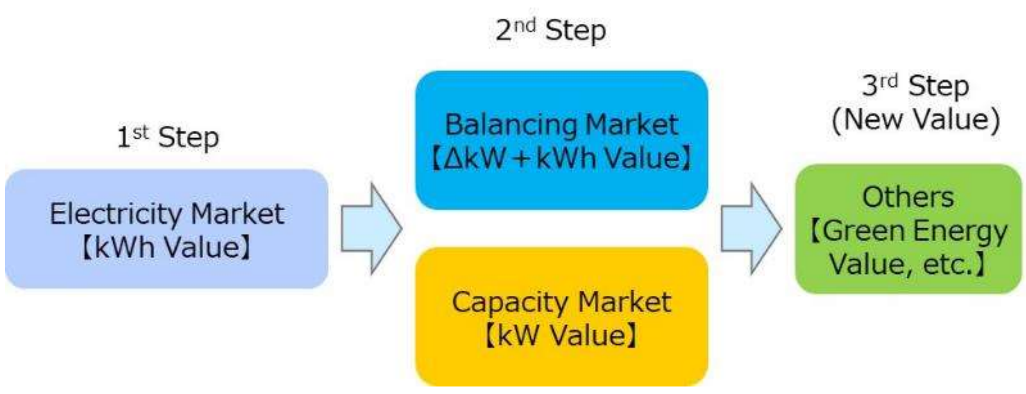
The unit cost for installation is the 37% value from two yeas ago

PV system cost for household [Japanese Yen/kW]

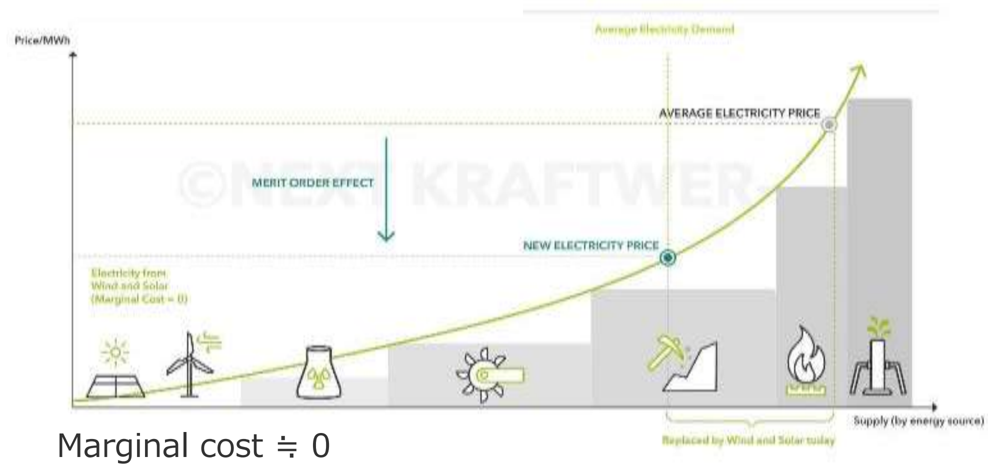
%	Installed in 2020	Installed in 2019	Installed in 2018
20%	210,400	228,500	257,300
25%	225,200	237,500	272,500
30%	238,700	247,900	288,100
35%	251,900	260,900	298,000
36%	255,000	263,300	300,500
37%	258,700	266,200	303,400
38%	261,700	269,100	305,600
39%	265,100	272,300	308,300
40%	268,600	275,400	311,100
45%	284,900	288,800	323,500
50%	300,800	303,100	335,200

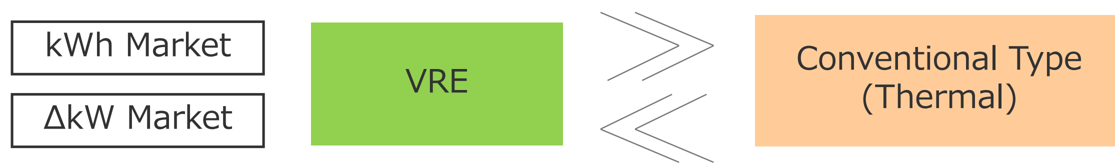
Comments on efforts to achieve higher goals (WG1)
② Action for introduction of Balancing market

- It is necessary to develop the market in stages
  - A) Wholesale Market (Platform of Free electricity trading, kWh value trading)
  - B) A market where values other than kWh can be evaluated
  - C) A market where new added value can be evaluated
- Since ΔkW is a value that is completely different from kWh value, it is necessary to understand it and design a market where appropriate reward is paid so that facilities with ΔkW value can survive.



Merit Order (kWh market)





Source: German Renewable Energies Agency

Comments on efforts to achieve higher goals (WG1)
③ Improvement of VRE Approval Process

- Since the situation of environment and policy could be changed easily, It is important to keep an eye on such situation and evaluate the process periodically to adopt the latest situation to it
- Other than approval process itself, there are obstacles that deter accelerating VRE developments, such as limited grid capacity and variable demarcated areas, it is important to share the ideas of overall improvement with related organization to achieve further objects

Comments on efforts to achieve higher goals (WG1)
④ Action for Financial condition improvement

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- Periodical revision of Financial Project Model to update with actual data and future projection including inter-divisional communication among CEB staff
- Discussions on the Recommendation Report with CEB's executive management, MOP, PUCSL and other decision makers/ stakeholders for necessary government measures and financial improvement of CEB including operational cost reduction
- Taking coordinated actions with authorities for speedy implementation of public investment/ IPP projects to comply with the latest LTGEP and necessary transmission system development
- Preparation and implementation of the roadmap for financial improvement of CEB based on the discussions with authorities to achieve financially sound and sustainable operation

04 Activity & Outcome of WG2 (Planning and Operation of Power System)

04-1 Activity / Outcome & Action Plan

4-1 Activity & Outcome (WG2)
Overall Activity

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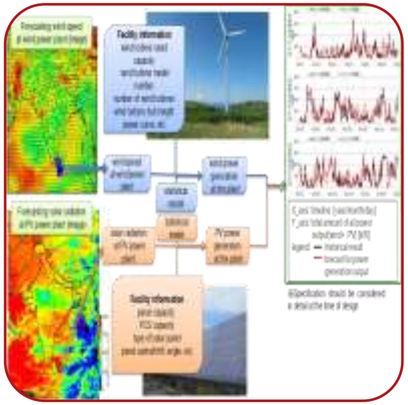

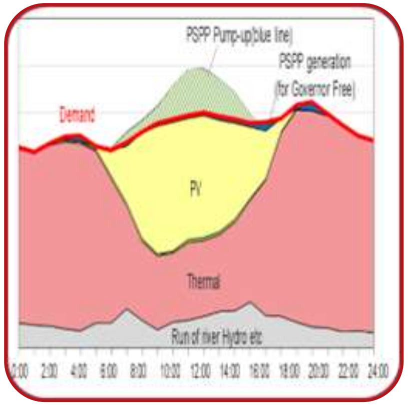

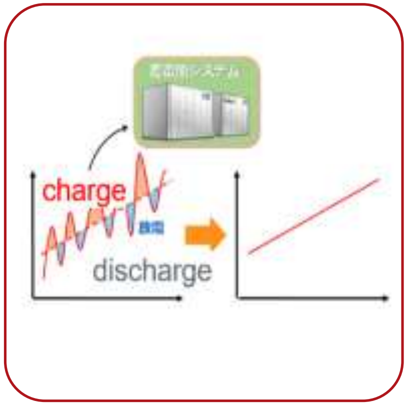

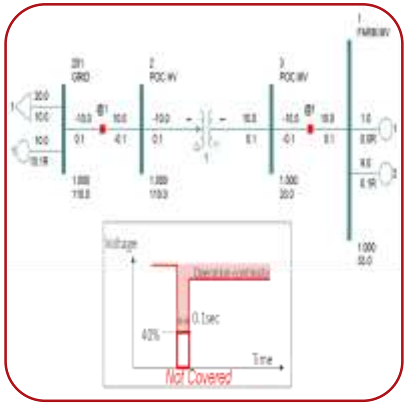

①VRE forecast

Supply demand operation

- ②Renewable Energy Desk (RED)

Energy storage

- ③Battery storage capacity consideration
- ④Pumped Storage Power Plant (PSPP)development →Geological investigation

Power system operation

- ⑤PSS/E analysis
- ⑥Grid Code Revision

4-1 Activity & Outcome (WG2)
①-1 VRE forecast

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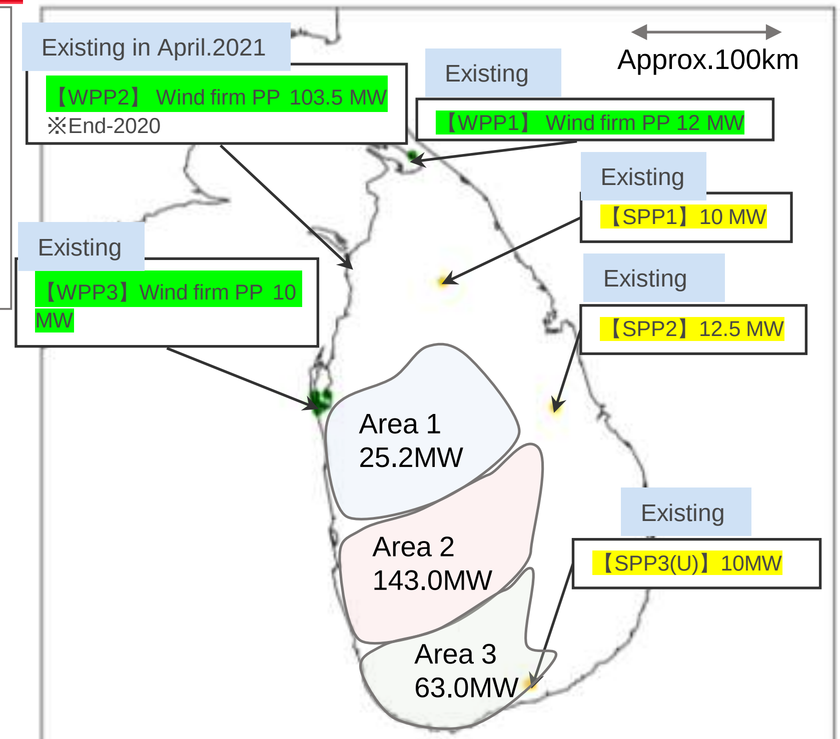
Situation

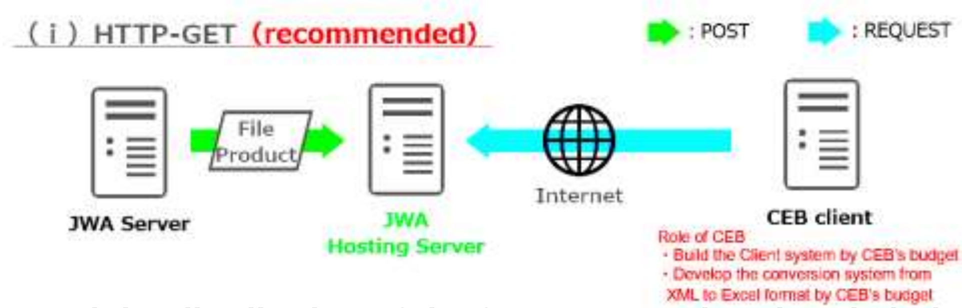
- ✓ Currently CEB does not have a methodology to forecast VRE output
- ✓ Embedded VRE output and self-consumption cannot be observed from NSCC due to no communication line

Study & Activity

- ✓ Selection of 8 VRE forecasting sites
- ✓ Developed the VRE forecast model for these sites and forecasting the VRE output using the model
- ✓ Decided specification for distribution of VRE forecast (weather data, output) and started distribution VRE forecast to CEB
- ✓ Developed the VRE Conversion Tool for estimating the VRE output from the weather forecast data
- ✓ Provided the Conversion Tool to CEB to forecast VRE output from weather data
- ✓ Forecast error compared with actual data to improve VRE forecast results



✓Sites of VRE forecasting model development



✓Started the distribution of the forecast weather data (Wind speed, wind velocity, irradiation) and forecast VRE output data from July1, 2021

4-1 Activity & Outcome (WG2)
①-2 VRE forecast

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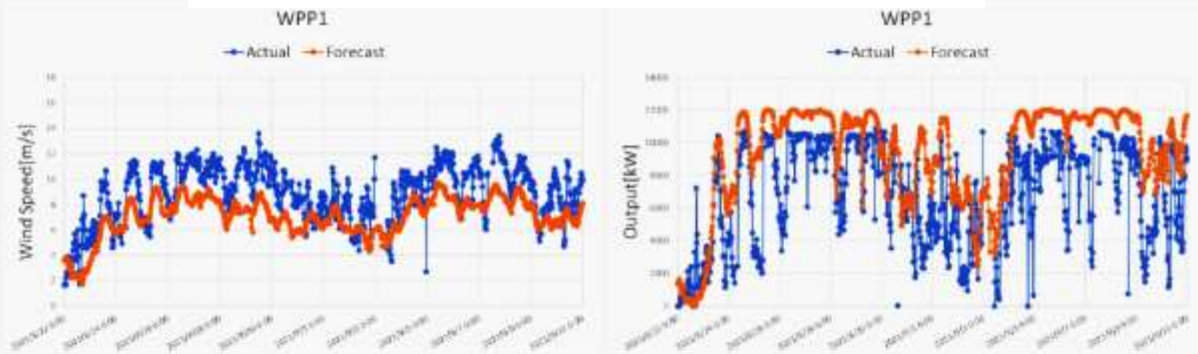
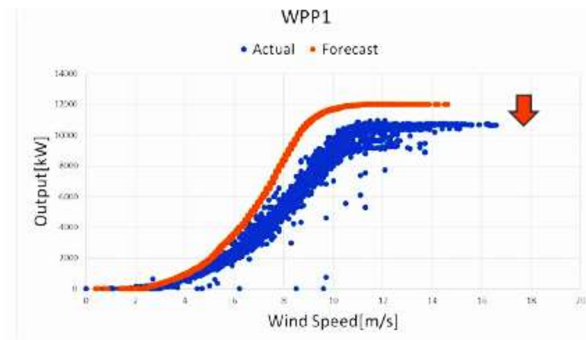
Outcome

- ✓ Started distribution of VRE forecast data from July 1, 2021,and provided the VRE Conversion Tool in Nov 2021, to CEB for its in-house use.
- ✓ Shared the evaluation technique of VRE forecast error and verification method of actual data and VRE forecast to improve the VRE forecast

✓Verification of forecast data and actual data

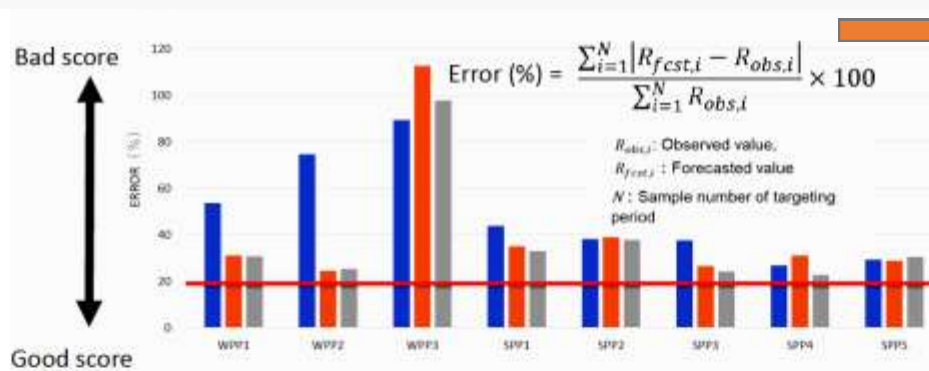


✓Improved method of the VRE forecast model



Applied image.

✓Evaluation of the accuracy of the VRE output forecast



Detail explanations of the legend

■ **1st model:** Developed only based on VRE facility information, evaluated with the instantaneous VRE output data

■ **2nd model:** Developed based on VRE facility information, VRE output data, and weather data regarding WPP1, WPP2, SPP1, and SPP2, evaluated with the instantaneous VRE output data.

■ **2nd model(averaged):** Evaluated 2nd model with the VRE output data averaged by the moving average method.

4-1 Activity & Outcome (WG2)
②-1 RED (Renewable Energy Desk)

Situation

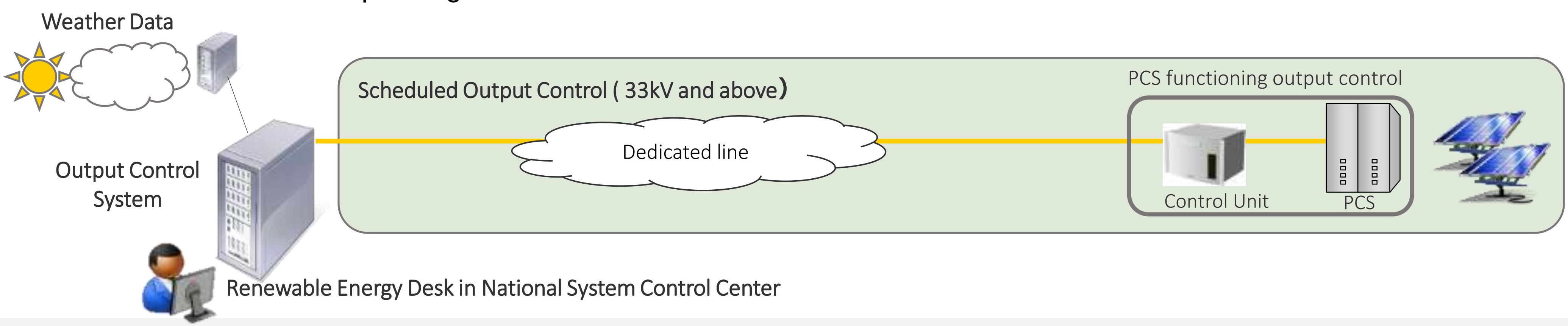
- ✓ CEB did not have a methodology to control supply demand balance under mass RE introduction
- ✓ CEB did not have a methodology to handle RE surplus power.

Study & Activity

JICA experts explained

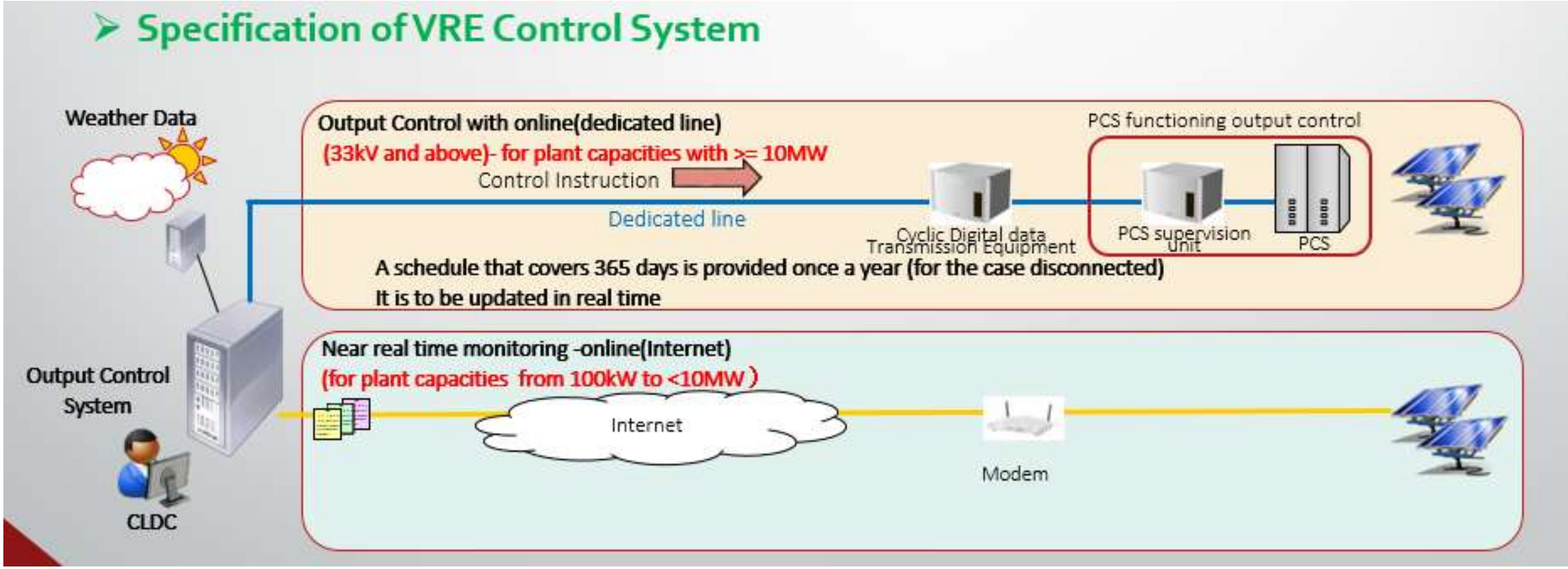
- ✓ System Specification of VRE Control System based on Japanese case.
- ✓ Future Configuration of RED.

✓ Control method of VRE equal or greater than 10MW



Outcome

- ✓ VRE control range is 10MW or more by reliable dedicated line.
- ✓ CEB made RED structure based on JICA experts idea.



CLDC : Central Load Dispatching Centre

②-3 Action for the Development of VRE forecasting system, Demand forecasting system and Renewable Energy Desk.

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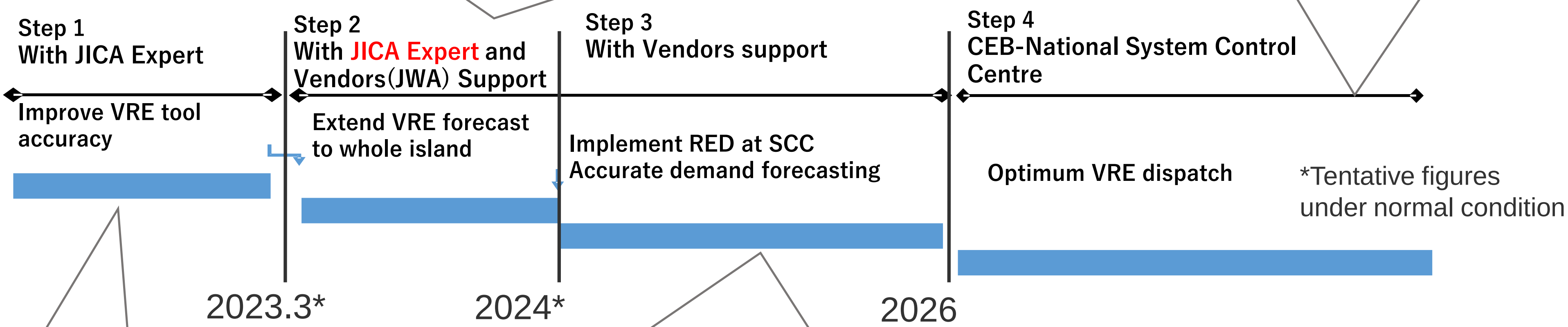
Next Goals:

- ✓ **Expand and Improve the accuracy of VRE forecasting system**
- ✓ **Implementation of Renewable Energy Desk**
- ✓ **Implementation of accurate demand forecasting system**

Planned steps:

Conversion Factor X SPP/WPP output forecast based on procured weather data from (JWA / DOM etc.)

- Optimum system Operation with accurate VRE forecasting
- Explore the possibility of introducing Market System



Verify forecast value by comparing with actual values

- Required amendments to Grid code and proper VRE curtailments policy should be introduced.
- Output Control with dedicated lines(>=10MW)
- Near real time monitoring based on capacity (100kW to <10MW)

4-1 Activity & Outcome (WG2)
③-1 Battery Storage

Situation

- ✓ CEB needed to simulate surplus power and consider necessary capacity of the energy storage to achieve 70% renewable energy in 2030.
- ✓ CEB required to support on how to evaluate cost-effectiveness of installing an energy storage system (battery storage, PSPP (Pumped Storage Power Plants)).

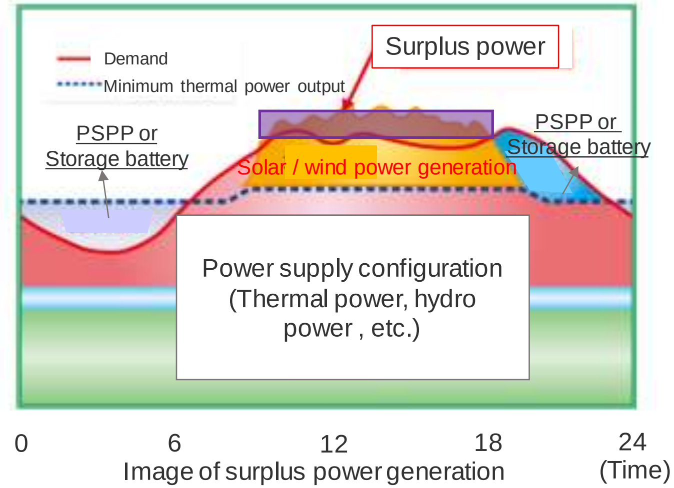
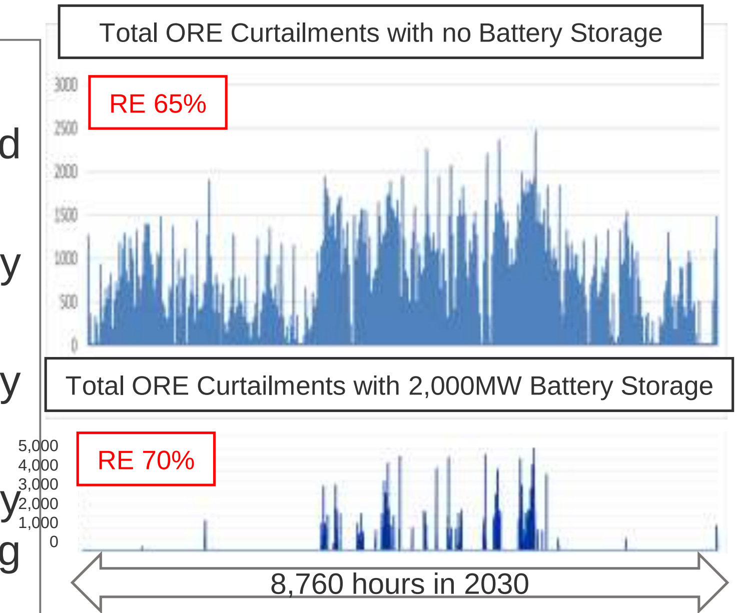


Image of surplus power generation

Study & Activity

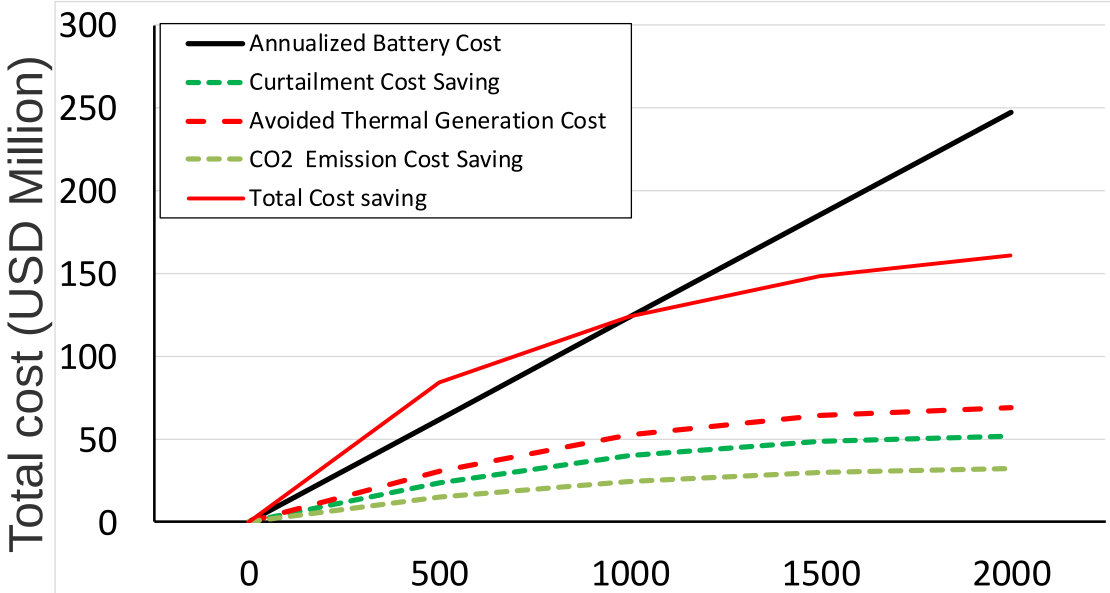
- ✓ The detailed characteristics (Energy density, Charge and Discharge efficiency, Cycle longevity, Initial cost)
- ✓ Calculation of total ORE curtailments in case of each battery capacity introduction by SDDP simulations.
- ✓ Calculation of necessary battery capacity under current supply and demand operating conditions
- ✓ Considering how to reduce the amount of battery capacity introduction by reviewing the supply and demand operating conditions to keep initial costs down.



4-1 Activity & Outcome (WG2)
③-2 Battery Storage

Outcome

- ✓ CEB can achieve 70%RE with 1,000MW battery storage introduction by reviewing the supply and operation conditions, it is reflected in the latest LTGEP.
- ✓ CEB could have a return on 90% of investment of 1,000MW battery storage introduction considering the cost evaluations (RE Curtailment opportunity cost, Thermal generation cost, CO_2 emission cost and PCS cost).
- ✓ JICA Expert suggest cost evaluation method for each breakdown of battery storage type (NaS: Supply and Demand control, Li: Frequency control) based on PSS/E analysis, CEB can evaluate the cost effectiveness of introduction of battery storages by themselves.



Introduction storage battery capacity [MW]

Capacity	Annualized Battery Cost	Total Cost Saving
(MW)	(USD million)	
0	0	0
500	62	69
1,000	124	117
1,500	186	143
2,000	247	153

4-1 Action Plan (WG2)
③-3 Action for Battery storage capacity consideration

✓ What CEB members learned through the project

- The Type of Battery Storages and their salient characteristics (Li, NaS, Redox)

✓ How to utilize WG2's activity results

- Deciding the type of Battery Storage technologies to be utilized based on their capabilities

✓ What CEB members take action in the future

2023
Preparation stage

- Procurement Strategy
- Detailed Technical Requirements

2024
Demonstration stage

- 1st Pilot Power Project 20MW
  - Frequency Control Support
  - Ramp Control
  - Energy Shifting

2025-2030
Development stage

- Combination of Stand Alone Battery Storage Project and Hybrid Solar with Battery Storage Projects
- As per LTGEP, 1,105MW Battery storage planed to be installed

4-1 Activity & Outcome (WG2)
④-1 Geological Investigation

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Situation

- ✓ Currently there is no surplus power storage in Sri Lankan power system
- ✓ Considered options are PSPP & Batteries
- ✓ Two PSPP sites have been identified (Mahaoya site, Victoria site)

Activities of WG2 Geo. Investigations & Knowledge sharing assignments:

- ✓ Some Geological investigations were done at Victoria site (only upper dam site) completed in Dec 2021.
- ✓ It has identified there is no fatal geological risk at upper dam site based on investigation results in this stage (2021).
- ✓ 2nd Technical Seminar (Evaluation of the results at the Victoria site)
- ✓ Conducted on-site training (Final Stage):Victoria site on October 26, 2021, On-line on October 28, 2021

✓Sample of core drilling

✓On-site training at Victoria site

4-1 Activity & Outcome (WG2)
④-2 Geological Investigation

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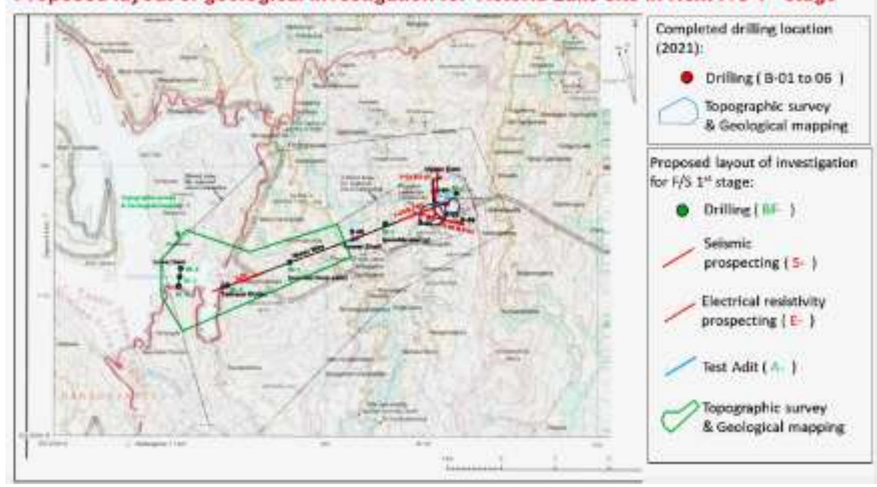
Outcome

- ✓ Through geological investigation and on-site training, the following points relating to the geological investigation of PSPP (Pumped Storage Power Plant) were shared.
  - ✓ How to plan the future studies related to PSPP
  - ✓ What are main check points of Geological Investigation for PSPP development

✓provide as idea on check points of Geological Investigation for PSPP development

Structures	Check Points
Underground power station	1. Rock condition
Lower water way	1. Landslide risks 2. Rock condition along water ways
Lower dam and reservoir	1. Safety of dam foundation, water tightness, landslide and water seepage risks.
Upper dam	1. Safety of dam foundation 2. Water tightness
Reservoir	1. Landslide risks 2. Water seepage risks
Upper water way	1. Landslide risks of portals 2. Rock condition along water ways

Proposed layout of geological investigation for Victoria Lake site in Next F/S 1st stage



4-1 Action Plan (WG2)
④-3 Action for Pumped Storage Power Plant (PSPP)development

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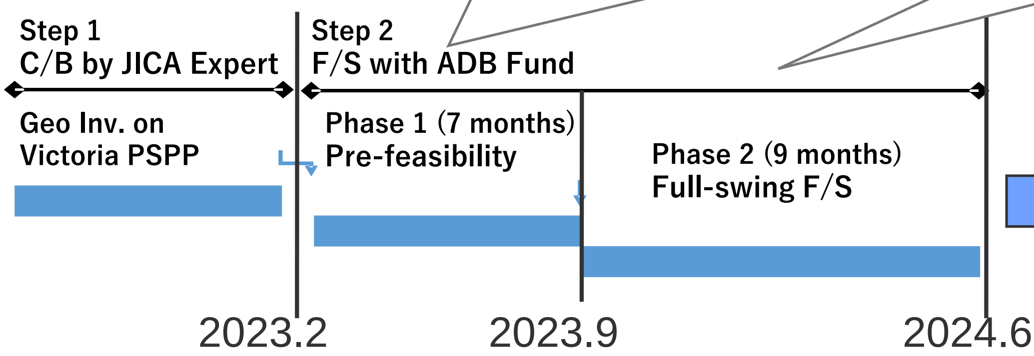
Next Goal:

- ✓ To carryout the required studies to select the best site to develop the PSPP

Planned steps:

- Pre-feasibility level study for Victoria site
- Comparison and select the best site from Maha oya and Victoria site

- Detailed feasibility study
- Construction plan for the selected site



After the studies detail design and construction phase should be started

Technical Feasibility

- ✓ Geology
- ✓ Hydrology
- ✓ Electro-mechanical
- ✓ Interconnection, etc.

Economic Feasibility

- ✓ Cost calculation
- ✓ Economic & Financial viability

Environmental Feasibility

- ✓ Physical
- ✓ Social
- ✓ Ecological

4-1 Activity & Outcome (WG2)
⑤-1 PSS/E

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Situation

- ✓ CEB did not have actual model parameters to simulate mass RE, PSPP and storage battery in PSS/E.
- ✓ CEB needed better understanding on how to set scenario to revise grid code.

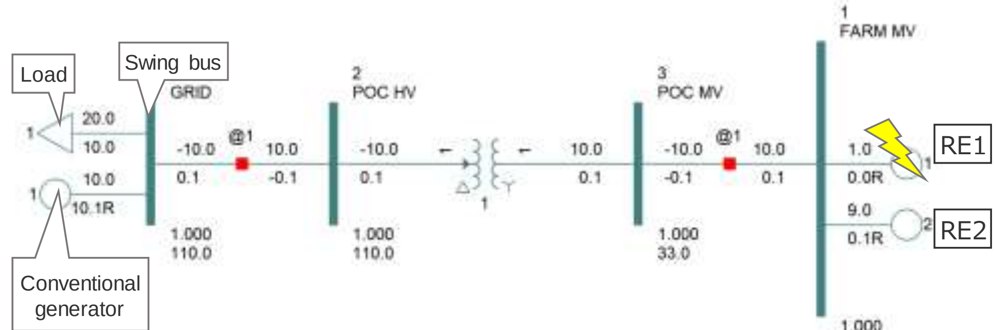
Study & Activity

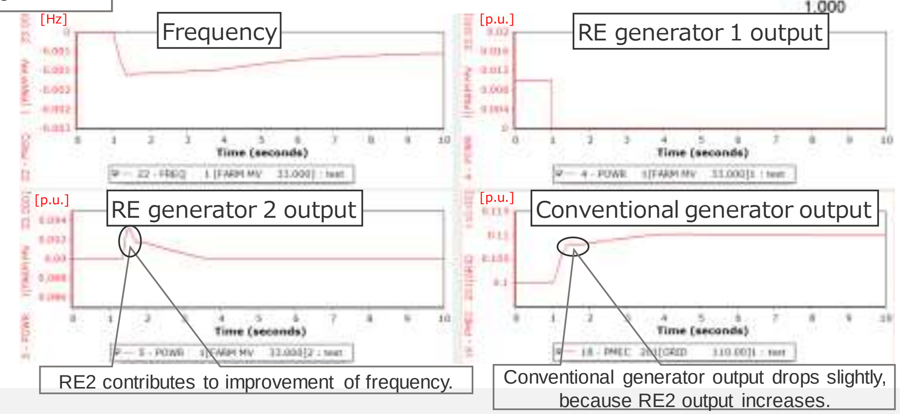
- ✓ 1st and 2nd generation RE model (Plant Control, Generator/Convertor, Electrical Control)
- ✓ Demonstration of SIM example (frequency control, voltage control)

Outcome

- ✓ CEB got idea on how to set PSPP and storage battery parameter in PSS/E
- ✓ CEB can run SIM in 70% RE case.

Model	Wind (W3&W4)	PV	BESS Battery Energy Storage System
Generator /Converter	REGCA1 (Current source model) REGCB (New model : Voltage source model)		
Electrical Control	REECA1 (Wind, PV)	REECB1	REECC1
	REECDU1 (New model: Recommended for Wind, large scale PV, BESS)		
Mechanical (Drive Train)	WTDTA1, WTDTB*		
Pitch Control	WTPTA1, WTPTB*		
Aero Dynamic	WTARA1		
Torque Control	WTTQA1		
Plant Control (Auxiliary Control)	REPCA1, REPCC*		
Weak Grid	WTGWGOA* (Reduce Pref for post-fault recovery)		
IBFFR (Inertia	WTGIBFFRA*		





4-1 Action Plan (WG2)
⑤-2 Action for PSS/E analysis

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✓ What CEB members learned through the project
- Modelling and parameters of Pump Storage Power Plant in PSS/E

✓ How to utilize WG2's activity results
- Use this model in 70% RE cases to model the PSPPs

✓ What CEB members take action in the future
- Introduce this model for the 2x350 MW PSPPs by 2030 in the LTTDP
- Check for the issues in steady state, contingency and transient stability
- Identify issues due to tripping of PSPP in transient studies and provide solutions to mitigate them
- Identify issues during startup of the PSPP and provide solutions

4-1 Activity & Outcome (WG2)
⑥-1 Grid Code Revision

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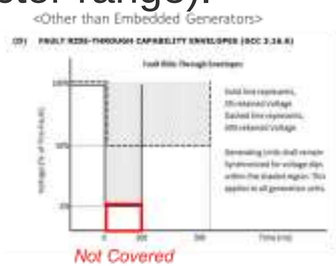
Situation

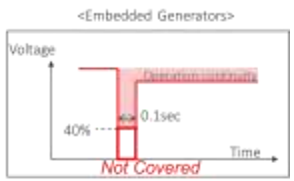
✓ After mass introduction of VRE, power system will not be stable unless grid code is revised.

Study & Activity

- Input of state-of-the-art technical knowledge
- Understanding CEB GRID CODE
- Comparison with Japan and Ireland
- PSS/E simulation for numerical criterion changes
- Analysis for PSS/E simulation

✓ Identified Grid Code parameters to be revised (RoCoF, FRT, ramp rate, Power Factor range).





✓ Proposed Simulation scenarios

✓ Provided PSS/E setting

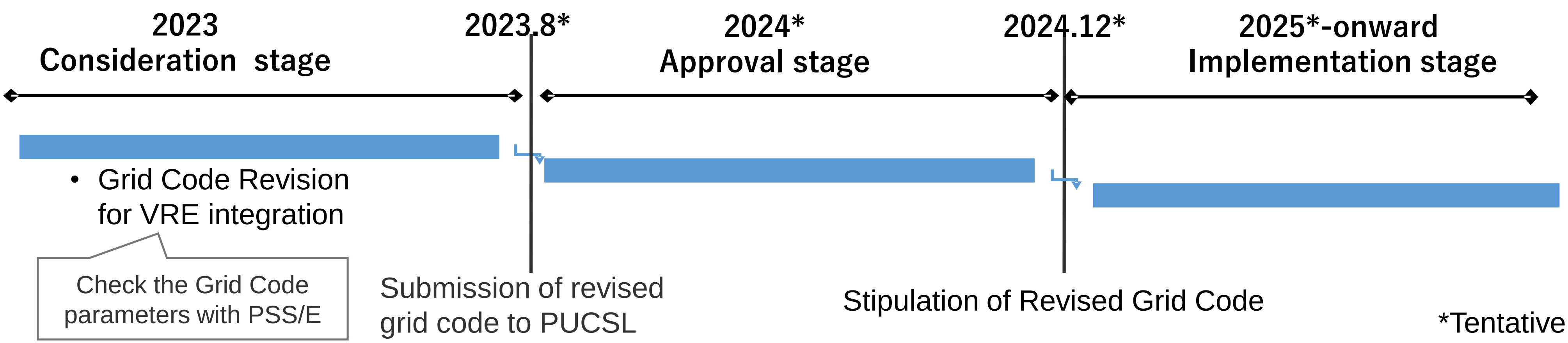
✓ Simulation conducted by CEB

Outcome

✓ CEB could get know-how to revise Grid Code.

4-1 Action Plan (WG2)
⑥-2 Grid Code Revision

- ✓ What CEB members learned through the project
  - ✓ Addition of Fault Ride Through studies to the Long Term Transmission Development Plan studies
- ✓ How to utilize WG2's activity results
  - ✓ Include these studies in the next planning cycle
- ✓ What CEB members take action in the future
  - ✓ Introduction of rooftop solar FRT models for the all rooftop solar in the system
  - ✓ Check for the FRT capability of these plants during a major fault
  - ✓ Check the system RoCoF by tripping the largest machine in the system while adding a fault and tripping all rooftop solar plants in the area at the system's Nadir point due to solar irradiance variation
  - ✓ Check different scenarios by applying the fault in different voltage levels to identify the significance of FRT



*Tentative

04-2 Results of Capacity Development

Results of Capacity Development (WG2)

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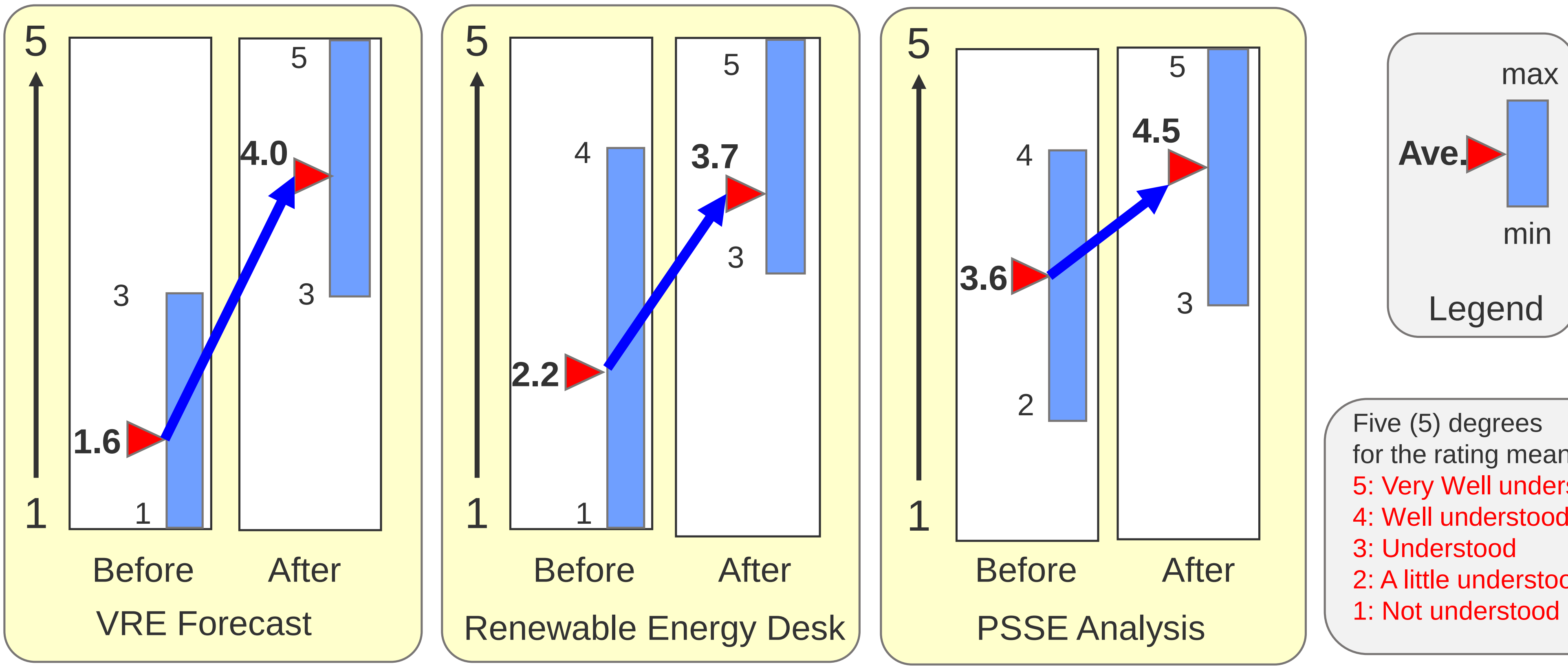
Understanding of **WG2 activity in this Project**.

WG2 members evaluated about capacity improvement of them in this Project.
Each WG2 member conducted the self-evaluation between before & end of the Project.



Five (5) degrees
for the rating means;
5: Very Well understood
4: Well understood
3: Understood
2: A little understood
1: Not understood

Results of Capacity Development (WG2)

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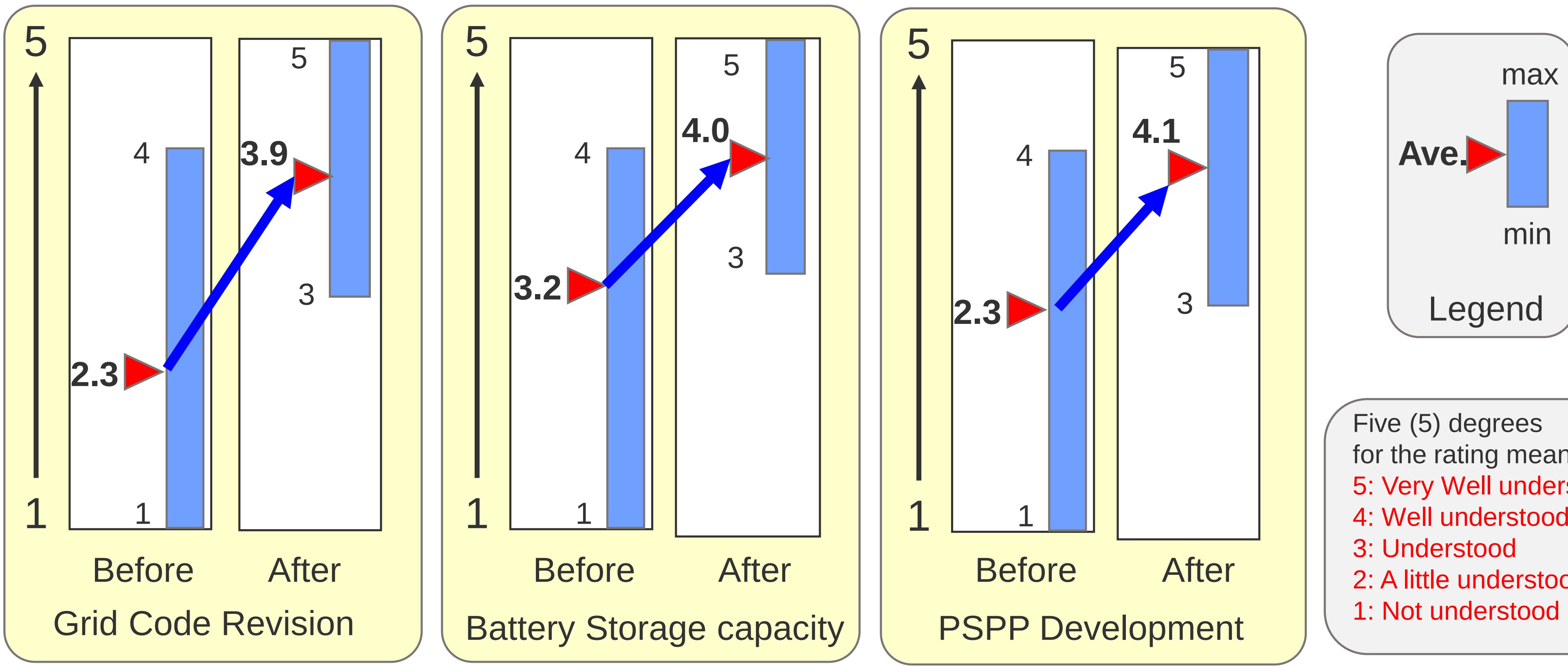

Five (5) degrees
for the rating means;
5: Very Well understood
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2: A little understood
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Results of Capacity Development (WG2)

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Example of comments after study about WG2 activity

- As RED is a new thing to us, it is very insightful and beneficial for us when we are going with more and more RE addition to the national grid.
- It was very useful for us to know the international experience on Grid Code parameters for a stable grid network
- The models of the battery energy storage and pump hydro storage that was provided will be quite useful for short term frequency stability studies and for transient stability studies as we were unable to simulate them due to lack of the models available
- System analysis using geological survey results, because it is very important for proper identification of weak geological zones and thereby identify any improvements to achieve a safe and economical implementation.
- I am really appreciate if you could train us regarding designing of geological investigation with respect to key finding used by remote sensing methods.

04-3 Comments on action to achieve higher goals

Comments on efforts to achieve higher goals (WG2)
Action for (1) VRE forecast, (2)Renewable Energy Desk(RED)

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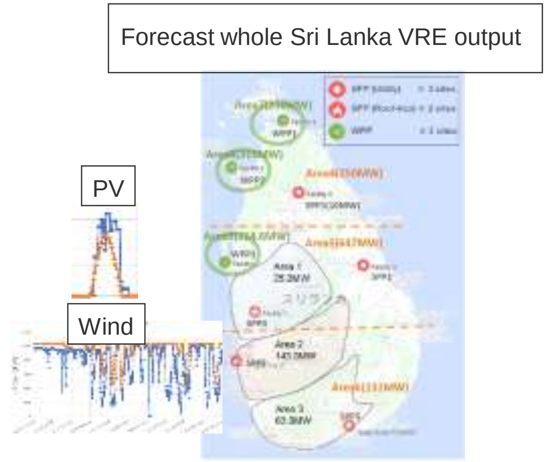
(1) Action for VRE forecast

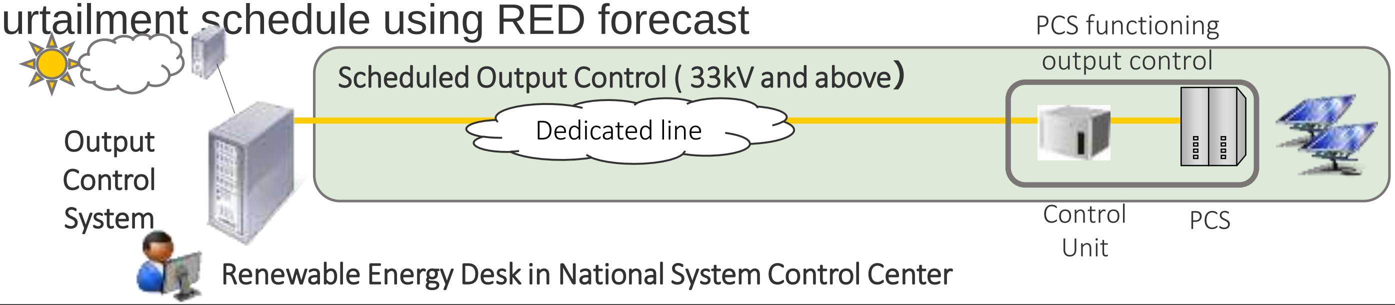
To achieve the higher goal of 20% forecast error or better, we recommend the following

- ✓ Extension of VRE forecast for whole of Sri Lanka
- ✓ Develop a VRE output model (by wind direction for wind power, by time of day for solar power)
- ✓ With accumulation of more historical weather data and VRE output, update the VRE model regularly.
- ✓ Compute the probability of forecast accuracy to decide the suitable reserve for stable power system operation
- ✓ After observing wind direction and speed, re-setting the power curve on the VRE Conversion tool for wind power.



(2) Action for Renewable Energy Desk (RED)

- ✓ Establishment of RED to monitor and control of VRE with 10MW or above in real time and later on extend it to up to lower capacity embedded generator
- ✓ Plan and manage supply and demand balancing operation using RED forecast
- ✓ Prepare & execute curtailment schedule using RED forecast



Comments on efforts to achieve higher goals (WG2)

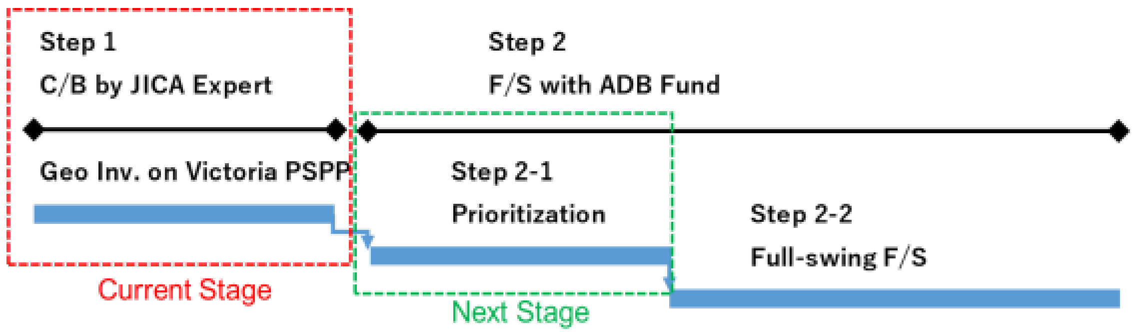
Action for (3) Battery storage capacity consideration, (4)PSPP development

(3) Battery storage capacity consideration

- ✓ Review of cost evaluation
  - ✓ Each cost (Battery system, fuel, CO2 emission etc…) may fluctuate significantly, it is necessary to reflect the latest trend of such cost while procuring the storage battery system.
  - ✓ In this project, the cost effectiveness was evaluated for the year 2030, however for a higher accuracy, the cost evaluation should be carried out yearly based on the latest LTGEP considering the life cycle (15-20 years) of the storage battery system.

(4) PSPP development

- ✓ In the next stage, it is suggested to conduct additional geological surveys especially at the lower pond and the downstream part of the waterway at the Victoria site, and other related feasibility studies referring to the result and recommendation in this Project.
- ✓ Prioritize the best candidate site for PSPP development out of Maha and Victoria sites based on the results of feasibility studies with ADB Fund

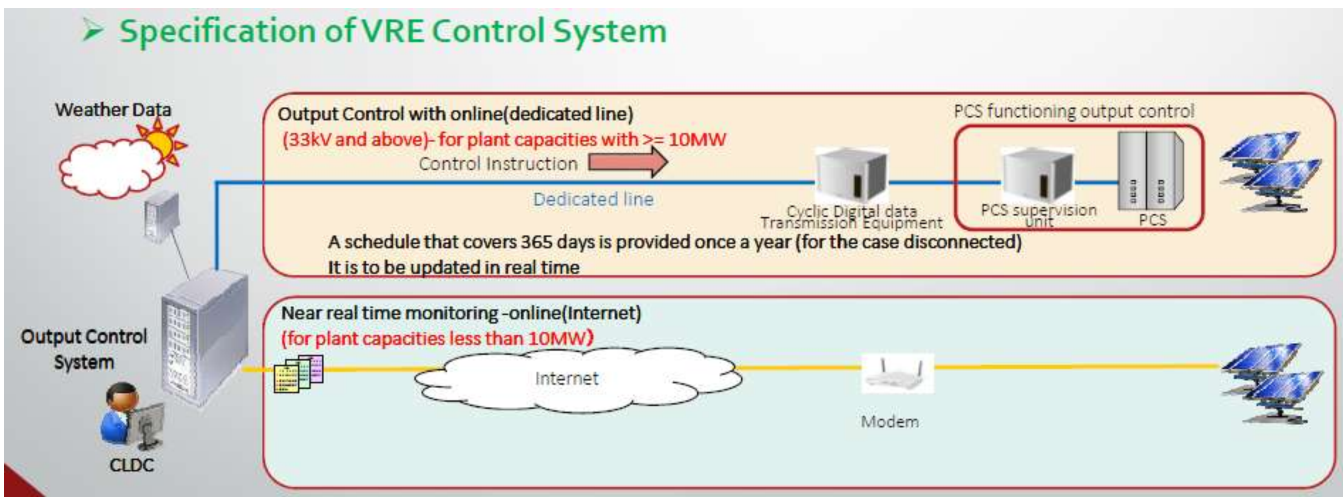


(5) PSS/E analysis

- ✓ Recommend to check grid code requirements periodically for carrying out power system analysis using PSS/E while taking into consideration different scenario of increasing VRE share and worst contingencies.

(6) Grid Code Revision

- ✓ Review the Grid Code requirements (RoCoF, FRT, ramp rate, Power Factor range, etc.) using the PSS/E results whenever the development plan for power sources are revised/changed.
- ✓ The target of RE control was set at 10 MW or more, need to consider expanding the control target (lowering the threshold value) when RE and battery storage development plan changes.



05 Activity & Outcome of WG3-1 (Improvement of Distribution System Reliability)

05-1 Activity / Outcome & Action Plan

5-1 Activity & Outcome (WG3-1)
Activity Record

Month **Field Activity**		Jan. – Mar.	Apr. - Jun.	Jul. - Sep.	Oct. – Dec.
2020	PHASE 1		#1 #2 Analysis and Study ・failure outage status ・ failure outage measures	#3 Procurement preparation ・Selection of pilot sites & countermeasure equipment	#4 #5
2021	PHASE 1	#6 Estimation ・effect of countermeasure equipment	Procurement of ARC/OCI/GFD	#7 #8 Record Power Outage Report in detail	#9 #10
2022	PHASE 2	#11,12 Record Power Outage Report in detail Procurement of ARC/OCI/GFD ARC Installation & OJT	#13 OCI Installation & OJT Evaluation	#14	#15 GFD Training

5-1 Activity & Outcome (WG3-1)
Failure records analysis

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Activity

- Importance of analyzing outage details to propose outage countermeasures
  - Under WG3-1 activities, existing failure records were analyzed thoroughly
  - Based on analyzed failure records, countermeasure equipment were proposed such a way that the maximum benefit of the equipment can be obtained

    (ie. Maximum improvement of SAIDI/SAIFI)

Outcome

- *It is understood that thorough analysis of failure records is essential to select appropriate outage countermeasure equipment and site locations*
- *This leaning outcome can be applied not only for outage countermeasure equipment proposed under this project but for existing & proposed countermeasure equipment in CEB (outside this project)*

5-1 Activity & Outcome (WG3-1)
Revised Failure Records

Activity

- Accuracy of failure records
  - It was noted that most of failure records are prepared based on the information provided by field staff

    (specially, information on the cause of the failure: *due to way leave, bird touching, etc.*)
  - Proper mechanism is not there to cross check the accuracy of the above failure records

Outcome

- *Accordingly, under this activity, new formats were introduced to record failures, which contains*
  - *Details of operated outage countermeasure equipment (AR, DDLO, etc.) during an outage*
  - *Failure cause with images*

5-1 Activity & Outcome (WG3-1)
Accumulation of Failure Records

Activity

- Effective use of failure records to measure the success of outage countermeasure equipment installed under the project
  - SAIDI & SAIFI are calculated and tabled monthly for feeders where outage countermeasure equipment are installed

SAIDI — Mahiyanganaya GSS F3

GFD		monthly												yealy
		1	2	3	4	5	6	7	8	9	10	11	12	
year	2021							58.0	61.0	11.0	55.0	32.0	59.0	
	2022	123.0	45.0	38.0	75.0	34.0	46.0	57.0	39.0	66.0	48.0			

Outcome

- *This practice can be applied for existing & proposed countermeasure equipment in CEB (outside this project), so that the effectiveness of such equipment can be monitored*

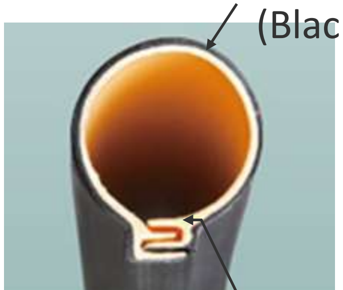
5-1 Activity & Outcome (WG3-1)
Abrasion Resistance Cover for Conductor

[Overview]

This product is used to protect electric conductors from trees, etc. by attaching it to electric conductors that are adjacent to trees, etc.

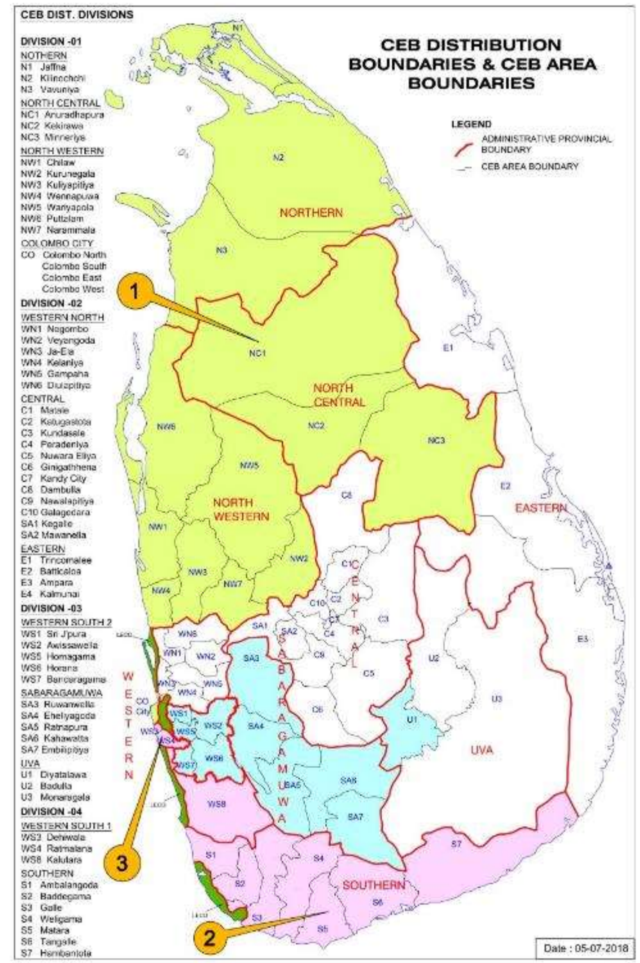
[Benefits]

- -This product is made of flame-retardant materials. (V-0 class)
- -The two-layer construction (outer layer: black, inner layer: yellow) makes it possible to visually check the time of replacement due to abrasion.
- -A locking mechanism is provided at the bottom of the joint to prevent it from opening.



5-1 Activity & Outcome (WG3-1) ARC Installation- Pilot Project sites

Division	DD1	DD4	LECO
Pilot Feeder	Town PSS - Pooja Nagaraya	Matara PSS - F1 Kalidasa Road	Kaluwamodara PSS - Moragalla feeder
SAIFI 2019 / No	10	2.4	56.2
Target SAIFI 2023 / No	3.8	1.3	37.5
Estimated Effect / %	- 62	- 45.9	- 33.3
SAIDI 2019 / min	1,192	110	1,450
Target SAIDI 2023 / min	397	53	967
Estimated Effect / %	- 66.7	- 51.8	- 33.4



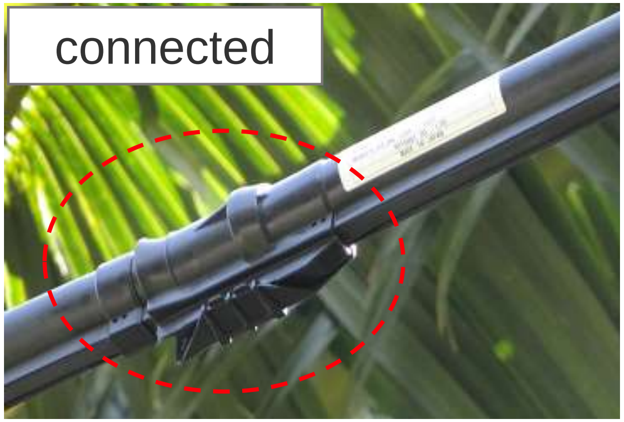
5-1 Activity & Outcome (WG3-1)
ARC Installation Sites

Town PSS - Pooja Nagaraya in DD1

Matara PSS - F1 Kalidasa Road in DD4

5-1 Activity & Outcome (WG3-1)
OJT at the ARC installation site

- How to install ARC in a place where work vehicles cannot enter.
- Advised on a more effective mounting range of ARC.



5-1 Activity & Outcome (WG3-1) Effectiveness of ARC Installation

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Period : ~ October 2022

Division	DD1	DD4	LECO
Pilot feeder	Town PSS - Pooja Nagaraya	Matara PSS - F1 Kalidasa Road	Kaluwamodara PSS - Moragalla feeder

Number of tree contact 2019/ No	10	6	18
ARC Installation	5th Apr 2022	8th Mar 2022	23rd Jan 2022
Number of tree contact 2022/ No	5	2	0
Number of tree contact reduced (Effect) / No	-5	-4	-18

5-1 Activity & Outcome (WG3-1)
Outcome of ARC Installation Activities

1. Check the feasibility of installing ARC in 33kV distribution network.
    - ARC installation could be used only for an 11kV network. CEB has a 33kV distribution network in many of areas except town areas and coastal areas.
    - Hence, ARC installation in 33kV network will be more effective in the CEB network.

2. Using ARC to maintain safety clearance in urban areas.
    - ARC can be used as cover to maintain safety clearance with buildings and other permanent structures in urban areas.

5-1 Activity & Outcome (WG3-1)
Over Current Indicator (OCI)

[Overview]

This product is with a function to detect and display the overcurrent (short-circuit current) flowing in the overhead distribution lines, and to automatically recover after a certain period of time.

[Benefits]

- Maintenance free (no batteries are required due to electromagnetic induction operation)
- Applicable to bare conductors

OCI Specification	
Rated operating current	300A
Min. detection current	250±30A
Indicates retractor current	2A or more
Indicates retreat time	5hours
Overcurrent strength	12.5kA
Rated frequency	50Hz
Operating temperature range	-20~40℃

5-1 Activity & Outcome (WG3-1)
OCI Installation- Pilot Project sites

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Division	DD1	DD2	DD3	DD4	LECO
Pilot feeder	Habarana F7 (1)	Kiribathkumbura F9 (2)	Ratnapura F2 (3)	Deniyaya F4 (4)	Beligaha-Boosa (5)
SAIDI 2019 / min	4620	1021	637.6	6052	3734
Target SAIDI 2023 / min	4126	955	355.9	5054	3437
Estimated Effect / %	-10.7	-6.5	-44.2	-16.5	-7.9

5-1 Activity & Outcome (WG3-1) OCI Installation SItes

■ DD1

■ DD2

5-1 Activity & Outcome (WG3-1)
OCI Installation Sites

■ DD3

■ DD4

5-1 Activity & Outcome (WG3-1) OCI Installation Sites

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■ LECO

5-1 Activity & Outcome (WG3-1)
OJT at the OCI installation site

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Noise coming from OCI（Case of DD1）

✓It is possible that the installation has not been done properly.
(The upper and lower cores may not be mated properly)

The other possible reasons are shown below.
✓There might be a gap in the core.
✓The core part might be dirty.

Fixed and shared the detail with each Division and LECO

5-1 Activity & Outcome (WG3-1)
Effectiveness of OCI Installation

CHUBU Electric Power
NIPPON KOEI

Period : ~ October 2022

Division	DD1	DD2	DD3	DD4	LECO
Pilot feeder	Habarana F7	Kiribathkumbura F9	Ratnapura F2	Deniyaya F4	Beligaha-Boosa

OCI Installation	30th Aug 2022	1st Sep 2022	18th Aug 2022	14th Sept 2022	24th Aug 2022
number of OC failure 2022 / No	68	16	12	36	0
Patrol time reduced (Effect) / min	-24	-499	-179	-6435	0

5-1 Activity & Outcome (WG3-1) Ground Fault Detetor (GFD)

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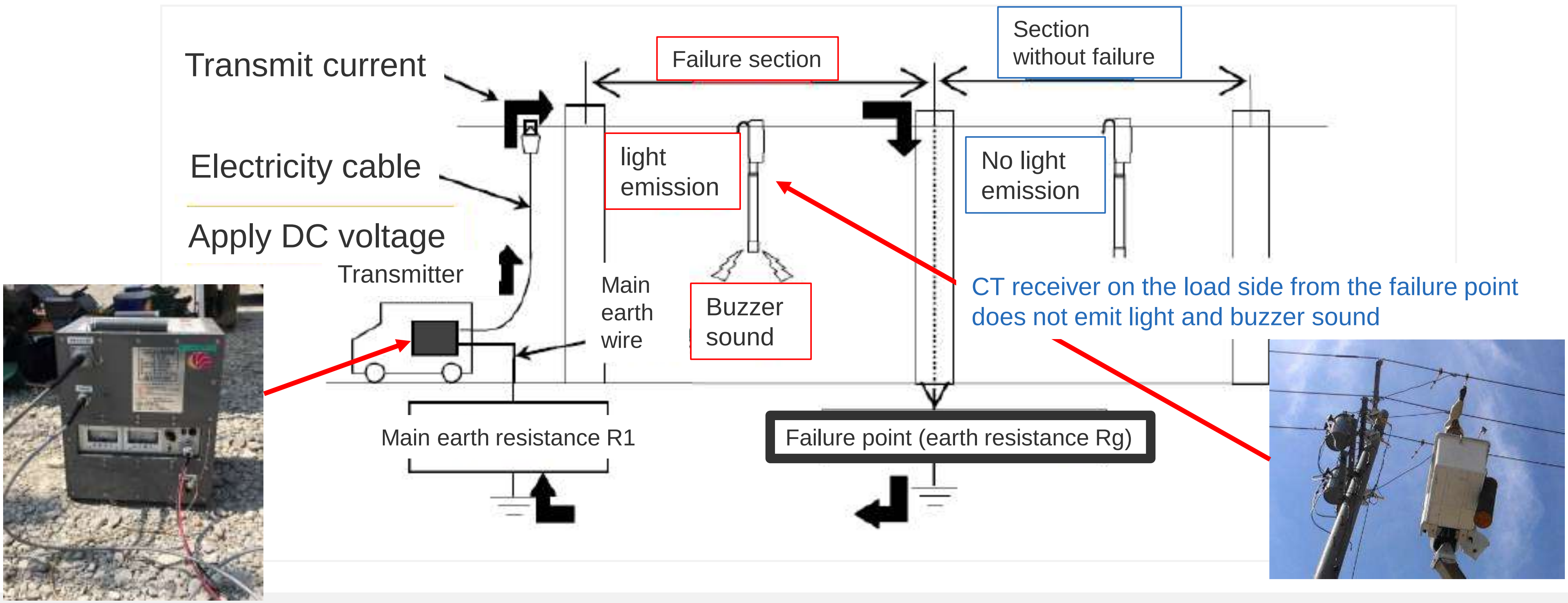
DC voltage (15 kV) is applied to the high voltage line in the power failure section by the fault detector, and the ground fault current is received.
The cause of the failure is identified by the light emission and buzzer sound of the receiver. This makes it possible to identify damages and internal failures of the arrester, which are difficult to check with the naked eye.



5-1 Activity & Outcome (WG3-1)
GFD Installation- Pilot Project sites

Division	DD1	DD2	DD3	DD4	LECO
Pilot feeder	Norochcholai F2(1)	Valaichchenai F6(2)	Mahiyanganaya F3(3)	Rathmalana F2(4)	Hikkaduwa Wewalamlla feeder(5)

SAIDI 2019 / min	490	552	68	417	4565
Target SAIDI 2023 / min	277	387	36	216	3241
Estimated Effect / %	-44	-30	-47	-48	-29

5-1 Activity & Outcome (WG3-1) GFD Training

Lecture by Manufacturer
at LECO Training Center
(10 November, 2022)

More than 40 participants

5-1 Activity & Outcome (WG3-1)
GFD Training

On-site Demonstration

Tree contact MV Line

5-1 Activity & Outcome (WG3-1) Effectiveness of GFD Installation

Period : ~ October 2022

	DD1	DD2	DD3	DD4	LECO
Pilot feeder	Norochchola i F2	Valaichchnai F6	Mahiyanganaya F3	Rathmalana F2	Hikkaduwa Wewalamilla feeder

SAIDI 2019 / min	490	552.1	68.37	417	4585
Target SAIDI 2023 / min	277	386.5	36.47	216	3241
SAIDI 2022 / [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Patrol ti… Reduced (Effect) / min	-XX	-XX	-XX	-XX	-XX

Effect will be evaluated
based on the result of November and December 2022

5-1 Action Plan (WG3-1)
(1) Action for effective use of failure records

- At the moment revised failure records are used only for pilot project sites as follows

Division	Scope of the use of revised failure records
DD1	Only Pilot Project site
DD2	Only Pilot Project site
DD3	Only Pilot Project site
DD4	Only Pilot Project site

- Considering the advantages of revised (detailed) failure record format, it is proposed to expand it to entire CEB as per the following action plan

Step	Action	Deadline
1	Recording outage data as per the revised format for one feeder having highest number of outages in each Customer Service Centre in a province	31st Mar 2023
2	Receiving feedbacks from workers and call centre/ control centre staff (difficulties, upgrades required for recording devices, suggestions for improvements, etc.)	30th Apr 2023
3	Reviewing and revising the outage format considering feedbacks as per the feedbacks received under step no. 2	30th Jun 2023
4	Introducing revised outage recording format among all provinces within the division, and formulating a mechanism to monitor/ evaluate outage records receive in new format	31st Aug 2023
5	Receiving feedbacks from all relevant stake holders who operates in different setups (different geographical areas, urban/ rural areas, etc.), and do appropriate modifications	31st Dec 2023
6	Sharing benefits of detailed outage records, aligning platforms used for outage recording/ monitoring, and expand best outage recording practices within entire CEB	30th Jun 2024

(2) Action for horizontal deployment of countermeasures

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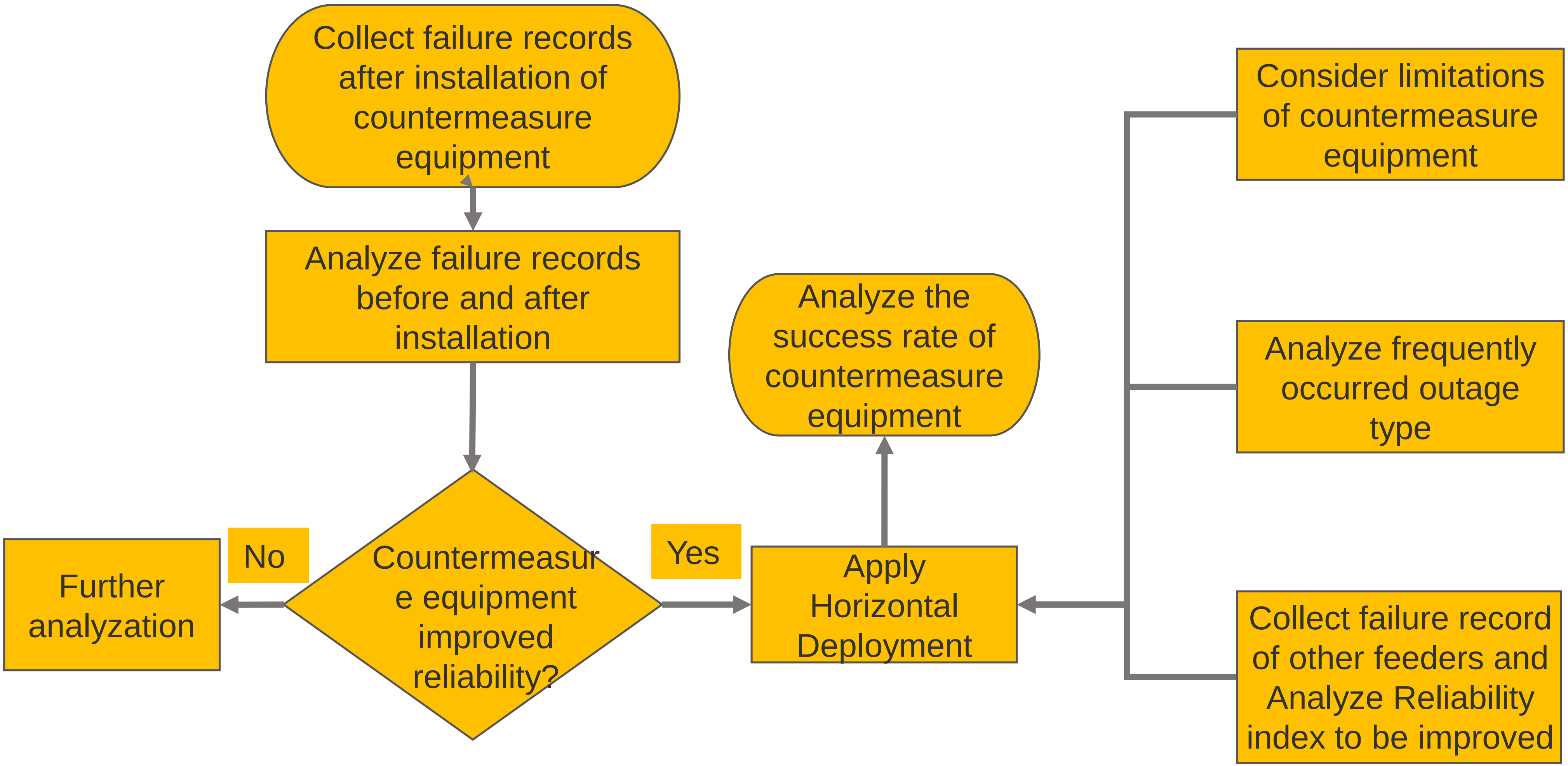
Process flow of horizontal deployment



(2) Action for horizontal deployment of countermeasures

Selection of suitable countermeasure equipment

	Reliability Improvement		Limitation
	SAIDI	SAIFI	
Counter Measure Equipment	ARC, TSS		・Cost ・Remote communication ・Effective in locating EF
	OCI, GFD, FLS	-	

Action Plan

Step	Action	Deadline
1	Collect failure records after installation of countermeasure equipment(ARC, OCI, GFD) (minimum 6 months)	15th July, 2023
2	Analyze failure records before and after installation	31st July, 2023
3	Further analysis on countermeasure equipment which does not contribute for reliability improvements	Only if applicable (31st August, 2023)
4	Apply Horizontal Deployment for other feeders based on outage types, reliability indicator to be improved and limitations of countermeasure equipment.	31st December, 2023
5	Propose the introduction of TSS and FLS to management.	After financial situation of Sri Lanka improved

5-1 Action Plan (WG3-1)
(3) Action for horizontal deployment of countermeasures

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Evaluation of countermeasure items for horizontal deployment

Countermeasure item	Deployment Status at pilot sites	Plan for Horizontal deployment
ARC	Installed, performances observed	Considered for horizontal deployment
OCI	Installed, performances under observation	To be considered based on performance observations
GFD	To be deployed	To be considered based on performance observations

(3) Action for horizontal deployment of countermeasures

ARC (1/2)

- To be utilize for locations with difficulty in tree trimming such as Boo Trees, Urban aesthetic improvement schemes, etc

5-1 Action Plan (WG3-1)
(3) Action for horizontal deployment of countermeasures

ARC (2/2)

- To be utilize as temporary cover for 11kV lines near construction sites to prevent accidental contact of heavy machinery, tools and materials.

5-1 Action Plan (WG3-1)
(3) Action for horizontal deployment of countermeasures

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Action Plan

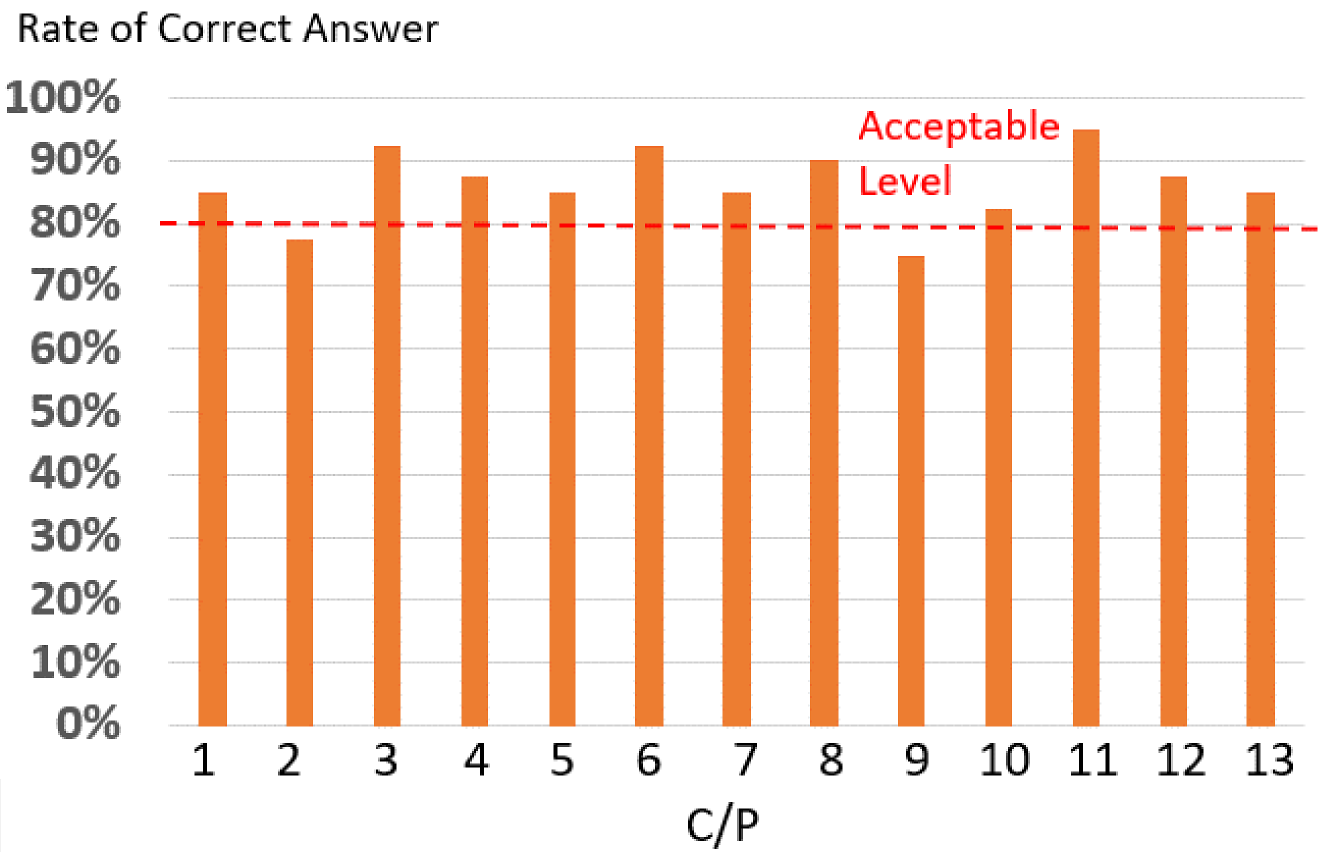
Step	Action	Deadline
1	Identification of locations for ARC deployment	31st Jan, 2023
2	Finalizing ARC specifications and procurement initiation	28th Feb, 2023
3	Installation of ARC at identified area	31st May, 2023
4	Six month data collection for OCI performance monitoring	24th Feb, 2023
5	Six month data collection for GFD performance monitoring	1st Jun, 2023
6	Evaluation of OCI performances for Horizontal deployment	24th Mar, 2023
7	Evaluation of GFD performances for Horizontal deployment	1st Jul, 2023
8	Identification of areas for OCI deployment upon success in no 06 above	21st Apr, 2023
9	Procurement and installation of OCI at proposed locations	31st Aug, 2023
10	Identification of areas for GFD deployment upon success in no 07 above	1st Sept, 2023
11	Procurement and supply of GFD for selected areas	31st Dec, 2023

05-2 Results of Capacity Development

Results of Capacity Development (WG3-1)

PDM : At least six (6) of counterparts build the capacity of power outage measures using facilities

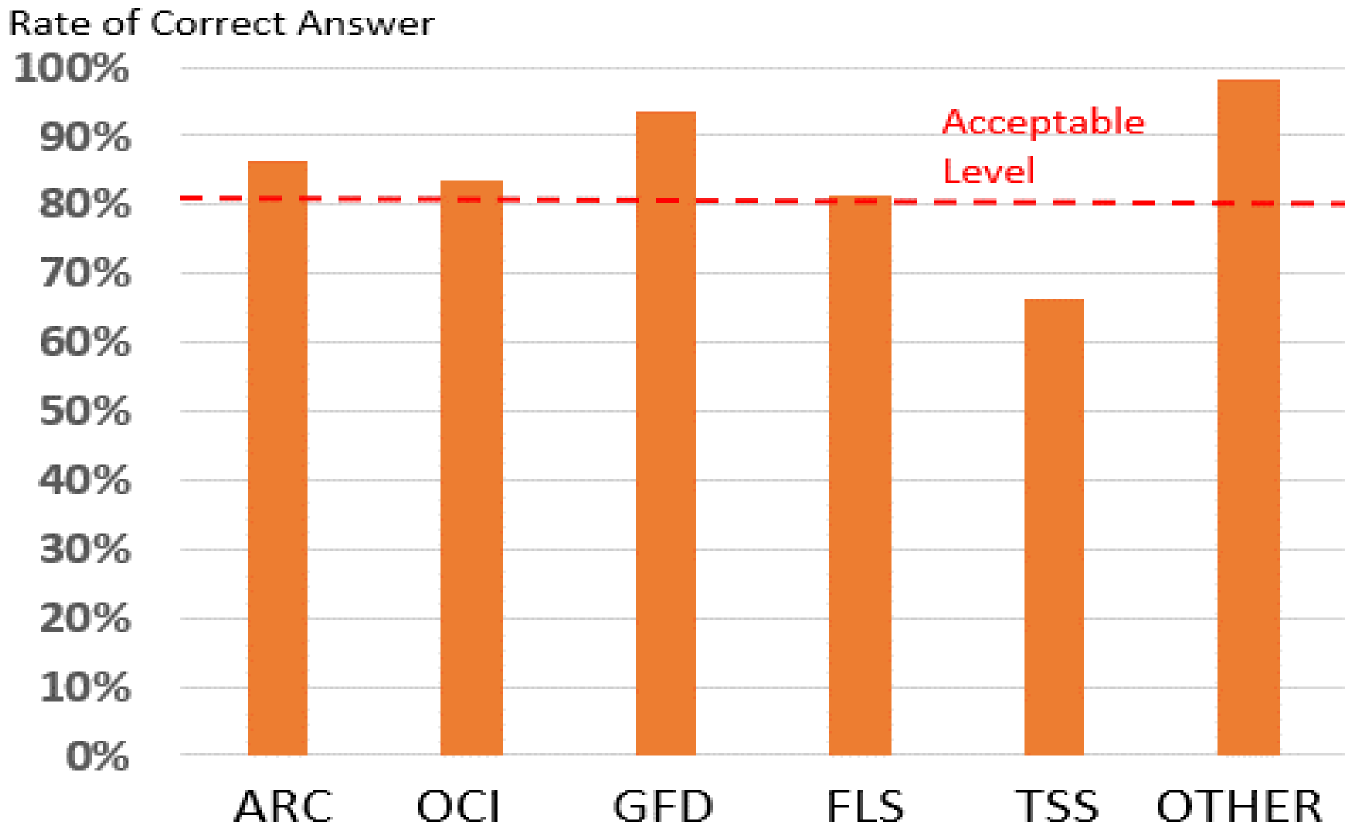
Verification Test of power outage countermeasure equipment was conducted. [Result] 11 out of 13 C/Ps scored more than 80%.



Results of Capacity Development (WG3-1)

- The understanding of TSS tends to be low score.

→JICA Expert follow-up on the questions with a low understanding questions to deepen the understanding of C/P.



05-3 Comments on action to achieve higher goals

Comments on efforts to achieve higher goals (WG3-1)
(1) Actions for Action for effective use of failure records

Promoting revised power outage report within an organization is important to clarify the cause of each power outage, and to formulate and implement measures to prevent recurrence of the failure.

On the other hand, the person responsible for failure restoration at the site required to record the cause of the failure and photos of the damaged equipment in detail. To this end, it is essential that each and every on-site worker understand the importance of the power outage report.

Therefore we recommend that C/P should continue the education of the purpose and importance of recording power outage for on-site workers.

Comments on efforts to achieve higher goals (WG3-1)
(2) Action for horizontal deployment of countermeasures

Since the introduction of countermeasure equipment (ARC,OCI,GFD) was delayed due to the impact of Covid-19, the verification is limited to short-term verification.

Therefore, we would like C/P to continue the operation and verification of the Pilot Project for several years and re-verify the cost-effectiveness.

Based on the results of the verification, we hope that the power outage countermeasure equipment will be deployed horizontally throughout Sri Lanka.

06 Activity & Outcome of WG3-2 (Improvement of Distribution System Reliability)

06-1 Activity / Outcome & Action Plan

6-1 Activity & Outcome (WG3-2)

Original Scope of Work Group 3-2

■ 3-2-1 To analyze fluctuation (output, voltage) on distribution system caused by VRE by installing measuring instrument.

■ 3-2-2 To conduct study at a pilot site to confirm the response ability for load fluctuation by installing batteries at distribution substation or distribution line.

6-1 Activity & Outcome (WG3-2)

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Original Scope of Work Group 3.2 (contd…)

No.	WG3-2 Activity for Load Fluctuation Suppression	Role	
		C/P	JICA Expert
3-2-1	Measurement and analysis of output power/voltage fluctuation according to increment of RE energy installation	◎:Primary, ○:Secondary	
(1)	**Collect power/voltage data around mass installation of PV/WT**	◎	○
(2)	**Summarize and categorize the power/voltage data**	◎	○
(3)	**Analyze the power/voltage data to grasp the matters, and Consider a pilot site**	◎	◎
(4)	**Coordinate the weather acquiring point and conditions with WG2**	◎	◎
(5)	**Select a pilot site**	◎	◎
(6)	**Set the estimation policy and the target**	◎	◎
(7)	**Determine the measuring conditions at a pilot site, and Procure the measuring facilities**	◎	◎
(8)	**Determine the specifications of a storage battery system, and Procure the storage battery system**	◎	◎
3-2-2	Evaluation of handling ability of distribution system by the storage battery system installation at the pilot site		
(9)	**Measure, collect and analyze the power/voltage data**	◎	○
(10)	**Measure, collect and analyze the weather data**	◎	○
(11)	**Plan the control scenario based on the measuring data**	◎	◎
(12)	**Simulate the pilot system based on the controlling scenario**	○	◎
(13)	**Set the control unit based on the simulation**	◎	◎
(14)	**Install and prepare the storage battery system**	◎	○
(15)	**Operate and test the storage battery system at the pilot site**	◎	◎
(16)	**Evaluate the handling ability of distribution system by the battery system based on the measurement**	○	◎

6-1 Activity & Outcome (WG3-2)

Summary

Study Procedure

1. Data collection and study on the distribution network having mass introduction of VRE
2. Consideration of site, battery system specifications.
3. Selection of target feeder to measure and analysis
4. Confirmation of load fluctuation matters by analyzing measured data
5. Proposal and estimation of countermeasures

Study & Activity

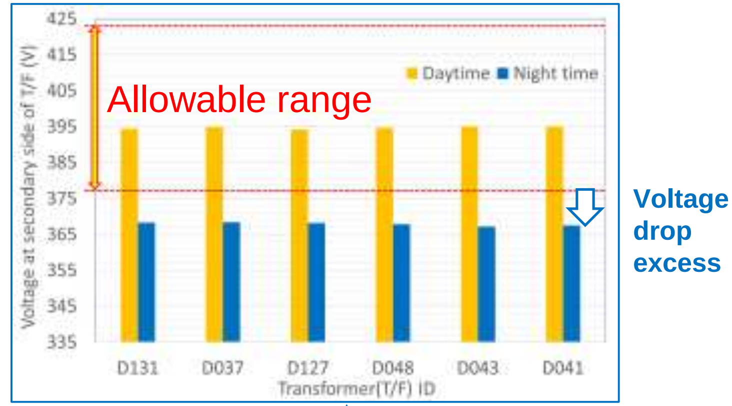
- Measurement and Analysis of Power/Voltage Fluctuation in MV Network due to Large Capacity of VRE ⇨ 33 kV Valachchenai F5 with 10 MW SPP (reverse power flow in day-time & low voltage during night-time)
- [Revised] Estimation of Power/Voltage Fluctuation in LV Network due to Large Number of VRE ⇨ LV feeder of Transformer TL-007 in Ethulkotte (Modeling and estimation)

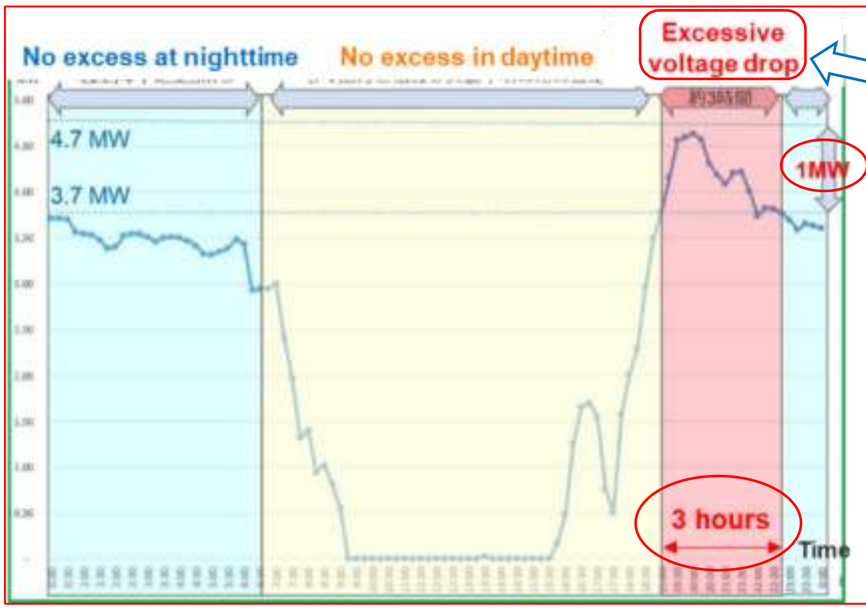
6-1 Activity & Outcome (WG3-2)
① Measurement/analysis of load fluctuation in MV grid

Activity in MV network for load fluctuation suppression

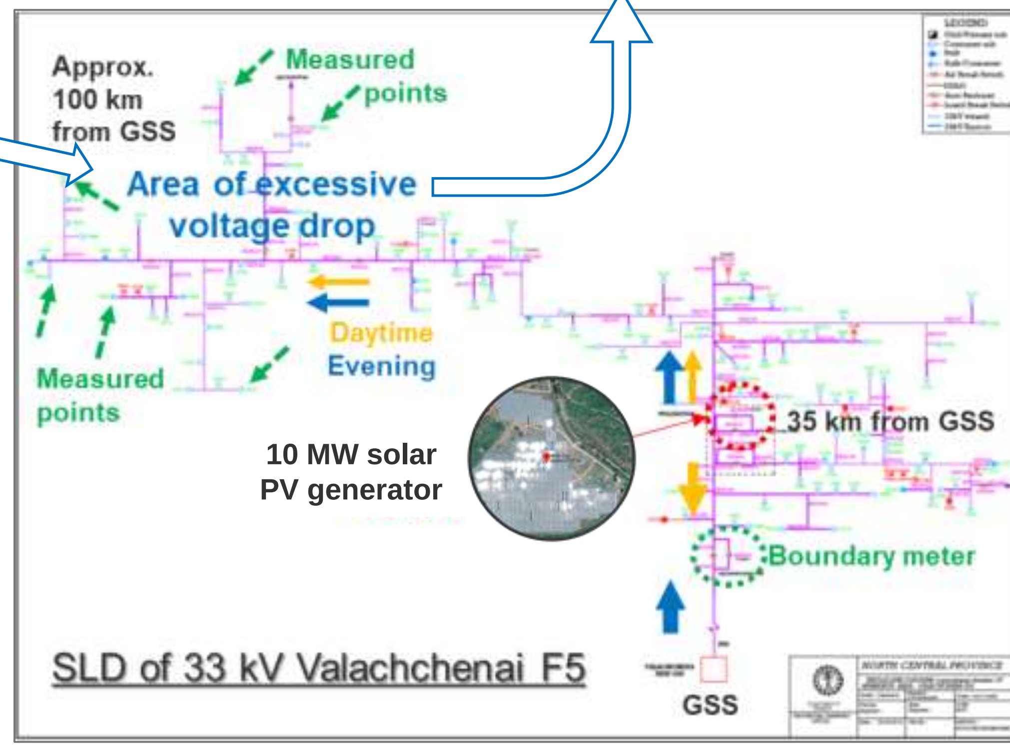
Measurement and analysis were conducted in 33 kV Valachchenai F5, and the voltage drop excess was quantitatively studied.

As a result, the BESS necessary to take its measures was estimated as 1 MW-3 hours class.





Power flow at the boundary meter between DD1 and DD2 in the 33 kV Valachchenai F5



6-1 Activity & Outcome (WG3-2)
- Change of the Project Scope -

	Project Contents
Original	Introduce a storage battery system as a measure to suppress load fluctuations associated with the mass introduction of VRE, and confirm the effect of suppressing load fluctuations.
Alternative	Improve the measurement technology and analysis/evaluation capability of system data (output voltage/current value) in order to quantitatively understand the impact of mass introduction of VRE on the distribution system.

6-1 Activity & Outcome (WG3-2)
② Measurement/analysis of load fluctuation in LV grid

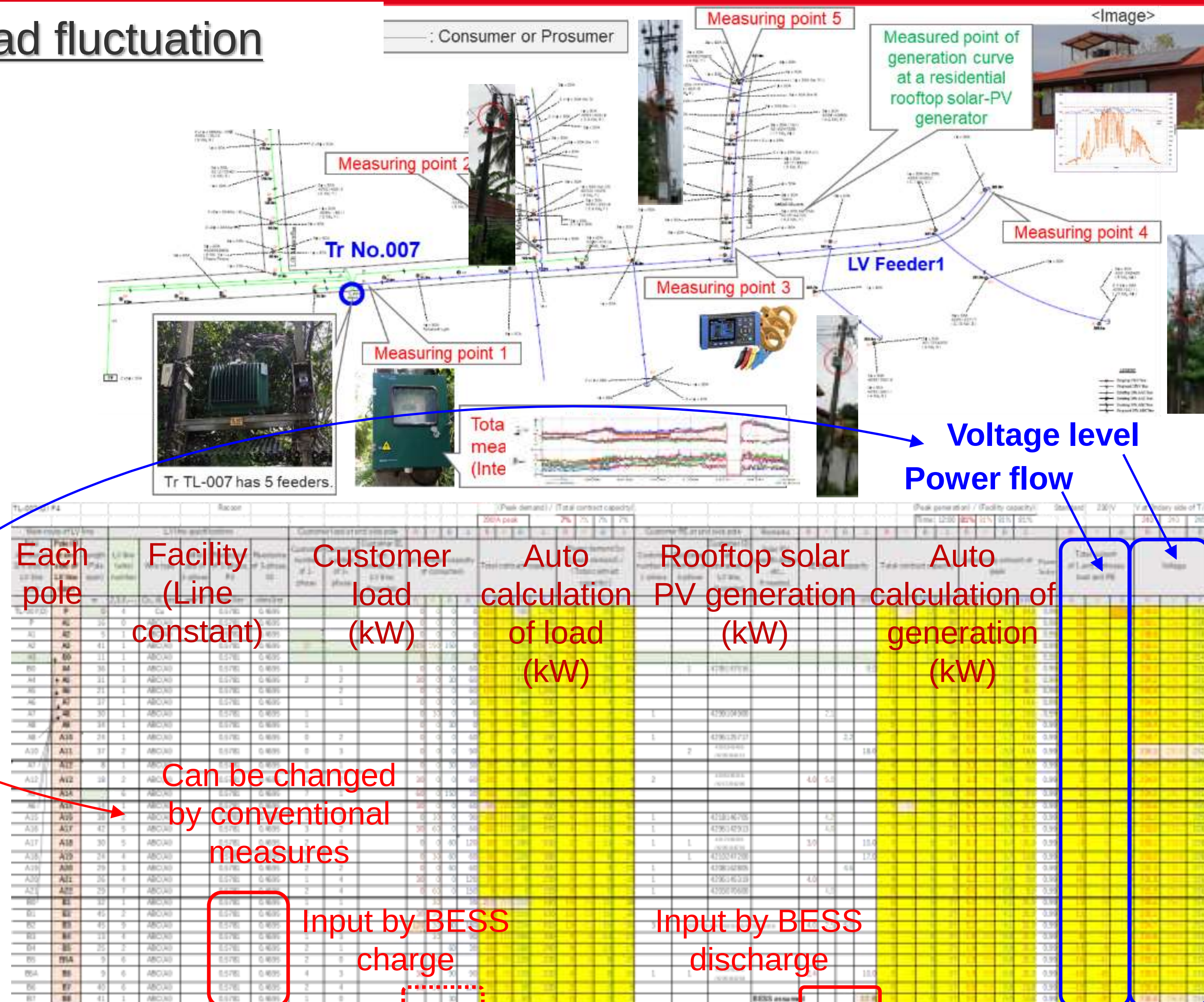
Activity in LV network for load fluctuation suppression

Measurement and data collection including prosumers per phase were conducted in the LV feeder 1 of TL-007 transformer in Ethulkotte.

Then, output power and voltage fluctuation per span was modeled and estimated.

By utilizing these data and the modeling sheet, the impact against the fluctuation was estimated in advance not only by conventional measures but also by BESS.

However, even conventional measures, which seem more economical than BESS, are not desirable in the view of economic measures.



6-1 Activity & Outcome (WG3-2)
③ Organizational enhancement for load fluctuation suppression

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Activity of organization enhancement for load fluctuation suppression

C/P shared the experienced and obtained technical capabilities to measure and analyze power/voltage fluctuation through both the measurement and the modeling to other C/P.

✓ Indication of measurement way and points from C/P to technical staff

✓ Online sharing with other C/P who could not come to the site through i-phone camera and mic

✓ Onsite sharing with other C/P in technology transfer of measurement

✓ Confirmation of the waveform recorded in the measuring instrument

6-1 Action Plan (WG3-2)

① Organizational capability enhancement on measurement

Purpose: To enhance measurement capability to solve the issues of load fluctuation

Effect: To deal with customer inquiries and requests such as voltage rising issues which may disturbs the introduction of solar PV generators

Goal: To promote a number of solar PV generators (No rejection to customer application)

Challenging milestones for Lateral spread in Organization

Step	Who	Action	Deadline
1	C/P ↓ Engineers	Increase the engineers up to 10 to instruct to measure voltage/current anywhere in LV lines with the measuring instrument of Clamp on power logger (HIOKI PW3360)	March 2023
2	Engineers ↓ Technical staff	Increase the technical staff up to 10 to measure output power/voltage with the measuring instrument of Clamp on power logger	September 2024
3	C/P ↓ Engineers	Increase the engineers up to 4 to instruct to measure voltage/current anywhere in LV lines with the measuring instrument of Power quality analyzer (HIOKI PQ3198)	September 2024

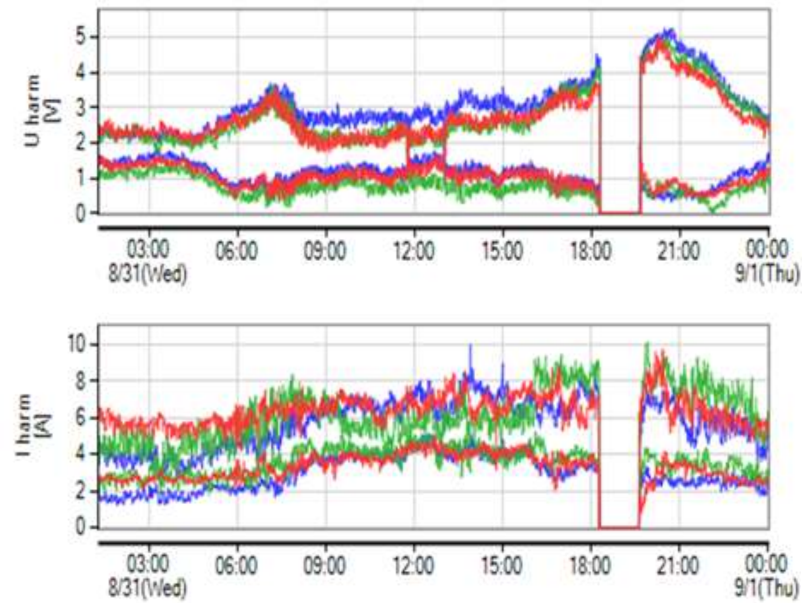
6-1 Action Plan (WG3-2)

② Organizational capability enhancement on analysis

Purpose: To enhance the capability to analyze output power/voltage by utilizing the measurement instrument and the modeling sheet

Effect: To be able to estimate the effect of countermeasures to take measures to suppress load fluctuation efficiently

Goal: To promote a number of solar PV generators (To reduce the cost to countermeasure)



Challenging milestones for Lateral spread in Organization

Step	Who	Action	Deadline
1	C/P ↓ Engineers	Increase the engineers up to 10 to analyze voltage/current in LV lines by planning the organizational training	March 2023
2	C/P ↓ Engineers	Request the system introduction to manage customer load and distributed energy resource and estimate their current/voltage fluctuation in LV lines.	September 2023

6-1 Action Plan (WG3-2)
③ Specifying PCS voltage support function for LV grid

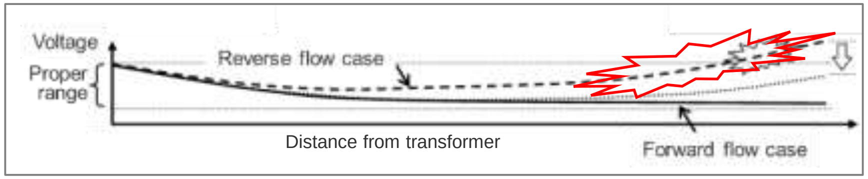
Purpose: To specify PCS voltage support function such as power factor regulation of the power generators to power distribution grid interconnection regulations (Specify to Distribution Interconnection Guideline)

Effect: To suppress voltage excess in LV distribution grid and promote rooftop solar PV generators fairly

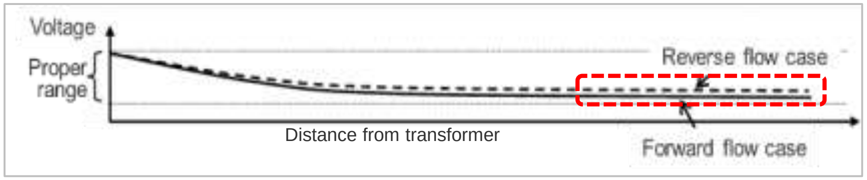
Goal: To promote a number of solar PV generators
(To promote solar PV generators fairly)

<u>Challenging milestones for requesting to the related orginizations</u>

Step	Who	Action	Deadline
1	C/P	Survey of the target LV feeders having voltage excess issues and rejection to customer application of power generators, etc. Request to SEA based on the survey	March 2023
2	C/P	Specify the voltage support function of PCS to the LV distribution grid regulation	Before the large number of PCS without voltage support function are interconnected.



Constant power factor regulation



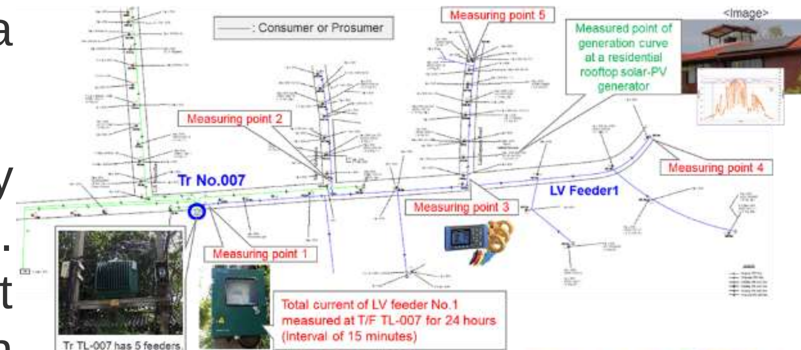
6-1 Action Plan (WG3-2)

④ Measuring facility procurement

Purpose:	Necessary data collection Measurement and data recording Modeling and estimation of load fluctuation Estimation and comparison of effects by fluctuation countermeasures
Effect:	To study the impact and variation along the LV feeders
Goal:	To promote a number of solar PV generators and improve LV network

- Purchased One power quality Analyzer and 4 data loggers for All four Distribution Divisions.

However, Normal LV distribution feeders consist of many spurs and need many data measurement points. Therefore, to conduct a proper measurement it is not sufficient to have one data logger for a distribution division. It is required to procure a few additional data loggers for the Planning and Development units of each province to conduct this kind of measurement and comprehensive analysis.
Its funding shall be requested considering the economic situation, after evaluating the requirement by CEB by the June 2023.



6-1 Action Plan (WG3-2)

⑤ Doing the same exercise in MV network

Purpose: To analyze fluctuation (output, voltage) on distribution system caused by VRE by installing measuring instrument

Effect: To study the impact and variation along the MV feeders and suppress the impact

Goal: To promote a BESS for MV network to promote more VRE

□ With the addition of VRE to the MV network, the requirement of BESS at the MV network will be inevitable. Therefore, looking ahead in near future, CEB will acquire the necessary capability to introduce a higher capacity BESS for the MV network as a pilot project, so that it will be promptly required to a donor to promote this requirement for the next project.

Step	Who	Action	Deadline
1	C/P	Collect Data of the target feeder	March 2023
2	C/P	Measure and evaluate the fluctuations	December 2023
3	C/P	Estimate and Prepare BESS introduction basic plan	March 2024
4	C/P	Request funding to a donor	April 2024
5	(Donor)	(Procurement of BESS)	(July 2025)

6-1 Action Plan (WG3-2)
⑥ LECO (01): 1. Disseminate knowledge, 2. Monitor Voltage

1. Disseminate the knowledge with all the engineers and technical staff.
   a) Target completion date – May, 2023.
2. Continuous voltage monitoring activity will be performed throughout the network
   a) Assessing the severity and required remedial measures for existing issues.
   b) As the first phase, if a particular transformer reaches 50% of installed Solar PV from its rated capacity, a Network Monitoring Device (NMD) will be installed.
   c) 2000 NMDs were procured last year and 2000 planned for this year.
   d) 08 nos of Power Quality Analyzers were procured for all the branches.

Power Quality Analyzer from JICA

LECO Procured Power Quality Analyzers

Network Monitoring Devices

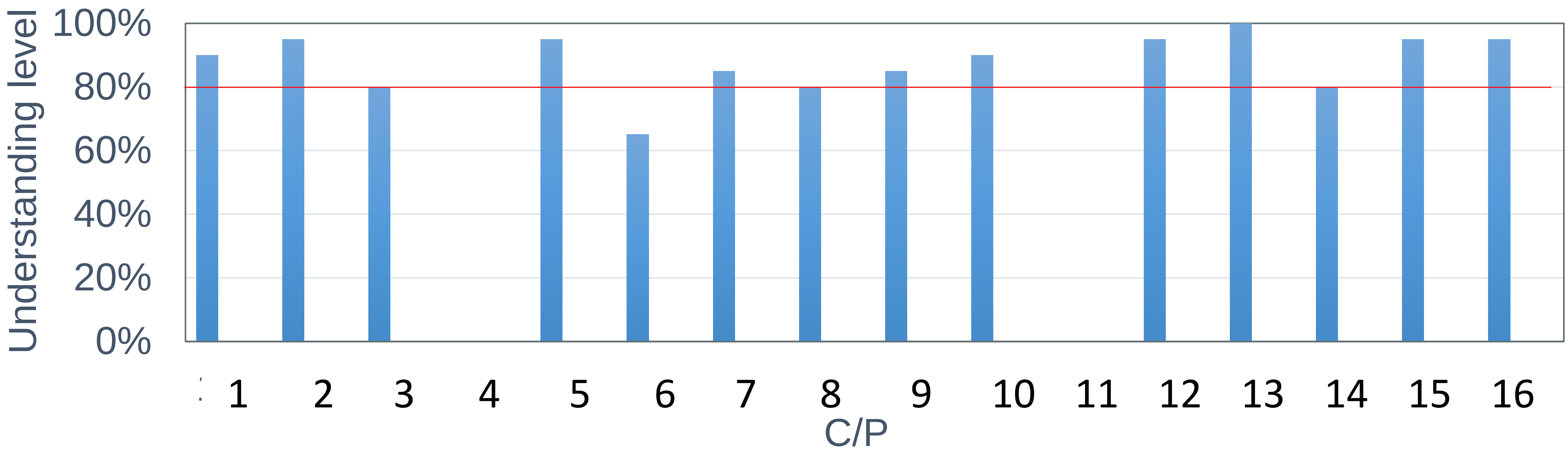
6-1 Action Plan (WG3-2) (contd…)

⑦ LECO (02): 3.Reinforce LV network, 4.Mandate to use IEEE 1547 (2018) 5.Initiate a pilot project on automated DR with storage

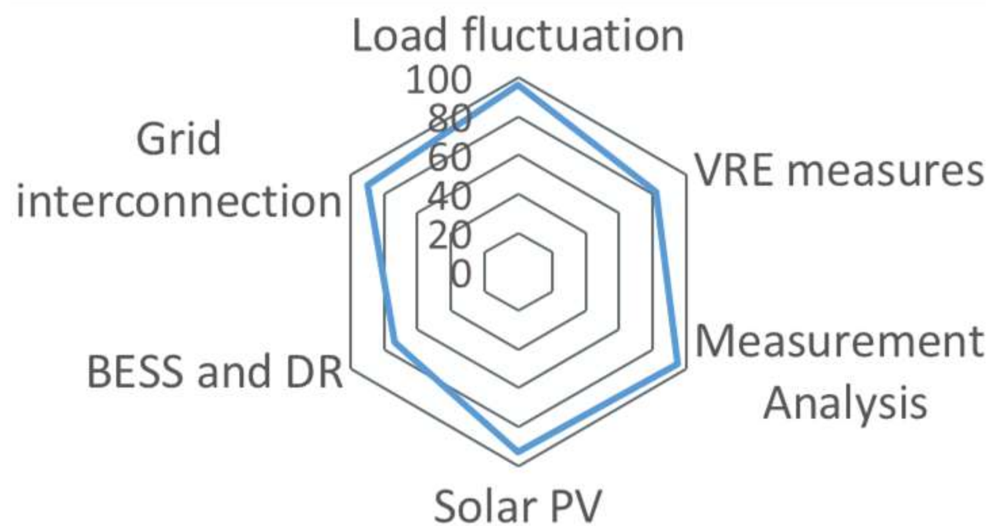
1. Disseminate the knowledge with all the engineers and technical staff.
   a) Target completion date – May, 2023.
2. Continuous voltage monitoring activity will be performed throughout the network
   a) Assessing the severity and required remedial measures for existing issues.
   b) As the first phase, if a particular transformer reaches 50% of installed Solar PV from its rated capacity, a Network Monitoring Device (NMD) will be installed.
   c) 2000 NMDs were procured last year and 2000 planned for this year.
   d) 08 nos of Power Quality Analyzers were procured for all the branches.
3. Reinforce the existing LV network with additional LV feeders and transformers to absorb more Solar PV – Field level Pilot has been initiated and expected to be completed by March 2023.
4. Mandate all the consumers to use IEEE 1547 (2018) comply smart inverters which can limit the voltage rise and increase the active power through reactive power compensation - By November 2023.
5. Initiate a Pilot project on grid interactive Automated Demand Response (ADR) with Storage. Project proposal has been submitted to the donor agencies and expected to be initiate by August 2023.

06-2 Results of Capacity Development

Results of Capacity Development (WG3-2)



Capacity development results of WG3-2 members by the examination.
(Total 14 members, as 2 out of 16 were transferred on the way.)



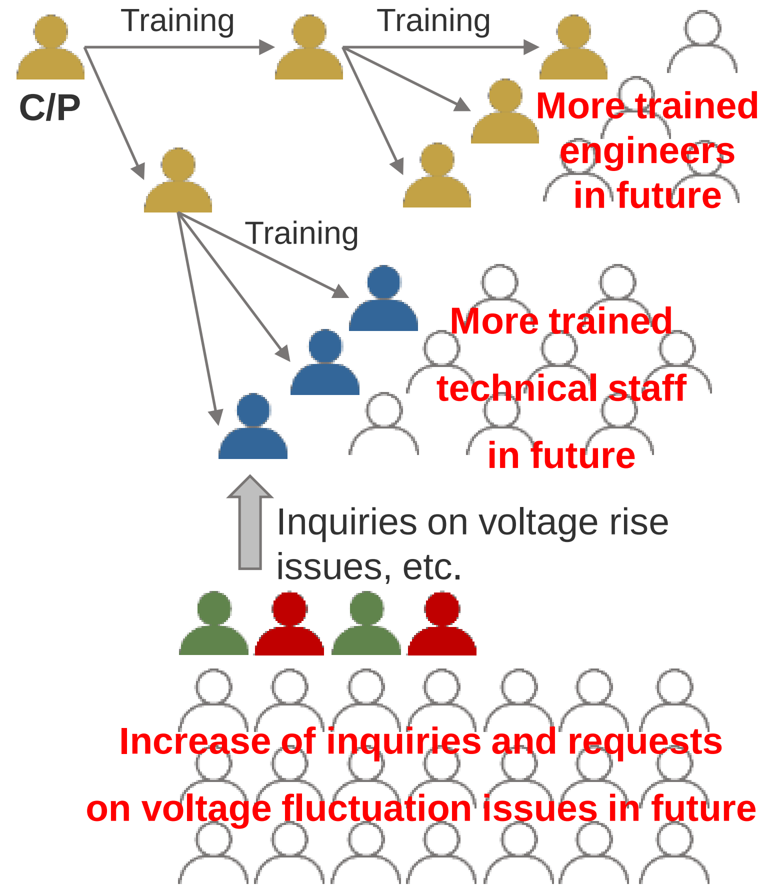
Capacity development results in each field in load fluctuation suppression

06-3 Comments on action to achieve higher goals

(1) Organizational enhancement of engineers/technical staff to measure and deal with load fluctuation issues

✓ The introduction of rooftop solar PV generation will progress further in the future, and it is conceivable that there will be an increase in the number of issues such as voltage rises and customer inquiries, especially in LV distribution systems.

In the project, C/P measured and analyzed output power/voltage fluctuations, using the procured measuring instruments and the modeling sheet. Then the experienced C/P promoted the sharing of measurement and analyzing technologies to other C/P. In the same way, it is necessary to increase the number of engineers/technical staff who can measure and deal with load fluctuations.



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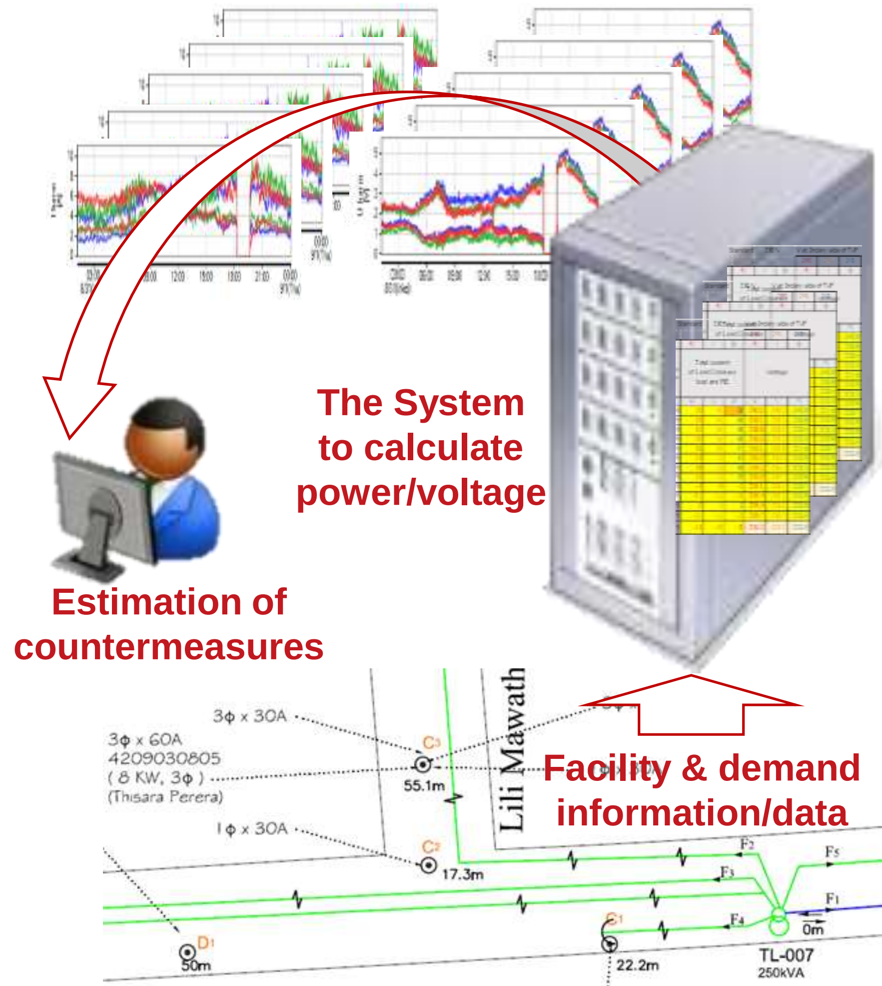
(2) Systematization of information/data for LV distribution systems

- ✓ C/P modeled and analyzed the aggregated data and estimated the impact of measures against load fluctuations. However, if a lot of feeders affected by load fluctuations increase in the future, it will be difficult to analyze and estimate the measures individually from the viewpoint of the number of staff work and equipment.

  Therefore, it is recommended that the present modeling way be used for training, and that a helpful system be introduced for business use that output power/voltage fluctuations and impact of measures be calculated automatically and quantitatively in LV distribution grid conditions.



Comments on efforts to achieve higher goals (WG3-2)

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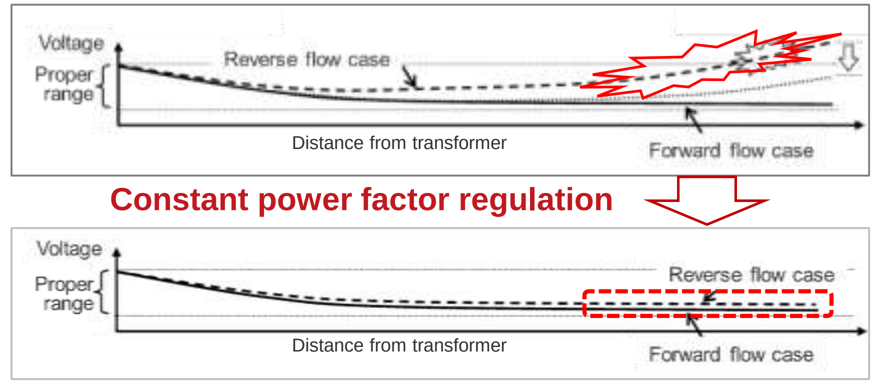
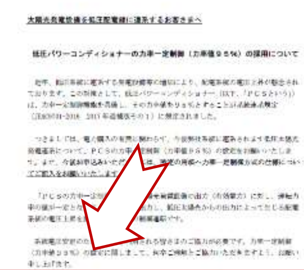
(3) Specifying power factor regulation of power generators to LV distribution grid interconnection regulations

✓ Rooftop solar PV generators are being introduced to LV distribution grids, but latecomers who wish to do so might be turned down due to voltage rising issues.
In order to suppress voltage fluctuation and promote fair introduction to more people, it is recommended to promptly revise distribution grid interconnection regulation/guideline that specifies voltage support function to power generators, and to promote the introduction of improved PCS that can specify power factors, before a large amount of existing type PCS is introduced and the introduction of solar PV generation is restricted due to voltage rises.



Ex) To an applicant to interconnect a solar PV generator to LV line



Requesting to set PCS power factor 0.95, based on the distribution grid interconnection code regulated in 2017

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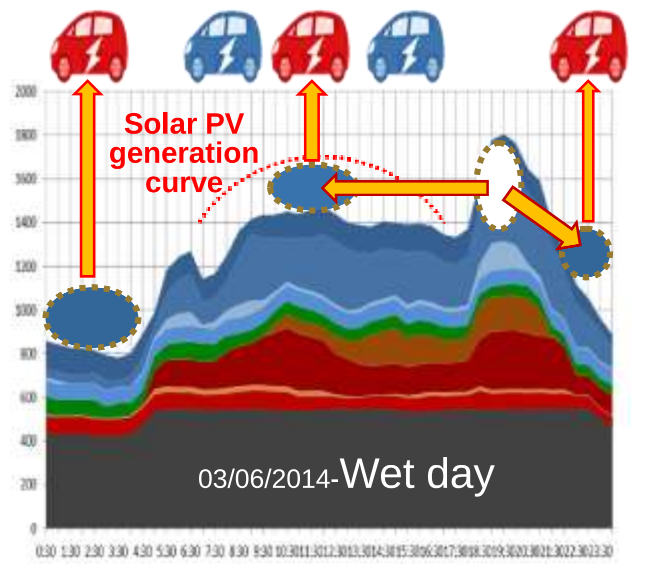
(4) Suppression of load fluctuations through promotion of EV introduction and EV charge/discharge control

- ✓ Introduction of BESS exclusively for suppressing voltage fluctuations is less economical than the conventional countermeasures. However, even the conventional countermeasures require burden as equipment costs.

  Since Sri Lanka does not have a full scale conventional automobile manufacturing factory, it is recommended to consider measures to promote the introduction of EV, including an attracting EV and storage battery manufacturing and maintaining factory, and to use EV batteries in distribution system for multi-purposes by introducing an effective tariff system that provides incentives for different lifestyle patterns, etc. in the future.

Shift charging from evening to solar PV generating hours or night hours



Ex) Development plan of work offices near mass PV generators for load leveling

07 Training in Japan

Training in Japan

Training is basically conducted through OJT (WG Activities) and Seminars (Technical Seminar, System and Policy Seminar), on the contrary, contents that are more effective if they are conducted in Japan are organized in Japan.

- The trainings for WG1, WG2 and WG3 will be conducted at once.
- After returning to Sri Lanka, a Training Reporting Session will be held, and the results of the training will be shared within each organization.

From December 6 to 17, 2022

No.	Themes	Schedule	Number of trainees
1	Electric Power Technology, System and Policy (WG1)	From December 6 to 15, 2022	11 executives (MOPE (1), PUCSL (1), SEA (1), CEB (8))
2	Power system planning and operation, Management of the power supply and demand (WG2)	From December 6 to 17, 2022	6 members
3	Distribution facilities (WG3)		10 members

Schedule of Training in Japan

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Purpose
- To learn the technologies of power supply systems
- To understand equipment of power transmission, substation and distribution by the introduction of Japanese technologies
- To understand the outline of human resource development and training system in Japan

Date	WG1（12 persons）	WG2 (6 persons)	WG3(10 persons)	Accommodation
Dec.5 Mon.	Departure from Sri Lanka	Same as WG1	Same as WG1	Flying overnight
Dec.6 Tue.	Arrival in Narita Briefing at JICA Tokyo	Same as WG1	Same as WG1	Tokyo
Dec.7 Wed.	Visit: Nishi-Sendai Battery Substation	Same as WG1	Same as WG1	Tokyo
Dec.8 Thu.	Visit & Lecture: Japan Weather Association Visit: Toshiba factory (battery)	Same as WG1	Same as WG1	Nagoya
Dec.9 Fri.	Visit: Meidensha factory (PV) Visit: Higashi-Shimizu FC substation	Same as WG1	Same as WG1	Nagoya
Dec.10 Sat	Holiday	Holiday	Holiday	Nagoya
Dec.11 Sun.	Holiday	Holiday	Holiday	Nagoya

(Continued on next page)

Schedule of Training in Japan (cont.)

Date	WG1（12 persons）	WG2 (6 persons)	WG3 (10 persons)	Accommodation
Dec.12 Mon.	Visit: Human Resource Developing Center	Same as WG1	Same as WG1	Nagoya
Dec.13 Tue.	Visit: Customer Service Center Visit: Chubuseiki factory (Smart meter)	Visit: Research & Development Center Visit: Nunoike-substation (Distribution substation)	Visit: Customer Service Center and site visit	Nagoya
Dec.14 Wed.	Visit: NGK Insulators (NAS battery) JICA Chubu Wrap-up meeting	Visit: Analog Simulator facility Visit: Meijo-substation (Underground substation)	Visit: Distribution Control system & Operation Center Visit: Aichi Electric Factory (TSS, SVR, BES, etc.)	Nagoya
Dec.15 Thu.	Move to Narita Departure to Sri Lanka	Visit: Okuyahagi hydropower	Visit: R&D Center Visit: Nippon Kouatsu Electric factory (GFD, OCI, etc.)	Nagoya
Dec.16 Fri.		Visit: NGK Insulators (NAS battery) JICA Chubu Wrap-up meeting	Same as WG2	Nagoya
Dec.17 Sat.		Move to Narita Departure to Sri Lanka	Same as WG2	―

CHUBU
Electric Power

NIPPON KOEI

Minutes of Meeting
of
The 4th Joint Coordination Committee
on
The Project for Capacity Development on the Power Sector Master Plan Implementation Program in Sri Lanka

JICA Expert Team of "The Project for Capacity Development on the Power Sector Master Plan Implementation Program in Sri Lanka (hereinafter referred to as "the Project")" organized by the Japan International Cooperation Agency (hereinafter referred to as "JICA"), headed by Mr. Akira HIRANO, has conducted the 4th Joint Coordination Committee (hereinafter referred to as "JCC") on November 22, 2022.

During JCC, Ceylon Electricity Board (hereinafter referred to as "CEB") and JICA Expert Team reported the results of the Project Activities and Capacity Development over the three year period to the institutions concerned.

As a result, both sides agreed on the matters referred to the document attached hereto.

November 22, 2022

平野 晶

Mr. Akira HIRANO
Project Team Leader
JICA Expert Team

Mr. M. P. D. U. K. Mapa Pathirana
Secretary
Ministry of Power

Ms. IDE Yuri
Senior Representative
JICA Sri Lanka

Attachment

1. Purpose and Discussion Outline

The 4th JCC was held to report widely on the results of the overall project activities and Counterpart (hereinafter referred to as "C/P") capacity building over the three-year period. Many participants from the institutions concerned, including Mr. M. P. D. U. K. Mapa Pathirana, Secretary, Ministry of Power and Energy participated in the active discussion. The participants expressed their interest in "the Action Plan to achieve the higher goals" declared by CEB, SEA and LECO, and thanked JICA for the very meaningful project activities to help Sri Lanka achieve its objective of 70% RE by 2030.

2. Main Point Confirmed

1) WG1
   - Rule and procedure of periodical reviewing of FIT is necessary since the market conditions are volatile. Based on the same, revisions will be proposed by CEB.
   - Recommendation report on CEB financial condition will be explained to CEB Management in Dec. 2022. Annual effective reviewing procedure of CEB financial condition will be considered, such as utilizing “Data summary sheet”.

2) WG3
   - WG3-1
     - The effect of the GFD will be estimated based on the results in November and December 2022 in the same way of ARC and OCI.
     - CEB will consider to install the additional countermeasure facilities in their wide area based on their yearly evaluation.
     - CEB will consider to spread the power outage report to the other area, reflecting the comments from the onsite workers.
   - WG3-2
     - In order to promote fair introduction of solar PV generators to more people, CEB will enhance the requirement of the power factor adjustment function to the generators in LV distribution grid interconnection, which will contribute to reduce the cost to suppress voltage fluctuations as one of the countermeasures.

For detail, refer to Annex- 4

3. Training in Japan

Presenter: Mr. Toshitaka YOSHIDA

✓The Training in Japan for WG1, WG2 and WG3 will be conducted at once.

✓After returning to Sri Lanka, a Training Reporting Session will be held, and the results of the training will be shared within each organization.

<table>
<tr><th colspan="2">Themes</th><th>Schedule</th><th>Number of Trainees</th></tr>
<tr><td>WG1</td><td>Electric Power Technology, System and Policy</td><td>December 6 to 15 , 2022</td><td>Twelve (12) executives (MOPE (2), PUCSL (1), SEA (1), CEB (8))</td></tr>
<tr><td>WG2</td><td>Power system planning and operation, Management of the power supply and demand</td><td rowspan="2">December 6 to 17 , 2022</td><td>CEB’s Engineer;
Six (6) members</td></tr>
<tr><td>WG3</td><td>Distribution facilities</td><td>CEB/LECO’s Engineer;
Ten (10) members</td></tr>
</table>

Annex- 1: Agenda of the 4th JCC

Annex- 2: 4th JCC material

Annex- 3: Participants List

Annex- 4: Questions and Answers

(End)

Long Term Generation Expansion Plan

2023-2042

Generation Planning Unit
Transmission & Generation Planning Branch
Ceylon Electricity Board

Background

2021 July

Conditionally approved !!!

2021 July-September

Key Highlights of Sri Lanka's Nationally Determined Contributions and Vision for a Low Carbon Future

Sri Lanka is highly vulnerable to the adverse impacts of climate change. The country focuses on building the resilience of **Agriculture, Fisheries, Livestock, Health, Water, Biodiversity, Coastal and Marine, Tourism, Urban Planning and Human Settlement** sectors

Sri Lanka's per capita greenhouse gas emission in 2010 was **1.02** tons and its global cumulative contribution in 2019 was **0.03%.**

Despite this low carbon footprint and highly vulnerable status, Sri Lanka commits to increase **32%** forest cover by 2030 and reduce greenhouse gas emissions by **14.5%** for the period of 2021-2030 from **Power (electricity generation), Transport, Industry, Waste, Forestry, and Agriculture**

In order to realize this ambitious target, Sri Lanka further commits;

- To achieve **70%** renewable energy **in electricity generation** by 2030
- To achieve **Carbon Neutrality** by 2050 in electricity generation
- **No** capacity addition of **Coal** power plants

Sri Lanka has already launched following major initiatives;

- Adopting 'Colombo Declaration on Sustainable Nitrogen Management' with an ambition to halve nitrogen waste by 2030
- Banning agro-chemicals and chemical fertilizer
- Promoting organic fertilizer and farming
- Banning single-use plastics
- Promoting E-mobility
- Promoting circular economy

Sri Lanka expects to achieve its **Carbon Neutrality** by 2050

2021 October

ශ්‍රී ලංකා මහජන උපයෝගිතා කොමිෂන් සභාව
இலங்கைப் பொதுப் பயன்பாடுகள் ஆணைக்குழு
PUBLIC UTILITIES COMMISSION OF SRI LANKA

ඔබේ අංකය / உமது இல. / Your No. }   මගේ අංකය / எமது இல. / Our No. } PUC/LIC/AP21/01   දිනය / திகதி / Date } 5th October 2021

- To achieve 70% renewable energy in electricity generation by 2030
- To achieve Carbon Neutrality by 2050 in electricity generation
- No capacity addition of Coal power plants

The Commission requires you to submit the Least Cost Long Term Generation Expansion Plan prepared in compliance with the government policy on or before 30th June 2022.

Thank you,
Yours Sincerely,

Public Utilities Commission of Sri Lanka

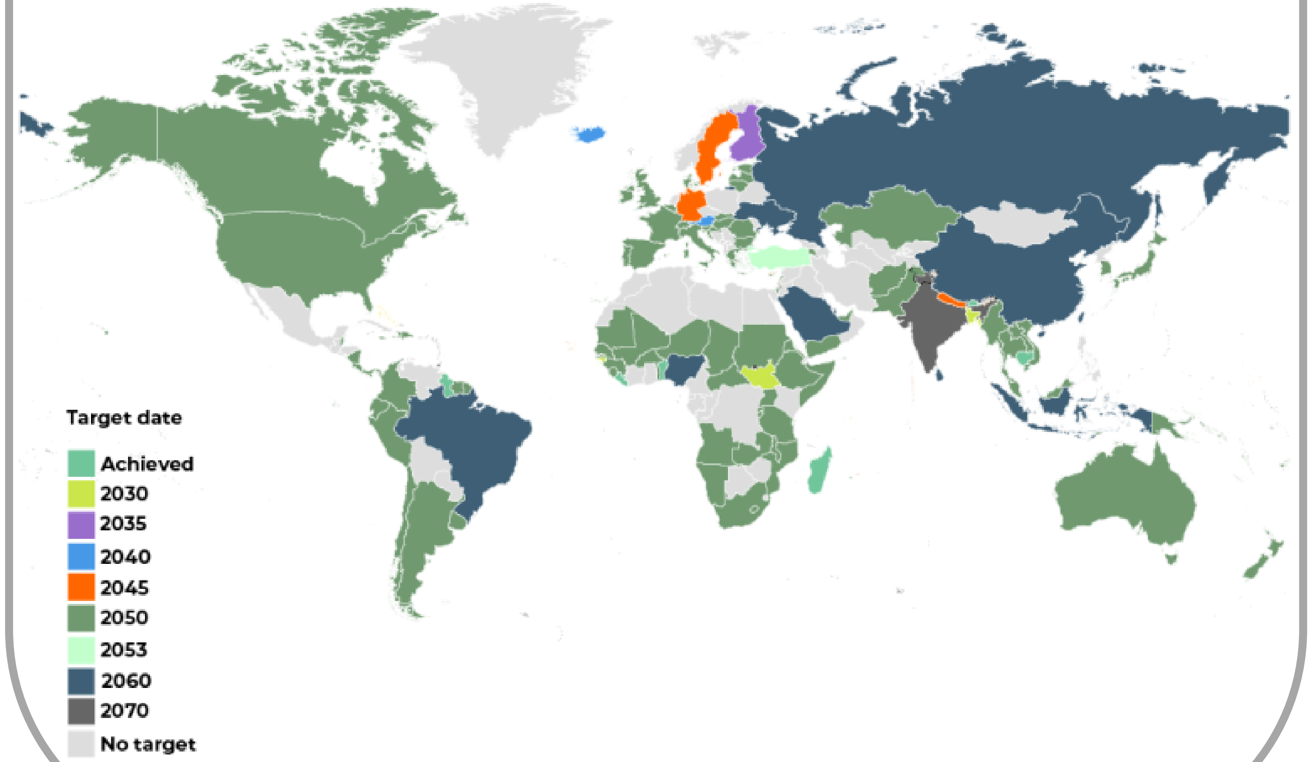
Janaka Ratnayake
Chairman

Global International Commitments

CLIMATE CRISIS

Net zero pledges

More than **137 countries have committed to net zero**. India and Nigeria were the latest nations to make the pledge at COP26, with India expecting to reach the target by 2070.



CLIMATE

Pledge to quit coal

At COP26, more than 40 countries have pledged to shift away from coal

- Afghanistan
- Albania
- Algeria
- Andorra
- Angola
- Antigua & Barbuda
- Argentina
- Armenia
- Australia
- Austria
- Azerbaijan
- Bahamas
- Bahrain
- Bangladesh
- Barbados
- Belarus
- Belgium
- Belize
- Benin
- Bhutan
- Bolivia
- Bosnia & Herzegovina
- Botswana
- Brazil
- Brunei
- Bulgaria
- Burkina Faso
- Burundi
- Cambodia
- Cameroon
- Canada
- Cape Verde
- CAR
- Chad
- Chile
- China
- Colombia
- Comoros
- DRC
- Congo
- Cook Islands
- Costa Rica
- Côte d'Ivoire
- Croatia
- Cuba
- Cyprus
- Czech Republic
- Denmark
- Djibouti
- Dominica
- Dominican Republic
- Ecuador
- Egypt
- El Salvador
- Equatorial Guinea
- Eritrea
- Estonia
- Ethiopia
- European Union
- Fiji
- Finland
- France
- Gabon
- Gambia
- Georgia
- Germany
- Ghana
- Greece
- Grenada
- Guatemala
- Guinea
- Guinea-Bissau
- Guyana
- Haiti
- Honduras
- Hungary
- Iceland
- India
- Indonesia
- Iran
- Iraq
- Ireland
- Israel
- Italy
- Jamaica
- Japan
- Jordan
- Kazakhstan
- Kenya
- Kiribati
- North Korea
- South Korea
- Kuwait
- Kyrgyzstan
- Laos
- Latvia
- Lebanon
- Lesotho
- Liberia
- Libya
- Liechtenstein
- Lithuania
- Luxembourg
- North Macedonia
- Madagascar
- Malawi
- Malaysia
- Maldives
- Mali
- Malta
- Marshall Islands
- Mauritania
- Mauritius
- Mexico
- Micronesia
- Moldova
- Monaco
- Mongolia
- Montenegro
- Morocco
- Mozambique
- Myanmar
- Namibia
- Nauru
- Nepal
- Netherlands
- New Zealand
- Nicaragua
- Niger
- Nigeria
- Niue
- Norway
- Oman
- Pakistan
- Palau
- Palestine
- Panama
- Papua New Guinea
- Paraguay
- Peru
- Philippines
- Poland
- Portugal
- Qatar
- Romania
- Russia
- Rwanda
- St. Kitts & Nevis
- St. Lucia
- St. Vincent & Grenadines
- Samoa
- San Marino
- São Tomé & Príncipe
- Saudi Arabia
- Senegal
- Serbia
- Seychelles
- Sierra Leone
- Singapore
- Slovakia
- Slovenia
- Solomon Islands
- Somalia
- South Africa
- South Sudan
- Spain
- Sri Lanka
- Sudan
- Suriname
- Eswatini
- Sweden
- Switzerland
- Syria
- Tajikistan
- Tanzania
- Thailand
- Timor-Leste
- Togo
- Tonga
- Trinidad & Tobago
- Tunisia
- Turkey
- Turkmenistan
- Tuvalu
- Uganda
- Ukraine
- United Arab Emirates
- United Kingdom
- United States
- Uruguay
- Uzbekistan
- Vanuatu
- Venezuela
- Vietnam
- Yemen
- Zambia
- Zimbabwe

Policy Directives

Ministry of Power

GENERAL POLICY GUIDELINES FOR THE ELECTRICITY INDUSTRY

General Policy Guidelines formulated in terms of Section 5(1) of the Sri Lanka Electricity Act No. 20 of 2009 was approved by the Cabinet of Ministers as required by Section 5(3) of the Said Act at its meeting held on 01.11.2021.

9. The GOSL has set the targets of achieving 70% of electricity generation in the country using renewable energy sources by 2030 and carbon neutrality in power generation by 2050, and has decided to cease building of new coal-fired power plants. The Cabinet of Ministers has approved these two policy elements that shall form the basis of Sri Lanka's future electricity capacity expansion planning.[1]. Further, new addition of firm capacity will be from clean energy sources such as regasified liquefied natural gas (RLNG).

<u>Repelling of clauses from 2019 General Policy Guideline that reflect.</u>

Removal of firm capacity requirement of 2/3rd of demand of power.

+

Removal of firm capacity mix ratios defined from coal, Natural gas, locally refined oil and Hydro

+

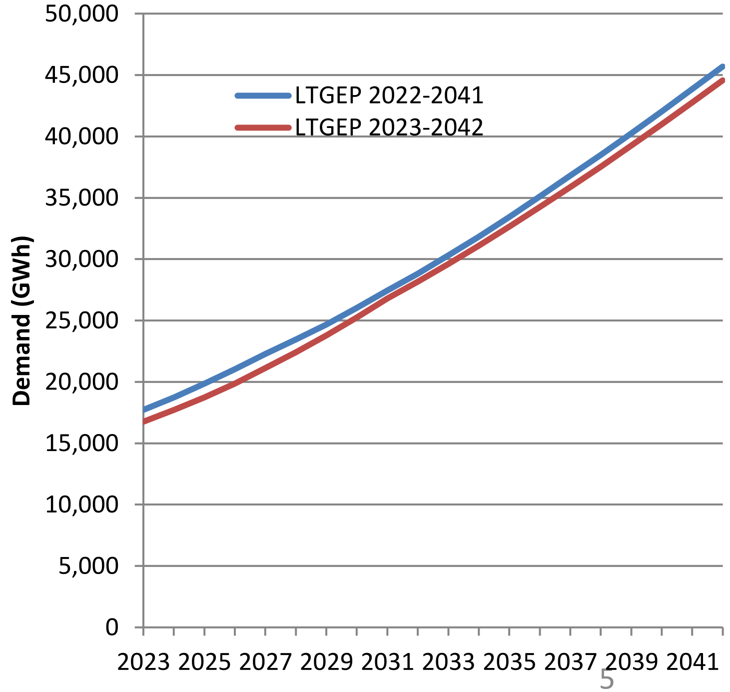
Removal of 1/3rd of demand of power from NCRE sources.

Demand Forecast 2023-2047

Year	Demand	System Loss	Generation	Peak
	GWh	%	GWh	MW
2023	16,741	7.95	**18,186**	**3,021**
2024	17,705	7.89	**19,222**	**3,149**
2025	18,725	7.83	**20,317**	**3,283**
2026	19,854	7.77	**21,526**	**3,432**
2027	21,124	7.70	**22,886**	**3,651**
2028	22,419	7.63	**24,272**	**3,890**
2029	23,794	7.57	**25,741**	**4,127**
2030	25,253	7.50	**27,300**	**4,378**
2031	26,801	7.45	**28,958**	**4,645**
2032	28,165	7.40	**30,415**	**4,880**
2033	29,601	7.35	**31,949**	**5,127**
2034	31,099	7.30	**33,548**	**5,385**
2035	32,646	7.25	**35,198**	**5,652**
2036	34,241	7.25	**36,917**	**5,929**
2037	35,879	7.25	**38,684**	**6,214**
2038	37,547	7.25	**40,482**	**6,504**
2039	39,253	7.25	**42,321**	**6,801**
2040	41,002	7.25	**44,207**	**7,106**
2041	42,777	7.25	**46,120**	**7,415**
2042	44,584	7.25	**48,070**	**7,730**
2043	46,431	7.25	**50,061**	**8,051**
2044	48,321	7.25	**52,098**	**8,380**
2045	50,259	7.25	**54,188**	**8,718**
2046	52,248	7.25	**56,332**	**9,064**
2047	54,315	7.25	**58,560**	**9,426**

Night Peak

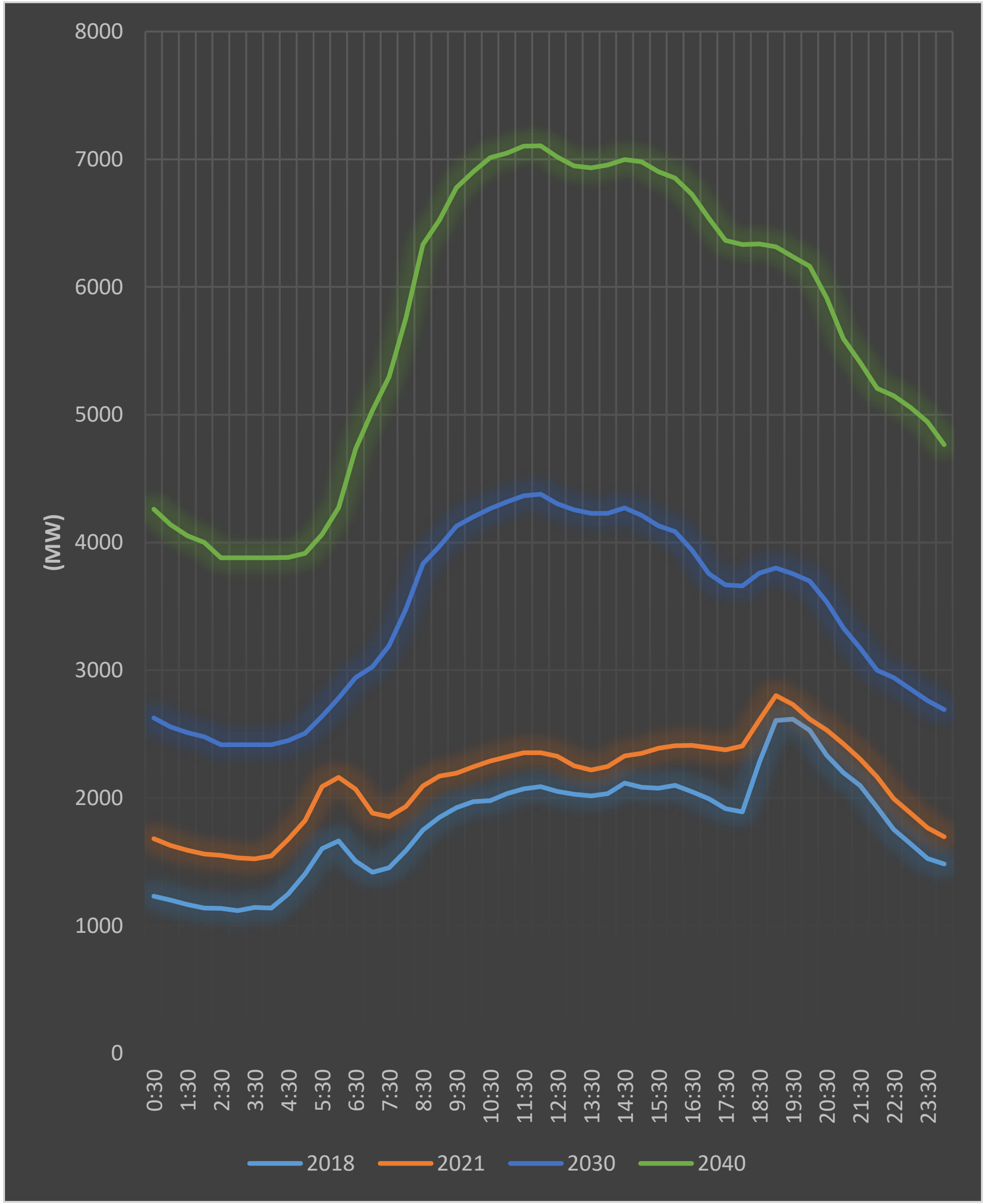
Day Peak



Typical Day Load Curve Pattern

- Day Peak Growth Faster than Night Peak Growth.

- Day peak would surpass the Night peak in year 2026



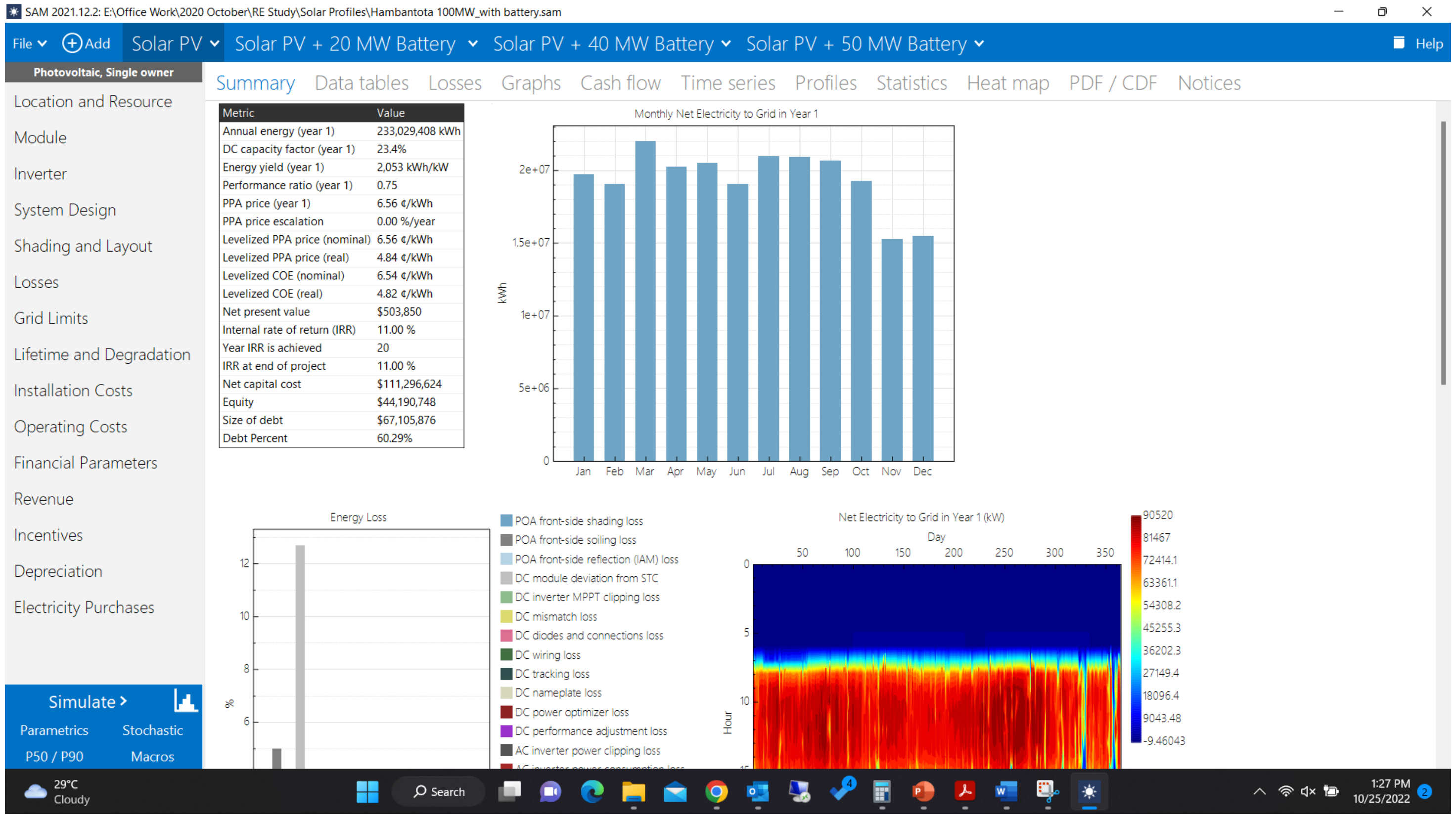
Consideration in Different timeframes

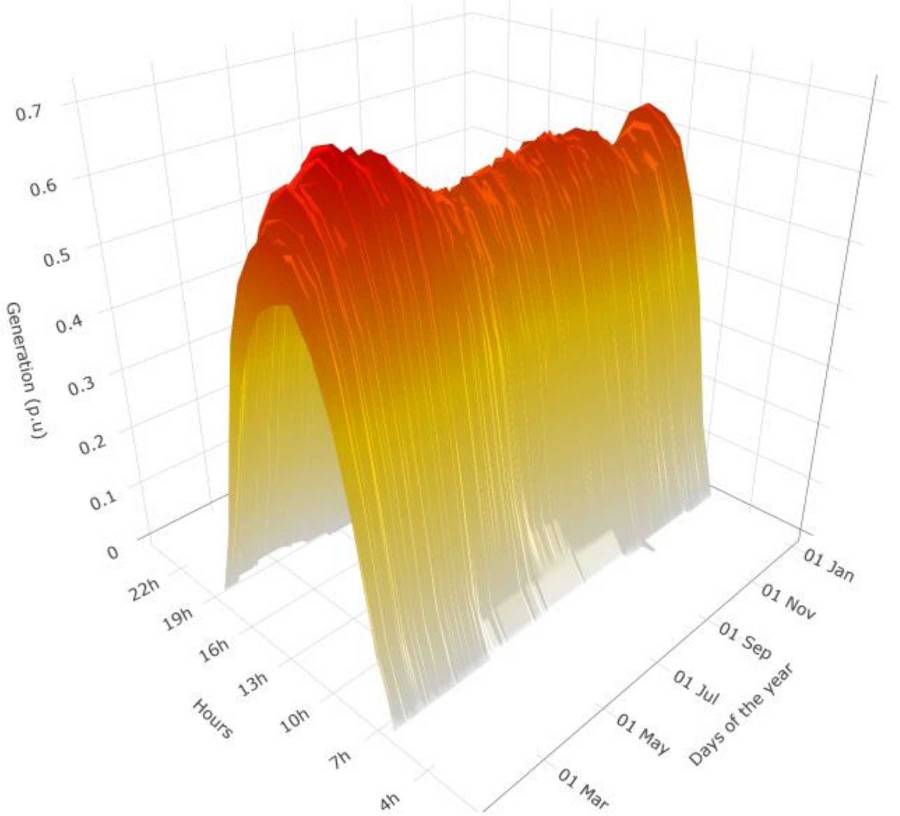
Ultra Short Term	Very Short Term	Short Term	Medium Term	Long Term	Very Long Term
Sub second to second	Second to Minutes	Minutes to Hours	Hours to Days	Days to Months	Months to years
Dynamic Stability (Inertia, Grid Strength)	Primary and Secondary Frequency Control (AGC)	Automatic Generation Control, Economic Dispatch, regulating reserves	Hourly Dispatch, Unit commitment for day ahead	Unit Commitment, Scheduling, Monthly Capacity Adequacy	Hydro Thermal Coordination, Capacity adequacy, System Reliability

Resource Modelling - Solar Parks

NREL NATIONAL RENEWABLE ENERGY LABORATORY **System Advisor Model (SAM)**

- Ground Mounted (Single Axis Tracking) / Floating Solar
- Hybrid Parks with Storage
- Dispatchable with Curtailment Policies





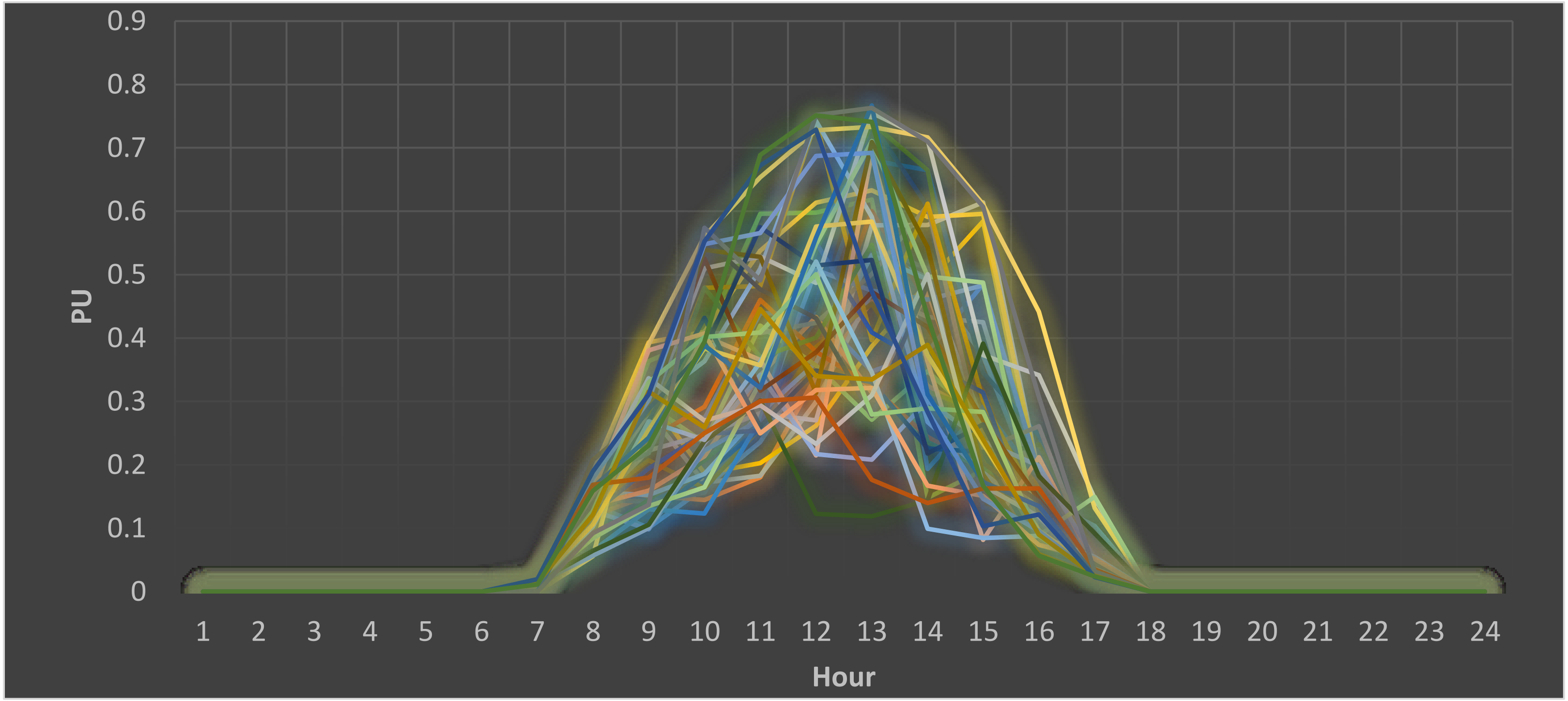
Resource Modelling - Distributed Solar

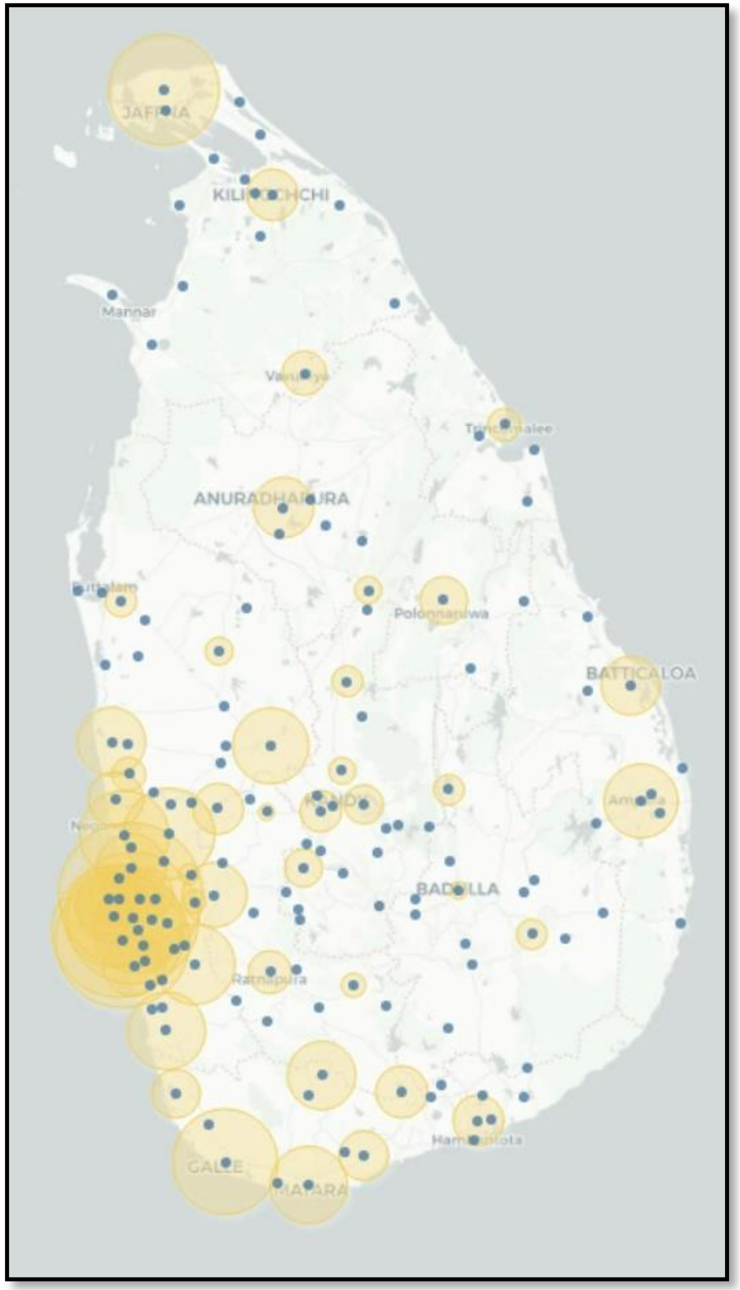
Location	Annual PF
Dehiwala	17.80%
Colombo	17.74%
Katunayaka	17.91%
Bolawatta	17.97%
Madampe	18.08%
Puttalam	18.07%
Panadura	17.49%
Pannipitiya	17.44%
Biyagama	17.39%
Aniyakanda	17.49%
Ambalangoda	18.01%
Kosgoda	17.82%

Location	Annual PF
Horana	16.98%
Veyangoda	16.90%
Pannala	18.03%
Chunnakam	18.50%
Mathugama	17.19%
Kirindiwela	17.35%
Galle	18.23%
Seethawaka	16.98%
Thulhiriya	17.33%
Maho	17.72%
Ratnapura	16.43%
Kegalle	17.21%

Location	Annual PF
Kurunegala	17.48%
Anuradhapura	17.86%
Vavuniya	17.72%
Kilinochchi	17.79%
Matara	18.49%
Deniyaya	16.46%
Nawalapitiya	15.87%
Kiribathkumbura	16.87%
Pallekele	16.89%
Ukuwela	16.52%
Naula	17.22%
Beliatta	18.24%

Location	Annual PF
Balangoda	17.36%
Nuwaraeliya	15.46%
Habarana	17.58%
Embilipitiya	17.80%
Mahiyanganaya	16.75%
Badulla	16.50%
Polonnaruwa	17.60%
Hambanthota	18.95%
Trincomalee	17.93%
Monaragala	17.38%
Ampara	17.69%
Vavunathivu	17.90%

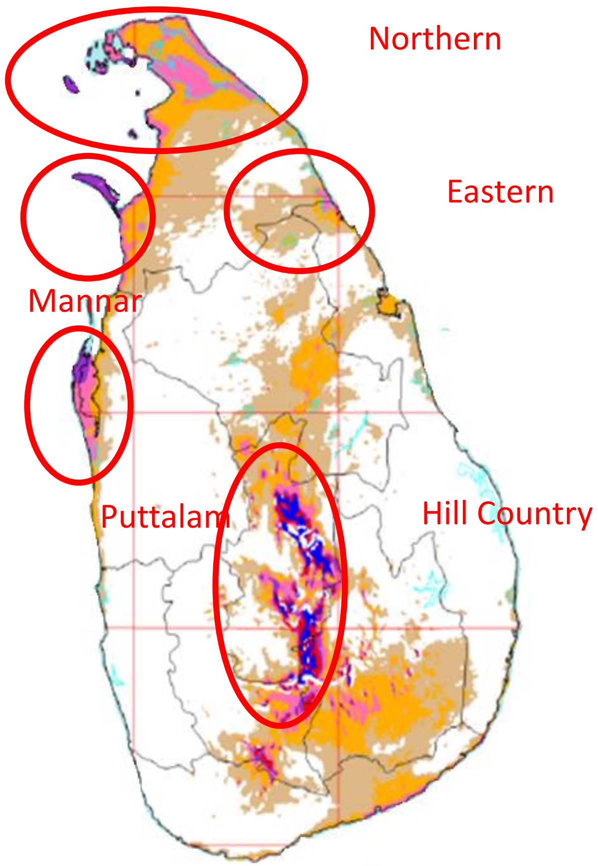




Resource Modelling - Wind

Five wind regimes were identified and wind plants were modelled based on actual site measurements for wind Production estimation

Wind Regime	Annual Plant Factor
Mannar	40.7%
Puttalam	31.4%
Hill country	19.1%
Northern	34.1%
Eastern	27.3%



Highlights of the Base Case Plan

Increased Level of VRE Integration

~ 500 MW Annual Solar PV Capacity Additions

~ 150 MW Annual Wind Capacity Additions

Large Scale Energy Storage Deployment

- **1,400** MW Pumped Storage development by 2032

- **1,125 MW** Battery Energy Storage development by 2030 / **4,670 MW** Battery Energy Storage development by 2042

70% RE TARGET

More Flexible Thermal Generation

- 1,130 MW Gas Turbine Power Plants

- 850 MW IC Engine Power Plants

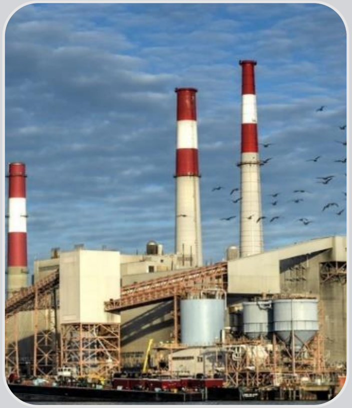
High Initial Investment

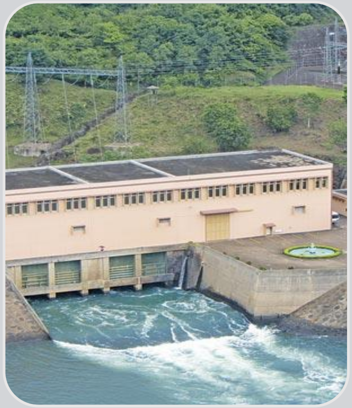
- Average annual generation and storage capacity investment of 1.25 USD Billion up to 2030

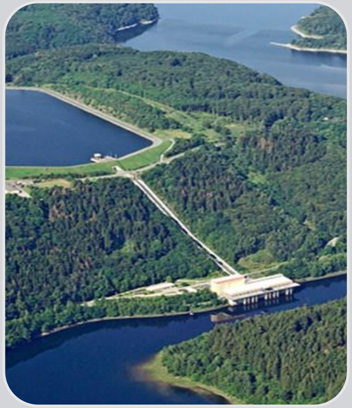
- Average annual generation and storage capacity investment of 1.43 USD Billion up to 2042

**This investment requirement contains only the investments needed on generation capacity and storage additions.*

Future Capacity Mix at Key Years





	Baseload , Intermediate Thermal	Flexible Thermal Power	Major Hydro	Other Renewable Energy	Grid Scale Battery Storage	Pumped Hydro Storage
	Coal Steam NG Combined Cycle Oil Combined Cycle Other Thermal	Gas Turbine Gas Engine		Solar Wind Mini Hydro Biomass		
2023	1,430 + 731	-	1,541	2,029	-	-
2025	2,104 + 24	330	1,571	3,302	120	-
2030	2,104 + 24	430	1,571	7,212	1,125	700

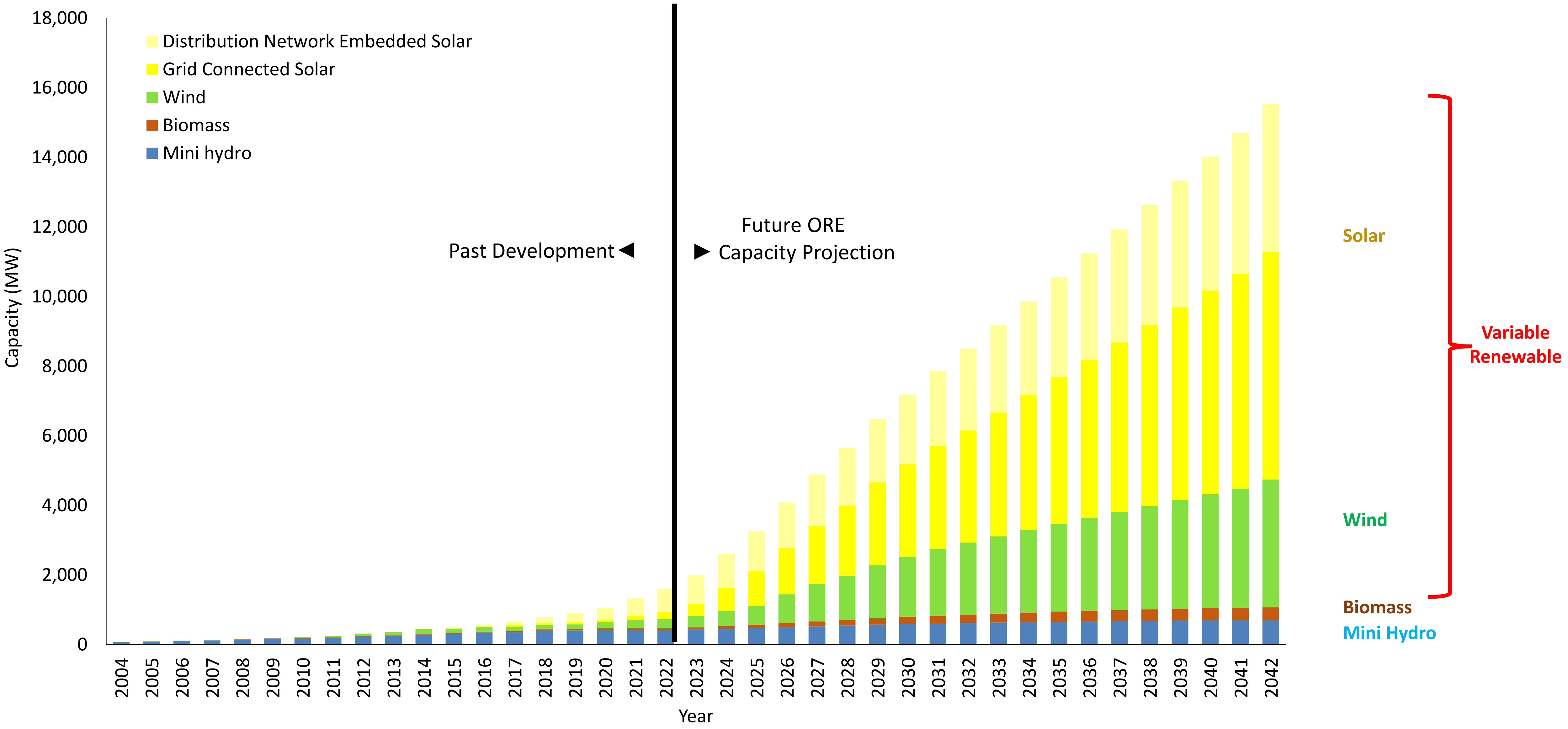
Base Case Plan Additions & Retirements

Year	Gross Capacity Addition (MW)										
	Gas Turbines	IC Engines	Coal	Combined Cycle	Major Hydro	Battery Storage	Pumped Hydro	Short Term	ORE	Existing Plant Retirements	Battery Storage Retirements
2022					155				309		
2023				240 (GT)				320	407		
2024	130			350 (ST+GT)	31	20		(200)	623	(130)	
2025				110 (ST)		100			650	(255)	
2026		200				180		(120)	835		
2027	100					200			795		
2028						350			775	(10)	
2029						150	350		835		
2030						125	350		711	(31)	
2031						125	350		692	(12)	
2032						125	350		660	(385)	
2033						150			694	(14)	
2034	100					200			737	(347)	(20)
2035	100	250				245			705	(25)	(100)
2036	200					380			730	(40)	(180)
2037	200					400			775	(85)	(200)
2038		200				550			785	(85)	(250)
2039	200					350			820	(120)	(150)
2040		200				340			793	(413)	(125)
2041	100			400		340			958	(278)	(125)
2042						340			958	(264)	(125)
Total	**1,130**	**850**	**0**	**1,100**	**31**	**4,670**	**1,400**	**0**	**14,938**	**(2,494)**	**(1,150)**

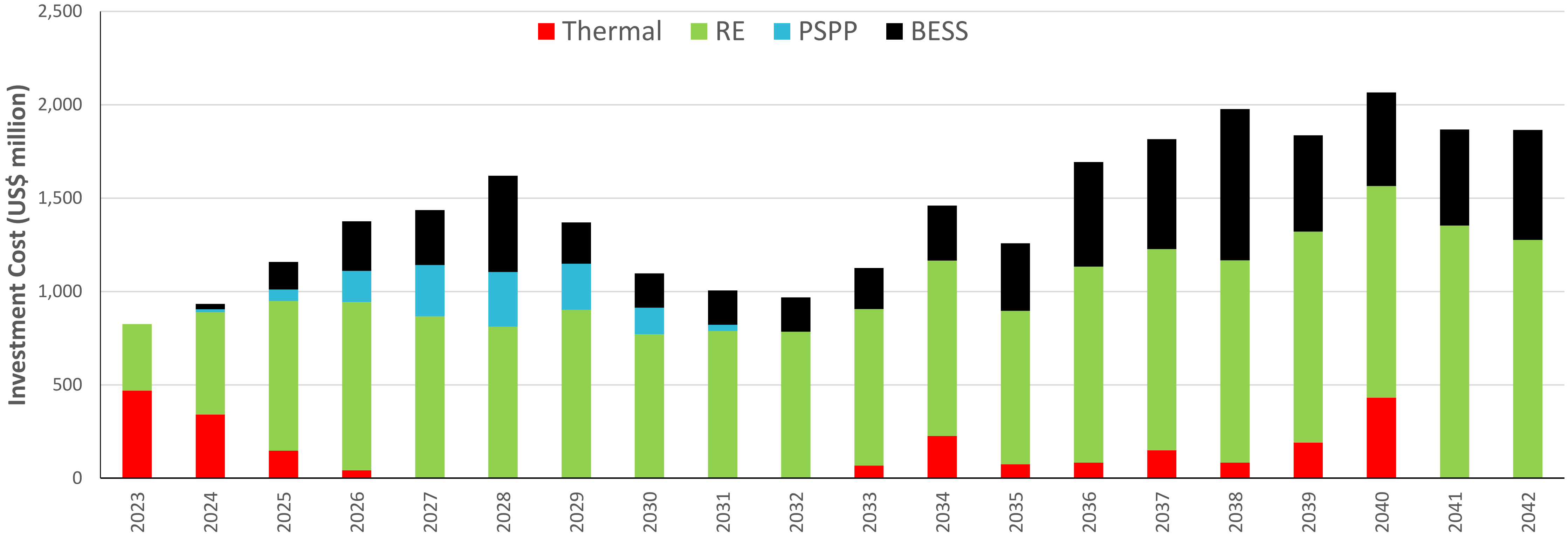
Renewable Energy Development Annual Additions (in MW)

Type	Major Hydro	Mini Hydro	Biomass	Wind	Distribution Network Embedded Solar	Grid Connected Partially Facilitated Solar	Grid Connected Fully Facilitated Solar (park)	Total Solar
Present Cumulative Capacity (2021)	1383	415	50	248	515	100	-	615
2022	155	20	10	-	160	94	-	254
2023	-	20	20	25	160	147	-	307
2024	31	20	20	60	160	223	100	483
2025	-	25	20	200	165	80	260	505
2026	-	25	20	290	170	70	260	500
2027	-	25	20	250	170	50	280	500
2028	-	25	20	200	170	40	310	520
2029	-	25	20	250	170	20	350	540
2030	-	10	20	200	170	30	250	450
2031	-	10	20	200	170	30	250	450
2032	-	10	20	150	170	30	250	450
2033	-	10	20	150	170	30	300	500
2034	-	10	20	150	180	30	300	510
2035	-	10	10	150	180	30	300	510
2036	-	10	10	150	190	30	300	520
2037	-	10	10	150	190	30	300	520
2038	-	10	10	150	200	30	300	530
2039	-	10	10	150	200	30	300	530
2040	-	-	10	150	200	20	300	520
2041	-	-	10	150	200	20	300	520
2042	-	-	10	150	200	20	300	520

Renewable Energy Development – Past & Future (Excluding Major Hydro)

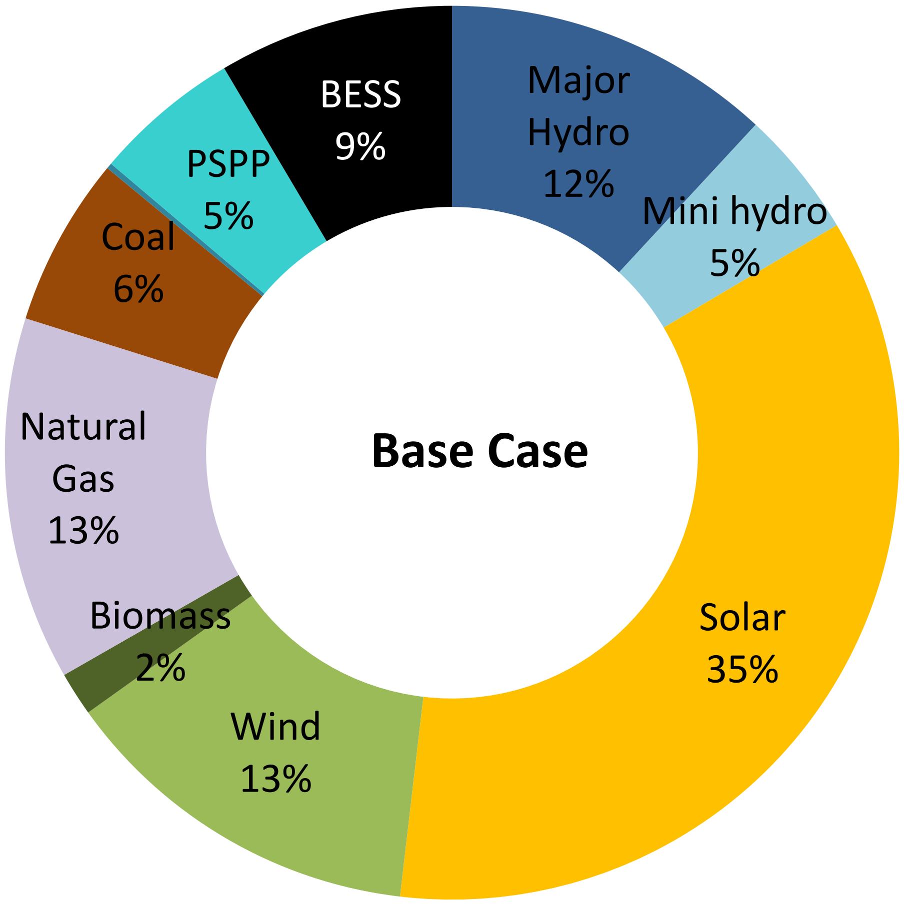


Base Case Plan – Annual Investment Requirement

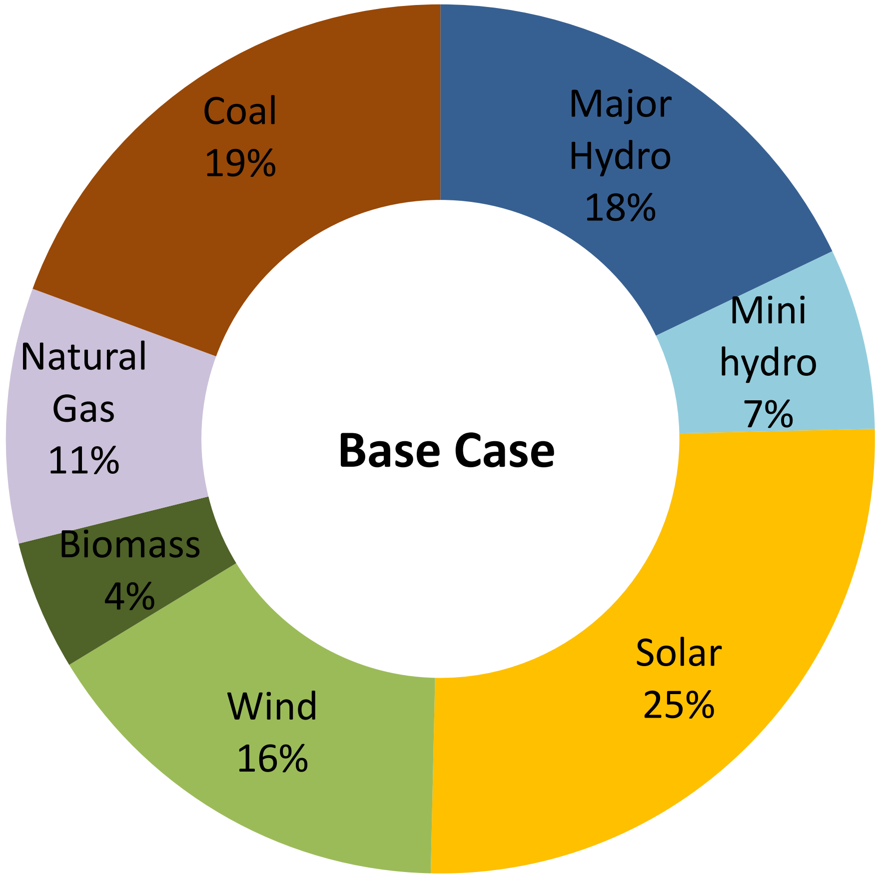


	Thermal	Renewables	Storage	Total
Average annual investment requirement for 2023-2030	**USD 125 million**	**USD 744 million**	**USD 358 million**	**USD 1,226 million**
Average annual investment requirement for 2031-2042	**USD 109 million**	**USD 1,022 million**	**USD 446 million**	**USD 1,578 million**
Average annual investment requirement for total horizon	**USD 116 million**	**USD 911 million**	**USD 411 million**	**USD 1,438 million**

Capacity Mix and Energy Mix (2030)

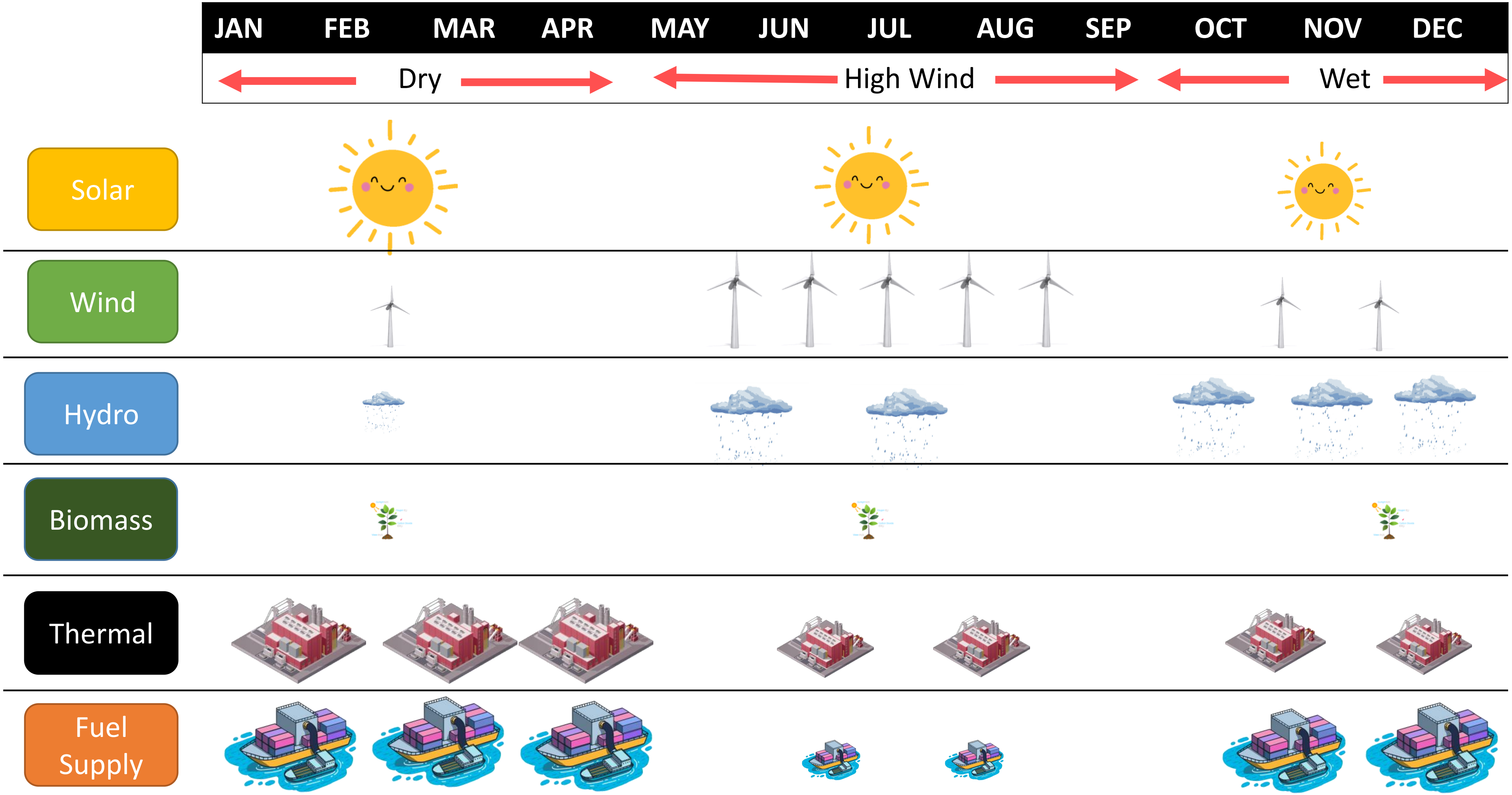


Capacity Mix

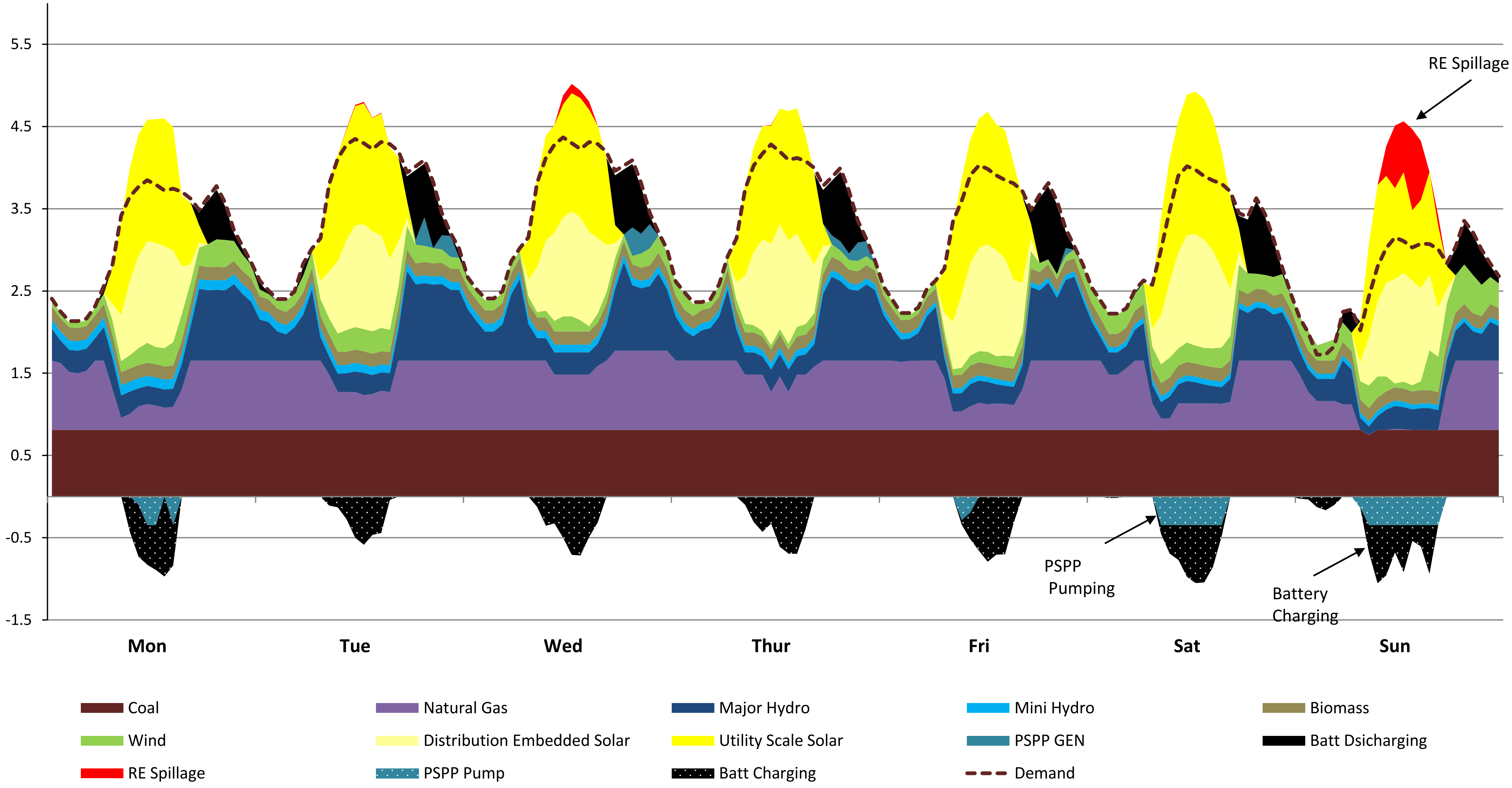


Energy Mix

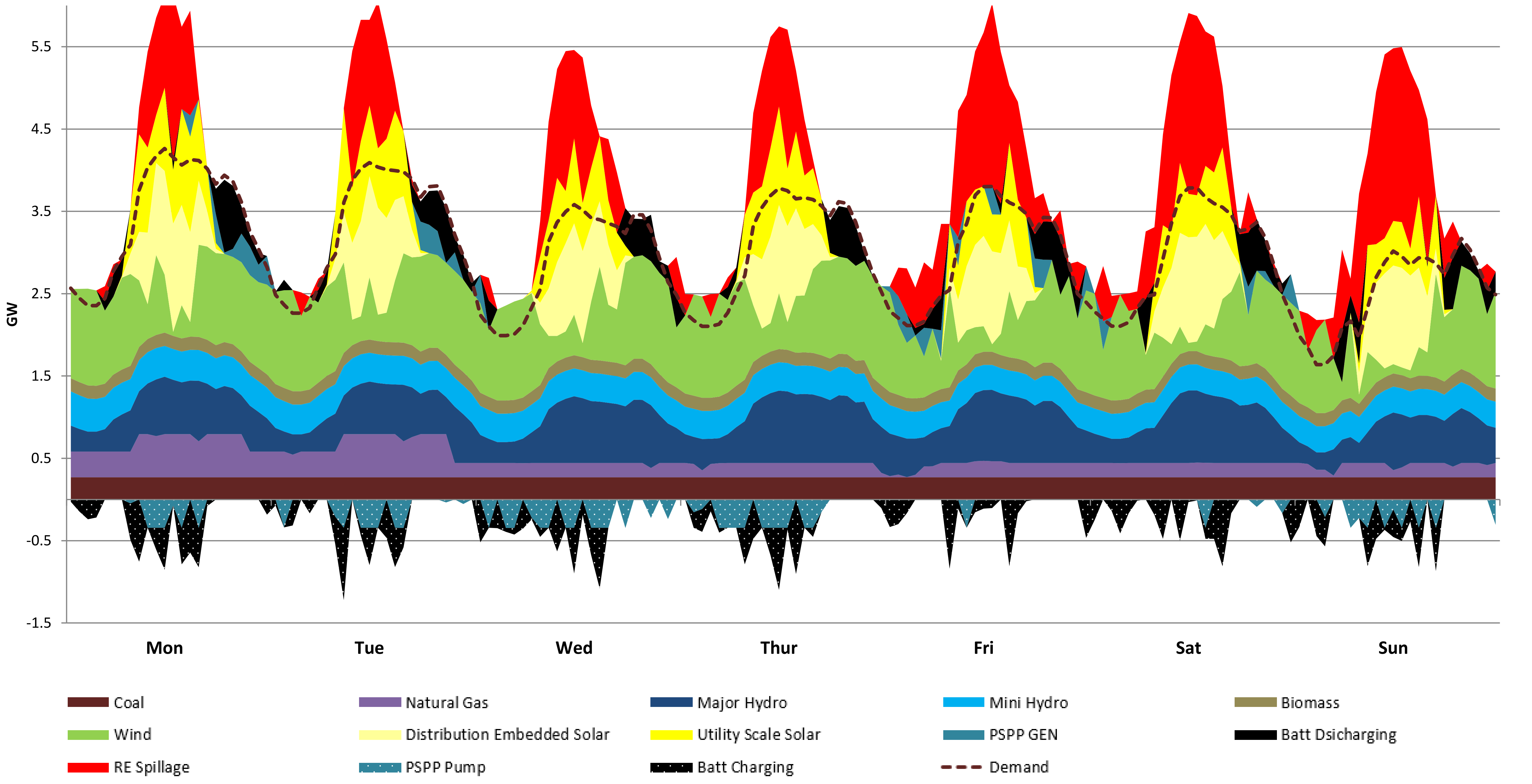
Seasonality with Source of Generation



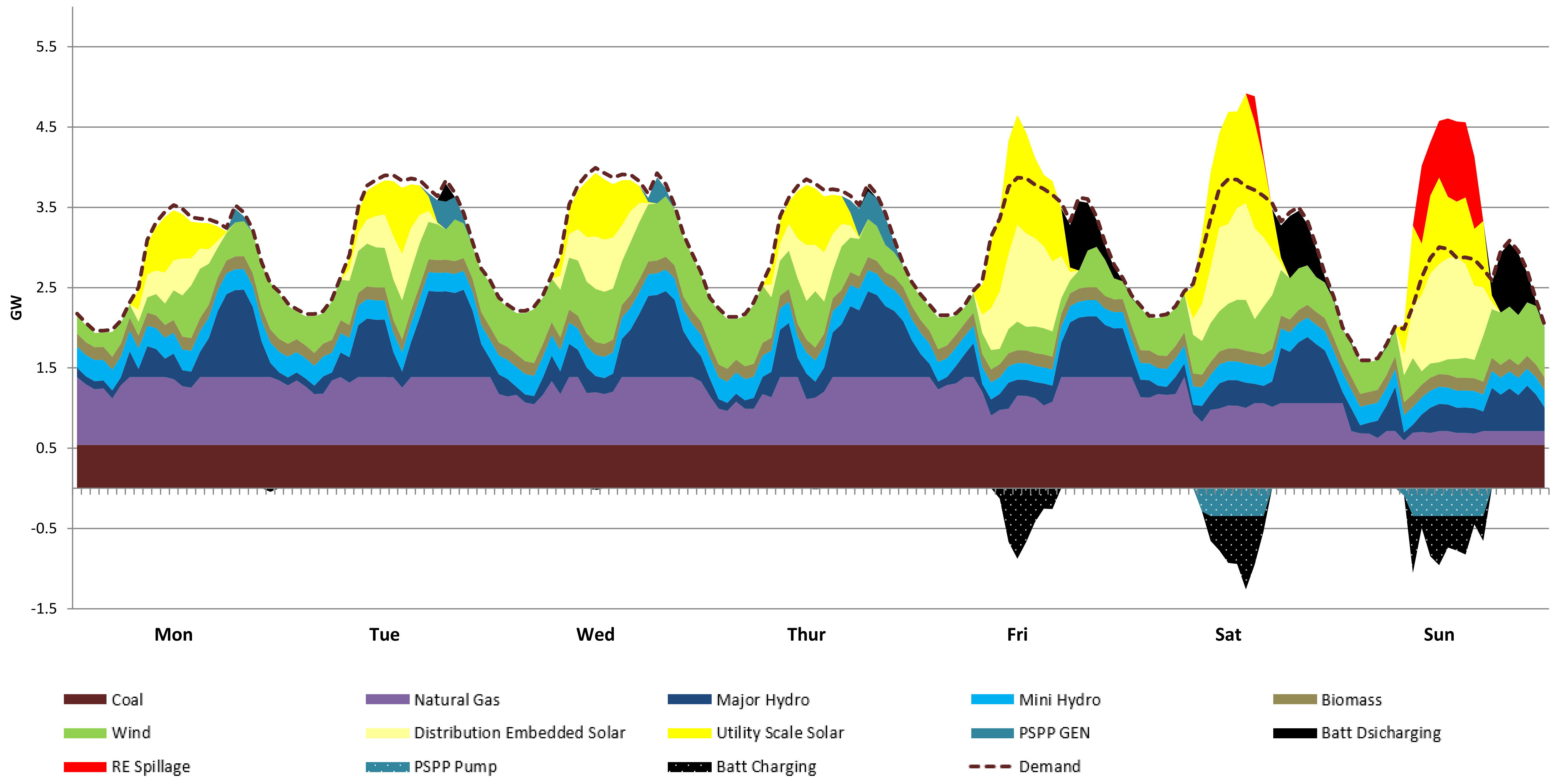
Typical Weekly Load Curve (Mon-Sun) - Dry Season 2030



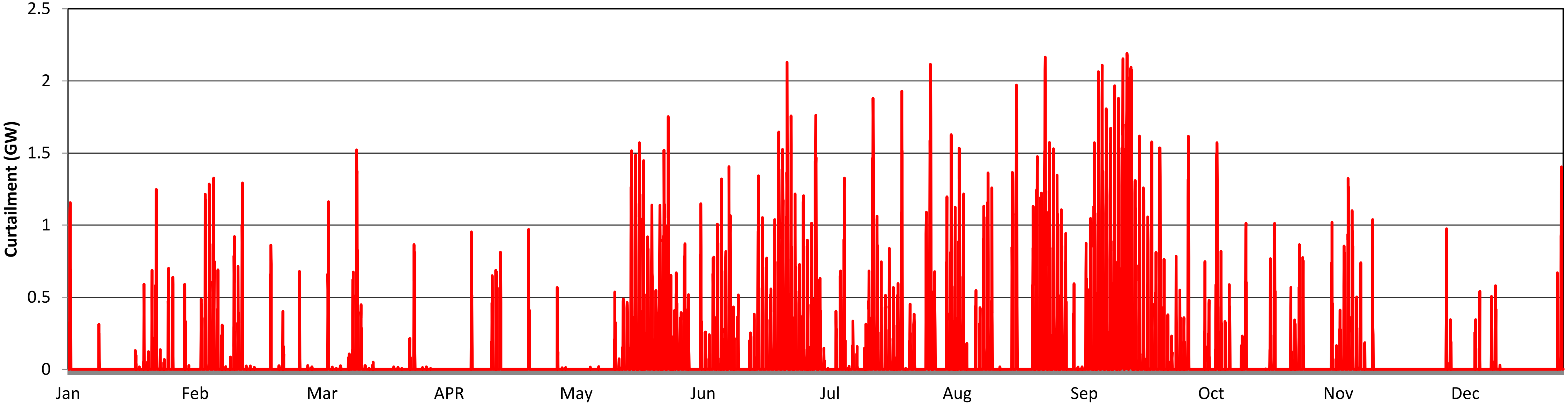
Typical Weekly Load Curve (Mon-Sun) - High Wind Season 2030



Typical Weekly Load Curve (Mon-Sun) - Wet Season 2030

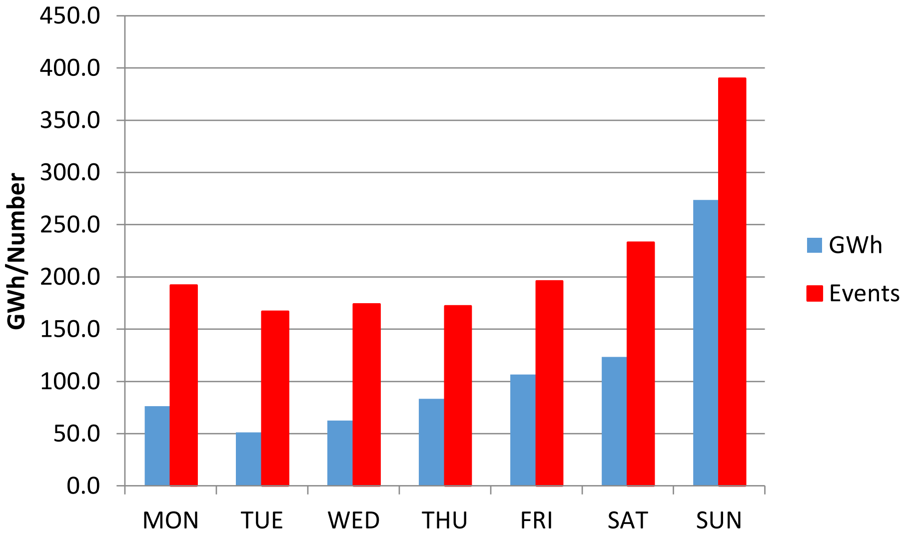


Renewable Curtailment for Year 2030

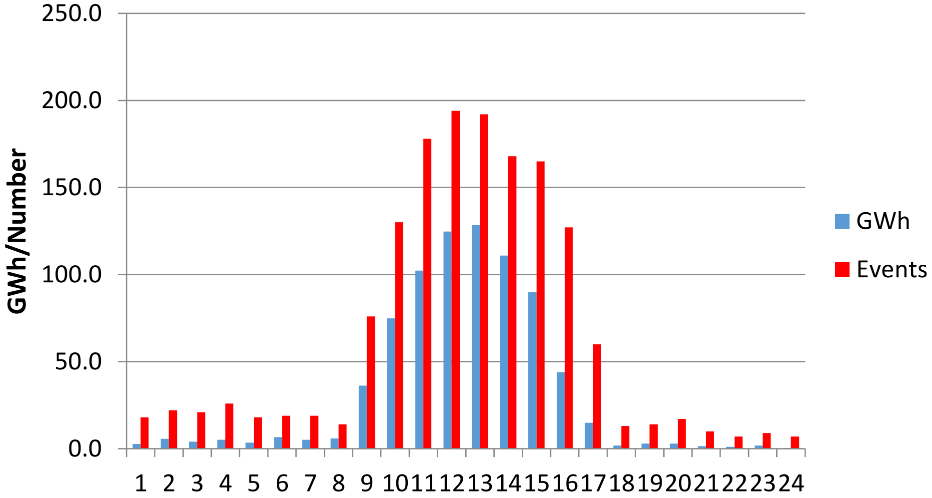


777 GWh

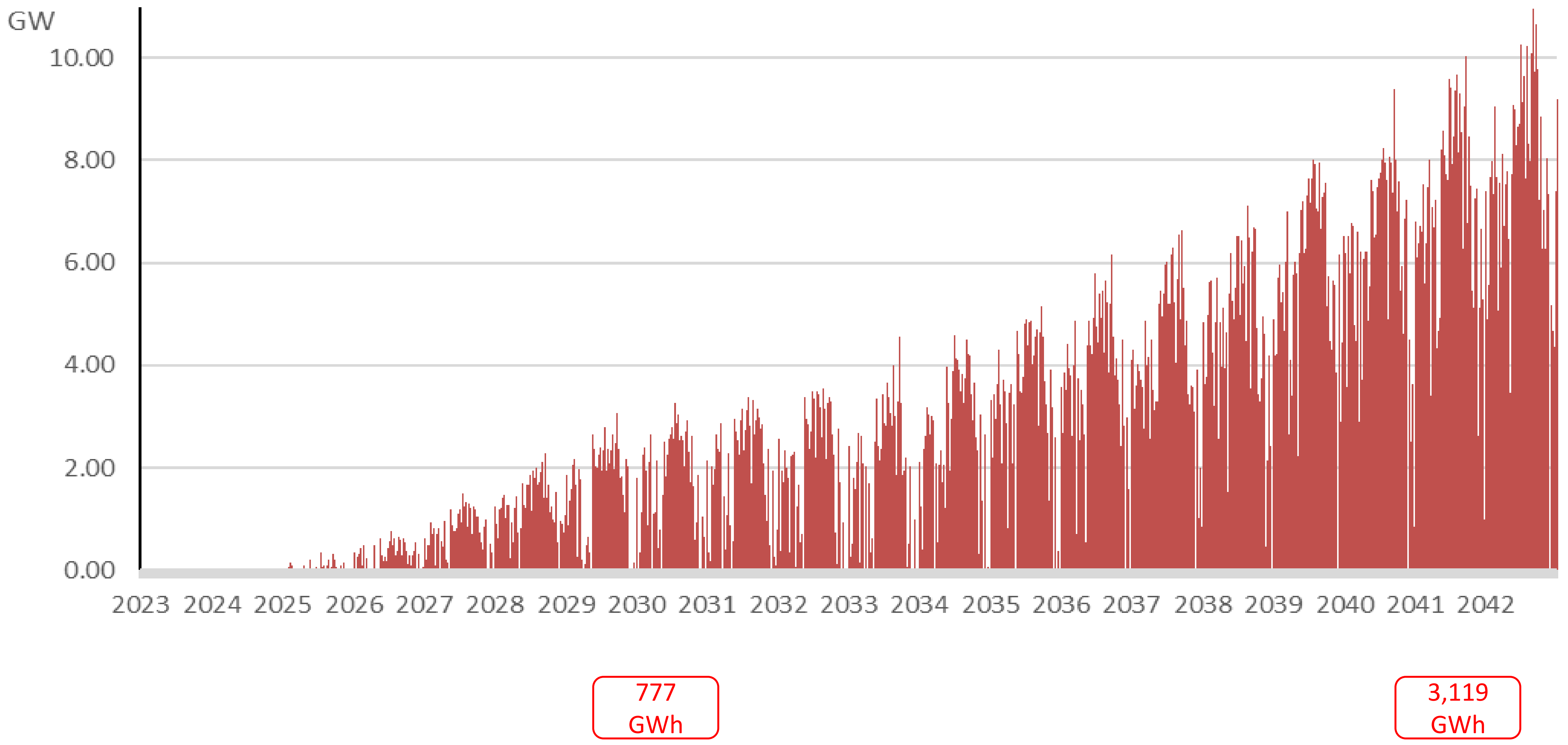
Distribution of RE Curtailments among days of the week



Distribution of RE Curtailments among hours of the day



Renewable Energy Curtailments (2023-2042)

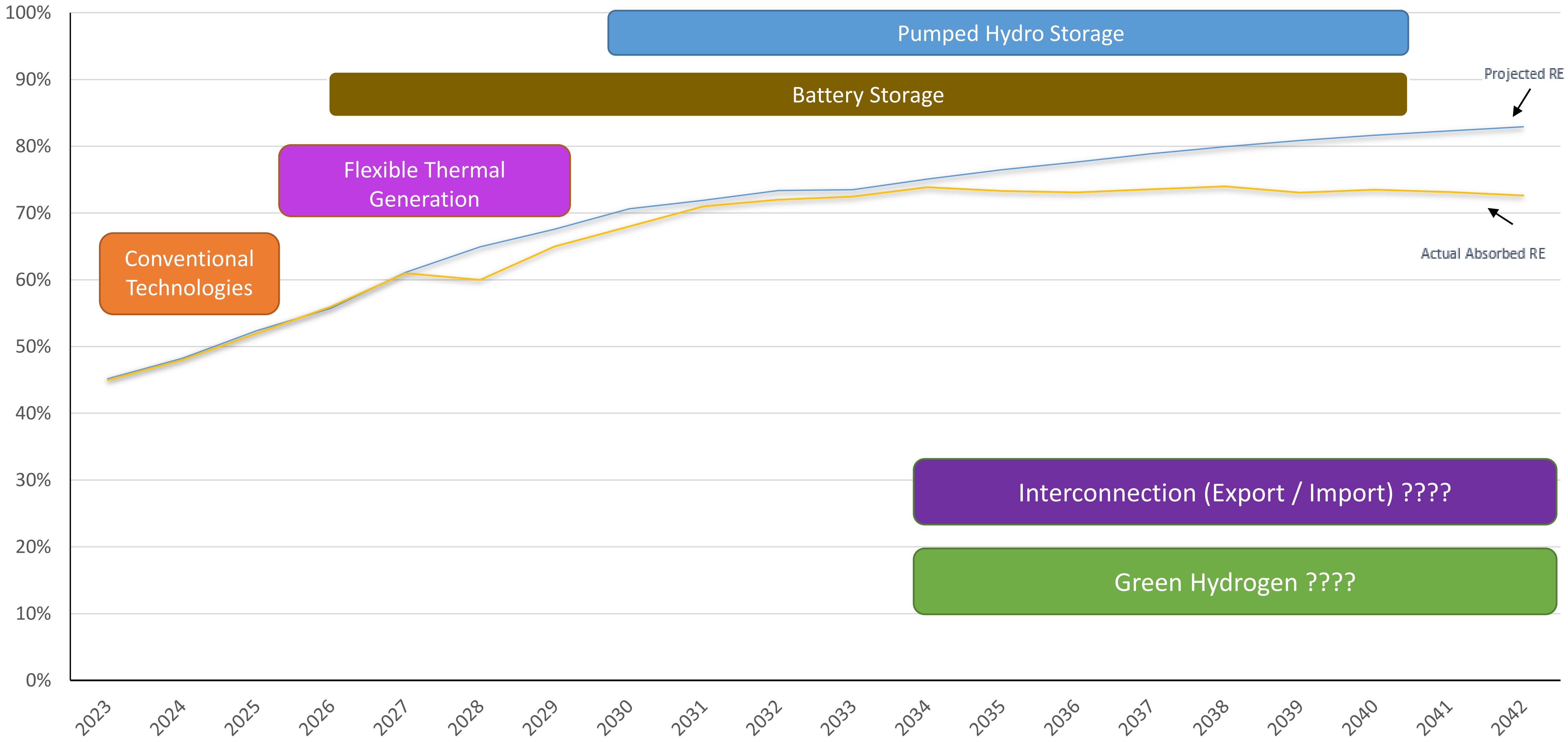


Key Scenarios - Results

		Policy Constrained Scenarios				Policy Unconstrained Scenarios		
		1. 70% RE by 2030 + No Coal (New Policy)	2. 70% RE by 2030 Increasing RE Share beyond 2030 + No Coal	3. 70% RE by 2030 HVDC Interconnection + No Coal	4. 70% RE by 2030 Nuclear 2040 + No Coal	5. 50% RE by 2030 With Coal Option Open Until 2030	6. 60% RE by 2030 With Coal Option Open Until 2030	7. 60% RE by 2030 + No Coal
Plant Additions 2023-2042 (MW)	Major Hydro	31	Need Additional Interventions	31	31	31	31	31
	ORE	13,795		13,795	13,795	10,097	11,608	11,065
	NG CCY	1,100		1,100	1,100	1,110	1,100	1,100
	NG GT/ ICE	1,930		1,580	1,880	4,030	3,820	4,130
	Coal	-		-	-	540	270	-
	Nuclear	-		-	600	-	-	-
	HVDC	-		500	-	-	-	-
	Battery	3,365		3,365	3,365	350	400	400
	PSPP	1,400		1,400	1,400	700	1,050	1,050
Present Value US$ Million	Investment	10,119	↑	10,400	10,220	7,589	7,946	7,498
	Operational	8,753	↓	8,483	8,766	10,203	9,561	10,357
	Total	18,872	↑	18,883	18,986	17,792	17,507	17,855

*Scenarios were developed considering fuel costs used for planning studies and imposing limits on instantaneous asynchronous penetration.

Renewable Share Growth and Interventions to achieve Carbon Neutrality



THANK YOU !!!