Democratic Socialist Republic of Sri Lanka

Project for Capacity Development on the Power Sector Master Plan Implementation Program in Sri Lanka
Project Completion Report

February 2023

Japan International Cooperation Agency (JICA)

Chubu Electric Power Co., Inc.

Nippon Koei Co., Ltd.

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Abbreviations and Acronyms

Word	Original
ADB	Asian Development Bank
AFD	French Development Agency
ARC	Abrasion Resistance Cover
BESS	Battery Energy Storage System
CA	Capacity Assessment
CD	Capacity Development
CEB	Ceylon Electricity Board
CF	Capacity Factor
C/P	Counter Part
DC	Direct Current
DD	Distribution Division
DR	Demand Response
EP	Energy Permit
FIP	Feed in Premium
FIT	Feed in Tariff
FLS	Fault Locating System
FRT	Fault Ride Through
GFD	Ground Fault Detector
HVDC	High Voltage Direct Current
IFC	International Finance Corporation
IMF	International Monetary Fund
IPP	Independent Power Producer
JCC	Joint Coordinating Committee
JICA	Japan International Cooperation Agency
LECO	Lanka Electricity Company
LOLP	Loss-of -Load Probability
LTGEP	Long Term Generation Expansion Plan
LTTDP	Long Term Transmission Development Plan
LV	Low Voltage
MOPE	Ministry of Power and Energy
MP	Master Plan
MR	Mixed Reality
MV	Medium Voltage
NCP	Novo Curto Prazo (New short term)”
NW	Net Work
OCI	Over Current Indicator
OJT	On the Job Training
PA	Provisional Approval

PCS	Power Conditioning System
PDM	Project Design Matrix
PSPP	Pumped Storage Power Plant
PSS/E	Power system simulator for engineering
PUCSL	Public Utility Commission of Sri Lanka
PV	Photovoltaics
RE	Renewable Energy
RoCoF	Rate of change of frequency
RED	Renewable Energy Desk
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control And Data Acquisition
SCC	System Control Center
SDDP	Stochastic Dual Dynamic Programming
SEA	Sustainable Energy Authority
SNSP	System Non-Synchronous Penetration
SVR	Step Voltage Regulator
TSS	Time Sequential Sectionalizer
TVR	Thyristor type step Voltage Regulator
USAID	U.S.Agency for International Development
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
WG	Working Group
WP	Work Plan

Chapter 1 Project Overview

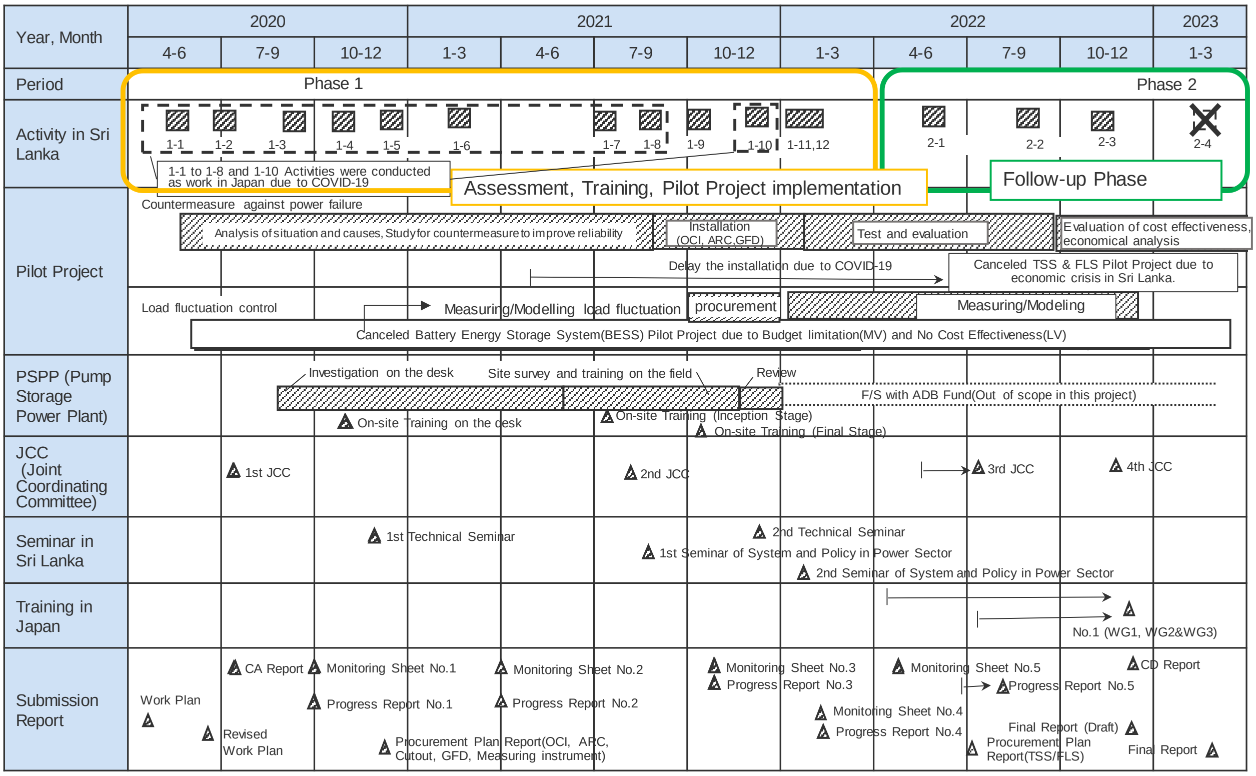
1.1 Project background

The Power Sector Master Plan in Sri Lanka (hereinafter referred to as “MP”) was formulated in FY 2017 by assistance of Japan International cooperation Agency (hereinafter referred to as “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 (hereinafter referred to as “MOPE”) and Ceylon Electricity Board (hereinafter referred to as “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 (hereinafter referred to as “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.

Purposes of “the Project for Capacity Development (hereinafter referred to as “CD”) of the Power Sector Master Plan Implementation Program” (hereinafter referred to as “the Project”) are to examine appropriate treatment of introduction of Variable Renewable Energy (hereinafter referred to as “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.

1.2 Schedule of the project

The project schedule is shown in Figure 1-1. Since overseas travel was restricted by the COVID-19 pandemic situation at the start of the project, the activities in Sri Lanka planned from April 2020 to September 2021 and December 2021 were held remotely from Japan. After the vaccination of the entire team was completed, members of the team were carefully selected from October 2021 and January 2022, and activities were carried out in Sri Lanka. Due to delays in travel to Sri Lanka, some equipment to improve the reliability of distribution lines (such as Fault Locating System and Time Sequential Sectionalizer) had to be procured later. However, due to the impact of the Sri Lankan economic crisis, the CEB members decided to discontinue the procurement. In addition, the training in Japan, which had been postponed in light of the Japanese government’s border measures due to the impact of COVID-19, was also implemented in December 2022 along with the review of border measures in October 2022.



(Source) JICA Expert Team

Figure 1-1　Schedule

1.3 Project structure

The implementing agencies of the recipient country are as follows.

- Implementing agency: Ceylon Electricity Board (CEB)
- Relevant CEB departments:

<Higher Organization>

Ministry of Power and Energy (MOPE)

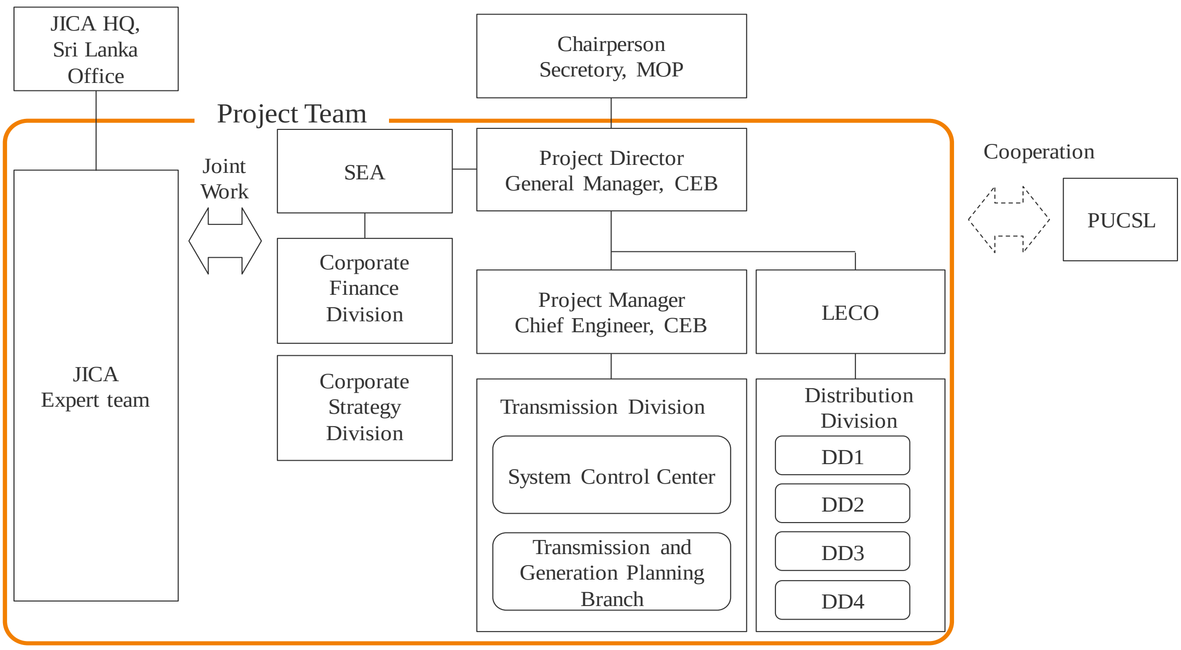
<Relevant organizations>

Public Utility Commission of Sri Lanka (hereinafter referred to as “PUCSL”)

Sustainable Energy Authority (hereinafter referred to as “SEA”)

Lanka Electricity Company (hereinafter referred to as "LECO")

Figure 1-2 shows the implementation structure of this project. The CEB became the main counterpart and proceeded with the project.



(Source) JICA Expert Team

Figure 1-2 Project Structure

Table 1-1 shows JICA experts engaged in the project.

Table 1-1 JICA Experts

No.	Name	Responsibility
1	Mr. HIRANO Akira	Team Leader / Electric Power Strategy
2	Mr. YOSHIDA Toshitaka	Deputy Team Leader / Electric Power Strategy
3	Mr. TANIHATA Osamu	System and Policy of Electric Power
4	Mr. MITSUI Shinichi (-June 30, 2021) Mr. TAKADA Shogo (August 1, 2021-)	Renewable Energy
5	Mr. MAKITA Yusaku	Finance
6	Dr. Suresh Chand Verma	Supply and Demand Management
7	Mr. TAKAMIZAWA Yu	Power System (Planning/Operation)
8	Mr. YASUTSUNE Hidenobu (-June 30, 2022) Mr. YAMAGA Shinichiro(July 1, 2022-)	Power System (System Analysis)
9	Mr. MATSUKAWA Muneo	Meteorological Forecast / Demand Forecast
10	Mr. TAKATSU Kenichiro (-June 30, 2022) Mr. MIZUNO Ryunosuke(August 1, 2022-)	Energy Management (Battery)
11	Dr. SHIKIMACHI Koji	Distribution Technology
12	Mr. NISHIKAWA Koji(-September 30, 2020) Mr. KAMIYA Yukihiro(October 1, 2020-)	Distribution (Planning/Design/Construction) / Coordinator
13	Mr. WADA Masaki	Hydraulic Civil Engineering (Planning/Design/Construction)
14	Mr. SHINGU Hirohisa	Geology

(Source) JICA Expert Team

Chapter 2 Objective and Goals

2.1 Objective

To facilitate the implementation of the MP, the Government of Sri Lanka requested technical cooperation from the Government of Japan to strengthen its capacity to implement the recommended priorities. The project aims to strengthen the institutional capacity of MOPE, CEB, SEA, and LECO, among others, to study and implement measures to address renewable energy sources, to enhance transmission and distribution networks, to improve reliability of supply, to revise grid codes, to improve generation forecasting and management technologies, and to improve financial management capabilities, in order to achieve optimal power supply configurations and to support the introduction of renewable energy.

2.2 Overall goals

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

2.3 Project purpose

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

2.4 Outputs of the Project

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.

Chapter 3 Contents of activities

3.1 JICA expert activities

The activities of the JICA experts of this project from April 2020 to the end of February 2023, including the remote activities, are as follows. Details of the JICA expert's activity records are shown in Appendix 1.

Table 3-1 JICA expert Activities

No.	Name	Responsibility	Activity days in Sri Lanka	Activity days in Japan
1	Mr. HIRANO Akira	Team Leader / Electric Power Strategy	63 days	172 days
2	Mr. YOSHIDA Toshitaka	Deputy Team Leader / Electric Power Strategy	63 days	146 days
3	Mr. TANIHATA Osamu	System and Policy of Electric Power	15 days	159 days
4	Mr. MITSUI Shinichi (-June 30, 2021) Mr. TAKADA Shogo (August 1, 2021-)	Renewable Energy	45 days	140 days
5	Mr. MAKITA Yusaku	Finance	48 days	116 days
6	Dr. Suresh Chand Verma	Supply and Demand Management	17 days	94 days
7	Mr. TAKAMIZAWA Yu	Power System (Planning/Operation)	28 days	84 days
8	Mr. YASUTSUNE Hidenobu (-June 30, 2022) Mr. YAMAGA Shinichiro (July 1, 2022-)	Power System (System Analysis)	61 days	240 days
9	Mr. MATSUKAWA Muneo	Meteorological Forecast / Demand Forecast	30 days	72 days
10	Mr. TAKATSU Kenichiro (-June 30, 2022) Mr. MIZUNO Ryunosuke (August 1, 2022-)	Energy Management (Battery)	23 days	156 days
11	Dr. SHIKIMACHI Koji	Distribution Technology	70 days	319 days
12	Mr. NISHIKAWA Koji (-September 30, 2020) Mr. KAMIYA Yukihiro (October 1, 2020-)	Distribution (Planning/Design/Construction) / Coordinator	51 days	227 days
13	Mr. WADA Masaki	Hydraulic Civil Engineering (Planning/Design/Construction)	0 days	82 days
14	Mr. SHINGU Hirohisa	Geology	14 days	71 days

(Source) JICA Expert Team

3.2 Changes to the Work Plan

In light of the impact of events such as the worldwide spread of COVID-19 and the economic crisis in Sri Lanka, the initial work plan was reviewed and the project was effectively managed. Major changes are as follows.

a. Due to restrictions on entry into Japan, the training in Japan (four times) planned for the first term was postponed to the second term, and the first and finalsession was held in December 2022 when the measures at the border were relaxed by the Japanese government.
   - Electricity Technology, System and Policy (March 2021, October 2022)
   - System Planning/Operation, Supply and Demand Management (scheduled for October 2021)
   - Distribution Facilities (scheduled for June 2021)

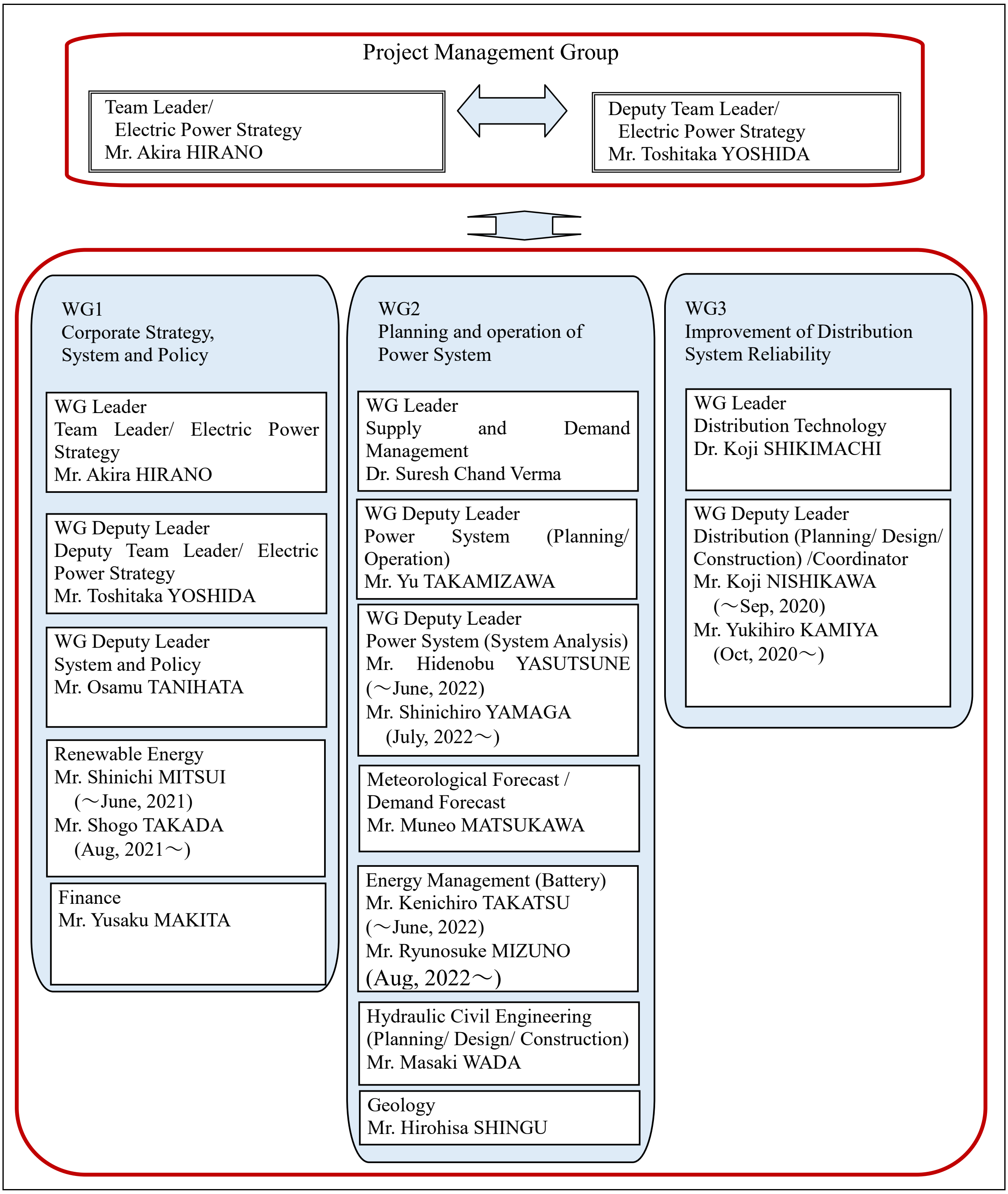
b. In the pilot project for the installation of distribution line equipment, priority was given to equipment (over-current indicator, fault detection device, abrasion-resistant cable cover, measuring equipment for electric power) that did not require site survey, and early procurement was hindered by the COVID-19.

c. Of the pilot projects for installation of distribution line equipment, equipment requiring on-site investigation by JICA experts to determine specifications (Time Sequential Sectionalizer and fault-point detection equipment) was in the process of a procurement plan. However, due to the impact of the economic crisis in Sri Lanka, it became difficult to bear some of the costs by CEB, and the introduction of these equipment was halted.

d. We planned to introduce storage battery systems into Medium Voltage (hereinafter referred to as "MV") distribution lines and selected Valachchenai distribution lines as candidate distribution lines. However, the cost of the storage battery system (capacity) required for the countermeasures was found to be far in excess of the project budget. Therefore, the installation of the storage battery system was halted and the knowledge about CEB /LECO members operation, measurement, and analysis technologies of CEB/LECO members was strengthened to introduce the storage battery system in the future.

3.3 To establish Working Group

In order to effectively promote the project, three working groups (hereinafter referred to as "WG") were established for each of the three themes of "Corporate Strategy, System and Policy," "Planning and Operation of Power System," and "Improvement of Distribution System Reliability," with each expert transferring technology. Figure 3-1 shows the structure of the working group of the JICA expert team, and Table 3-2 shows the members of each working group of the C/P.



(Source) JICA Expert Team

Figure 3-1 Structure of the Working Group

Table 3-2 Working Group Members of Sri Lanka

	Name	Role	Position/Organization
WG1			
1	A. M. A. Alwis(~May, 2021) K.K.P.Perera(June, 2021~)	Leader of Management	Deputy General Manager (Renewable Energy Development), CEB
2	K. V. S. M. Kudaligama	Deputy Leader of Management	Chief Engineer (Tariff), CEB
3	A. W. S. Peiris	Member	Chief Engineer (Renewable Energy Development), CEB
4	U. N. Sanjaya	ditto	Electrical Engineer (Transmission Planning), CEB
5	K. M. C. P. Kulasekara	ditto	Electrical Engineer (System Studies), CEB
6	T. L. B. Attanayake	ditto	Electrical Engineer (Transmission Planning), CEB
7	G.B. Alahendra	ditto	Electrical Engineer (Transmission Planning), CEB
8	M. D. R. K. Karunarathna	ditto	Electrical Engineer (Plant Scheduling), CEB
9	A. W. M. R. B. Wijekoon	ditto	Electrical Engineer (Generation Planning), CEB
10	D. C. Hapuarachchi	ditto	Electrical Engineer (Generation Planning), CEB
11	M. D. V. Fernando	ditto	Electrical Engineer (Generation Planning), CEB
12	Ruwani Kiriwendala	ditto	Accountant (Consolidation), CEB
13	T.K.G.Thiyambarawatha	ditto	Accountant (Planning), CEB
14	J.C.Haandagama	ditto	Accountant (Planning), CEB
15	J. M. Athula	ditto	Director from Sri Lanka Sustainable Energy Authority (SEA)
WG2			
1	D. S. R. Alahakoon	Leader of Management	Deputy General Manager (System Control), CEB
2	V. B. Wijekoon	Deputy Leader of Management	Chief Engineer (Generation Planning), CEB
3	V. V. Janeth(~May, 2021) W.G.Pawithra(June, 2021~)	Member	Electrical Engineer (Transmission Planning), CEB
4	A.W.S. Peiris	ditto	Chief Engineer (Renewable Energy Development), CEB
5	E.N.K. Kudahewa	ditto	Chief Engineer (System Operations), CEB
6	U. N. Sanjaya	ditto	Electrical Engineer (Transmission Planning), CEB
7	K. M. C. P. Kulasekara	ditto	Electrical Engineer (System Studies), CEB
8	T. L. B. Attanayake	ditto	Electrical Engineer (Transmission Planning), CEB
9	G.B. Alahendra	ditto	Electrical Engineer (Transmission Planning), CEB
10	M. D. R. K. Karunarathna	ditto	Electrical Engineer (Plant Scheduling), CEB
11	A.W. M. R. B. Wijekoon	ditto	Electrical Engineer (Generation Planning), CEB
12	K. A. M. N. Pathirathna	ditto	Electrical Engineer (Generation Planning), CEB
13	K. H. A. Kaushalya	ditto	Electrical Engineer (Generation Planning), CEB
14	H. D. K. Herath	ditto	Electrical Engineer (Transmission Planning), CEB
15	D. R. K. Bowatte	ditto	Electrical Engineer (Transmission Planning), CEB

			Name	Role	Position/Organization
	16	Sampath Fonseka		ditto	Chief Engineer (Tr. & Gen. Planning Branch)
WG3-1					
	1	N. H. C. Janaka(～Sep,2022) D. M. D. Ranawaka(Oct,2022~)		WG Leader of Management	CE (Construction), SP2, DD4, CEB(~Sep,2022) EE (Planning and Development), WPSII, DD3, CEB(Oct,2022~)
	2	DD1	H. I. S. Jayasundara	Sub-leader of Management	CE (Planning & Development), NWP, DD1, CEB
	3		A. Selvarasa	Member	EE (Distribution Control Centre), NP, DD1, CEB
	4		K. G. Lakmali(~Jan, 2021) L.B.S.N.Kularathne (Feb, 2021~Oct,2022)	Member	EE (Planning & Development), DD1, CEB
	5	DD2	K. G. N. A. Kumari	Sub-leader of Management	CE (Planning & Development), CP, DD2, CEB
	6		W. K. L. P. K. Welagedara	Member	EE (Planning & Development), CP, DD2, CEB
	7		S. Gowrithasan (~Aug, 2021、Apr, 2022～) V. Nilojan (Sep, 2021~Mar, 2022)	Member	EE (Planning), EP, DD2, CEB
	8	DD3	K. A. N. Jayantha (~Apr, 2022)	Sub-leader of Management (～Apr, 2022)	CE (Planning & Development), WPSII, DD3, CEB
	9		P. M. Piyasena	Member	CE (Planning & Development), Sabaragamuwa, DD3, CEB
	10		D. M. D. Ranawaka (~Sep,2022)	Member (～Apr, 2022) Sub-leader of Management (May, 2022 ～ Sep,2022)	EE (Planning and Development), WPSII, DD3, CEB
	11	DD4	P. H. L. J. Ranasinghe	Sub-leader of Management	CE (Construction), SP, DD4, CEB
	12		T. D. Nirmalie	Member	EE (Distribution Control Centre), SP, DD4, CEB
	13		W. C. H. Dhanapala	Member	EE (Development), WPS1, DD4, CEB
	14	LECO	Sampath Dissanayake	Sub-leader of Management	Control Engineer
	15		Thanuja Fernando	Member	System Development Engineer
	16		Raveen Patthamperuma	Member	Regulatory Engineer
WG3-2					
	1	M. Ganes		WG Leader of Management	CE (Planning Development), DD4, CEB
	2	DD1	U. G. J. K. Gamlath	Sub-leader of Management	CE (Planning & Development), DD1, CEB
	3		W. P. S. Sudarshani	Member	CE (Planning & Development), NCP, DD1, CEB
	4		D. M. D. K. Dissnayake	Member	EE (Primary Substation Maintenance), Col City, DD1, CEB
	5	DD2	R. M. J. Rathnayake	Sub-leader of Management	CE (Planning & Development), WPN, DD2, CEB
	6		K. V. R. Perera	Member	EE (Planning & Development), WPN, DD2, CEB
	7		K. M. M. Hikam	Member	EE (Planning & Development – Eastern Province), DD2, CEB

			Name	Role	Position/Organization
	8	DD3	J. M. S. Kumara(~May, 2021) K. P. J. P. Premathilake(June, 2021~)	Sub-leader of Management	CE (Planning and Development), Uva, DD3, CEB EE (Development), DD3, CEB
	9		K. P. J. P. Premathilake L.W.Gajanayake, Priyan Gamachige (June,2021~)	Member	EE (Development), DD3, CEB
	10		H. G. N Sandamali	Member	EE (Planning), WPSII, DD3, CEB
	11	DD4	D. D. K. G. Sandasiri	Sub-leader of Management	EE (P&D), WPS1, DD4, CEB
	12		U. S. Gunathunga(~May, 2021) K.G.Lakmali(June, 2021~)	Member	EE (Sys. Pl.) I, SP1, DD4, CEB
	13		B. P. L. De Silva	Member	EE (P&D), DGM, DD4, CEB
	14	LECO	Janaka Sanjeewa	Sub-leader of Management	Test Engineer
	15		Tharindu De Silva	Member	System Development Engineer
	16		Gayan Wijendrasiri (~June, 2022)	Member	System Development Engineer

(Source) JICA Expert Team

3.4 Response to COVID-19

(1) Change from original plan

Due to the prohibition of travel to overseas due to the spread of COVID-19, travel to Sri Lanka was postponed from the start of the project until the end of September 2021, and activities were carried out remotely from Japan.

From October 2021, JICA expert members were carefully selected and started their trip, and their activities were carried out in a hybrid manner, i.e. remotely and in Sri Lanka.

The following seminars and training were held remotely due to the postponement of overseas trips.

a. The first technical seminar was held remotely in December 2020 and the second technical seminar in December 2021.

b. The first System and Policy Seminar was held remotely in August 2021, and the second System and Policy Seminar was held in January 2022 in a hybrid manner, i.e. remote and in Sri Lanka.

c. In October 2020, a desktop training course on pumped storage power generation was held remotely in July 2021 at the Inception Stage. On-site training for the Final Stage was held in October 2021 in Udathenna village and remote (classroom) locations.

(2) Improvements and effects across the entire project

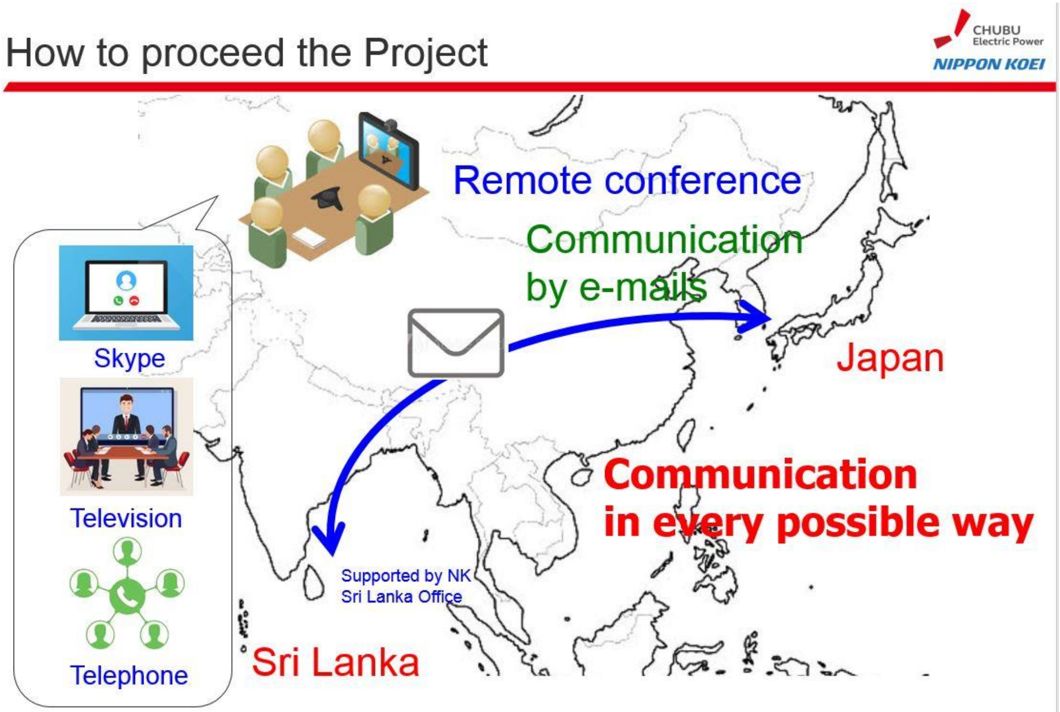
JICA experts made the following efforts to promote more effective projects and transfer technologies, despite being constrained by the restrictions on trips to Sri Lanka due to the COVID-19 and the restrictions on activities due to the corona infection countermeasures during travel to Sri Lanka.

Table 3-3 Improvements to the Project

Improvements	Effects
To gather information via videoconferencing and e-mail, and to check progress regularly Use of Live Chat (literal communication) to make both JICA experts and Sri Lankan members a video conference in English, the second language. Participants were carefully selected for the video conference.	Since there are concerns about the quality and delay of voice calls due to video conferencing via Internet lines, communication could be supplemented by letters. By selecting the participants carefully, the responsibilities were clarified and information was obtained and opinions were exchanged smoothly.
Holding teleconferences under new Zoom contracts. Provision of equipment for video conferencing systems to enable large-scale teleconferencing in multiple locations at the same time.	The use of Zoom enabled smooth teleconferencing without device constraints. By using the video conferencing system in the Joint Coordinating Committee (hereinafter refered to as “JCC”), technical seminars, and System and Policy seminars, it was held on a large scale even during COVID-19.
Information and materials are shared between JICA experts and Sri Lankan members through the project data room (JICA GIGA POD).	Since the materials can be shared by all members of JICA experts and Sri Lankan members, efficient work was carried out, including the review of materials.
After the presentation, a questionnaire was conducted to confirm the level of awareness and understanding of the explanation. In order to efficiently request and aggregate questionnaires, the Forms questionnaire was used.	The explanation contents and degree of awareness and understanding by Sri Lankan members ware quantitatively grasped, and subsequent presentations were carried out effectively.
The questionnaire and explanatory materials were concise and supplemented with explanations, assuming that direct explanations were not possible. In addition, on-demand materials were prepared for self-study before meeting.	By understanding the necessity of the project, Sri Lankan member’s independence was enhanced.
The draft monitoring sheets and project milestones prepared by JICA experts were presented to the Sri Lankan members, and the Sri Lankan members were encouraged to take the lead in finalizing and managing the progress.	Sri Lankan member's ownership and management capacity for the project were improved.
Questionnaires were presented by priority. Example: At the 1st time, 1st priority item. After the second time, the questions will be reviewed depending on the detailed contents and the status of the responses.	Answers were obtained quickly by dividing the questions by priority.
The information of Sri Lankan member responders (name, department, and e-mail address) for each item in the questionnaire was summarized and organized.	Sri Lankan member’s response person were clarified, and their independence were improved and prompt responses were obtained.
Based on information on ADB's (donor) staff obtained from JICA, the JICA expert members obtained information on key persons (donors) such as AFD and IFC. Information on the project was explained at the TV conference, and the status of donor activities were grasped.	The status of other donors activities were grasped by video conferences and e-mail exchanges. After the resumption of travel to Sri Lanka, interviews were conducted promptly, and a good relationship was built.

Improvements	Effects
In the JCC, on-site training (pumped storage power generation), and on-site seminars (1st and 2nd Technical Seminars, 1st and 2nd System and Policy Seminars), the following measures were taken. ・Holding by TV conference ・Proposing activities to call for participation using JICA's Sri Lanka office and Japanese embassies in Sri Lanka ・Follow-up when there is insufficient time for questions and answers (using Zoom's chat box function to put together questions; later answered by e-mail from CEB)	At the seminar, more than 50 people participated due to the cooperation of various parties in Sri Lanka and the on-line meeting as countermeasure against COVID-19. In addition, using the teleconference function, sufficient answers were given to the participants.
Materials were shared with participants in various seminars in advance.	Participants understanding deepened and actively exchanged opinions and asked questions.
Supplementary meetings were held to confirm items for which there was insufficient consultation in the field activities (remote) and to sort out issues for the next on-site activities (remote).	In addition to regular field activities (remote), supplementary meetings were established to meet the progress of each WG's activities, leading to the promotion of projects in line with the plan.
CEB member presentations were held in various seminars and WG activities.	In addition to presentations by JICA experts, CEB member presentations by themselves deepened mutual understanding between JICA experts and Sri Lankan members, and confirmed the degree of understanding of Sri Lankan members.
Consideration was given to how equipment could be procured without on-site inspection by JICA experts.	Some equipment could be arranged early, limiting project delays.
In the whole meeting with Sri Lankan members, because speakers were limited, small meetings were held for each organization (DD1, DD2, DD3, DD4, and LECO).	This encouraged the Sri Lankan members to speak out on a non-speech basis, which led to the resolution of questions that had been raised by the Sri Lankan members and the confirmation of their understanding.

(Source) JICA Expert Team



(Source) JICA Expert Team

Figure 3-2 Image of Remote Activity

3.5 Capacity Assessment

(1) Purpose of the Capacity Assessment

In order to set specific numerical targets for this project on the Project Design Matrix (hereinafter referred to as "PDM"), as well as to measure the improvement (capacity development) of the organizational structure, technology, knowledge, and institutions of the Sri Lankan parties under this project, a capacity assessment (hereinafter referred to as “CA”) was conducted as a grasp of the current situation. In the first quarter of the project (from inception to September 2020), JICA expert team and Sri Lankan team discussed the specific targets based on the capacity assessment and the results.

(2) Capacity Development and Project Design Matrix

a. 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 (hereinafter referred to as “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 evaluated degrees of achievement about CD on each target of the Project and discussed measures for future development of C/Ps with refer to results of the Project. CD report had been prepared with results of the CD at the end of the Project.

b. Project Design Matrix (PDM)

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 Chapter 5.3.

(3) Capacity assessment items

Table 3-4 shows the main capacity assessment items.

Table 3-4 Capacity Assessment items

Indicator	Assessment items	Remarks
System and Policy	- The CEB's strategy for Variable Renewable Energy (VRE) development and its periodic review - Procedures and understanding from VRE introduction plan to start operation - Formulation of VRE introduction plan based on Sri Lanka's energy policy - Status of the wholesale and balancing markets - Systems to promote VRE development (subsidies, low-interest loans, etc.) - Current electricity tariff system	As additional information, the status of assistance by other donors in the power sector was confirmed.
Renewable Energy	- Understanding of the advantages and disadvantages of VRE types	—
Finance	- Financial status of CEB - CEB financial structure support system - Debt and government subsidies for CEB	Collect current information Analysis was conducted in accordance with activities in Sri Lanka.
Power system operation	- Establishment of a system to relax the restrictions on grid connections - Establishment of power generation curtailment rules - Current System Operation Based on VRE - System stabilization measures based on the introduction of VRE - Skills of system and operation in consideration of VER - VRE training for engineers	—
Distribution line Operation and maintenance	- Current reliability of distribution lines - Status of measures against power distribution line failures - Improvement of distribution line voltage fluctuation - Training of power distribution line engineers	—
Human Resource Development	- Training of CEB staff	—
Project baseline	- System Average Interruption Duration Index (hereinafter referred to as “SAIFI”), System Average Interruption Duration Index (hereinafter referred to as “SAIDI”), and Loss-of -Load Probability (hereinafter referred to as “LOLP”) - Voltage and frequency fluctuation - Photovoltaics (hereinafter referred to as “PV”) and wind power output forecast system error	Check the current value.

(Source) JICA Expert Team

(4) Main findings

Capacity assessment results were compiled as a report, and final edition was submitted to JICA in October 2020. (See Appendix 1 for details)

3.6 Joint Coordination Committee (JCC)

3.6.1 1st Joint Coordination Committee (July 8, 2020)

(1) Agenda

The 1st JCC was held on July 8, 2020 as follows.

1. Date: July 8 (Wednesday), 2020 10:00 - 13:00

2. Venue: Holding as a video conference (Zoom conference)

3. Agenda:

Opening Remarks by MOPE and JICA

Introduction to Sri Lanka Power Sector by CEB

Variable Renewable Energy(VRE) projects and issues in Power Sector in Sri Lanka by CEB

Presentation by JICA Expert Team Member and discussion

- Progress of the Project (Brief Explanation) Introduction of Chubu Electric Power and Nippon Koei
- Outline of the Project activities
- Role of Joint Coordination Committee (JCC) and Working Group (WG)
- Project Schedule, Progress of the Project
- Capacity Assessment (CA), Project Design Matrix (PDM), Project Monitoring
- WG1, WG2, and WG3 Activities
- Approval of WP and PDM

Question and Answer

4. Participants

<Sri Lanka side>

- MOPE (Ministry of Power and Energy)
- CEB (Ceylon Electricity Board)
- SEA (Sustainable Energy Authority)
- LECO (Lanka Electricity Company)
- PUCSL (Public Utilities Commission)

<Japan side>

- JICA Expert Team
- JICA Sri Lanka Office, - JICA Headquarters

Before the JCC was held, the CEB made efforts to hold the JCC efficiently by explaining to the relevant executives in advance. The JCC was attended by a number of members of the SEA, the LECO, and the regulatory body PUCSL. Participants are referred to the first JCC List of Participants in Annex 3.

(2) Results

At the JCC, as noted above, CEB gave a presentation on the power sector challenges associated with the large-scale introduction of VRE. For details of the JCC, the JCC presentation material is shown in Appendix 3.

It was explained that it is necessary to obtain agreement at the JCC on the contents of the Work Plan and PDM. After the end of JCC, PUCSL, SEA and LECO confirmed and agreed on the contents of the Work Plan (WP) and PDM items.

(Source) JICA Expert Team

Figure 3-3 1st JCC

(Left: Opening Remarks, Right: Video Conference on the Japanese side)

3.6.2 2nd Joint Coordination Committee (July 30, 2021)

(1) Agenda

The 2nd JCC was held on July 30, 2021 as follows.

1. Date: July 30 (Friday), 2021 10:00 - 12:30
2. Venue: Holding as a video conference (Zoom conference)
3. Agenda:
   Opening Remarks by MOPE and JICA
   Recent Introduction Plan of Variable Renewable Energy and Formulation Status of the Next Long Term Generation Expansion plan by CEB
   Presentation by JICA Expert Team Member and discussion
   - Progress of the Project
   - Objectives and Schedule of the Project
   - WG1, WG2, and WG3 Activities
   - 1st System and Policy Seminar
   - Training in Japan

   Discussion
4. Participants

<Sri Lanka side>

- MOPE (Ministry of Power and Energy)

- CEB (Ceylon Electricity Board)
- SEA (Sustainable Energy Authority)
- LECO (Lanka Electricity Company)
- PUCSL (Public Utilities Commission)

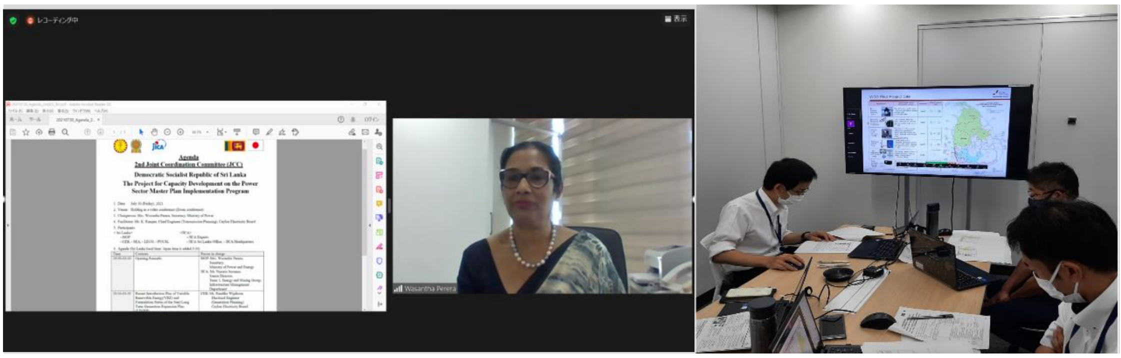
<Japan side>

- JICA Expert Team
- JICA Sri Lanka Office, - JICA Headquarters

At the JCC, CEB members took the initiative to make presentations. Many members, including SEA, LECO and the regulator PUCSL, participated. The list of attendees of the 2nd JCC is shown in Annex 5.

(2) Results

The JICA expert team explained the progress of the project, the details of technical transfer, and future efforts to achieve the project's goals to participants from MOPE, CEB, LECO, SEA, and PUCSL. The CEB also presented on the development of the LTGEP. JCC presentation materials are shown in Appendix 5.



(Source) JICA Expert Team

Figure 3-4 2nd JCC

(Left: Opening Remarks, Right: Video Conference on the Japanese side)

3.6.3 3rd Joint Coordination Committee (July 5, 2022)

(1) Agenda

The 3rd JCC was held on July 5, 2022 as follows.

1. Date: July 5 (Tuesday), 2022 13:30 - 16:00
2. Venue: Holding as a video conference (Zoom conference)
3. Agenda:

   Opening Remarks by MOPE and JICA

   Presentation by JICA Expert Team Member and C/P

   - Progress of the Project
   - Objectives and Schedule of the Project
   - WG1, WG2, and WG3 Activities
   - Cancellation of Pilot Project (TSS & FLS)

- Training in Japan

Discussion

4. Participants

<Sri Lanka side>

- MOPE (Ministry of Power and Energy)
- CEB (Ceylon Electricity Board)
- LECO (Lanka Electricity Company)

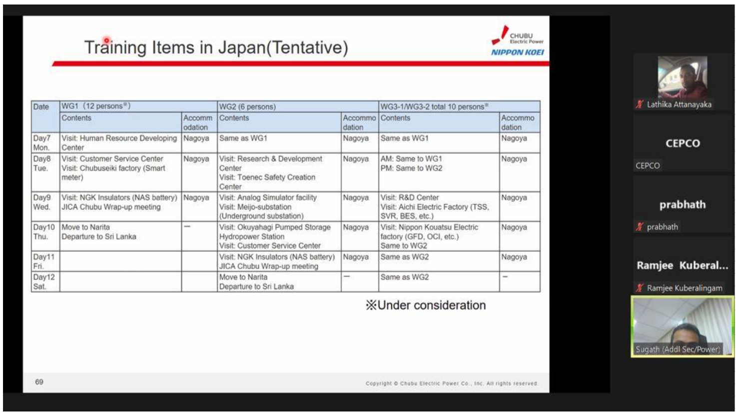
<Japan side>

- JICA Expert Team
- JICA Sri Lanka Office, - JICA Headquarters

The JCC has made efforts to increase the level of involvement of the CEB by providing a forum for the CEB and JICA experts to jointly announce project progress, technology transfer, and future plans. In organizing the JCC, we spoke to SEA, LECO, and the regulatory body PUCSL, and many people attended the meeting. Participants are referred to the third JCC List of Participants in Appendix 6.

(2) Results

The JICA Expert Team and the CEB jointly explained to the MOPE, CEB, LECO and other participants the progress of the project, the content of technology transfer, and future efforts toward achieving the project's goals. For details, please refer to the JCC presentation material in Appendix 7 and the Minutes of Meeting in Appendix 8.



(Source) JICA Expert Team

Figure 3-5 3rd JCC

(Left: Presentation, Right: Japanese Video Conference)

3.6.4 4th Joint Coordination Committee (22 November 2022)

(1) Agenda

The 4th JCC was held on 22 November 2012 as follows.

1. Date: November 22 (Tuesday), 2022 14:00 - 16:35
2. Venue: Holding as combination of Conference Room of Ministry and video conference (Zoom conference)
3. Agenda:
Opening Remarks by MOPE and JICA
Presentation by JICA Expert Team Member and C/P
• Outline of latest LTGEP
• Project result, and future efforts to achieve higher goals
• Result of Capacity Development
• Training in Japan
Discussion
4. Participants
<Sri Lanka side>
- MOPE (Ministry of Power and Energy)
- CEB (Ceylon Electricity Board)
- SEA (Sustainable Energy Authority)
- LECO (Lanka Electricity Compan)
- PUCSL (Public Utilities Commission)
<Japan side>
- JICA Expert Team
- JICA Sri Lanka Office, - JICA Headquarters

As the 4th JCC was the last JCC in this project, CEB took the lead in presenting the results of the project and efforts after this project. And it was widely convened by SEA, LECO and PUCSL, and many people participated. The 4th JCC list of participants is shown in Annex 10.

(2) Results

The CEB presented the outcomes of the project and future efforts to achieve the higher-level objectives. The JICA expert team presented the results of capacity development and recommendations on future actions of the CEB towards the achievement of the higher-level objectives. The JCC presentation materials are shown in Appendix 10 and the Minutes of Meeting is shown in Appendix 11.

3.7 Setting Project Indicators

The project indicators for confirming the outcome of the project based on the Record of Discussion (R/D), which is the result of discussions between JICA and Sri Lanka regarding this project, were determined as follows and reflected in the PDM.

Table 3-5 Project Indicators

Indicator items	Description
Overall Goal	Stability and reliability of transmission and distribution networks are maintained/improved even with increased share of VRE (Variable Renewable Energy).
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).

(Source) JICA Expert Team

Indicator items for Overall Goal and Project Purpose were drafted by JICA experts, discussed with Sri Lankan members, and set as follows based on the results of capacity assessment. Of these, the Overall Goal items indicate the indicators and targets for 2026, the third year after the completion of the project, and the Project Purpose items indicate the indicators and targets for 2023, the year of completion of the project.

Table 3-6 Indicators of Overall Goals

<table>
<tr><th>Items</th><th>Indicator</th></tr>
<tr><td>Overall Goal</td><td>
(1) Fluctuations of voltage and frequency in power system: the same level as before large amount installation of PV and wind power
(2) SAIFI in 2026.
Practical values to be set after evaluation of investment cost effectiveness based on the pilot project.
<table>
<tr><th>Organization</th><th>SAIFI [Number](reference)</th></tr>
<tr><td>DD1</td><td>15.1 (2018)</td></tr>
<tr><td>DD2</td><td>43.8 (2018)</td></tr>
<tr><td>DD3</td><td>56.8 (2018)</td></tr>
<tr><td>DD4</td><td>36.2 (2018)</td></tr>
<tr><td>LECO</td><td>108.9 (2017)</td></tr>
</table>
(3) SAIDI in 2026.
Practical values to be set after evaluation of investment cost effectiveness based on the pilot project.
<table>
<tr><th>Organization</th><th>SAIDI [Minutes] (reference)</th></tr>
<tr><td>DD1</td><td>4,532 (2018)</td></tr>
<tr><td>DD2</td><td>4,468 (2018)</td></tr>
<tr><td>DD3</td><td>4,885 (2018)</td></tr>
<tr><td>DD4</td><td>5,911 (2018)</td></tr>
<tr><td>LECO</td><td>4,196 (2017)</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Items</th><th>Indicator</th></tr>
<tr><td></td><td>
(4) LOLP: 1.5% or less at 2026
<table>
<tr><th>Organization</th><th>SAIFI [Number]</th></tr>
<tr><td>DD1</td><td>15.1 (2018)</td></tr>
<tr><td>DD2</td><td>43.8 (2018)</td></tr>
<tr><td>DD3</td><td>56.8 (2018)</td></tr>
<tr><td>DD4</td><td>36.2 (2018)</td></tr>
<tr><td>LECO</td><td>109 (2017)</td></tr>
</table>
<table>
<tr><th>Organization</th><th>SAIDI [Minutes]</th></tr>
<tr><td>DD1</td><td>4,532 (2018)</td></tr>
<tr><td>DD2</td><td>4,468 (2018)</td></tr>
<tr><td>DD3</td><td>4,885 (2018)</td></tr>
<tr><td>DD4</td><td>5,911 (2018)</td></tr>
<tr><td>LECO</td><td>4,196 (2017)</td></tr>
</table>
(5) Error of the prediction system of PV and wind turbine output in 2026:
within 20% (Average)
</td></tr>
<tr><td>Project Purpose</td><td>
(1) Corporate finance plan is updated periodically
(2) Standard procurement plan is implemented.
(3) Seven (7) Engineers of Power System Planning understand the advanced system analysis(Analysis with PSS/E under 70% energy share of RE)
(4) The improvements of Grid Codes are recommended.
(5) At least one (1) countermeasure for RE fluctuation is employed.
(6) SAIFI at the pilot sites where the facilities against power outage are installed:
[Abrasion Resistance Cover (ARC)]
<table>
<tr><th>Organization (Pilot Site)</th><th>SAIFI [Number]</th></tr>
<tr><td>DD1 (Pooja Nagaraya GSS Town Primary Feeder)</td><td>3.8 (2023)</td></tr>
<tr><td>DD2(-)</td><td>—</td></tr>
<tr><td>DD3(-)</td><td>—</td></tr>
<tr><td>DD4 (Matara GSS F1)</td><td>1.3 (2023)</td></tr>
<tr><td>LECO (Kaluwamodara PSS Moragalla Feeder)</td><td>37.5(2023)</td></tr>
</table>
(7) SAIDI at the pilot sites where the facilities against power outage are installed:
[ARC]
<table>
<tr><th>Organization (Pilot Site)</th><th>SAIDI [Minutes]</th></tr>
<tr><td>DD1 (Pooja Nagaraya GSS Town Primary Feeder)</td><td>397 (2023)</td></tr>
<tr><td>DD2(-)</td><td>—</td></tr>
<tr><td>DD3(-)</td><td>—</td></tr>
<tr><td>DD4 (Matara GSS F1)</td><td>53 (2023)</td></tr>
<tr><td>LECO (Kaluwamodara PSS Moragalla Feeder)</td><td>967 (2023)</td></tr>
</table>
[Over Current Indicator (OCI)]
<table>
<tr><th>Organization (Pilot Site)</th><th>SAIDI [Minutes]</th></tr>
<tr><td>DD1 (Habarana GSS F7)</td><td>4,126 (2023)</td></tr>
<tr><td>DD2 (KiribathkumburaGSS F9)</td><td>955 (2023)</td></tr>
<tr><td>DD3 (Ratnapura GSS F2)</td><td>356 (2023)</td></tr>
<tr><td>DD4 (Deniyaya GSS F4)</td><td>5,054 (2023)</td></tr>
<tr><td>LECO (Beligaha GSS Boosa Feeder)</td><td>3,437 (2023)</td></tr>
</table>
</td></tr>
</table>

Items	Indicator
	[Ground Fault Detector (GFD)] <table><tr><th>Organization (Pilot Site)</th><th>SAIDI [Minutes]</th></tr><tr><td>DD1 (Norochcholai F2)</td><td>277 (2023)</td></tr><tr><td>DD2 (Balachchenai F6)</td><td>387 (2023)</td></tr><tr><td>DD3 (Mahiyanganaya F3)</td><td>36 (2023)</td></tr><tr><td>DD4 (Rathmalana F2)</td><td>216 (2023)</td></tr><tr><td>LECO (Hikkaduwa PSS Wewalamlla Feeder)</td><td>3,241 (2023)</td></tr></table>(8) At least one (1) plan to promote the introduction of VRE to meet Sri Lanka's national energy policy is formulated. (9) Advanced forecasting systems for PV and wind turbine output are established, and the supply and demand operation is implemented using it.

(Source) JICA Expert Team

These PDM Project Target Indicator Items were proposed and agreed to by JCC members at the first JCC (Remote Meeting) held on July 8, 2020.

Specific target values for the PDM project indicators were set in consultation with the Sri Lankan members based on the draft values established by JICA experts based on the results of the capacity assessment. Indicator values for each PDM target are shown in the PDM in Annex 1. Meanwhile, the equipment (Time Sequential Sectionalizer (TSS) and Fault locating System (FLS)) whose specifications were scheduled to be decided after traveling in Sri Lanka due to the impact of COVID-19 were not included in the SAIFI and SAIDI indices because C/P's cost (tax and domestic transportation cost) became difficult to cover due to the impact of Sri Lanka's economic crisis, and the introduction was cancelled at the third JCC meeting in July 2022.

3.8 Each Working Group (WG) activities

3.8.1 WG1 activities

(1) Aims of Activities

In order to achieve "Outputs 1: Capacity of corporate strategy and planning for VRE is enhanced", the aim is to establish a system in Sri Lanka where promotion of renewable energy introduction can be carried out sustainably and smoothly by CEB which takes a main role in the power sector.

Therefore, it was taken a two-pronged approach, focusing on (i) system and policy and (ii) financial aspects.

(i) In terms of system and policy, it was decided to revise the FIT (hereinafter referred to as “FIT”) Price system to suit the current situation ((i)-I). In order to promote the introduction of variable renewable energy, it is necessary to establish the power market so that the grid is stable and power balancing is available. At present, there is no market and it is not yet at the stage for introduction of the market, so it is decided to improve base knowledge for future introduction ((i)-II). (ii) On the financial aspect, FIT and Electricity Tariff were evaluated, and it was decided to recommend what is necessary for the CEB to continue to implement sound management of CEB.

Renewable energy business developers must obtain development permission from SEA. However, smooth receipt of renewable energy business developers can reduce development risk and significantly lower the barriers to market entry. Therefore, (iii) improvement of the development permission procedure is decided as one of targets.

Table 3-7 Focus of activities

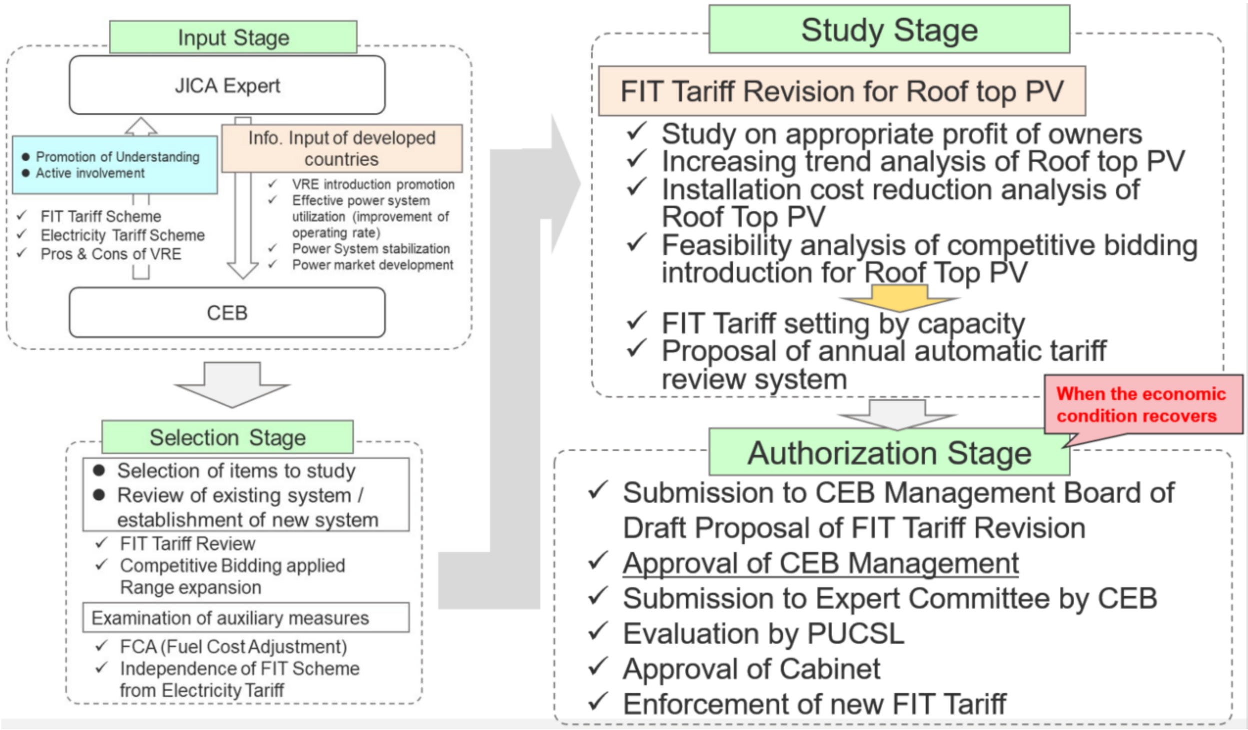
Item	Main activities
(i)-I	● Method of establishing appropriate FIT (calculation method based on appropriate calculation standards, periodic review method, etc.) for Roof Top PV, which is expected to be most promoted. ● Revision procedure and period
(i)-II	● Promotion of understanding of types of power markets and their roles ● Promotion of understanding of the existence of balancing power market and its role ● Brainstorming for the introduction of the necessary balancing power market in Sri Lanka in the future
(ii)	● CEB's financial forecast at the time of continuation of the current plan ● CEB financial forecast at FIT Revision ● Analysis of appropriate electricity tariff ● Financial advice to the CEB through preparation of the Recommendation Report
(iii)	● Understanding of problems with the current development permission procedures ● Proposals for streamlining the development permit procedures

(Source) JICA Expert Team

(2) How to proceed

Activities were basically divided into the Input Stage, Selection Stage, Study Stage, and Authorization Stage in order to achieve the high-level objectives, project objectives and expected outputs. At the Input Stage, JICA Expert Team explained systems and technologies of Japan and of the countries where the introduction of renewable energy is advanced, and shared information with CEB on the status, systems and challenges of the power sector in Sri Lanka. In the Selection Stage, the content to be approached was selected based on the information shared by JICA Expert Team and CEB in Input Stage. In order to realize the content selected in the Selection Stage, the Study Stage conducted further surveys and studies, and disseminated the content of the examination in the Authorization Stage to the relevant sections and started operation of the established systems and technologies.

Work flow chart is shown in. Figure 3-6.



(Source) JICA Expert Team

Figure 3-6 Work Flow Chart (WG1 System & Policy)

a. System & Policy

(Input Stage)

Promoting the introduction of renewable energy requires a multifaceted approach. Some items were introduced or studied in the past in Sri Lanka, but basically they were not organized. Therefore, in order for the C/P to gain sufficient knowledge and use it as a basis for discussions, we input some case studies of efforts of Japan and other developed countries.

Specifically, the following items were explained and opinions were exchanged.

Table 3-8 Input Items

	Main Items	Explained Items
(i)	Support for Power Producers	● In addition to the FIT that has been introduced in Sri Lanka, other measures (subsidy, RPS[1], FIP[2], etc.) to subsidize renewable energy power sources with low price-competitiveness. ● Efforts in Developed Countries and Similar Developing Countries
(ii)	Effective use of existing systems	● It is necessary for existing grids to have sufficient free capacity to transmit power for renewable energy generation. However, there are many cases in which existing grids do not have sufficient available capacity, and it takes

[1] An abbreviation for Renewables Portfolio Standard, it is also called a renewable energy usage rate standard system. A system that promotes the spread of new energy by obliging electric power companies to use electricity generated from renewable energy at a certain ratio or more.

[2] An abbreviation for Feed-in Premium, a system in which a certain premium (subsidy amount) is added to the price when a renewable energy power generation company sells electricity in the wholesale market or bilateral transactions.

		time and money to reinforce and expand them. Therefore, as an effective measure in the short term, it is necessary to establish new power system interconnection requirements for power generators, thereby increasing the capacity utilization rate of existing grids. ● Measures to alleviate congestion by setting wheeling charges that differ from area to area (UK case) ● Measures to induce interconnection to locations with low transmission losses (Australia case)
(iii)	CEB financial soundness	● CEB collects FIT as part of its electricity bill (eg. Net Metering, Net accounting and Net accounting systems[3] introduced for rooftop solar projects). However, the electricity charge collected is lower than the FIT, which has resulted in constant operating income. One way to solve this problem is to collect FIT separately from electricity charges and return it to the power producer, which is then managed by a third party. ● The significance and role of the fuel cost adjustment system (CEB has introduced once in the past. This system was suspended after about one year of implementation)
(iv)	Maintenance of conventional output controllable power supply	● Renewable energy power sources are based on renewable energy, so the marginal cost is zero and the power dispatch is ordered with priority. On the other hand, conventional power sources capable of controlling output, such as thermal power generation, have high marginal costs and are inferior to others due to the problem of fuel, and therefore cannot generate profits due to the lack of instructions for power supply. However, the VRE power supply is variable, and a certain amount of controllable power is required to maintain the supply-demand balance. Therefore, there is a need for a new power market that enables the continued existence of controllable power supply.
(v)	To stabilize the system	● As it becomes difficult to maintain the supply-demand balance when the ratio of renewable energy sources to the total amount of power generation is increased, it is necessary to impose restrictions on output fluctuations and restrict power generation as a requirement of grid interconnection.
(vi)	Other	Explanation of various other policies related to system and policies ● Burden allocation of grid connection costs ● Priority power supply system

[3] 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.

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.

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.

		● Policy to abolish inefficient thermal power plants in Japan with the aim of introducing renewable energy, etc.

(Source) JICA Expert Team

(Selection Stage)

Because it is impossible to do everything, we prioritized what is most necessary for Sri Lanka. The revision of the Roof Top PV FIT was the most interesting item to achieve at least 70% (energy base)(37% as of 2020) of renewable energy sources by 2030 (LTGEP2023-2042 is also in compliance with this government policy (the latest LTGEP is shown in Appendix 12)). It is expected that the Roof Top PV will be introduced explosively in the future and become the main power source for renewable energy, and the revision will also contribute to the improvement of the financial statement of CEB. Since it was established in 2016, it has not been revised, and there is a strong need for it. Therefore, we decided to deepen our study on it. (Note: By the 4th Quarter of 2022 published the new FIT for roof top solar)

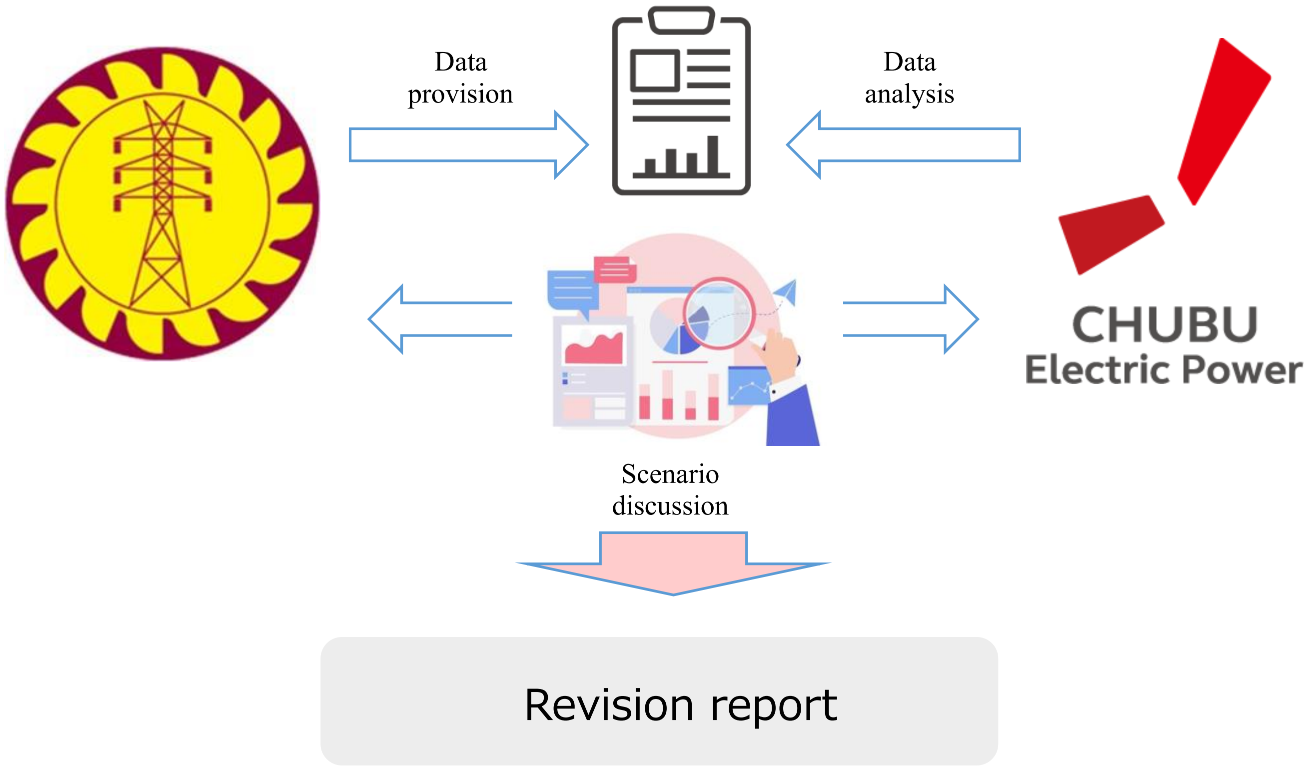
From the viewpoint of the supply-demand balance, C/P showed strong interest in the importance of securing a certain quantity of conventional controllable power supply due to the increased fluctuation of VRE power supply. Therefore, although there is no wholesale market for electricity and the timing of the introduction is still ahead, we decided to study the Balancing market further.

The specific ratio of conventional balancing power sources cannot be determined indiscriminately, and the phase of the balancing power required for the entire power system changes depending on the amount of VRE introduced. According to the International Energy Agency, there are six phases that correlate with the VRE share and the state of the power system. As the phase progresses, it will be necessary to secure flexibility not only on the power generation side but also on the demand side. According to LTGEP, with RE70%, VRE (solar, wind) accounts for 48%, corresponding to phase 5. In this situation, VRE supply frequently exceeds demand, requiring flexibility that leverages not only conventional balancing power but also the demand created by the electrification of energies such as transport and heat.

(Study Stage)

i) PV FIT revised

In the FIT revision, the CEB actively investigated and provided materials necessary for consideration, such as capacity factor (CF), market interest rate, preferential interest rate from ADB, funding costs, and O&M costs. In particular, since CF, expected return, and funding costs have a significant impact on the results, careful discussions were held between the Sri Lankan members and JICA Experts. The appropriate FIT was calculated by JICA Expert Team after discussions on the scenario based on this information. Large-scale power producers in particular have high procurement capabilities, so measures were taken to categorize them according to the scale of their introduction. In addition, since procurement costs continue to decline, JICA experts proposed a mechanism that would automatically correct procurement costs every year. The results of these studies were prepared as revision proposal that included necessary items such as background, introduction to studies, scenarios, results and considerations, based on "The report of committee on upgrading the Net-measuring Scheme to Net-accounting Scheme" and "Decision on Non-Conventional Renewable Energy Purchase Tariffs 2012-2013.", which are past FIT review reports.



(Source) JICA Expert Team

Figure 3-7 Roof Top PV FIT revision

ii) Examination of the Balancing market

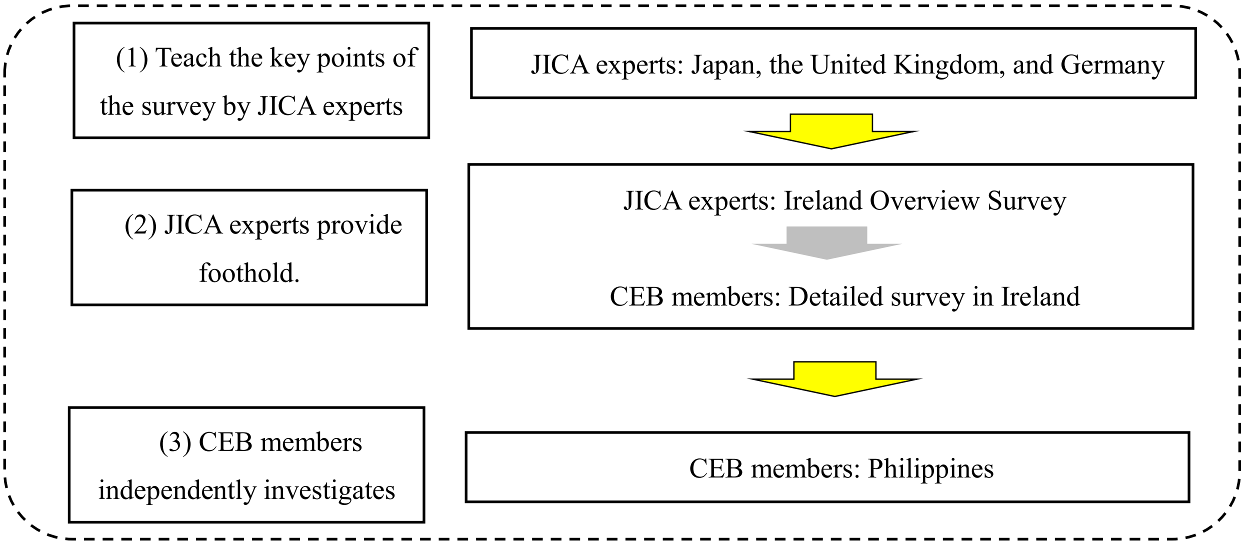
WG1 selected and surveyed countries from the viewpoint of developed countries, similar developing countries, and island countries with geographical similarities, in which Balancing markets have already been introduced.

Table 3-9 Countries surveyed

Classification	Selected Countries
Developed countries	Japan, Germany and the United Kingdom
Similar developing countries	Philippines
Island nations of the same size	Ireland

(Source) JICA Expert Team

JICA Expert Team has helped C/P to develop the basic knowledge through the past inputting activities. Based on this condition, JICA Expert Team decided to have C/P actively investigate this time.



Specifically, the following measures were taken.

(Authorization Stage)

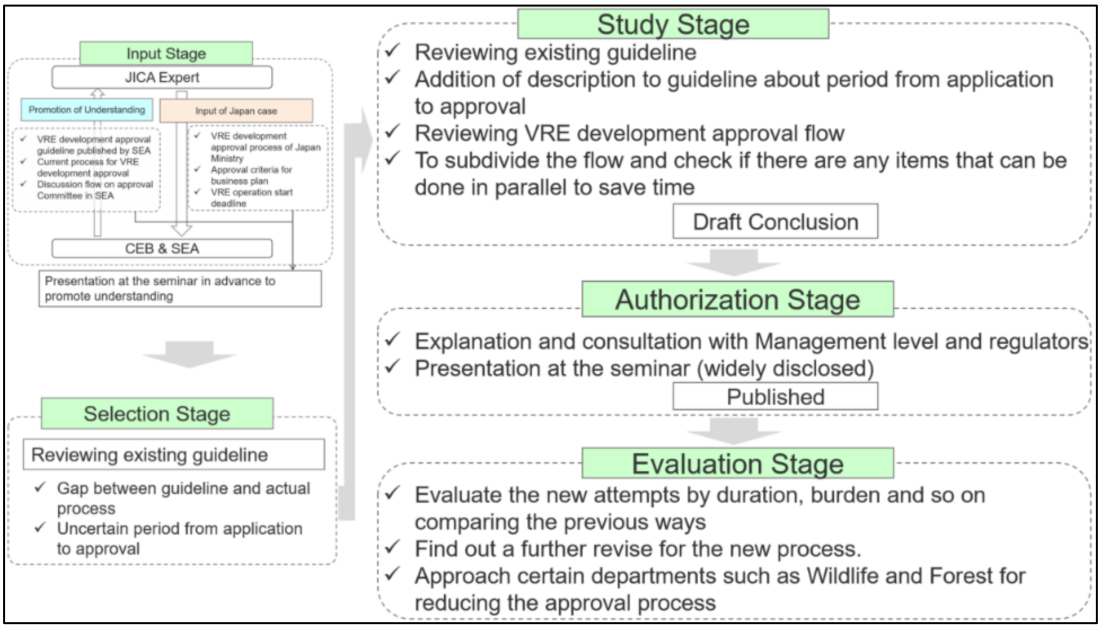
The results of these deliberations were disclosed using two system and policy seminars and JCCs. Especially at the seminar, not only project members but also a wide range of donors, relevant ministries and agencies, and academic institutions were invited to participate, and the information was disclosed as widely as possible.

At each meeting, presentations were made by both JICA experts and Sri Lankan members in order to enhance the independence of Sri Lankan members.

The revision of the rooftop PV FIT was assisted by JICA experts so that the revision could be completed within the project by CEB members.

b. VRE Approval Process

The outline from the input stage to the evaluation stage is shown below.



(Source) JICA Expert Team

Figure 3-8 Flow Chart (WG1 VRE Approval Process)

The detailed contents at each stage are described below.

(Input Stage)

As an introduction, we outlined the types and features of VRE. In response to the issues that it takes much time to obtain approval for VRE, we examined potential improvement factors by inputting and comparing cases in Japan.

Table 3-10 Inputs

Main Items	Explained Items
Operation and Maintenance of PV Power Generation	● Characteristics, operation method, and maintenance and management method of PV power generation
Operation and Maintenance of Offshore Wind Power Generation	● Characteristics, operation method, and maintenance and management method of offshore wind power generation
VRE Approval Process by the Ministry of Economy, Trade and Industry (Japan)	● Flow from application to installation of PV ● Segregation of Bids from FIT Application ● Approximate time required for each process
Relevant Laws and Regulations in Japan	● Legal requirements to be considered to applicants ➢ Outline of the Forest Law, related procedures and its points when installing VRE

(Source) JICA Expert Team

(Selection Stage)

The current status was grasped based on the guideline (A Guide to the Project Approval Process for On-Grid Renewable Energy Project Development) provided by C/P and the progress management table of the application. From the viewpoint of time-consuming approval process, it was pointed out that it would take a long time to obtain approval (EP: Energy Permit) for the VRE development, and JICA experts have recognized the necessity of reviewing inefficient operation of the VRE approval process. In fact, the guideline has not been revised since 2011, and since when there have been some instances where the guidelines has not been implemented in accordance with actual conditions. In order to improve the process, the current process was to be visualized and problems were identified between the conditions from the registration to EP.

(Study Stage)

The visualized process was further divided into three categories. In each category, the factors causing process longer were identified as problems and countermeasures were considered. JICA Experts sorted out improvement items by reviewing processes, constructing systems, and clarifying the guideline.

Table 3-11 Raised issues and considered countermeasures

Raised issues	Proposed countermeasures	Items for improvement
Applicant's burden on requesting approval	Timely involvement of SEA	Review of processes
Coming and going process, and returning back of application	Elimination of unnecessary processes, and saving the time	
Land ownership problems occur in the late process	Putting an emphasis on the issues and making solutions early in the process	
Land acquisition issues caused by the change of protected environmental area	Sharing the information of VRE facility installation area and environmental protection	System building
Lack of manual progress management of paper materials	Managing the progress of the entire process	
Delays in approvals by relevant ministries and agencies	Setting the standard processing period	Clarification of guidelines

(Source) JICA Expert Team

(Authorization Stage)

The new guideline was released and introduced in January 2022 with the agreement of the relevant organizations. The basic tone and specific content of the new guidelines are as follows.

Table 3-12 New Guidelines

<table>
<tr><th>Tone</th><th>Content</th></tr>
<tr><td>Involvement of SEA</td><td rowspan="3">Reduce of the burden on applicants
Reduction of the going and coming process
Setting deadline to each process
Reduction of time-consuming processes
Labor saving for items that require time
Initial Clarification of Land Ownership
Establishment of Steering Committee</td></tr>
<tr><td>Ministry-level support</td></tr>
<tr><td>Support for low-progress projects</td></tr>
</table>

(Source) JICA Expert Team

The online system is in the construction stage and is scheduled to be released later this year. The design concept of the system is as follows.

Table 3-13 Contents of Online System

<table>
<tr><th>Process</th><th>System design</th></tr>
<tr><td>1. Initial screening</td><td rowspan="7">・ Progress management from beginning to end
・ Simultaneous access to the same documents by related parties
・ Updating application documents and processing parallel
・ Only authorized persons will access specific applications and approval
・ Accurate reflection of map information
・ Automatic reflection of process management
・ Introduction of electronic signatures</td></tr>
<tr><td>2. Initial payment</td></tr>
<tr><td>3. CEB approval</td></tr>
<tr><td>4. PA (Provisional Approval)</td></tr>
<tr><td>5. External approvals</td></tr>
<tr><td>6. EP (Energy Permit)</td></tr>
<tr><td>7. Under EP</td></tr>
</table>

(Source) JICA Expert Team

(Evaluation Stage)

The effects of the introduction of the new guidelines were evaluated based on how VRE approval process has been influenced between 2017 and June 2022. On the other hand, the online system is under construction and needs to be evaluated after implementation. The C/P recognized that continuous evaluation would lead to further improvement.

(Source) JICA Expert Team

Figure 3-9 A discussion on VRE approval process

c. Financial analysis of CEB

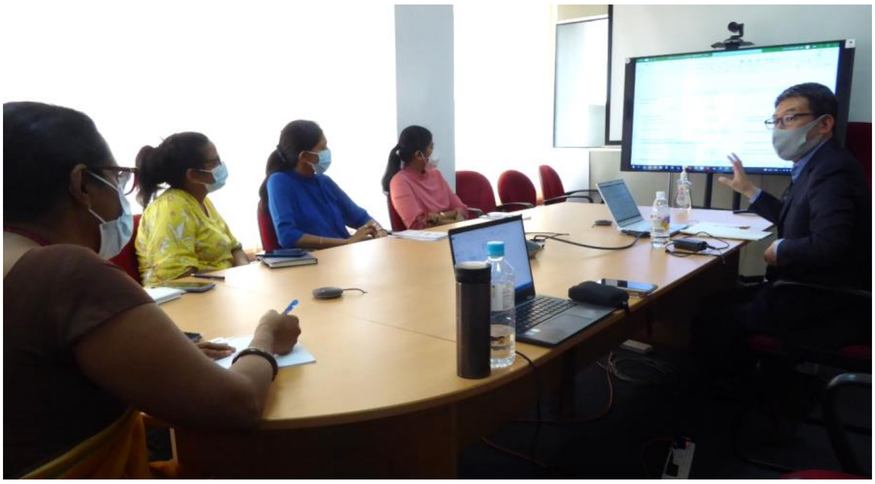
With regard to CEB finances, the initial discussions at the start of WG1 activities confirmed the major flow of activities: (a) analyze the current status of CEB finances and identifying key issues and causes; (b) prepare financial projection based on the current tariff system and regulatory setup; and (c) prepare financial projection based on scenarios such as institutional improvements and tariff revisions.

In the first half of the activities, the current financial status of CEB, the electricity tariff revision system, and the response of the government were grasped and analyzed. A question-and-answer session was held between WG1 members and JICA Expert Team to collect information about CEB finances and to analyze the current situation. Explanatory presentations were also made by WG1 members to deepen the understanding on the issues among the members.

As the next step after assessing the current state of CEB finances, the future financial projection of CEB and analyses were conducted from fiscal 2021 to fiscal 2022. Through its 2021 activities, JICA Expert Team consulted with WG1 members and presented the CEB Financial Projections in different case scenarios, such as the current electricity tariff and FIT case, the FIT revisions, and the electricity tariff increases and government support cases in the Second System and Policy Seminar in January 2022. In June 2022, WG1 members, including officials from the CEB Finance Division, were given a lecture on the financial models so that CEB staff could use them while updating them in the future.

Finally, in the second half of 2022, the Recommendation Report was prepared on CEB financial analysis. It summarizes the CEB's current situation, CEB's future financial projection, financial improvement options, and the results of these projections. This reflects the latest financial conditions of

CEB, including a sharp increase in fuel costs due to the severe economic environment since March 2022, the electricity tariff level revised for the first time in approximately eight years by the government in August 2022, and the latest draft LTGEP 2023-2042. The report is expected to be used by CEB staff for discussions with CEB's executive management, the government authority, and PUCSL after the JICA project.



(Source) JICA Expert Team

Figure 3-10 Discussion on Financial Projection Model

(3) Outcome of activities

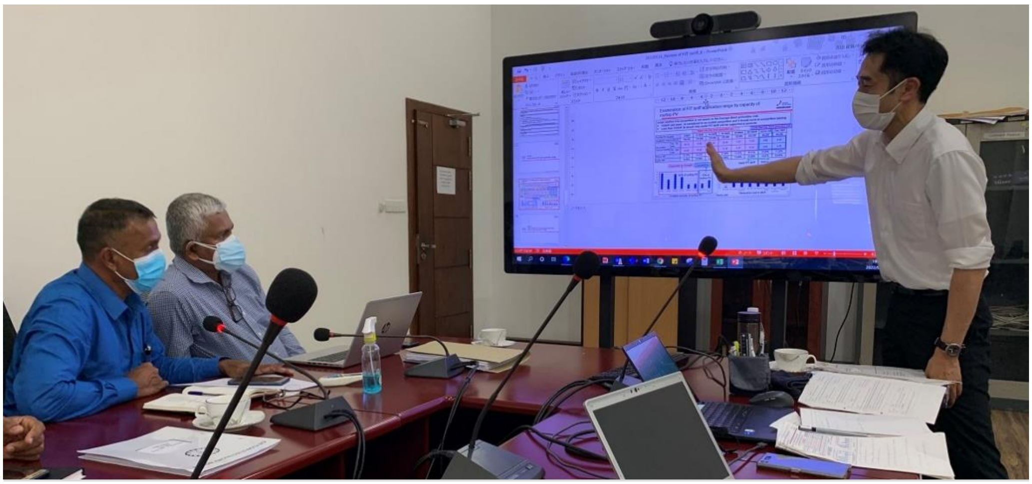
Outcome 1 (WG1): Capacity for corporate strategy and planning for VRE is enhanced

In Outcome 1, the proposition is to maintain the environment for the large-scale introduction of renewable energy while creating a foundation for the CEB to manage its business in a sound and sustainable manner as an electric utility. In order to achieve this, the following four points were considered and the following outcomes were achieved: studying of a sustainable renewable energy introduction system, deepening of the understanding of the electricity market (supply and demand balancing market, etc.) that is necessary in parallel with promotion of the introduction of renewable energy, CEB's financial analysis based on the newly thought-up renewable energy introduction system (FIT review of Rooftop PV), and improvement of VRE approval process to facilitate the smooth entry of renewable energy businesses.

a. Study of renewable energy introduction system

As a result of reviewing the operational status and issues related to the system, such as the introduction of renewable energy and tariffs, the FIT has not been reviewed in Sri Lanka since the introduction of the FIT system in 2016 despite the global downward trend in PV introduction costs, and the uniform FIT has been set for small capacity (several kW class) to large capacity (MW class) despite the difference in unit cost (LKR/kW) depending on the size of the equipment. Therefore, it was decided to review the rooftop PV FIT in WG1. When discussing the revision of the FIT for rooftop PV with PUCSL, they also commented that they were aware of the situation where the reduction in the prices of PV panels was not reflected in the FIT and that the revision was appropriate. In examining the FIT, the generation cost at which the developer can secure a given profit was calculated using the unit installed cost for each installed capacity, and the FIT was divided into three categories with 10kW and 100kW as the thresholds at which generation cost differ greatly. If the calculated FIT is lower than the Direct Generation Cost (the average of all the generation costs including thermal and hydro power generation), tariffs to secure the Direct Generation Cost in order to secure incentives for development were proposed, and compiled it as a proposal for revision of the FIT and submitted it to the CEB. The revised rooftop PV FIT methodology was explained at the 2nd System and Policy seminar and disseminated not only to the CEB but also to relevant ministries and agencies.

Initially, the rooftop PV FIT proposal was to be submitted to the Expert Committee composed of representatives from the relevant ministries and agencies during the project period, and following the Cabinet decision, a revised rooftop PV FIT was to be in operation. However, the sudden economic downturn that began in March 2022 prevented the review from being carried out, and the CEB also strongly requested that the proposal be postponed. As a result of discussions with the CEB, WG1 member explained the results of the FIT revision study to AGM (Additional General Manager) in charge of this matter, although the procedure for approval of the rooftop PV revision to the CEB upper management would be postponed, and in June 2022, WG1 member explained the background of the review of rooftop PV FIT and the concept of FIT calculation, and obtained the understanding of AGM. As a result, the CEB's top management understood the need to review FIT, and it is hoped that the CEB members will be able to promptly proceed with procedures when economic conditions recover and contribute to the sound operation of the electric utilities business. In addition, in order to enable CEB members to undertake FIT revisions on their own when economic conditions recover, the procedures for FIT revisions and the required period of procedures were compiled as a milestone, and the flow of FIT revisions was clarified. Subsequently, the Cabinet urgently approved a review of the Roof Top PV FIT on October 25, 2025, against the increasing development cost and borrowing interest burden of Roof Top PV due to the economic crisis. The new Roof Top PV FIT is LKR 37.0/kWh up to 500kW and LKR 34.5/kWh (fixed for 20 years) for the excess of 500kW. Although detailed evaluation is difficult due to the lack of disclosure of calculation parameters, the fact that the purchase price is set separately for the 500kW category is evaluated as it reflects the difference in installation costs by PV capacity. Periodic revision of the FIT in response to changes in development costs is desirable in the future.

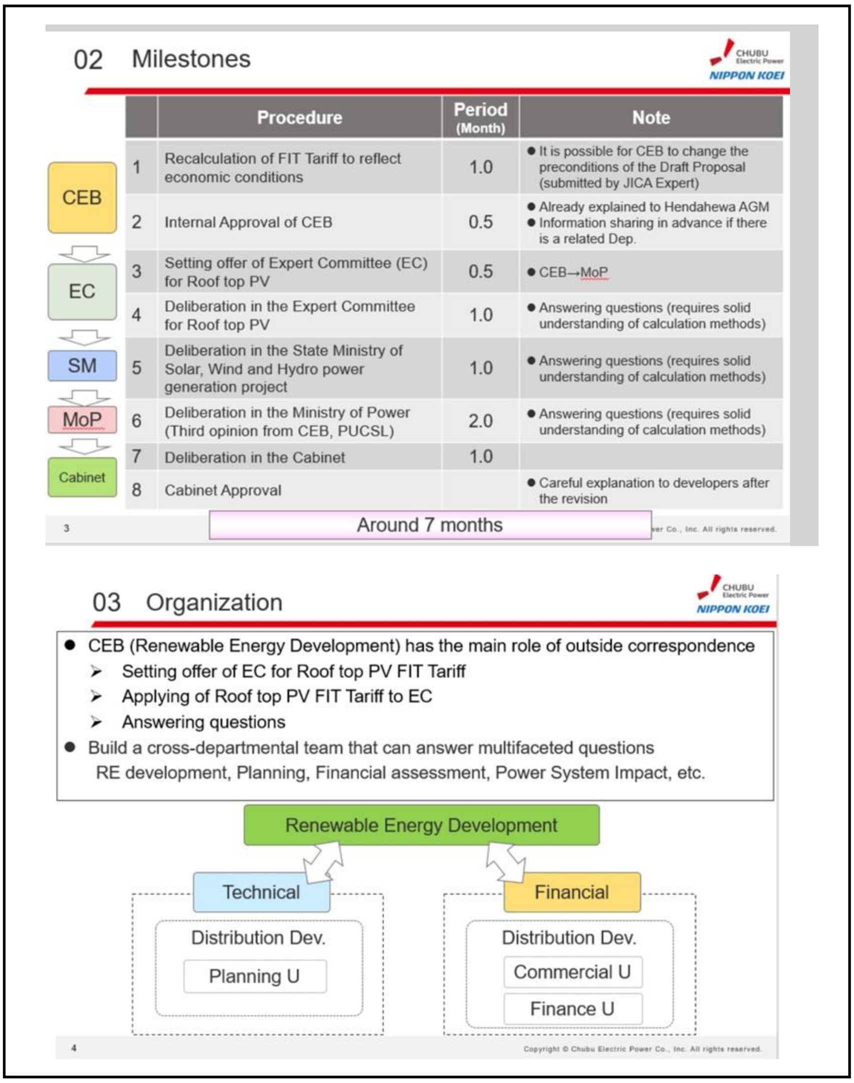


(Source) JICA Expert Team

Figure 3-11 Discussion on FIT

(Source) JICA Expert Team

Figure 3-12　Explanation of FIT revisions to the CEB's top management (Hendahewa AGM)



	Procedure	Period (Month)	Note
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.
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)
5	Deliberation in the State Ministry of Solar, Wind and Hydro power generation project	1.0	● Answering questions (requires solid understanding of calculation methods)
6	Deliberation in the Ministry of Power (Third opinion from CEB, PUCSL)	2.0	● Answering questions (requires solid understanding of calculation methods)
7	Deliberation in the Cabinet	1.0	
8	Cabinet Approval		● Careful explanation to developers after the revision

(Source) JICA Expert Team

Figure 3-13　Milestones up to the expected revision and the system for implementing the measures

b. Deepening the understanding of the electric power market

In the future, VRE such as PV and Wind Turbine Generator will play a major role in promoting the introduction of renewable energy. Just supporting only the VRE power generators will not be enough. As the penetration level of VRE power generation to total power generation becomes higher, more balancing power will be necessary. For this reason, conventional power sources such as thermal power generation with inertia are necessary, but the general market is merit-order, and thermal power generation suffers from high marginal costs due to fuel costs and is inferior to others regarding dispatch order. Therefore, it is impossible to raise profits and is forced to leave the market. Therefore, a new power market (Balancing market) is needed to secure this controllable conventional power supply. Past series of inputs allowed C/Ps to better understand the needs of this market.

Furthermore, with an awareness of the introduction of a Balancing market in the not-too-distant future, JICA experts and C/Ps cooperated to select and investigate the target countries from the viewpoint of developed countries, similar developing countries, and island countries with geographical similarities.

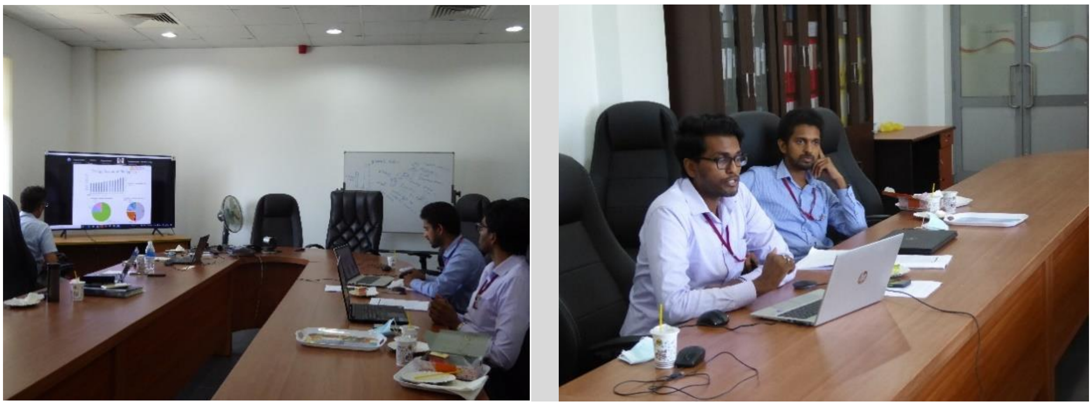
C/P was in charge of a survey of countries similar to Sri Lanka. The similarity made them image easier in addition examining by themselves enabled to deepen understanding. C/P showed a high degree of satisfaction because they learned a lot from the meaningful activities.

(Source) JICA Expert Team

Figure 3-14 Expectations for technology transfer from DGM

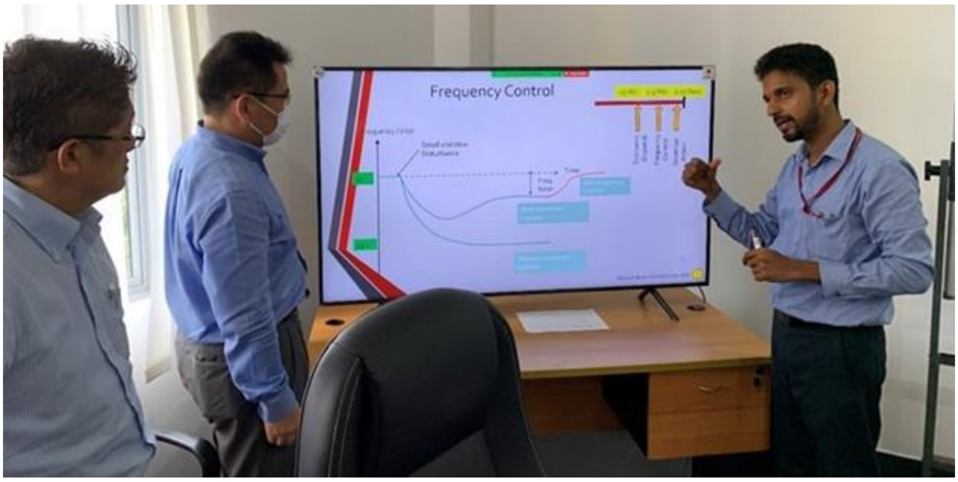
(Source) JICA Expert Team

Figure 3-15 Explanation of the Developed Country's Balancing Market from JICA Expert Team



(Source) JICA Expert Team

Figure 3-16 A presentation on the Balancing market in the Philippines from CEB



(Source) JICA Expert Team

Figure 3-17 Discussions on the Ideal Future Balancing Market

Finally, the C/P could sort out the problems to be solved for the introduction of the Balancing market. This has laid the groundwork for effective discussions on developing a future electricity market in Sri Lanka.

(a) Accurate demand forecasts
(b) Real-time monitoring (Supervisory Control Data Acquisition (SCADA) system development)
(c) Accurate power generation forecast for VRE (variable renewable energy)
(d) Declaration of plant availability for dispatch plan preparation for all power plants
(e) Realizing a 500 kV HVDC interconnection with India
(f) Setting a power generation share limit (avoiding price manipulation) to ensure healthy market competition
(g) Setting the upper limit of the Balancing market price cap (curbing price spikes)
(h) Introduction of large-scale grid batteries
(i) Establishment of requirements to be met by generators participating to Balancing market

These are discussed in the section on Recommendations.

c. Financial analysis of CEB

A financial projection model was developed for CEB corporate financial planning and explained at the Second System and Policy Seminar. Also, a lecturing session on the model was held during Phase II to explain and discuss the financial projection methodology and underlying financial data and assumptions. In addition, as advice on corporate financial planning, JICA Expert Team assisted in the preparation of the "Recommendation Report" and discussed the draft. Through these activities, it is expected that WG1 members will deepen their understanding of the financial situation of the CEB and its future outlook, and that CEB staff will utilize the financial projection model developed by the CEB staff while updating it for discussions within the organization and with CEB senior management, as well as explanations and discussions with the Ministry of Power, PUCSL, and other governmental authorities.

In 2022, the government's debt problems and the sudden deterioration of the economic environment caused fuel costs to triple or quadruple. This greatly affected the business conditions of CEB, forcing CEB to implement rolling blackouts and other measures to continue its electric power services. For this reason, the government decided to revise electricity tariff in August 2022, which had not been implemented for a long time. While this increase averages more than 70 percent, it still does not reach a cost-recovery level, and will require further price increases and cost reductions by CEB.

CEB's financial conditions are undergoing major changes, triggered by external shocks. First of all, CEB made the first electricity tariff revision in eight years. This was a major achievement for the CEB staff who wanted to implement regular tariff revisions. Going forward, if the government is to launch an International Monetary Fund (IMF) program and reform state-owned enterprises, it may be required to make further tariff revisions to a level that allows cost recovery and to make efforts to reduce CEB costs. In this drastically changing environment, the Chief Engineer (Tariff) and Finance Division staff, who are also key members of WG1, were busy working with the government and the Parliament on electricity tariffs, as well as formulating and modifying the CEB budget. It can be said that those WG1 activities about CEB finances have contributed to their going through these crucial events in a sense that they actively utilized the understanding of CEB finances deepened through this project.

There was also a need for the financial projection model and the Recommendation Report reflecting higher fuel and other prices, the revision of electricity tariff in August 2022, and the latest LTGEP 2023-2042, for which the draft was completed. Accordingly, updated information was provided by CEB members, including the 2021 financial statements and the 2022 revised budget. The revision of the financial model and report draft was made, and discussions were held with the CEB in the second phase of the WG1 activities. In particular, the Chief Engineer (Tariff) refers to her intention to use this Recommendation Report and the financial projection in explaining it to CEB executives and in discussing it with the government, and is expected to be used by CEB staff, mainly WG1 members.

The revised Roof Top PV FIT, urgently approved by the Cabinet on October 25, 2022 to absorb the cost increase caused by the economic crisis, is LKR 37.0/kWh up to 500 kW and LKR 34.5/kWh in excess of 500 kW (fixed for 20 years). Although this is higher than the current average electricity tariff of LKR 29.14 /kWh and is a revision that will cause losses to the CEB, it is significantly lower in comparison to CEB thermal power (LKR 83.57/kWh) and IPP thermal power (LKR 95.11/kWh), and in view of the amount of electricity generated, the cost impact of the economic crisis is much greater for thermal power generation due to the skyrocketing fuel prices[4].

Thus, PV, including Roof Top PV, is a power source that should be utilized more effectively under the situation of rising fuel costs. On the other hand, Roof Top PV is not implemented by IPPs but is a side business by residential consumers and business entities in other industries, and there is little motivation to continue power generation and supply with a significant adverse cost impact. From the standpoint of the principle of cost reflection, it is unavoidable to revise the FIT level in accordance with the actual situation in order to reduce the burden of financial costs and price increases, etc., from the standpoint of fairness with IPPs that can pass on all fuel costs to the Energy Charge. Compared to the existing FIT level (LKR 19.84/kWh), the impact of the current FIT revision on the CEB's finances will be a loss of around LKR 1 billion/month based on the estimation of average generation of 60 GWh by this category. The impact is relatively small compared to the total monthly generation costs (approximately LKR 31 billion) that the CEB will have to bear. If the same amount of electricity is generated by thermal power, it is estimated that the CEB would lose approximately LKR 5 billion/month, much larger than the expenses anticipated for the increased FIT.

It is observed by JICA Expert Team that the authorities apparently might consider that those residential consumers and business entities that supply electricity through the Rooftop PV FIT are also the electricity consumers and customers of the CEB, and that if only their own electricity prices increase sharply by the electricity tariff revision like that of August 2022 while the FIT remains the same as before the economic crisis, those consumers will not understand the further electricity tariff revisions in the future, It is understandable that the authorities may believe that they will not be able to gain the consumers' understanding for further tariff revisions in the future, which will be unavoidable in the current situation.

There is a common consensus among authorities and CEB that ideally the electricity tariff should reflect all justifiable costs and the government itself is strongly committed to the second revision of the CEB electricity tariff in order to obtain fiscal support from IMF. The fact that CEB has prepared and proposed the new cost-reflective tariff to the authorities shows that the knowledge and experience required for the financial evaluation of CEB and the estimation of appropriate electricity tariff are firmly in place among CEB staff members as one of the positive outcome of the present technical cooperation project. The second tariff revision is expected to be raised to the cost-recovery level, and CEB finances are expected to further improve.

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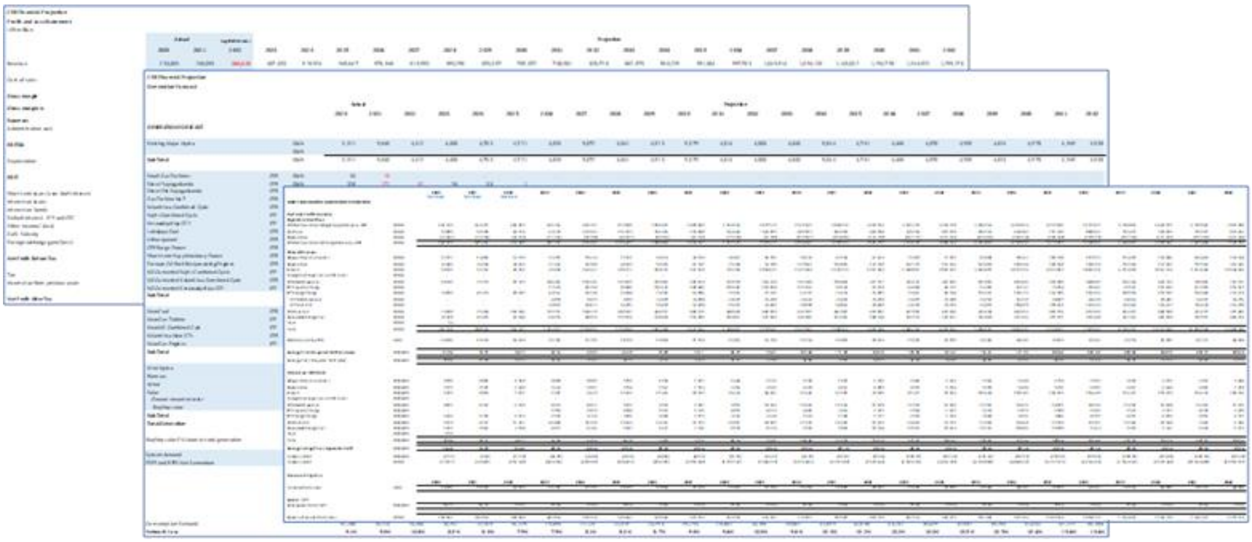
[4] The average electricity tariff revenue and cost data are the average of September – December 2022 estimates based on the revised budget prepared by CEB.

Table 3-14　CEB Financial Plan after Electricity Tariff Revision in August 2022

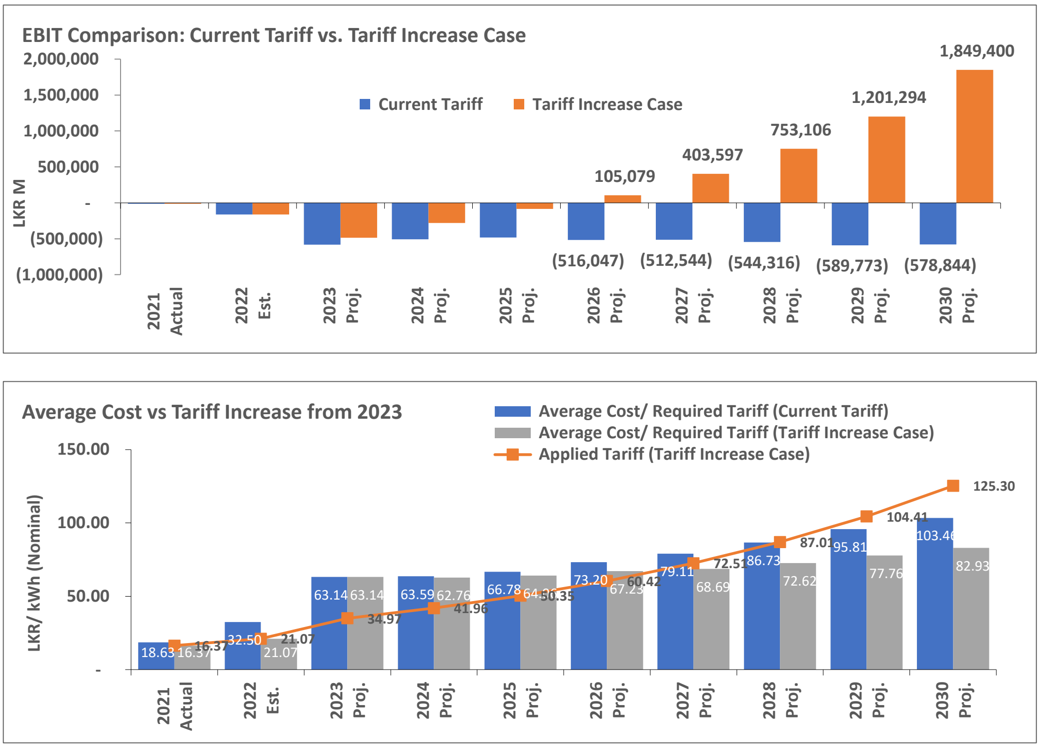
Summary Income Statement		**August 2022 Estimates (LKR mn)**	
Income		311,458	
Sale of Electricity			300,420
Other Income			11,037
OPEX		463,394	
Direct Generation Cost			384,182
Indirect OPEX without Depreciation			77,907
Net Profit/ (Loss) before Depreciation		(151,937)	
Operational Summary		**August 2022 Estimates**	**% change from 2021**
Sale of Electricity	GWh	14,260	-6.3%
Net Generation	GWh	16,370	-2.1%
Annual Average Tariff (Jan-Dec)	LKR/kWh	21.07	28.7%
Annual Average Cost (Jan-Dec)	LKR/kWh	32.50	74.4%
Average Tariff (Sep-Dec)	LKR/kWh	29.14	78.0%
Annual Average Cost (Sep-Dec)	LKR/kWh	39.94	114.4%

(Source) JICA Expert Team



(Source) JICA Expert Team

Figure 3-18　Excel worksheets of "Financial Projection Model" (Image)



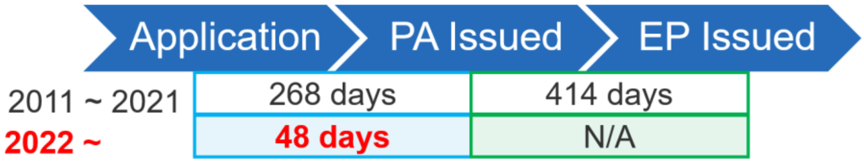
(Source) JICA Expert Team

Figure 3-19　Financial Projection Results of "Tariff Increase Case"

d.　VRE Approval Process

JICA Experts provided C/P with an explanation of the Act on special measures concerning VRE procurement and approval process, which contribute C/P to fostering the knowledge of the basic system and the introduction measures concerning VRE introduction. Based on this knowledge, discussions were held with the aim of accelerating VRE approval process in Sri Lanka.

JICA Experts visualized VRE approval process in Sri Lanka using a flowchart, identified the processes that could make the process more efficient with C/P, and examined the rational way of the process based on the knowledge of the procedures implemented in Japan. In the process, through discussion with SEA and CEB, we have focused on the procedures which are repeated and returned to the developers, and we have found the measures to rationalize the procedures and put them into practice. In the improvement report process of SEA, with the support of JICA Experts, SEA finally submitted the new guideline document for VRE approval process, and the process was revised in 2022. The new guideline was published on 4 January 2022. In evaluation process, we have evaluated the progress data of the application for VRE approvals between January 2011 and June 2022. The average time required for PA approval from 2011, when the guideline was established, to 2021 was 268 days, while that from 2022 onwards was 49 days on average (Figure 3-20). After the guideline revision in January 2022, PA approval, which had been stagnant until now, was shortened, resulting in a significant improvement. Since the evaluation period for EP is insufficient, it is necessary to continuously monitor and evaluate the evaluation. Online systems should also be evaluated after implementation.



(Source) JICA Expert Team

Figure 3-20 Average required period for each process

e. Beneficial supports for activities in CEB

CEB required information and know-how of system and policy, since CEB felt that some kind of measures were necessary. Accordingly, JICA Expert Team sought questions through daily communication with CEB members. In response, JICA Expert Team prepared materials for an explanation, and exchanged opinions with CEB members. CEB members mentioned that the challenges will be cleared issues that are currently being faced and the vague questions of the future and will useful as a guideline for the future.

Table 3-15 Example of explained contents

Contents	Interested matters of CEB
Rapid increase in the introduction of renewable energy in Vietnam	Factors behind Vietnam's strategies for accelerating promotion of the introduction of renewable energy
Cost sharing for expansion of existing power systems through renewable energy interconnection	It will be necessary to improve and expand power system due to reverse current flow, if many VREs are introduced in the future.. Who should bear the cost and how much cost would be necessary?
Aggregator business	Roof rental business for PV will increased in Sri Lanka. There is a possibility that some models will be engaged in aggregator business by bundling small-scale Roof Top PV in the future..

(Source) JICA Expert Team

(Source) JICA Expert Team

Figure 3-21 Explanation and opinion exchange with CEB members

3.8.2 WG2 Activities

(1) Aims of Activity

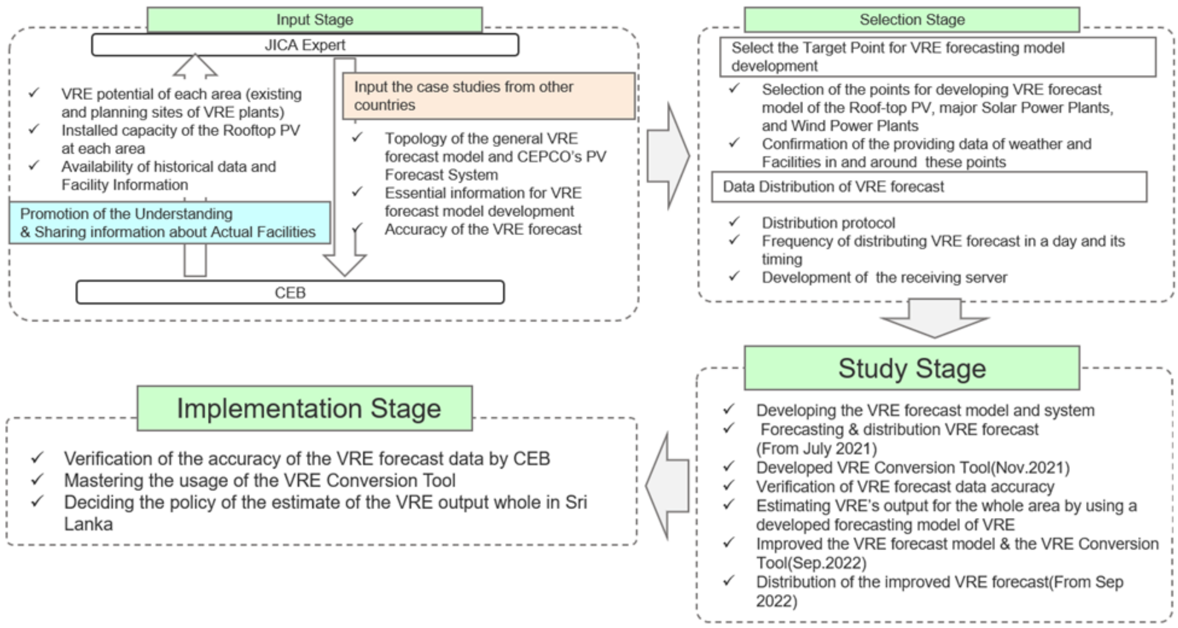
In order to achieve the goal of "Results 2: Enhancement of transmission system operation and development capacity due to increase in RE introduction", the stabilization measures of the electric power system according to the amount of RE introduction were studied, and the system and capacity of the CEB were established and strengthened in order to utilize the results for actual supply and demand operation and system operation.

Therefore, WG2 examined the following four aspects: (a) VRE output forecast, (b) supply and demand operation, (c) Measures for the mass introduction of VRE, and (d) Geological survey on pumped storage power plant.

(2) How to proceed

Regarding above four aspects, we firstly input basic knowledge about the items, and from among them, the important items for CEB were selected through consultation between JICA expert team and CEB. Then JICA expert team and CEB researched and presented the selected item to each other, and proceeded with the procedure of achieving the goals of this project (As shown in the workflow of each aspects).

a. VRE output forecast



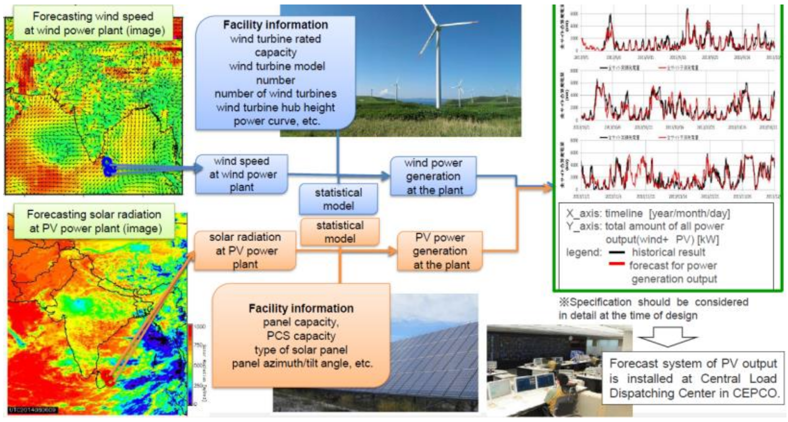
(Source) JICA Expert Team

Figure 3-22 Work Flow chart (VRE generation forecast)

(Input Stage)

Regarding the VRE forecast, JICA Expert Teams and the CEB input each other as follows:

Table 3-16 Input Items

	Action Items	Action Details
(a)	General VRE forecast model and Japan's VRE power generation forecast system	・JICA expert team outlined the general VRE forecast model (weather and power generation) and how to develop it, and then outlined Chubu Electric Power's PV forecast system as an example of Japan's VRE power generation forecast system. This VRE forecast system consists of a two-stage forecasting model. The first one is a model that forecasts weather information (solar radiation, wind direction/speed) using VRE facility location and weather model, and the second one is a model that forecasts VRE power generation from weather forecast and facility information. 
(b)	Information needed to develop a VRE forecast model	・JICA expert team explained trends in forecast accuracy due to differences in information required to develop the VRE forecast model (i.e., facility information, weather information, and generation data) and information obtained.
(c)	Current Status of CEB VRE output forecast	・CEB explained that the current VRE output forecast is based on the previous day's weather forecast, actual power generation, and experience.
(d)	Current Situation and Development Plan of VRE Facilities in Sri Lanka	・CEB explained the status of existing VRE facilities (including Rooftop PV) and plans to develop VRE facilities in the future.
(e)	Current status of Rooftop PV in Sri Lanka	・CEB described the status of existing Rooftop PV installations in different regions of Sri Lanka.
(f)	Sharing of information available to develop VRE forecast model	・CEB explained the availability of information for each VRE forecast candidate site based on the information needed to develop the VRE forecast model.

(Source) JICA Expert Team

(Selection Stage)

The following items were determined based on discussions between JICA expert team and CEB at the input stage.

Table 3-17 Selected items

	Action Items	Action Details
(a)	Determining the framework of the VRE forecast system	・CEB requested that JICA expert team to establish a VRE forecast system in CEB. Since the operation and maintenance of weather forecast, which is a part of the VRE forecast system, requires expertise skills, JICA experts emphasized the need to first implement VRE forecast (weather, power generation) and then develop the system step by step ・As a result, during the term of this project, JICA expert team decided to implement VRE forecasts (weather and power generation) and provide the results to CEB, and to determine the distribution specifications (methods, frequency, time, etc.) for VRE forecasts (weather and power generation).
(b)	Creation of VRE power generation conversion tool	・ It was agreed that JICA expert team will develop a VRE output conversion tool to calculate VRE power generation from weather information, assuming that the weather forecast will be obtained by CEB from the meteorological company after the completion of the project,.
(c)	Determination of the forecast points of the VRE forecast model	・CEB and JICA expert team decided eight VRE forecast points (three for wind power plants and five for solar power plants) based on the current operation status (output size, location, etc.) of existing facilities of VRE, as well as the future development plan (output size, location, etc.) of VRE and the availability of information necessary to build a model.

(Source) JICA Expert Team

(Study Stage)

Based on the implementation items decided in the Selection stage, JICA expert team conducted studies on the following items.

Table 3-18 Study Items

	Action Items	Action Details
(a)	Development of VRE forecast model and system, and provision of VRE forecast	・At the stage of March 2021, JICA expert team obtained equipment information from CEB on VRE forecast points (eight points), constructed a VRE forecast system that operates the VRE forecast model (weather forecast, power generation forecast) at the same time, and began providing VRE forecasts (weather and power generation) to CEB in July 2021.
(b)	Construction of VRE output conversion tool	・A JICA team of experts developed a VRE output conversion tool based on the development of a VRE forecast model and provided it to CEB in November 2021.
(c)	Validation and improvement of	・During the 2-1 and 2-2 activities in January 2022 and June 2022, JICA expert team verified the accuracy of VRE forecasts (weather and power generation) by

	accuracy of VRE forecast model	obtaining the actual outputs at VRE forecast points and a part of meteorological observation data from CEB, and improved the VRE forecast model based on the results. Then, the provision of VRE forecasts (weather and power generation) based on the improved VRE forecast model started on September 1, 2022.
(d)	Improvement of VRE output conversion tool	・In September 2022, JICA expert team provided CEB with an upgraded VRE output conversion tool along with an upgraded VRE forecast model.
(e)	Estimation of VRE output and actual VRE output throughout Sri Lanka	・CEB and JICA expert team discussed how to forecast VRE output throughout Sri Lanka and how to estimate the actual VRE output required to verify it.

(Source) JICA Expert Team

(Implementation Stage)

The following items were implemented by CEB based on the results of the study stage.

Table 3-19 Implementation items

	Action Items	Action Details
(a)	Comparison of forecasted and measured VRE forecasts (initial model)	・With regard to VRE output forecasts provided since July 2021, CEB independently compared VRE generation forecasts and actual VRE outputs measured at three of the eight VRE forecast points provided by JICA expert team (two wind power generation sites, one solar power generation site) where actual measured VRE outputs were available on the same day, and provided the results to JICA expert team in the 2-2 activity.
(b)	Comparison of forecasted and measured VRE output (modified model in September 2022)	・With regard to VRE output forecasts, which started to be available in September 2022, CEB compared actual and forecasted VRE output at three locations where measured power generation were available on an instant basis.
(c)	Comparison of Previous and New Model Forecasts and Actual Values of VRE output conversion tool	・CEB used the VRE output conversion tool before and after improvements to compare measured and forecasted VRE forecast at two points of solar power forecast points.
(d)	Determine the policy for forecast VRE output throughout Sri Lanka using VRE forecasts.	・CEB has decided how to forecast VRE output throughout Sri Lanka after the project. (1) Determine the area represented by each of the 8 VRE forecast points, and calculate the total rated output of the same type of wind power generation, commercial solar power generation, and rooftop solar power generation included in that area. (2) Calculate the output ratio between the rated output of each VRE forecast point and the total rated output of the same type of VRE in the representative area. (3) In operation, obtain the necessary weather forecasts (wind power generation: wind speed, solar power generation: solar radiation) for the 8 VRE forecast points, and use the VRE conversion tool to calculate the VRE power generation amount at the 8 points. (4) Multiply the VRE power generation at the 8 VRE forecast points by the rated output ratio of the representative region to estimate the total power generation of the same type of VRE in each region. Table Rated output of VRE forecast points and representative areas

Forecast site (Total rated value)	Information on forecast site	Representative area (Total rated value)
WPP1(**12MW**)	Northern Wind Power Plant	Area7(**250MW**)
WPP2(**103.5MW**)	Mannar Wind Power Plant	Area8(**315MW**)
WPP3(**10MW**)	Mampuri Wind Power Plant	Area9(**214.6MW**)
SPP1(**10MW**)	Vydexa solar Power Plant	Area4(**250MW**)
SPP2(**12.5MW**)	Solar One Ceylon Power	Area5(**647MW**)
SPP3(**10MW**)	Saga Solar Power	Area6(**131MW**)
		Area3(**63MW**)
SPP4(**50KW**)	Kuliyapitiya Area	Area2(**143MW**)
SPP5(**90.9KW**)	CEB Head office	Area1(**25.2MW**)

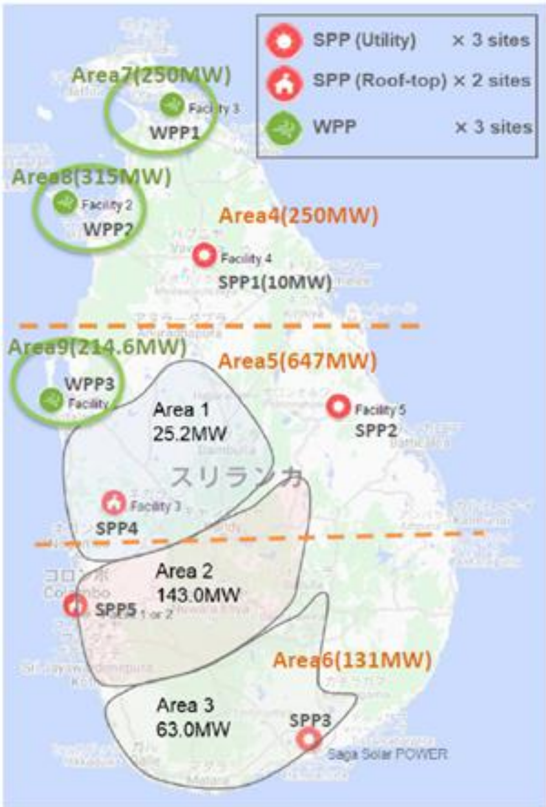


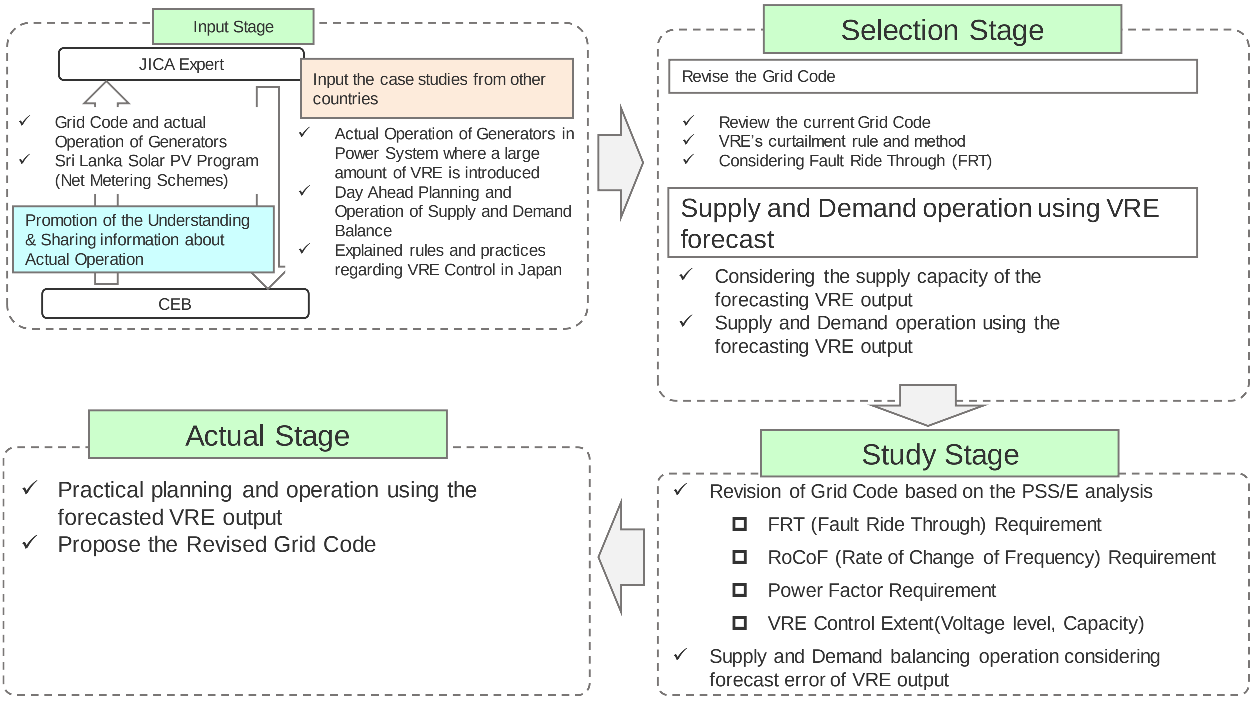
Figure VRE forecast points and representative areas

Table Rated output ratio of VRE forecast points and representative areas

Forecast area (VRE type)	Conversion factor	Forecast area (VRE type)	Conversion factor
Area1 (Roof top PV)	504	Area6(Utility PV)	13.1
Area2(Roof top PV)	1,573	Area7(Wind)	20.8
Area3(Roof top PV)	6.3	Area8(Wind)	3.04
Area4(Utility PV)	25	Area9(Wind)	21.46
Area5(Utility PV)	51.76		

(Source) JICA Expert Team

b. Supply and Demand Operation



(Source) JICA Expert Team

Figure 3-23 Work Flow Chart (Supply and Demand Operation)

(Input Stage)

In line with the mass introduction of RE, the measures that Japan has taken have been inputted. The input items are as follows.

Table 3-20 Input Items

	Main Items	Matters described
(a)	Actual operation of generators in power system at the time of mass introduction of RE	・Operation method of pumped storage power plants and thermal power generation to absorb surplus power during daytime due to PV increase
(b)	Day ahead planning and supply-demand balance operation	・Operation schedule of thermal power generators was changed based on the forecast error of RE output.
(c)	Rules and Initiatives for RE Control in Japan	・Communication method for RE control ・How to set the control schedule pattern ・How to set the upper limit of the number of days and time that can be controlled
(d)	Grid Code requirements to be considered for mass introduction of RE	・Fault Ride Through (hereinafter referred to as “FRT”) requirements (in Japan) ・RoCoF、SNSP ・Requirements for suppressing changes in RE output (Case Studies in Japan)

(Source) JICA Expert Team

(Selection Stage)

The following items were selected based on the discussion with C/P at the input stage.

Table 3-21 Selected Items

	Main Items	Matters described
(a)	Revision of Grid Code	・As of 2030, Sri Lanka is similar to Japan (Hokkaido) and Ireland in terms of the scale of electricity demand and the interconnection with other areas. By comparing Grid Codes among these three countries, the revision requirements for Grid Codes were identified as follows; (FRT, RoCoF, suppression of output fluctuations of RE, power factor adjustment range, supply/demand adjustment capacity of thermal power stations, installation of communication facilities to be controlled with RE, priority order in controlling RE, scope of control of RE ・Communication method for RE control
(b)	Supply and demand operations using VRE forecasts	・Consideration about expected supply capacity of VRE output ・Supply-demand Operation using VRE output forecast

(Source) JICA Expert Team

(Study Stage)

i) PSS/E analysis using a RE model

- Characteristics of PSS/E RE Model

JICA expert explained the procedure of dynamic analysis under various faults using the PSS/E RE model so that the C/P can simulate the impact on the power system in the case of fault even in 70% RE case. The dynamic analysis requires the setting of generator models, electrical control models and plant control models, indicating the background and characteristics of the first and second generation RE models. C/P was interested in whether the RE model could contribute to voltage improvement, and therefore the function of voltage compensation for voltage drop was introduced in the case of fault using the RE model.

- Practice of Power System Analysis Using PSS/E RE Model

JICA expert conducted an exercise on how to perform frequency control and voltage control using a RE model. JICA expert created a typical simple system simulating a generator (conventional hydro power generator and RE generators), and the following two types of faults, the simulations were performed.

➢ Frequency control in the event of a generator tripping for RE

➢ Voltage control in case of bus fault

In each case, the changes in frequency, voltage, and generator output with time were checked in the pattern of ON and OFF control.

When the frequency control is ON, the frequency drop due to the RE1 generator fault is suppressed by increasing the power generation output of RE2. On the other hand, when the frequency control is

OFF, the output of RE2 does not change with respect to the frequency drop due to the generator fault of RE1, and the range of frequency drop is larger than when it is ON.

When the voltage control is ON, the voltage drop due to bus fault is suppressed by increasing the reactive power from RE2. On the other hand, when the voltage control is OFF, the reactive power of RE2 does not change with respect to the voltage drop due to the fault of the bus, and the voltage drop is larger than when it is ON.

Model	Wind				PV	BESS (Battery Energy Storage System)
	W1	W2	W3	W4		
Generator /Converter	WT1G1	WT2G1	WT3G1, WT3G2	WT4G1, WT4G2	PVGU1	CBEST
Electrical Control		WT2E1	WT3E1	WT4E1, WT4E2	PVEU1	
Mechanical (Drive Train)	WT12T1		WT3T1		PANELU1 (Panel's output curve)	
Pitch Control			WT3P1		IRRADU1 (Solar irradiance profile)	
Aero Dynamic /Pseudo Governor	WT12A1					

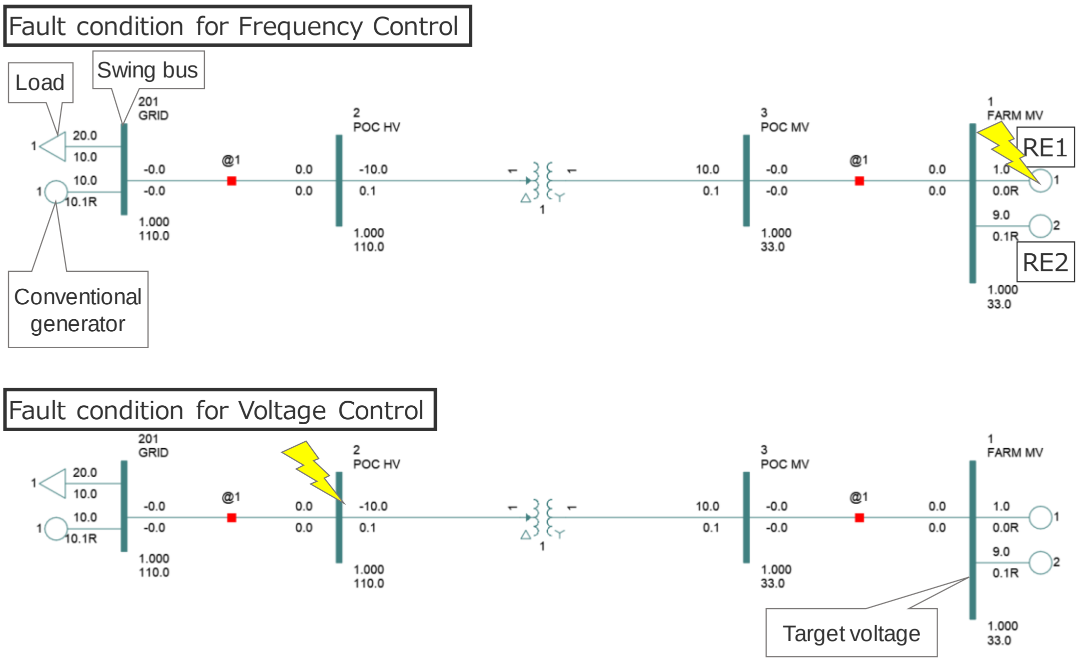
(Source) JICA Expert Team

Figure 3-24 List of First-Generation RE Models

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 Based Fast Frequency Response Mode)	WTGIBFFRA* (Synthetic Inertia)		

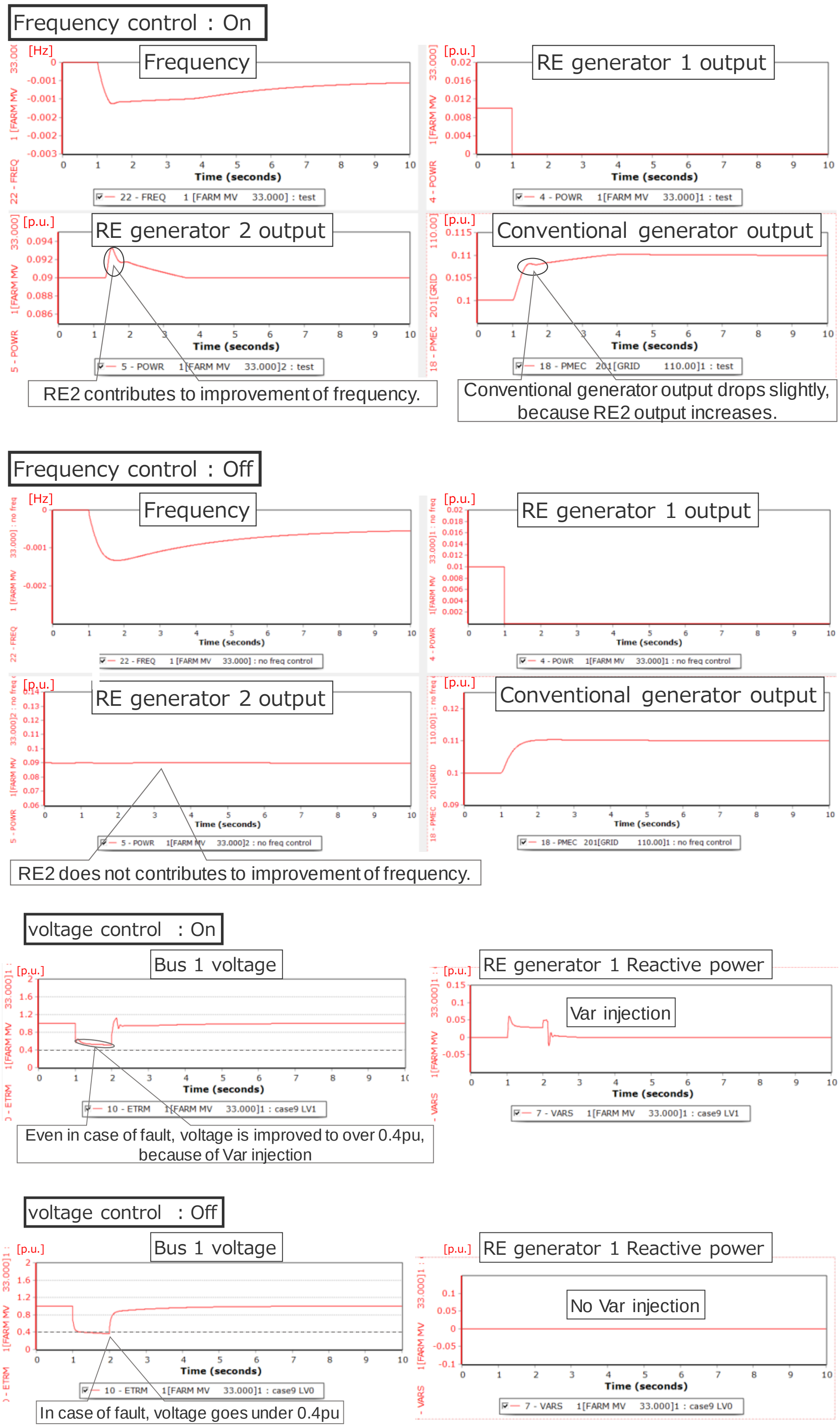
(Source) JICA Expert Team

Figure 3-25 List of second-generation RE models



(Source) JICA Expert Team

Figure 3-26　Typical power system with RE models used in simulations model



(Source) JICA Expert Team

Figure 3-27 Simulation results for changes of Generator Output, Frequency and Voltage with Time

- Consideration of PSS/E scenario to revise Grid Code to achieve stable supply at 70% RE

  Scenario studies were conducted to establish Grid Code values that require revision as specified in the Study Stage. At the time of mass introduction of RE, the disturbance in the higher voltage system may affect the PCS (power conditioning system) of PV and cause unnecessary PV trip. As a countermeasure against this, the FRT requirements to be defined in the PCS so that the operation can be continued even under higher voltage drops or the frequency drops. In the PSS/E study, C/P only simulated the trip of the maximum generator (300 MW Lakvijaya coal-fired power) and the decrease of PV output due to sudden changes in the weather, even under the most severe scenario, and it does not assume the unnecessary PV trip in the event of a system fault. In order to identify the stability limit at 70% RE, JICA expert proposed scenarios to simulate more severe cases, because the PV trip in case of system fault should be taken into consideration in addition to the conventional analysis.

ii) Revision of Grid Code for mass introduction of RE

- Simulation progress of C/P

  C/P has performed power system analysis with 50% RE case, but has not been able to do with 70% RE case. As the LTGEP with 70% RE is in the approval process as of December 2022, and RE development sites are not decided yet, so the transmission plan with 70% RE cannot be completed. Thus, 70% RE analysis could not be performed.

- In the analysis of the 50% RE case, C/P made the hourly supply and demand balance as of 2030, selected the most severe 21 cases and performed simulations under different types of faults. Among these 21 cases, there are cases of heavy/light load, cases where hydro power generation can be expected/cannot be expected during the rainy/dry season, cases where solar power can be expected/cannot be expected during the daytime/nighttime, and cases where wind power generation can be expected or not depending on the wind condition. As mentioned above, the simulation method assumes the dropout of the largest generator (300 MW Lakvijaya coal-fired power plant) and the decrease of solar output due to sudden changes in weather. As measures to stabilize frequency and voltage in case of a fault, the increasing of hydro and thermal power output, storage battery discharging, and load shedding are used as spinning reserve. As a result of simulation studies, the frequencies were found to be within the statutory range in all 21 cases. However, JICA expert proposed to implement the PSS/E scenarios set above, because the most critical point where the power system becomes unstable due to the steep frequency drop has not been identified.

- Calculation of numerical standards

  Among the revision requirements specified in the Selection Stage, it is necessary to calculate a value that is suitable for Sri Lanka and to include in the numerical standards (FRT, RoCoF, suppression of output fluctuations of RE, power factor adjustment range) by using PSS/E. The JICA expert proposed simulation scenarios, and based on these scenarios C/P will perform the

PSS/E simulations in order to clarify the decisive roles of these requirements. As a result of discussions on effective scenario to revise Grid Code items appropriately, JICA expert proposed the following scenarios.

<FRT>

(a) Busfault at the PUTTALAM substation
- ✧ Coal-fired power plant Trip
- ✧ PV output decrease
- ✧ PV Trip due to voltage drop of 5% or less at substation with voltage 132 kV or more
- ✧ PV Trip due to voltage drop of 40% or less at substation with voltage 33 kV or less

(b) Bus fault 1 at 132/33 kV substation
Select the substation where the total capacity of solar power plants is the highest.
- ✧ Decrease in solar irradiation
- ✧ PV Trip due to voltage drop of 5% or less at substation with voltage 132 kV or more
- ✧ PV Trip due to voltage drop of 40% or less at substation with voltage 33 kV or less

(c) Bus fault 2 at 132/33 kV substation
Select the substation where the total capacity of solar power plants is the second highest.
- ✧ Conditions are the same as for bus line fault 1.

→Judgment conditions and revision requirements

- Judgment conditions

In case the RoCoF is found to be 2 Hz/s or more (referring to the examples in Japan and other countries, and referring to the values required in multiple countries) or Nadir (the minimum value of frequency reached during the transient period) is observed to be below 47.0 Hz i.e., the lower limit of the generator's operational frequency considering load shedding.

-Revision requirements

The range of residual voltage for continued operation of all power plants including VRE in case of fault needs to be extended to 0% from the current standard of "5% for power plants to be connected to 132 kV or more" and "40% for power plants to be connected to 33 kV or less". Additionally, it is recommended for stable supply to extend the current range of FRT up to 0%, regardless of simulation result for accelarating RE introduction in the future.

<RoCoF>

Performed according to scenario (a) regarding the FRT above. However, if the FRT requirement is extended to 0% by simulation of FRT, only the Trip of the coal-fired generator and the decrease of the PV output are simulated.

→Judgment conditions and revision requirements

The RoCoF-tolerant numerical standards calculated in the simulation are specified in the Grid Code.

<Mitigation of output fluctuation>

In addition to the RoCoF simulations under fault conditions described above, the frequency variation due to the change in the RE output during normal condition is simulated.

→Judgment conditions and revision requirements

Fault case: Performed simulations with the same scenario as RoCoF, while RE output variation (ramp rate) is changed in order to check whether the Nadir does not drop below 47.0 Hz that is the lower lmit of generator operational frequency.

Normal case: Perfomed simulations with various RE output variations (ramp rates), to check whether the Nadir does not drop below 48.75 Hz that is threshold to start load shedding.

Based on these results, the RE output variation (ramp rate) should be decided and stipulated in the Grid Code.

<Power factor adjustment range>

Performed simulations under the normal condition in order to check whether the voltage fluctuation does not exceed the operational standard i.e. (132-400 kV ± 5% and 11-33 kV ± 6%), while the demand is low, RE output is high and the power factor adjustment range of generator is the same as defined in the current Grid Code.

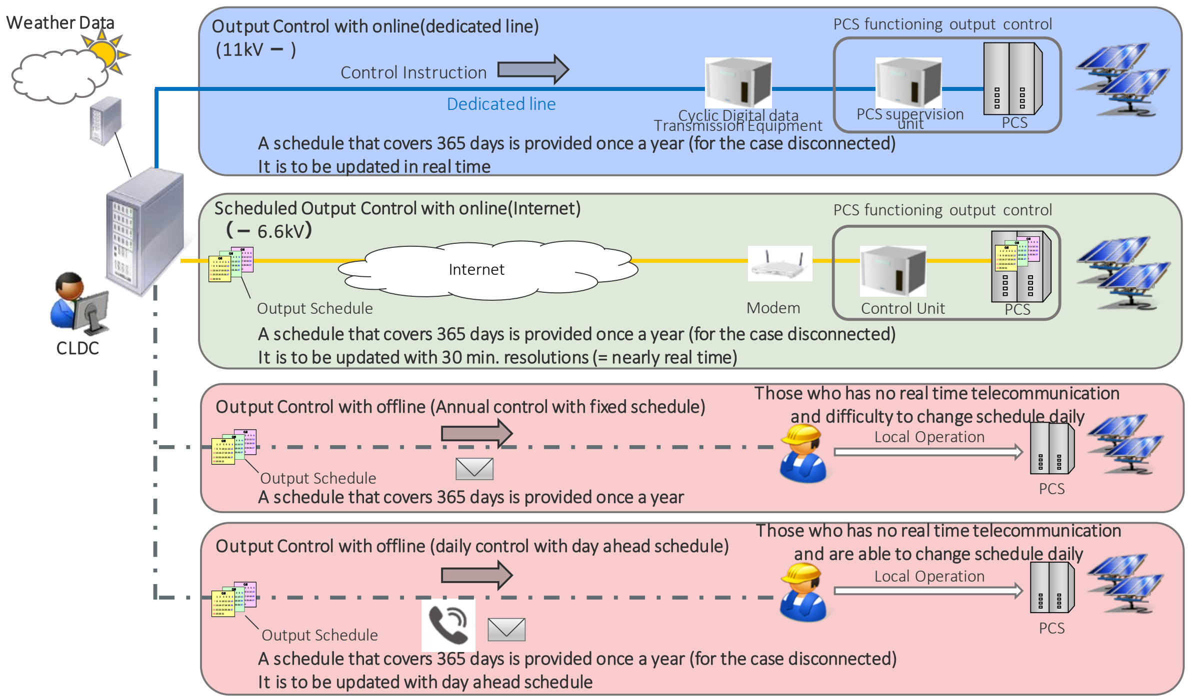
→Judgment conditions and revision requirements

If the voltage exceeds 132-400 kV: ±5% and 11-33 kV: ±6%, expand the power factor adjustment range. Based on these results, the power factor range should be decided and stipulated in the Grid Code.

- RE controlability conditions
  - ✓ In August 2021, the Sri Lankan government announced a target of achieving 70% RE. In January 2022, the C/P developed a supply-demand model for 70% RE. Based on this model, C/P calculated hourly demand and power generation capacity and the extent of RE controlability at each plant in 2030 without battery installation.
  - ✓ RE capacity categories as of 2030 (10 MW and above, 1 MW ~ 10 MW, up to 1 MW) were provided by C/P, and JICA experts considered the category-wise RE controlability in 2030.
  - ✓ Considering the lead time required to revise the Grid Code and the inability to apply revised Grid Code to the existing facilities, JICA expert calculated required amount of control capacity considering controlable RE with a capacity of 10 MW or more to be installed during 2026 - 2030. As a result, it was identified that up to 820 MW of control capacity would be insufficient in 2030, and it was discussed and agreed with C/P that required battery capacity is equal to more than 820 MW.
  - ✓ As C/P plans to install 1,000MW of batteries by 2030, which is sufficient for absorbing RE surplus power, and hence it was agreed with C/P that the amount of RE to be controlled in the Grid Code should be 10 MW or more.

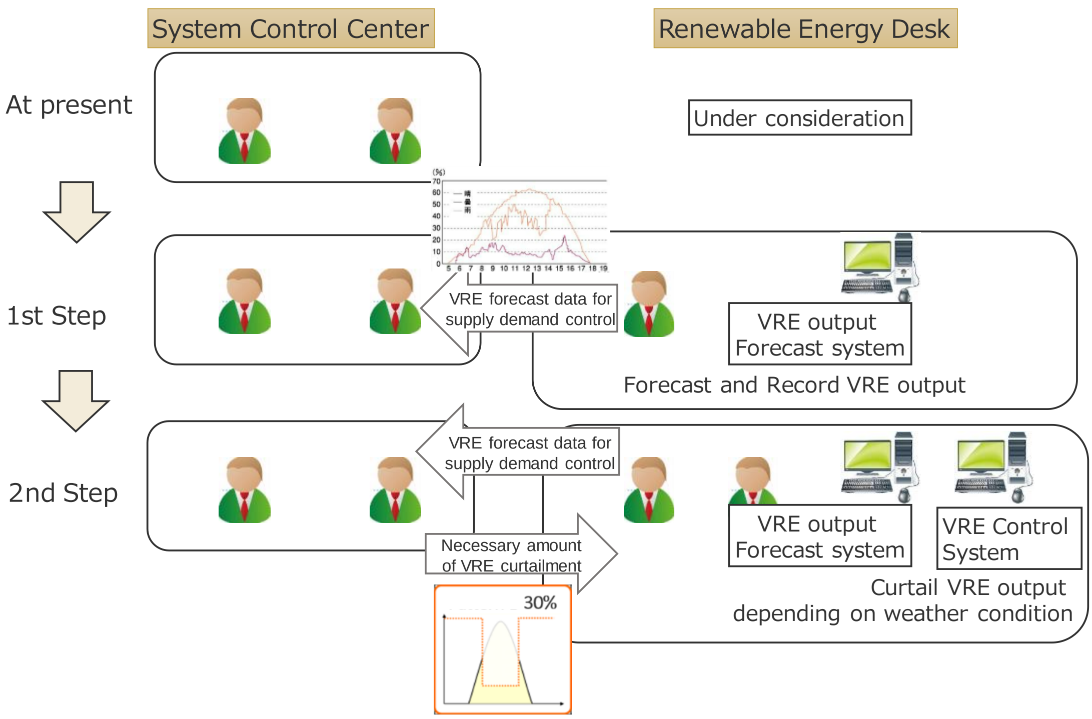
iii) Investigation of installation of RED (Renewable Energy Desk)

- Role of RED
  - ✓ In order to control the output of VRE, JICA expert introduced Japanese methods (control priority rule for power supply sourcces, PCS controlability through dedicated line / Internet / telephone / e-mail etc.).(Figure 3-28)
  - ✓ For the introduction of RED, JICA expert proposed 2 stages. In the 1st stage, it is proposed to carry out the VRE output forecast and recording, and in the 2nd stage it is proposed to implement VRE output control functions (Figure 3-29, Figure 3-30). With regards to these steps, the specific details are as follows;
    - ✧ Step 1: VRE forecast using VRE power conversion tools provided during this project and in order to use this tool, weather data from the relevant vendors needs to be procured.
    - ✧ Step 2: Development of a system which can forecast and control VRE generation for whole of Sri Lanka based on weather data provided by relevant vendors.
- It was suggested that if 1,000 MW of storage batteries were installed, CEB would be required to monitor and control VRE of 10 MW or more based on the latest LTGEP, and the surplus power would be managed adequately.
- It was agreed with the C/P that VRE of 10 MW or more should be controlled by a secure, reliable and dedicated lines and that the plants under 10 MW should be monitored only by the Internet and the details in this regard should be specified in the grid code.
- Composition of future REDs
  - ✓ The case study of Chubu Electric Power Company was used to propose an inter-system connection for controlling RE (Figure 3-31).
  - ✓ JICA expert confirmed that the NCP (software for the next day's supply and demand plan) needs to be improved in order to implement the RED function when surplus power occurs.
  - ✓ JICA expert explained the classification of entities responsible for construction and cost of dedicated lines using the case of Chubu Electric Power Company and provided information on the cost sharing when constructing RED in the future. In addition, JICA expert shared the construction cost per unit length and kW for each overhead and underground transmission line according to their voltage class, while using some example cases.



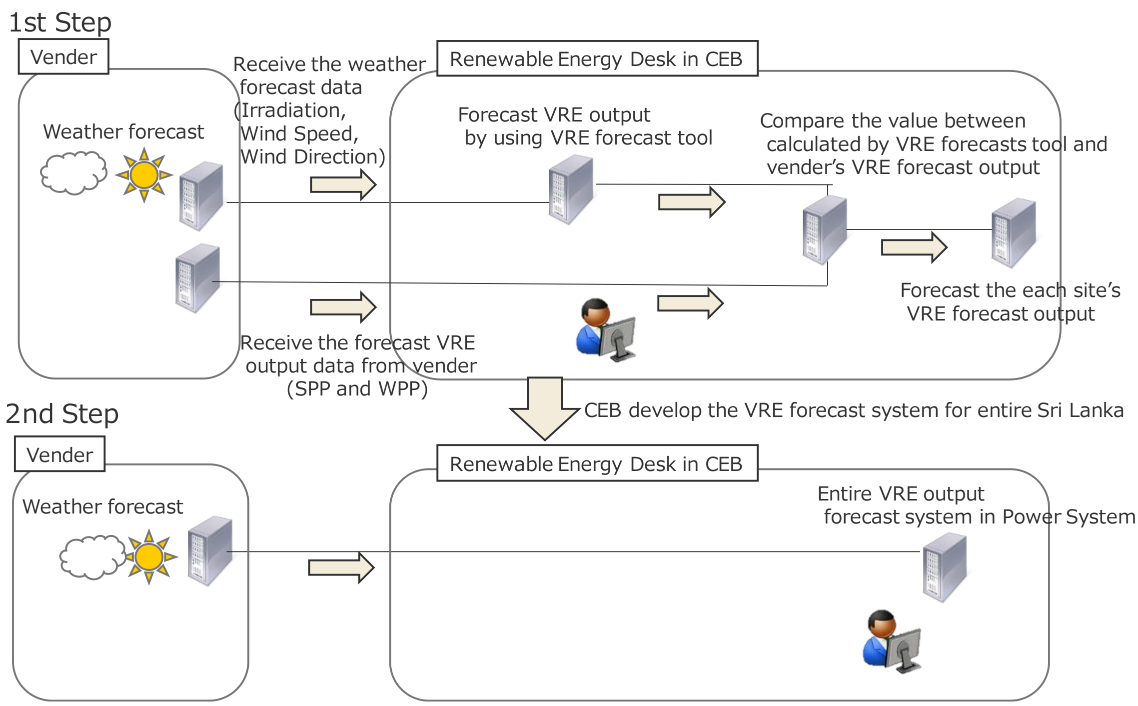
(Source) JICA Expert Team

Figure 3-28 Communication method of VRE control in Japan



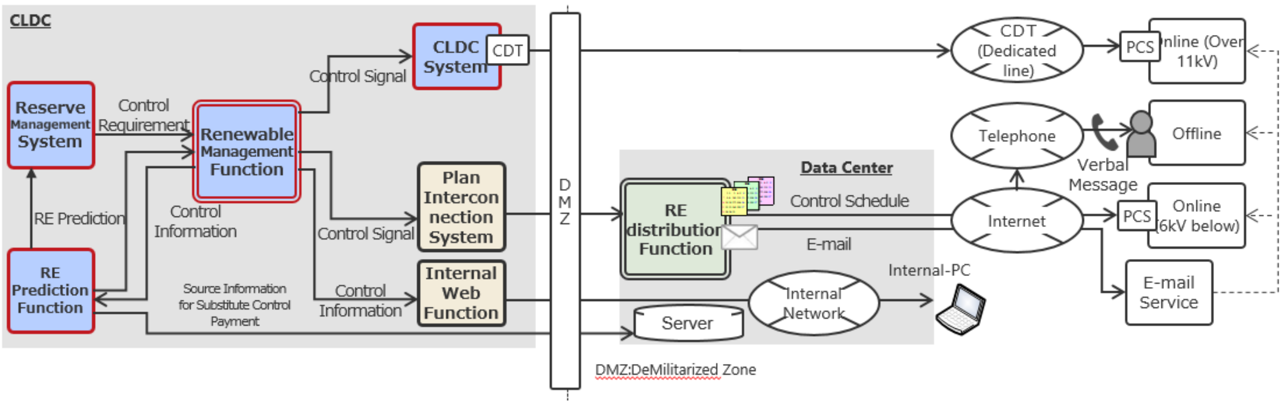
(Source) JICA Expert Team

Figure 3-29 Future organization of REDs



(Source) JICA Expert Team

Figure 3-30 Future System Configuration of REDs

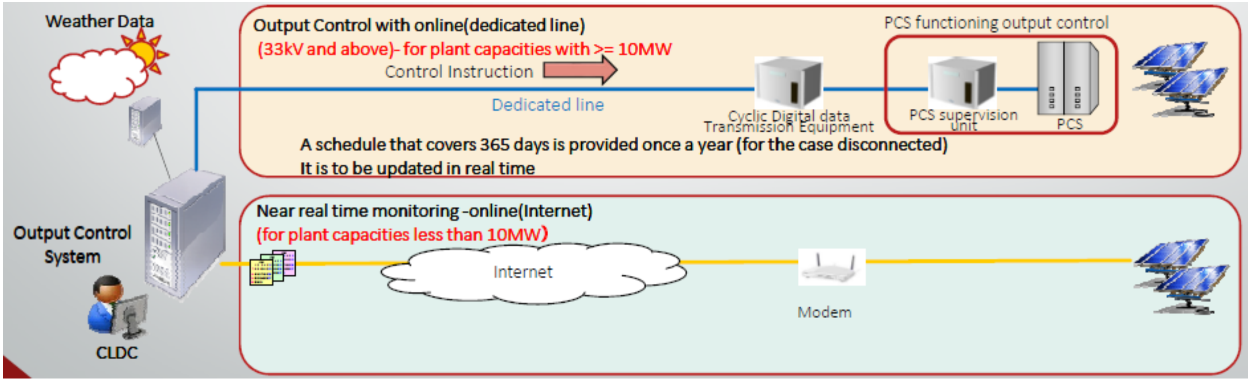


(Source) JICA Expert Team

Figure 3-31 Configuration of RE Control System and Other Systems at the Central Load Dispatching Center in Japan

(Actual Stage)

- Practical planning and operation using VRE forecasts
  Based on the technical data provided by JICA expert, C/P themselves added their own ideas to create a vision for the future RED (Figure 3-32).

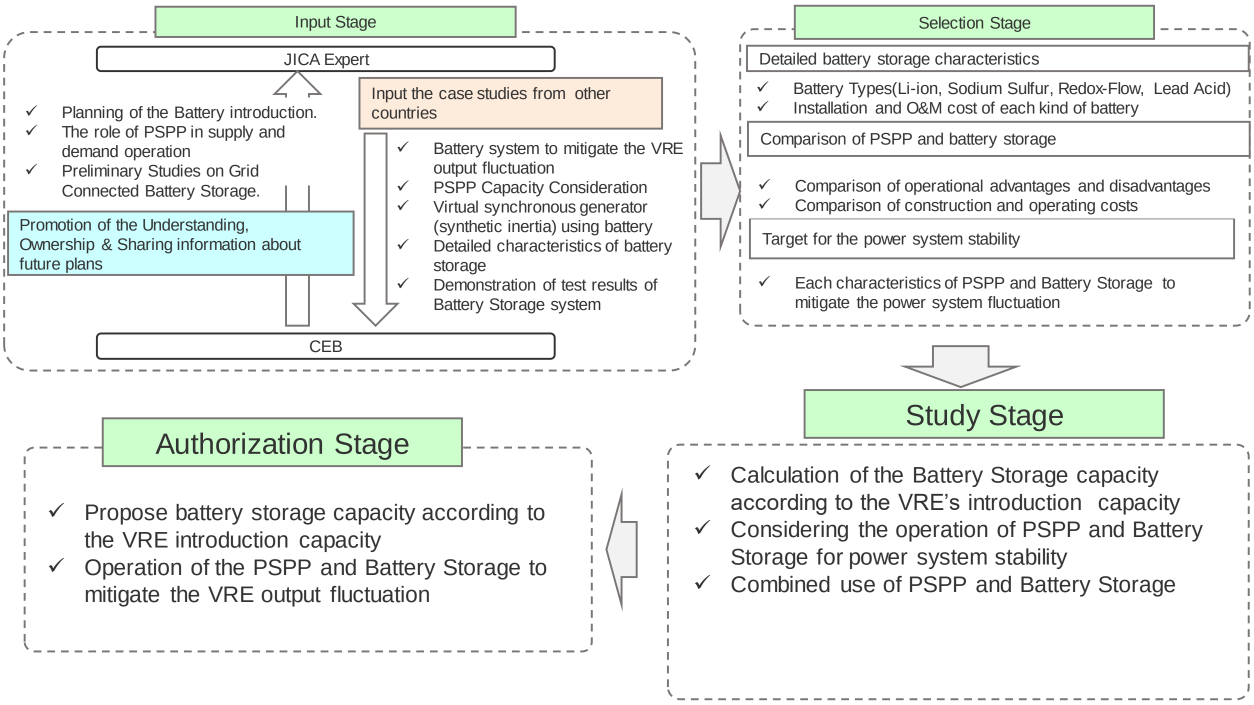


(Source) JICA Expert Team

Figure 3-32 Future RED of the C/P

- Revision of Grid Code
  Based on the PSS/E analysis for various scenarios considering the FRT requirements explained in the study stage, C/P acquired the ability to revise themselves the Grid Code even in 70% RE case.

c. Measures for the mass introduction of VRE



(Source) JICA Expert Team

Figure 3-33 Process Flow Chart (Measures for the mass introduction of VRE)

(Input Stage)

In order to conduct stable supply and demand operation at the time of the mass introduction of RE, it is necessary to introduce energy storage systems and appropriately operate along with thermal and hydro power generation in accordance with fluctuations in the output of VRE.

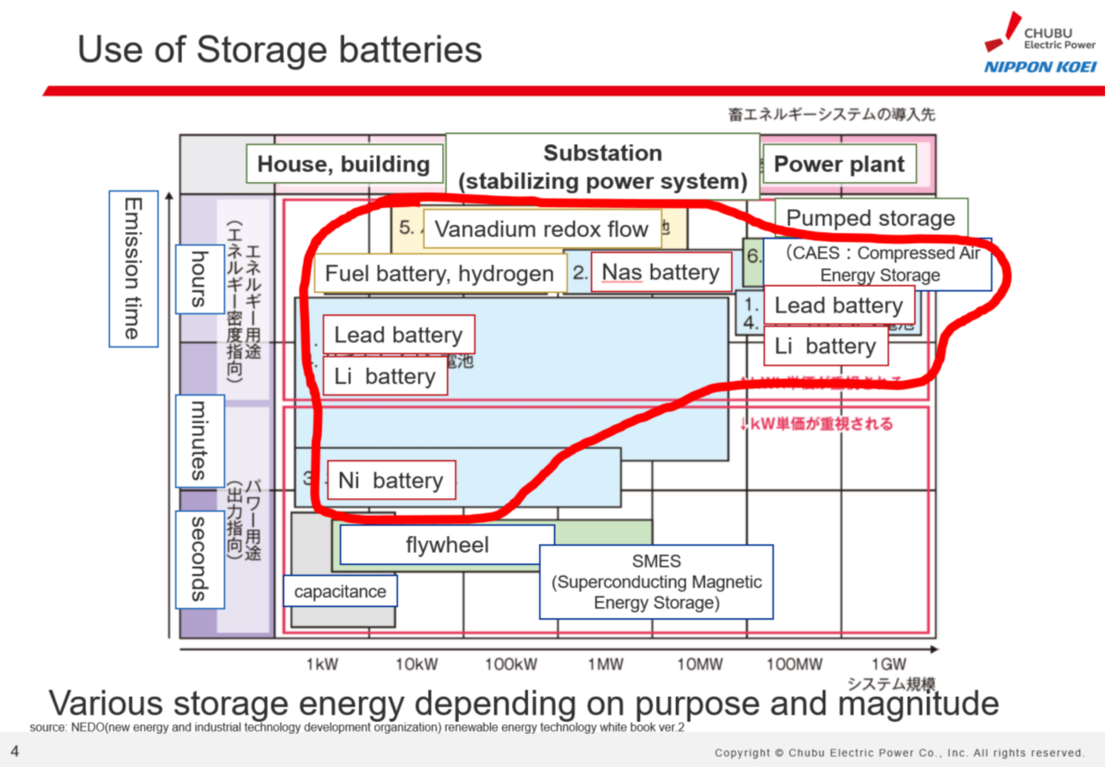
As energy storage has not yet been implemented in Sri Lanka, JICA expert explained the overall outline of energy storage system, the operation method of PSPP (pumped storage power plant) at CEPCO, and the demonstration research using storage batteries. In addition, JICA expert explained the characteristics of main types of storage battery as measures against long-term frequency and short-term frequency output fluctuations. Input items are shown in the Table 3-22.

On the other hand, C/P explained the plan for the introduction of storage batteries and the method of simulation of annual supply and demand operation.

Table 3-22　Input Items

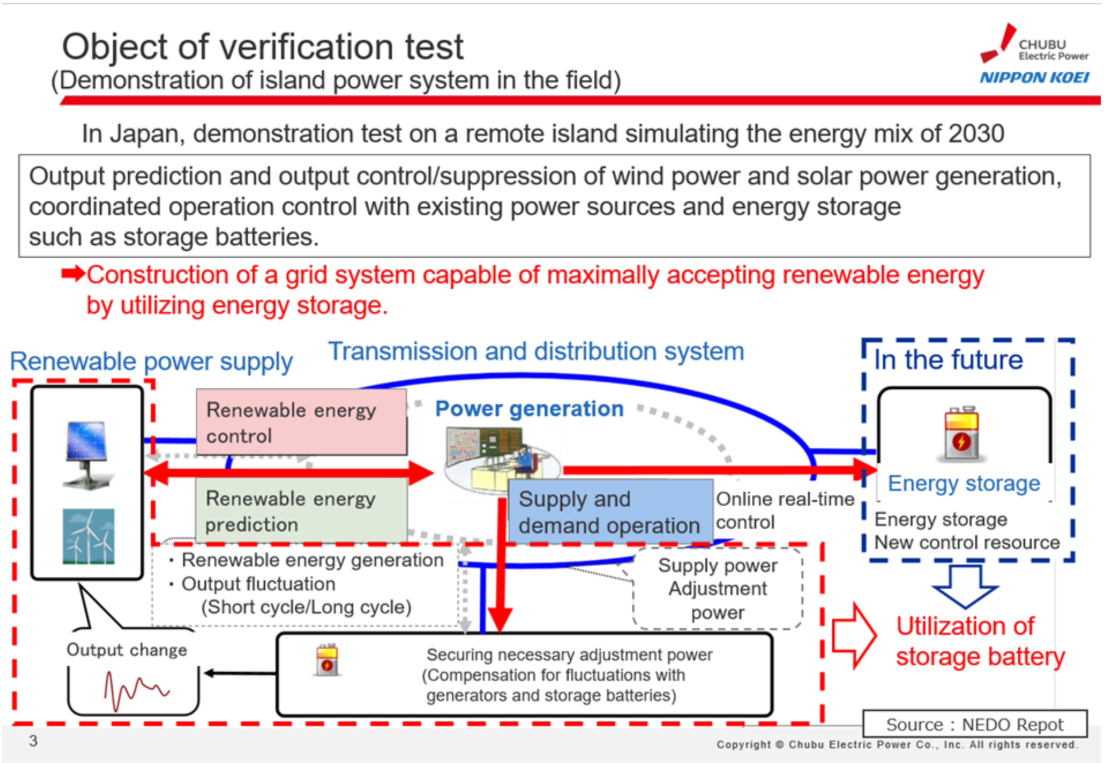
	Main Items	Matters described
(a)	Overview of energy storage systems for absorbing VRE output fluctuations	・Characteristics and use cases of storage batteries, PSPP, hydrogen storage, and CAES (Compressed Air Energy Storage) (Figure 3-34)
(b)	Overview of demonstration research using storage batteries	・Demonstration overview of wind and solar power output control on remote islands and cooperative operation control with existing power sources and storage batteries(Figure 3-35) ・Example of virtual synchronous generator prototype using storage batteries
(c)	Operation method of PSPP	・Introduction of LFC (load frequency control) and governor-free capacity during power generation ・Relaxation of the N-1 generation shedding criteria by VRE curtailment during pumping-up mode of PSPP and load shedding during generation mode of PSPP
(d)	Overview of System Stabilization Measures for Short and Long-term frequency	・Introduction of the countermeasures for each unstable state (short and long-term frequency fluctuations and insufficient transmission capacity) during the mass introduction of VRE (Figure 3-36) ・Introduction of the examples for the countermeasures against voltage flicker due to increased share of PV

(Source) JICA Expert Team



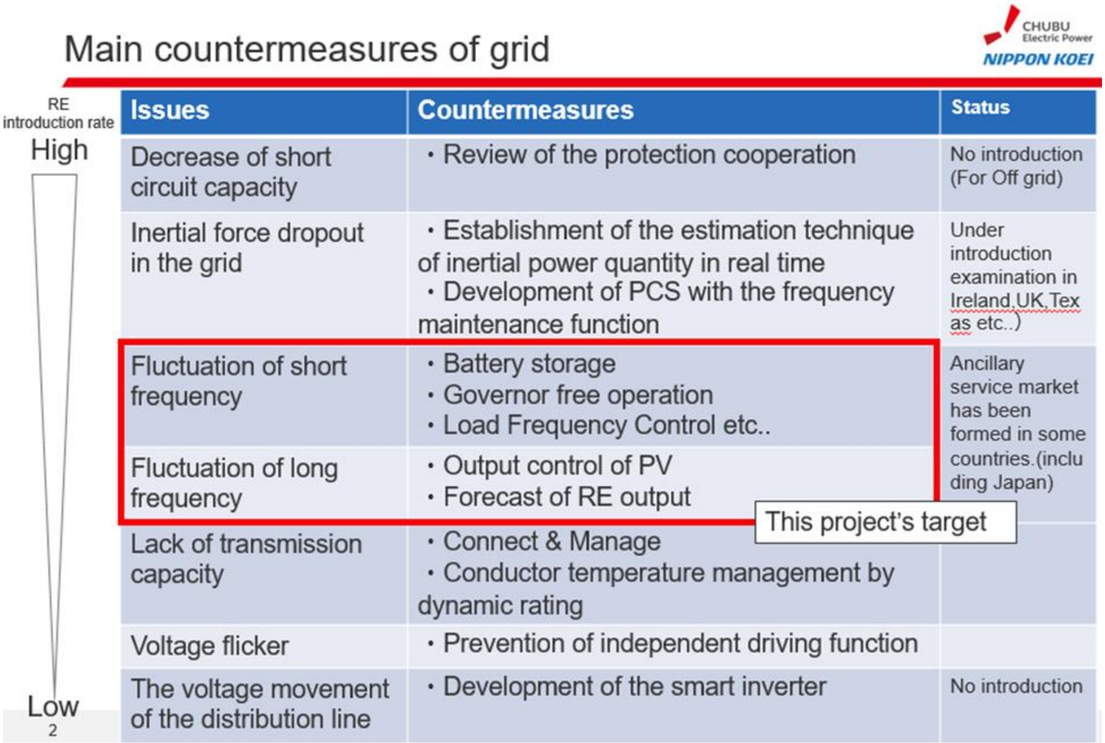
(Source) JICA Expert Team

Figure 3-34　Usage of the Energy Storage System



(Source) JICA Expert Team

Figure 3-35　Overview of demonstration using RE and storage batteries



Main countermeasures of grid

CHUBU Electric Power / NIPPON KOEI

RE introduction rate	Issues	Countermeasures	Status
High	Decrease of short circuit capacity	・Review of the protection cooperation	No introduction (For Off grid)
	Inertial force dropout in the grid	・Establishment of the estimation technique of inertial power quantity in real time ・Development of PCS with the frequency maintenance function	Under introduction examination in Ireland,UK,Texas etc..)
	Fluctuation of short frequency	・Battery storage ・Governor free operation ・Load Frequency Control etc..	Ancillary service market has been formed in some countries.(including Japan)
	Fluctuation of long frequency	・Output control of PV ・Forecast of RE output	
	Lack of transmission capacity	・Connect & Manage ・Conductor temperature management by dynamic rating	
	Voltage flicker	・Prevention of independent driving function	
Low	The voltage movement of the distribution line	・Development of the smart inverter	No introduction

This project's target

2

(Source) JICA Expert Team

Figure 3-36 List of System Stabilization Measures against VRE Introduction

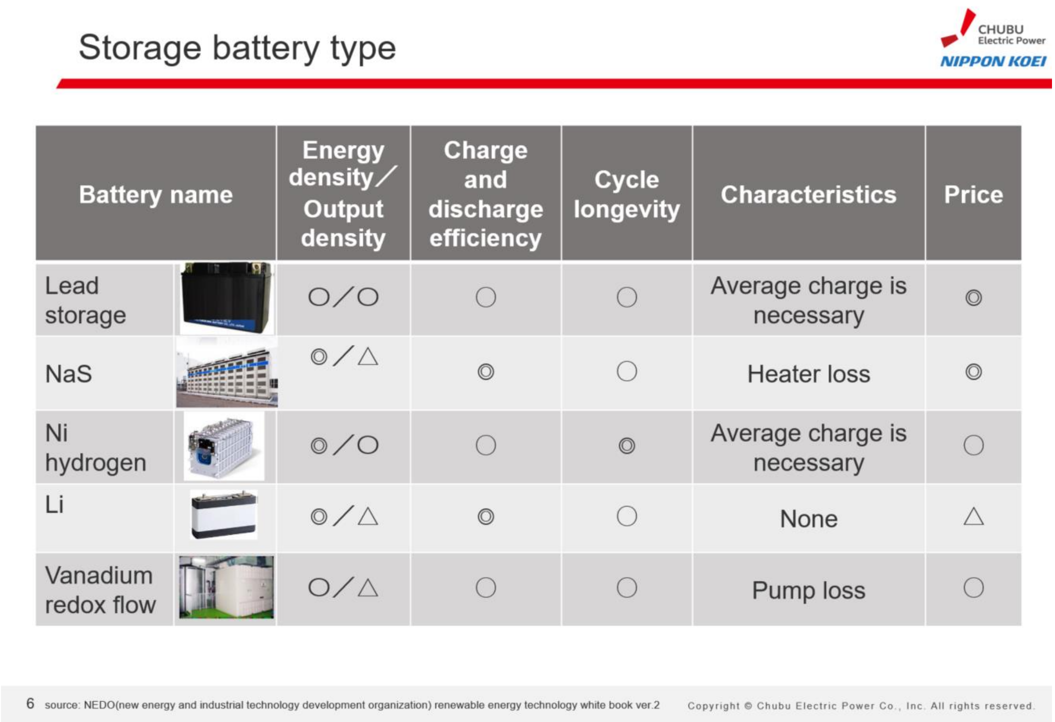
(Selection Stage)

The following items were selected based on the discussion with C/P at the input stage.

Table 3-23 Input Items

	Main Items	Detail
(a)	Detailed features of the battery	・The characteristics (energy density, charge/discharge efficiency, cycle life, operating temperature, etc) of NaS batteries, Li batteries, redox flow cells, etc.(Figure 3-37) ・The selection of types of storage batteries based on thier features and installation and operation cost ・NaS (for supply and demand control) and Li (for frequency control)
(b)	Comparison of PSPP and storage batteries	・Necessary period and cost for PSPP and storage battery installation ・Based on the SDDP results of VRE surplus power based on the LTGEP, CEB calculated the capacity of storage batteries and PSPP required to achieve the 70% RE by 2030.(Figure 3-38)
(c)	Targets for system stabilization	・The system non-synchronous penetration (SNSP) is used as an index to confirm the power system stability in case of 70% RE.

(Source) JICA Expert Team



Storage battery type

Battery name	Energy density／Output density	Charge and discharge efficiency	Cycle longevity	Characteristics	Price
Lead storage	○／○	○	○	Average charge is necessary	◎
NaS	◎／△	◎	○	Heater loss	◎
Ni hydrogen	◎／○	○	◎	Average charge is necessary	○
Li	◎／△	◎	○	None	△
Vanadium redox flow	○／△	○	○	Pump loss	○

6 source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

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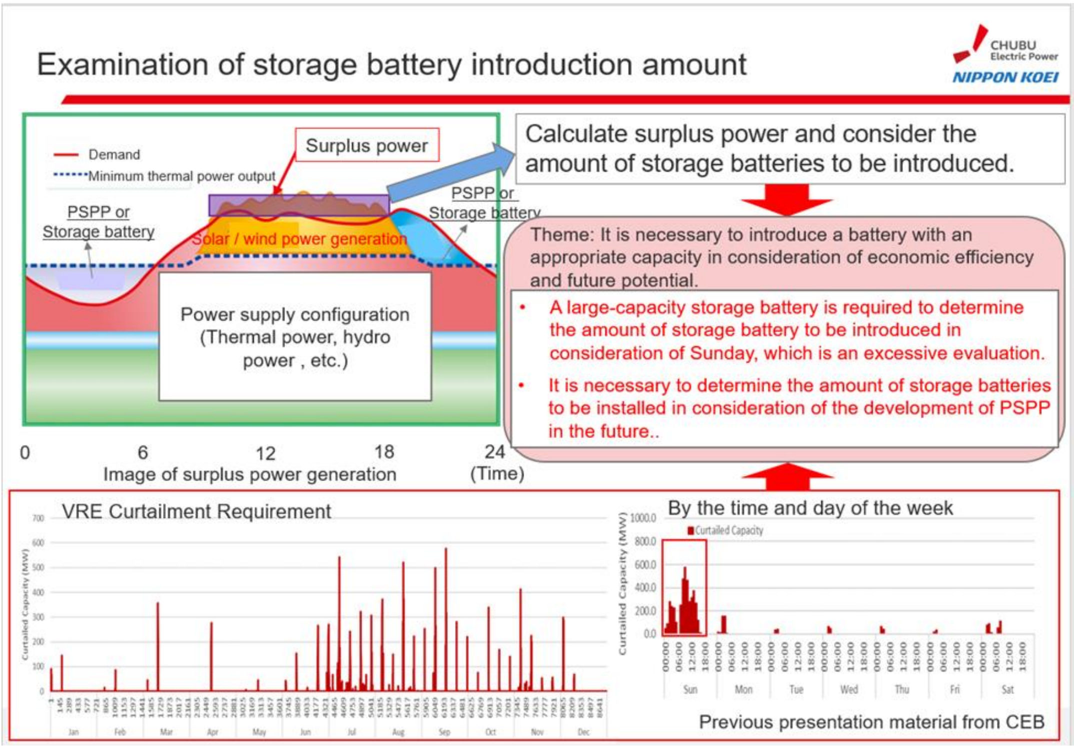
(Source) JICA Expert Team

Figure 3-37　Characteristics of each battery type



(Source) JICA Expert Team

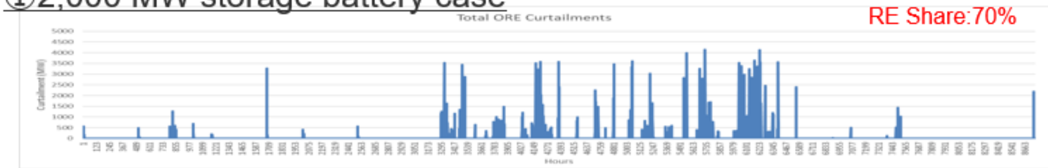
Figure 3-38　Image of battery capacity determination method

(Study Stage)

- Since PSPP development requires much time and the number of development sites is limited, the capacity which already planned is fixed as the PSPP capacity when calculating the SDDP. The necessary storage battery capacity was calculated, and it was confirmed that the 70% RE can be achieved by introducing a 2,000 MW storage battery (Figure 3-39).
- It is too expensive for CEB to introduce 2,000 MW storage battery, so JICA expert reviewed the results of SDDP calculation conducted by CEB. Although it was proposed that the output of thermal power unit was not reduced to the lowest level when VRE curtailment was occurred, and it was confirmed that the output of thermal power unit could not be reduced to keep the SNSP within the allowable value.
- JICA expert explained how to determine the SNSP and how to reconsider the SNSP with reference to Ireland case where the introduction of RE is progressing rapidly (Figure 3-40). RoCoF and Nadir are different for each kind of power system and SNSP. By setting multiple scenarios for SNSP in performing fault analysis for the country specific power system, it is possible to identify the SNSP limit value where frequency falls within the stable range.

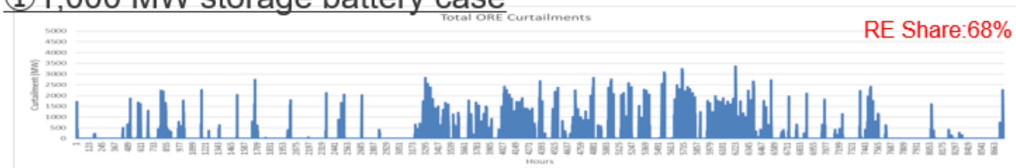
SDDP simulation calculation result

①2,000 MW storage battery case



	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	499.63	68.98	106.50	75.19	74.37	67.49	10.91	5.51	86.66	1.22	0.00	0.02	2.77
Annual CO2 Emissions (Tons)	8322133	1884600	2909900	2054500	439480	398820	64493	32588	512070	9180	0	157	16345

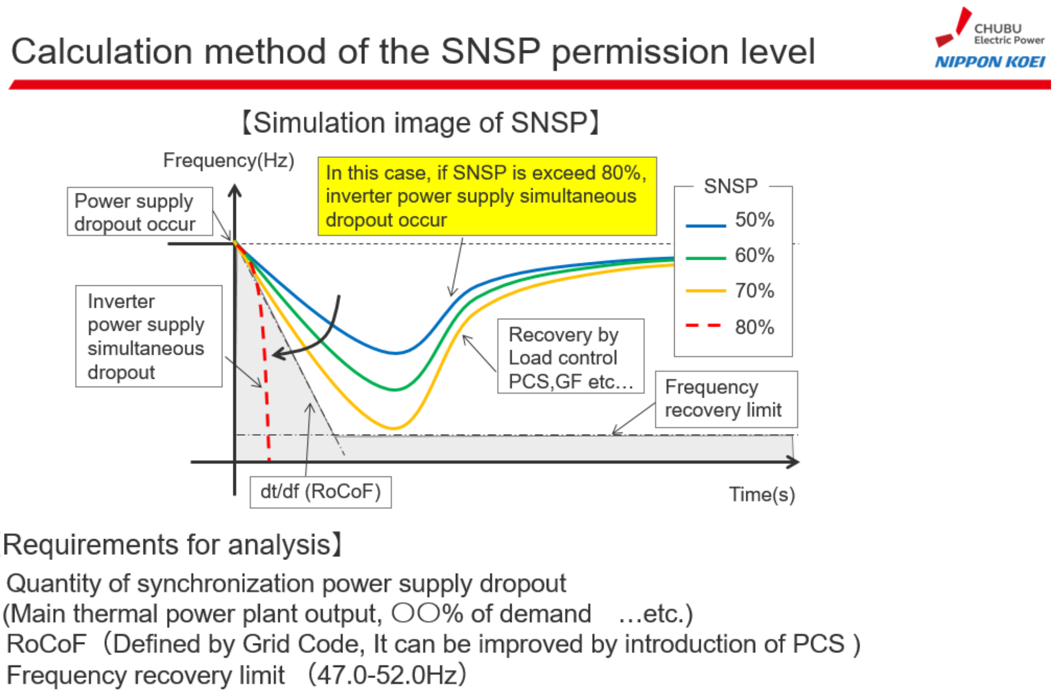
①1,000 MW storage battery case



	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	522.22	77.11	106.32	74.87	80.82	74.83	13.02	5.59	86.43	1.29	0.00	0.11	1.82
Annual CO2 Emissions (Tons)	8619086	2106700	2904800	2045700	477570	442200	76933	33055	510720	9730	0	896	10782

(Source) JICA Expert Team

Figure 3-39 Effect of reducing VRE curtailment according to storage battery capacity



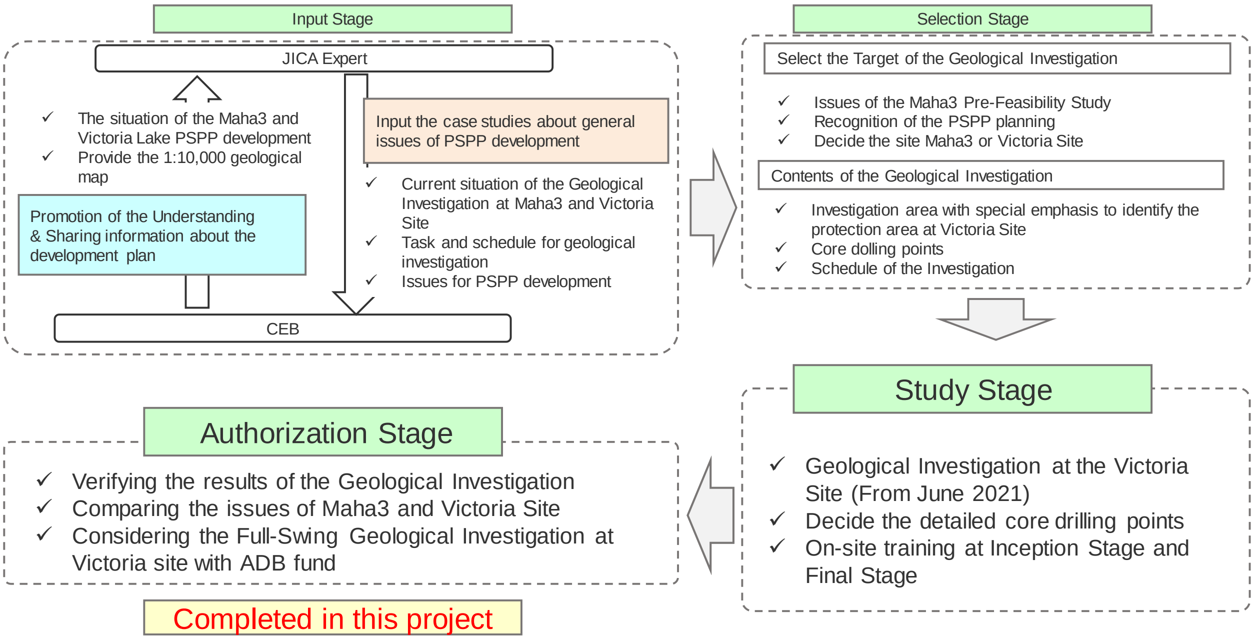
(Source) JICA Expert Team

Figure 3-40 Simulation method of SNSP tolerance calculation

(Authorization Stage)

- It was confirmed that the PSS/E can be used as a method for simulating SNSP tolerances.
- It was confirmed that 70% RE can be achieved with 1,000MW storage batteries by reducing thermal power output to the minimum when VRE is curtailed. This was reflected in the latest LTGEP.
- It was suggested that the SNSP in 2030 should be confirmed by the results of the PSS/E analysis with 70% RE and SDDP calculation should be performed accordingly.
- The types of storage batteries (NaS: supply and demand control, Li: frequency control) need to be determined based on the PSS/E analysis results and the cost evaluation. The cost evaluation method for each type of storage battery system was presented. CEB acuired capability to formulate the policy for introducing the storage batteries, considering the system stability and cost benefit analysis as soon as completion of the PSS/E analysis by themselves.

d. Geological survey on PSPP (pumped storage power plant)



(Source) JICA Expert Team

Figure 3-41 Operation Flow Chart (Geological Survey of PSPP)

(Input Stage)

Based on the general guidelines for hydropower and pumped storage power plant development and previous JICA reports, general issues of PSPP in Sri Lanka were input.

Table 3-24 Input Items

	Main Items	Matters described
(a)	Geological issues related to Sri Lanka's PSPP	For each of the Maha 3 and Victoria sites, geological issues related to PSPP development were explained for each structure (upper/lower ponds, upper/lower dams, waterway, and underground powerhouse).
(b)	Proposals for the scope and process of geological surveys that will be required in the future	For the Maha 3 and Victoria sites, JICA expert proposed the scope and processes of geological surveys required for feasibility studies.
(c)	Challenges in PSPP development	General civil engineering problems in the development of PSPP are explained in the case of Maha3 and Victoria from the perspectives of geology, environment and technology. 1.Geological survey: Geophysical exploration, boring survey, field/laboratory test 2.Environment: Natural environment (protected area) and social environment (resettlement) 3.Technological aspects: Pumping head, dam construction in existing lakes

(Source) JICA Expert Team

(Selection Stage)

Based on the discussion with C/P at the input stage, the following items were confirmed.

Table 3-25 Selected Items

	Main Items	Matters described
(a)	Geological survey target sites	JICA expert confirmed that the geological survey of the Maha 3 site has already been conducted (excluding some items), while the geological survey of the Victoria site has not been conducted except for the site reconnaissance. JICA expert confirmed that the knowledge necessary for the study of the development of PSPP is insufficient at the Victoria site. After discussion with C/P, it was decided to conduct geological survey at the Victoria site at the same level as the Maha 3 site in this project.
(b)	Contents and period of geological survey	JICA expert confirmed the contents and duration of geological surveys at Victoria. 1.Basic contents: topographic survey, topographic mapping, boring survey, various tests 2.Period: March to December 2021 (including the procurement period of local subcontractors) 3. Investigation site: Except for the Environmental Protection Area (part of upper pond and lower pond) Based on the above, local subcontract specifications were prepared, and the procurement procedures were implemented.

(Source) JICA Expert Team

(Study Stage)

Based on the decisions made at the selection stage, the following survey and on-site training were conducted.

Table 3-26 Implementation Items

	Main Items	Matters described
(a)	Geological survey	Implementation period: July to December 2021 Subcontractor: Central Engineering Consultancy Bureau (CECB) Survey items and quantities ・Topographic survey and mapping: 20 km2 (1/10,000) and 2.5 km2 (1/1,000) ・Geological mapping: 2.5 km2 (1/1,000) ・Six borings (four in upper pond and two in waterway) for a total of 240 m. ・Field survey: Standard penetration test, permeability test ・Laboratory tests: Uniaxial compression test, tensile test, etc.
(b)	Adjustment of boring survey points	Based on the results of confirmation of landslide conditions by visual inspection at the initial stage of the survey, the boring survey positions at two points of upper pond and two points of waterway were changed from the original plan. When changing the survey location, land owners and CEB confirmed on the basis of photographs and location information that the site was not located in the

		natural protected area.
(c)	On-site training	Inception Stage: July 8, 2021 (on desk) ・Explanation of the progress of geological surveys ・Method of changing the boring survey position according to the actual geological condition ・Procedure of field exploration for geological confirmation Final Stage: October 26, 2021 (at field) and 28 (on desk) ・Joint field reconnaissance and observation of boring cores ・Method of evaluating geological survey results ・How to proceed with geological surveys

(Source) JICA Expert Team

(Authorization Stage)

The following items were explained based on the results of the survey at the study stage and discussions with the C/P in the on-site training.

Table 3-27 Proposed Items

	Main Items	Matters described
(a)	Verification of the geological survey results	At this time, JICA expert confirmed that there is no fatal geological risk at the uppder pond associated with the development of PSPPs, where this survey was conducted. However, as there still may be potential issues, confirmation is needed in the subsequent feasibility study. 1. Risk of landslides seems to be low in the vicinity of the upper dam and the open penstock. 2. Water permeability around the upper dam and pond seems to be low, but possible minor seepage should be considered at the right bank. 3. Quartzite around the right bank of the upper dam foundation seems fragile in core samples, but seems hard in outcrop.
(b)	Comparison of Maha3 and Victoria sites	The geological survey at the Victoria site in this project was conducted only at the upper pond and upstream of the waterway to avoid nature reserves. In order to compare with the Maha 3 site, it is necessary to investigate the lower pond and the downstream of the waterway in the next stage survey.
(c)	FS (ADB) recommendations for the next phase	JICA expert proposed geological survey items and quantities at Victoria site which may be included in the feasibility study (additional survey at Maha3 and Victoria and comparison at both sites, and detailed survey at the prioritized site) which CEB will implement with the funding by ADB.

(Source) JICA Expert Team

(3) Outcome of Activities

Results 2 (WG2): Strengthening transmission system operation and development capabilities with increased RE introduction

Results 2 requires that long-period and short-period considerations be made and necessary measures taken for the mass introduction of VRE from the viewpoint of the stable operation of the electric power system. The following six points were achieved in the study; (a) providing VRE output forecasts through the development of the VRE forecast model; (b) the consideration of Renewable Energy Desk (RED), which has VRE output forecasts and VRE output control functions from the viewpoint of supply and demand operation; (c) measures against frequency and voltage fluctuations and fault analysis using PSS/E with RE models for mass VRE introduction; (d) grid code requirements for mass VRE introduction; (e) consideration of capacity and operation method of storage batteries required for effective use of VRE surplus power and stable power system operation; and (f) geological surveys related to PSPP. The geological surveys were conducted at Victoria, one of the candidates for the development of PSPP.

a. VRE power output forecast

For the VRE output forecast, a total of eight VRE locations (three wind power and five PV power plants) were selected as development locations of the VRE forecast model from among existing VRE plants while taking into consideration the upcoming wind and PV power plants and the geographical distribution. From the C/P, the necessary information on facilities and actual power output were obtained, and data about weather and VRE forecasts (twice a day) were provided from Japan via the Internet from July 2021.

The results of VRE output at all eight VRE forecast points were obtained only part of the period during the 2-1 activity. JICA expert confirmed that the accuracy of VRE output forecast was improved at six out of the eight VRE forecast points as a result of the verification and improvement of the VRE forecast model (weather and power generation). JICA expert team started providing the improved VRE forecast (weather and power generation) to CEB from September 1, 2022, and verified the accuracy of the VRE output forecast model by using the actual data of VRE output at three points provided by CEB during 2-2 activity. As a result, CEB and JICA Expert Team confirmed the improved accuracy of the forecast. In addition, it was found that the actual data of VRE output used for the verification were all instantaneous values. On the other hand, since the VRE output forecast was an average of 15 minutes, the obtained VRE output data were averaged (with moving average method) and re-verified. Consequently, the forecast accuracy was improved at one wind power point and at four PV power plants points.

The improvement in forecast accuracy in PV output was remarkable. This is beacuse the amount of PV output fluctuates rapidly in response to changes in the weather (amount of solar irradiation), and as such the forecast error tends to be large in the case of instantaneous measured data is used without any averaging effect. On the other hand, in the case of wind power generation, it is inferred that the effect of averaging the measured data was small, because the presence of wind turbine inertia tends to suppress rapid fluctuation of the output due to the weather change.

In addition, JICA expert team developed a tool that can convert weather forecast into VRE output, so that CEB can forecast VRE output by themselves even after the completion of this project. The VRE output conversion tool were provided to CEB in November 2021(the first version) and September 2022 (the second version) and verification of both versions was conducted in the 2-2 activity. CEB and JICA expert team jointly confirmed that the forecast accuracy was improved.

In the second phase of the project, JICA expert team transferred technology to CEB to conduct VRE forecast for whole of Sri Lanka, which will be required for supply and demand planning.

During and after the 2-3 activity, JICA expert team collected meteorological data (wind direction and speed) from the Mampuri wind power plant and improved the VRE forecast model for the same site, which improved the accuracy of the WPP3 output forecast. The deliverly of VRE forecast data calculated with the improved VRE forecast model was started in February 2023, and the VRE output conversion tool with revised WPP3 power curve was provided to the CEB in February 2023.

b. Operation of supply and demand

With the mass introduction of VRE, C/P understood the need to control surplus power from PV and wind power, but had no idea how to implement it with the existing System Control Center (hereinafter referred to as “SCC”). JICA expert explained a series of steps right from the RE control rules to the concepts of the system design and the actual operation method using Japanese cases. Based on the technical data provided, C/P acquired capability to formulate a vision of the future of RED by adding their own ideas.

c. Fault analysis exercise using PSS/E RE model

Grid Code revision requires a power system analysis corresponding to the mass introduction of VRE to determine the stability limits of frequency and voltage. Therefore, lectures on the structure and function of the PSS/E with RE model and a power system simulation exercise using the RE model were conducted, and opportunities were provided for C/P to acquire these techniques. When explaining the RE model, JICA expert team showed the differences between the first and second generation models, as well as the background of the different generation models. In the power system simulation exercise, the RE was simulated with and without the frequency control and voltage control functions, and the improvement effects of these control functions on frequency and voltage drop were shown.

In addition, the sample parameters of pumped storage power generation models and storage battery models were shared. As a result, C/P can themselves simulate pumped storage power generation and storage batteries, which will be developed in the future.

d. Revision of Grid Code for mass introduction of RE

When mass introduction of VRE leads to large-scale output fluctuation due to weather change, the existing hydro/thermal power generators must be stopped or operated with reduced output, which may lead to grid instability during grid fault. In order to avoid such situation, Grid Code plays important role in ensuring grid stability.

Sri Lankan Grid Code was revised in 2018, but there was no description of the installation of communication facilities or RoCoF for RE control, and the requirements for FRT and power factor adjustment range were relatively loose, as there was small share of RE. Therefore, with increasing share of VRE, JICA expert team explained the outline and necessity to revise the Grid Code at the Input Stage. And shared the Grid Code practices in Ireland and Japan (Hokkaido) at the Selection Stage to deepen the understanding of the C/P in handling massive introduction of VRE.

In the Study Stage, JICA expert explained the simulation and evaluation methods for setting numerical standards necessary for Grid Code revision. During this project, C/P acquired capability to develop simulation scenarios, conduct simulations, and evaluate the results even if further expansion of RE is planned/implemented in the future. In addition, it was possible for C/P to explain logically the content of the Grid Code revision to PUCSL.

Furthermore, regarding the output curtailment of PV in the light-load period, it was proposed that PV power plants of 10 MW or more connected to the 132 kV grid should be controlled by a reliable, secured and dedicated communication line.

e. Measures for the mass introduction of VRE

CEB was able to understand the outline of the necessary stabilization measures for the power system against the phase-wise introduction of RE. At the beginning of the project, the LTGEP set a target of 50% RE, but the target for RE was increased to 70% under the latest initiative of the government. Therefore, JICA expert team explained the range of measures against power fluctuations and confirm that not only measures against short-term fluctuations (frequency fluctuations, etc.) but also measures against long-term fluctuations (effective use of surplus power from VRE, etc.) are necessary. For 70% RE realization, JICA expert team explained the necesity of the development of PSPP and introduction of storage batteries, and CEB could understand it.

In addition, JICA expert team explained the concept of the development plan for the balancing power using PSPP and storage battery necessary for effective utilization of surplus power from VRE to achieve 70% RE. In the case of PSPP, the fixed capacity of planned site is only incorporated into the plan, while in the case of storage batteries, it is possible to develop in a short time and expand its capacity step by step. Accordingly, JICA expert team explained methodology to calculate the required capacity of the storage battery.

In order to achieve 70% RE, it was found that 2,000 MW was necessary as a result of the calculation of storage battery capacity. However, since the introduction of 2,000 MW of storage batteries is not realistic in view of Sri Lanka's present financial situation, JICA expert team reconsidered the supply and demand operation policy and confirmed that it is possible to reduce the required storage battery capacity by revising the allowable value of SNSP (System Non-Synchronous Penetration).

In addition, CEB deepened their understanding of the cost evaluation method to introduce the storage battery. The method comprehensively evaluated the opportunity loss costs to be paid by CEB through VRE power generation control and the effects of reducing fuel costs and CO2 emissions costs by reducing thermal power generation.

Finally, JICA expert reconsider the optimal capacity of storage battery introduction to achieve 70% RE target with the most cost-effective plan, JICA expert discussed and agreed that 1,000 MW storage battery is suitable, which was reflected in the latest LTGEP.

In addition, C/P acquired capability to develop the necessary balancing capability by themselves comprehensively considering the aspects of supply and demand operation, system stability, and cost, even if further expansion of RE is planned/implemented in the future.

f. Geological survey on PSPP

For the PSPP development, two sites, Maha 3 and Victoria, are listed as candidate sites. In this project, a part of geological survey similar to Maha 3 was conducted at Victoria, where geological survey had not been conducted earlier.

The geological survey at Victoria was completed in December 2021, including the assessment, and it was confirmed that there was no fatal geological risk associated with the development of PSPP within the scope of the geological survey conducted under this project.

As for technology transfer related to geological surveys, the desk training was held in October 2020, on-site training (on the desk) of the Inception Stage was held in July 2021, and on-site training of the Final Stage (on-site training and on-site lectures) was held in October 2021, thereby achieving the target set for this component of the project.

3.8.3 WG3 Activities

(1) Aims of Activities

In order to achieve "Results 3: Strengthening power distribution and operation capacity," the project aims to possess the technical capabilities and capabilities that the CEB Distribution Department and the LECO themselves can cope with in relation to (a) power outage measures to improve the reliability of power supply and (b) load fluctuation control at the time of VRE introduction. Additionally, the enhancement of capacity contributing to the improvement of reliability of supply was divided into WG3-1 and the enhancement of capacity contributing to the reduction of load fluctuations was divided into WG3-2.

With regard to WG3-1, (a)-I power failure records were analyzed, and (a)-II current operation and management status of distribution facilities was evaluated, and (a)-III power outage countermeasures were proposed using the equipment. The effects of power outage countermeasures were examined through (a)-IV pilot projects.

With regard to WG3-2, (b) -I we investigated the state of load fluctuation due to the introduction of VRE in the distribution system, (b) -II we modeled and measured distribution lines that are the two issues, and (b) -III we proposed measures to control fluctuations in the distribution system.

(2) How to proceed

a. Power outage countermeasures to improve the reliability of power supply

WG activities were divided into the Input Stage, Selection Stage, and Study and Evaluation Stage to achieve high-level objectives, project objectives, and expected results. In order to grasp the current level of reliability of supply and to consider effective measures according to the priority, the current power failure record was aggregated and analyzed. Since the selection stage had insufficient information on power failure records and it was difficult to examine statistical measures, the SAIFI/SAIDI for each MV feeder was investigated in the area to which the WG members belong (each DD and LECO) with a view to solving the problems of each organization. Based on the survey results, a candidate feeder for countermeasures was selected and the expected effects of introduction of countermeasures were individually estimated. The Study and Evaluation Stage introduced countermeasure devices to the feeder selected by the Selection Stage, and continued to record and investigate the power failure to compare the effects before and after the introduction of countermeasure equipment.

b. Suppression of load fluctuation

Activities were divided into the Input Stage, Selection Stage, Study and Evaluation Stage to achieve high-level objectives, project objectives, and expected results. In the input stage, the output and voltage fluctuations and grasped the status of the introduction of variable renewable energy were measured and analyzed, in order to select the MV distribution system that is highly influenced by load fluctuations as a pilot site. In the Selection Stage, the influence of load fluctuations by medium pressure feeder was investigated to the WG members under the control of each DD and LECO, and target feeders of medium and low pressure were selected. In the Study and Evaluation Stage, the target feeder was selected in the Selection Stage, the recorded data were collected and the missing data were measured, and their data were analyzed and the impact of the load variation were evaluated based on the collected and measured data.

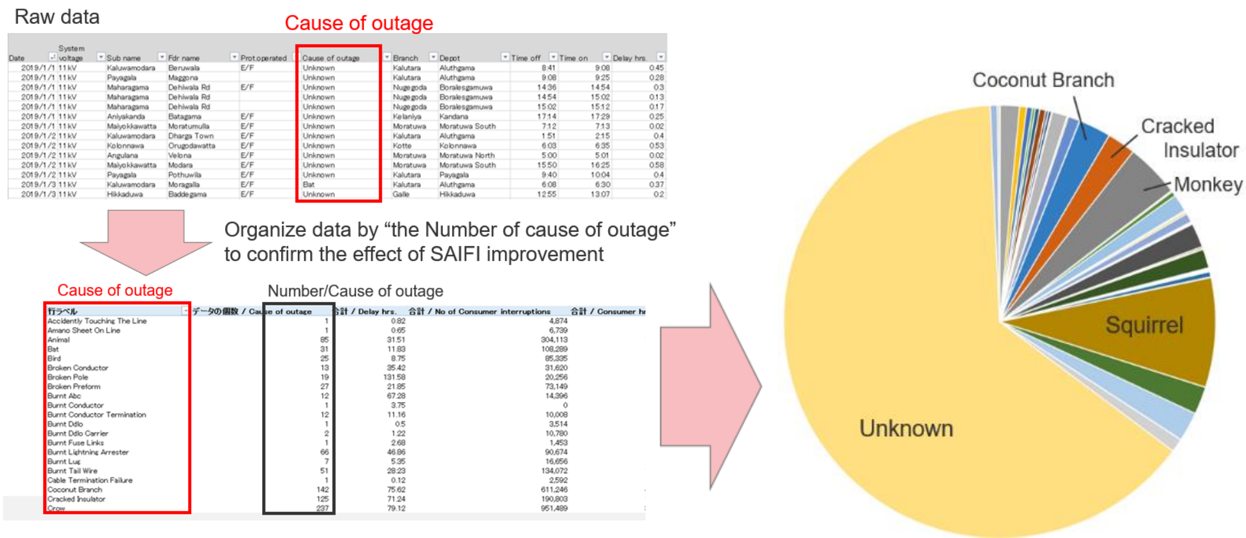
(3) Outcome of Activities

Results 3 (WG3): Strengthening power distribution and operation capacity

a. Strengthening Capacity to Enhance Reliability of Supply (WG3-1)

i) Analysis of power failure records

In Sri Lanka, we reviewed the power outage records for fiscal year 2019 and explained how to quantitatively analyze the failure trends and the priority of countermeasures for each substation and distribution line by categorizing the cause of the failure (contact with others, natural disaster, etc.) and the type of failure (ground fault, short circuit fault, etc.). In addition, by having C/P calculate SAIFI and SAIDI based on these records, technology was transferred for data and analysis necessary for the calculation of SAIDI and SAIFI.



(Source) JICA Expert Team

Figure 3-42 Organizing and Analyzing Failure Records

ii) Assessment of the current state of operation and management

In the course of reviewing the power failure records for FY2019, the records of "information (specific cause of failure, failure status photographs, etc.)" necessary to consider countermeasures and early recovery measures against failure were insufficient. Therefore, we proposed a new form of power outage records that covers information on the cause of failure, damaged equipment, etc. and discussed with them. After explaining and approving the power outage records at each C/P to the top management of the organization and explaining them to the person in charge who actually prepared the power failure records, the accumulation of power outage records using this form was started in July 2021.

The accuracy of the failure records was improved by checking the status of implementation of the failure records about once every three months, thoroughly recording the missing information, and implementing follow-up measures such as sharing of the power outage record creation points.

iii) Proposal for power outage countermeasures using equipment in Japan

In order to broaden the knowledge of C/P, we introduced to C/P an overview of the power outage countermeasure equipment (Japanese products) widely used in Japan, as well as the range of countermeasures available and the effects thereof, because the power outage countermeasures used in Sri Lanka were limited. It proposed the introduction of Abrasion Resistance cover (ARC), over-current indicator (OCI), and ground fault detector (GFD), which are relatively wide-ranging and economical power outage countermeasures, as well as the introduction of Fault Locating System (FLS) and Time Sequential Sectionalizer (TSS), which are capable of automatically identifying fault points and fault sections.

iv) Selection of power outage countermeasure equipment

With a view to introducing equipment in Sri Lanka, detailed specifications for each proposed equipment and examples of its use in Japan were explained, and C/Ps and C/Ps were discussed on specific equipment installation and operation methods to deepen the understanding of C/Ps. In addition, each C/P analyzed past failure conditions and failure trends toward the selection of candidate distribution lines (MV), and selected distribution lines (MV) that were considered to be highly effective from the viewpoints of SAIDI and SAIFI based on the characteristics of each countermeasure equipment.

Table 3-28 Pilot Project Distribution Lines

Equipment	Installation Feeder/Province				
	DD1	DD2	DD3	DD4	LECO
Abrasion Resistance Cover for Conductor	Pooja Nagaraya Feeder from Town primary	—	—	Matara F1	Kaluwamodara
Over Current Indicator	Habarana F7	Kiribath -kumbura F9	Ratnapura F2	Deniyaya F4	Beligaha Feeder Boossa
Ground Fault Detector	Norochcholai F2	Valaichchenai F06	Mahiyan -ganaya F3	Rathmalana F2	Hikkaduwa Feeder Wewalamilla

(Source) JICA Expert Team

v) Study of specifications of equipment to be introduced and on-site investigation

Following the decision on the equipment to be introduced, individual specifications were examined and on-site investigations were carried out. However, travel restrictions continued due to the impact of the new coronavirus, and travel to the site by JICA experts remained unavailable. Since the expansion of the new coronavirus was unlikely to be halted, in order to control the delay of the pilot project, (a) the equipment (ARC, OCI, GFD) that can be checked by the C/P and the specifications determined by the interview, and (b) the equipment (FLS, TSS) that requires the on-site survey by JICA experts due to their high expertise, were separated, and the investigation, field survey, and procedures necessary for the introduction of (a) were carried out in advance.

vi) Estimation, implementation, and verification of the expected effects of the pilot project

The technology was transferred to C/P to calculate the expected improvement effects of SAIFI and SAIDI through the introduction of each countermeasure equipment (ARC, OCI, GFD, FLS, and TSS). In addition, we deepened their understanding by having each C/P calculate SADI and SAIFI and explain the calculation parameters within WG3-1 members.

Regarding countermeasure equipment (ARC, OCI, GFD) which was decided to be introduced in advance, technology transfer was carried out with photographs and demonstration videos because C/P itself needed to acquire construction technology in anticipation of the horizontal deployment of each countermeasure equipment in the future. Even after the delivery of the equipment, the C/P carried out the construction of all the countermeasure equipment based on the construction plan planned by C/P. JICA Experts checked the construction status and conducted on-the-job training at the sites extracted after installation of the equipment. As for GFD, since it is necessary for C/P to operate it every time a power failure occurs, face-to-face training by manufacturers was conducted for two days. Using C/P's training facilities, C/P actually operated and acquired the skills along with the demonstration by the manufacturer.

On the other hand, since the impact of Covid-19 was mitigated, the field survey was completed for equipment (FLS and TSS) requiring on-site investigation by JICA Experts, and the technical approval of the CEB Transmission Division executives was obtained. However, due to the impact of Sri Lanka falling into an economic crisis at that time, it was necessary for CEB to bear some of the costs for the introduction of countermeasure equipment (FLS and TSS) and their pilot projects were cancelled. However, there are their high expectations for TSS, and when the economic situation in Sri Lanka recovers, C/P of both CEB and LECO will actively consider and discuss to introduce TSS within their organizations.

OCI construction

GFD education by manufacturer

Installation of ARC

Confirmation and OJT of OCI installation

(Source) JICA Expert Team

Figure 3-43 Pilot Project Implementation Status

Table 3-29 to Table 3-33 show the results during the pilot project implementation period (from installation completion month to evaluation month) for each countermeasure equipment. The index values SAIDI and SAIFI are calculated based on the results during the introduction period of several months for the feeders with ARC and OCI, but power outage factors other than tree contact are included in the ARC evaluation, and power outage factors other than OC failure are included in the OCI evaluation. For this reason, it is difficult to identify only the effects of their countermeasures for SAIDI and SAIFI, so the number of failures before and after introduction by limiting to failures related to each were compared.

As for the GFD, the procurement was delayed and the introductory training was conducted in December 2022, so the C/P will use it when a failure occurs and confirm the effect by the same method. In addition, ARC and OCI will continue to be installed and operated, and similar effects will continue to be confirmed after the evaluation month.

Table 3-29 SAIFI and SAIDI of the ARC introduction feeders before and after the ARC introduction

Division	DD1	DD4	LECO
Pilot Feeder	①Town PSS - Pooja Nagaraya	②Matara PSS - F1 Kalidasa Road	③Kaluwamodara 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

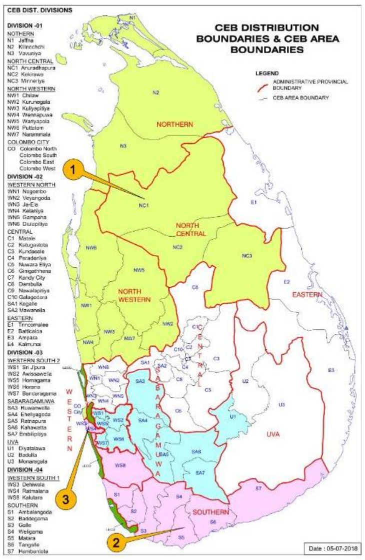


Table 3-30 Tree touching failure number in of the ARC introduction feeders before and after the ARC introduction

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

Table 3-31 SAIFI and SAIDI of the OCI introduction feeders before and after the OCI introduction

Division	DD1	DD2	DD3	DD4	LECO
Pilot feeder	① Habarana F7 (1)	②Kiribath kumbura F9 (2)	③ Ratnapura F2 (3)	④ Deniyaya F4 (4)	⑤ 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

Table 3-32 OC failure number in of the OCI introduction feeders before and after the OCI introduction

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

Although it was not possible to introduce TSS in this project, TSS can automatically identify a faulty section and supplies power to sound sections, so the expected effect was calculated if TSS were introduced at the selected candidate pilot site. Since short-term failures are not accounted for, it is expected that the SAIFI of the feeder's consumers will be significantly improved.

Table 3-33 Assumed failure data of Seethawaka F1 in 2022 (with or without TSS)

Result		Assumption			
Fault section	Fault number (Mar~Oct, 2022)	Supplying section	Outage section	SAIFI without TSS	SAIFI with TSS
1	29	2, 3, 4, 5	1	43.5	8.7
2	29	1, 3, 5	2, 4	43.5	17.4
3	32	1, 2, 4, 5	3	48.0	9.6
4	39	1, 2, 3, 5	4	58.5	11.7
5	28	1, 2, 3, 4	5	42.0	8.4
Total	157	-	-	235.5	55.8

Regarding the index values three years after the end of the project, based on the average improvement rate of SAIFI and SAIDI of the introduced feeders, the index values for FY2026 are the same for each target feeder. In addition to SAIFI and SAIDI, it is recommended to set the number of related failures additionally so that the effect of countermeasure equipment can be clearly judged. In addition, it is recommended to determine the person in charge and the feeder in charge of the target area in consideration of the site environment, organizational labor, etc. according to the current situation.

vii) Evaluation of cost effectiveness of countermeasure equipment

To analyze the contribution of the countermeasure equipment to financial soundness, the approximate cost of introducing ARC, OCI and GFD and the effect due to the introduction were estimated and compared under the current assumed conditions, based on the results of the pilot project in vi) above. In the comparison with the total cost of the equipment (A) and installation or education cost (B) in the first year, the annual electricity sales incomes [increase in electricity sales due to avoiding power outages or shortening the recovery time from failures x electricity charges] (C) and the annual reduction amount in labor costs for patrol and restoration [technical staff unit cost × number of technical staff × reduction time in patrol and restoration work] (D) were integrated until the condition that (A+B)＜Σ(C+D) held, where the needed integration years were counted as the cost recovery year. Although the evaluation results differs depending on future electricity charges and technical staff operation system, if the system can be operated for more than the cost recovery period, it will be possible to contribute to the organization's finances. It is expected that C/P in technical departments will continue to take a similar approach to the financial soundness of their organizations and analyze their contributions in response to changes in various systems.

(a) ARC

Evaluation period: March 2022 (installation completion month) to October 2022

Equipment cost (estimated): 16,500,000 LKR (33,000 LKR × 500 pieces)

Countermeasure equipment	Equipment fee (First year) (thousand LKR)	Installation fee (First year) (thousand LKR)	Electricity sales income (10 years) (thousand LKR)	Patrol/restoration work cost reduction (10 years) (thousand LKR)	Cost payback (year)
ARC	16,500	250	17,560	554	10

(b) OCI

Evaluation period: August 2022 (installation completion month) to October 2022

Equipment cost (estimated): 5,843,000 LKR (194,767 LKR × 30 pieces)

Countermeasure equipment	Equipment fee (First year) (thousand LKR)	Installation fee (First year) (thousand LKR)	Electricity sales income (First year) (thousand LKR)	Patrol/restoration work cost reduction (First year) (thousand LKR)	Cost payback (year)
OCI	5,843	36	37,113	132	1

(c) GFD

Evaluation period: November 2022 (month of establishment completion) to December 2022

Total equipment cost (unit price): 73,500,000 LKR (14,700,000 LKR × 5 sets)

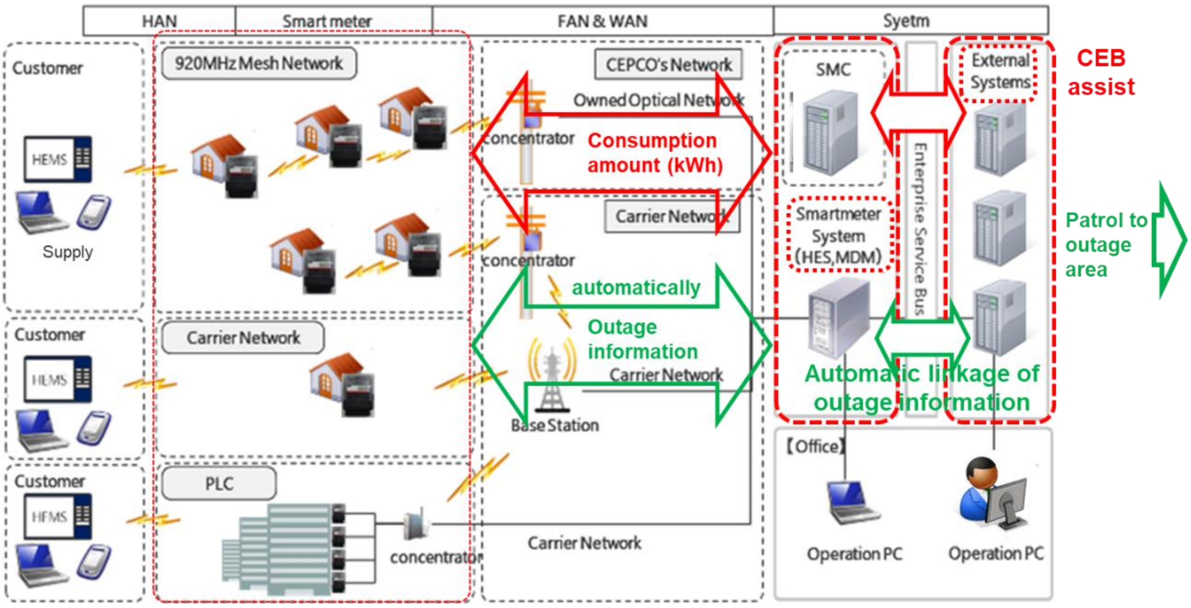
※Manufacturer education (by 6,321,000 LKR)

Countermeasure equipment	Equipment fee (First year) (thousand LKR)	Installation fee (First year) (thousand LKR)	Electricity sales income (8 years) (thousand LKR)	Patrol/restoration work cost reduction (8 years) (thousand LKR)	Cost payback (year)
GFD	73,500	6,321	86,200	408	8

iv) Outage area detection by utilizing a smart meter

Since the introduction of TSS and FLS to the pilot site was cancelled, as an alternative, methods that can similarly contribute to the early detection of power outage areas without the introduction cost of equipment were investigated.

The introduction of smart meters is progressing in Japan, and it is possible to identify power outage areas more precisely than those specified by TSS, based on power outage information of individual smart meters. The introduction of 1,000 smart meters began as a pilot project in Sri Lanka in 2019, and currently the metering data is linked to “CEB Assist,” and the efficiency of operations such as invoicing was realized. As a way to further utilize smart meter data, how to link and use the data in a system in identifying power outage areas and ensuring public safety by disconnection information was introduced. Figure 3-44 shows a system interconnection diagram using a smart meter. The part shown in red is the flow of smart meter power consumption to CEB assist, and the part shown in green is an image of utilization of power outage information.



(Source) JICA Expert Team

Figure 3-44 System interconnection diagram using a smart meter

It was found that the function of the smart meters currently being introduced is limited to power consumption acquisition in order to keep the costs down and it was not possible to respond by changing the software alone. It is expected to contribute to the identification of power outage areas, the estimation of the failure causes by phase disconnection or outage scale, the securement of public safety, etc.

b. Strengthening Capacity to Contribute to Load Fluctuation Suppression (WG3-2)

i) To study load fluctuation according to the introduction of Mass VRE

In order to implement technology transfer for load fluctuation measures according to the introduction of VRE in the power distribution system, existing load fluctuation conditions were studied. As shown in Table 3-34, although there were aggregate records by District and Province, there were no aggregate records by unit of distribution lines to measure the impact of load fluctuations. Therefore, the individual interviews on the influences by 33 kV and 11 kV distribution lines were conducted. It was confirmed that reverse currents were occurring at several distribution substations and MV distribution lines, but only the F5 of the Valachchenai substation was the power distribution system where problems were identified obviously, as shown in

Table 3-35.

Table 3-34 Progress of Battle of Solar Energy as of December 2018

Division	Province	District	Before Soorya Bala Sangramaya (2016-09-06)		After Soorya Bala Sangramaya					
			Net Metering		Net Metering		Net Accounting		Net Plus	
			No of Consumers	Capacity (KW)	No of Consumers	Capacity (KW)	No of Consumers	Capacity (KW)	No of Consumers	Capacity (KW)
DD1	North Western	Kurunegala	111	482	104	495	168	920	24	1,276
		Puttalam	101	461	127	738	180	964	3	268
		Total	**212**	**943**	**231**	**1,233**	**348**	**1,884**	**27**	**1,544**
	North Central	Anuradhapura	41	396	53	423	84	815	25	560
		Polonnaruwa	38	181	37	209	33	283	2	4
		Total	**79**	**577**	**90**	**632**	**117**	**1,098**	**27**	**563**
	Northern	Jaffna	146	596	138	624	340	1,599	33	238
		Kilinochchi	9	157	4	85	8	22	3	853
		Mullaitivu	2	14	4	31	2	34	1	350
		Vavuniya	5	11	9	93	12	47	2	26
		Mannar	6	20	6	22	4	7	2	79
		Total	**168**	**798**	**161**	**855**	**366**	**1,709**	**41**	**1,546**
	Colombo City	**Colombo**	**1,402**	**11,500**	**714**	**7,139**	**160**	**1,321**	**17**	**1,368**
	DD1 Total		**1,861**	**13,819**	**1,196**	**9,860**	**991**	**6,013**	**112**	**5,020**
DD2	Eastern	Batticaloa	17	106	10	69	0	0	1	1,650
		Ampara	26	155	63	326	15	130	2	1,010
		Trincomalee	8	105	16	155	3	19	2	103
		Total	**51**	**366**	**89**	**550**	**18**	**149**	**5**	**2,763**
	Central	Nuwa Eliya	8	259	4	33	1	16	0	0
		Kandy	167	767	125	1,203	81	506	20	1,489
		Matale	16	128	11	422	30	326	2	142
		Kegalle	34	985	81	6,862	34	265	6	287
		Total	**225**	**2,139**	**221**	**8,521**	**146**	**1,113**	**28**	**1,918**
	WPN	**Gampaha**	**613**	**3,989**	**540**	**2,570**	**670**	**3,074**	**36**	**6,856**
	DD2 Total		**889**	**6,494**	**850**	**11,641**	**834**	**4,336**	**69**	**11,537**
DD3	Sabaragamuwa	Rathnapura	46	337	99	918	119	673	28	2,437
		Kegalle	5	19	55	181	23	136	7	417
		Total	**51**	**356**	**154**	**1,099**	**142**	**809**	**35**	**2,854**
	Uva	Badulla	18	142	58	476	28	138	3	499
		Monaragala	5	72	51	423	11	144	6	558
		Total	**23**	**214**	**109**	**899**	**39**	**282**	**9**	**1,057**
	WPS II	Colombo	811	2,599	1,303	8,000	481	3,267	52	5,590
		Kalutara	55	187	168	1,542	80	423	13	1,991
		Total	**866**	**2,786**	**1,471**	**9,541**	**561**	**3,691**	**65**	**7,581**
	DD3 Total		**940**	**3,356**	**1,734**	**11,540**	**742**	**4,781**	**109**	**11,493**
DD4	Southern	Galle	71	555	76	740	60	483	4	134
		Matara	106	849	191	2,227	252	2,359	23	4,298
		Hambantota	38	515	78	608	82	871	13	911
		Total	**215**	**1,919**	**345**	**3,576**	**394**	**3,713**	**40**	**5,342**
	WPS I	Colombo	732	3,342	614	4,926	311	1,761	14	3,110
		Kalutara	30	127	49	402	37	206	6	729
		Total	**762**	**3,469**	**663**	**5,328**	**348**	**1,967**	**20**	**3,839**
	DD4 Total		**977**	**5,388**	**1,008**	**8,903**	**742**	**5,681**	**60**	**9,182**
CEB Total			**4,667**	**29,057**	**4,788**	**41,944**	**3,309**	**20,811**	**350**	**37,231**

(Source) JICA Expert Team

Table 3-35　MV Distribution Lines Having Relatively Mass VRE

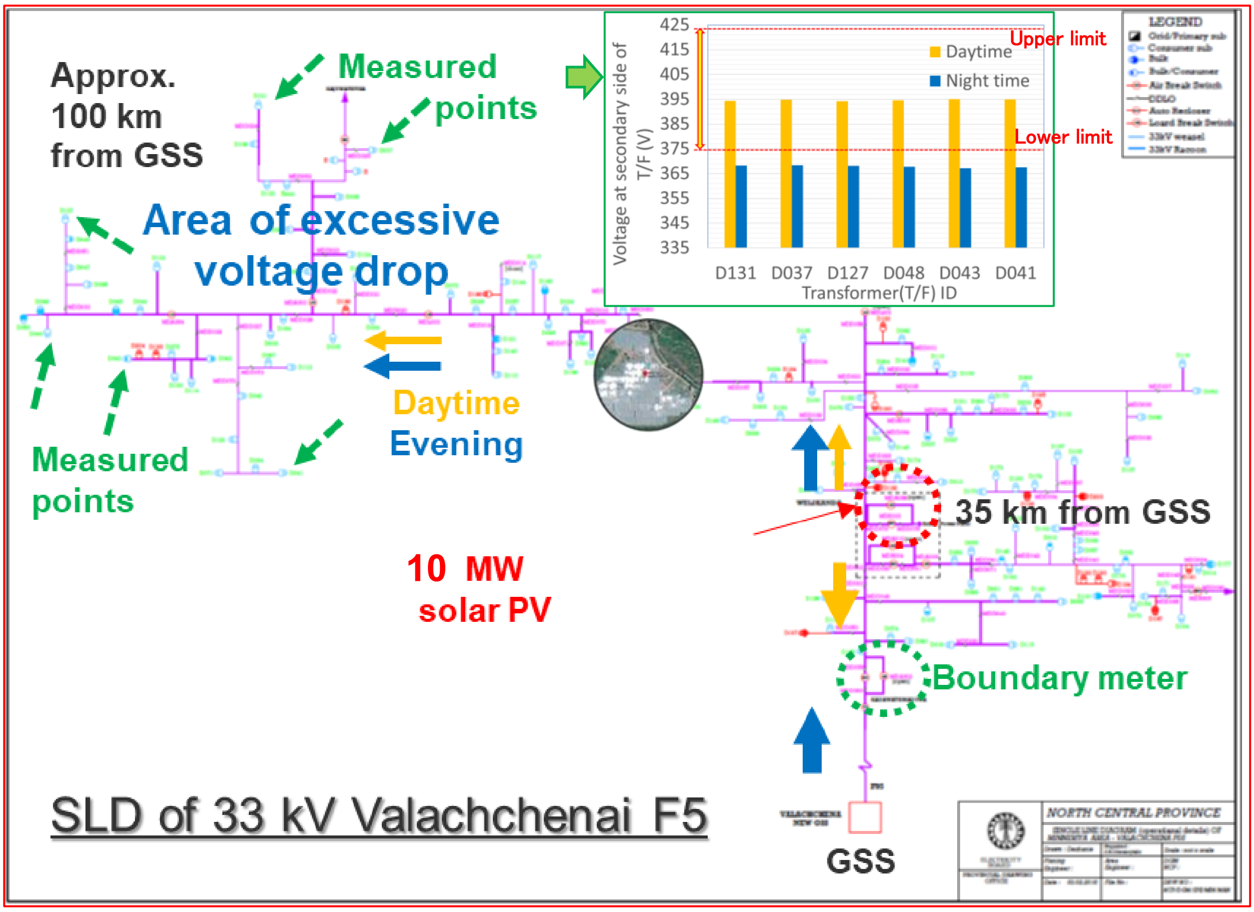
DD LECO	Substation	2ndary kV	Feeder number	Active power flow		Reactive power flow		Power factor	Current umbalance			Voltage		Voltage umbalance			Harmonic injection		Freqency
				Forward MW	Backward MW	Forward MW	Backward MW		R %	Y %	B %	Max. kV	Min. kV	R %	Y %	B %	Max. %	at degree n %	Hz
DD1	Valachchenai	33	F05	No pre-identified problem	**Identified problem**	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
	Norochcholei Wind	33	F02	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
	Polonnaruwa	33	F01 Walikanda	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
DD2	Sapugaskanda	33	F0	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
	Veyangoda	33	F08	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
DD3	Panadura	33	F01	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
	Pannipitiya	33	F04	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
	Horana	33	F04	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
	Horana	33	F06	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
DD4	Hambantota	33	F02	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
	Hambantota	33	F04	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
	Panadura	33	F07	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem
	Panadura	33	F08	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem	No pre-identified problem

(Source) JICA Expert Team

On the other hand, it was confirmed with C/P that there are many low-voltage (hereinafter referred to as “LV”) distribution lines where solar power generation equipment for residential use is in progress and problems such as excessive voltage occur during power generation. The technology transfer for responsiveness to issues is described later in “iii) Measurement and analysis evaluation of load fluctuations in the LV system, and consideration of countermeasures.”

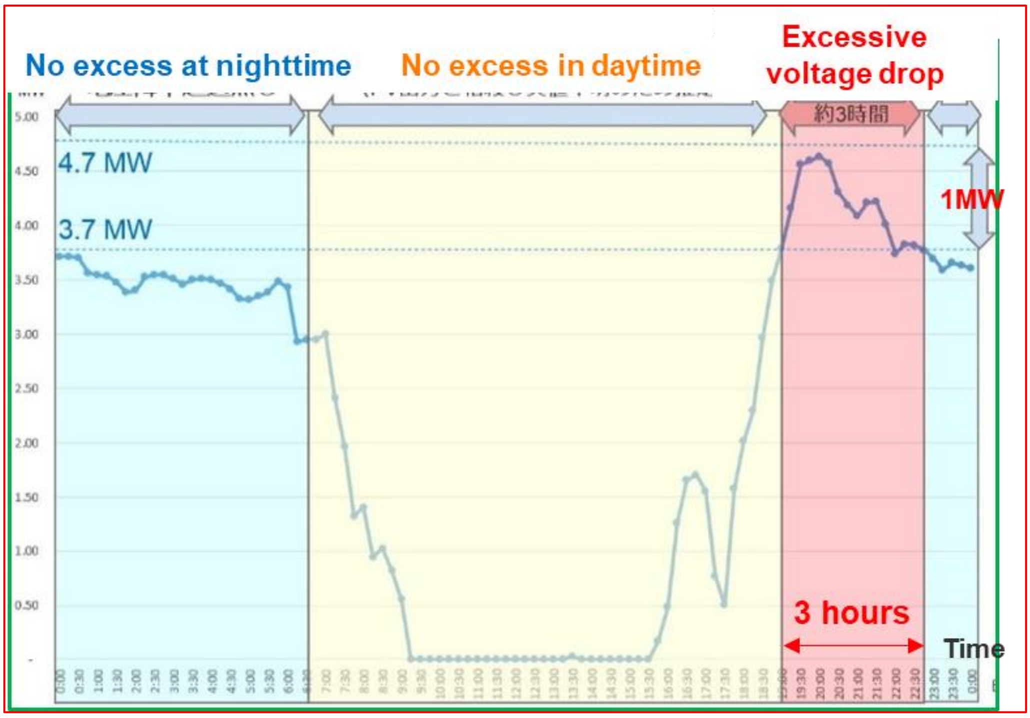
ii) Measurement, analysis and evaluation of load fluctuations, and consideration of measures using BESS for an MV distribution systems

Figure 3-45 shows the Valachchenai GSS F5 where 10 MW-class large-scale solar PV is installed. As a result of quantitative evaluation of reverse flow caused by VRE in the feeder, it was confirmed that there was no problem for the time being at the level below the reference capacity value. Meanwhile, the voltage at the end of the feeder was actually measured, and it was found that the lower limit was exceeded. As a result of examining the measures by the battery system to improve the exceedance of the standard value, we found that a 1 MW-3 hour class battery system might be necessary as shown in Figure 3-46.



(Source) JICA Expert Team

Figure 3-45 Valachchenai GSS F5 System Diagram



(Source) JICA Expert Team

Figure 3-46 Power flow at the boundary meter Between DD1 and DD2 in 33 kV Valachchenai F5 having 10 MW class solar-PV generator

Through the above activities, C/P learned how to measure and analyze load fluctuations according to the introduction of VRE, and understood what measures are effective. In addition, it was understood how to calculate how much battery capacity is required when implementing measures using a storage battery system.

The capacity of the storage battery system required for the countermeasure was estimated by the above investigation, but the introduction of the storage battery system was cancelled because the cost of the storage battery system that satisfied the capacity exceeded the project budget. As an alternative, other voltage suppression countermeasures for the voltage problem in MV systems are shared as follows, and also countermeasures for LV systems which has a lot of problems are studied as referred to “iii) Measurement and analysis evaluation of the amount of load fluctuation in the LV system, and consideration of countermeasures.”

The feeder, which is the only problem among the whole MV systems, has an issue of only excessive voltage, and other economic countermeasures are also possible. For this reason, technology transfer was also implemented regarding voltage countermeasures such as Step Voltage Regulator (SVR) and Thyristor type step Voltage Regulator (TVR). At the time of discontinuation, it was stubbornly recognized that measures other than BESS were not necessary, but eventually understood the effect and economic efficiency of these countermeasure devices, and as shown in Table 3-36, SVR in the future The C/P's action plan indicates that the introduction of TVR, etc. will be considered.

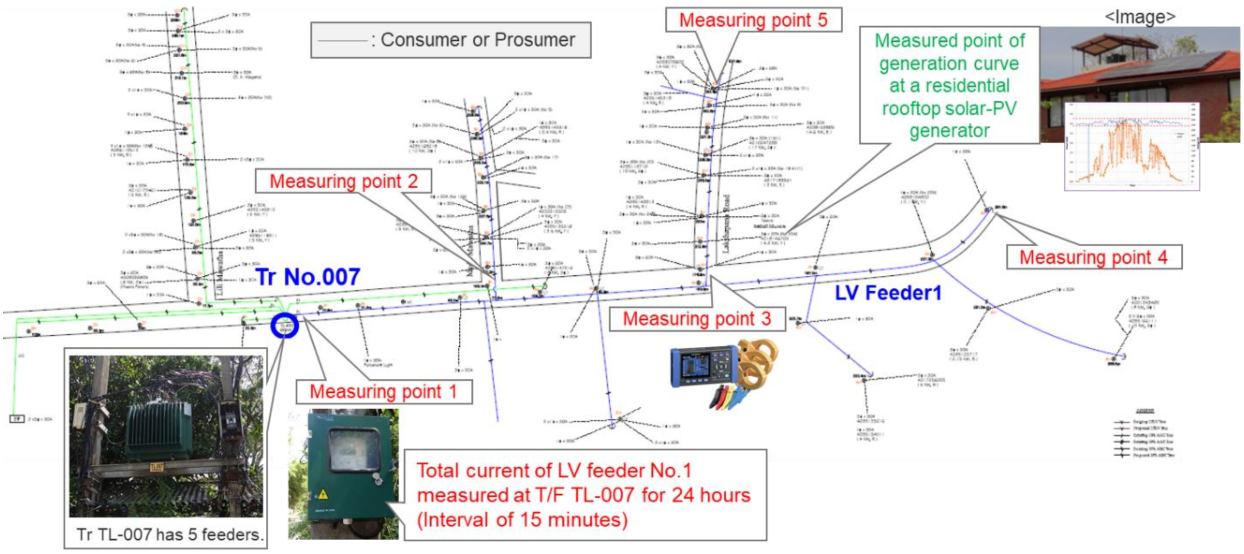
Table 3-36 One of the action plans regarding countermeasures against load fluctuation in MV systems

My Actions	1st Q	2nd Q	3rd Q	4th Q
Procure adequate measuring equipment	—			
Collect data and analysis of down stream supply performance (voltages fluctuations) in longer / highly solar connected MV feeders		—		
Survey the potential of new addition of rooftop solar and other solar generation facilities	—	—		
Recommend the solution and prepare specification for TVR			—	
Procure and install TVR to the system to mitigate the rapid voltage fluctuation				—

iii) Measurement and analysis of load flactuation in LV system, and investigation of battery system measures

As described in i) above, there are a lot of problems with voltage fluctuations in LV distribution lines, so the related technology to solve these problems was transferred. In addition, for the data measurement at the Valachchenai F5 mentioned above, the CEB distribution department had to borrow measuring instruments from the CEB other departments, so the measuring instruments was granted CEB and LECO in this project.

Since there are many problems with voltage fluctuations in LV distribution lines, in the beginning the No.1 feeder on the secondary side of the TL-007 transformer in the Ethulkotte area (DD3) was selected as the target line for problem to be solved and investigated. Many rooftop solar power generation systems are connected to this line, and there is a "rejection to power generation" due to the exceedance of the voltage limit and a "rejection to connection of new power generation facilities." Figure 3-47 shows the LVdistribution system diagram of the line.



(Source) JICA Expert Team

Figure 3-47 LV distribution system diagram on secondary side of TL-007 transformer

In addition to acquiring the power generation curve of the rooftop solar power generation facility (owned by the customer: 4 kW) and the voltage fluctuation curve of the connected points, the load fluctuation was measured at the branch point and the end of the line, and the actual voltage fluctuation was quantitatively grasped. As a result, it was confirmed that the voltage fluctuation was mostly within the reference value as far as the measurement periods, since the measurement had to be conducted mostly in cloudy and rainy days. In the same way, the measurement will be conducted to examine the voltage excess, etc.

In addition, as shown in Figure 3-48, all the loads and all the distributed solar PV generators interconnected to the distribution lines were modeled for each phase, and the distribution and fluctuation of the output and voltage at each point were simulated. It is possible to grasp in advance the effects of countermeasures such as thickening of lines and introduction of BESS by modeling.

TL-007(D) F4 | Racoon, etc. | (Peak demand) / (Total contract capacity): 290 A peak; R 7%, Y 7%, B 7%, 3 7% | (Peak generation) / (Facility capacity): Time: 12:00; R 81%, Y 81%, B 81%, 3 81% | Standard 230 V | V at 2ndary side of T/F: R 240, Y 240, B 240

Main route of LV line				LV line specifications					Customer load at end side pole			R	Y	B	3	R	Y	B	3	R	Y	B	3
Distance from TL-007	Pole number at S/S side of LV line span	Pole ID at end side of LV line span	Length (Pole span)	LV line (wire) number	Wire type	Wire size of 3-phase	Resistance of 3-phase, R3	Reactance of 3-phase, X3	Customer number of 1-phase	Customer number of 3-phase	Customer ID, etc. connected to LV line, if needed.	a) Contract capacity of consumers				Total contract capacity				Power demand by [(peak demand) / (Total contract capacity)]			
m			m	2,3,4,---	Cu, Al, etc.	mm^2	ohm/km	ohm/km				A	A	A	A	A	A	A	A	A	A	A	A
0	TL-007(D)	**P**	0	4	Cu		0.5781	0.4695				0	0	0	0	630	587	780	1,740	44	41	55	122
16	P	**A1**	16	0	ABC(Al)		0.5781	0.4695				0	0	0	0	630	587	780	1,740	44	41	55	122
21	A1	**A2**	5	1	ABC(Al)		0.5781	0.4695				0	0	0	0	630	587	780	1,740	44	41	55	122
63	A2	**A3**	41	1	ABC(Al)		0.5781	0.4695	17			210	150	150	0	630	587	780	1,740	44	41	55	122
74	A3	**B0**	11	1	ABC(Al)		0.5781	0.4695				0	0	0	0	420	437	630	1,740	29	31	44	122
109	B0	**A4**	36	1	ABC(Al)		0.5781	0.4695		1		0	0	0	60	210	210	420	1,200	15	15	29	84
140	A4	**A5**	31	3	ABC(Al)		0.5781	0.4695	2	2		30	0	30	60	210	210	420	1,140	15	15	29	80
161	A5	**A6**	21	1	ABC(Al)		0.5781	0.4695		2		0	0	0	60	120	210	240	1,050	8	15	17	74
198	A6	**A7**	37	1	ABC(Al)		0.5781	0.4695		1		0	0	0	30	30	30	60	270	2	2	4	19
227	A7	**A8**	30	1	ABC(Al)		0.5781	0.4695	1			0	30	0	0	0	30	30	150	0	2	2	11
262	A8	**A9**	34	1	ABC(Al)		0.5781	0.4695	1			0	0	30	0	0	0	30	0	0	0	2	0
252	A8	**A10**	24	1	ABC(Al)		0.5781	0.4695	0	2		0	0	0	60	0	0	0	150	0	0	0	11
289	A10	**A11**	37	2	ABC(Al)		0.5781	0.4695	0	3		0	0	0	90	0	0	0	90	0	0	0	6
206	A7	**A12**	8	1	ABC(Al)		0.5781	0.4695	1	1		0	0	30	30	30	0	30	90	2	0	2	6
223	A12	**A13**	18	2	ABC(Al)		0.5781	0.4695	1	2		30	0	0	60	30	0	0	60	2	0	0	4
	A5	**A14**		6	ABC(Al)		0.5781	0.4695	7	1		60	0	150	30	60	0	150	30	4	0	11	2
175	A6	**A15**	14	1	ABC(Al)		0.5781	0.4695	1	1		30	0	0	60	90	180	180	720	6	13	13	50
213	A15	**A16**	38	2	ABC(Al)		0.5781	0.4695	1	3		0	30	0	90	60	180	180	660	4	13	13	46
255	A16	**A17**	42	5	ABC(Al)		0.5781	0.4695	3	2		30	60	0	60	60	150	180	570	4	11	13	40
285	A17	**A18**	30	5	ABC(Al)		0.5781	0.4695	2	4		0	0	60	120	30	90	180	510	2	6	13	36
309	A18	**A19**	24	4	ABC(Al)		0.5781	0.4695	3	2		0	30	60	60	30	90	120	390	2	6	8	27
337	A19	**A20**	29	3	ABC(Al)		0.5781	0.4695	2	2		0	0	60	60	30	60	60	330	2	4	4	23
363	A20	**A21**	26	4	ABC(Al)		0.5781	0.4695	1	4		30	0	0	120	30	60	0	270	2	4	0	19
391	A21	**A22**	29	7	ABC(Al)		0.5781	0.4695	2	4		0	60	0	150	0	60	0	150	0	4	0	11
105	B0	**B1**	32	1	ABC(Al)		0.5781	0.4695	1	1			30		30	210	227	210	540	15	16	15	38
150	B1	**B2**	45	2	ABC(Al)		0.5781	0.4695	2	0		30	30			210	197	210	510	15	14	15	36
195	B2	**B3**	45	9	ABC(Al)		0.5781	0.4695	6	4		120	30	30	180	180	167	210	510	13	12	15	36
208	B3	**B4**	13	4	ABC(Al)		0.5781	0.4695	1	3			30		90	60	137	180	330	4	10	13	23
232	B4	**B5**	25	2	ABC(Al)		0.5781	0.4695	2	1				60	30	60	107	180	240	4	7	13	17
	B5	**B5A**	9	6	ABC(Al)		0.5781	0.4695	2	0			60			60	107	120	210	4	7	8	15
249	B5A	**B6**	9	6	ABC(Al)		0.5781	0.4695	4	3		30		90	90	60	47	120	210	4	3	8	15
289	B6	**B7**	40	6	ABC(Al)		0.5781	0.4695	2	4		30	30		120	30	47	30	120	2	3	2	8
330	B7	**B8**	41	1	ABC(Al)		0.5781	0.4695	1	0	**BESS assumed**		17	30		0	17	30	0	0	1	2	0

Pole ID at end side of LV line span	Customer RE at end side pole			Remarks	R	Y	B	3	R	Y	B	3	R	Y	B	3		R	Y	B	R	Y	B
	Customer number of 1-phase	Customer number of 3-phase	Customer ID, etc. connected to LV line, if needed.	Solar PV specifications, etc., if needed.	RE facility capacity				Total contract capacity				Generating amount at peak				Power factor	Total current of 1 and 3 phases load and RE			Voltage		
				-	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW		A	A	A	V	V	V
P									17	22	12	80	14.1	17.7	9.5	64.8	0.99	50	42	68	240.0	240.0	240.0
A1									17	22	12	80	14.1	17.7	9.5	64.8	0.99	50	42	68	239.1	239.3	238.8
A2									17	22	12	80	14.1	17.7	9.5	64.8	0.99	50	42	68	238.8	239.0	238.4
A3									17	22	12	80	14.1	17.7	9.5	64.8	0.99	50	42	68	236.5	237.1	235.3
B0									17	22	12	80	14.1	17.7	9.5	64.8	0.99	36	32	57	236.1	236.7	234.6
A4		1	4295147516					8.0	11	19	7	53	8.9	15.6	5.5	42.9	0.99	23	13	43	235.2	236.2	233.0
A5									11	19	7	45	8.9	15.6	5.5	36.5	0.99	28	18	48	234.2	235.6	231.3
A6									11	19	7	45	8.9	15.6	5.5	36.5	0.99	15	12	29	233.9	235.3	230.6
A7									4	7	2	18	3.2	5.8	1.7	14.6	0.99	-5	-9	-1	234.1	235.6	230.7
A8	1		4299104900			2.1			0	2	2	18	0.0	1.7	1.7	14.6	0.99	-11	-11	-11	234.4	236.0	231.0
A9									0	0	0	0	0.0	0.0	0.0	0.0	0.99	0	0	2	234.4	236.0	231.0
A10	1		4295125717				2.2		0	0	2	18	0.0	0.0	1.7	14.6	0.99	-11	-11	-13	234.7	236.3	231.4
A11		2	4201343405 /4295166111					18.0	0	0	0	18	0.0	0.0	0.0	14.6	0.99	-15	-15	-15	235.3	236.9	232.0
A12									4	5	0	0	3.2	4.1	0.0	0.0	0.99	4	0	8	234.0	235.6	230.6
A13	2		4295135216 /4217256205		4.0	5.0			4	5	0	0	3.2	4.1	0.0	0.0	0.99	2	-2	4	234.0	235.7	230.5
A14									0	0	0	0	0.0	0.0	0.0	0.0	0.99	6	2	13	234.2	235.6	231.3
A15									7	12	5	27	5.7	9.9	3.7	21.9	0.99	16	17	26	233.6	235.0	230.3
A16	1		4218146705			4.2			7	12	5	27	5.7	9.9	3.7	21.9	0.99	10	12	21	233.2	234.5	229.4
A17	1		4295142913			4.0			7	8	5	27	5.7	6.5	3.7	21.9	0.99	4	9	15	233.0	234.1	228.7
A18	1	1	4217199201 /4295118710		3.0			10.0	7	4	5	27	5.7	3.2	3.7	21.9	0.99	-3	5	11	233.1	233.9	228.3
A19		1	4210247200					17.0	4	4	5	17	3.2	3.2	3.7	13.8	0.99	4	9	10	233.0	233.7	228.0
A20	1		4208162805				4.6		4	4	5	0	3.2	3.2	3.7	0.0	0.99	20	23	22	232.3	233.0	227.3
A21	1		4295145319		4.0				4	4	0	0	3.2	3.2	0.0	0.0	0.99	16	18	19	231.9	232.5	226.8
A22	1		4203070600			4.0			0	4	0	0	0.0	3.2	0.0	0.0	0.99	11	10	11	231.5	232.1	226.5
B1									6	3	5	27	5.2	2.0	4.1	21.9	0.99	13	19	15	235.6	236.0	234.1
B2									6	3	5	27	5.2	2.0	4.1	21.9	0.99	11	15	12	235.1	235.3	233.5
B3	3		4295171018/4200315505/4295135518		4.0	2.5	5.0		6	3	5	27	5.2	2.0	4.1	21.9	0.99	9	12	12	234.7	234.7	232.9
B4									2	0	0	27	1.9	0.0	0.0	21.9	0.99	-8	1	4	234.8	234.7	232.8
B5									2	0	0	27	1.9	0.0	0.0	21.9	0.99	-14	-8	-3	235.1	234.9	232.9
B5A									2	0	0	27	1.9	0.0	0.0	21.9	0.99	-16	-10	-9	235.3	235.0	233.0
B6	1	1	4295143316 /4295169218		2.4			10.0	2	0	0	27	1.9	0.0	0.0	21.9	0.99	-16	-14	-9	235.5	235.1	233.1
B7									0	0	0	17	0.0	0.0	0.0	13.8	0.99	-10	-8	-10	235.9	235.5	233.5
B8				**BESS assumed**				17	0	0	0	17	0.0	0.0	0.0	13.8	0.99	-20	-19	-18	236.8	236.4	234.3

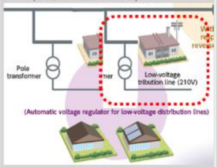
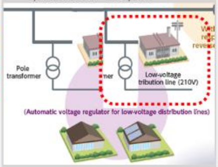
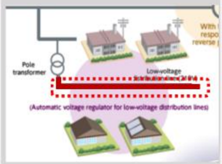
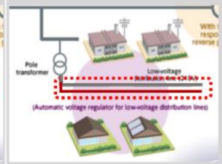
(Source) JICA Expert Team

Figure 3-48 Ethulkotte TL-007 Secondary Distribution Line Simulation Model

Furthermore, the costs of the conventional measures (LV line addition, LV area division, Wider LV line and so on) and the measures by introducing the storage battery system against the load fluctuation in the LV system were estimated, and it was confirmed with C/P that the conventional measures are more economical. Table 3-37 shows an example of cost estimation by countermeasures.

In addition, the contractor Chemonics informed that 100kVA class Battery Energy Storage System (BESS) supported by USAID would be introduced in 11kV distribution line in LECO but the details were undecided as of December 2022. JICA expert team shared the information at that time that the LV system had more problems than the MV system in Sri Lanka and the conventional measures were more economical than the BESS in LV system at present.

Table 3-37 Example of the cost estimation in conventional countermeasures and BESS

Measures	LV BESS	LV area division(1)	LV area division(2)	Wider LV line	LV line addition
Main spec.	300 kWh (100 kW - 3 hours)	Addition of transformer 100 kVA	33/0.4 kV 50 kVA (if approved)	Replacement to thicker line 1 km (70sqmm ABC)	Addition of 2nd line 1 km (70sqmm ABC)
Material Cost	657 thousand USD	6 thousand USD	5 thousand USD	10 thousand USD	5 thousand USD
Image	657,174 (USD) = 1,314,348 (LKR)  Multi- combined general-purpose residential BESS	6,034 (USD) = 1,206,800 (LKR) = 4,132 x 100 + 793,600 	5,001 USD = 1,000,200 (LKR) = 4,132 x 50 + 793,600 	9,500 (USD) = 1.9 million (LKR) 	4,600 (USD) = 0.92 million (LKR) 
Duration	3 hours	24 hours			
Useful life	15~20 years	25 years or more			

In this project, C/P acquired a series of measurement and analysis capabilities that were transferred technologically, and already shared them once within the organization. In the future, as shown in Figure 3-49 as an action plan, in order to suppress load fluctuations, C/P will continue to record the necessary data in the LV system, analyze the recorded data, compare and study the countermeasures (area division by adding transformers, that take into consideration the adoption of capacities less than 100 kVA, addition of LV lines, thicker lines, etc.) to try to solve the problem more economically.

MY ACTION PLAN

- Problem: Increased grid integration of NCRE
  - ✓ Power quality issues due to integration
- Goal: Regular measurement and analysis of electrical parameters using measuring instruments to reduce power quality issues

MY ACTIONS	1st Q	2nd Q	3rd Q	4th Q
Procurement of measuring equipment	■	■		
Select candidate feeders for measurement		■		
Data collection and analysis			■	
Implement countermeasures				■

MY ACTIONS	1st Q	2nd Q	3rd Q	4th Q
Collect information of recorded power quality issues in distribution transformers	——			
Survey and collecting of additional required data of the particular issue		——		
Measurement ,detail surveying and analyze the issues and the root cause of the power quality issues		——	——	
Recommending the solution 1.To install a new T/F 2.To use 33/0.4 kV transformer 3. To use less than 100kVA T/F 4. To construct additional feeder 5. To construct higher capacity feeder				——

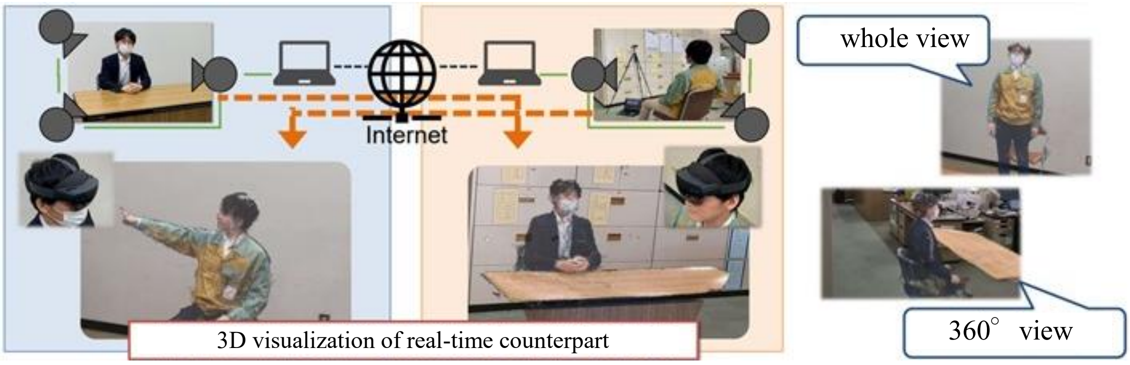
Figure 3-49 Examples of C/P action plans for load fluctuation in LV network

c. Verification of Remote Technology Transfer Using MR Technology

The effects of remote technology transfer using mixed reality (MR), one of the DX (Digital Transformation) technologies, were verified in the second and first field activities with the cooperation of C/P.

An MR is a technology that uses a dedicated display (HoloLens2) to display 3D images of actual objects as if they were in front of one's eyes. By superimposing "digital content" on "real-life scenes," digital content looks like it really exists on the spot. This technology is a further development of AR (expansion reality), which expands the virtual world into the real world.

Mixing real-time space with virtual space can be utilized to realize web conferencing as if they actually face each other, to realize practical training by remote personnel, and to realize remote support by sharing the actual work site.



(Source) JICA Expert Team

Figure 3-50 Three-Dimensional Video Remote Communication by MR

Since the MR technology is 3D, there are many problems, such as the need for data transfer with a very large capacity. Therefore, we proceeded with the verification step by step as shown below.

a. Verification of remote assist technology (2D). (one local site in Sri Lanka – another local site in Sri Lanka)

b. Verification of MR technology (3D). Confirm whether the 3D image is organized locally and recognized locally (Sri Lanka).

c. Verify that the 3D image built locally can be transferred to Japan (Sri Lanka-Japan).

In each of the above steps, verification was carried out from the following perspectives.

1. Is there any problem in the communication between Japan and Sri Lanka?
   - ✓ Region Code

     It started up without any problems and was able to cooperate with Japan.
   - ✓ Communication quality

     At the stage of remote assist technology (2D), even though five people participated in the Teams there was no problem regarding audio and image. In addition, although there was a slight delay and communication stop, they were not critical issues

For MR technology, we used Dialog's LTE (4G) line SIM to test communications using a WiFi router. Despite concerns about communications volume, Sri Lanka's LTE was generally as good as Japan's LTE. On the other hand, the size of the three-dimensional image is large, and at present, it is necessary to narrow the shooting range or reduce the frame rate. From these results, it has been found that it is important to reduce the amount of transmission while maintaining image quality and frame rate.

2. Can you feel differences in remote assist technology (2D) and MR technology (3D)?

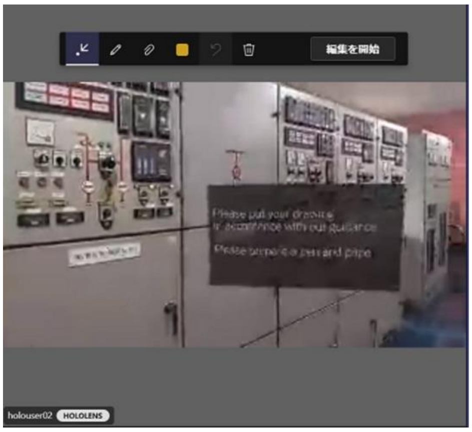
In remote assist technology, local engineers were able to confirm values and conditions and communicate them to Japan by being navigated to the target location (next room) with voice instruction from Japan and being instructed using arrow figures on the target meter that Japan wanted to confirm from among many meters in the sight. This time, since it was a verification, we did not actually operate the equipment, but we confirmed that it was possible to operate the equipment sufficiently. We also confirmed that the instructions from Japan can be conveyed in more detail by the instructions with PowerPoint and popping them up on the HoloLens2 screen of the local engineer.

In MR technology, two cameras were used to create 3D images that were projected to HoloLens2. Three-dimensional images can be projected in real time to check up, down, left, and right angles. In reality, the images taken are visualized from a remote location (this time in Japan). However, in this verification, in order to provide the field C/P with the experience, the creation and projection of 3D images and confirmation of 3D images using HoloLens2 were carried out on the Sri Lankan side without telecommunication.

The C/P who actually experienced the training said that it was necessary to improve the resolution, but it was effective to provide remote assistance. As for practical use in substations, opinions such as "it would be better to be able to display enlarged images" and "it would be better to be able to read the small letters on the operational panels and identify the communicating lines one by one in the panel." On the other hand, there was an opinion that "it would be sufficient to see via view camera attached to HoloLens2 as a supplement," From this trial, ideas for practical use were obtained.

(Source) JICA Expert Team

Figure 3-51 Experience by CEB members



(Source) JICA Expert Team

Figure 3-52 (left) Viewpoints of local engineers instructed by Japan (right)

3.9 Other Donor's Support

Information obtained from ADB, AFD, IFC, USAID, and Chemonics is shown below.

(1) ADB

Information was exchanged to confirm ADB's status of assistance activities. ADB mainly provides support for transmission lines and distribution lines, and currently provides support for five projects.

Table 3-38 ADB's Support

Video conferencing		Wednesday, June 24, 2020: 13:00-14:00 (Japan time: 16:30-17:30)
Participants		
	ADB	Prathaj Hapthanthri, Associate Project Officer (Energy), Sri Lanka Resident Mission Sainthan Sivanesan, Project Analyst, Sri Lanka Resident Mission Two people in total
	JICA experts	WG1: Team leader Hirano (Electricity Strategy), Deputy Team leader Yoshida (Electricity Strategy), and Member Tanihata (Systems and Policies) WG2: Member Yasutsune (Power System Analysis) WG3: Members Nishikawa (Distribution (planning, design, construction)/Coordinator) Five people in total
	JICA	Sri Lanka office, Representative Ms. Ichikawa, and a project specialist Mr. Serasinghe Two people in total
Status of support		(1) Green Energy Project • Moragolla Hydropower Station (30 MW), four substations, and 33 kV distribution lines (2) Green Energy Project • Transmission lines between Nadukeda and Mannar and the 33 kV distribution lines related to Smart meters (1,000 will be installed as a pilot project, and 10,000 will be installed thereafter) (3) Reliability Project •33kV distribution line interconnection with remote islands Hybrid system using solar power, storage batteries and a diesel generator for backup (4) Mannar Project • The Mannar Wind Project located on the west side. 200 million USD project to be completed in 2020 Reactor to be installed as a measure against voltage fluctuation (5) 500 Million USD Project • Cooperating with the Ministry of Finance to support Roof Top PV

(Source) JICA Expert Team

Video conferencing	Wednesday, September 8, 2021: 14:00-15:00 (17:30-18:30 JST)
Participants	
ADB	Prathaj Hapthanthri, Associate Project Officer (Energy), Sri Lanka Resident Mission Sainthan Sivanesan (Project Analyst [Energy], Sri Lanka Resident Mission) Two people in total
JICA experts	WG1: Team leader Hirano (Electricity Strategy), Deputy Team leader Yoshida (Electricity Strategy), and Member Tanihata (Systems and Policies) WG2: Member Yasutsune (Power System Analysis) and Member Wada (Hydropower Civil Engineering (Planning, Design, Construction))
Status of support	(1) Wind Power Generation Project (mainly Mannal Wind Park project (100MW)) ・Wind Development Project in Mannar (100 Million USD) (2) Green Energy Development and Energy Efficiency Improvement Investment Program Tranche 1 ・Mainly hydropower development and 33kV transmission line development (supported with AFD) ・Support for the Hydro power development support of 30 MW Moragolla and others ・Investigation of pumped storage power plant development. Preliminary Study completed at the candidate development site Victoria Dam. Pre-FS completed in Maha. ・A 300 MW wind and solar project in Poonyryn (northern part) supported with IFC. (3) Green Energy Development and Energy Efficiency Improvement Investment Program Tranche 2 ・Mainly expansion of transmission facilities and renovation of distribution facilities (supported with AFD) ・Support for the development of transmission lines and mediam-volume networks for Mannar. ・Support for the development of long-distance transmission lines to develop and improve the reliability of renewable power. (4) Roof top solar Power Generation Project ・Mainly introducing Roof top PV and developing technical requirements

(Source) JICA Expert Team

<table>
<tr><td colspan="2">Date and time of meeting</td><td>June 15, 2022 (Wednesday) 15:30-17:00</td></tr>
<tr><td colspan="2">Venue</td><td>Granbell hotel conference room</td></tr>
<tr><td colspan="3">Participates</td></tr>
<tr><td rowspan="2"></td><td>ADB</td><td>Prathaj Hapthanthri, Associate Project Officer (Energy), Sri Lanka Resident Mission</td></tr>
<tr><td>JICA experts</td><td>Hirano Operations Chief (electric power strategy) and Yoshida Deputy Operation Chief (electric power strategy)</td></tr>
<tr><td colspan="2">Status of support</td><td>(1) Wind Power Generation Project
・This is a wind development project in Mannar. Development of 100 MW of wind power and development of reactive power generators in neighboring substations was completed. Additional 50 MW wind power and transformers to neighboring substations are under development using the budget created by cost reduction.
(2) Green Power Development and Energy Efficiency Improvement Investment Program Tranche 1&2
・Trench 1: 30.5 MW of hydropower, associated transmission lines and distribution lines have been constructed and substations work remains. In addition, the cost-reduced budget (USD 2 million) will be used for FS of the Victoria Dam.
Tranch 2: Development of 220 kV transmission lines from Mannar to nearby substations and 220 kV transmission lines from the hydroelectric power plant to Hambantota in the central part of the island in order to develop and improve the reliability of renewable power.
(3) Supporting Electricity Supply Reliability improvement
・33kV distribution system in the central part of the island is being strengthened to improve the reliability of supply.
(4) Rooftop Solar Power Generation Project
・A project to subsidize a portion of the interest rates on loans when introducing Rooftop PV. Recently, the budget for the USD 50 million was used up and the project was completed. The Government of Sri Lanka requested to continue the implementation, but there are no plans to implement additionally.
(5) Others
・Unless the CEB business condition changes, such as electricity tariff revisions and economic recovery, new projects cannot be launched.</td></tr>
</table>

(Source) JICA Expert Team

Date and time of meeting	November 23, 2022 (Wednesday) 9:30-11:00
Venue	Meeting room of the ADB Colombo office
Participates	
ADB	Prathaj Hapthanthri, Associate Project Officer (Energy), Sri Lanka Resident Mission
JICA experts	Hirano Operations Chief (Electric power strategy), Yoshida Deputy Operation Chief (Electric power strategy) and Member Takada (Renewable Energy)
Status of support	(1) Promoting Increased Renewable Energy Development, Energy Efficiency and Power System Resilience This is a project of Technical Assistance and has two initiatives. (a)Formulation of Renewable Energy Development Action Plan The Renewable Energy Development Action Plan complements the LTGEP that the CEB prepares every two years. It shows renewable energy development plans, candidate sites, system information, etc., and used for consideration for the timing and location of development by renewable energy developers. This Action Plan will support the achievement of the government target of 70% renewable energy by 2030. This Action Plan has been completed and is in the process of being approved by the MOPE It will be published after MOPE approval. (b) Formulation of Policy Base Loan Originally, it was support to provide due diligence technology for projects for renewable energy developers. As the number of projects implemented decreased due to the deterioration of the economic situation, the support policy was changed and the framework of Policy Base Loan was established. The Policy Base Lan is a loan to the government to support the realization of measures aimed at improving the power sector, such as CEB's reorganization, efficiency improvement, and tariff system review. Preparations are underway at the request of the government. The project will be implemented after approval of the IMF financial assistance project. (2) Wind Power Generation Project This is a wind power development project in Mannar and has completed the development of 100MW wind power and reactive power countermeasure equipment at the neighboring substation. An additional 50MW wind power development and an additional transformer at a nearby substation were planned using the budget for the cost reduction, but due to the worsening economic situation in Sri Lanka, there were no bidders and the additional development was canceled. (3) Green Power Development and Energy Efficiency Improvement Investment Program Tranche 1&2

	Trench1: Construction of 30.5MW hydropower, associated transmission lines, substations and distribution lines is underway and will be implemented with the budget for cost reduction (USD 2 million). FS is under negotiation with CEB for implimentation. Tranch2: Transmission line reinforcement work for the purpose of developing renewable energy power sources and improving reliability. 220kV transmission line reinforcement work from Mannar to neighboring substations has been completed. The development of the 220kV transmission line from the hydropower station in the central part of the island to Hambantota is 90% complete. (4) Supporting Electricity Supply Reliability improvement The 33kV distribution system in the center of the island was reinforced for the purpose of improving supply reliability. Scheduled for completion in 2024. (5) Rooftop Solar Power Generation Project The project subsidizes a portion of the interest rate on loans to install Rooftop PV. As of June 2022, the project has been completed with a budget of USD 50 million. Although the Sri Lankan government has requested to continue the project, there are no plans to implement the Second phase until the IMF financial assistance project is approved.

(Source) JICA Expert Team

(2) AFD

Information was exchanged to confirm AFD's status of assistance activities. In addition to renewable energy promotion, AFD also provides support for improving the reliability of transmission and distribution systems.

Table 3-39 AFD's support

Video conferencing		July 14, 2020 (Tuesday) 11:00-12:00 (14:30-15:30 Japan time)
Participants		
	AFD	Ms. Rebecca BIELMANN, Project Officer, AFD Colombo Office 1 person
	JICA experts	WG1: Team leader Hirano (Electricity Strategy), Deputy Team leader Yoshida (Electricity Strategy), and Member Tanihata (Systems and Policies) WG2: Member Yasutsune (Power System Analysis) WG3: Members Nishikawa (Distribution (planning, design, construction)/Coordinator) Five people in total
	JICA	Sri Lanka office, Representative Ms. Ichikawa 1 person
Status of support		(see table below)

Project	Amount	Description	Particularities	Progress Status
Renewable Energy Absorption Transmission Development Project	30 Million Euros	In order to absorb renewable energy produced by small hydropower plants to the national grid, the grid has to be upgraded and new four grid substations have been identified based on their location. These four (4) substations are at Maliboda, Wewalwatta, Nawalapityia and Ragala.		Started in 2015 Expected end date : early 2021
Green Power Development and Energy Efficiency Improvement (Tranch 1)	22 Million Euros	This project includes: (i) the construction and installation of three new substations in Kalutara, Kesbewa and Old Anuradhapura, and (ii) the augmentation of a 132/33kV grid substation in New Anuradhapura.	Co-financed with ADB (lead)	Started in 2015 Expected end date : early 2021
Green Power Development and Energy Efficiency Improvement (Tranch 2)	30 Million Euros	This project includes : (i) the construction or augmentation of several transmission lines and (ii) of MV distribution lines, (iii) the construction of a substation in Colombo (B) and (iv) the augmentation of another one (C).	Co-financed with ADB (lead)	Started in 2018 Ongoing Expected end date : 2024

(Source) JICA Expert Team

Video conferencing		September 15, 2021 (Wednesday), from 14:30 to 16:00 (from 18:00 to 19:30 Japan time)
Participants		
	AFD	Mr. Sylvain, Ms. Morgane Begon Two people in total
	JICA Expert	WG1: Team leader Hirano (Electricity Strategy), Deputy Team leader Yoshida (Electricity Strategy), and Member Takada (Renewable Energy) WG3: Member Kamiya (Distribution (planning, design, construction)/Coordination of operations), 5 members in total
Status of support		(1) Renewable Energy Absorption Transmission Development Project ・Supporting the expansion of the grid to absorb renewable energy produced by micro-hydro power plants in their own grids (2) Green Power Development and Energy Efficiency Improvement (Tranch 1) ・Supporting with ADB the construction and installation of new substations (3) and the expansion of new 132/33 kV grid substations. (3) Green Power Development and Energy Efficiency Improvement (Tranch 2) (with ADB) ・ Assistance with ADB includes the construction and reinforcement of transmission lines, the construction of MV distribution lines, and the construction and reinforcement of substations in Colombo and elsewhere. (4) CAPACITY BUILDING FOR INCREASING INTEGRATION OF RENEWABLE ENERGIES ・Support capacity building of CEB organizations through technical cooperation with EDF. ・Support capacity building in network modeling and stability research, renewable energy expertise, and network strengthening expertise.

(Source) JICA Expert Team

Date and time of meeting	Friday, June 10, 2022, 15:30-17:00
Venue	Meeting room of the AFD Colombo office (19th floor of the World Trade Center)
Participants	
AFD	Mr. Sylvain Rouzeau, Directeur adjoint Mr. Reda Souirgi, Country Director
JICA Expert	Team leader Hirano (Electricity Strategy), Deputy Team leader Yoshida (Electricity Strategy)
Status of support	(1) Renewable Energy Absorption Transmission Development Project ・Construction of four substations was completed in fiscal 2021. (2) Green Power Development and Energy Efficiency Improvement (Tr1) ・A cofinancing project with ADB will soon complete construction of the Anuradhapura substation. The final AFD/ADB loan to the CEB was completed, and it is expected to be used to complete the construction. (3) Green Power Development and Energy Efficiency Improvement (Tr2) ・A cofinancing project is under way to construct a transmission line. It will be completed in 2023. Recently, the second loan disbursement to the CEB was completed, but it is unclear whether the next (third) loan disbursement can be made due to the problem of the creditworthiness of the country and the CEB. (4) Capacity Building for Increasing Integration of Renewable Energy ・Technical cooperation to promote the introduction of renewable energy. The results of this project will lead to the contents of the Clean Energy Absorption Transmission Project. As part of this technical cooperation, a network modeling and stability study will be conducted, and plans will be made to increase transmission lines and substations. (5) Clean Energy Absorption Transmission Project ・The project is currently being formulated, and the Ministry of Finance will consult with the Ministry of Finance to decide whether or not to implement the project. However, given the current situation in Sri Lanka, implementation is difficult. In addition, since the Ministers and Secretaries of the relevant ministries and agencies, including the MoF, have changed many times, the consultations have not progressed. (6) Other ・At present, there are no plans for new projects due to Sri Lanka's deteriorating financial situation.

(Source) JICA Expert Team

Date and time of meeting	Friday, November 25, 2022, 10:00-11:15
Venue	Meeting room of the AFD Colombo office (19th floor of the World Trade Center)
Participants	
AFD	Mr. Reda Souirgi, Country Director Ms. Lea Sobrevila, Chargee de Project
JICA Expert	Team leader Hirano (Electricity Strategy), Deputy Team leader Yoshida (Electricity Strategy), Member Takada (Renewable Energy)
Status of support	(1) and (2) confirmed the details of projects to be launched in the future, and (3) to (5) confirmed the progress based on the information obtained at the interview in June 2022. Loans other than grants will be made after approval of the support from the IMF. For this purpose, it is recognized that the CEB's financial improvement and raising the electricity rate level until it reaches the business profitability base are inevitable. (1) Capacity Building for Increasing Integration of Renewable Energies (Grant)Energy Absorption Transmission Development Project The project starts in December 2022 and has a duration of 18 months. The following three components of Technical Assistance will be implemented. EDF (French Electricity Agency) will be assigned as a consultant. (a) Network modeling and stability study: Technical support for planning and review of power generation and grid expansion for CEB to achieve 70% renewable energy. (b) Renewable energies expertise: Various trainings to strengthen the site and profitability analysis and start-up skills of renewable energy projects for the Renewable Energies department of CEB, making use of development experience on a large island in France. (c) Expertise on network strengthening projects: Technical assistance for strengthening substation design, procurement methods, and construction management capabilities related to system expansion for mass introduction of renewable energy. (2) Clear Energy Absorption Transmission Project New construction projects of 220kV Habarana-Kappalturei transmission line and 220/133kV Vavuniya substation. The design is currently underway at CEB. Implementation of the loan is subject to approval of the IMF financial assistance project. (3) Renewable Energy Absorption Transmission Development Project Construction of the four substations will be completed in FY2021. (4) Green Power Development and Energy Efficiency Improvement (Tr1) A co-financed project with ADB, the Anuradhapura substation

	expansion and construction work is scheduled to be completed in 2023. (5) Green Power Development and Energy Efficiency Improvement (Tr2) A co-financed project with ADB, the transmission line reinforcement work is scheduled to be completed in 2023.

(Source) JICA Expert Team

(3) IFC

Opinions were exchanged and confirm the status of support for IFC. The target of the assistance is the Private Sector, which supports the development of renewable energy sources such as wind and solar power. In August 2021 and June 2022, we arranged to hold a video conference with IFC to obtain the latest information, but this was not realized due to the circumstances of the other party.

Table 3-40 IFC's Support

Video conferencing		July 27, 2020 (Monday) 11:00-12:10 (14:30-16:40 Japan time)
Participants		
	IFC	Ms. Saule Imanova, Investment Officer, PPP Transaction Advisory, South Asia 1 person
	JICA Expert	WG1: Team leader Hirano (Electricity Strategy), Deputy Team leader Yoshida (Electricity Strategy), and Member Tanihata (Systems and Policies) WG2: Member Yasutsune (Power System Analysis) WG3: Members Nishikawa (Distribution (planning, design, construction)/Coordinator) Five people in total
	International cooperation agency (JICA)	-
Status of support		(1) Solar: 100 MW, 30 MW and 150 MW (2) Wind: 300 MW Green Energy Project (3) Mannar wind power and related northern transmission lines

(Source) JICA Expert Team

(4) USAID

Opinions were exchanged in Sri Lanka and video conferences to confirm the status of support for USAID. USAID is designing a system that enables investors to enter Sri Lanka rather than invest themselves.

Table 3-41 USAID's Support

Date and time of meeting		June 9, 2022 (Wednesday) 13:30-14:30 (Sri Lanka time) (Japan time: 17:00-18:00)
Venue		Granbell hotel conference room (Colombo), Zoom conference
Participants		
	USAID	Mr. Mark Peters: Economic Growth Advisor, USAID/Sri Lanka Ms. Rozanne Croos Moraes: Project Development Specialist (Energy), USAID/Sri Lanka
	JICA Expert	(local) Member Yasutsune (Power System Analysis), Member Matsukawa(Meteorological Forecast/Demand forecast), Member Yamaga (Power System Analysis) <Remote> Member Verma (Supply and Demand Management), Member Takamizawa (Power System (Planning/Operation)), Member Takatsu (Energy Management (Battery))
	JICA	—
Status of support		・Design the system so that investors can enter Sri Lanka instead of making their own investments. ・To date, 2 Billion USD support programs have been implemented ・Provide support for reviewing and procuring systems. ・As there is no comprehensive plan for distributed generation, it is impossible to grasp the trend of prosumers (both users and generators) at the distribution level. Therefore, support for asset management and electricity tariffs is necessary. ・The CEB, as the borrower, has no trust in raising funds to advance the several Billion USD battery project.

(Source) JICA Expert Team

(5) Chemonics

Opinions were exchanged at a local and video conference to confirm the status of support for Chemonics (USAID Contractor). Chemonics is implementing technical proposals for the introduction of clean energy to the electricity sector, the formation of electricity markets, and improved finance.

Table 3-42 Chemonics’s Support

Date and time of meeting		Friday, 27 May 2022, from 14:00 to 15:00 (Sri Lanka time) (from 17:30 to 18:30 Japan time)
Venue		Zoom Conference
Participants		
	Chemonics	Mr. Rick Whitaker:Chief of Party Ms. Kosala Gunawardana: Advanced Energy Technologies Specialist Ruchit Kandage Dhinali Peiris Jinesha Kodikara Mr. Nadeera Wijesinghe: Tariff & Demand Side Mgt Lead
	JICA Expert	Member Verma (Supply and Demand Management), Member Takamizawa (Power System (Planning/Operation)), Member Yasutsune (Power System Analysis), Member Takatsu (Energy Management (Battery)), Member Yamaga (Power System Analysis)
	JICA	—
Status of support		・As a contractor for USAID, Webinar was held seven times between April and June 2022 for the power sector in Sri Lanka. ・The introduction of storage batteries into the 11 kV grid under the jurisdiction of LECO is under consideration (excluding the introduction of storage batteries into the transmission system). Concrete capacity of storage batteries will be examined from now on. ・I want to exchange opinions locally in June 2022 → Approved by Chemonics

(Source) JICA Expert Team

Date and time of meeting		Friday, June 10, 2022, from 13:30 to 14:30 (Sri Lanka time) (from 17:00 to 18:00 Japan time)
Venue		Granbell hotel conference room (Colombo), Zoom conference
Participants		
	Chemonics	Mr. Rick Whitaker:Chief of Party Mr. Nadeera Wijesinghe: Tariff & Demand Side Mgt Lead Ms. Kosala Gunawardana: Advanced Energy Technologies Specialist Mr. Punsara Nagasinghe: Tariff Analyst & Power System Specialist
	JICA Expert	(local) Member Yasutsune (Power System Analysis), Member Yamaga (Power System Analysis) <Remote> Member Verma (Supply and Demand Management), Member Takamizawa (Power System (Planning/Operation)), Member Takatsu (Energy Management (Battery))
	JICA	—
Status of support		・Activities for five years from November 2021 (Kick-off) ・Introduction of clean energy to the electric power sector, formation of the electric power market, and improvements in finance ・In order to alleviate the voltage problems caused by PV, a 100 kW storage battery is planned to be introduced to 33 kV or 11 kV in the LECO area. ・We are accelerating projects of small subsidy funds, with five financing schemes, such as India. Looking for future sources of funding ・Projects that are easy to secure financing are floating PV. Currently, environmental surveys are being conducted, and the RFP stage is being carried out. ・There is no problem with finance in the current economic situation. The lender considers the renewable energy business to be bankable. The challenge is where the project will proceed.

(Source) JICA Expert Team

3.10 Provision of equipment for video conferencing systems

JICA experts arranged and purchased video conference system equipment in order to hold a Joint Coordination Committee (JCC), discuss with Sri Lankan members in each working group (WG), collect information based on the questionnaire, conduct interviews, and technical transfer remotely. The installation was completed at the end of September 2020.

By utilizing this system not only in remote meetings between Japan and Sri Lanka but also in large-scale meetings such as technical seminars and JCC, efficient and effective activities can be implemented.

Table 3-43 Video Conference System

Equipment	Number of units installed
Video conferencing system Logitech Group (camera, microphone, speaker, operating terminal, etc.)	3
Display Size: 65 inches	3

(Source) JICA Expert Team

3.11 JICA Public Relations Response

(1) JICA Sri Lanka Office Press Release and Provision of Photographs to ODA MIERUKA Site 1

In August 2020, a material of Sri Lanka office press release was submitted and photographs of the ODA MIERUKA site were provided. The links to the ODA MIERUKA site are as follows.

https://www.jica.go.jp/oda/regions/asia.html

(2) Japan Weather Association Press Release

In August 2021, the Japan Meteorological Association released a press release on the project entitled "Solar and Wind Power Forecasting Data from July for Democratic Socialist Electricity Company of the Democratic Socialist Republic of Sri Lanka-Japan Meteorological Association, First Initiative for the Overseas Power Sector."

Links to this press release are as follows:

(3) Supporting postings to the JICA office in Sri Lanka, FACEBOOK 1

In August 2021, JIICA expert team supported the creation of materials and provided photos to be posted on the Facebook of the JICA Sri Lanka office. The Facebook linkages are as follows.

https://jpn01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.facebook.com%2Fjicasrilanka%2F&data=04%7C01%7CHirabayashi.Yurie%40jica.go.jp%7C235b6e69db7047a21b5b08d96b89506d%7Ceba9fc4255884d318a4e6e1bf79d31c0%7C0%7C0%7C637659059761403403%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=5bfi7kEUvy7B10mz0iMWH8sIzFNpvlCzu6LHbsEYpxg%3D&reserved=0

(4) Provision of Photographs to ODA Visualization Site 2

In February 2022, a photo of the ODA MIERUKA site was provided.

The links to the ODA MIERUKA site are as follows.

https://www.jica.go.jp/oda/regions/asia.html

(5) Supporting postings to the JICA office in Sri Lanka (FACEBOOK)

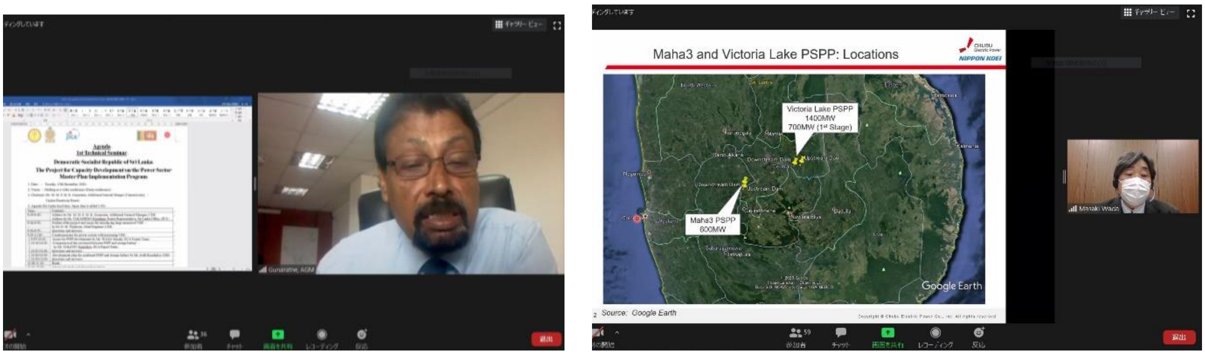
In February 2022, JIICA expert team supported the creation of materials and provided photos to be posted on the Facebook of the JICA Sri Lanka office. The Facebook linkages are as follows.

https://jpn01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.facebook.com%2Fjicasrilanka%2F&data=04%7C01%7CHirabayashi.Yurie%40jica.go.jp%7C235b6e69db7047a21b5b08d96b89506d%7Ceba9fc4255884d318a4e6e1bf79d31c0%7C0%7C0%7C637659059761403403%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=5bfi7kEUvy7B10mz0iMWH8sIzFNpvlCzu6LHbsEYpxg%3D&reserved=0

3.12 Technical Seminar

3.12.1 1st Technical Seminar (December 15, 2020)

The first technical seminar was held remotely using the video conference system (Zoom). The seminar was attended not only by the CEB but also by SEA and LECO. Table 3-44 shows attendance list At the seminar, presentations and question-and-answer sessions were held on the themes listed in Table 3-45. The published material is presented in Appendix 13. Since the construction of pumped storage power generation has been decided through the seminar, it was decided that the development of pumped storage power generation combined with storage batteries would be discussed in WG 2.



(Source) JICA Expert Team

Figure 3-53 1st Technical Seminar

Table 3-44 Participants list of 1st Technical Seminar

〇Counterparts (Sri Lanka)

	Name	Position, Organization
1	Dr. Kamal Laksiri	Project Director (Broadland Hydropower Project), CEB
2	M. L. Weerasinghe	DGM(Transmission & Generation Planning), CEB
3	K.P.K. Shanthi	DGM(Design & Environment), CEB
4	D. S. R. Alahakoon	Deputy General Manager (System Control), CEB
5	A. M. A. Alwis	DGM(Renewable Energy Development), CEB
6	Mrs.G Karunathilaka	Acting Additional Finance Manager (HQ), CEB

	Name	Position, Organization
7	Dr. H.M. Wijekoon	Chief Engineer (Transmission Planning), CEB
8	V. B. Wijekoon	Chief Engineer (Generation Planning), CEB
9	Mrs. K. V. S. M. Kudaligama	Chief Engineer (Tariff), CEB
10	A.W.S. Peiris	Chief Engineer (Renewable Energy Development), CEB
11	E.N.K. Kudahewa	Chief Engineer (System Operations), CEB
12	Mr. N.H.C Janaka	CE (Planning and Development) -DD3, CEB
13	Ms. H.I.S. Jayasundara	CE (Planning & Development) – NWP, CEB
14	Ms. K.G.N.A.Kumari	CE (Planning & Development – Central Province), CEB
15	Mr. K.A.N. Jayantha	CE (Planning and Development) -WPSII, CEB
16	Mr. P.M. Piyasena	CE (Planning and Development) –Sabaragamuwa, CEB
17	Mr. P. H. L. J. Ranasinghe	CE (Construction) – SP, CEB
18	V. V. Janeth	Project Manager-KNGTP, CEB
19	P.S. Fonseka	Electrical Engineer(Generation Development Studies), CEB
20	U. N. Sanjaya	Electrical Engineer (Transmission Planning), CEB
21	K. M. C. P. Kulasekara	Electrical Engineer (System Studies), CEB
22	T. L. B. Attanayake	Electrical Engineer (Transmission Planning), CEB
23	G. B. Alahendra	Electrical Engineer (Transmission Planning), CEB
24	M. D. R. K. Karunarathna	Electrical Engineer (Plant Scheduling), CEB
25	A. W. M. R. B. Wijekoon	Electrical Engineer (Generation Planning), CEB
26	D. C. Hapuarachchi	Electrical Engineer (Generation Planning), CEB
27	M. D. V. Fernando	Electrical Engineer (Generation Planning), CEB
28	K. A. M. N. Pathirathna	Electrical Engineer (Generation Planning), CEB
29	K. H. A. Kaushalya	Electrical Engineer (Generation Planning), CEB
30	H. D. K. Herath	Electrical Engineer (Transmission Planning), CEB
31	Ms. A. Selvarasa	EE (Distribution Control Centre) – NP, CEB
32	Ms. K.G. Lakmali	EE (Planning) – DD1, CEB
33	Ms. W.K.I.P.K.Welagedara	EE (Planning & Development – Central Province), CEB
34	Ms. S. Gowrithasan	EE (Commercial – Eastern Province), CEB
35	Mr. D.M.D. Ranawaka	EE (Planning and Development) –WPSII, CEB
36	Ms. T. D. Nirmalie	EE (Distribution Control Centre) – SP, CEB
37	Ms. W. C. H. Dhanapala	EE (Development) – WPS1, CEB
38	Kelum Niranjana	Environment Officer, CEB
39	Mrs. Chathuri Rajapaksha	Civil Engineer, CEB
40	Ranjith kumara	Civil Engineer, CEB
41	Vidura Sonnadara	Civil Engineer, CEB
42	Ruwani Kiriwendala	Accountant (Consolidation), CEB
43	T.K.G.Thiyambarawatha	Accountant (Planning) , CEB
44	Dr. Asanka S. Rodrigo	Director General , SEA
45	H. A. Vimal Nadeera	Deputy Director General (Supply Side Management), SEA
46	J. M. Athula	Director (Renewable Energy Services) , SEA
47	Chamila Jayasekera	Director (Research and Development) , SEA
48	Mrs. Apsara Katugaha	Assistant Director, SEA
49	Anuruddha Kariyawasam	Deputy Director, SEA
50	Nuwan Premadasa	Assistant Director, SEA
51	Mrs. Tamara Dilhani	Deputy Director, SEA
52	Mr. Sampath Dissanayake	Control Engineer, LECO
53	Ms. Thanuja Fernado	System Development Engineer, LECO
54	Mr. Raveen Patthamperuma	Regulatory Engineer, LECO

(Source) JICA Expert Team

〇JICA Expert Team (Chubu Electric Power Co., Inc. and Nippon Koei Co., Ltd.)

	Name	Position, Organization
1	Mr. HIRANO Akira (Team Leader / Electric Power Strategy)	General Manager, Chubu Electric Power Co., Inc.

	Name	Position, Organization
2	Mr. YOSHIDA Toshitaka (Deputy Team Leader / Electric Power Strategy)	Senior 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)	Senior 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)	General 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))	Senior Manager, Chubu Electric Power Co., Inc.
9	Mr. MATSUKAWA Muneo (Meteorological Forecast / Demand Forecast)	Chubu Electric Power Co., Inc. (Japan Weather Association)
10	Mr. TAKATSU Kenichiro (Energy Management (Battery))	Senior Manager, Chubu Electric Power Co., Inc.
11	Mr. WADA Masaki (Hydraulic Civil Engineering (Planning/Design/Construction))	Deputy Chief Engineer, Nippon Koei Co., Ltd.
12	Dr. SHIKIMACHI Koji (Distribution Technology)	Senior Manager, Chubu Electric Power Co., Inc.
13	Mr. KAMIYA.Yukihiro (Distribution (Planning/Design/ Construction) / Coordinator)	Senior Manager, Chubu Electric Power Co., Inc.
14	Mr. TAKAMASU Atsushi	Japan Weather Association

(Source) JICA Expert Team

〇JICA(Japan International Cooperation Agency)

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

(Source) JICA Expert Team

Table 3-45 Outline of 1st Technical Seminar

Theme	Contents	Point
(a) Example of System Countermeasures for Large-Scale Renewable Energy Introduction	・Comparison between pumped storage power generation and storage batteries ・RE prediction technology ・ C/P: Presentation of development schedule and construction of renewable energy prediction model using combined pumped storage and storage batteries	・Cost comparison of pumped storage power generation and storage batteries ・Expectations for pumping and storage batteries ・Measures combining pumped storage power generation and storage batteries

		・Construction of renewable energy prediction model and prediction accuracy
(b) Operation of high-level supply and demand when introducing renewable energy sources	・Points of supply and demand operation in large-scale introduction of variability and renewable energy ・The C/P made a presentation on issues and countermeasures related to supply and demand operation toward the introduction of large-scale variability renewable energy.	・Ensuring adjustment capacity with consideration for renewable energy ・Example of operation of supply and demand including renewable energy
(c) Increasing the reliability of power distribution systems	・Efforts to reduce the number and duration of power outages	・Capital investment that takes cost-effectiveness into consideration ・Introduction of the latest Japanese technology step by step

(Source) JICA Expert Team

3.12.2 2nd Technical Seminar (December 22, 2021)

The second technical seminar was held remotely using the video conference system (Zoom). The seminar was attended not only by the CEB but also by SEA and LECO. Table 3-46 lists the participants.

At the seminar, presentations and question-and-answer sessions were held on the themes listed in Table 3-47.

The materials are shown in Appendix 14.

(Source) JICA Expert Team

Figure 3-54 2nd Technical Seminar

Table 3-46 Participants list of 2nd Technical Seminar

〇Counterparts (Sri Lanka)

	Name	Position, Organization
1	Mr. P. W. Hendahewa	Additional General Manger (Transmission)
2	Mr. M. L. Weerasinghe	Deputy General Manager (Transmission & Generation Planning), CEB
3	Mr. K. Ramjee	Chief Engineer (Transmission Planning), CEB
4	Mr. D. S. R. Alahakoon	Deputy General Manager (System Control), CEB
5	Mr. V. B. Wijekoon	Chief Engineer (Generation Planning), CEB
6	Mr. N.H.C Janaka	Chief Engineer(Construction) –SP2 DD4 CEB
7	Mr. P.M. Piyasena	Chief Engineer (Planning & Development) Sabaragamuwa DD3, CEB
8	Mr. K.A.N. Jayantha	Chief Engineer (Planning and Development) -WPSIICEB

	Name	Position, Organization
9	Ms. U.G.J.K. Gamlath	Chief Engineer (Planning & Development) DD1, CEB
10	Ms. K.G.N.A.Kumari	Chief Engineer (Planning & Development) CP DD2, CEB
11	Mr. E.N.K. Kudahewa	Chief Engineer (System Operations), CEB
12	Mr. Lasith Ranasinghe	Chief Engineer (Construction)PV DD4, CEB
13	Mr. P.S. Fonseka	Electrical Engineer(Generation Development Studies), CEB
14	Mr. K. Ramjee	Chief Engineer (Transmission Planning), CEB
15	Mr. K. M. C. P. Kulasekara	Electrical Engineer (System Studies), CEB
16	Ms.W.K.L.P.K. Welagedara	Electrical Engineer (Planning & Development) CP DD2, CEB
17	Mr. T. L. B. Attanayake	Electrical Engineer (Transmission Planning), CEB
18	Mr. M. D. R. K. Karunarathna	Electrical Engineer (Plant Scheduling), CEB
19	Mr. G.B. Alahendra	Electrical Engineer (Transmission Planning),CEB
20	Mr. D. R. K. Bowatte	Electrical Engineer (Transmission Planning),CEB
21	Mr. A. W. M. R. B. Wijekoon	Electrical Engineer (Generation Planning), CEB
22	Mr. G. Kishokumar	Electrical Engineer (System Control), CEB
23	Ms. D. C. Hapuarachchi	Electrical Engineer (Generation Planning), CEB
24	Mr. K. A. M. N. Pathirathna	Electrical Engineer (Generation Planning), CEB
25	Ms. M. D. V. Fernando	Electrical Engineer (Generation Planning), CEB
26	Mr. B. P. L. De Silva	Electrical Engineer (P&D – DD4), CEB
27	Ms. V. Nilojan	Electrical Engineer (Development – East), CEB
28	Mr. Prabhath Ilangakoon	Electrical Engineer (R&D), CEB
29	Mr. K. H. A. Kaushalya	Electrical Engineer (Generation Planning), CEB
30	Ms. H. D. K. Herath	Electrical Engineer (Transmission Planning), CEB
31	Mr. K.P.J.P. Premathilake	Electrical Engineer (Development) DD3, CEB
32	Ms. W. G. Pawithra	Electrical Engineer (Transmission Planning), CEB
33	Ms. Madhurika Palatuwa	Electrical Engineer (PnD DD1), CEB
34	Mr. Sampath Dissanayake	Control Engineer, LECO
35	Mr. Raveen Patthamperuma	Regulatory Engineer, LECO
36	J. M. Athula	Director (Renewable Energy), SEA
37	Ms. Poornima Kalhari	Electrical Engineer, SEA
38	Ms. Saule	Investment Officer, IFC
39	Mr. Seung Lee	Senior Operations Management Officer, AIIB

〇JICA Expert Team (Chubu Electric Power Co., Inc. and Nippon Koei Co., Ltd.)

	Name	Position, Organization
1	Mr. Akira HIRANO (Team Leader / Electric Power Strategy)	General Manager, Chubu Electric Power Co., Inc.
2	Mr. Toshitaka YOSHIDA (Deputy Team Leader / Electric Power Strategy)	Senior Manager, Chubu Electric Power Co., Inc.
3	Mr. Osamu TANIHATA (System and Policy of Electric Power)	General Manager, Chubu Electric Power Co., Inc.
4	Mr. Shogo TAKADA (Renewable Energy)	Manager Chubu Electric Power Co., Inc.
5	Mr. Yusaku MAKITA (Finance)	Chubu Electric Power Co., Inc. (Group Leader/ Senior Economist, Koei Research & Consulting Inc.)
6	Dr. Suresh Chand Verma (Supply and Demand Management)	General Manager, Chubu Electric Power Co., Inc.
7	Mr. Yu TAKAMIZAWA (Power System (Planning/Operation))	Senior Manager, Chubu Electric Power Co., Inc.
8	Mr. Hidenobu YASUTSUNE (Power System (System Analysis))	Senior Manager, Chubu Electric Power Co., Inc.
9	Mr. Muneo MATSUKAWA (Meteorological Forecast / Demand Forecast)	Chubu Electric Power Co., Inc. (Japan Weather Association)
10	Mr. Kenichiro TAKATSU (Energy Management (Battery))	Senior Manager, Chubu Electric Power Co., Inc.

	Name	Position, Organization
11	Mr. Masaki WADA (Hydraulic Civil Engineering (Planning/Design/Construction))	Deputy Chief Engineer, Nippon Koei Co., Ltd.
12	Dr. Koji SHIKIMACHI (Distribution Technology)	Senior Manager, Chubu Electric Power Co., Inc.
13	Mr. Yukihiro KAMIYA (Distribution (Planning/Design/Construction) / Coordinator)	Senior Manager, Chubu Electric Power Co., Inc.
14	Mr. Atsushi TAKAMASU	Japan Weather Association

〇JICA(Japan International Cooperation Agency)

	Name	Position, Organization
1	Mr. Kiyofumi TAKASHIMA	Senior Representative, Japan International Cooperation Agency, Sri Lanka Office
2	Yurie HIRABAYASHI	Representative, Sri Lanka Office
3	Mr. Susumu YUZURIO	Senior Director, Japan International Cooperation Agency
4	Ms. Kuri SHIBATA	Program Officer, Japan International Cooperation Agency

(Source) JICA Expert Team

Table 3-47 Outline of 2nd Technical Seminar

Theme	Contents	Point
(a) Operational measures for supply and demand based on output forecast of renewable energy	・Technical Challenges and Measures for Achieving 70% Renewable Energy in 2030 ・Construction and evaluation of a renewable energy prediction model ・Examination of actual supply and demand operation method using renewable energy output forecast	・ Introduction of VRE power generation prediction system for the entire system ・Consideration of introduction of storage batteries and pumped storage power plants as measures against surplus electricity generated by renewable energy ・Measures against frequency and voltage fluctuations by VRE
(b) Power grid measures associated with the increase in renewable energy power sources	・Consideration of renewal of grid code for supply and demand operation measures for large-scale introduction of variability and renewable energy	・Frequency and voltage fluctuation ranges and FRT requirements for Grid Code ・Measures to control the output of surplus solar power during daytime ・Measures against frequency and voltage fluctuations of wind power generation in light load zone
(c) Geological survey in Victoria	・Evaluation of survey results ・ Review of future PSPP development methods	At this time, there is no fatal geological risk associated with the development of pumped storage power plants in Kamiike, where geological surveys were conducted. ・ After implementing pre-F/S at Victoria in the future, a candidate development site for pumped storage power plant (Maha3 or Vicroria) was decided.

(d) Increasing the reliability of power distribution systems	・Reduction in the number of power outages and power outages due to the introduction of countermeasures ・Introduction to the Toyota VPP Demonstration Test	・Estimation of reliability improvement effects at pilot sites ・Introduction of the latest Japanese technology

(Source) JICA Expert Team

3.13 System and Policy Seminar

3.13.1 1st System and Policy Seminar (August 17, 2021)

The first System and Policy Seminar was held remotely using the video conference system (Zoom). The seminar was attended not only by the CEB but also by PUCSL and SEA. Table 3-48 shows list of the participants. At the seminar, Mr. Ranjith Sepala, Engineer and SEA explained plans and targets for renewable energy in Sri Lanka. Thereafter, presentations and questions were made on the themes listed in Table 3-49. Sri Lanka aims for acheveing 70% renewable energy by 2030 and is now in the Challenging Phase. SEA will support CEB, which plays a leading role in promoting the introduction of renewable energy, and JICA Experts expressed their expectation to support the achievement of this high goal. The published material is presented in Appendix 15.

Table 3-48 Participants list of 1st System and Policy Seminar

〇Counterparts (Sri Lanka)

	Name	Position, Organization
1	Mr. G. J. Aluthge	Additional General Manger (Transmission), CEB
2	Mr. K. K. P. Perera	Deputy General Manager (Renewable Energy Development), CEB
3	Mr. V. B. Wijekoon	Chief Engineer (Generation Planning), CEB
4	Ms. K. V. S. M. Kudaligama	Chief Engineer (Tariff), CEB
5	Mr. A.W.S. Peiris	Chief Engineer (Renewable Energy Development), CEB
6	Ms. M Ganes	Chief Engineer (Planning Development) DD4, CEB
7	Mr. D. D. K. G. Sandasiri	Chief Engineer (Planning Development) – SP2. CEB
8	Ms. H.I.S. Jayasundara	Chief Engineer (Planning & Development) – NWP 2, CEB
9	Mr. N.H.C Janaka	Chief Engineer(Construction) –SP2 DD4 CEB
10	Ms. U.G.J.K. Gamlath	Chief Engineer (Planning & Development) DD1, CEB
11	Mr. P.M. Piyasena	Chief Engineer (Planning & Development) Sabaragamuwa DD3, CEB
12	Mr. E.N.K. Kudahewa	Chief Engineer (System Operations), CEB
13	Mr. R. Weeratunga	Chief Engineer (Operations Planning), CEB
14	Mr. K. Ramjee	Chief Engineer (Transmission Planning), CEB
15	Mr. U. N. Sanjaya	Chief Engineer (Renewable Energy Development), CEB
16	Mr. K. M. C. P. Kulasekara	Electrical Engineer (System Studies), CEB
17	Ms. S. Gowrithasan	Electrical Engineer (Commercial) EP DD2, CEB
18	Ms. A. Selvarasa	Electrical Engineer (Distribution Control Centre) NP DD1, CEB
19	Ms.W.K.L.P.K. Welagedara	Electrical Engineer (Planning & Development) CP DD2, CEB
20	Mr. G.B. Alahendra	Electrical Engineer (Transmission Planning),CEB

	Name	Position, Organization
21	Mr. M. D. R. K. Karunarathna	Electrical Engineer (Plant Scheduling), CEB
22	Mr. D.M.D.K. Dissnayake	Electrical Engineer (Primary Substation Maintenance) Col City, DD1, CEB
23	Ms. M. D. V. Fernando	Electrical Engineer (Generation Planning), CEB
24	Mr. K. A. M. N. Pathirathna	Electrical Engineer (Generation Planning), CEB
25	Mr. K. H. A. Kaushalya	Electrical Engineer (Generation Planning), CEB
26	Ms. K. G. Lakmali	Electrical Engineer (Sys. Pl. 1) – SP1, CEB
27	Mr. K.P.J.P. Premathilake	Electrical Engineer (Development) DD3, CEB
28	Ms. W. G. Pawithra	Electrical Engineer (Transmission Planning),CEB
29	Mr. T. Samarasinghe	Electrical Engineer (Planning & Development) Sabaragamuwa DD3, CEB
30	Mr. L.B.S.N. Kularathne	Electrical Engineer (Planning) – DD1 CEB
31	Mr. R. Sepala	Chairman, Sri Lanka Sustainable Energy Authority
32	Mr. K. Siriwardana	Director, Tariff and Economic Affairs, Public Utility Commission of Sri Lanka
33	Mr. Janaka Sanjeewa	Test Engineer, LECO
34	Mr. Tharindu De Silva	System Development Engineer, LECO
35	Mr. Gayan Wijendrasiri	System Development Engineer, LECO
36	Mr. Sampath Dissanayake	Control Engineer, LECO
37	Mr. Raveen Patthamperuma	Regulatory Engineer, LECO
38	Ms. Thanuja Fernando	System Development Engineer

〇JICA Expert Team (Chubu Electric Power Co., Inc. and Nippon Koei Co., Ltd.)

	Name	Position, Organization
1	Mr. HIRANO Akira (Team Leader / Electric Power Strategy)	General Manager, Chubu Electric Power Co., Inc.
2	Mr. YOSHIDA Toshitaka (Deputy Team Leader / Electric Power Strategy)	Senior Manager, Chubu Electric Power Co., Inc.
3	Mr. TANIHATA Osamu (System and Policy of Electric Power)	General Manager, Chubu Electric Power Co., Inc.
4	Mr. TAKADA Shogo (Renewable Energy)	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	Mr. YASUTSUNE Hidenobu (Power System (System Analysis))	Senior Manager, Chubu Electric Power Co., Inc.
7	Mr. KAMIYA Yukihiro (Distribution(Planning/Design /Construction) / Coordinator)	Senior Manager, Chubu Electric Power Co., Inc.

〇JICA(Japan International Cooperation Agency)

	Name	Position, Organization
1	Mr. YUZURIO Susumu	Senior Director, Team 1, Energy and Mining Group, Infrastructure Management Department

	Name	Position, Organization
2	Ms. SHIBATA Kuri	Infrastructure Management Officer, Team 1, Energy and Mining Group, Infrastructure Management Department
3	Mr. DEN Takashi	South Asia Division 3 (Sri Lanka/ Maldives), South Asia Department
4	Mr. TAKASHIMA Kiyofumi	Senior Representative, Japan International Cooperation Agency, Sri Lanka Office
5	Ms. HIRABAYASHI Yurie	Representative, Sri Lanka Office
6	Mr. Cabral, SL	National Staff, Sri Lanka Office

(Source) JICA Expert Team

Table 3-49　Outline of 1st System and Policy Seminar

Theme	Contents	Presenter
(a) Renewable energy development plan	・Sri Lanka's plans and targets for renewable energy to 2030	Mr. Ranjith Sepala, Engineer, Sri Lanka Sustainable Energy Authority (SEA)
(b) Current Tariff Settings and CEB Financial Status - Issues to be addressed for improvement	・Electricity Tariff structure ・CEB financial analysis ・Financial improvement and promotion of VRE introduction	JICA Experts (Mr. Tanihata, Mr. Makita, Mr. Hirano)
(c) Introduction of other kind of measures	・Establishment of FIT independent from electricity tariff ・Promotion of renewable energy in Asian countries	JICA Experts (Mr. Tanihata, Mr. Yoshida)

(Source) JICA Expert Team

3.13.2 2nd System and Policy Seminar (January 20, 2022)

The 11th field acitivity used the conference room in CEB and the video conference system (Zoom) to hold the second seminar on the System and Policy. Table 3-50 shows list of participatns. In the seminar, Mr. M. Lakshita Weerasinghe, Deputy General Manager (Transmission & Generation Planning) of CEB, conducted a Keynote speech on plans and targets for renewable energy introduction. Thereafter, the presentation and question-and-answer sessions were held on the themes shown in Table 3-51. While there were many participants in the technical field, they were not familiar with the topics. However, in the promotion of renewable energy, they were able to mutually confirm the importance of thorough understanding of the topics and deepening of discussions, since they were important in all the topics including power market development, financial improvement, and speeding up of renewable energy approval. The published materials are shown in Appendix 16.

Table 3-50　Participants list of 2nd System and Policy Seminar

〇Counterparts (Sri Lanka)

	Name	Position, Organization
1	Mr. M. L. Weerasinghe	Deputy General Manager (Transmission & Generation Planning), CEB
2	Mr. K. Ramjee	Chief Engineer (Transmission Planning), CEB
3	Mr. K. K. P. Perera	Deputy General Manager (Renewable Energy Development), CEB
4	Ms. K. V. S. M. Kudaligama	Chief Engineer (Tariff), CEB

	Name	Position, Organization
5	Mr. A.W.S. Peiris	Chief Engineer (Renewable Energy Development), CEB
6	Mr. D. D. K. G. Sandasiri	Chief Engineer (Planning Development) – SP2, CEB
7	Ms. U.G.J.K. Gamlath	Chief Engineer (Planning & Development) DD1, CEB
8	Mr. P.M. Piyasena	Chief Engineer (Planning & Development) Sabaragamuwa DD3, CEB
9	Mr. K. Ramjee	Chief Engineer (Transmission Planning), CEB
10	Mr. K. M. C. P. Kulasekara	Electrical Engineer (System Studies), CEB
11	Mr. T. L. B. Attanayake	Electrical Engineer (Transmission Planning), CEB
12	Mr. G.B. Alahendra	Electrical Engineer (Transmission Planning),CEB
13	Mr. M. D. R. K. Karunarathna	Electrical Engineer (Plant Scheduling), CEB
14	Ms. D. C. Hapuarachchi	Electrical Engineer (Generation Planning), CEB
15	Mr. D. R. K. Bowatte	Electrical Engineer (Transmission Planning),CEB
16	Mr. A. W. M. R. B. Wijekoon	Electrical Engineer (Generation Planning), CEB
17	Ms. M. D. V. Fernando	Electrical Engineer (Generation Planning), CEB
18	Mr. K. A. M. N. Pathirathna	Electrical Engineer (Generation Planning), CEB
19	Ms. W. C. H. Dhanapala	EE (Development), WPS1, DD4, CEB
20	Mr. K. H. A. Kaushalya	Electrical Engineer (Generation Planning), CEB
21	Ms. H. D. K. Herath	Electrical Engineer (Transmission Planning),CEB
22	Ms. W. G. Pawithra	Electrical Engineer (Transmission Planning),CEB
23	Mr. L.B.S.N. Kularathne	Electrical Engineer (Planning) – DD1 CEB
24	Mr. Sampath Dissanayake	Control Engineer, LECO
25	Mr. Tharindu De Silva	System Development Engineer, LECO
26	Mr. Gayan Wijendrasiri	System Development Engineer, LECO
27	Mr. Raveen Patthamperuma	Regulatory Engineer, LECO

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

	Name	Position, Organization
1	Mr. HIRANO Akira (Team Leader / Electric Power Strategy)	General Manager, Chubu Electric Power Co., Inc.
2	Mr. YOSHIDA Toshitaka (Deputy Team Leader / Electric Power Strategy)	Senior Manager, Chubu Electric Power Co., Inc.
3	Mr. TANIHATA Osamu (System and Policy of Electric Power)	General Manager, Chubu Electric Power Co., Inc.
4	Mr. TAKADA Shogo (Renewable Energy)	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	Mr. YASUTSUNE Hidenobu (Power System (System Analysis))	Senior Manager, Chubu Electric Power Co., Inc.
7	Mr. TAKATSU Kenichiro (Energy Management (Battery))	Senior Manager, Chubu Electric Power Co., Inc.
8	Dr. Suresh Chand Verma (Supply and Demand Management)	General Manager, Chubu Electric Power Co., Inc.

〇JICA(Japan International Cooperation Agency)

	Name	Position, Organization
1	Mr. YUZURIO Susumu	Senior Director, Team 1, Energy and Mining Group, Infrastructure Management Department
2	Ms. SHIBATA Kuri	Infrastructure Management Officer, Team 1, Energy and Mining Group, Infrastructure Management Department
3	Ms. HIRABAYASHI Yurie	Representative, Sri Lanka Office
4	Mr. HOSHINO Harufumi	Infrastructure Engineering Department

(Source) JICA Expert Team

Table 3-51 Outline of System and Policy Seminar

Theme	Contents	Presenter
(a) Plan and target for introduction of renewable energy	・Long-Term Generation Expansion Plan in CEB ・Medium-and long-term plans for renewable energy ・Large-scale renewable energy introduction strategy	Mr. M. L. Weerasinghe, Deputy General Manager, Transmission & Generation Planning, Ceylon Electricity Board (CEB)
(b) Revision of FIT for Rooftop PV	・Power Supply Structure and FIT in future ・Results of FIT review	JICA Expert (Mr. Yoshida)
(c) CEB's financial forecasts	・Understanding and forecasting financial conditions ・Financial conditions and electricity tariff reflecting the revision of FIT	JICA Expert (Mr. Makita)
(d) Rationalization of renewable energy permission procedures	・Grasping the current status of application process for approval ・Identifying and specifying improvement items	JICA Expert (Mr. Takada)
(e) Introduction of wholesale Power market in Japan	・JEPX structure and transaction details ・Actual power transaction prices and the impact of rising prices	JICA Experts (Mr. Hirano)
(f) Introduction of Balancing power market in the U.K.	・Power trading processes and mechanisms ・Technology in use	JICA Experts (Mr. Tanihata)
(g) Power market analysis	・Analysis of Power market	Mr. D. R. K. Bowatte Electrical Engineer, Transmission Plannig, Ceylon Electricity Board (CEB)

(Source) JICA Expert Team

3.14 Procurement of power outage countermeasure equipment

Due to the impact of the spread of COVID-19 infection, we postponed travel. Therefore, prioritized procedures for procuring power outage countermeasure equipment that could be procured without on-site survey. At the completion of this project, the procurement results of each power outage countermeasure equipment are as follows.

Table 3-52　Classification of Power Outage Countermeasure Equipment and Procurement Results

WG	Power outage countermeasure equipment	Classification (On-site survey to determine specifications)		Procurement results
		Unnecessary	Necessary	
3-1	Fault location system	—	○	Confirmed on-site (Jan. 2022) Completed the draft procurement plan (Mar. 2022) Discontinuation of introduction (Jul. 2022)
	Time sequential sectionalizer	—	○	
	Over current indicator	○	—	Delivered (Jun. 2022) On-site construction completed (Aug. 2022)
	Abrasion resistant cover for conductor	○	—	Delivered (Dec. 2021) On-site construction completed (Feb. 2022)
	Ground fault detector	○	—	Delivered (Oct. 2022) On-site Training completed (Nov. 2022)
3-2	Battery system (MV, LV)	○	—	Discontinuation of introduction (Jul. 2022)
	Measuring instruments for electric power	○	—	Delivered (Jan. 2022) On-site construction completed (Jan. 2022)

(Source) JICA Expert Team

The FLS and TSS were completed through on-site inspections and approval by CEB Transmission and Substation Management. However, due to the impact of the economic crisis in Sri Lanka, it became difficult for the C/P to cover some of the costs (taxes, domestic transport costs, etc.) at the time of equipment procurement. Therefore, the C/P decided to cancel equipment procurement and pilot projects. As for the battery system, as a result of examining the specifications required for the measures for the current problem, the introduction was halted because the budget of this project was exceeded. Meanwhile, as an alternative to stopping the battery system, measuring instruments for electric power were procured for the purpose of measuring the output/voltage fluctuation of the VRE mass-introduced distribution line and improving the analysis technology of C/P.

3.15 Training in Japan (reflecting the results of December 2022)

Initially, the training was scheduled to be conducted in Japan separately for WG 1, 2, and 3, but the training was postponed because immigration restrictions were imposed on the implementation of countermeasures against the COVID-19.

Subsequently, in response to the easing of entry conditions, JICA planned to accept trainees for training in Japan in December 2022.

Based on the remaining schedules of the project, it was decided that the training in Japan of WG 1, 2, and 3 would be conducted in one time.

(1) Training Period

December 6, 2022 to December 15, 2022 (for WG1)

December 6, 2022 to December 17, 2022 (for WG2, WG3)

(2) Number of trainee

WG1: 12 persons (MOPE: 2, PUCSL: 1, SEA: 1, CEB: 8)

WG2: 6 (CEB: 6)

WG3: 10 persons (CEB: 8, LECO: 2)

(3) Overview of Training

Table 3-53 shows the outline of this training.

Table 3-53 Purpose and Items of training

	Training purpose	Main training items
Common	Contribute to strengthening the institutional capacity of the power sector organizations in Sri Lanka to enhance the reliability of the transmission and distribution grid to increase renewable energy installations in long-term power development plans by effectively complementing technology transfers that have been conducted through WG activities, technical seminars, and system and policy seminars.	Battery substations, the Japan Meteorological Association (weather forecasting), battery manufacturers
WG1	Deepening understanding of electric power technology and of system and policy	Visit to and exchange opinions with training institutes, distribution offices, etc.
WG2	Deepening understanding of system planning/operation, supply and demand management (storage) and improving technical capabilities	Visit and exchange of opinions with pumped storage power stations, frequency conversion stations, training institutes, system analysis equipment, etc.
WG3	Deepening of understanding of power distribution technology and improvement of technical capabilities	Visit and exchange opinions with power distribution equipment manufacturers, distribution offices, training institutes, etc.

(Source) JICA expert team

(4) Results and findings of training

a. Site visit

i) Site visit of power facilities

Trainees visited the following power facilities, where are useful for improving the reliability of power supply and system operation technology as the amount of renewable energy introduced increases in Sri Lanka. In Sri Lanka, as the amount of RE introduction increasing, the introduction of batteries into the grid and construction of large-scale pumped-storage power plants are being planned. The trainees actively exchanged opinions with the engineers at the sites regarding equipment specifications, operation methods, construction, and other matters.

- ✓ Tohoku Electric Power Network Co., Inc.
  Nishi-Sendai Substation (20MW Battery Substation)
- ✓ Chubu Electric Power Grid Co., Inc.
  Higashi Shimizu Substation (60/50Hz Frequency Converter Substation)
  Naka Customer Service Center (Distribution automation system, construction site visit)
  Nunoike Substation (154kV distribution substation)
  Meijyo Substation (275kV underground substation)
  Okuyahagi Hydropower (Pumped storage power plant)

Visiting Nishi-Sendai Substation

Visiting Higashi-Shimizu Substation

Visiting Meijyo Substation

Visiting Nunoike Substaion

Figure 3-55 Visiting Power Facilities

ii) Visit to Training Facility

Trainees visited the following facilities in order to gain a deeper understanding of the training system in the electric power sector. Through these facility visits, the trainees understood the training system and training methods of Japanese electric power company.

- ✓ Chubu Electric Power Grid Co., Inc.
  Transmission Engineering Training Center (GIS, Switchgears, Substation facilities, Protection

relay system, Overhead transmission line, Underground transmission line)

Distribution Training Center (Training house for outdoor wiring, Training house for indoor wiring)

Training overview explanation — Visiting Distribution training center

Figure 3-56 Visiting Training Center

iii) Visit to a power equipment manufacturer

Trainees visited the following manufacturers of batteries, power distribution equipment to increase supply reliability, and smart meters that are related to the themes dealt with in this project. In addition to inspecting the manufacturing facilities of each device, there was a lively exchange of opinions with manufacturers' engineers regarding the effects of introducing the devices and the specifications related to their operation.

- ✓ Toshiba Energy Systems & Solutions Corporation (lithium-ion battery)
- ✓ NGK INSULATORS, LTD. (NaS battery)
- ✓ Meidensha Corporation (Photovoltaic equipment)
- ✓ Chubu Seiki Co., Ltd. (Smart meter)
- ✓ Aichi Electric Co., Ltd. (Transformer)
- ✓ Nippon Kouatsu Electric Co., Ltd. (Distribution failure point detection device)

iv) Other research facilities, etc.

In introducing a large amount of renewable energy, trainees visited the following facilities and exchanged opinions with engineers about renewable energy power generation forecasting methods using weather forecasting technology and system analysis technology that will be necessary in the future.

- ✓ Japan Weather Association (Generation forecast)
- ✓ Chubu Electric Power Co., Inc.
  Electric Power Technology Laboratory (Power system analysis)
- ✓ Chubu Electric Power Grid Co., Ltd.
  Power System Analysis Center (Power system analysis)
  Distribution control system operation center (Distribution automation system)

Tour at the Japan Weather Association

Tour of the R&D Center

Tour of the Power System Analysis Center

(Source) JICA Expert Team

Figure 3-57 Visiting Other Facilities

b. Discussion/Presentation

During the training in Japan, JICA experts always accompanied the trainees and supported technical question-and-answer sessions and opinions exchanges. In addition, at the wrap-up meeting on the final day, all the trainees presented action plans for their own tasks based on the activities of this project and what they learned during the training in Japan. The trainees commented that they were able to learn a lot of techniques through this visit, and expressed their gratitude towards the places visited and the JICA experts. Furthermore, some were highly interested in Japanese electric power equipment, including batteries, and many expressed their desire to introduce them in Sri Lanka

c. Utilization of Training Outcomes

The trainees listened intently and enthusiastically to both the lecture and the tour, and asked many questions. In addition, there were many opinions that they would like to introduce Japanese power equipment such as batteries in Sri Lanka. After returning to Sri Lanka, a debriefing session on the training in Japan will be held. It is expected that the results of the activities of this project, including the training in Japan, will be widely disseminated to the people concerned.

Chapter 4 Issues, innovations, and lessons learned from project implementation and operation (operational methods, operational systems, etc.)

(1) Impact of deterioration in financial position

In Sri Lanka, an economic crisis has occurred since March 2022, including a fuel shortage caused by a shortage of foreign currency and severe inflation. This affected some of the activities of the project as shown below.

a. Modification of the FIT revision work of Rooftop PV

In Sri Lanka, the FIT for Rooftop PV has not been reviewed since it was introduced in 2016, in the face of a global downward trend in PV introduction costs. Therefore, as a WG1 activity, JICA experts submitted a proposal for FIT revision to the CEB in March 2022, aiming for internal approval of the CEB, submission of a proposal to the Expert Committee (a committee to consider FIT revision) by CEB, and approval of the government, in order to realize the revision of the FIT of Rooftop PV.

However, as the economic crisis occurred at the same time, the FIT revision was no longer in progress, and the CEB strongly wanted to suspend it.

In response to this situation, as a result of discussions with the CEB, it was decided to explain the results of the review to the CEB senior management. In June 2022, we explained the background of the review of the FIT of Rooftop PV and the concept of FIT calculation to AGM who is in charge of this matter. In addition, the FIT revision procedures and the required period of procedures were compiled as a milestone to clarify the flow of FIT revision work.

Preparations were done so that CEB will be able to undertake their own FIT revisions when economic conditions recovered as a result of these additional activities.

b. Partial cancellation of equipment procurement

With regard to some power outage countermeasure equipment (FLS and TSS), a procurement plan (draft) was submitted (July 2022) with on-site investigation and technical approval from the CEB transmission and substation division executives. However, the impact of the economic crisis in Sri Lanka made it difficult for the C/P to cover some of the costs (taxes, domestic transport costs, etc.), so CEB decided to suspend the introduction and the third JCC approved the decision.

(2) C/P's active participation in projects

For some time since the start of the project, the main activity was the transfer of technology and interviews by JICA experts at online meetings, due to the travel restrictions imposed by the countermeasures against the new-type COVID infection. As a result, there were few opinions and ideas about this project from CEB members.

JICA experts also explained the activities up to the third JCC. Subsequently, the resumption of on-site activities resulted in deeper communication. Consequently, for example, in WG1 activities related to the electricity market, the CEB members themselves selected the countries to be surveyed and made presentations on the survey results and the markets and systems needed in Sri Lanka in the future. Thus, there was a change in their active stance. At the fourth JCC, the final JCC, CEB members made presentations at the JCC on the contents of the action plan prepared by themselves after the completion of the project.

(3) Insufficient sharing of project progress information within C/P

At a donor meeting hosted by the MOPE (held on December 1, 2021, chaired by the undersecretary of the MOPE, and donors USAID, ADB, and JICA), the contents of the project were not well known.

In fact, the undersecretary of MOPE participated in the first and second JCC meetings and made remarks, and the main members of PUCSL and SEA also participated in the WG activities, technical seminars, and system and policy seminars of this project. In donor relations, JICA experts regularly exchanged views with ADB, AFD, and IFC. Therefore, there is no possibility that this project is not known to CEB or donors, but there is a possibility of insufficient sharing of information within whole C/P. Therefore, JICA experts requested main C/P CEB to share the minutes of their respective activities and JCC meetings with the relevant ministries and agencies.

(4) Insufficient cooperation between CEB organizations (distribution and transmission/substation department)

In the field survey of power outage countermeasure equipment (FLS, TSS) in WG3, JICA Experts requested that the C/P (Distribution Division) notify the substation engineer (Transmission and Substation Division) of the date and time of the survey and the items of the survey in advance, and arrange for engineers who can check the situation on site. However, cooperation between the internal sections of the organization was not successful, and when visiting the substations, it was often impossible to confirm and judge the situation. Accordingly, coordination between JICA Experts and project managers of CEB was carried out.

Through these activities in this project, they repeatedly visited the substations and conducted face-to-face field surveys with C/P (Distribution Division) and substation engineers (Transmission and Substation Division). This gradually created a sense of unity and facilitated communication.

This project could not introduce power outage countermeasure equipment (FLS, TSS).

However, we hope that the power transmission and distribution will be integrated in order to improve the reliability of supply in the future.

Chapter 5 Achievement of Project Objectives

5.1 Achievement of Project Objective

All activities up to September 2021 were conducted remotely from Japan due to the interruption of travel because of the impact of the Coronavirus. The Project was carried out without significant delay by creating materials that could be understood without explanation, sending on-demand materials, adding meetings for each WG that were not restricted to the initial survey, and implementing technology transfers that could be carried out in advance without traveling to Sri Lanka.

WG1: Project goals were generally achieved.

See chapter 5.3 PDM for details on project goals and their indicators. Specific efforts to achieve the goals are described below.

From October 2021, JICA Experts were carefully selected to travel to Sri Lanka, and local and remote activities were carried out in parallel. In the pilot project, JICA Experts requested CEB for information on on-site facilities, submitted (in December 2021) a draft procurement plan for power outage countermeasure equipment (Over Current Indicator, Abrasion Resistance Cover, Ground Fault Detector, and Electric Power Measuring Instrument) that can be specified even in remote activity, and completed delivery of ARC (December 2021), EPMI (January 2022), OCI (June 2022), and GFD (October 2021). With regard to the remaining two power outage countermeasure equipment (Fault Locating System and Time Sequential Sectionalizer), on-site inspections were completed at the time of travel in January and June 2022, and a procurement plan (draft) was submitted (July 2022). Once CEB approved the introduction of the equipment technically, however, in the third JCC, it was approved that the introduction of the equipment was suspended because the impact of the economic crisis in Sri Lanka made it difficult for CEB to cover some of the costs (taxes, domestic transportation costs, etc.).

In terms of System and Policy, JICA Experts provided input from the beginning of the project on systems in Japan and in Asian and European countries where the introduction of renewable energy is advancing, and CEB members shared information on systems and issues related to the introduction of renewable energy in their own countries and tariffs through WG activities. Among these, it was decided to consider reviewing the FIT of Roof top PV as an action to achieve Sri Lanka's targets for the introduction of renewable energy while alleviating the financial burden on the CEB. In the FIT review of Rooftop PV, FIT was calculated by dividing it into three categories with a threshold of 10 kW and 100 kW, which vary greatly in power generation cost. Using the results, JICA Experts prepared the proposed FIT revision and shared it with the CEB in order to promote the FIT revision work by the CEB. The FIT revision process was suspended due to the economic crisis that started in March 2022. However, the CEB explained the background and necessity of the FIT revision and the method of calculating the FIT to the top management members of the CEB, summarized the procedures for the FIT revision and the required period of time as a milestone, and prepared the preparations for CEB members to proceed with the FIT revision when the economic situation in Sri Lanka recovers. At the same time, other measures aimed at stabilizing the CEB's balance of payments include the CEB's financial impact through the FIT revision of the Roof top PV and the CEB's financial impact analysis that reflects the latest data from LTGEP (2023-2041). Finally, the report was developed as a Recommendation Report that fully reflected the opinions of CEB and served as a guideline for the future improvement of the CEB's finances.

In addition, in order to further introduction of VRE, information was collected and discussions were held on issues such as the efficiency of VRE development permission and the shortening of the investigation period for grid-interconnection. SEA, they are member of WG1, has revised the Renewable Energy Permission Guidelines in January 2022, which had not been revised since their enactment in 2011. In October, 2022, the company is developing an online submission system with an aspect of further improvements. In addition, regarding the power market, which is expected to require consideration for expanding the introduction of renewable energy, JICA Experts and CEB members could deepen understanding of Balancing Power market, which is of particular interest to the CEB, including a survey of cases in other countries, and identify the issues that need to be addressed in order to build the market in Sri Lanka.

WG2: Project goals were generally achieved.

See chapter 5.3 PDM for details on project goals and their indicators. Specific efforts to achieve the goals are described below.

JICA expert team provided information to the CEB for development of the VRE forecast model. Eight VRE forecast sites were determined in consultation with the CEB, and a JICA expert team developed the VRE forecast model at eight sites (five solar and three wind) using the minimum VRE equipment information required to develop the VRE forecast model. The distribution of VRE forecast data (weather and power output) twice a day started in July 2021 so that it can be reflected in the supply and demand operation. In November 2021, a JICA team of experts provided CEB with a VRE output conversion tool that can convert weather forecast data at VRE forecast points into power output. Through the distribution of VRE forecast data and the provision of VRE output conversion tools, CEB has created an environment in which VRE forecast data can be used for supply and demand operations. In the2-1 phase of the project, the CEB provided JICA expert teams with actual power output data at eight VRE forecast points and meteorological data at four VRE forecast points for a limited period. JICA expert team used actual output data and meteorological observation data obtained from the CEB to verify and refine the VRE forecast model. JICA expert team began to deliver the improved VRE forecast model in September 2022, and provided the CEB with the improved VRE conversion tool.

During the 2-2 Activity Period, CEB learned how to use the VRE output conversion tool by verifying the improved VRE forecast using the actual measured power output data at the VRE forecast point and converting the weather forecast data to power output using the new and old VRE output conversion tools. In the 2-1 phase of the project, the actual power generation data provided by the CEB was found to be instantaneous. As a result, JICA's expert team averaged the actual power output data and reconfirmed the data to ensure consistency with the forecast data. As a result, the accuracy at the five of the eight forecast points was improved. As a result, the project has largely achieved its high-end goal of 20% error in VRE poweroutput (average as of 2026). From the viewpoint of supply and demand operation, we were able to input the technology required for C/P from the viewpoint of VRE control rules, system configuration, and operation method, and the C/P was able to draw a future vision of RED. In the future, C/P will examine the detailed requirements necessary for the construction of RED independently for the time when RE control is actually necessary. In addition, lectures and exercises were conducted using PSS/E's RE model, and technical assistance was provided for the modeling of PSPP and storage batteries to be introduced in Sri Lanka.

Regarding the revision of the Grid Code, the existing renewal and planned renewal of the Output2-1 "The analysis report on VRE projects and Grid Codes for VRE" in PDM were identified by capacity. After examining the target of renewal control, the revision was described in the JICA expert-prepared document Review of Grid Code. Specific calculations were carried out in collaboration with the C/P and technology transfer was completed. In addition, the revision items of Grid Code (control of output fluctuations of FRT, RoCoF, and renewable energy, power factor adjustment width, supply/demand adjustment capacity of thermal power plants, installation of communication facilities with controlled renewable energy, and priority order in controlling renewable energy) are described in the Review Results of Grid Code.

Of these, the simulation of the numerical standards is required for suppression of output fluctuations of FRT, RoCoF, and RE, and the power factor adjustment width is described in the simulation scenario and evaluation method, and the technology transfer is completed. As a measure for the mass introduction of VRE, an outline of the energy storage system and the use cases were explained, and the understanding of the measures required to achieve the C/P target of RE 70% (introduction of storage batteries and PSPP) was deepened. In addition, the battery capacity required to achieve RE 70% was comprehensively evaluated in terms of supply-demand operation, system stability, and cost, and the required capacity (1,000MW) was selected and reflected in LTGEP.

These technology transfers also enabled the C/P to develop the necessary coordination capability by themselves even if the renewable energy introduction plan is exceeded in the future. For pumped storage power plants, two sites, Maha 3 and Victoria, were listed as candidate sites for development. In this project, geological surveys on the same scale as Maha 3 were conducted at Victoria, where geological surveys had not been conducted. Within the scope of the geological survey conducted under this project, it was confirmed that there was no fatal geological risk associated with the development of pumped storage power generation at Victoria. In this project, technology transfer was carried out on the desk and through on-site training on how to proceed with geological surveys and how to evaluate the survey results.

WG3: Project goals were generally achieved.

See chapter 5.3 PDM for details on project goals and their indicators. Specific efforts to achieve the goals are described below.

The pilot project for introducing BESS to control load fluctuations in the power distribution network was canceled, but it is expected that more and more solar PV generation equipment will be introduced into the power distribution system, and requests to cope with load fluctuations will increase in the future. For this reason, additional power measuring instruments were procured, and C/P measurement technical capabilities and capacity for load fluctuation analysis and evaluation of output/voltage were strengthened. As a special note, JICA expert team repeatedly discussed that the latest technology and equipment that are attracting attention, such as battery systems will not be introduced unless they are economical, and deepened understanding of the C/P. In the future, C/P will reaffirm the importance of economic considerations when considering capital investment, and we expect C/P to move toward improvement from the current critical economic situation.

In addition to confirming local facilities in Sri Lanka, through the activities of WGs 1 to 3, explanations and discussions to the C/Ps are repeated to deepen mutual understanding of local and Japanese institutional policies, and technology transfer is promoted by flexibly responding to C/P needs.

5.2 Project Evaluation based on DAC 6 items

Evaluation results based on DAC (Directive Administration Cooperation) 6 items (Relevance, Coherence, Effectiveness, Impact, Efficiency and Sustainability) are shown below.

Items	Evaluation	Consideration
Relevance	High	The activities of this project contribute to the policy of expanding the introduction of renewable energy based on Sri Lanka's Long-Term Generation Development Plan (LTGEP), and can be evaluated as highly relevant. The government's target for the introduction of renewable energy was changed midway through the project to "achieve 70% renewable energy by 2030," and the support for the project is highly relevant for this target as well. Specifically, on the system and policy side, the review of the Rooftop PV FIT, the formulation of CEB financial improvement measures, and the study of the introduction of electricity markets to increase the amount of renewable energy introduction were supported. In terms of power system operation technology, support was provided for VRE forecasting technology for stable grid supply and demand planning and operation, support for revision of the Grid Code for power system operation, and transfer of survey and skills for development of pumped storage power plants. For the revised renewable energy target, technology transfer was implemented in line with the achievement of the target, including review of financial improvement measures and reconsideration of the amount of battery storage introduction. On the other hand, for the high social need to reduce power outages, support for reducing distribution line faults including enhancement of distribution line operation and maintenance capabilities can be evaluated as relevant. Specifically, the unification of distribution line fault recording formats, improvement of fault response systems, and introduction of fault identification support equipment have contributed to the reduction of power outages by making it faster and easier to determine the causes of faults and to respond to them. From the viewpoint of fairness for beneficiaries, consideration of the optimization of the current electricity tariff system, which imposes excessive CEB financial burden, will lead to the correction of electricity tariff disparities among consumers, including the elimination of excessive cross subsidies. In addition, technical assistance, such as strengthening grid operation technology

		and distribution line fault reduction capacity, is an initiative that will benefit all consumers who receive electricity supply.
Coherence	High	The activities of this project are consistent with the promotion of high quality growth, which is a priority area (medium-term goal) of Sri Lanka's development cooperation policy （The project will actively support the development of infrastructure such as transportation, electricity, water supply and sewage systems, both in terms of hardware and software, while considering the use of Japanese technology, in order to promote economic development in Sri Lanka and to contribute to the improvement of the operating environment for Japanese companies.).
Effectiveness	High	The effectiveness of the project in strengthening the capacity to expand the introduction of renewable energy can be evaluated as high. Specifically, the project goals and expected effects were achieved by strengthening the skills of practitioners and collaboration among related organizations and departments through the review of FIT, enhancement of knowledge for the introduction of electricity markets, technology transfer of technologies related to supply, demand, and stable operation of power grids, measures to reduce power outages, and measures to prevent voltage fluctuations through VRE, etc. In distribution line outage reduction, the ability to record and analyze outages, install and operate outage prevention equipment, and measure and analyze power quality will lead to improved supply reliability and power quality. In addition, the entire organization's capacity has been strengthened because a mechanism has been established for horizontal deployment of acquired skills from the C/P to the organization during the activities.
Impact	High	The project had a positive impact because it contributed to reducing environmental impacts and stabilizing social systems through the stable supply of electricity by transferring system and technological transfer to expand the introduction of renewable energy. The project has no negative impact in terms of human rights and gender equality, as it contributes to the expansion of renewable energy introduction and stable electricity supply.
Efficiency	Slightly high	Although remote activities were conducted via videoconference from Japan until the middle of the project in order to prevent the COVID-19 infection, capacity assessment, technology transfer related to various systems and power system operations for the introduction of renewable energy, and surveys for the introduction of equipment were conducted according to the initial activity plan. In response to changes in the government's policy to expand the introduction of renewable energy during the project period, the project proceeded by flexibly modifying the activity plan, such as by reviewing the conditions for electricity

		tariff simulation and financial analysis, and considering the capacity of storage batteries to be installed. In the introduction of equipment for distribution line faults, it became necessary to revise the initial equipment introduction plan because the C/P side could not bear the cost of modifying existing facilities for the introduction of the equipment. Therefore, considering the introduction effect and the introduction delivery date, alternative effective equipment was introduced within the original planned budget.
Sustainability	High	The project has provided technology transfer not only to engineers but also to staff involved in the formulation of renewable energy introduction systems and in tariffs and finance, thereby fostering human resources in a wide range of areas for the realization of LTGEP and further strengthening the organizational capacity of the CEB, which is the main C/P. Since the C/Ps themselves have prepared their own action plans based on their respective work to realize LTGEP and have already started their activities, it is expected that they will continue their work even after the completion of the project.

5.3 Project Design Matrix

The achievement status of each indicator set in the Project Design matrix is shown below.

Project Design Matrix

Project Title:	The Project for Capacity Development on the Power Sector Master Plan Implementation Program	Version: 7	
Implementing Agency:		Ceylon Electricity Board (CEB)	Dated: February 28, 2023
Target Group:	MOPE, SEA, LECO and PUCSL		
Period of Project:	From March 2020 to March 2023		
Project Site:	The whole country of Domestic Socialist Republic of Sri Lanka		
Model Site:	To be determined through the discussion with C/Ps and JICA		

<table>
<tr><th>Narrative Summary</th><th>Objectively Verifiable Indicators</th><th>Means of Verification</th><th>Important Assumption</th><th>Achievement</th><th>Remarks</th></tr>
<tr><td rowspan="5">Overall Goal
Stability and reliability of transmission and distribution networks are maintained/ improved even with increased share of VRE (Variable Renewable Energy).</td><td>(1) Fluctuations of voltage and frequency in power system: the same level as before large amount installation of PV and wind power</td><td>CEB’s technical data</td><td></td><td>JICA experts shared the knowledge which enhanced the understanding and expertise of CEB to carry out Grid Code Revision and to realize the importance of storage battery for voltage and frequency regulation and system stability.</td><td></td></tr>
<tr><td>(2) SAIFI by MV feeder in 2026: 10% less than the average of the past three years (2019-2021)
➢ Tree touching outage number: 0 by ARC</td><td>CEB’s technical data</td><td></td><td rowspan="2">Improvement of fault outage report and fault response systems, and introduction of countermeasure equipment have been contributing to determine the fault causes and to respond to them earlier, which are expected to reduce SAIFI and SAIDI.
The movement for horizontal development to utilize failure outage report and countermeasures equipment was established from a pilot feeder to other feeders and other provinces through the pilot projects by C/P in each organization.</td><td rowspan="2">Setting SAIFI and SAIDI by MV feeder is proposed to evaluate the effects of proper management and countermeasures.
Fault outage number and duration of measures-applied MV feeders are proposed to be added as a proper evaluation indicator to check the direct effect of countermeasures.</td></tr>
<tr><td>SAIDI by MV feeder in 2026: 20% less than the average of the past three years (2019-2021)
➢ Over current fault outage duration: 44% less by OCI
➢ Ground fault outage duration: 50% less by GFD</td><td>CEB’s technical data</td><td></td></tr>
<tr><td>LOLP: 1.5 or less in 2026</td><td>CEB’s technical data</td><td></td><td>1,000MW storage battery installation and RED by 2030 will be enough for keeping LOLP 1.5 or less in 2026 and achieving 70% RE share in 2030</td><td></td></tr>
<tr><td>(3) Error of the prediction system of PV and wind turbine output in 2026: within 20% (Average)</td><td>CEB’s technical data</td><td></td><td>VRE output forecast accuracy at some locations is already close to the target value, however, at other locations as more and more VRE actual data will accumulate, the accuracy is bound to get closer to the target more.</td><td></td></tr>
<tr><td rowspan="6">Project Purpose
Institutional Capacity for improving transmission and distribution operational reliability is enhanced to get prepared for increased share of VRE planned in LTGEP.</td><td>(1) Corporate finance plan is updated periodically.</td><td>CEB management report</td><td rowspan="4">Counterparts continue commitment to the Project by continuing resource allocation as well as assignment of personnel for the post-Project activities.</td><td>2022 Action plan and budget were prepared.
Draft LTGEP 2023-2042 was prepared and submitted to PUCSL</td><td></td></tr>
<tr><td>(2) Standard procurement plan is implemented.</td><td>CEB management report</td><td>100%
The measures against VRE approval process have been arranged and put into revising process of the new guideline. The new guideline has been published in Jan. 2022.</td><td></td></tr>
<tr><td>(3) Seven (7) Engineers of Power System Planning can understand the advanced system analysis (Analysis with PSS/E under 70% share of RE)</td><td>Project report</td><td>100%
・All the five transmission planning engineers can understand and perform the advanced power system analysis like VRE grid integration studies with PSS/E while incorporating latest models like battery, PSPP etc. under 70% share of RE</td><td></td></tr>
<tr><td>(4) The improvements of Grid Codes are recommended.</td><td>Project report</td><td>100%
・All the five transmission planning engineers can understand and perform the power system analysis with PSS/E and can analyze and reflect the results in order to revise the Grid Code from time to time.</td><td></td></tr>
<tr><td>(5) At least one (1) countermeasure for VRE fluctuation is employed.</td><td>Project report</td><td rowspan="2">Secure of facility procurement budget</td><td>100%
・Countermeasures against VRE like VRE forecast, how to control VRE at RED, how to set storage battery capacity and how to revise Grid Code were explained to CEB. VRE forecast was employed during the project.</td><td></td></tr>
<tr><td>(6) SAIFI at the pilot sites (one target feeder per each DD/LECO) where the facilities against power outage are installed: SAIDI in 2023
[ARC] [times]<table><tr><td>DD1</td><td>DD2</td><td>DD3</td><td>DD4</td><td>LECO</td></tr><tr><td>3.8</td><td>N.A.</td><td>N.A.</td><td>1.3</td><td>37.5</td></tr></table></td><td>CEB Report</td><td>66% (2 Feeders / 3 Feeders)
[Pilot Project Period] March, 2022 ~ October, 2022
[ARC] [times]<table><tr><td>DD1</td><td>DD2</td><td>DD3</td><td>DD4</td><td>LECO</td></tr><tr><td>0.3
(△3.5)</td><td>N.A.</td><td>N.A.</td><td>18.2*1
(+16.9)</td><td>17.2
(△20.3)</td></tr></table></td><td>*1: The failure number by other than tree touching were increased though those by tree touching were decreased.</td></tr>
</table>

<table>
<tr><th>Narrative Summary</th><th>Objectively Verifiable Indicators</th><th>Means of Verification</th><th>Important Assumption</th><th>Achievement</th><th>Remarks</th></tr>
<tr><td></td><td>SAIDI at the pilot sites (one target feeder per each DD/LECO) where the facilities against power outage are installed: SAIDI in 2023

[ARC] [minutes]
<table><tr><td>DD1</td><td>DD2</td><td>DD3</td><td>DD4</td><td>LECO</td></tr><tr><td>397</td><td>N.A.</td><td>N.A.</td><td>53</td><td>967</td></tr></table>
[OCI] [minutes]
<table><tr><td>DD1</td><td>DD2</td><td>DD3</td><td>DD4</td><td>LECO</td></tr><tr><td>4,126</td><td>955</td><td>356</td><td>5,054</td><td>3,437</td></tr></table>
[GFD] [minutes]
<table><tr><td>DD1</td><td>DD2</td><td>DD3</td><td>DD4</td><td>LECO</td></tr><tr><td>277</td><td>386</td><td>36</td><td>216</td><td>3,241</td></tr></table>
</td><td>CEB Report</td><td></td><td>66% (2 Feeders / 3 Feeders)
[Pilot Project Period] March, 2022 ~ October, 2022
[ARC] [minutes]
<table><tr><td>DD1</td><td>DD2</td><td>DD3</td><td>DD4</td><td>LECO</td></tr><tr><td>13
(△384)</td><td>N.A.</td><td>N.A.</td><td>307*2
(+254)</td><td>55
(△912)</td></tr></table>
100% (5 Feeders / 5 Feeders)
[Pilot Project Period] August, 2022 ~ October, 2022
[OCI] [minutes]
<table><tr><td>DD1</td><td>DD2</td><td>DD3</td><td>DD4</td><td>LECO</td></tr><tr><td>404
(△3,722)</td><td>156
(△799)</td><td>211
(△145)</td><td>2011
(△3,043)</td><td>840
(△2,597)</td></tr></table>
X% (5 Feeders / 5 Feeders)
[Pilot Project Period] November, 2022 ~ December, 2022
[GFD] [minutes]
<table><tr><td>DD1</td><td>DD2</td><td>DD3</td><td>DD4</td><td>LECO</td></tr><tr><td>438
(161)</td><td>59
(△327)</td><td>685
(+649)</td><td>396
(+180)</td><td>624
(△2617)</td></tr></table>
※Training of GFD was implemented in November, 2022 and GFD started to be used in practical after their own training to their technical staff.</td><td>*2: The failure number by other than tree touching were increased though those by tree touching were decreased.

As the operation periods of the countermeasure facilities were short to evaluate, they will be operated and evaluated continuously.</td></tr>
<tr><td></td><td>(7) At least one (1) plan to promote the introduction of VRE to meet Sri Lanka's national energy policy is formulated.</td><td>Government Policy, CEB Report</td><td></td><td>100%
● Economic crisis causes the suspension of FIT proposal for tariff revision.
● However, FIT Draft Proposal for Tariff revision of roof top PV was completed and explained to the AGM in CEB.
● Milestone of the FIT revision procedure is shown.</td><td></td></tr>
<tr><td></td><td>(8) Advanced forecasting systems for PV and wind turbine output are established, and the supply and demand operation is implemented using it.</td><td>Project report</td><td></td><td>100%
● VRE output conversion tool was provided to CEB. CEB understood how to use it and how to set parameters. As a result, CEB was able to calculate VRE output and can add forecast points even after the project was completed.</td><td></td></tr>
<tr><td>Outputs
1. Capacity of corporate strategy and planning for VRE is enhanced.</td><td>1-1 The assessment and recommendation reports on CEB finance are prepared.</td><td>Project report</td><td></td><td>100%
● The assessment of CEB finance was made in Capacity Assessment Report prepared in 2020. The assessment of the latest developments of CEB finance was made in Recommendation Report prepared in 2022.
● Recommendation Report was prepared in 2022 based on the latest draft LTGEP 2023 – 2042.</td><td></td></tr>
<tr><td></td><td>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</td><td>Project report</td><td></td><td>100%
● Financial projection was prepared in Recommendation Report based on the current regulatory conditions including the existing tariff setting and draft LTGEP 2023 -2042 as of August 2022.
● The Recommendation Report also presents the financial projection in cases of potential Rooftop Solar PV FIT revision, future electricity tariff revision, etc.</td><td></td></tr>
<tr><td></td><td>1-3 Corporate strategy of VRE (VRE installation amount and timing) is prepared by CEB periodically.</td><td>CEB Report</td><td></td><td>● Roof Top PV FIT Revision: Conditionally 100%
The proposal, which is the technical basis for the revision work, has been prepared and explained to the CEB management. Although it was not revised due to the external factor of the economic crisis, prospective milestones for the future revision was confirmed with C/Ps.

● Balancing Market: 100%
C/Ps and JICA Expert Team investigated the balancing markets in five countries through corroborative works. Through this activity, C/P's understanding was greatly deepened, and it became a foothold for future introduction to Sri Lanka's market.</td><td></td></tr>
<tr><td></td><td>1-4 At least one (1) C/P is certified as key person who understand the pros and cons regarding each kind of VRE.</td><td>CD report</td><td></td><td>100%
Through discussions with key persons, it was possible to raise appropriate problems and execute solutions.</td><td></td></tr>
</table>

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
	1-5 At least 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.	CD report		100% SEA was able to implement the revision of the guideline and the development of the online system with their ownership.	
2. Capacity of system development and operation for transmission network in response to increased share of VRE is enhanced.	2-1 The analysis report on VRE projects and Grid Codes for VRE	Review report by Project		100% ・Based on the information about present and upcoming VRE plant locations, VRE forecast points were identified mutually between JICA Experts and CEB. ・Based on the information about VRE output characteristics and surplus power, battery type and capacity were identified to achieve RE70%.	
	2-2 The analysis report on issues and impact of transmission system considering increased share of VRE	Review report by Project		100% ・ JICA experts shared the knowledge which enhanced understanding and expertise of CEB to devise countermeasures according to the phase of VRE introduction amount.	
	2-3 50% (Seven (7) Engineers: Power System Planning) of counterparts understand the advanced system analysis for VRE introduction. (Analysis with PSS/E under 70% share of RE)	CD report		100% ・Through the PSS/E training, all five of the five transmission planning engineers could analyze power system including VRE.	
	2-4 50% (Seven (7) Engineers: Power System Planning) of counterparts understand how to handle the increased share of VRE.	CD report		100% ・Two of the two NSCC engineers understood the importance of forecasting VRE and the function of RED.	
	2-5 The recommendation report on the measures for adjusting power fluctuations	Project report		100% ・ JICA experts shared the knowledge which enhanced the understanding and expertise of CEB to revise Grid Code, and to use storage battery and PSPP effectively to mitigate power fluctuation.	
	2-6 The report on the on-site trainings for planning pumped storage power plant (PSPP)	Project report		100% ・Technical Transfer of Geological Investigation was completed	
	2-7 C/P compiles the training materials that are assisted by JICA Expert Team.	Project report		100% ・JICA experts prepared material based on the technical transfer seminar, and provided them to CEB.	
	2-8 Nine (9) Engineers (Powers System Operation) of counterparts build the capacity of supply and demand/ power system operation considering PV and wind turbine output.	CD report		100% ・Two of the two NSCC engineers understood the VRE forecasting method and the method to expand to whole of Sri Lanka.	
	2-9 Eight (8) Engineers of counterparts build the capacity of formulation of optimal power source plan / power system plan considering PV and wind turbine output.	CD report		100% ・Three of the three members of the power generation planning division understood the cost and the optimum amount of storage batteries installed in the operation. ・Five of the five members of the Transmission Planning Division understood how to set parameters for storage batteries and pumped storage power generation.	
	2-10 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.	CD report		100% ・Five of the five members of the Transmission Planning Department understood the scenario setting method and the FRT requirements to be defined.	
3. Capacity of distribution network operation is improved.	3-1 The analysis report on current status of power supply in terms of reliability and quality	Technical report by Project		100% The trends of causes of power outages in Sri Lanka were grasped, and technology transfer was carried out on similar causes of power outages in Japan and countermeasures against them. The C/P enhanced their knowledge on both countermeasures using countermeasure equipment and countermeasures by operation and maintenance.	

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
	3-2 The review report on current O&M practice of distribution network	Technical report by Project		100% Initially, more than half of all failures had unknown causes, and there were no detailed failure records, making it difficult to consider countermeasures. Through this project, a foundation for accumulating information necessary for considering future power outage countermeasures was built by changing the format of failure records and educating on-site engineers by C/Ps.	
	3-3 The recommendation report on the countermeasures to improve reliability and quality of power supply	Technical report by Project		100% The ARC, OCI, GFD, FLS and TSS were recommended to improve reliability and quality of power supply as countermeasures, and their necessary knowledge and technologies to be introduced, operated and maintained were transferred to the C/Ps.	
	3-4 The effectiveness of the recommendations from the pilot projects to improve reliability and quality of distribution network(OCI,ARC,GFD)	Review report by CEB management	Secure of facility procurement budget	100% The effectiveness of the recommended countermeasures of OCI, ARC and GFD to improve reliability and quality of distribution network were verified at the pilot project sites. On the other hand, the pilot projects of TSS and FLS were cancelled but their expected effectiveness was estimated with the assumption of their installation to the candidate sites.	The pilot project of TSS and FLS was cancelled due to Economic Crisis in Sri Lanka. However expected effectiveness is being estimated within this project.
	3-5 The review report on the fluctuation on distribution system	Technical report by Project		100% The fluctuations on all the distribution systems were reviewed and it was found only Valachchenai F5 had the obvious matter which was not voltage rise but drop among the MV distribution systems.	
	3-6 The study report on the pilot sites to confirm the response ability for load fluctuation by modeling	Technical report by Project		100% The response ability for load fluctuation was confirmed by measuring, modeling and estimating with the procured measurement instruments at the MV and LV pilot sites.	BESS Installation was cancelled due to budget limitation. However, the response ability for load fluctuation is being confirmed within this project by modeling.
	3-7 At least six (6) of counterparts build the capacity of power outage measures using facilities	CD report		100% It was confirmed through the examination to C/Ps that 11 out of 16 C/Ps have built the capacities of power outage measures using facilities of ARC, OCI, GFD, FLS and TSS.	
	3-8 At least six (6) of counterparts build the capacity of measuring and analyzing power/ voltage fluctuations caused by photovoltaic/ wind turbine output	CD report		100% It was confirmed through the examination to C/Ps that 13out of 16 C/Ps have built the capacities of measuring and analyzing power/ voltage fluctuations caused by solar photovoltaic output in both MV and LV distribution systems.	

Activities	Inputs		Pre-Conditions
	The Japanese Side	**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 for the corporate finance planning to meet VRE investment requirements 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. 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 SCC. 2-2-4 To conduct study to confirm the response ability for load fluctuation and forecast power generation in preparation for the future VRE dominated system. 2-2-5 Conduct the on-site trainings for planning PSPP. Activities of WG3	(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 (2) Training in Japan - Power technology, system and policy	(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	**<Issues and countermeasures>**

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.(Pilot Projects of TSS and FLS were cancelled due to Economic Crisis in Sri Lanka) 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. (Pilot Project of a battery system was cancelled due to budget limitation)	- Power system planning and operation, management of supply and demand - Power distribution (3) Equipment - Facilities for power outage countermeasures(OCI,ARC,GFD) (Procurement of TSS and FLS were cancelled due to Economic Crisis in Sri Lanka) - A battery system responding to load fluctuation (Procurement of a battery system was cancelled due to budget limitation.) > Electric Power Measuring Instruments was procured alternatively, to enhance capability of measuring and analyzing load fluctuation by VRE		

5.4 Assessment by Sri Lankan side members

In order to evaluate the PDM on capacity development, the performance improvement results of each C/P were confirmed in each WG through questionnaires and knowledge verification tests.

The results of the implementation of each WG are shown below.

(1) WG1

WG1 members learned four themes: (1) systems and policies to the expansion of renewable energy introduction, (2) revision to optimizing FIT, (3) financial analysis of the CEB, and (4) shortening the period for renewable energy development procedures. For each theme, JICA Expert Team confirmed the level of improvement in understanding of WG1 member at the beginning and end of the Project by self-evaluation.

a. System and Policy

Regarding systems and policies, WG1 members self-evaluated the level of understanding and improvement of the 15 major themes studied in the project on five-degrees (lowest: 1, highest: 5).

As a result, as shown in the table below, the knowledge of WG1 members has improved significantly in all themes, and the usefulness of CEB work is generally recognized.

Table 5-1 Results of Self-Evaluation of Understanding by WG1 Members on "System and Policy"
Year/Month of evaluation: October 2022, Number of WG1 member: 10 persons in CEB

(Average of self-evaluation)

Study Themes (Month Year)	Self-Evaluation on understanding: Before the Project	→	End of the Project	Evaluation of the usefulness of learned knowledge in CEB
Output Limitation in VRE in Japan (May 2020) Priority Dispatch (Oct. 2020)	2.2	→	3.5	3.7
FIT scheme in Japan (May 2020)	2.2	→	3.7	3.7
Connect and Manage in Japan (May 2020)	1.9	→	3.4	3.3
Fading out of Inefficient Coal Power Plant in Japan (Oct. 2020)	2.1	→	3.5	3.2
Balancing Market in Japan (Sep. 2020)	1.7	→	3.7	3.5
Capacity Market in Japan (Sept. 2020)	1.8	→	3.5	3.2
Fuel Cost Adjustment in Japan (Jul. 2021)	1.6	→	3.6	3.7
Imbalance Pricing in Japan (Sep. 2021)	1.6	→	3.7	3.7
Whole Sale Market in Japan (Jan. 2022)	1.8	→	3.7	3.4
Balancing Market in UK (Jan. & Jun. 2022)	1.7	→	3.4	3.3
Power Market in Ireland (May & Aug. 2022) presentation by CEB	1.7	→	3.7	3.4

Power Market in Germany (Aug. 2022)	1.7 ➡ 3.3		3.2
Aggregator Business in Japan (Aug. 2022)	1.7 ➡ 3.6		3.3
Lesson from Vietnam Case for Promotion of VRE Installation (Sep. 2022)	1.6 ➡ 3.7		3.3
Power Market in Philippines (Jun. 2022) presentation by CEB	1.7 ➡ 3.6		3.3
Average for all Themes	**1.8** ➡ **3.6**		**3.4**

※Shaded themes indicate online lectures
（Source：JICA Expert Team）

Rating five degrees	Understabding Level	usefulness of theme in CEB work
5:	I have more knowledge than study	Quite useful･effective
4:	Well understood	Very useful･effective
3:	Understood	Useful･effective
2:	A little understood	A little useful･effective
1:	Not understood	Not useful･effective

As a result of the self-evaluation, the main comments received from WG1 members on System and Policy are as follows.

- N-1 generation shedding and non-firm type connection to the power system is definitely looked at in CEB in the near future. This will enable CEB to optimize on transmission infrastructure expansion cost while integrating more VRE power plants utilizing the existing transmission facilities particularly at a very short period.
- Fuel adjustment cost was introduced to the consumer tariff in CEB before as well.
Re-introduction of the same scheme will be essential in consideration of the volatility in the global fuel prices and the exchange rate.
- A cost reflective tariff scheme is essential for Sri Lanka especially with the present fuel price revised regularly with the high inflation levels in the country. Therefore, fuel adjustment cost mechanism presented can be applied to mitigate the issue.
- With the integration of more VRE power plants in large scale, it is going to be a hard task for the system operators. Therefore, the principals of balancing markets or even the concepts of aggregator models could be handy if utilized as per the Sri Lankan requirements.
- The presentations on balancing market were very informative and useful in finding out the advantages of having the market competition for power utility industry. Salient points between each kind of market is quite fascinating.
- Electricity power market structure and the role of TSO in that scenario will be very much helpful for future activity in Sri Lankan power system.
- Sri Lanka is in the vision of achieving 70% of renewable energy by 2030 and this goal will be more realistic with the introduction of the electricity market system to the Sri Lankan power system. It is possible to increase the market competitiveness through the introduction of the energy market and hence it can be facilitated to integrate more renewable energy plants through independent power plant developers. Accordingly, the government energy policy of achieving 70% renewable penetration level can be achieved in a broader way with the

involvement of private developers.

- ➢ The knowledge of electricity power market operations in Ireland and wholesale electricity power market operations and integration of Ireland into the European market were very valuable.
- ➢ Electricity power market concept was studied in details by analyzing electricity power market system in several countries such as UK, Philippine, Ireland and Japan etc. Especially challenges in moving to electricity power market with increasing renewable generation share was studied so that necessary policies can be formulated to introduce possible electricity power market system for Sri Lanka in future with its ambitious renewable energy targets.

b. FIT Revision

Regarding the FIT revision, WG1 members self-evaluated the degree of understanding and improvement in the items shown in the table below on a five-degree rating.

In Sri Lanka, WG1 members had knowledge of FIT because the FIT system was in operation at the start of the project, however, this project deepened understanding of more specific studies and operations of FIT, such as FIT calculation methods, calculation elements, and the need for periodic review.

Table 5-2 Results of Self-Evaluation of Understanding by WG1 Members on "FIT Revision"

Year/Month of evaluation : October 2022, Number of WG1 member : 10 persons in CEB

(Average of self-evaluation)

Contents	Results of Self-evaluation Before the Project ➡ End of the Project
Were you able to get an idea of the Application Procedure and Implementation Structure for the FIT revision?	1.9 ➡ 3.7
Were you able to recognize the necessity for periodic review of FIT (reflecting the global downward trend in PV installation cost, etc.)?	2.4 ➡ 4.1
Were you able to recognize that it's necessary to set the FIT by scales of installation capacity of PV? Because unit cost for the installation defers depending on its scale.	2.4 ➡ 4.0
Did you understand how to apply historical trends of the installation cost to periodic revisions reasonably?	2.0 ➡ 3.6
Please evaluate how degrees did you understand on the factors which was necessary for calculation of the FIT revision and on the calculation process. (Key words: Spread Sheet for FIT calculation, PV panel cost, Capacity Factor, IRR, O&M cost, etc.)	2.3 ➡ 3.7
Average for all Contents	**2.2 ➡ 3.8**

* Self-evaluation is conducted on a five-degree rating. The evaluation level is the same as Table 3-5

(Source: JICA Expert Team)

As a result of the self-evaluation, the main comments received from WG1 members on FIT revision is as follows.

- It was really impressive the way for the computation of FIT.
- The many factors which contribute to the cost implication, in terms of a solar roof-top customer was considered during this computation process.
- We understood that it is important to have an attractive FIT structure to compensate for the high equipment cost.
- With the intention of independent spread of RE, feed in premium (FIP) scheme was introduced in Japan. Thus, to promote more small scale renewable energy developments in Sri Lanka, the scheme like FIP will be more favorable.
- It was a good learning experience to identify the correct methodology for the FIT scheme.
- Periodic review of the FIT is also important to sustain the solar generation as well as for the viability of CEB.

c. Financial Analysis of CEB

Regarding the Financial Analysis of CEB, WG1 members self-evaluated the level of understanding and improvement in the two items shown in the table below on a five-degree rating.

Through this project, JICA Experts and WG1 members discussed CEB's financial analysis and the impact of revision of the electricity tariff rate on CEB's financial situation. As a result, understanding level by WG1 members on CEB financial situation was greatly improved.

In addition, knowledge of WG1 members on CEB finance improved through discussions in the Project, and their understanding of the Recommendation Report and Financial Forecasting Model compiled by JICA Experts also showed high self-evaluation results.

Table 5-3 Results of Self-Evaluation of Understanding by WG1 Members on "Financial Analysis"

Year/Month of evaluation: October 2022, Number of WG1 member: 10 persons in CEB

(Average of self-evaluation)

Contents	Results of Self-evaluation	
	Before the Project →	Before the Project
Regarding the discussions on CEB financial analysis, how much did you understand the financial status of CEB?	2.8 →	4.1
Did you understand the contents of Recommendation Report and Financial Projection Model?	—	3.9

* Self-evaluation is conducted on a five-degree rating. The evaluation level is the same as Table 3-5

(Source: JICA Expert Team)

The main comments from WG1 members on the financial analysis and the Recommendation Report as a result of the self-evaluation are as follows:

【Comments for the Financial Analysis】

- It is important to set a cost reflective tariff considering all the macro economic factors and the actual generation cost of the overall generation mix of CEB.
- Setting electricity rates that reflect costs will certainly pave the way to mitigate the revenue shortages against the expenditure.
- Cost reflective tariff systems should be introduced with immediate effect to overcome this financial burden.
- Overall cost optimization in development of transmission network is important to integrate RE in the country.
- Timely tariff revisions are required to accommodate the increasing costs.
- Frequent analysis, regular financial planning and budgeting, and actual income and expense management enabled strategic decision-making and tight control over both OPEX and CAPEX cost savings.

【 Comments for the Recommendation Report】

- We plan to revise the Report annually and will use it to justify the future tariff revisions especially with and without FIT is useful.
- The recommendations suggested to improve CEB financial status is commendable. It is important for CEB to take swift and appropriate actions within an identified timeline to reach the expected goals.
- Recommendations made by this project will be very much helpful to promote Renewable Energy in Sri Lanka in the journey of achieving 70% target by 2030.
- The Recommendation Report suggested that the periodical tariff increase (annual 20% increase) will have significant effects to improve CEB financial status. We also agree with that point and 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.
- The actual generation cost of each and every power plant 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.

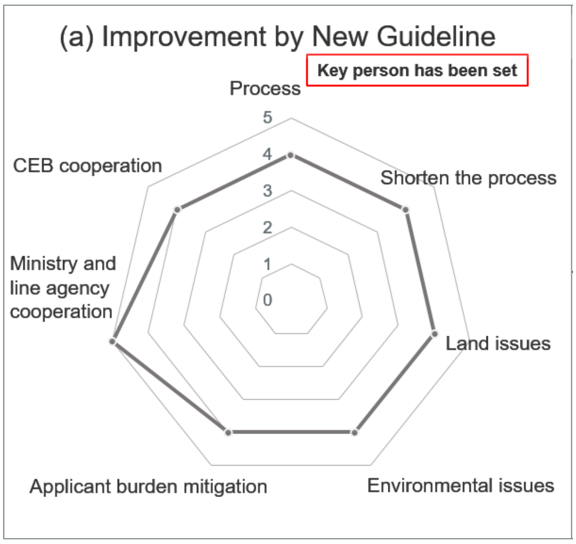
d. Shortening Period for Renewable Energy Development Approval Procedures

Regarding the shortening period for renewable energy development approval procedures, SEA took a role as a counterpart. SEA members self-evaluated the level of understanding. The results are as follows.

i) Revision of the Guideline on the approval process

Regarding the improvement of the renewable energy development approval procedure by setting new guidelines, SEA members self-evaluated the seven items shown in the figure below.

As a result, both were highly evaluated.



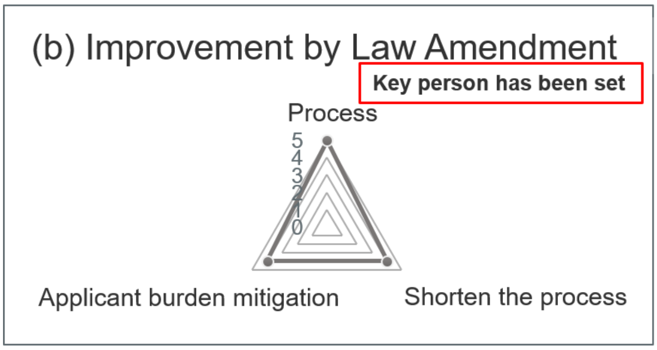
（Source: JICA Expert Team）

Figure 5-1 Evaluation results on improvement of development procedures based on new Guideline for the introduction of renewable energy

ii) Improvement by Law Amendment

Regarding the improvement of the renewable energy development approval procedure by the revision of laws or regulations, SEA members self-evaluated the three items shown in the figure below.

As a result, both were highly evaluated.



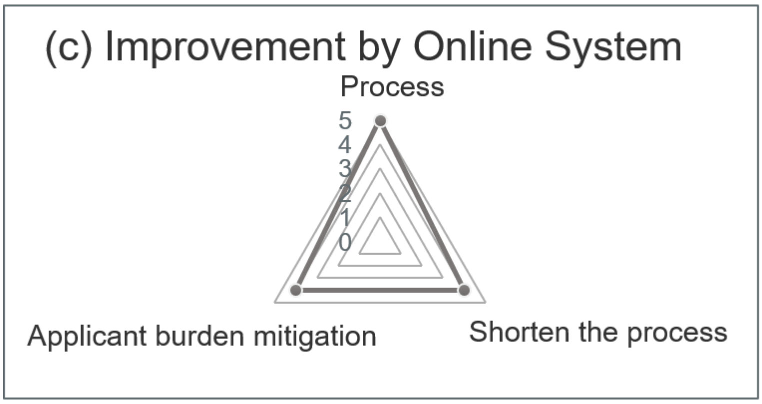
（Source: JICA Expert Team）

Figure 5-2 Evaluation results on improvement of development procedures by amendment of law or regulation

iii) Improvement by introduction of online system

Regarding the improvement of the renewable energy development approval procedure by introducing an online system, SEA self-evaluated the three items shown in the figure below.

As a result, the evaluation results were high as in the previous section.



(Source: JICA Expert Team)

Figure 5-3 Evaluation results on improvement of development procedures by introduction of online system

e. Feedback from WG1 members on the Project

WG1 members made feedback on the Project. It was highly evaluated to the Project by WG1 members.

- I thank all JICA Experts who spend their time and energy during the last couple of years conducting really useful training sessions physically as well as online, amid many obstacles such as Covid19 pandemic in Sri Lanka. The capacity development as expected in the Project would have definitely fulfilled by these competent Experts.

  So once again thank you very much for all your effort and job well done.

- I coordinated the Project, as the CEB Engineer, from the very beginning since 2019, and I must thank you a lot for sharing your knowledge and experience with us.

  I must admire JICA Experts' effort in building capacity of CEB Engineers. Also, we must be grateful to you for your willingness to deliver knowledge even during the COVID19 pandemic time.

- I'm glad to be participating in this capacity development project and it really enhances my knowledge in different aspects. Some topics were totally new areas for me and with the help of the JICA Expert Team, I was able to grab more knowledge on those areas.

  I'm expecting to apply that knowledge for the development of the Sri Lankan power system and enhance the quality of the energy sector in the whole island.

  Finally, I sincerely appreciate JICA Expert Team commitments to enhance our knowledge while giving international experience about present and future power systems.

  It was a great opportunity to learn and understand on the renewable energy sector in Japan as well as in several other countries. I was able to enhance my knowledge on pricing and tariff structures, which I would be able to utilize in my career, in the future.

(2) WG2

a. Evaluation sheet result

In WG2, C/P conducted self-evaluate the understanding regarding the content transferred against mass introduction of VRE between before and after this project. The self-evaluation (see Appendix 20) is conducted about main 6 item (VRE Forecast, Renewable Energy Desk, PSS/E Analysis, Grid Code Revision, Battery Storage Capacity, PSSP development). We checked the level of understanding of important points for above six items. The understanding of C/P regarding each item between before and after this project is shown in Figure 5-4.

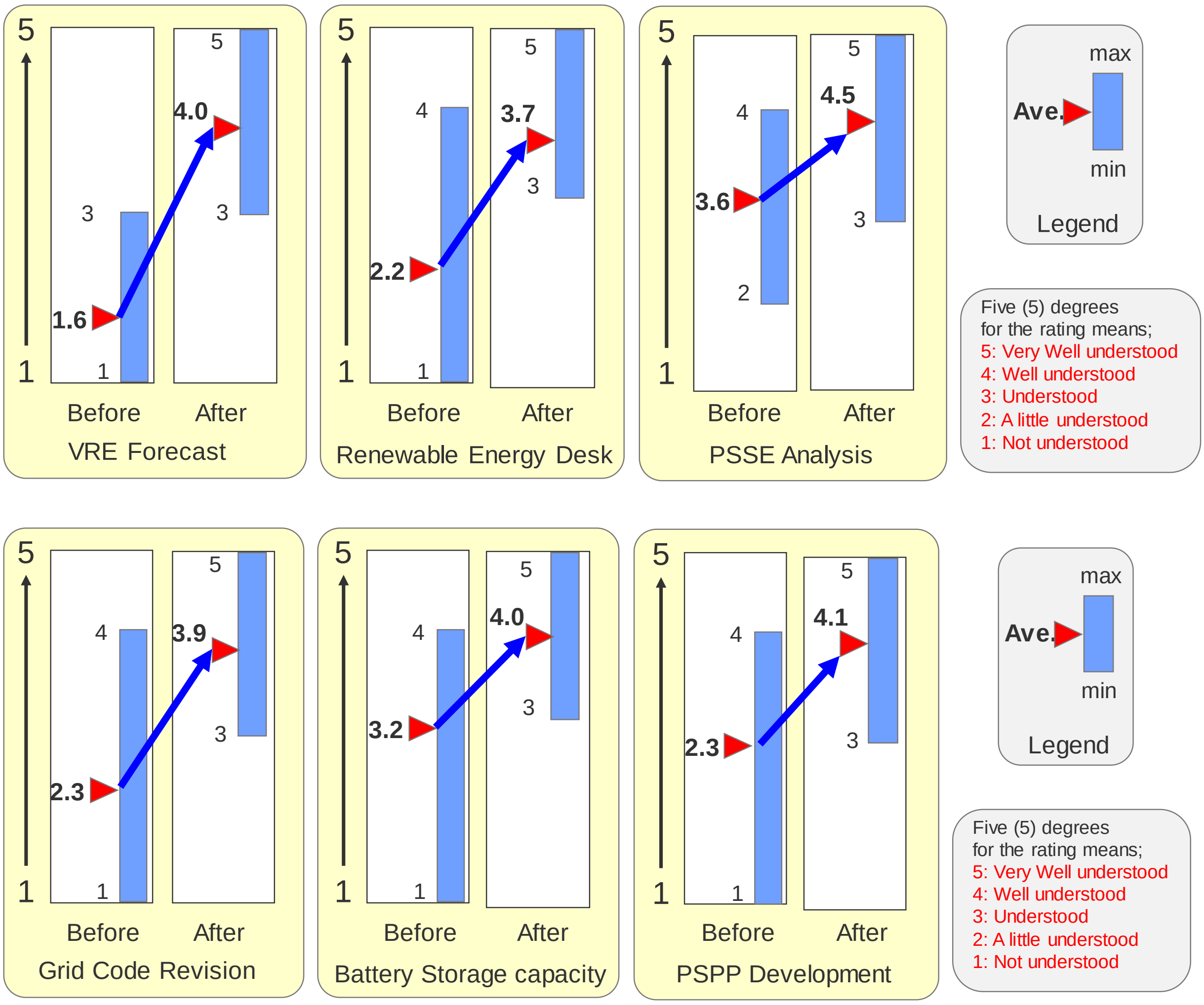


Figure 5-4 Result of understanding of self-evaluation

Before this project, there are some members who can't understand each content (rating 1 or 2) , however after this project the ratings of all members are more than 3(Understood), all members can understand all items. In our first target (PDM), we aimed to make 50% of C/P members understand the issues and measures against mass introduction of VRE, so we achieve the target significantly.

b. Feedback from WG2 of the project

WG2 members made feedback on the Project. It was highly evaluated to the Project by WG2 members.

- 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.

(3) WG3-1

In WG3-1, technology transfer was carried out through three years of activities and pilot projects to improve power outage countermeasure capabilities using C/P power outage countermeasure equipment. In order to evaluate the technical capabilities of C/P at the end of the project, a knowledge verification test was conducted. As a result, 11 persons (out of 13 persons *) reached the acceptable level (80 points). The percentage of correct answers for each C/P is shown in Figure 5-5.

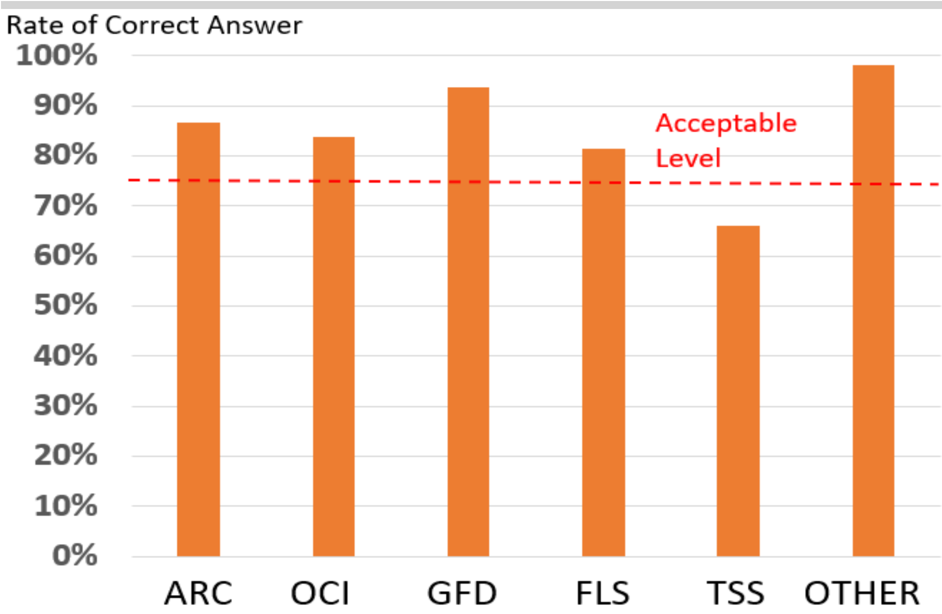


Figure 5-7 Figure 5-5 percentage of correct answers for each device.

*: At the end of the project, 13 persons belonged to WG3-1, although the initial number was 16.

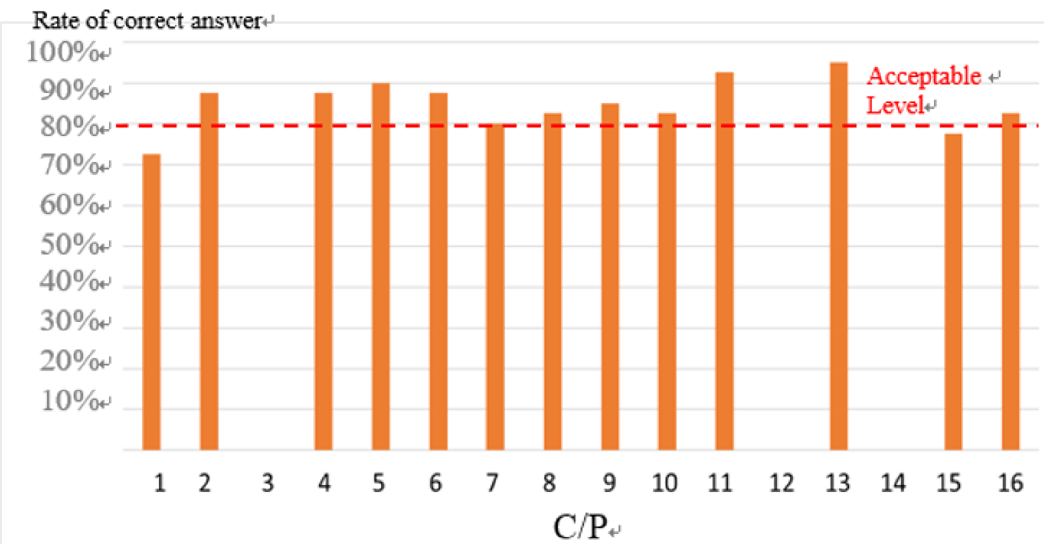


Figure 5-6 Test results for each C/P

The initial goal (PDM) was to build the capabilities of power outage measures of at least six people. However, as shown in Figure 5-7, most of the C/P scored the passing score, so it is said that it was possible to achieve results significantly in excess of the target.

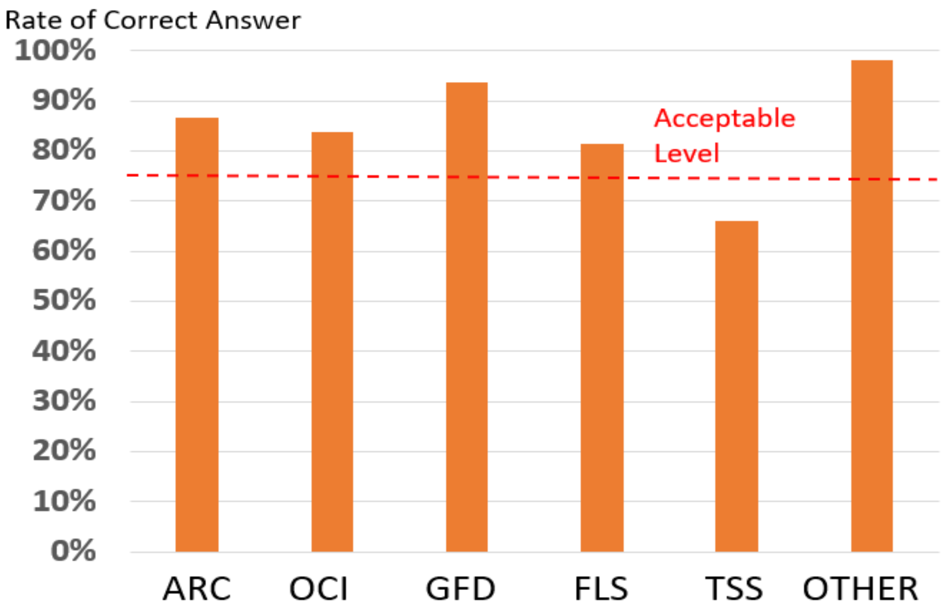


Figure 5-7　Test Results for Measure Equipment

However, the understanding of FLS and TSS, which were not introduced this time, tends to be low when looking at the percentage of correct answers by countermeasure equipment. The trend of each FLS and TSS question was that the percentage of correct answers was over 80% for basic problems related to functions and specifications, but the percentage of correct answers was low for application problems that need to be considered in terms of system-based operating principles. Therefore, JICA Expert feedback on the test results and follow-up on the questions with a low understanding parts to deepen the understanding of C/P.

While FLS and TSS are more complicated than other countermeasure devices, these equipment have a higher effect on the supply reliability. JICA Expert would like C/P to take the initiative in promoting positive consideration of the introduction in near future.

(4)　WG3-2

In order to confirm the ability level that the C/P has acquired through three years of activities such as remote lectures on load fluctuation control, on-site current and voltage measurement, and analysis of collected data, a knowledge check test was conducted at the end of the project.

Figure 5-8 shows the test results for each C/P. The initial goal (PDM) was to improve the technical skills of at least 6 people, but It was confirmed that 13 out of 14 people was reached the passing level (80%). In addition, the contents of the test were followed up with post-test explanations so that the C/P could understand 100%.

Figure 5-9 shows the degree of comprehension by field. Nearly 80% understanding is obtained for the areas of BESS and Demand Response (DR), which have the lowest level of understanding. In particular, with regard to on-site measurement and analysis, which is expected to have a large impact on actual work due to increasing inquiries from consumers, measuring instruments were procured and on-site data were collected and measured, then the recorded data were analyzed as a practical problem-solving activities in this project. As a result, C/P gained a high degree of understanding in that field.

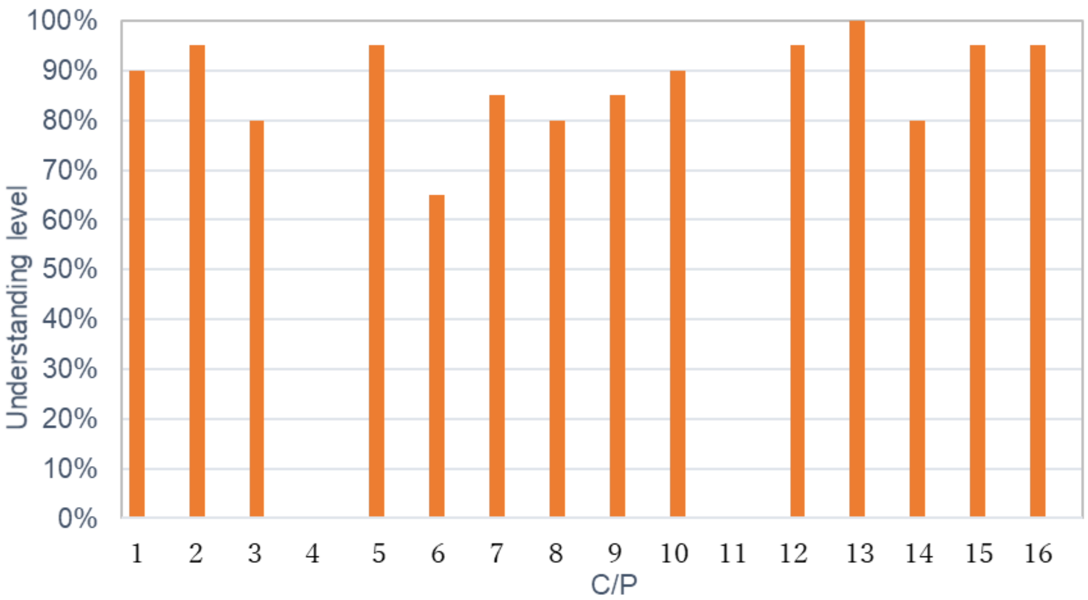


Figure 5-8　Test results for each C/P

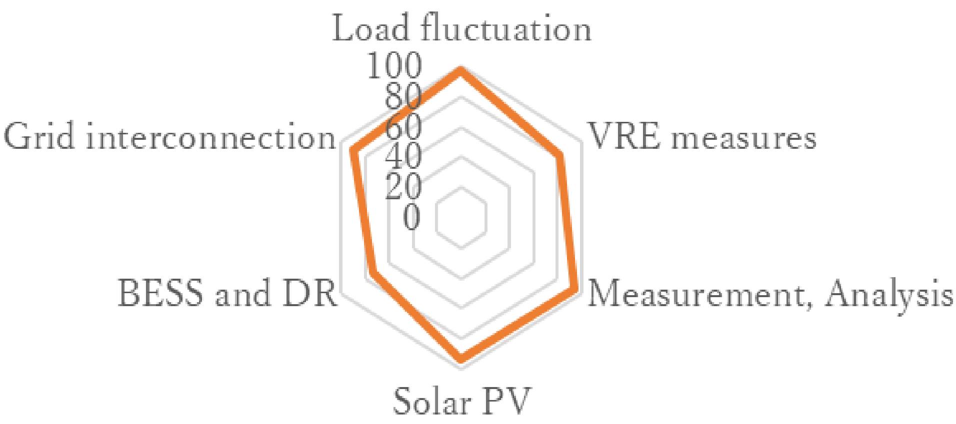


Figure 5-9　Test Results on load fluctuation suppression

a. Feedback from WG3-1 and WG3-2 of the project

- In this project, especially through the pilot project of countermeasure equipment, C/P were able to learn the construction method and operation method of each countermeasure equipment, and were able to realize the effect. C/P were also grateful that C/P were able to build personal connections both inside and outside the company through this project.
- C/P felt that it was a very good way to look back on the knowledge C/P had learned so far in the form of a test (see Appendix 21, 22). In particular, C/P were able to ascertain their own knowledge acquisition status for each countermeasure device. In the future, C/P would like to utilize this test itself as a material to confirm the outline of the equipment.
- Because of the COVID19, remote activities continued, but C/P were very happy to finally be able to go to Japan for the training in Japan. After seeing a demonstration of TSS, which was not introduced this time, C/P once again felt that it was a very effective system for improving the supply reliability of distribution lines, so C/P would like to actively propose it for future

introduction.

- It was very meaningful and enjoyable to visit various electric power equipment and manufacturers in Japan and discuss with Japanese engineers while looking at the actual equipment. In addition, C/P would like to incorporate the way of thinking cultivated by Japanese engineers and contribute to the improvement of supply reliability in Sri Lanka.
- When C/P actually visited the human resource development center and training institute in Japan, C/P were surprised at the wide range of training systems that had been established. In order to build a similar training system in Sri Lanka, C/P would like to make a long-term action plan and implement it.

Chapter 6 Recommendations for Achieving Overall Objectives

6.1 Recommendations from JICA Expert team

(1) WG1

a. Periodic review of FIT

The FIT system is a system in which the tariff and duration of electricity purchase in advance are indicated by the government. By utilizing this system, the renewable energy business operators can easily forecast the operation and secure profits. Therefore, they will be encouraged to enter the renewable energy business. This will promote the continued introduction of renewable energy and contribute to the achievement of the government's renewable energy targets. On the other hand, depending on the FIT, there will be a large difference between the purchase price of electricity (FIT) and the tariff for electricity sold, which could affect the finances of the CEB. Therefore, it is recommended that the annual FIT review be implemented in consideration of the trends in the prices of PV panels and other equipment, the market interest rate, the cost of generating power from other power generation systems, and the national policy of the renewable energy introduction plan. In addition, since the introduction unit cost (equipment price), market interest rate, expected profit rate, and other calculation conditions used for calculating FIT change from year to year, it is desirable to establish a scheme that automatically revises the calculation conditions used in the FIT review by updating the calculation conditions used in the FIT review from past performance, in consideration of streamlining the revision procedure.

Here, JICA experts introduce a case in Japan in which the cost of future introduction unit cost is automatically calculated. In Japan, the introduction unit cost is calculated based on the distribution of the introduction unit cost two years before the year to be calculated. As shown in Table 6-1, the 50 percent value for the 2020 introduction unit cost distribution corresponds to the 36 to 37 percent value for 2018. Therefore, the introduction unit cost in 2022 will automatically be set at 259,000 yen, which is 37% of the cost in 2020.

As shown in the case of Japan, in Sri Lanka, the use of historical introduction unit cost statistics and the use of that information could facilitate the automatic review of FIT.

Table 6-1 Price Distribution of Residential PV Systems in Japan

	PV system cost for household[Japanese Yen/kW]		
%	Installed in 2020	Installed in 2019	Installed in 2018
5%	162,500	182,500	202,500
10%	175,800	202,900	233,300
15%	191,900	217,800	249,000
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

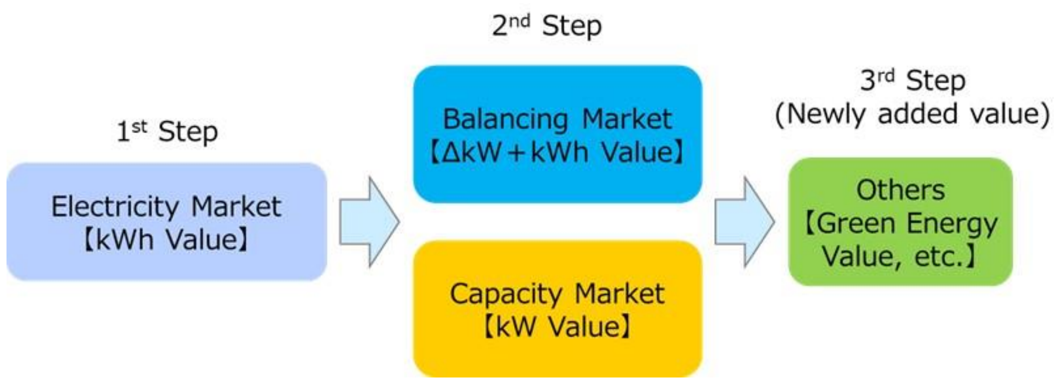
(Source) Natural Resource and Energy

b. Preparations for the introduction of the electric power market

In order to introduce the Balancing market, it is necessary to create a wholesale trade market firstly and establish an infrastructure for free electric power trade. In Japan, JEPX (Japan Electric Power Exchange) was established in 2003 with the investment of major electric power utilities and new electric power companies, and began trading in 2005. As the only one power trading market, not only major electric power utilities but also new electric power companies that do not have power generation facilities can equitably enter the market.

In this base market, only energy (kWh value) is traded. However, as mentioned above, conventional thermal power generation, which has the capacity to adjust supply and demand but marginal cost is quite high, cannot survive.

Therefore, it is desirable to further develop the Balancing market (ΔkW value). Since VRE cannot be expected as a supply capacity, it is desirable to develop the capacity market (kW value) for trading capacity in parallel. After these measures have been developed, the non-fossil value trading market will be further developed considering the environmental value.



(Source) JICA Expert Team

Figure 6-1 Market development concept

Next, issues from the viewpoint of liberalization are considered. With the revision of the Electricity Utilities Industry Law in June 2022, power generation facilities of 25 MW or more were previously limited to those with 51% or more of the shares held by the CEB, the Local Authority, and the government. However, these restrictions were removed and completely liberalized.

On the other hand, retail business is conducted only by the CEB or the LECO, and liberalization is still underway. Therefore, it is hoped that the liberalization of the retail sector will proceed gradually, and that it will start from large-scale users (high-voltage power receiving, large-capacity consumption) to medium-scale users such as small factories and stores, and ultimately to general households. Retail liberalization and the development of the wholesale market will be proceeded simultaneously. If the wholesale market starts, it can be expected that the market will be revitalized by the entry of many retailers.

In addition, it is assumed that the network (NW) is fundamentally operated by one company in order to avoid excessive burdens on beneficiaries. However, it is assumed that NW will be spun off into a separate company and NW information will be disclosed transparently so that users (power producers and general customers) can use it fairly.

c. Consideration of implementation of measures for the promotion of renewable energy power generation

Learning from other countries' systems and policies is very effective for studying systems and policies to promote the renewable energy power in Sri Lanka. In this project, WG1 members, C/Ps together with JICA experts, have studied basic systems and policies in Japan and Europe, including “Connect and Manage” and “Non-Farm Connectivity”. In addition, WG1 members have learned about recent measures to promote renewable energy, such as successful case in Vietnam, where the expansion of renewable energy has been remarkable in recent years, as well as the aggregator business becoming mainstream in each country.

Sri Lanka currently lacks adequate systems and policies to cope with the large-scale introduction of renewable energy. In Sri Lanka, the rapid expansion of renewable energy is expected to achieve a 70% from renewable energy. Based on the knowledge and experience learned in this project, it is expected that the CEB will propose measures to promote the expansion of renewable energy introduction in Sri Lanka and power system operation measures to cope with the expansion of renewable energy introduction.

Next, the issues that should be solved in order to introduce the Balancing market raised by the C/P are considered below.

i) Accurate demand forecasts

Accurate forecasting of electricity demand is an important factor in both the stable supply of electricity and the economic system operation.

Based on the demand forecast, daily plans are made to operate generators with appropriate characteristics in order to ensure appropriate balancing power.

If demand forecast is too high, the balancing power (increase/decrease capacity of generator output) will also be large, resulting in extra cost and economical loss.

On the other hand, if it is too low, the risk of insufficient balancing power and the stable supply is impeded. Therefore, in order to achieve a stable supply of electricity at low cost, high-precision demand forecasting is necessary. It is desirable to develop methods and systems that can predict demand using weather data such as temperature, humidity, discomfort index, solar radiation, and the day of the week as variables.

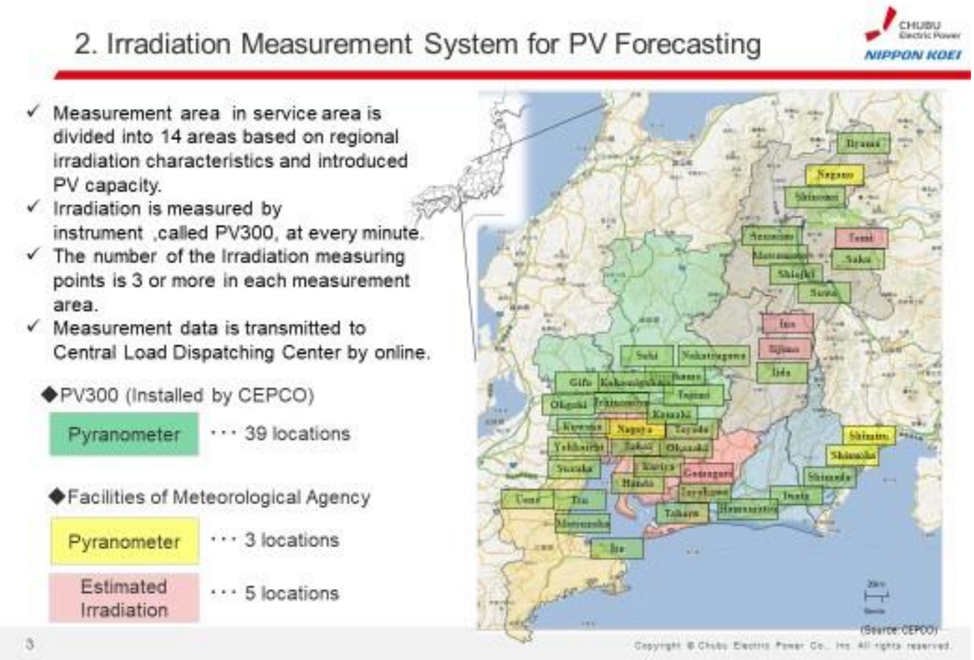
ii) Real-time monitoring (SCADA system development)

If the introduction of renewable energy is accelerated, oversupply may occur in the future even if all balancing power (lower margin) of the regulated power supply is fully used. Under such circumstances, the VRE power supply should be suppressed as an interconnection condition (control right). In actual operation, when an unexpected situation arises due to demand forecast error or weather forecast error, it is effective to exercise this control right. For this purpose, it is necessary to develop a system that can monitor each power generation status at any time. It is also necessary to equip the renewable energy power supply with a remote control system so that remote control from the SCC is possible.

iii) Accurate power generation forecast for VRE (variable renewable energy)

Accurate generation forecast for renewable energy are very important because they are closely related to planning the start-up and control plans for economical operation of power sources. It is desirable to continue to obtain weather data after completion of this project. Since there are many meteorological vendors around the world, it is recommended to comprehensively judge the cost and accuracy.

Climate projections can also be improved by comparing them with measured values. Although improvements have been made in this project, it is not sufficient because the actual data collecting points was limited. Therefore, it is desirable to increase the accuracy by sequentially installing as many observation points as possible and collecting data. For reference, Chubu (Supply area: 39,000 km2) has 39 solar radiation measurement points. It is also recommended that projections be continued based on weather data obtained using the simple model provided by this project. In the future, it would be desirable to develop a CEB-original generation prediction model with the aim of further improving accuracy.



(Source) JICA Expert Team

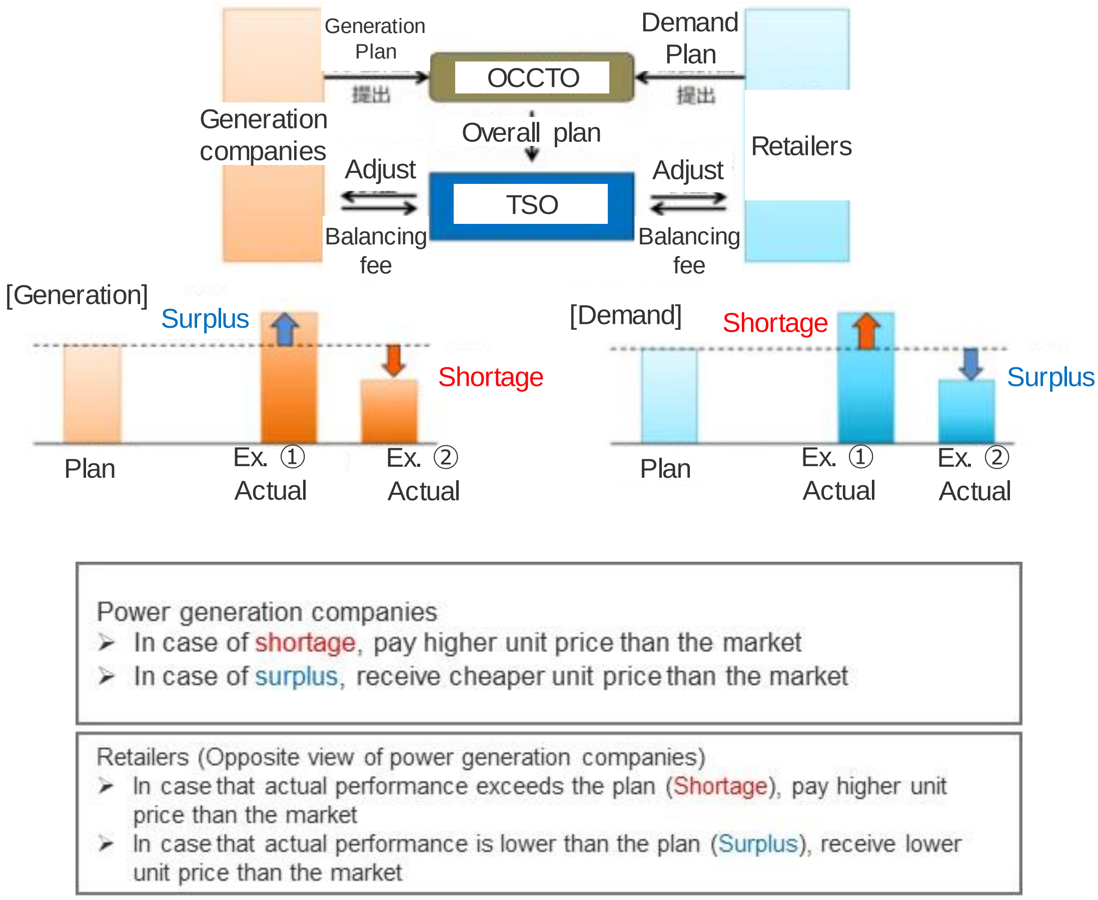
Figure 6-2 Observation points for solar radiation in service area of Chubu Electric Power Co., Inc.

iv) Declaration of plant availability for dispatch plan preparation for all power plants

In addition to in-house development by CEB, development by IPP will become the mainstream in the future, and businesses will diversify. It is difficult to secure a supply-demand balance if each company generates electricity in an unregulated manner.

It will be necessary to establish a system in which all major power producers submit generation plans to system operators beforehand, and any deviation from those plans will be settled as an imbalance.

Retail sales are not liberalized at present, but the same is true for retailers. It is assumed that any deviation from the demand plan will be settled as an imbalance. In any case, it is important to think that the participants will defend their positions with the best efforts.



(Source) JICA Expert Team

Figure 6-3 Imbalance system in Japan

v) Realizing a 500 kV HVDC interconnection with India

From the viewpoint of the cost of development of interconnected lines and transmission loss, the ideal is to balance supply and demand within each area and make up for the excess and insufficiency by interconnection. It is desirable that the basic policy of the power system operation in Sri Lanka should be to maintain the supply and demand balance in its own area. On the other hand, DC interconnection does not contribute to the supply and demand balance in terms of frequency because each system is independent. However, since mutual power interchange is possible, it has the advantages of improving the operation rate of power generation facilities, leveling the load, and improving the operational efficiency due to peak time differences.

Based on these points, there is no problem if interconnection is meaningful for Sri Lanka, but it is necessary to fully consider the merits and development costs.

vi) Setting a power generation share limit (avoiding price manipulation) to ensure healthy market competition

vii) Setting the upper limit of the Balancing market price cap (curbing price spikes)

Intentional manipulation is a serious problem and must be prevented. One idea for that is to set a power generation share cap. In addition, introduction of an imbalance system and the setting of market price ceilings to protect consumers are effective. It is desirable to carefully examine the power sector status at that time and select the optimal countermeasures.

viii) Introduction of large-scale grid batteries

Grid storage batteries and pumped storage power generation are two major options, but pumped storage power generation requires long-term development. Therefore, it is desirable to develop a combination of grid batteries in stages and an introduction of pumped storage power generation at an appropriate time. In addition, it is recommended to increase flexibility in supply and demand balance by installing storage batteries that can be used not only for long-term-period output fluctuations but also for short-term-period one.

This issue was discussed in WG2 and the results of this discussion were reflected in LTGEP 2043-2042.

ix) Establishment of requirements to be met by generators participating to Balancing market

As mentioned above, it is desirable to establish an imbalance system so that power producers can balance supply and demand through self-efforts through this incentive.

Separately, as a technical factor, it is necessary to develop grid interconnection guidelines for restrictions on frequency, voltage, harmonics, and other requirements affecting the grid, as well as essential functions to be provided by the generator as a balancing power source, and to ensure that the generator complies with them. It is desirable that the necessary interconnection requirements will be discussed and finalized in WG2 and C/P will sort out finally.

d. Efforts to improve CEB finances

In order to comply with the soon-to-be-approved LTGEP 2023-2042 in a rapidly changing economic environment, the financial projection model and the Recommendation Report should be actively used for discussions and explanations with CEB senior management and the government authorities, as stated by WG1 members, while CEB staff will continue to update them. In the near future, the government may decide to revise electricity tariff again, but the CEB is also strongly required to make ceaseless management efforts such as cost reductions and early implementation of the CAPEX projects. As stated in the Recommendation Report, the results of the financial projection model show that, along with periodic tariff revisions, financial support from the government, such as the conversion of CEB debt to capital (Debt-Equity Swap) and the injection of government funds into the CAPEX projects, is also very effective for improving CEB's financial soundness. Therefore, if the government avoids a sudden tariff hike due to social considerations, it is also required to consider financial support that will make CEB operation sustainable.

e. VRE Approval Process

(Periodic Review and Revision of the Guideline)

It is necessary to periodically review and revise the process and the guideline for applications for VRE approval in order to respond flexibly to changes in the system, policy and environment.

(Total optimization involving relevant organizations)

In order to accept further VRE installment in the future, it is necessary to resolve any problems other than the process itself (such as insufficient transmission capacity and applications in areas close to protected areas) by comprehensively optimizing the whole process.

(2) WG2

a. VRE output forecast

To achieve the higher goal of 20% forecast error (monthly average), we recommend the following to the CEB:

i) With regard to wind power generation, the VRE forecast model will be improved by performing correlation analysis of the forecast and actual measurements of the generation amount by wind direction forecast. Thess studies have been carried out since July 2022 and should be continued in the future.

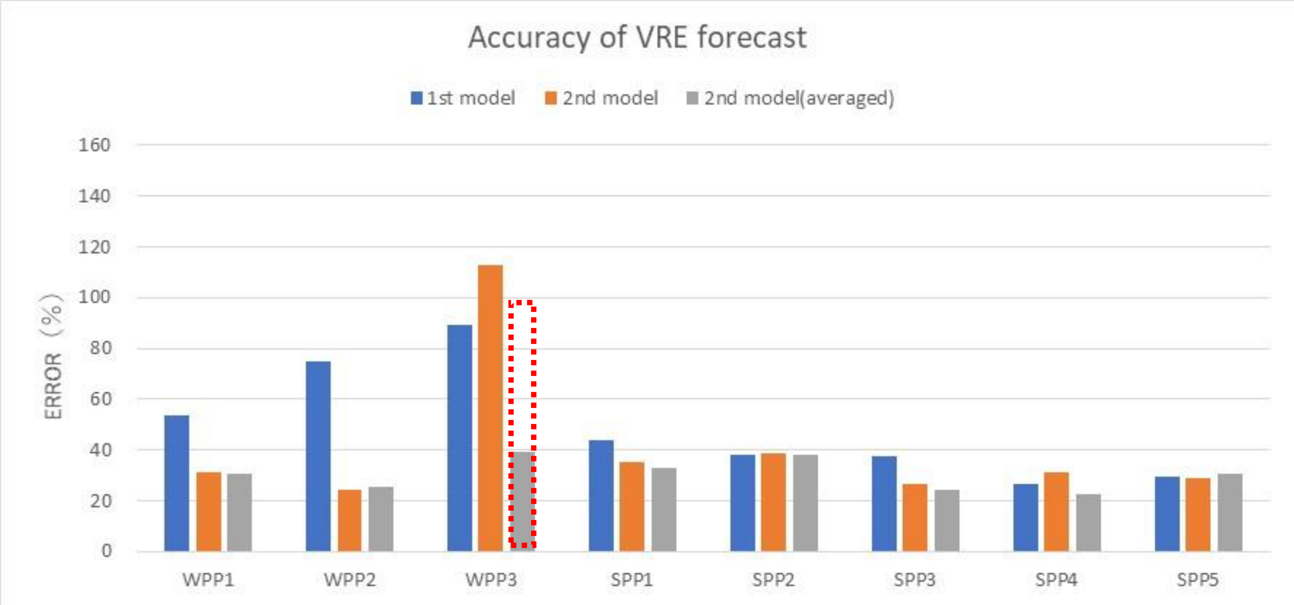
ii) As for solar power generation, the VRE forecast model will be improved by analyzing the generation by time of the day using the actual data of generation collected in this project and the forecasted data of generation for the same period. It should be continued in the future.

iii) The JICA expert team collected meteorological data (wind direction and speed) from WPP3 (Mampuri wind power plant) immediately after the 2-3 activity and modified the power curve of the wind turbine to improve the VRE forecast model, resulting in a significant improvement in accuracy (see Figure 6-4). Further improvement can be expected in the future by collecting and analyzing the operational information of the wind turbines at WPP3.

iv) It is preferable for CEB to continue to obtain the weather forecast data provided during this project even after its completion. However, if it is impossible to continue, in that case, the efforts should be made to obtain the accurate weather forecast from any other vendors.

v) When using the VRE output conversion tool to forecast the VRE output after completion of this project, the operating conditions (the number of turbines) of wind turbines at each forecast site shall be reflected in the VRE output forecast.

vi) In order to verify the accuracy of VRE output forecasts even after the completion of this project, the 15-minute average value shall be used as the actual output of each forecast site, rather than the instantaneous value.



Note: The Error before improvement of WPP3 is shown by the red dotted line.

(Source) JICA Expert Team

Figure 6-4 Accuracy evaluation of VRE output forecast (after WPP3 improvement)

b. Operation of supply and demand

When introducing a RED, it is necessary to make a high-precision RE forecast in order to implement appropriate RE control.As a 1st step, it is recommended that the VRE forecast for whole of Sri Lanka should be expanded using the information of all 8 sites as a macroscopic approach, and it should be implemented in the supply and demand operation. As a 2nd step, it is desirable to establish a system to obtain VRE information and self-consumption of individual embedded generators as a microscopic approach in order to further improve the accuracy of VRE forecast. This is because the information of individual embedded generators of 33 kV or less is not available at present.

c. Power System Analysis with PSS/E considering the mass introduction of VRE

It is recommended that power system analysis should be carried out periodically using PSS/E to ensure stable power system operation with changing phases of VRE introduction. The measures to be taken change with the phases depending on VRE introduction. In this study, we gave lectures on RE models, but we believe that when new technologies such as VRE curtailment, Demand Side Management, and hydrogen are introduced in the future, CEB should deepen its understanding of these technologies based on the current practices and reflect them in the power system analysis of Sri Lanka. In addition, it is assumed that changes in power output of PV and wind due to changes in the weather conditions will cause the phenomenon unique to the climatic environment in Sri Lanka during the operation of RE. For example, there may be cases where the largest units of existing thermal power plants overlap with the low wind conditions and the rare large ramp-down of PV. Under such circumstances, the scenarios should also be considered where PV which does not meet the FRT requirements should trip. It is desirable to independently enhance the ability to foresee possible severe cases in the future through technical support gained by CEB during this project, and to realize a stable supply of electricity.

d. Revision of grid code for large-scale introduction of RE

In order to maintain the same acceptable level of voltage and frequency variation as before large-scale introduction of RE, which is the overall goal, we recommend that CEB should periodical review the Grid Code with evolving phases of VRE introduction.

The various scenarios during this project were simulated using PSS/E data as of 2030, and numerical standards required in revising the grid code were clarified and set. The similar simulations need to be carried out whenever the phases of RE introduction or the development plans of the power supply sources tend to change, and the results must be reflected in the Grid Code as necessary. In particular, in this project, the target of RE control was set at 10 MW or more, but there is a possibility that RE with a capacity of 10 MW or more may not be developed as planned. On the contrary, if the share of RE in the small-scale capacity tends to increase, there is a possibility of insufficient amount of controllable VRE. Therefore, it is necessary to consider the expansion of the control target (lowering of the threshold). Since this threshold is a prerequisite for maintaining the balance of supply and demand by introducing 1,000 MW batteries, it is necessary to pay attention to the case where the plan for introducing batteries is changed. In addition, it is also necessary to consider whether the revised Grid Code requirements affect the protection function of Sri Lanka's transmission and substation facilities.

e. Measures for the mass introduction of VRE

The assumptions for calculating SDDP, such as SNSP generally reviewed based on the revision of grid codes must carefully be taken in SDDP simulation, which calculates the amount of controllable VRE.

Regarding cost-benefit analysis of battery storage system, the cost assessments are based on current fuel costs, forecasts of future storage battery prices, and CO2 emissions costs. In recent years, the above-mentioned costs, including fuel costs, are likely to fluctuate from the current forecast. Therefore, it is necessary for the battery storage system to review its cost benefit analysis with the recent values as and when the generation developmen plans are updated.

The purpose of this project was to transfer technology, and as such a simple evaluation of the cost-benefit analysis of storage batteries was carried out for the year 2030. However, it is necessary to evaluate the benefits of storage batteries according to the RE yearly development plan while considering the life cycle of storage batteries as 15 to 20 years. In addition, this project adopted technologies that can be realized based on current technological trends but the technological development pace of the energy storage system is remarkable. We recommend that CEB should pay close attention to the technological trends in 2030 and 2040, as new technologies are rapidly replacing the existing technologies.

f. Geological survey on pumped storage power generation

In the next phase, the CEB will continue the future studies with ADB assistance. It includes a pre-feasibility level study for the Victoria site, a comparison between Victoria and Maha 3 sites and selecting the best site. Then a detail feasibility study needs to be carried out for the selected site. In this project, geological surveys at Victoria site were conducted only at the upper pond and upstream of the waterway to avoid natural protected area. In order to compare with the Maha 3 site, the additional geological surveys of the lower pond and downstream of the waterway at Victoria site are required in the next step. In this project, we proposed additional geological survey items and quantities at Victoria. We recommend that CEB will plan and implement the next stage survey based on these items and quantities. However, it should include the complete technical, economical and environmental studies.

(3) WG3

a. Measures Based on Power Outage Record

In the midst of this project, the format of the power outage report was changed and the records of the recovery steps are relatively described. Therefore, we believe that awareness of the need to reduce the failure time is increasing. On the other hand, there were many power outage reports that did not include the causes of the failures or photos of damaged facilities, and there was not enough information that could be used to prevent power outages in the future. This was because the power outage report was prepared by the centralized department, and the communication of information (identification of the fault equipment, photography, identification of the cause of the fault, etc.) with the person who actually visited the site is not properly carried out. In order to improve supply reliability, it is essential to clarify the cause of each power outage, and to formulate and implement measures to prevent recurrence of the failure. Therefore, in order to accurately grasp the cause of each failure, it is important that the person responsible for failure restoration at the site record the photos of the damaged equipment. To this end, it is essential that each and every on-site engineer understand the importance, so C/P are requested to continue the education for on-site engineers. It should be noted that the new power outage report adopted during this project can attach these photos and provide details of the cause of the failure. In the future, it will be necessary to improve the amount and accuracy of individual power outage reports and to compile a database by accumulating them, and to consider and implement measures based on the failure trends and cost-effectiveness of each region.

b. Appropriate operation, maintenance, and horizontal deployment of installation measures

It is necessary to properly operate and maintain the installed equipment (ARC, OCI, GFD) for power outage countermeasures. Since the introduction of countermeasure equipment was delayed due to the impact of Covid-19, the verification is limited to short-term verification. C/P are requested to continue the verification in several years and re-verify the cost-effectiveness. Based on the results of the survey, we hope that the power outage countermeasure equipment will be deployed horizontally throughout Sri Lanka.

On the other hand, this project helped to deepen the understanding of the C/P on the outline and effectiveness of the TSS and FLS, which were not introduced in Sri Lanka under the current circumstances. In addition, the on-site inspections required for the installation of equipment have been completed together with the C/P and CEB transmission and distribution engineers, indicating that the foundation for the introduction has been established. Therefore, we expect that the technology will be widely shared within the C/P and that a positive introduction will be considered so that it will not become a temporary knowledge.

In particular, the TSS can automatically judge the section without failure cause and transmit power, which means that the failure area is limited and the patrol time can be significantly reduced. Therefore, it is expected that the SAIDI will be greatly improved by early recovery in a healthy section and shortening of the inspection time. After the economic situation recovered in the near future, we recommend C/P to consider the introduction of TSS again. It will be expected to contribute to the improvement of SAIDI.

c. Proposals for measures to improve current operations, changes to existing rules based on proposals

When proposing improvement measures to the C/P, there was a tendency to stall due to the current facility specifications and rules. Therefore, it is necessary to develop human resources who can actively revise the current equipment specifications and current rules, if reasonable, when considering the solution of the problem. As specific measures, it is recommended to consider the adoption of small capacity transformers that contribute to the reduction of load fluctuations, the adoption of insulated electric wires that secure phase separation which are more economical than MV twisted and insulated cables of ABC type, and the adoption of relays at GSS and PSS that can be re-closed more than twice and that will lead to the introduction of TSS in the future.

d. Strengthening the number of personnel capable of measuring and dealing with load fluctuations caused by increased installation of rooftop-type solar power generation

In the future, the introduction of rooftop-type solar power generation will be further advanced, and it is expected that issues such as voltage increases and responses to inquiries will increase, especially in the LV distribution system. In this project, measurement, data collection, and analysis of load fluctuations were carried out at the C/P using the provided measuring instruments. In the future, we hope that each C/P will play a leading role in promoting education on measurement technologies throughout the organization and increasing the number of personnel capable of dealing with load fluctuations. At the same time, it is necessary to prepare a sufficient number of measuring instruments.

e. Early improvement of power distribution system interconnection conditions

The installation of rooftop photovoltaic power generation systems for LV systems has progressed, and some distribution lines are unable to be connected due to voltage rises due to late-generation applicants exceeding the standard. It is effective to specify the power factor of the power generation equipment to control the voltage rise, but the current interconnection specification does not specify the power factor in LV lines, and the existing PCS does not have such a function.

In the future, it is expected that the content of the power factor specification will be added to the liaison regulations before the large-scale of existing PCSs without the power factor designation function will be interconnected.

f. Development and systemization of data for LV power distribution systems

We conducted on-site surveys individually, modeled the aggregated data as a pilot site, and quantified the impact of load fluctuations. However, if the number of feeders that are affected by load fluctuations increases due to the introduction of solar PV generators in the future, it will be difficult to investigate and analyze them individually from the viewpoint of the number of artificial devices and equipment. For this reason, we recommend that the present model be used only for training, and that a system be introduced that automatically collects data on LV distribution systems and quantitatively calculates the output and voltage fluctuations in the system for business use.

g. Mitigation of output and voltage fluctuations through promotion of EV introduction and EV charge/discharge control

The introduction of rooftop photovoltaic power generation has progressed, and the LV distribution system has already been faced with the problem of limiting interconnection due to voltage increases. However, as, introducing a battery dedicated to suppressing voltage fluctuations into a LV distribution system their countermeasures is less economical than conventional measures.

Since Sri Lanka does not have a conventional automobile manufacturing plant, it is recommended to consider measures to promote the introduction of EV, including an attracting EV factory. In addition, we expect that EV batteries will be utilized in the power distribution system by considering electricity tariff in which the EV owned by ordinary residents is "incentivized to be charged and discharged to suppress load fluctuations".

6.2 Action Plan of C/P

(1) WG1

Each Action Plan item shown in the table below was presented by the C/P.

Table 6-2 Activities related Rooftop PV FIT revision

	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

(Source) 4th JCC

Table 6-3 Activities to establish a future balancing market

	Action Plan	Time period
1	The CEB will continue to monitor the composition of the European balancing market and consider its applicability to Sri Lanka. Involving the members of NSCC, who are in charge of supply and demand adjustment, CEB will consider milestones for the future introduction of the balancing market.	Within 6 months (by May 2023)
2	Immediate introduction of the balancing market is difficult, but as a preliminary step, CEB will consider measures to promote demand management. Specifically, currently three-tiered prices (TOU in the table below) targeting only EVs are set, but CEB will consider expanding the scope.	Promptly

(Source) 4th JCC

Table 6-4 ToU of current CEB electricity tariff

EV CHARGING OF CEB CHARGING STATIONS		
Time of Use (ToU)	DC Fast Charging (Rs/kWh)	Level 2 AC Ch. (Rs/kWh)
Day (05:30 – 18:30 hrs)	81.00	70.00
Peak (18:30 – 22:30 hrs)	105.00	90.00
Off Peak (22:30 – 05:30 hrs)	50.00	30.00

Table 6-5 Activities to improve CEB's financial status

	Action Plan	Time period
1	Tariff chief engineer reports the recommendation report to the CEO of CEB	December 2022
2	Financial analysis will be conducted using the financial forecast model created in this project. Since the basis for the necessary parameters extends across various departments, CEB will create a new Summary Sheet and circulate it to each department so that data can be collected efficiently.	Every year (After financial information is finalized)
3	Since there is currently only one person in charge of financial analysis in the CEB, the CEB will assign personnel from the Tr. & GP Branch, Finance Division, etc., to create a system that can continue to update the CEB financial forecasting model created in this project.	December 2022
4	In order to obtain financial support from the IMF, CEB is required to revise its electricity tariffs until it can manage its electricity business sustainably. CEB Board approved the new tariff on November 16, 2022. The application will be submitted to PUCSL.	Expected to be revised in December 2022 or early 2023
5	Electricity tariffs after 2023 will be based on a cost recovery tariff that fully recovers costs. The tariff structure will be simplified (Low-	Promptly

	Voltage (LV) customer, LV Bulk, and Mid-Voltage (MV) customer), and the progressive metering rate system will be abolished. Also, consider using the Bulk supply account (transmission business account) as a way of taking up the slack in case costs cannot be recovered (subsidies are received from the government in this account).	

(Source) 4th JCC

Table 6-6　Activities to improve of VRE approval process

	Action Plan	Time period
1	Migration of application and approval procedures to an online system	2023
2	Online system for information sharing with related agencies	2025
3	Obtain data on the time it takes to obtain development permits and make statistics (to identify new problems)	2025
4	Review of the guidelines (revised in 2022) and the Online system	After 5 years (2028)

(Source) 4th JCC

(2)　WG2

Each Action Plan item shown in the table below was presented by the C/P.

Table 6-7　Action for the Development of VRE forecasting system, Demand forecasting system RED

	Action Plan	Time period
①	Improve VRE tool accuracy	Until Mar 2023*
②	Extend VRE forecast to whole island	Until Dec 2024*
③	Implement RED at SCC Accurate demand forecasting	Until Dec 2025
④	Optimal VRE operation	After 2026

Table 6-8　Action for Battery storage capacity consideration

	Action Plan	Time period
①	procurement strategy and detailed technical requirements	Until December 2023
②	1st Pilot Power Project 20MW	Until December 2024
③	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	Until December 2030 _

Table 6-9　Action for Pumped Storage Power Plant (PSPP) development

	Action Plan	Time period
①	Geological Insvestigation on Victoria site	Until February 2023
②	With ADB Fund, Pre-feasibility level study for Victoria site. Compare and select the best site from Maha oya and Victoria site	September 2023
③	With ADB Fund, Detailed feasibility study and construction plan for the selected site	Until June 2024
④	After the studies detail design, construction phase should be started	After June 2024

Table 6-10　Action for Grid Code revision

	Action Plan	Time period
①	Grid Code Revision for VRE integration, Submission of revised grid code to PUCSL	Until August 2023*
②	Receipt of approval from PUCSL, Stipulation of Revised Grid Code	Dec 2024*
③	Actual operation of revised Grid Code	After 2025*

*tentative

(3)　WG3-1

C/P showed a positive attitude to each action plan item shown in the tables below,.

Table 6-11　Action plan for utilization of power outage record

	Action plan	Assigned time
①	Power failure outages of one feeder at each customer service center in the representative province will be recorded by using the newly prepared format.	By March 2023
②	The feedback on the operation/specifications of power failure outage recording will be provided from call centers and customer service centers.	By April 2023
③	The format will be modified based on the feedback.	By June 2023
④	The modified format will be used in all provinces and the scheme to manage/evaluate the outage records will be established.	By August 2023
⑤	The feedback from related staff will be collected and appropriate operation/specification will be conducted.	By December 2023
⑥	The benefits of power failure outage records will be shared and deployed to whole CEB.	By June 2024

［Reference］The forth JCC

Table 6-12 Action plan for horizontal development of power failure countermeasure equipment (CEB)

	Action plan	Assigned time
①	Collect outage records of the distribution lines where countermeasure equipment is introduced for at least 6 months.	By 15 July, 2023
②	Analyze power outage records before and after installation of countermeasure equipment.	By July 2023
③	If there is any countermeasure equipment that is not effective, the power outage record is further analyzed.	By August 2023
④	Introduce countermeasure equipment to other feeders according to failure causes	By December 2023
⑤	Propose the introduction of TSS and FLS to management.	After Sri Lanka's economic crisis subsides

［Reference］The forth JCC

Table 6-13 Action plan for horizontal development of power failure countermeasure equipment (LECO)

	Action plan	Assigned time
①	Select areas for ARC deployment.	By January 2023
②	Determine ARC specifications and start procurement.	By February 2023
③	Install ARC.	By May 2023
④	Collect OCI introduction effect (for 6 months).	By February 2023
⑤	Collect GFD introduction effect (for 6 months).	By May 2023
⑥	Evaluate OCI introduction effect for horizontal deployment.	By May 2023
⑦	Evaluate GFD introduction effect for horizontal development.	By June 2023
⑧	Select OCI development areas based on the evaluation result.	By August 2023
⑨	Procure and install OCI.	By August 2023
⑩	Select GFD development areas based on the evaluation result.	By August 2023
⑪	Procure and install GFD.	By December 2023

［Reference］The forth JCC

(4) WG3-2

As shown in Table 6-14 to16, the C/P prepared action plans in response to recommendations from JICA experts and showed their willingness to work on them.

Table 6-14 Action plan for increasing the number of personnel who can measure and deal with load fluctuations

	Action plan	Assigned time
①	General measurement technology will be transferred from C/P to up to 10 CEB engineers using the clamp-on power logger, HIOKI PW3360.	By March 2023
②	Output power/voltage analysis technology will be transferred from C/P to up to 10 CEB engineers.	By March 2023
③	The acquired technology will be transferred from C/P to all of LECO engineers and technical staff.	By May 2023
④	C/P will make sure the necessary number of data loggers required for future measurements in CEB distribution divisions and apply for their budget while considering the economic situation.	By June 2023
⑤	Measuring instrument utilization technology will be transferred from the engineers to up to 10 CEB technical staff using clamp-on power logger, HIOKI PW3360.	By September 2024
⑥	Advanced measurement technology will be transferred from the C/P to up to four CEB engineers using the power quality analyzer, HIOKI PW3198.	By September 2024

［Reference］The forth JCC

Table 6-15 Action plan for systematization to manage and calculate the data in LV distribution networks

	Acton plan	Assigned time
①	C/P will request the system to manage consumer loads and distributed energy resources such as rooftop solar PV generators and calculate voltage and current in the LV distribution network automatically.	By September 2023

［Reference］The forth JCC

Table 6-16 Action plan for early observation of distribution grid interconnection code

	Acton plan	Assigned time
①	CEB will investigate the problem of excess voltage in LV distribution systems and the actual number of the standby for solar PV generator interconnections.	By March 2023
②	LECO will request all the consumers to equip all their PCS with IEEE 1547 (2018) specifications for LV distribution grid interconnection.	By November 2023
③	CEB will specify to equip PCS with the same function for LV distribution grid interconnection.	Before the interconnection of a lot of PCS without voltage supporting function

［Reference］The forth JCC

Chapter 7 Technology transfer materials

Technology transfer materials implemented for the CEB through the first and second projects are as follows:

(1) WG1

1. System and policy for introduction of renewable energy in Japan
   - 1.1 Output Limitation in VRE
   - 1.2 Priority Dispatch
   - 1.3 Connect and Manage in Japan
   - 1.4 Aggregator Business in Japan
   - 1.5 Fading out of Inefficient Coal Thermal Plant in Japan
   - 1.6 Mandatory Battery Installation when VRE is introduced (Case in Hokkaido of Japan)
   - 1.7 Power Development Promotion Tax
   - 1.8 Global Warming Tax
   - 1.9 Upgrade Cost Allocation
   - 1.10 Amendment of Renewable Energy procurement Act
   - 1.11 Promoting Act of Maritime Renewable Energy Resources

2. Electricity tariff system and FIT scheme in Japan
   - 2.1 FIT Scheme in Japan
   - 2.2 Fuel cost Adjustment in Japan
   - 2.3 Estimation of Purchase Price and IRR in JPN
   - 2.4 Connection Charge to Power Grid
   - 2.5 Interconnection Usage

3. Policy on Renewable energy introduction of other countries
   - 3.1 Lesson from Vietnam Case
   - 3.2 Renewable energy introduction promotion system in major countries
   - 3.3 RE in Asian countries
   - 3.4 Auxiliary measure Tax Benefit in USA (PTC, ITC)

4. Considerations for revising Sri Lanka's FIT and electricity tariff
   - 4.1 FIT revision for rooftop PV in Sri Lanka
   - 4.2 FIT Detailed Condition in Japan and Future Scheme in SL
   - 4.3 FIT and Competitive Bidding Scheme for PV
   - 4.4 Parameters to Calculate FIT
   - 4.5 Review of FIT
   - 4.6 FIT and IRR Calculation sheet
   - 4.7 Milestone of FIT Revision
   - 4.7 Fuel Cost Adjustment System

9.5 Proposed Power Market Structure for Sri Lanka (CEB)
9.6 Financial Model CEB (CEB)
9.7 Present Electricity Tariff and issues (CEB)

10. SEA presentation material
10.1 RE Development Process through PAC (SEA)

(2) WG2

1. Generation projections for variable renewable energy
   1.1 Outline of VRE forecast method
      1.1.1 General method of VRE forecast
      1.1.2 VRE forecast method and system configuration in Chubu Electric power
      1.1.3 Development sites for VRE output forecast model in CEB
   1.2 Structure of the weather and VRE forecast model
      1.2.1 Outline of VRE forecast model
      1.2.2 Way of thinking of the candidate of VRE model development point
      1.2.3 Data and the acquisition method for the development of VRE forecast model
   1.3 Verification of accuracy of VRE forecast model
      1.3.1 Comparison result of the actual and the predicted value
      1.3.2 Review contents of the VRE forecast model on the basis of a verification result of the accuracy
   1.4 Structure of the VRE forecast model of the whole land of Sri Lanka from the VRE forecast model
      1.4.1 Development of VRE conversion tool
      1.4.2 Validity evaluation of the VRE forecast model
   1.5 Process of future VRE forecast

2. Operation of supply and demand
   2.1 The current situation of the short-term and long-term supply and demand operation in Sri Lanka
   2.2 LTGEP(Long Term Generation Expansion Plan) and Long Term Transmission Development Plan (hereinafter referred to as "LTTDP") (CEB part)
      2.2.1 LTGEP
      2.2.2 LTTDP
   2.3 RED(Renewable Energy Desk)
      2.3.1 The role of RED(Including other country's example)
      2.3.2 Future Configuration of RED
   2.4 De-rating factor and EUE to estimate supply power of VRE
   2.5 System analysis using PSS/E
      2.5.1 Characteristic of the 1st, 2nd generation RE model
      2.5.2 Example of Analysis result using the 1st, 2nd generation RE model
      2.5.3 Scenario selection

2.6 Grid Code
2.6.1 The present Grid Code summary in Sri Lanka
2.6.2 Lack contents of Grid Code(Sri Lanka) in comparison with the other countries
2.6.3 numerical criteria of Grid Code based on PSS/E analysis result for LTTDP
2.6.4 Grid Code revision plan

3. Measures that contribute to the stabilization of the electricity system
3.1 The current situation of the electric power system against mass introduction of VRE(Variable Renewable Energy)
3.1.1 General issues in the electric power system by mass introduction of VRE
3.1.2 General countermeasures in the electric power system against mass introduction of VRE
3.2 Energy storage system
3.2.1 Outline of energy storage system
3.2.2 Characteristics of battery storage system
3.2.3 Example of the virtual synchronization generator using the battery (to be confirmed)
3.2.4 Characteristics of PSPP
3.2.5 Operating example of the PSPP(Pumped Storage Power Plants) in Chubu Electric Power
3.3 Comparison with the battery storage and the PSPP
3.3.1 Necessary capacity of the PSPP and battery storage from the supply and demand operation side
3.3.2 Cost comparison between the battery storage and the PSPP in the long-term operation
3.4 Examination of the necessary battery capacity against mass introduction of VRE
3.4.1 Calculation of optimal power plant operation for the VRE ratio improvement
3.4.2 Concrete examination matter to keep power system stability against mass introduction of Non-synchronous Power
3.4.3 The cost evaluation of each battery storage introduction capacity

4. Development of pumped storage power generation
4.1 Issues of PSPP development
4.1.1 General issues
4.1.2 Geologic issues of PSPP development in Maha3
4.1.3 Geologic issues of PSPP development in Victoria lake
4.2 Geological survey contents
4.2.1 Existing geological survey result in Maha3
4.2.2 Geological survey contents in Victoria lake on the basis of a result of Maha3
4.2.2 Instructions at the time of the geological survey
4.3 Geological survey results
4.3.1 Geological survey results in Victoria lake
4.3.2 Instructions in the future geological survey
4.4 On-site training

4.5 Future issues

(3) WG3

1 Power failure outage record

1.1 Format of power failure outage report

1.2 Example of power failure outage report for discussion

2 Power outage control equipment

2.1 Procurement Plan (Draft)

2.2 ARC (Abrasion Resistance Cover for Conductor)

2.3 OCI (Over Current Indicator)

2.4 GFD (Ground Fault Detector)

2.5 ECF (Enclosed Cutout Fuse)

2.6 FLS (Fault Locating System)

2.7 TSS (Time Sequential Sectionalizer)

3 Power outage countermeasures and SAIFI/SAIDI estimation

3.1 Power outage cause and countermeasures

3.2 Activities for improving SAIDI

3.3 Activities for improving SAIFI

3.4 Failure analysis method

3.5 Calculation method of SAIDI and SAIFI

3.6 Estimation of equipment introduction effect

3.7 Automatic detection of detailed outage area by smart meter

4 Power distribution grid interconnection code

4.1 Classification of grid interconnection in Japan

4.2 Guideline regarding power quality securement for grid interconnection requirement in Japan

4.3 Grid interconnection code in Japan

5 Photovoltaic power generation

5.1 Outline of solar PV generation system

5.2 Rooftop PV connection to 400V line

6 Battery system

6.1 Utilization of storage battery system in distribution grid

6.2 Sample of BESS main specifications

6.3 Application for grid interconnection of BESS with documents and drawings

6.4 Interconnection procedure of BESS