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Study on Enhanced Flexibilisation of Coal-fired Power Plants for Optimal Grid Stabilisation in the ASEAN Region

Edited by

Yamada Fumiko

Murakami Kazuyuki

Han Phoumin

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Economic Research Institute for ASEAN and East Asia (ERIA)
Sentral Senayan II 6th Floor
Jalan Asia Afrika No. 8, Gelora Bung Karno
Senayan, Jakarta Pusat 10270
Indonesia

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List of Project Members

Working Group Members

Mr Pramudya, ST, MT, Policy Analyst, Directorate of Programming, Directorate General of Electricity, Ministry of Energy and Mineral Resources, Indonesia

Mr Hery Wahyudi Wibowo, ST, MT, Electricity Inspector, Directorate of Electricity Engineering and Environment, Directorate General of Electricity, Ministry of Energy and Mineral Resources, Indonesia

Mr Andi Hanif, ST, M.Eng, Electricity Inspector, Directorate of Electricity Engineering and Environment, Directorate General of Electricity, Ministry of Energy and Mineral Resources, Indonesia

Mr Arief Sugiyanto, Manager of System Planning for Java, Madura and Bali, System Planning Division, PT. PLN (Persero)

Mr Herian Atma, Engineer of System Planning for Java, Madura and Bali, System Planning Division, PT. PLN (Persero)

Ir Mohd Helmi bin Mohd Zaihan, Assistant Director, Energy Commission (Suruhanjaya Tenaga), Malaysia

Ms Rose Adila binti Bujal, Senior Engineer, Grid System Operator (GSO), Malaysia

Ms Melanie C. Papa, Senior Science Research Specialist, Power Market and Development Division – EPIMB, Department of Energy, Philippines

Mr Noriel Christopher R. Reyes, Senior Science Research Specialist, Power Planning and Development Division – EPIMB, Philippines

Mr Nguyen Minh Quang, Deputy Manager of Power System Analysis and Planning Department, National Load Dispatch Centre (A0), Viet Nam Electricity (EVN), Viet Nam

Mr Nguyen Tuan Anh, Senior Expert of Technical and Operational Department, Viet Nam Electricity (EVN), Viet Nam

Ms Nguyen Minh Hai, Expert of International Relations Department, Viet Nam Electricity (EVN), Viet Nam

ERIA Project Organiser

Dr Han Phoumin, Senior Energy Economist, Energy Unit, Research Department, Economic Research Institute for ASEAN and East Asia (ERIA)

JCOAL Study Team

Dr Kazuyuki Murakami, Program Manager and Senior Material Scientist, Research and Development Department

Mr Yasuo Otaka, Deputy Director, Resources Development Department

Mr Masahiro Ozawa, Chief Engineer, International Collaborations Department

Ms Yamada, Fumiko, Assistant Director, International Collaborations Department

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List of Abbreviations and Acronyms

AEO6	The 6th ASEAN Energy Outlook
AMS	ASEAN Member States
ASEAN	Association of Southeast Asian Nations
ATS	ASEAN target scenario
BESS	battery energy storage system
CES	clean energy scenario
CFB	circulating bed
CFPP	coal-fired power plant
CO_2	carbon dioxide
COD	commercial operation date
COVID-19	Novel Coronavirus (2019-nCoV)
CSR	corporate social responsibility
DOE	Department of Energy, Philippines
EIA	Energy Information Administration
ERIA	Economic Research Institute for ASEAN and East Asia
ESS	energy storage system
EV	electric vehicle
EVN	Vietnam Electricity
GDP	gross domestic product
GHG	greenhouse gas
GSO	Grid System Operator of Malaysia
HP	high pressure
LP	low pressure
IEA	International Energy Agency
MEMR	Ministry of Energy and Mineral Resources of Indonesia
MFO	marine fuel oil
NAS	sodium-sulphur
NRE	new and renewable energy
PLN	Perusahaan Listrik Negara (Persero) of Indonesia
PSP	pumped storage power
RETR	Renewable Energy Transition Roadmap
RH	reheater
RUPTL	*Rencana Usaha Penyediaan Tenaga Listrik*
SEDA	Sustainable Energy Development Authority of Malaysia
SH	super heater
TNB	Tenaga Nasional Berhad
VRE	variable renewable energy
WRB	wide range burner

Chapter 1

Background, Objectives, and Methodology of the Study

1. Background

ASEAN is now one of the most dynamic and fastest-growing economic regions in the world, and the current growth is expected to continue. The region is projected to see its annual growth of at least 4% or even more over the next 5 years.

While member states of the Association of Southeast Asian Nations (ASEAN) (AMS) bear minimal responsibility for global carbon emissions, they are equally suffering from the recent impacts of climate change. It is natural that the AMS committed to the Paris Agreement not long after the international agreement was in place. Malaysia is targeting to reduce greenhouse gas (GHG) emissions intensity against gross domestic product (GDP) by 45% by 2030. Thailand is committed to an unconditional 20% emissions reduction by 2030 against its business-as-usual scenario under which emissions may increase in the same period by as much as 25%. Indonesia is consistent with its commitment to reduce emissions by 29% or by 41% with international support by 2030.

The rest of the AMS follow; all AMS are trying hard to address the emission reduction requirements mainly through renewable energy introduction. ASEAN sets an aspirational target to increase the component of renewable energy to 23% by 2025 in its primary energy mix. The four countries deemed to be more vulnerable in view of their ambitious target of renewable energy development are Indonesia, Malaysia, the Philippines, and Viet Nam.

Indonesia is committed to 23% renewable energy in total primary energy supply by 2025, while Malaysia is confident about its target of 2,080 MW of renewable energy installed capacity by 2020 (excluding large hydro). The Philippines is making strenuous efforts towards the target of 15.2 GW of renewable energy in 2030. Viet Nam is committed to the target of 32% renewable energy against the overall installed capacity of 130.37 GW by 2030. Some AMS are struggling to enhance renewable energy introduction to expedite regional electrification in addition to achieving the emission reduction targets.

It is to be noted that renewable energy is variable and intermittent by nature. Looking at the issue from a technical point of view, the ongoing and forthcoming massive introduction of renewables will enhance energy sustainability and resilience only if the existing fossil fuel power plants are appropriately controlled and operated with enough flexibilisation as per the requirements dispatched by the grid through the introduction of techniques, best practices, and technologies such as the Internet of Things and/or artificial intelligence.

The situation may vary from one country to the other. Usually, gas power plants are given the role. However, some countries where coal power is dominant over gas power use coal-fired power plants (CFPPs), as in the case of India.

To sustain the present high growth while enhancing energy resilience, ASEAN will be required to address the emerging issue of possible grid fluctuation with the massive introduction of renewables.

2. Objectives

The ultimate objective of this study is to provide best practices and applicable measures and technologies for CFPPs for the flexible and yet optimal operation to contribute to the

1) stabilisation and sustainability of the national and transnational grids, and
2) minimisation of possible negative impacts by the massive introduction of renewables on the grid and the existing CFPPs.

3. Methodology

1) Formulation of by-country strategies for technology introduction, implementation, and sharing

   The study focuses on identifying and formulating by-country strategies to facilitate introduction, implementation, and sharing

   - electronic communication with Working Group members for information and advice to formulate the optimal strategy for each target AMS,
   - collective discussions at the two-time Working Group meetings as referred to 2), and
   - internet surveys to enhance the accuracy of the strategies to be formulated.

2) Working Group activities

   - Two-time Working Group meetings are planned as part of the Study Working Group activities, for which members will be nominated through the relevant government institutions and utilities, as shown in the quoted list of institutions below, to provide advice and support for the sake of enhanced outcomes of the study.
   - Working Group members are to interact with the Study Team about energy and electricity policy updates, observed issues and barriers, etc. to jointly identify the optimal scenario of grid stabilisation supported by the required measures to be taken at the plant end.
   - Working Group members may be asked to provide views on the possibility and/or necessity of plant surveys in case relevant crucial information is not available through literature study.

- The purpose of each Working Group meeting is as follows:

- 1st Working Group meeting: Discussion on topics such as potential technology introduction in each AMS, issues to be addressed, envisaged best practices, policy measures to be taken, benefits, and advantages, etc.
- 2nd Working Group meeting: Draft report presentation by JCOAL covering proposals for each AMS discussion on the draft for incorporating comments and advice from the Working Group members to formulate policy recommendations as referred to in section 5.

4. Expected Recommendations

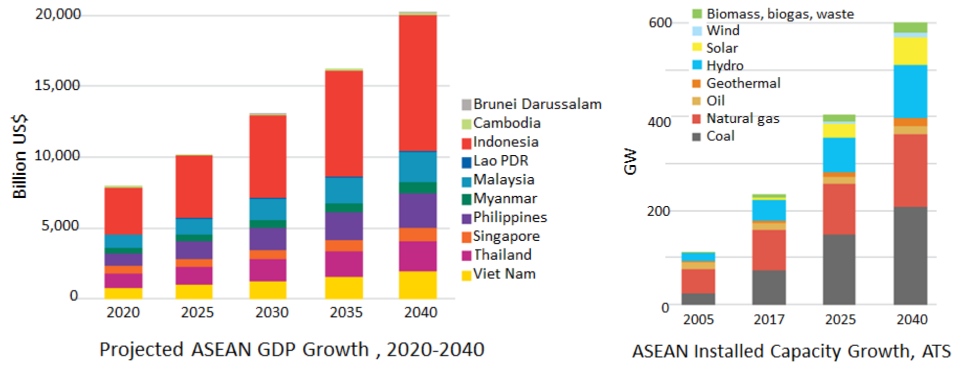
1) Guidelines for the optimal policy framework for ASEAN to facilitate the flexible operation of coal-fired power s to ensure the optimal stabilisation of the grid
2) By-country strategies for introduction, implementation of flexible operation at CFPPs, and sharing of best practices
3) Guidelines for the optimal policy framework for ASEAN to facilitate the flexible operation of CFPPs to ensure the optimal stabilisation of the grid.
4) By-country strategies for introduction, implementation of flexible operation at CFPPs, and sharing of best practices.
5) Policy recommendation to the East Asia Summit to facilitate the by-country policy efforts based on the proposed strategies.

Chapter 2
Energy Transition Outlook and Best Available Technologies

1. Outlook in the Energy Transition Period

ASEAN's GDP growth in the coming 2 decades is projected to be one of the highest surges in the world (Figure 2.1, left). ASEAN's GDP is projected to nearly triple from 2020 to 2040. Indonesia is the largest economic zone in ASEAN, followed by Malaysia, the Philippines, Thailand, and Viet Nam. In these expanding economies, electricity demand will remarkably increase (Figure 2.1, right). The energy policies in 2018, when the 6th ASEAN Energy Outlook (AEO6) was compiled, revealed that each country has no choice but to rely on fossil energy of coal- and gas-fired power. The renewable source is expected to play a critical role in the energy supply, simultaneously addressing climate change.

Figure 2.1. Projected ASEAN GDP Growth (left) and ASEAN Installed Capacity Growth (right) under AEO6

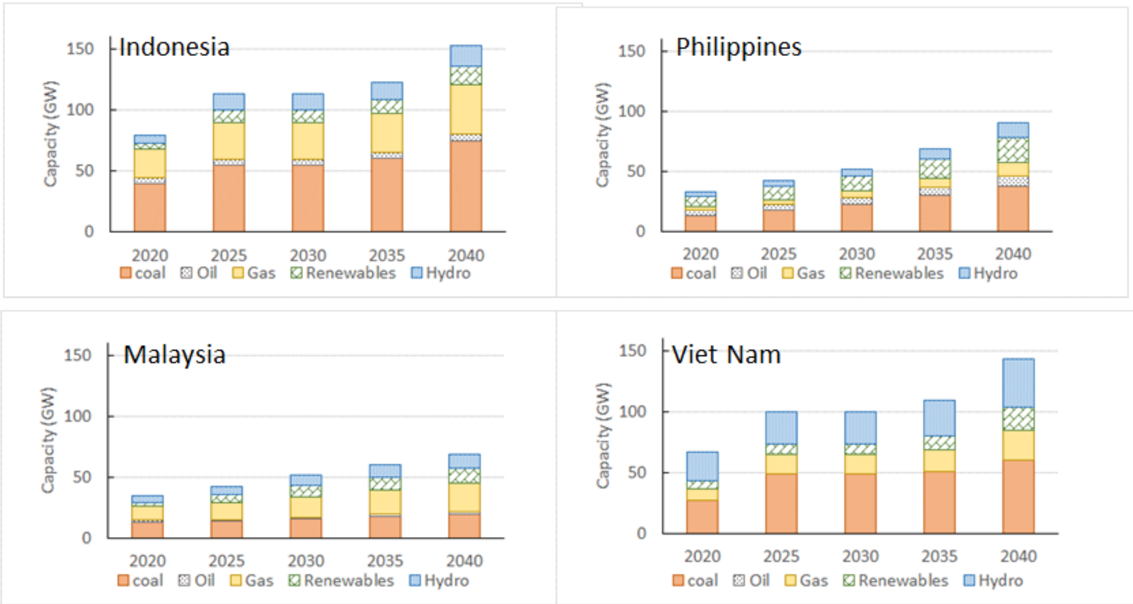


ATS = ASEAN Target Scenario.
Source: ASEAN Centre for Energy (2020).

Figure 2.2 shows the generation outlook of four countries based on the data from the AEO6. Despite the massive installation of renewable capacity, coal and gas energy is still the mainstay of power generation. In such a situation, grid fluctuation might occur by an un-optimised generation mix.

Each country aims for further carbon neutrality by adding renewable energy and reducing fossil energy, incorporating it into the latest power development plan. In such an energy transition, grid fluctuation might become severe if intermittent renewable energy, such as solar and wind, is introduced. Currently, this grid fluctuation issue should be addressed by all other energy sources connected to the same grid for further flexibilisation.

Figure 2.2. Generation Growth of ASEAN Target Scenario, 2020–2040

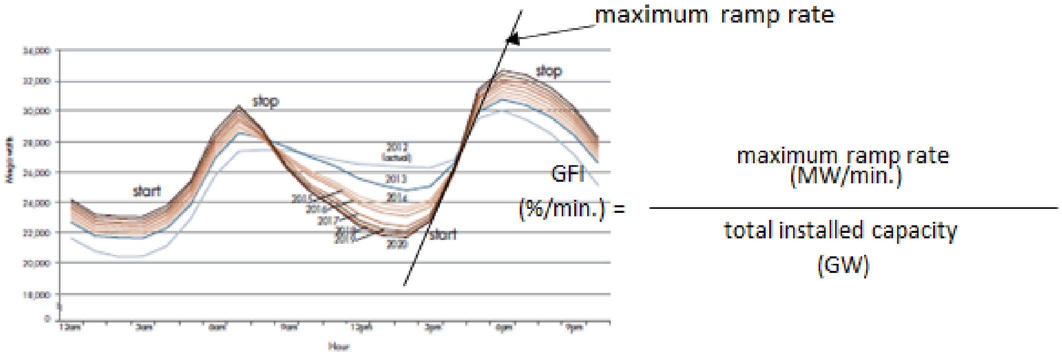


Source: ASEAN Centre for Energy (2020).

1.1. Grid Fluctuation Index (GFI) for preliminary analysis of future grid fluctuation

The daily variation curve of the energy demand is often shown as the 'Duck Curve' (Figure 2.3). The maximum ramp rate is to be a parameter showing the degree of grid fluctuation. But the value itself strongly depends on the grid size. The GFI is newly defined as a parameter to express the degree of grid fluctuation by calculating the maximum ramp rate and the total installed capacity of the grid.

Figure 2.3. Example of Duck Curve and Definition of GFI



Source: Duck curve: www.caiso.com.

Since such duck curves, especially future ones, are extremely limited to be obtained from the public domain, a GFI prediction formula was obtained by multivariate analysis from the limited data. Its details are described in the reference (IEC, 2021). The result of the GFI prediction formula is shown in formula (1):

$$GFI = w_1X_{coal} + w_2X_{nuclear} + w_3X_{renew} + w_4X_{solar} + E \qquad (1)$$

where, X_{coal}, $X_{nuclear}$, X_{renew}, X_{solar} are energy availability factors of coal, nuclear, total renewables, solar, respectively; w_1, w_2, w_3, w_4 are coefficients for X_{coal}, $X_{nuclear}$, X_{renew}, X_{solar}, respectively; and E is a residual error of the regression.

Table 2.1. GFI Regression Model

X	Coefficient	Value
X_{coal}	w_1	0.0015
$X_{nuclear}$	w_2	-0.0001
X_{renew}	w_3	-0.0003
X_{solar}	w_4	0.0071
Residual error	E	-0.1258

Source: Authors' calculation.

The Q&A of GFI analysis in the 1st Working Group is in the Appendixes.

1.2. GFI behaviour of ASEAN, 2020–2040

Table 2.2 shows an estimated GFI of ASEAN by multivariate regression analysis.

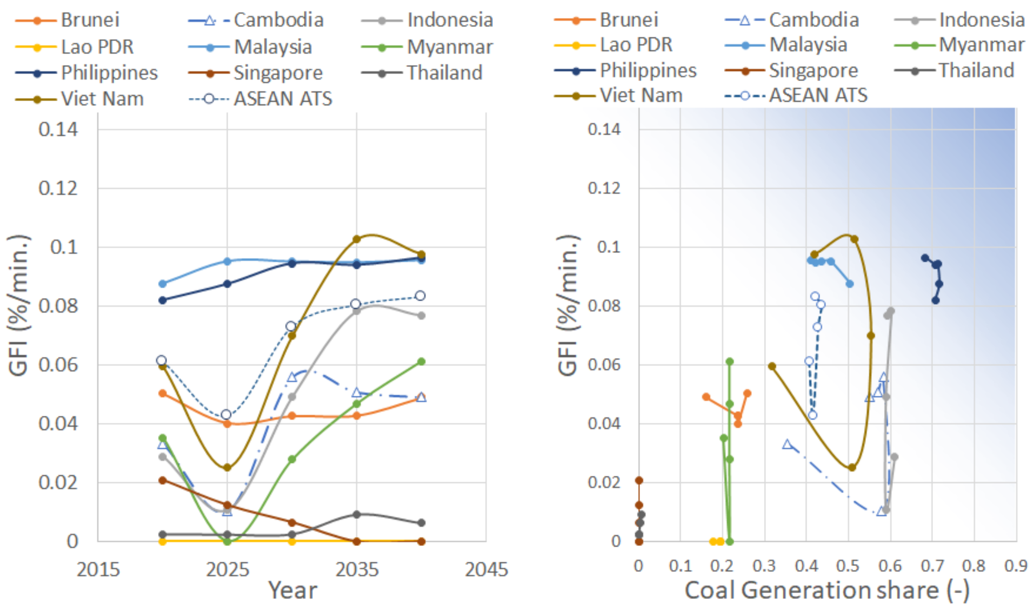
Table 2.2. Estimated GFI of ASEAN Countries, 2020–2040

Country	2020	2025	2030	2035	2040
Brunei Darussalam	0.050	0.040	0.043	0.043	0.049
Cambodia	0.033	0.010	0.056	0.051	0.049
Indonesia	0.029	0.011	0.049	0.078	0.077
Lao PDR	0.000	0.000	0.000	0.000	0.000
Malaysia	0.088	0.095	0.095	0.095	0.096
Myanmar	0.035	0.000	0.028	0.047	0.061
Philippines	0.082	0.088	0.095	0.094	0.097
Singapore	0.021	0.012	0.007	0.000	0.000
Thailand	0.002	0.002	0.002	0.009	0.006
Viet Nam	0.059	0.025	0.070	0.103	0.098
ASEAN average	0.061	0.043	0.073	0.080	0.083

Source: IEC (2021).

The GFI of many countries – especially Indonesia, Malaysia, the Philippines, and Viet Nam – will remarkably increase from 2030. On the other hand, Singapore and Thailand seem to have less concern about grid fluctuation. Brunei, the Lao PDR, Cambodia, and Myanmar have relatively smaller grid sizes. There seems to be less concern about grid fluctuation. The grid scales of Indonesia, Viet Nam, the Philippines, and Malaysia are growing without any remarkable change in the power supply share; the grid fluctuation concern is likely to become apparent after 2030.

Figure 2.4. Estimated GFI Overview of ASEAN, by Year (left), by Coal Share (right)



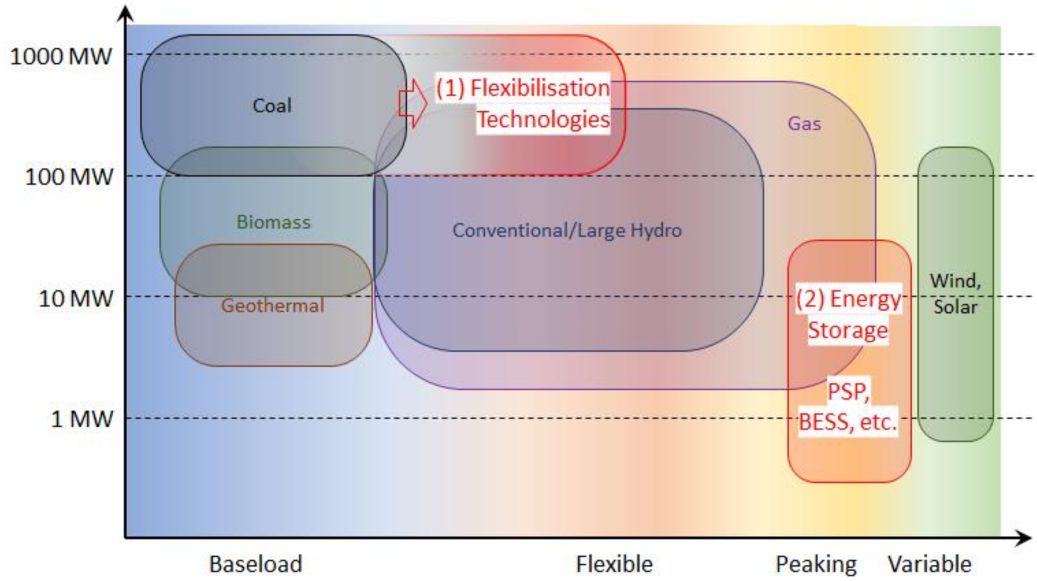
Source: IEC (2021).

Indonesia is projected to see its GFI surging after 2035. Flexibilisation with the CFPPs would be one major option to address the possible fluctuation of the national grid. The GFI of Malaysia will stay at a relatively high level at 0.09–0.1. Coal accounts for less than 50% of the generation mix. The GFI of the Philippines will remain at a relatively high level at approximately 0.08–0.1, which would require flexibilisation measures. High dependence on coal-fired power generation is deemed to be a major factor to expedite it. The local grid system fluctuation might occur more severely if the more flexible power supply sources such as gas and/or hydro are less available. The GFI of Viet Nam will stay relatively at a low level up to 2025, following which a sharp increase will be observed towards 2035. Installed capacity will continue to increase for the long term. As of 2040, coal will account for less than 40% of the generation mix. The ASEAN ATS in Figure is an average GFI of the ATS.

2. Key Resources and Technology for Grid Flexibilisation

This is an overview of the by-resource potential contribution to grid flexibility. All kinds of generations are plotted in this graph. Horizontal is a type of generation; vertical is generation capacity.

Figure 2.5. Overview of By-resource Potential Contribution to Grid Flexibility



Source: Authors' calculation.

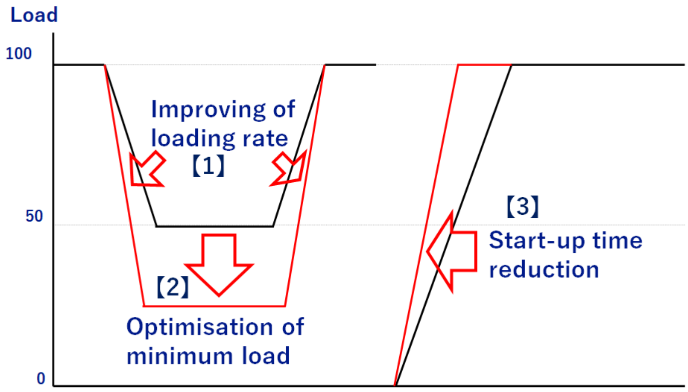
Coal and biomass generation is normally operated as baseload generation. Conventional large hydro and gas are operated widely from the baseload, flexible to peaking. Wind and solar are operated as intermittent variable renewable energy (VRE), the main reason for future grid fluctuation. Two major technologies are considered flexibilisation measures: technologies of CFPPs and energy storage, such as pump storage power (PSP) and battery energy storage system (BESS), etc.

2.1. Technical measures at the CFPPs

There are six key points in the flexibilisation technology of CFPPs: (i) improving loading rate, (ii) optimising minimum load, (iii) reducing start-up time, (iv) reducing life consumption, (v) Improving the control system, and (vi) modifying existing plants.

The first three key points are especially important. Figure 2.6 shows the three key points of the flexibilisation technology of CFPPs.

Figure 2.6. Three Key Points of Flexibilisation Technology

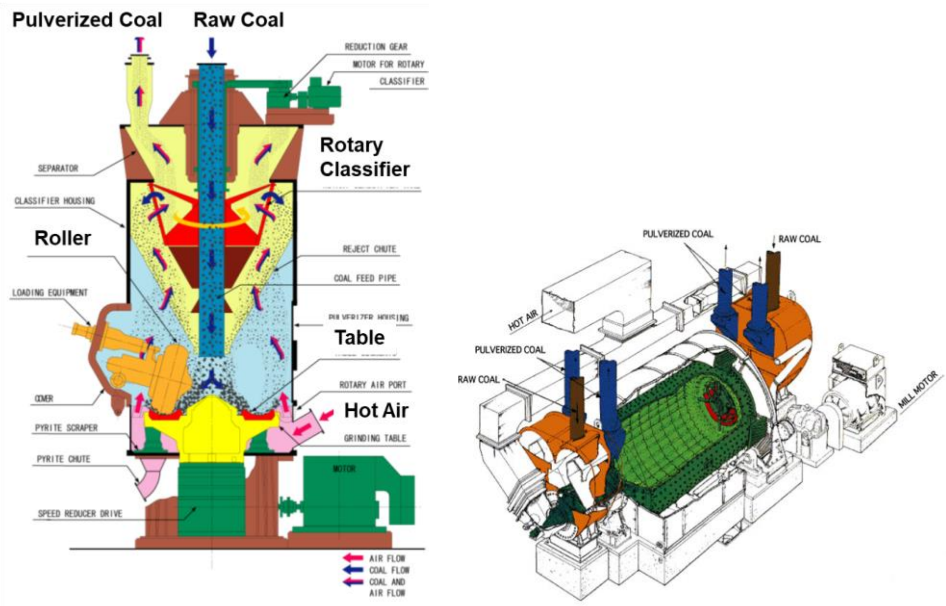


Source: Authors' calculation.

The most important factor in regulating the load of CFPPs is to improve the rate of load change. The first is improving the burning characteristics of coal. There are various types of mill pulverisers in CFPPs. Figure 2.7 shows the vertical mill pulveriser and the ball mill pulveriser. The second is improving steam temperature controllability.

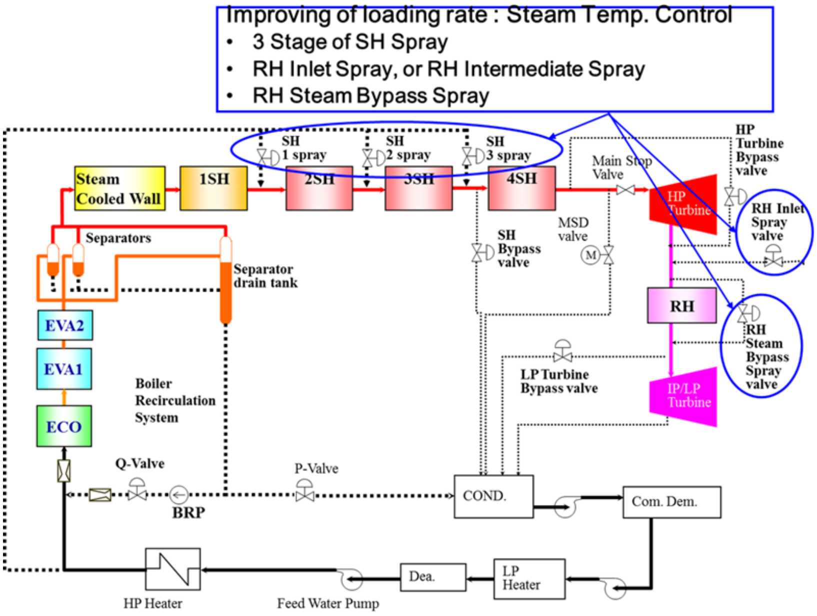
Figure 2.8 shows an example of the main flow diagram. The third is the appropriate capacity of accessories, such as pulverisers, fans, pumps, and valves, and advancement of control equipment for steam temperature control. By introducing these, the load change rate can be improved from 3%/min to 5%/min.

Figure 2.7. Vertical and Ball Mill Pulverisers



Source: Edited by JCOAL Original data from IHI.

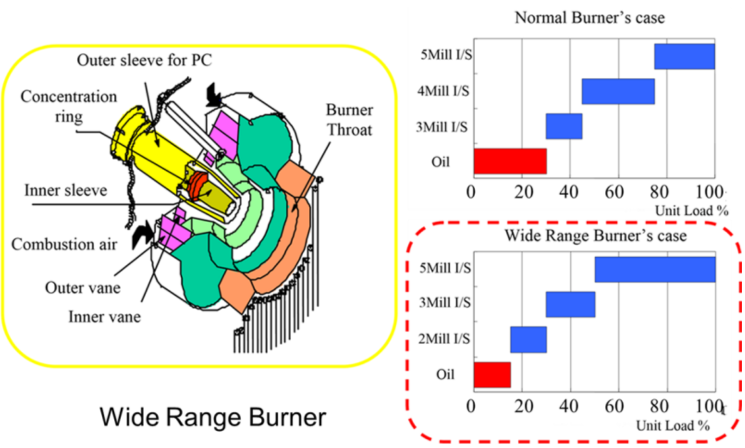
Figure 2.8. Example of Main Flow Diagram



Source: Authors' calculation.

The next important point is optimisation of the minimum load. When the mill pulveriser is at low load, the pulverised coal at the outlet of the mill pulveriser is excessively lean as the air ratio is too high against coal. In this case, coal or oil must be increased to reach stoichiometric air–fuel ratio. Conventionally, the minimum load of coal-firing without oil support is limited to 30%–50% load. Figure 2.9 shows an example of a wide range burner (WRB) and burner turndown. The concentration ring is installed in the WRB. The figure on the right is an example of a burner turndown. The figure above is for a normal burner and the figure below is for a WRB. In the case of the WRB, the minimum load of coal firing without oil support is about 15%.

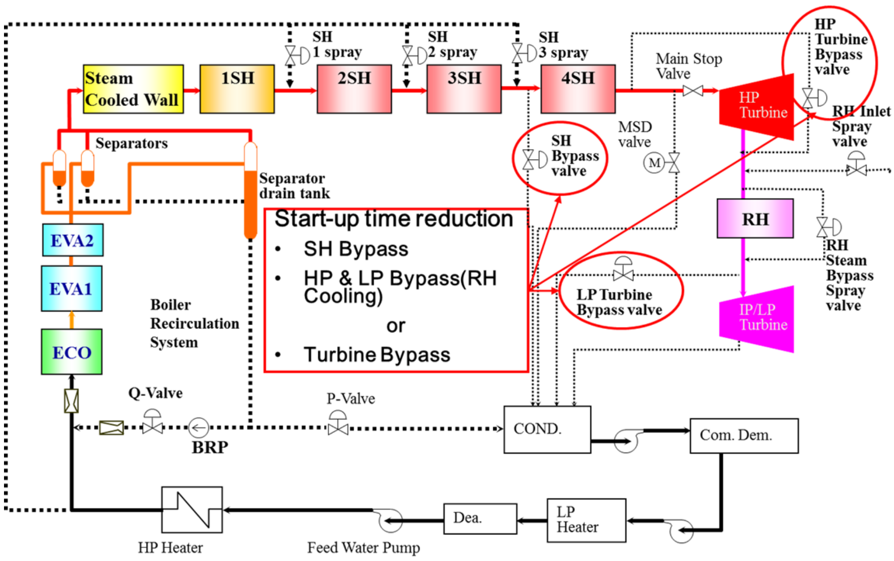
Figure 2.9. Wide Range Burner and Burner Turndown



Source: Edited by JCOAL Original data from IHI.

The next third important point is reducing the start-up time. To shorten the start-up time, it is important to raise the turbine inlet steam temperature quickly. To that end, installing the following start-up bypass system, SH (super heater) bypass system, and high pressure/low pressure (HP/LP) turbine bypass system with RH (reheater) cooling or turbine bypass system without RH cooling. This start-up bypass system reduces the start-up time from ignition to full load from 120 minutes to 180 minutes. Figure 2.10 shows an example of a start-up bypass system diagram.

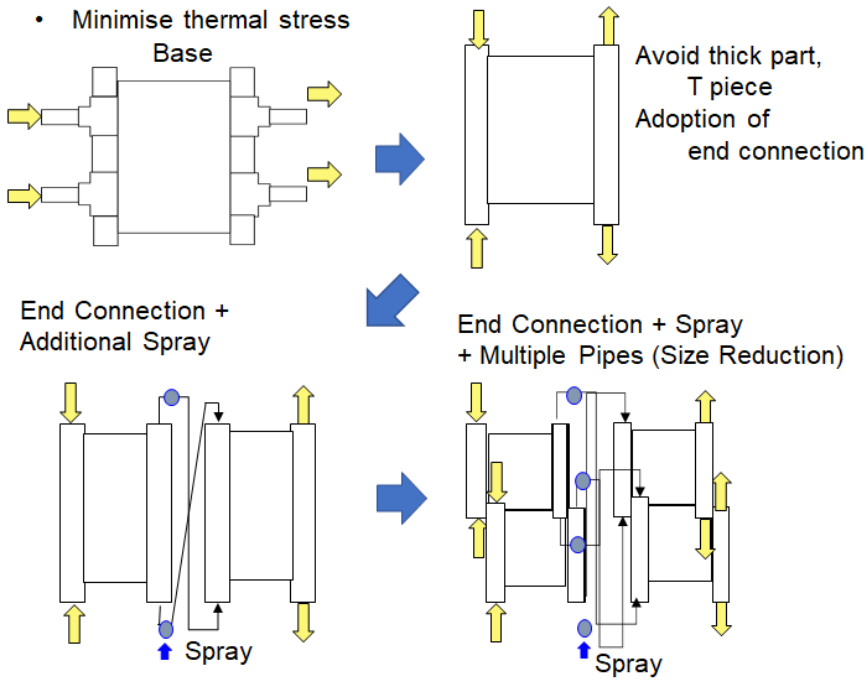
Figure 2.10. Example of a Start-up Bypass System Diagram



Source: Authors' calculation.

The improvement of the load change rate and the shortening of the start-up time lead to increased life consumption of the thick heat transfer part of the boiler. Here, the example of the reduction measures of the life consumption of the thick part of the boiler heat transfer part is introduced. Figure 2.11 shows some examples of the configuration of the heat transfer surface to minimise the thermal stress of the high-temperature parts. The upper left is the configuration of the heat transfer surface of the base, using the T piece. The upper right does not use the T piece; it adopts the end connection. The lower left is an example of adopting the end connection, splitting the heat transfer surface, and adding a spray between them. The lower right corner is an example that further improves by dividing the heat transfer surface in the furnace width direction.

Figure 2.11. Examples of Configuration of the Heat Transfer Surface



Source: Authors' calculation.

To improve the load adjustment function, it is important not only to improve equipment and systems but also to improve the control device and optimise the adjustment.

The operation ability improvement in the existing plant is explained. In the case of existing plants, it is important to clarify the purpose of functional improvement and comprehensively examine and remodel two small areas such as goals, effects, costs, and remodelling periods.

Some examples of remodelling existing plants are shown below.

- Modification of combustion equipment for a low load operation
- Number of mills: 1 mill, 2 mills, or all mills
- Number of burners: 1 row or 2 rows of burners, or all burners
- Improvement of steam temperature control
- Addition of SH spray 1 stage
- Reduction of start-up time
- Capacity increase of start-up bypass system

The following are examples of CFPPs in Japan that adopted WRBs.

Table 2.3. Examples of Adoption of Wide Range Burners (WRBs)

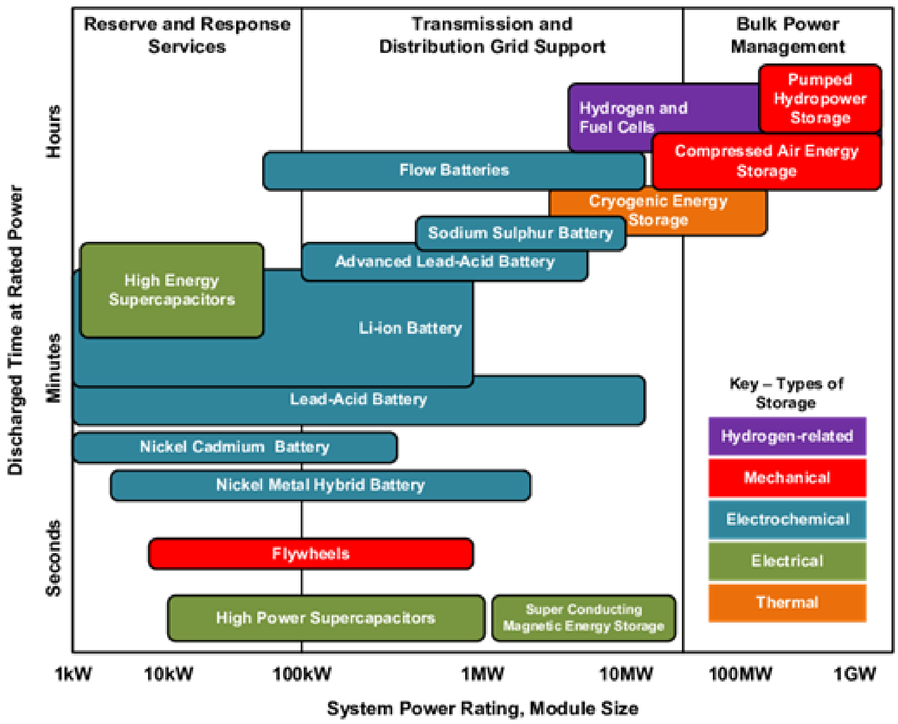
MW	No. of Mills	No. of Burners	No. of Mills that Adopted WRBs	No. of WRBs
33	2	8	1	4
250	4	24	2	8
600	6	36	2 → 6	12 → 36
700	6	36	6	36

Source: Authors' calculation.

2.2. Energy storage

Figure 2.12 shows the categories of energy storage technologies; horizontal is the module size and vertical is the discharge response. Pumped hydropower storage is plotted at the top right area, which means a moderate response and larger size. Compressed air and cryogenic energy are relatively smaller in size than the PSP. Several types of BESS, shown in blue, are positioned in the middle size and response. Especially, lithium-ion is now expanding its share each year globally because of its high energy densities.

Figure 2.12. Categories of Energy Storage Technologies

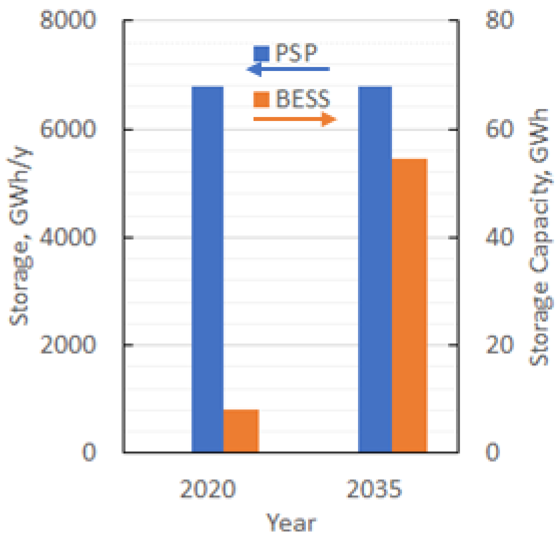


Source: Sprake et al. (2017).

Regarding quick response, high energy supercapacitor and superconducting magnetic energy device are shown. These kinds of technology are mainly used for uninterruptable power supply. BESSs of smaller size are normally used for ancillary support. According to this category, PSP, compressed air, and BESS are considered flexibilisation measures in this study.

Figure 2.13. Energy Storage Capacity in Japan

(GWh/y, GWh)	2020	2035
PSP	6800	6800
BESS	8	54.4



Source: Edited by JCOAL.

Figure 2.13 shows the energy storage capacity in Japan. Currently, PSP is the main energy storage; its annual energy storage is about 6.7 TWh/year. Since further suitable site situations for the PSP plant are limited, PSP is not expected to increase. On the other hand, mainly lithium-ion type BESS is drastically increasing.

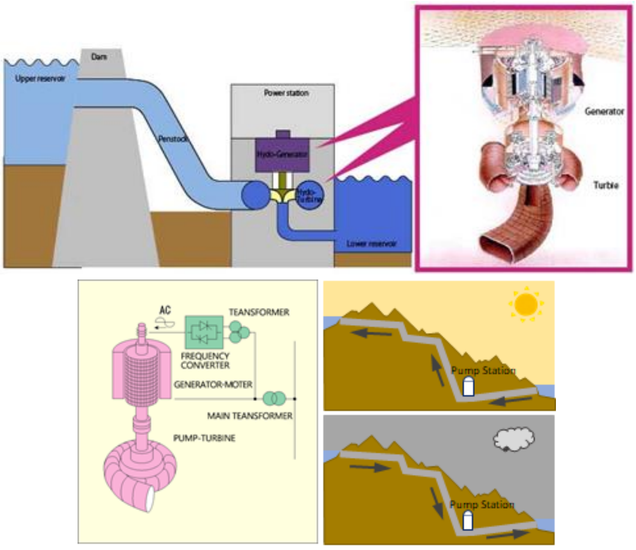
Table 2.4 summarises the three main kinds of large energy storage technologies. Various electric energy conversions to potential, compressed, and electrochemical are currently available. PSP is a kind of potential energy. Small hydro can be easily converted to this type by renovating the turbine and generator with an additional pump function. The second is compressed energy. The energy charge is done by an electric power–driven pump up to the upper reservoir. Liquid air storage is an application of compressed energy. Charge–discharge is done by a simple mechanical operation of well-proven facilities and heat exchange without AD-DA conversion. The application of electrochemical energy is normally known as BESS. In this system, three technologies are suitable for large-scale energy storage: lithium-ion, sodium-sulphur, and redox flow batteries.

Table 2.4. Available Energy Storage Technologies

Technologies	Features	
Potential energy Pumped storage power	Pumped storage stores and generates energy by moving water between two reservoirs at different elevations. Excess energy is used to pump water to an upper reservoir at times of low electricity demand, like at night or on weekends,.	
Compressed energy Liquid air energy storage	The liquified air is converted back into pressurised gas, which drives turbines to produce electricity. Cost-effective supply–demand balancing besides ancillary services, such as grid stability, inertia, and reactive power	
Electrochemical energy Lithium-ion	Lithium-ion batteries are suitable for storing high-capacity power. They are used in various applications, including consumer electronics such as smartphones and personal computers, industrial robots, production equipment, and automobiles.	
Electrochemical energy Sodium Sulphur (NAS)	NAS battery is a high-temperature battery. Full discharge (SOC 100% to 0%) is available without capacity degradation. No self-discharge. Best performed with a long-duration application.	
Electrochemical energy Redox flow	Redox flow batteries are rechargeable batteries that are charged and discharged through the oxidation–reduction reaction of ions of vanadium or the like. The batteries are expected to serve as a technology to stabilise the power grids needed to expand the introduction of renewable energy, including solar and wind power.	

Source: Company websites: Toshiba Energy Systems & Solutions, https://www.toshiba-energy.com/en/renewable-energy/product/index.htm; Sumitomo Heavy Industries, Ltd., https://www.shi.co.jp/english/products/energy/cryobattery/index.html; NGK Insulators, Ltd. Sumitomo Electric Industries, Ltd., https://www.ngk-insulators.com/en/product/nas-solutions.html.

Figure 2.14. Pumped Storage Power



Source: Toshiba Energy Systems & Solutions website, https://www.toshiba-energy.com/en/renewable-energy/product/index.htm (accessed 1 October 2021).

Figure 2.14 shows a typical PSP system and water stream in charge and discharge.

'Adjustable-speed' PSP generation is mainly applied in Japan. The features of this technology are the following:

- Automatic frequency adjustment function during pumping operations
- Higher efficiency and expanded operation range during both generating and pumping operations
- Improved power grid stability
- Functions for maintaining the grid voltage.

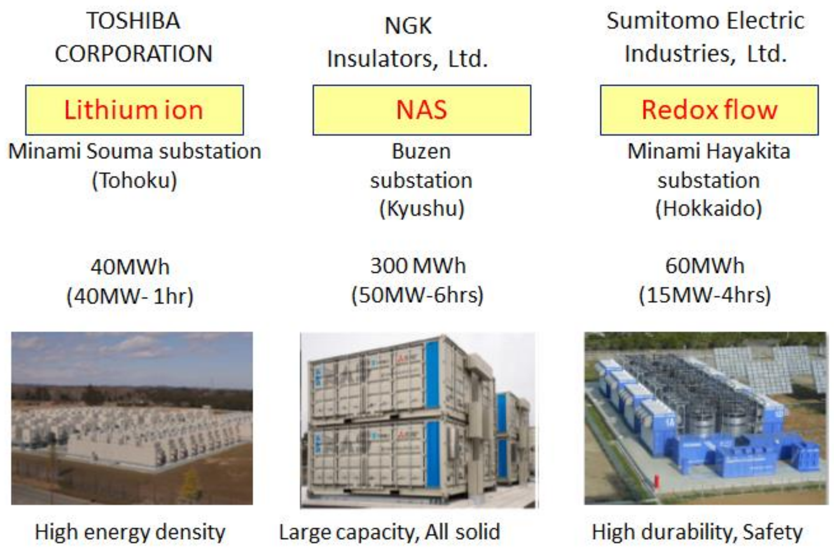
Liquid air energy storage (LAES) technology (Figure 2.15) uses a freely available resource, air, cooled and stored as a liquid. As the discharging part, the liquified air is converted back into pressurised gas, which drives turbines to produce electricity. Air used for the driving turbine is recycled as an energy transfer medium with heat exchange at the charging part. LAES is ideal for replacing fossil fuel–based power plants by providing long-duration storage in renewable power systems. It offers cost-effective supply–demand balancing besides ancillary services, such as grid stability, inertia, and reactive power.

Figure 2.15. Liquid Air Energy Storage

Source: Sumitomo Heavy Industries, Ltd. website, https://www.shi.co.jp/english/products/energy/cryobattery/index.html (accessed 1 October 2021).

Figure 2.16 shows the three kinds of BESSs; these are demonstrated in major Japanese electricity utilities through governmental support. At the left is lithium-ion of 40 MWh; at the centre is sodium sulphur of 300 MWh; at right is a redox flow system of 60 MWh. Table 2.5 lists the typical performance of these three types. Lithium-ion has the highest energy density, making it the most advantageous to be developed and commercialised. That is why we use lithium-ion from mobile to vehicle in such large-scale energy storage.

Figure 2.16. BESS with a Wide Range of Choices



Source: Kyushu Electric Power, http://www.kyuden.co.jp/press_h160303-1_smt.html; Tohoku. Electric Power, https://www.tohoku-epco.co.jp/pastnews/normal/1191223_1049.html; Hokkaido Electric Power, https://www.hepco.co.jp/network/renewable_energy/efforts/large_accumulator/index.html.

Sodium-sulphur battery is initially developed for industrial applications to back up energy and uninterrupted power supply. Redox flow battery, most recently developed in Japan, uses metal ion reactions at room temperature. This technology has the advantage of long duration, and its capacity is easy to expand, only expanding the tanks of metal iron solution.

Table 2.5 Typical Performance of BESS

	Lithium Ion	Sodium Sulphur	Redox Flow
Cell voltage (V)	2.4–3.6	2.1	1.2–2.1
Energy density (W/kg)	70–200	100–130	10–30
Charge/discharge cycle	1,000 <	2,500–4,500	10,000 <

Source: Electric Power, http://www.kyuden.co.jp/press_h160303-1_smt.html; Tohoku. Electric Power, https://www.tohoku-epco.co.jp/pastnews/normal/1191223_1049.html; Hokkaido Electric Power, https://www.hepco.co.jp/network/renewable_energy/efforts/large_accumulator/index.html.

Examples of the commercial application of each BESS are shown in Figure 2.17, Figure 2.18, and Figure 2.19. All technology suppliers are now tackling system cost reduction and improvement of durability for expanding the global commercial network.

Figure 2.17. BESS Application by Toshiba

Tohoku Electric Power Network Co., Inc

- ✓ Improving the supply and demand balance of renewable energy.
- ✓ BESS specifications:
  Maximum output: 40 MW,
  Capacity: 40 MWh

Willey Battery Utility, LLC in the U.S.

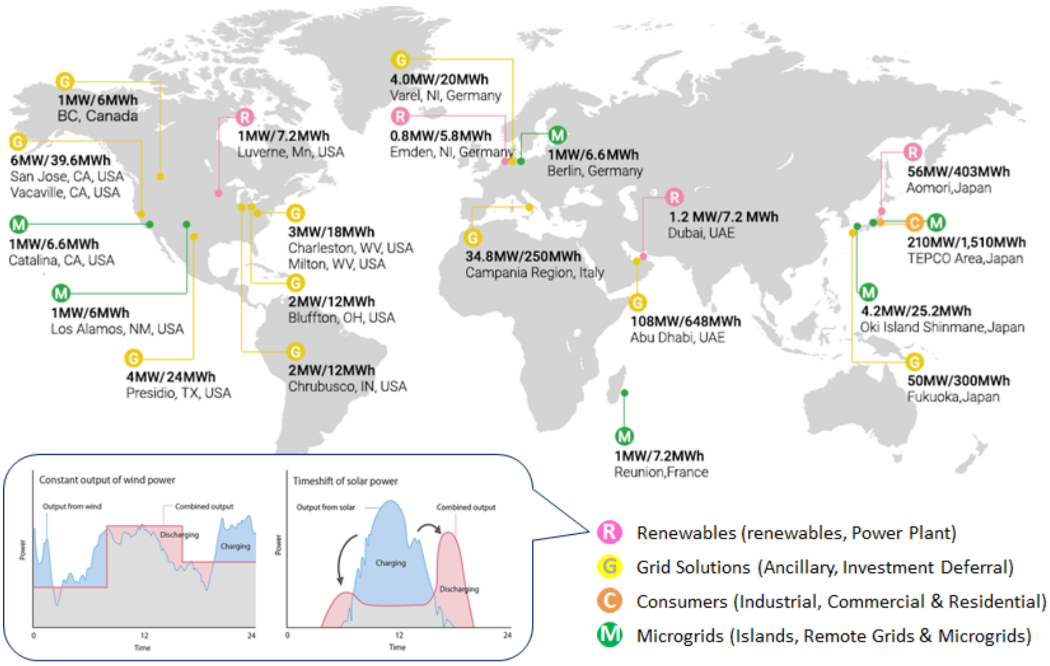
- ✓ Frequency regulation in the suburbs of Cincinnati, Hamilton, Ohio, U.S.
- ✓ Providing an ancillary services through a frequency regulation market
- ✓ BESS specifications:
  Maximum output: 6 MW
  Capacity: 2 MWh

Terna S.p.A in Italy

- ✓ Frequency regulation purpose.
- ✓ Realising stable grid by controlling frequency and grid fluctuation.
- ✓ BESS Specification:
  Rated Output 1 MW,
  Capacity 1MWh (for both 2 sites)

Source: Toshiba Corporation, https://www.global.toshiba/jp/products-solutions/battery/scib/application/power-system.html (accessed 1 October 2021).

Figure 2.18. BESS Application by NGK Insulators



Source: NGK Insulators, Ltd., https://www.ngk-insulators.com/en/product/nas-solutions.html (accessed 1 October 2021).

Figure 2.19. BESS Application by Sumitomo Electric Industries

Source: Sumitomo Electric Industries, Ltd., https://sumitomoelectric.com/sites/default/files/2021-04/download_documents/Redox_Flow_Battery_En.pdf (accessed 1 October 2021).

Chapter 3
By-Country Situation and Perspectives

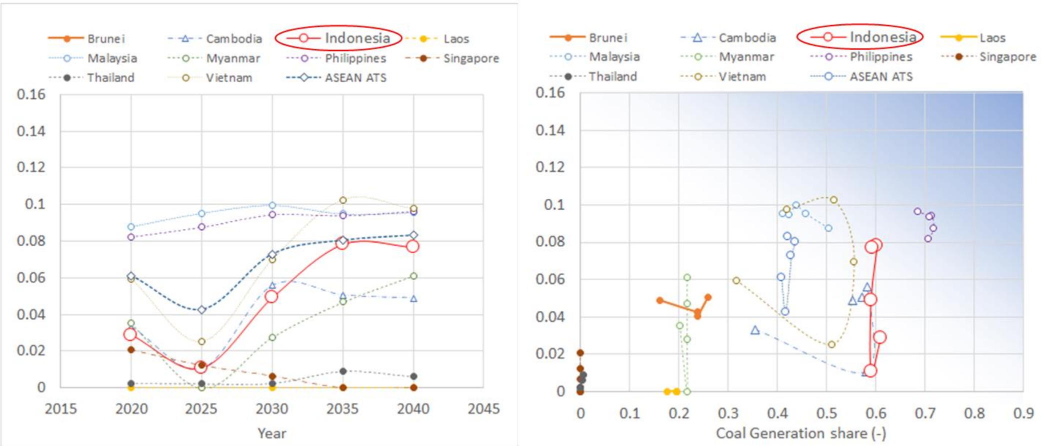
1. Indonesia

1.1. Grid fluctuation of Indonesia

Figure 3.1 shows Indonesia's future grid fluctuation analysis by GFI based on AEO6 data.

Indonesia is projected to see GFI surging after 2035. Flexibilisation with the CFPPs would be one of the major options to address the possible fluctuation of the national grid system.

Figure 3.1. Future Grid Fluctuation of Indonesia by GFI

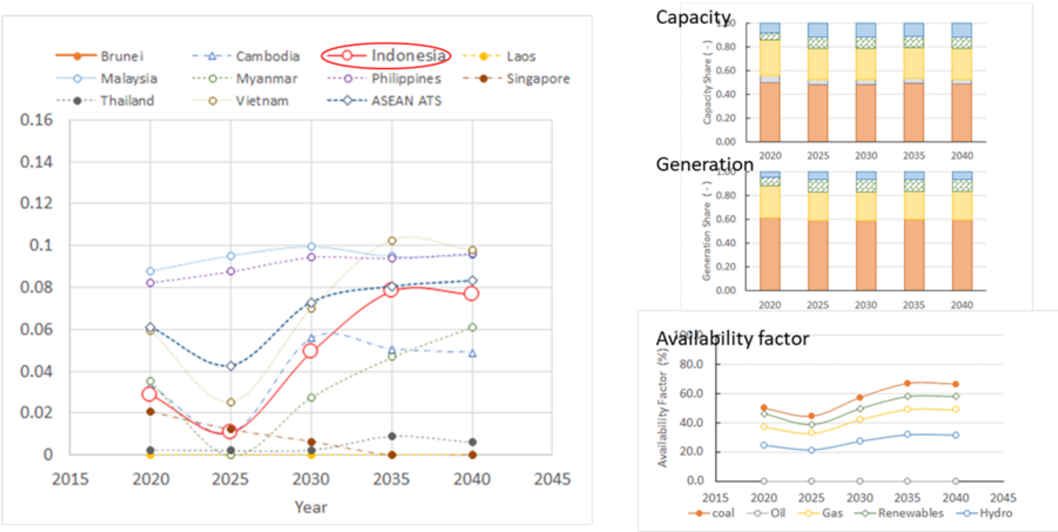


Source: Authors' calculation.

Figure 3.2 shows the GFI analysis and capacity, generation, and availability factor.

Towards 2040, Indonesia will not experience a major change in electricity mix for both installed capacity and generated capacity. The availability factor of all fuels will rise as years go by. Coal is projected to be over 80%.

Figure 3.2. GFI Analysis and Capacity, Generation, and Availability Factor



Source: Authors' calculation.

1.2. Power generation development plan

1) Power plant capacity

Indonesia's electricity supply business plan, known as RUPTL (*Rencana Usaha Penyediaan Tenaga Listrik*), is prepared by the Perusahaan Listrik Negara (PLN), the state-owned power company. The RUPTL is published annually to review the detailed electricity supply plan for 10 years.

It took more than one year since the issuance of the RUPTL in 2019[1] until the RUPTL in 2020 was released, because they had to take time to observe the unusually slugging electricity demand growth due to the COVID-19 pandemic and were trying to identify how and to what extent they would have to reflect the impact of the pandemic and energy transition requirements to formulate the new RUPTL. The Government of Indonesia also shifted to renewable energy due to Indonesia's commitments under the Paris Agreement and its recently declared carbon neutrality objectives. The new RUPTL was released on 5 October 2021 after reviewing and revising the power supply configuration as follows:

- Maintaining demand–supply balance for each electricity grid to ensure the adequacy of electricity supply,
- No additional CFPP and sequential reduction of existing plants, and
- Increase new and renewable energy (NRE) to achieve the minimum target of 23% NRE mix starting in 2025.

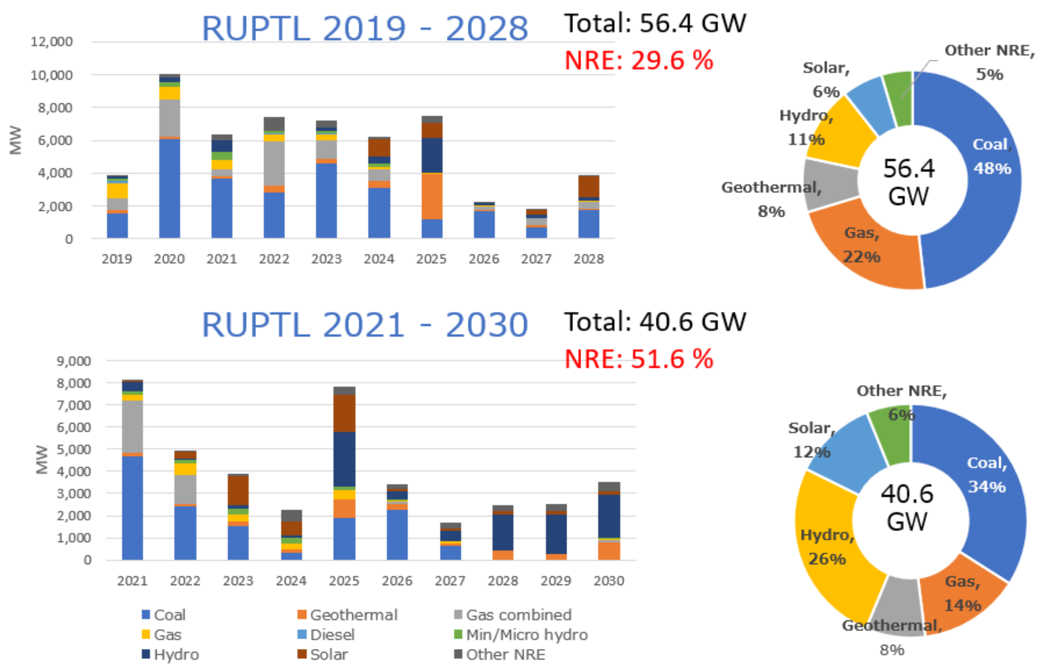
[1] RUPTL 2019, https://web.pln.co.id/statics/uploads/2021/08/5b16d-kepmen-esdm-no-39-k-20-mem-2019-tentang-pengesahan-ruptl-pt-pln-2019-2028.pdf (accessed 13 September 2021).

Figure 3.3 compares the power plant capacity plan in RUPTL 2021 and RUPTL 2019.

In RUPTL 2019, the total power plant installed capacity is 56.4 GW; CFPP share is 48%.

In RUPTL 2021, the capacity is 40.6 GW, 15 GW less than RUPTL 2019. In addition, coal accounts for 34% of the total capacity, while NRE accounts for more than 50%.

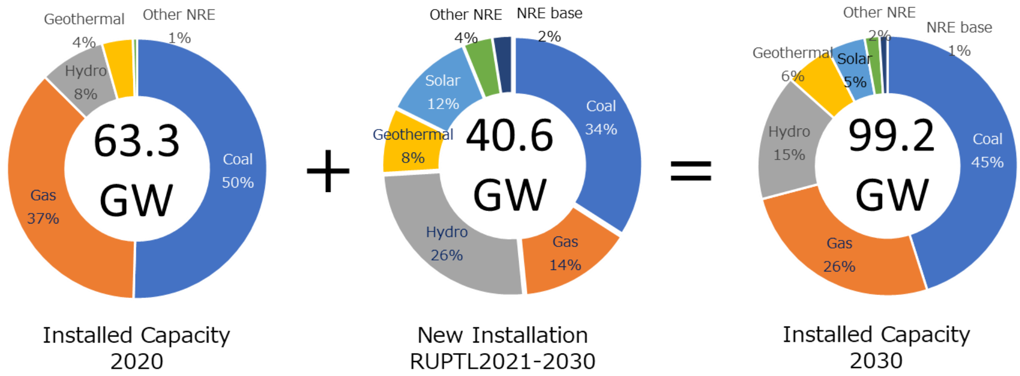
Figure 3.3. New Power Plant Capacity Plan Compared with RUPTL 2019



Source: RUPTL 2021, https://web.pln.co.id/statics/uploads/2021/10/ruptl-2021-2030.pdf (accessed 15 October 2021).

Figure 3.4 shows installed generation capacity of Indonesia in 2020 and 2030. The installed capacity in 2020 is 63.3 GW, and the expansion in RUPTL 2021–2030 is 40.6 GW. The total power plant capacity will be 99.2 GW in 2030. By substituting CFPPs with NRE power plants, the share of coal power in the projected installed capacity mix in 2030 will be less than half, and the NRE share will be 29%.

Figure 3.4. Power Plant Capacity Installed by 2030

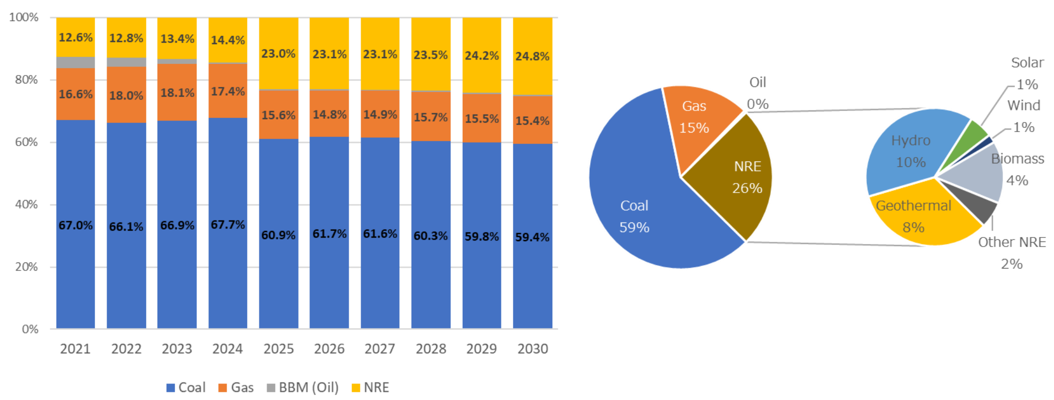


Source: RUPTL 2021, https://web.pln.co.id/statics/uploads/2021/10/ruptl-2021-2030.pdf accessed 15 October 2021).

2) Power generation energy mix

Figure 3.5 shows the electricity production and energy mix of power generation in 2030 based on RUPTL 2021. Total electricity production in 2030 will be 445 TWh. In 2025, NRE will significantly increase due to a policy response of 23% NRE generation. The main NRE are hydro, geothermal, and biomass, which are baseload power sources. But coal still accounts for 60% of electricity generation.

Figure 3.5. Electricity Production and Power Generation Energy Mix in 2030



Source: RUPTL 2021, https://web.pln.co.id/statics/uploads/2021/10/ruptl-2021-2030.pdf (accessed 15 October 2021).

Biomass cofiring in CFPPs is promoted as an effective and easy way to increase NRE share and manage municipal waste disposal. Table 3.1 shows PLN's biomass cofiring plan. The PLN has conducted cofiring tests with a 5% biomass addition rate at 32 out of 52 power plants. The PLN will increase renewable energy to 23% by 2025; therefore, the biomass cofiring rate will increase to 20%–30%. Finally, biomass will be consumed at a rate of 8–14 million tons.

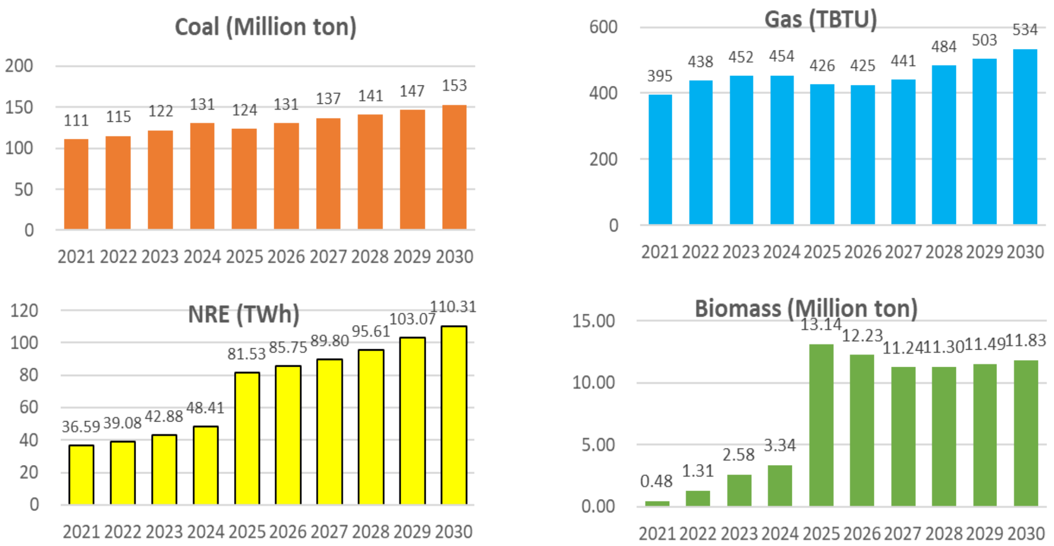
Table 3.1. Plan of Biomass Cofiring with Coal

	CFPP		Biomass	Waste Pellet
	No.	MW	(Million ton/year)	
Sumatra	13	2,315	2.82	0.122
Jawa	16	14,845	2.73	0.693
Kalimantan	10	979	1.16	0.053
Sulawesi	6	478	0.77	0.026
Papua & Maluku	3	41	0.17	0.002
Nusa Tenggara	4	237	0.40	0.0136
Total	52	18,895	8.05	0.9096

Source: RUPTL 2021–2030 (accessed 15 October 2021).

Figure 3.6 shows the fuel consumption based on the new RUPTL. Coal and gas consumption will slightly increase. NRE and biomass will be increased rapidly in 2025 to achieve the target of 23% NRE share. In particular, biomass consumption is increasing rapidly, therefore it is important to ensure its procurement.

Figure 3.6. Fuel and Energy Consumption in Power Generation



Source: RUPTL 2021–2030 (accessed 15 October 2021).

1.3. Electricity policy towards carbon neutrality

GHG emissions also affect the power generation plan. Indonesia had announced that it would reduce GHG emissions and make the country carbon neutral by 2060.

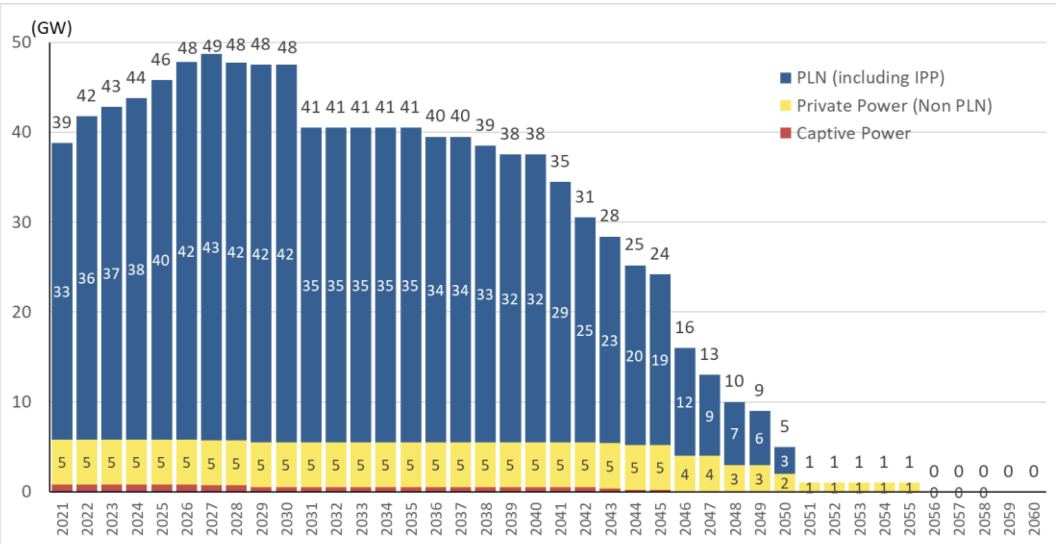
As shown in Figure 3.1-5, even in 2030, 59% of electricity will be generated from CFPPs, which emit the most GHGs in power generation. Therefore, reducing CFPPs and replacing them with renewable energy for carbon neutrality is necessary.

Figure 3.7 shows the phase-out plan of the CFPPs, which will be gradually reduced from 2031 and abolished by 2056.

The basic principles are as follows:

- CFPP capacity will increase until 2027, coming from ongoing projects. There will be no new plants other than those contracted or being constructed
- The CFPPs of independent power producers will operate until the power purchase agreement has ended; it cannot be extended.
- A retirement programme is applied to all CFPPs, including those for non-PLN and own use.
  - 2031: First stage retirement of CFPPs with sub-critical technology
  - 2037: Second stage retirement of sub-critical and some super-critical CFPPs
  - 2054: The last group of combined cycle power plants are retired.
  - 2055: CFPPs are completely retired.
- Action is needed to accelerate the retirement plan:
  - Study further the retirement of PLN's CFPPs before 2030 because of revaluation issues of PLN's assets.
  - Prepare the CFPP regulation to support the implementation of retirement.
  - Ban new CFPP permits.

Figure 3.7. Phase-out Plan of Coal-fired Power Plants



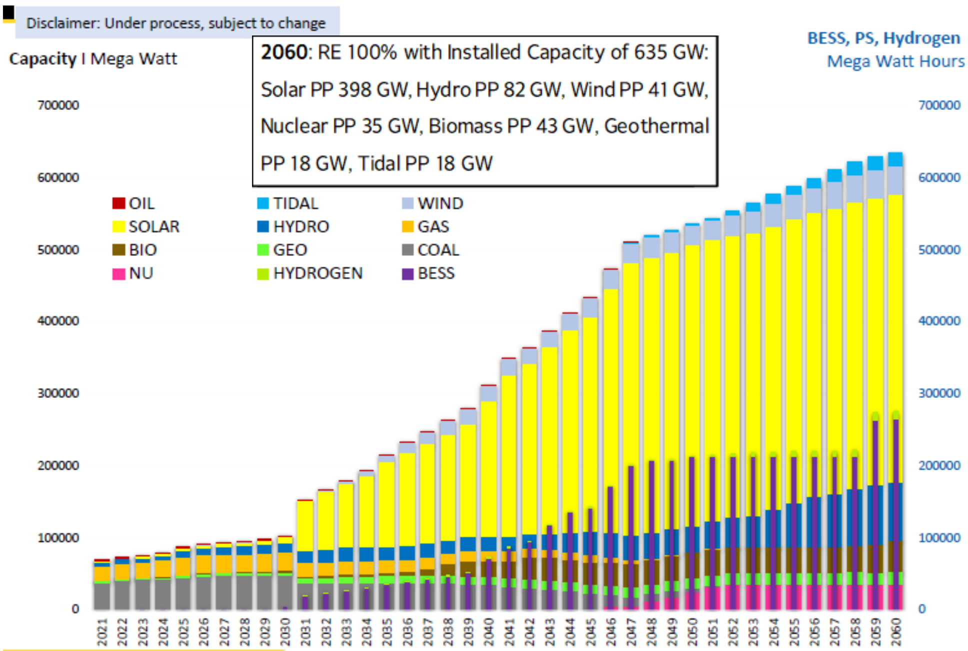
Source: Mulyana (2021).

Figure 3.8 shows the power supply plan until 2060 that was considered based on this CFPP phase-out plan.

For the years 2021 to 2030 of this plan, the RUPTL is applied; for 2031 to 2060 of the plan, the following conditions are considered:

1. CFPP/CCPP (combined cycle power plant): No new CFPP unless it has been contracted and constructed. The CFPP and CCPP will be retired according to age and/or contract (remaining < 1 GW: CFPP 2052, CCPP: 2050).
2. NRE: Additional power plant after 2030 only from NRE. It will be dominated by VRE, such as solar power plants, starting in 2035 and, in the following year, by wind and tidal power plants.
3. Geothermal: maximised up to 75% from total potency
4. Hydropower: maximised, and the electricity is sent to load centres on other islands; hydropower also provides balancing for VRE plants.
5. Storage: pump storage, BESS, and hydrogen fuel cells will be massively used after 2035. Hydrogen is used gradually, starting in 2031 and massively in 2051.
6. Nuclear power plant: to maintain system reliability, nuclear power plants will operate around 2045; in 2060, the total installed capacity of nuclear power will reach 35 GW.

Figure 3.8. Power Plant Capacity and Electricity Production by 2060



Source: Mulyana (2021).

With the retirement of CFPPs starting in 2031, solar power will increase, followed by wind and tidal power. Since solar, wind, and tidal power are VRE, it is necessary to balance these VRE plants with hydropower, which is the baseload power source.

1.4. Policy recommendations

Due to the COVID-19 pandemic, electricity growth in 2020 was below the target initially set out in RUPTL 2019-2028. In the new RUPTL, the national generation mix is revised to maintain demand–supply balance as follows:

- No additional CFPPs and sequential reduction of existing plants
- Increase NRE to achieve the minimum target of 23% NRE mix starting in 2025.

Additionally, towards carbon neutrality in 2060, only NRE power plants will be added after 2031, and CFPPs will be phased out. Therefore, reducing CFPPs and increasing NRE by reviewing oversupply are also effective from the carbon neutrality perspective.

As mentioned earlier, the Indonesian government is considering the new electricity development plan:

1) Rapid increase in NRE from 2025, especially biomass, will enhance procurement in terms of fuel availability. In addition, due to its high cost, it is necessary to consider efficiency improvement and economic efficiency.

2) NRE will increase as a substitute for coal. Since hydropower, geothermal, and biomass are the main sources for the time being, grid stabilisation and load adjustment are not necessary. However, in response to the abolition of CFPPs and the increase in NRE, especially solar power, towards carbon neutrality in 2060, a detailed study on securing base power sources, battery development, and grid stabilisation is needed.

2. Malaysia

2.1. Energy policy and power sector overview

1) Energy power sector overview

While Malaysia holds a large share of Southeast Asia's fossil fuel resources, the country has always been conscious of the importance of sustainable energy supply and has had very clear energy policies addressing various important elements of energy utilisation. The country's energy policy has been evolving to facilitate energy security and clean energy. Table 3.2 outlines the major relevant energy policies to date.

Table 3.2. Major National Energy and Electricity Policies of Malaysia

Year	Title of Policy/Act	Outline
1979	National Energy Policy	- Adequate, secure, and cost-effective energy supply - Efficient utilisation of energy - Minimise negative impacts to the environment
1980	National Depletion Policy	- Prolong the life span of national gas and oil reserves
1981	Four Fuel Policy/National Diversification Policy	- Ensure reliability and security of supply through diversification of fuel (oil, gas, hydro, and coal)
1990	Electricity Supply Act	- Stipulate how electricity supply is ensured and implemented
2001	Five Fuel Policy	- Encourage utilisation of renewable resources such as biomass, solar, mini-hydro, etc. - Efficient utilisation of energy
2001	Energy Commission Act	- Establish the Energy Commission
2011	Renewable Energy Act	- Establish a system of feed-in tariffs for renewables
	Sustainable Energy Development Authority Act	- Establish the Sustainable Energy Development Authority (SEDA)
Forthcoming	Renewable Energy Transition Roadmap (RETR)	- Establish the national energy roadmap with a focus on renewables

Source: Country Presentation at the 1st Working Group Meeting (June 2021) and Energy Commission (2021a).

The federal government established the Sustainable Energy Development Authority (SEDA), a new wing for renewable energy development, in 2011. As of November 2021, under SEDA's initiative, the Renewable Energy Transition Roadmap (RETR) is being formulated with the target year revised to be 2050 from the initially set 2040. The RETR is anticipated to constitute the new backbone of the country's energy policy and policy implementation in the ongoing energy transition as renewable energy gradually takes the central position in the country's power sector.

2) Organisation of the power sector in Malaysia

The Ministry of Energy and Natural Resources (Ketsa), as the line ministry that took over from the then Ministry of Energy, Science, Technology, Environment and Climate Change in March 2020, currently oversees the energy and electricity sector. The Economic Planning Unit also oversees the sector as the government institution in charge of national development policy. SEDA implements the renewable energy policy, while the Energy Commission regulates and facilitates clean and sustainable energy utilisation at the national level.

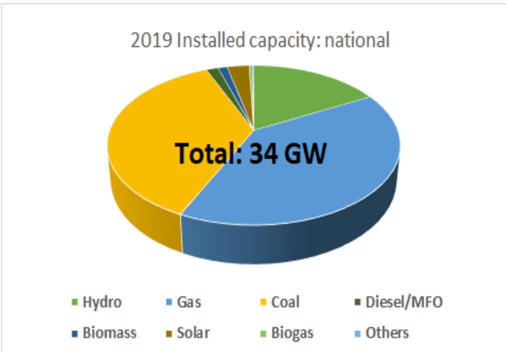
While the federal government formulates national policy, different institutions handle the day-to-day power sector management of each of the three regions. Power generation, transmission, and distribution in Peninsular Malaysia are under the Tenaga Nasional Berhad (TNB) and the Grid System Operator (GSO); the same for Sabah is handled by the Sabah Electricity Corporation under the provincial government. The Electrical Inspectorate Unit under the Ministry of Utility Sarawak oversees the power sector in Sarawak. The fully privatised Sarawak Energy is in charge of generation, transmission, and distribution.

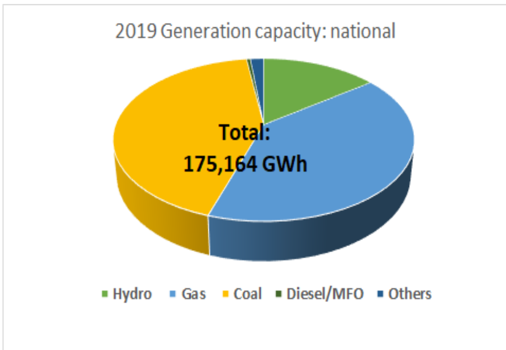
3) Diverse generation portfolio in the three regions

Figure 3.9 shows the national installed capacity mix and generation mix in 2019.

Coal and gas respectively account for 36.7% and 39.8% of the national installed capacity and 42.8% and 40.2% of the national generation capacity in 2019, indicating that Malaysia is still fossil fuel dependent.

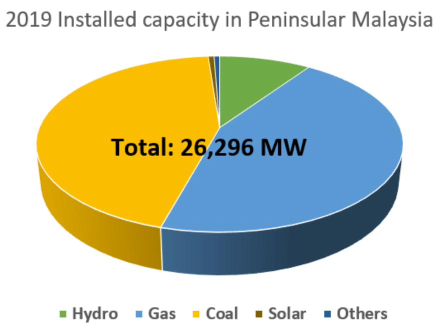
Figure 3.9 Malaysia National Installed Capacity and Generation Capacity





Source: Energy Commission (2020).

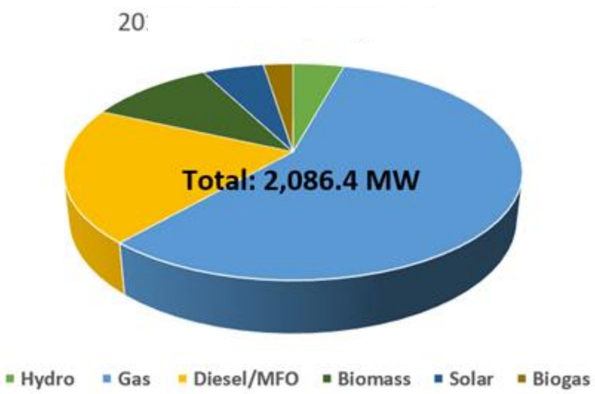
Figure 3.10 Power Plants and Installed Capacity in Peninsular Malaysia



Source: Country presentation at the 1st Working Group (2021).

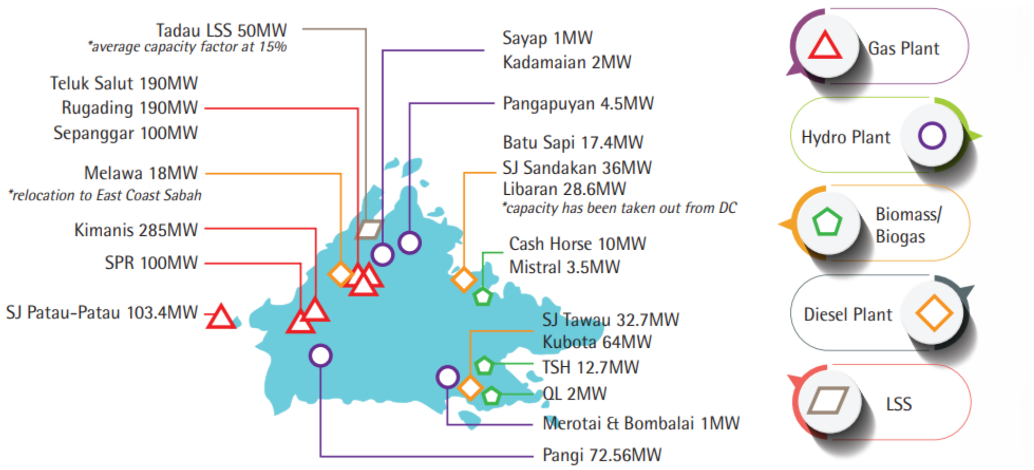
Figure 3.10 shows power plants in Peninsular Malaysia and the installed capacity mix. The region has over 83% of the national population and holds over 73% of the national power capacity, including several large-scale CFPPs. The peninsula is heavily dependent on fossil fuels, i.e. gas and coal.

Figure 3.11. Installed Capacity in Sabah, 2019



Source: Energy Commission (2019).

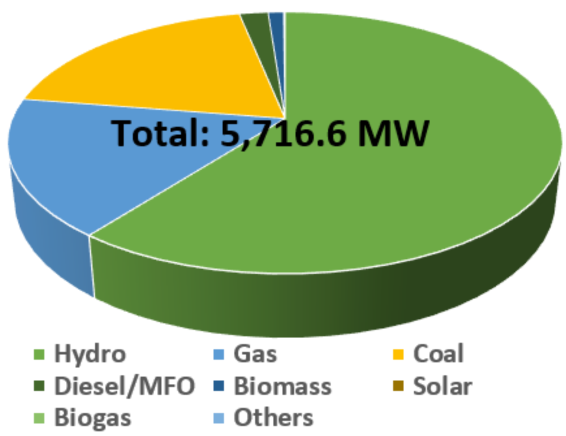
Figure 3.12. Power Plants in Sabah



LSS = large-scale solar.
Source: Energy Commission (2019).

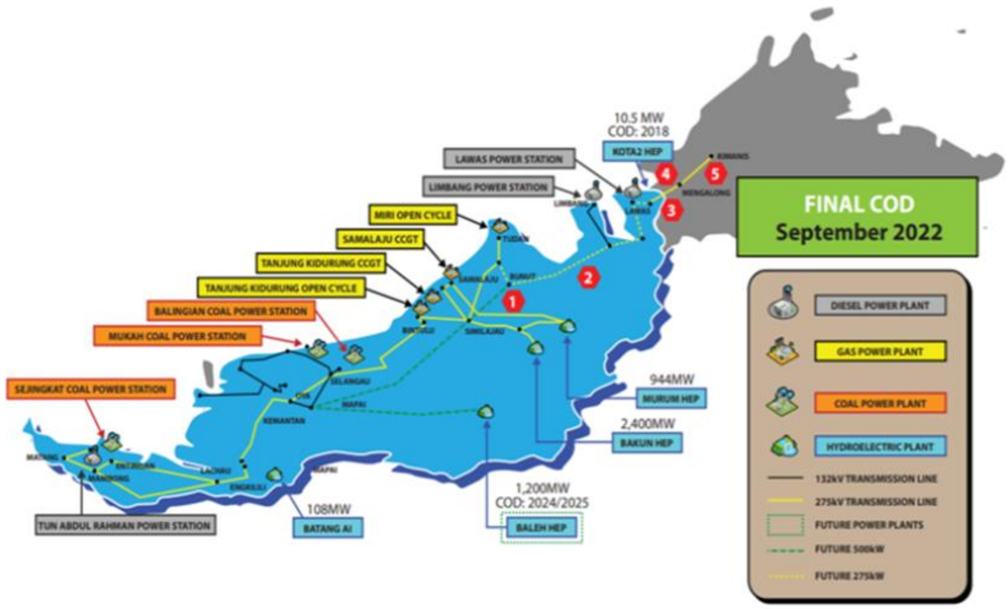
Sabah has several micro- to mid-scale power plants, mostly located on the west side of the region (Figure 3.11). It also heavily depends on fossil fuels (Figure 3.12), but has no coal power and is mostly dependent on gas and diesel. The authorities think about electricity import from Sarawak that has less population and has surplus power to export.

Figure 3.13. Installed Capacity in Sarawak, 2019



Source: Energy Commission (2019).

Figure 3.14. Power Plants in Sarawak



Source: Energy Commission (2019).

In Sarawak, the Electrical Inspectorate Unit under the Ministry of Utility Sarawak government oversees the entire power sector. Sarawak Energy is the sole implementer from generation, transmission, and distribution to retail.

Endowed with abundant natural resources, Sarawak has a well-balanced electricity mix (Figure 3.13). Thanks to its large- and mid-scale hydro projects (Figure 3.14), which are boosting the total supply capacity of the region with the smallest population of all three regions in Malaysia.

Sarawak began to export electricity to West Kalimantan, Indonesia, in January 2016 through a 275 kV interconnection operated by Sarawak Energy. This project is the first successful power trading project for Malaysia.

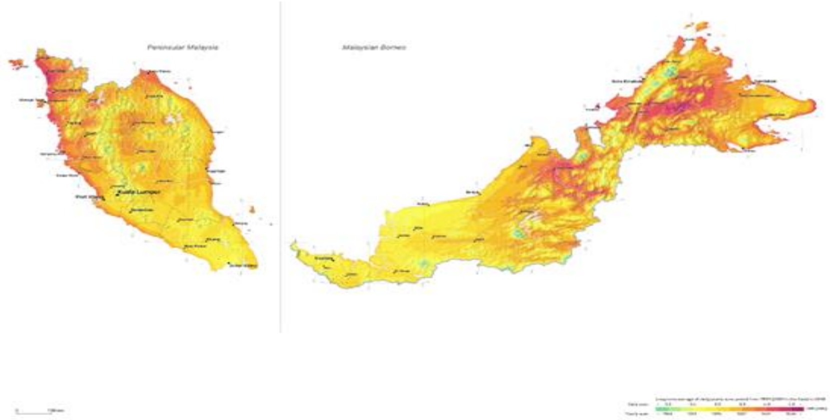
Given the above situation of the three regions of such a variety and difference and the quantitative dominance of Peninsular Malaysia in the national power capacity, the measures to address the possible future grid fluctuation and subsequent issues should be pursued by observing the case of the peninsula.

2.2. Mid- to long-term grid fluctuation potential of Malaysia

1) Major renewable potential

Figure 3.15 shows the solar power potential of Malaysia. SEDA sees huge potential, especially in the rooftop solar PV – 37,429 MW in Peninsular Malaysia alone, exceeding that of the current overall national power demand.

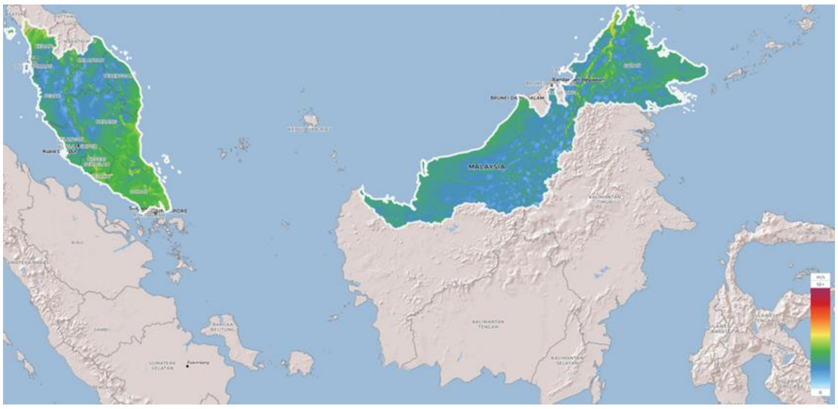
Figure 3.15. Map of Solar PV Potential in Malaysia



Source: World Bank (2020).

Malaysia has wind power potential as well (Figure 3.16). However, geographical location around the equator naturally limits the scale and availability of the country's wind power potential. Wind power, being quite seasonable and at times unreliable in equatorial areas, is deemed to comprise a relatively minor share of the future electricity mix of the country.

Figure 3.16. Wind Power Potential in Malaysia

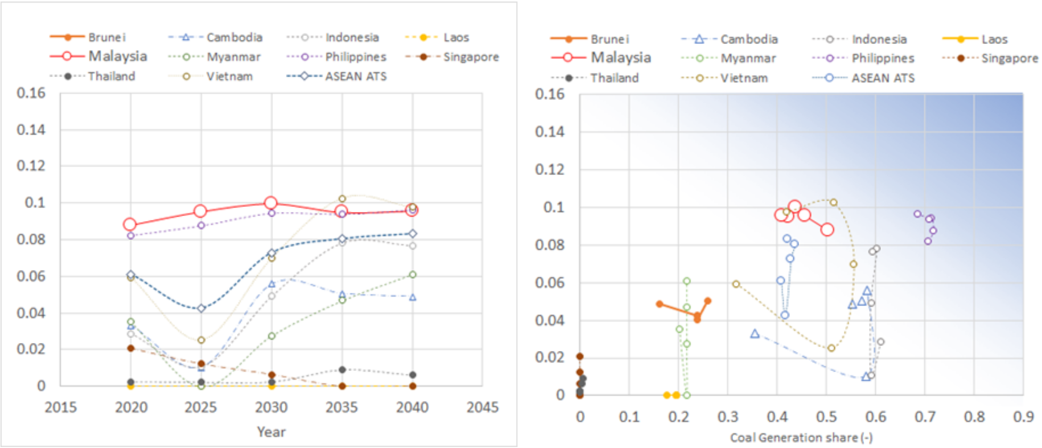


Source: Denmark Technical University (2019), 'Global Wind Atlas'. (Global Wind Atlas 3.0 is a free, web-based application developed, owned, and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 is released in partnership with the World Bank Group, utilising data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program. For additional information: https://globalwindatlas.info.

2) Future grid fluctuation potential by GFI

Figure 3.17 shows the year-by-year GFI projection of the AMS (left) and the same against coal generation share in the generation mix. In AEO6, which provides the data of the GFI projections, the generation mix in 2040 consists of 20% renewables, 39% gas, and 22% coal.

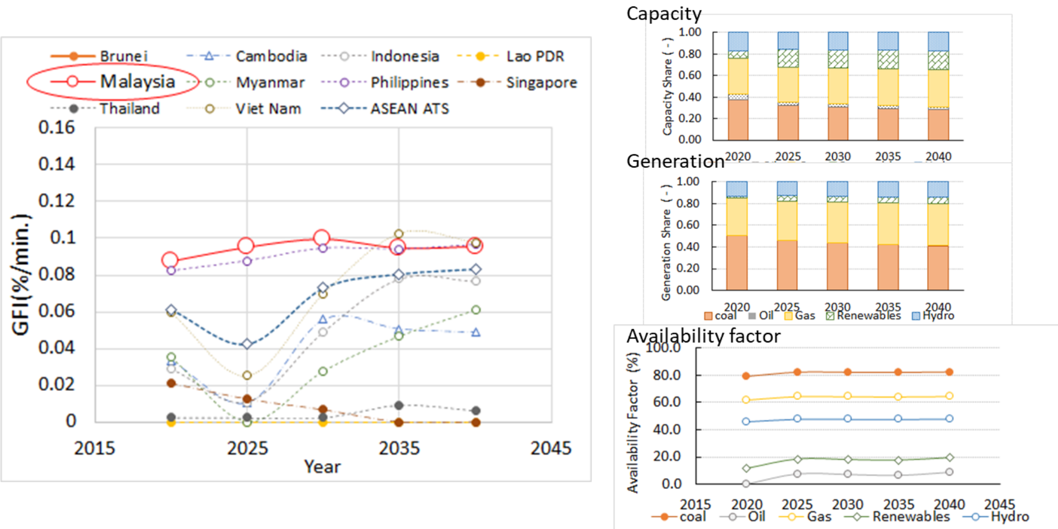
Figure 3.17. Future Grid Fluctuation of Malaysia by GFI



Source: Authors' calculation.

Malaysia is envisaged to have increased grid fluctuation, especially after 2030, if the country's generation mix remains as forecasted and no particular measures are taken.

Figure 3.18. GFI Analysis and Capacity, Generation, and Availability Factor



Source: Authors' calculation.

2.3. Energy transition and coal phasing-out scenario of the power sector in Malaysia

1) Generation development plan of Peninsular Malaysia

As mentioned, under this plan published in March 2021, Malaysia was committed to not having new greenfield CFPPs. The plan retires 7,044 MW of coal power from 2021 to 2039. The same plan refers to 2,800 MW of coal power that will replace the retiring ones. However, recently, Malaysia's Prime Minister announced no more new coal power capacity to speed up coal phasing out given the outcomes of COP26. The government will have to wait for some time – probably until the RETR is finalised – to know the exact policy direction and power development Malaysia will follow and implement along with the energy transition.

Table 3.3 shows the generation development plan of Peninsular Malaysia for 2021–2039. As mentioned, under this plan published in March 2021, Malaysia was committed to not having new greenfield CFPPs. The plan retires 7,044 MW of coal power from 2021 to 2039. The same plan refers to 2,800 MW of coal power that will replace the retiring ones. However, recently, Malaysia's Prime Minister announced no more new coal power capacity to speed up coal phasing out given the outcomes of COP26. The government will have to wait for some time – probably until the RETR is finalised – to know the exact policy direction and power development plan Malaysia will follow and implement along with the energy transition.

Table 3.3. Peninsular Generation Development Plan 2031–2039

Year	Generation Capacity (31% RE Capacity Mix for Malaysia)	Retiring Plants
2021	Edra Energy (CCGT) (3X747 MW) RE (860 MW)	YTL Power (CCGT) (585 MW)
2022	RE (652 MW)	TNB Pasir Gudang (CCGT) (275 MW) GB3 (CCGT) (640 MW)
2023	RE (663 MW)	Panglima (CCGT) (720 MW)
2024	TADMAX (CCGT) (2x600 MW) RE (855 MW)	SKS Prai CCGT (341 MW) TTPC (CCGT) (650 MW) TNB Gelugor (CCGT) (310 MW)
2025	RE (818 MW)	TNB Putrajaya GT4 & GT5 (OCGT) (249 MW)
2026	THB (CCGT) (2x600 MW) RE (117 MW)	KLPP (CCGT) (675 MW)
2027	Nenggiri (Hydro) (300 MW) RE (184 MW)	Segari Energy Ventures (CCGT) (1,303 MW)
2028	RE (192 MW)	TNB Tuanku Jaafar PD1 (CCGT) (703 MW)
2029	CCGT (1x700 MW) CCGT (1X500 MW) RE (199 MW)	KEV Gas U1 & U2 (Thermal Gas) (578 MW) KEV Coal U3-U6 (Coal) (1,474 MW)

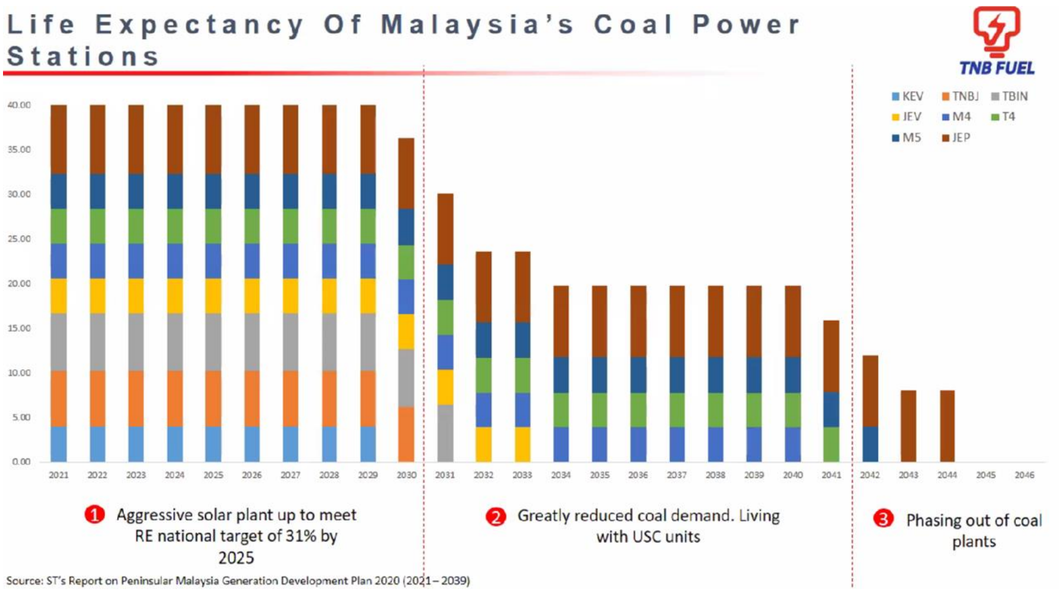
2030	CCGT (4x700 MW) RE (207 MW) BESS (1x100 MW)	TNB Tuanku Jaafar PD2 (CCGT) (708 MW) TNB Janamanjung (Coal) (2,070 MW)
2031	CCGT (1x700 MW) Coal (2X700 MW) BESS (1x100 MW) RE (215 MW)	Tanjung Bin Power (Coal) (2,100 MW)
2032	CCGT (1x700 MW) BESS (1x100 MW) RE (224MW)	
2033	CCGT (2x700 MW) BESS (1x100 MW) RE (232MW)	Jimah Energy Venture (Coal) (1,400 MW)
2034	Coal (1X700 MW) BESS (1x100 MW) RE (242 MW)	
2035	RE (278 MW)	
2036	CCGT (1x700 MW) RE (80 MW)	
2037	CCGT (1x700 MW) Coal (1X700 MW) OCGT (1x100 MW) RE (77 MW)	TNB Prai (CCGT) (1,071 MW) TNB CBPS (CCGT) (375 MW)
2038	CCGT (1x700 MW) RE (76 MW)	Pengerang Power (Co-Gen) (600 MW)
2039	CCGT (1x700 MW)	

Source: Energy Commission (2021b).

2) Malaysia's coal phasing-out scenario

Malaysia will continue utilising CFPPs in the cleanest possible manner in the foreseeable future. At the same time, it is committed to gradually reducing CFPPs, as shown in its phasing-out plan (Figure 3.19). The government and the TNB are meticulously planning the phasing out by targeting approximately 50% of CFPPs from the first phase (2021–2030) to the second phase (2031–2041). The third and final phase (2042–) will see the total abolition only in 3 years. Even if the phasing out plan proceeds accordingly, the fluctuation potential after 2030 remains.

Figure 3.19. Utilisation and Phasing Out of Coal-fired Power Plants in Malaysia



Source: TNB presentation at the 1st International Seminar on Mineral and Coal Technology (ISMCT) (virtual), 23 June 2021.

We should note that Malaysia started utilising coal in the power sector because of the economic advantages of coal utilisation for power generation. How and to what extent a country will reduce coal and increase gas would impact the grid flexibility and the economy and affordability of electricity utilisation. While using more gas will better address the possible issue of fluctuation expected from 2030 onwards, the government will possibly have a dilemma, as switching to more gas will offset such economic advantages. Such an offset may be felt more in Malaysia as CFPPs are well maintained and have a longer life than such power plants in other ASEAN countries.

2.3. Policy recommendations

Malaysia is steps ahead of other AMS in considering its energy transition pathway, as we understand from the past policies and legal frameworks in the power sector. According to the GSO, in expectation of the possible grid fluctuation, a study on renewable energy penetration is in progress. They envisage that CFPPs will be cycled to minimum loading during solar peak time, possibly 50% to 70% during weekdays, and the technical and power purchase agreement minimum during weekends or public holidays. In the case of high solar penetration, whose variation is considered higher, the range will be 30% to 70%. They also envisage the possible challenges in managing the three cycles of load variation in a day.

As we have seen, Malaysia is expected to experience grid fluctuations after 2030 even if the government will go for the new scenario, i.e. no more new CFPPs, regardless of greenfield or brownfield. Therefore, in the medium term, flexibilisation measures with thermal power, including coal-fired power and hydropower, will address the requirements of the grid while renewable energy penetration proceeds. Storage technology will help ensure a non-intermittent power supply in the medium to long term. The government is already planning to introduce energy storage facilities in power development.

Recommendations for ensuring grid stability in the period of energy transition

In the medium term, flexibilisation measures with thermal power, including coal-fired power and hydropower, will address the grid's requirements while renewable energy penetration proceeds.

Storage technology will help ensure a non-intermittent power supply in the medium to long term. Consideration of policy initiatives from this stage to enable local manufacturing in the near future is recommended. It is also possible for Malaysia to make a hub supplying made-in-Malaysia storage facilities.

Consideration of policy initiatives by the federal government to enable local manufacturing in the near future is recommended.

According to the 12th Malaysia Plan [2], the federal government encourages local manufacturing in emerging industries, so such direction is in line with the government policy.

Enabling policy for battery and other key products local manufacturing is crucial, as it will enable Malaysia to maintain growth and development while maintaining system stability. It is important in terms of energy economy and energy security through sustainable supply. Also, such an arrangement will benefit neighbouring countries and contribute to ensuring ASEAN's energy security.

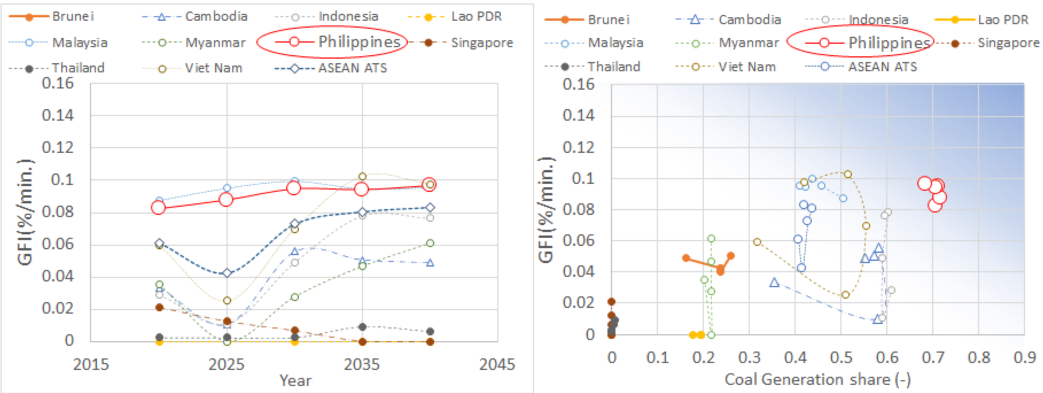
[2] 12th Malaysia Plan, https://rmke12.epu.gov.my/en (accessed 15 October 2021).

3. Philippines

3.1. Preliminary grid analysis by GFI

Figure 3.20 presents the future grid fluctuation analysis of the Philippines using the GFI method based on the data from AEO6. The GFI will remain at a relatively high level at approximately 0.08–0.1, which would require flexibilisation measures. High dependence on coal-fired power generation is deemed a major factor to expedite it. The local grid system fluctuation might occur more severely if the more flexible power supply sources such as gas and/or hydro are less available.

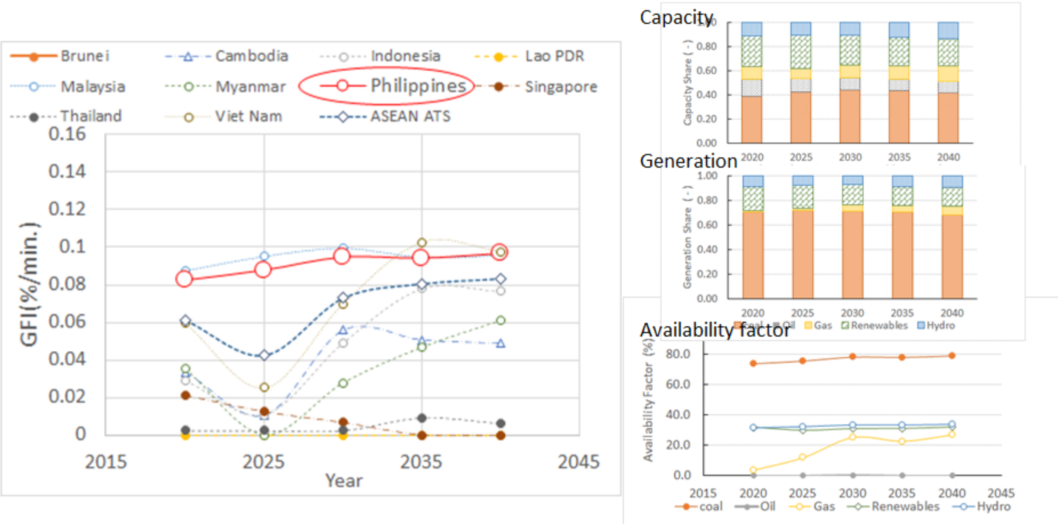
Figure 3.20. Future Grid Fluctuation of the Philippines by GFI



Source: JCOAL.

Diversification is sustained in the well-balanced installed capacity from 2020 to 2040. However, overdependence on coal will continue to be observed in the generation mix. As shown in Figure 3.21, the availability factor of coal-fired power is much higher than that of other sources. The foregoing will constitute the major cause to push up the level of the GFI from 2030 to 2040.

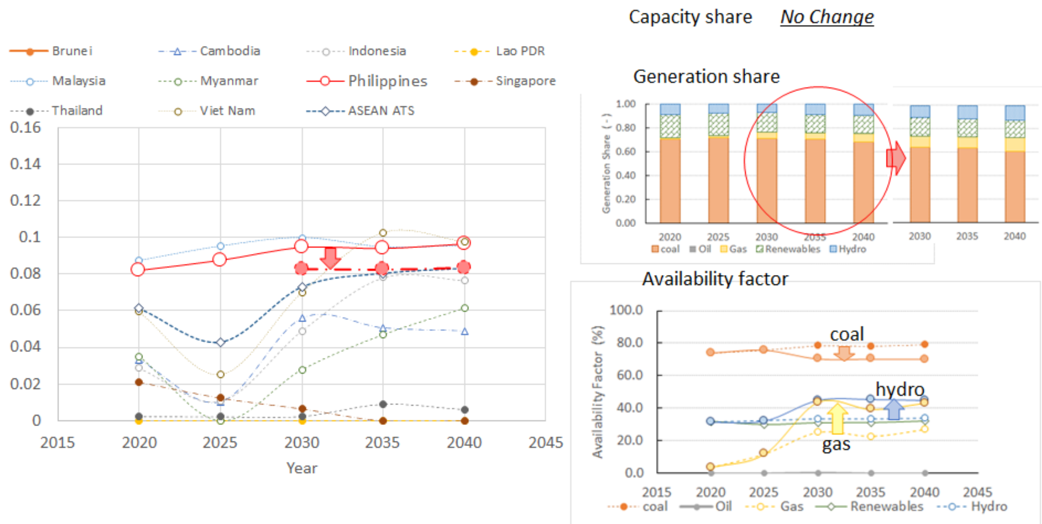
Figure 3.21. GFI Analysis and Capacity, Generation, and Availability Factor



Source: JCOAL.

The generation shift from coal to gas and hydro may contribute to a levelling of the availability factor amongst coal, hydro, and gas. In this case, if the availability factor of hydro and gas in 2030–2040 increases by 10% to 17%, the availability factor of coal-fired power can be reduced by 8% to 9%. As a result, the GFI is expected to become milder to the ASEAN average level (Figure 3.22).

Figure 3.22. Tentative Recommendations of Flexibilisation Measures



Source: JCOAL.

3.2. Clean energy scenario (CES), input by the Department of Energy (DOE)

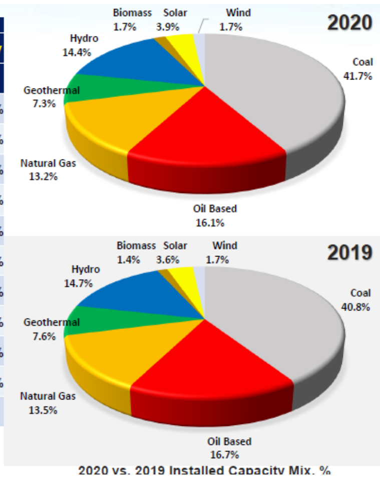
The Philippine power sector set up four sectors: generation, transmission, distribution, and supply. The generation sector, a business affecting the public interest, shall be competitive and open. Generation companies only need to secure from the energy regulatory commission a certificate of compliance and health, safety, and environmental clearances from appropriate government agencies under existing law and comply with gross ownership provisions.

Energy dispatch, scheduling, and pricing are made through the electricity market, called the wholesale electricity spot market. It is a real-time market where prices and schedules are determined 24/7. But now, the Philippines is ready to transition into a 5-minute market. Hopefully, by the end of October 2022, the DOE will commercially launch the 5-minute market.

Focusing on the installed capacity (Figure 3.23), the country has 26 GW of capacity from coal, oil, diesel, natural gas, and various renewable energy resources from geothermal, hydro, biomass, or solar wind. In terms of capacity or MW, the highest percentage share for this capacity mixes that of coal, which accounts for 41.7% of the total installed capacity of the Philippines. It is followed by oil at 16.1%, natural gas at 13.2%, and the others at 29% in terms of MW installed capacity or from renewable energy source technologies.

Figure 3.23. Installed and Dependable Capacity

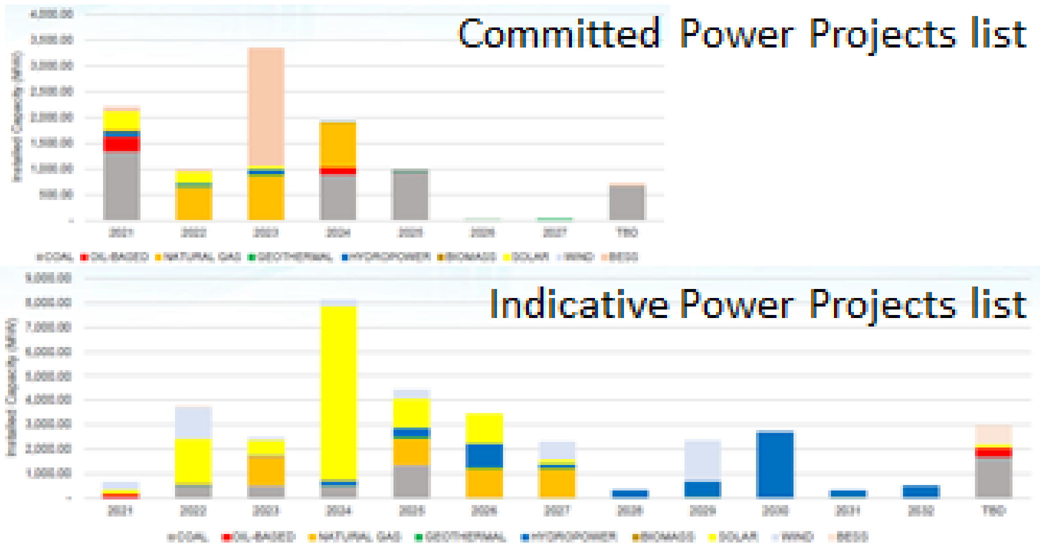
FUEL TYPE	2020				2019			
	Installed Capacity		Dependable Capacity		Installed Capacity		Dependable Capacity	
	in MW	% Share	in MW	% Share	in MW	% Share	in MW	% Share
Coal	10,943.9	41.7%	10,245.3	43.8%	10,417.2	40.8%	9,743.3	42.9%
Oil Based	4,236.6	16.1%	3,053.6	13.0%	4,262.4	16.7%	3,015.3	13.3%
Natural Gas	3,452.5	13.2%	3,286.1	14.0%	3,452.5	13.5%	3,286.1	14.5%
Renewable Energy (RE)	7,616.9	29.0%	6,824.9	29.2%	7,399.3	29.0%	6,691.2	29.4%
Geothermal	1,928.1	7.3%	1,753.1	7.5%	1,928.1	7.6%	1,792.3	7.9%
Hydro	3,779.3	14.4%	3,526.6	15.1%	3,759.8	14.7%	3,508.1	15.4%
Biomass	447.4	1.7%	285.4	1.2%	363.4	1.4%	227.0	1.0%
Solar	1,019.3	3.9%	816.9	3.5%	921.1	3.6%	736.9	3.2%
Wind	442.9	1.7%	442.9	1.9%	426.9	1.7%	426.9	1.9%
TOTAL	26,249.9	100.0%	23,409.9	100.0%	25,531.4	100.0%	22,736.0	100.0%
BESS	11.0		11.0		11.0		11.0	



Source: Presentation by DOE, Philippines, at the 1st Working Group meeting, July 2021.

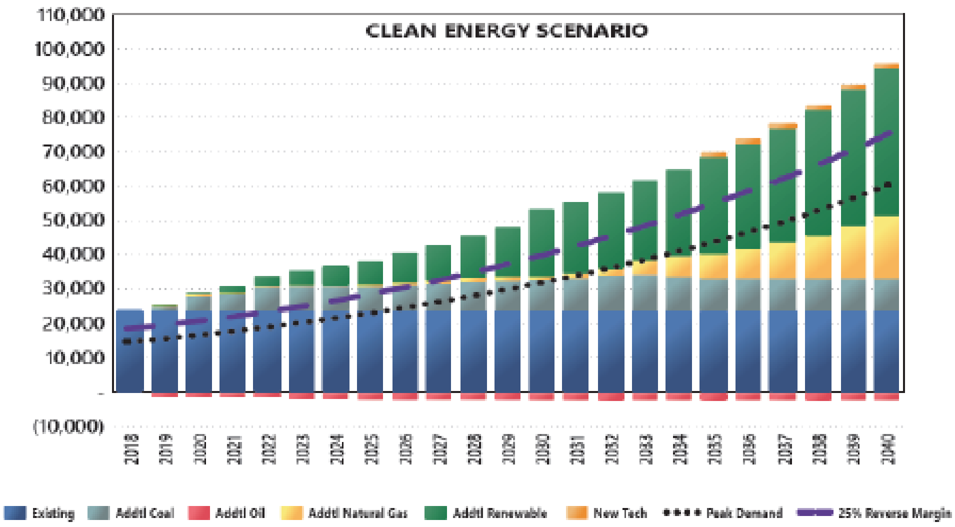
Figure 3.24 summarises the line-up of power plant capacities for committed projects granted in the pipeline, which is estimated to be online by specific years. These are projects that have secured financial closing or are already being constructed. The majority or a big chunk of these capacities will come from the pool for 2021. There are also natural gas power plants, renewable energy capacities, and the inclusion of BESSs. The indicative project list is also illustrated in Figure 3.24. The difference with the committed power project is that the indicative project list refers to power-generating companies that already signified to the DOE their intent to pursue building a generating facility. However, these projects are still fulfilling various permitting requirements and are in their pre-development stages.

Figure 3.24. Capacity Addition Plan up to 2032



Source: Presentation by DOE, Philippines, at the 1st Working Group meeting, July 2021.

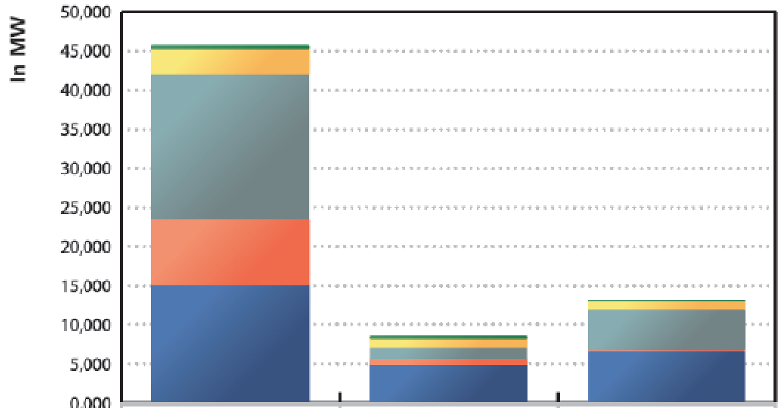
Figure 3.25. Clean Energy Scenario under the Philippines' Energy Plan 2018–2040



Source: Presentation by DOE Philippines at the 1st Working Group meeting, July 2021.

From the Philippines' energy plan 2018–2040, DOE has incorporated a reference and a CES to highlight the country's commitment in its nationally determined contributions and find a way on the side of the energy sector on what is the possible mix (Figure 3.25). Considering the demand level the Philippines needs to meet in terms of capacity or outlook, Figure 3.26 shows the additional capacities projected for each grid for the whole Philippines.

Figure 3.26. 2040 Additional Capacities per Grid (MW)



	Luzon	Visayas	Mindanao
Peaking	420	200	40
Flexible	3,200	1,340	1,100
Variable	18,500	1,324	5,148
Intermediate	8,400	700	200
Baseload	15,220	5,000	6,553

**net capacity addition (less retiring plants between 2018-2040)*

Source: Presentation by DOE Philippines at the 1st Working Group meeting, July 2021.

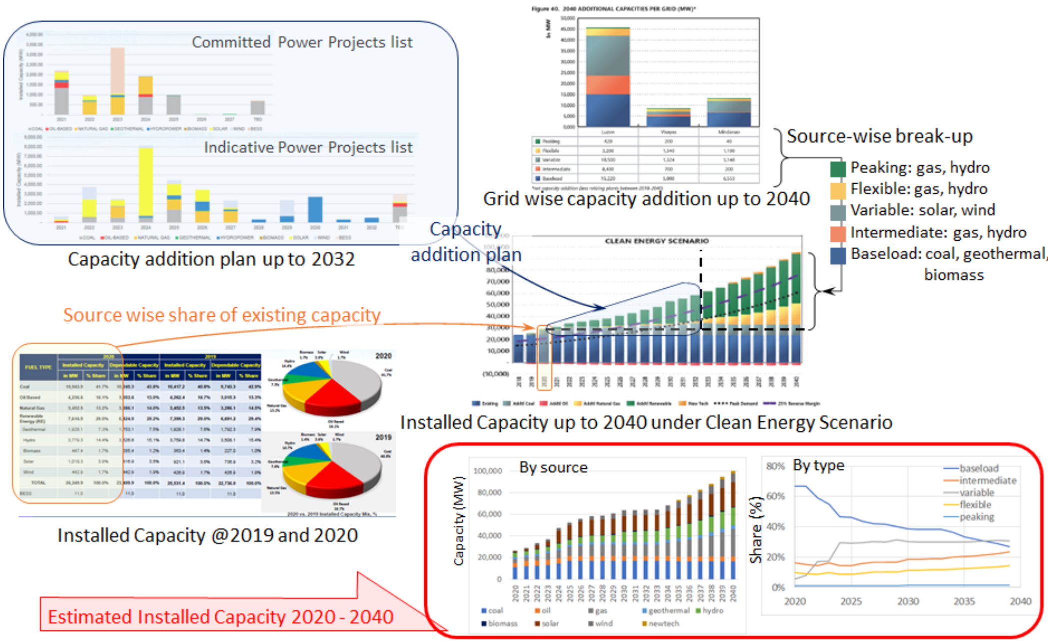
In 2020, a coal-fired power project moratorium or a moratorium on new coal-fired power facilities was implemented. Based on this policy, the Philippines will not be providing approvals for new coal-fired power facilities except for those already committed and all power projects already having significant development in terms of the projects before the moratorium. So, the Energy Secretary had signed this moratorium, and the DOE will not be entertaining new coal-fired power facilities in the near future.

These are also in preparation for the reserve market currently being finalised by DOE to encourage additional investment in those generating facilities that project owners are exploring possibilities of reserve provisions to the grid. For the distribution sector, DOE has a competitive selection process to facilitate the procurement process of distribution companies with the generating companies to ensure that their rates will be at the least cost per the end users.

3.3. Source and grid-wise breakdown of clean energy scenario (CES)

Based on DOE data, a detailed analysis of CES was conducted. The process of breakdown of CES by the power source is shown in Figure 3.27. The existing capacity shown in Figure 3.25 is divided by the data in Figure 3.23. Source-wise capacity addition can be accumulated using the data in Figure 3.24. The source-wise capacity from 2032 to 2040 is predicted from the additional capacity for each grid in 2040 in Figure 3.26. Integrating these data conversions, the installed capacity by a power source from 2020 to 2040 was estimated (Figure 3.27). Based on the information from DOE, the operation type of each power supply can also be categorised (Table 3.4). By converting the capacity for each power source to the one for each operation type, the relation between the grid fluctuation and the capacity sufficiency or insufficiency can be clarified. Since gas and hydro are operated in various modes such as peaking, flexible, and intermediate, their distribution to each type was considered using the data in Figure 3.23 and Figure 3.26.

Figure 3.27. Process of Source-wise Breakdown



Source: Edited by JCOAL, data: Presentation by DOE Philippines at the 1st Working Group meeting, July 2021.

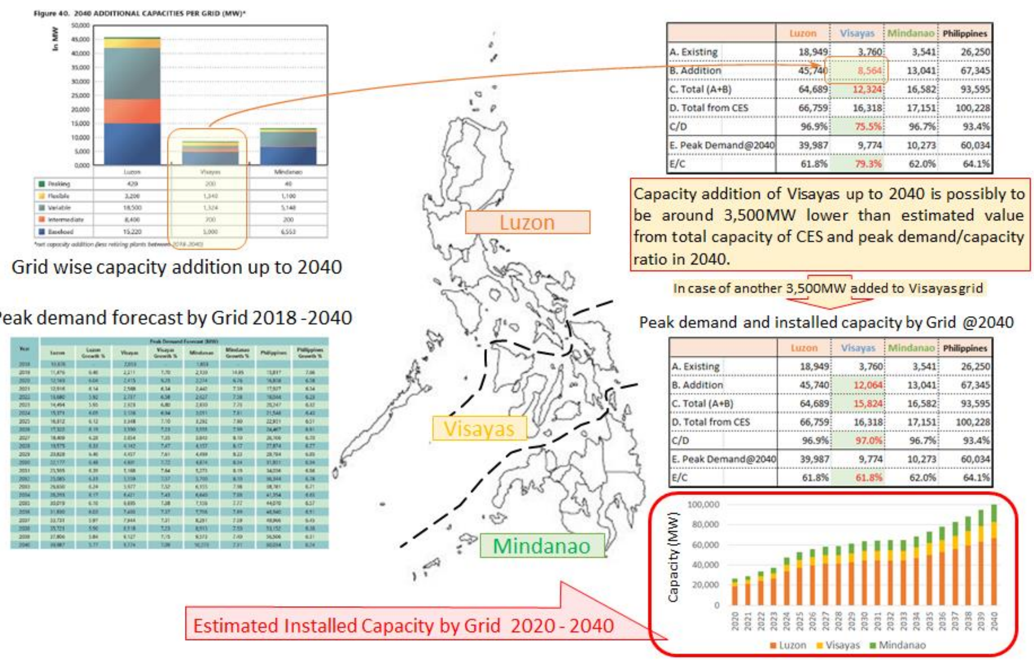
Table 3.4. Type of Operation, by Source

Type of Operation	Source
Peaking	Gas, Hydro
Flexible	Gas, Hydro
Variable	Solar, Wind
Intermediate	Gas, Hydro
Baseload	Coal, Geothermal, Biomass

Source: Email communication with DOE Philippines.

From the growth of peak demand forecast for each grid in Luzon, Visayas, and Mindanao, the installed capacity for each grid was assumed, and the installed capacity was further divided by power source and operation type. The process is shown in Figure 3.28. In the installed capacity forecast from the peak demand for each grid, only Visayas showed a result of about 3.5 GW less than the capacity of CES. Still, Luzon and Mindanao showed a good agreement. Although the details are unknown, they do not affect the data of the ratio by the power source and operation type, so the analysis was continued as it is.

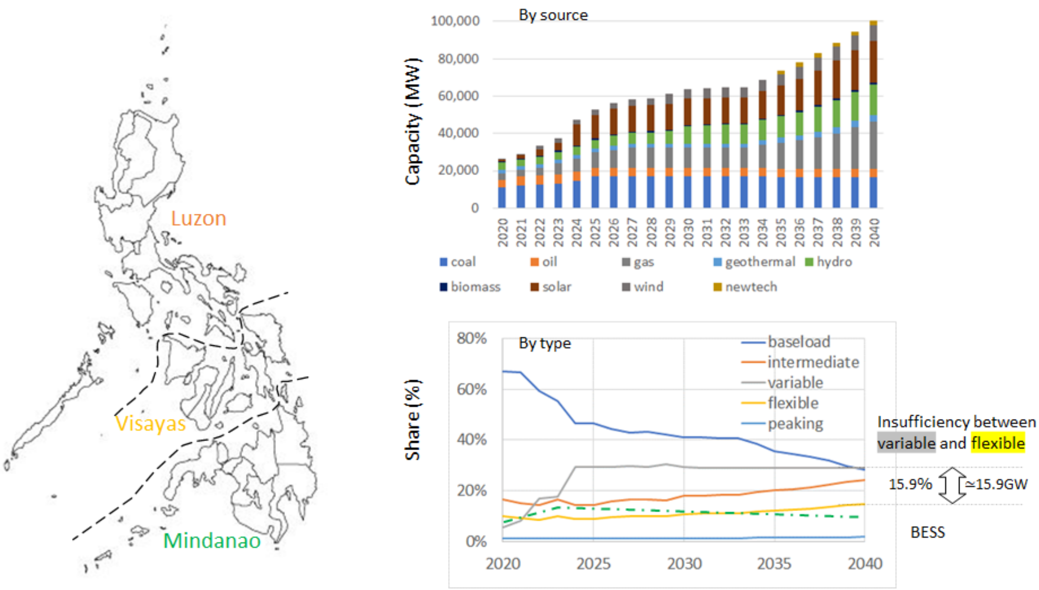
Figure 3.28. Process of Grid-wise Breakdown



Source: Edited by JCOAL, original data: Presentation by DOE Philippines at the 1st Working Group meeting, July 2021.

These analyses provided capacity predictions for each grid up to 2040 (Figure 3.28). Per the analysis results in this study, Figure 3.29 shows the changes in the source-wise capacity and operation type share of the entire Philippines up to 2040. The ratio of baseload operation will decrease due to the decrease in coal-fired power and the increase in renewable energy. This trend will be remarkable from now to 2024 and will gradually decrease after that. On the other hand, solar and wind power, which will be in variable operation, will increase in terms of installed capacity while maintaining a certain share after 2024. As for flexibilisation, it is possible to judge the surplus or insufficiency of correspondence from the share of variable and flexible operation. In the Philippines, the difference in installed capacity between variable and flexible is about 16 GW as of 2040. But it can be accommodated by the gas-fired and hydropower of Intermediate operation and BESS, which are expected to increase. To address flexibilisation, it is recommended for the policy to divert the gas and hydropower of intermediate operation to flexible operation as needed.

Figure 3.29. Source-wise Breakdown of the Whole Philippines



Source: Edited by JCOAL, original data: Presentation by DOE Philippines at the 1st Working Group meeting, July 2021.

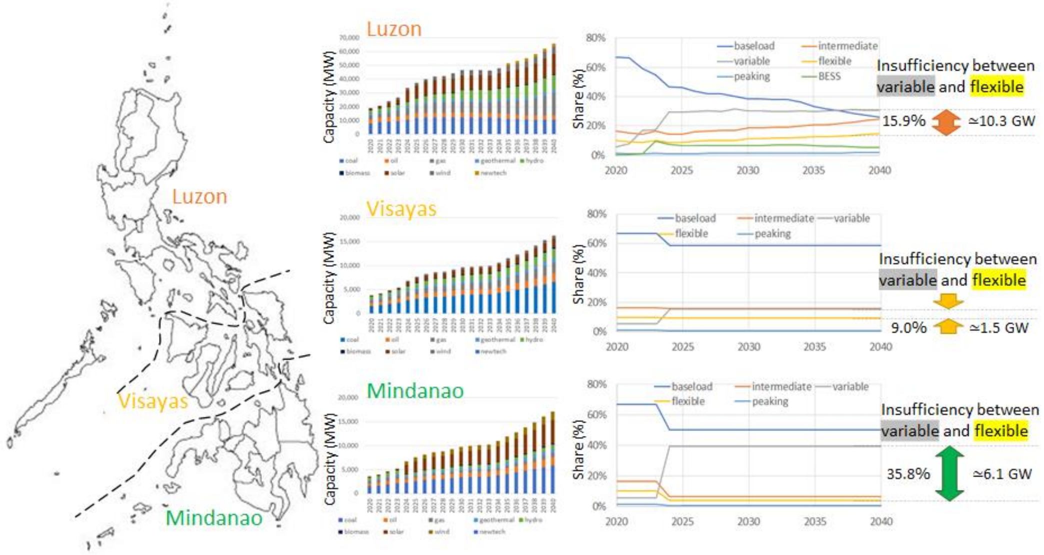
Figure 3.30 shows the Luzon, Visayas, and Mindanao grid forecasts of installed capacity by the power source and share by operation type by 2040. The data on the share by driving type is limited. There are two data: the current and the one as of 2040.

However, Luzon has the largest grid, which occupies 70% of the country. It is calculated approximately by the ratio from the data of the whole country. The difference in installed capacity between 'variable' and 'intermediate' in 2040 on the Luzon grid was 10.3 GW. Therefore, the countermeasure is to maximise the operation shift from intermediate to flexible, as shown in the Philippines.

For the Visayas grid, the insufficiency between variable and flexible is as small as 1.5 GW. Therefore, it is expected that operation shift of some part of intermediate or the installation of BESS, etc., can address it.

In contrast to the Visayas, the Mindanao grid has a large insufficiency between variable and flexible, 6.1 GW. This difference is still insufficient even if all the intermediate capacities are shifted to flexible operation. Even with BESS, etc., it is necessary to take measures so that part of the coal-fired power of baseload operation can be operated flexibly. Drastic measures such as renovating coal mills, enhancing the operation mode, and introducing software associated with them are required to improve the flexible capability of coal-fired power, as described in section 2.1.

Figure 3.30. Source-wise Breakdown of Luzon, Visayas, and Mindanao Grids



Source: Edited by JCOAL, original data: Presentation by DOE Philippines at the 1st Working Group meeting, July 2021.

The results of future prediction analysis of grid fluctuations in this study and their flexibilisation measures are summarised in Table 3.5 for the whole Philippines and each island group: Luzon, Visayas, and Mindanao.

Table 3.5. Summary of the Grid Analysis and Measures

Grid	Grid Analysis	Measures
Philippines	・The renewable energy capacity will increase by 2024; the capacity to cope with fluctuations by gas and hydropower is secured. ・After 2024, the increase in flexible capacity is lower than the increase in renewable capacity. ・Insufficiency of variability/flexibility in 2040; 15.9 GW	Intermediate gas and hydro => Flexible operation Introduction of large energy storage such as BESS and pumped hydro
Luzon	・The situation is mostly the same as the whole Philippines since around 70% of the capacity belongs to the Luzon grid. ・Insufficiency of variability/flexibility in 2040; 10.3 GW	As described above
Visayas	・The Visayas grid has a flexible capacity of comparable scale as the fluctuation. ・A small part of the intermediate capacity is to be operated as flexible.	・Intermediate gas and hydro => Flexible operation

	・ Insufficiency of variability/flexibility in 2040; 1.5 GW	
Mindanao	・ Due to the large variable capacity in the Mindanao grid, a part of the coal-fired power should be operated flexibly. ・ Insufficiency of variability/flexibility in 2040; 6.1 GW	Maximise the flexible operation by gas and hydro. Introduction of large energy storage such as BESS and pumped hydro Flexible operation by coal-fired power

Source: JCOAL.

3.4. Policy recommendations

Based on DOE data, a detailed analysis was conducted to find the measures to be taken in the three grids, mainly from the viewpoint of balance of the generation type. The flexibilisation measures to be taken in the power grid are as follows:

- Maximise the flexible operation by gas and hydro, which is normally operated as an intermediate mode;
- Install large-scale energy storage such as BESS and pumped hydro;
- Operate a part of the coal-fired power flexibly like partial load and/or 'daily start and stop' mode.

Implementation of the above-mentioned flexibilisation measures is recommended.

Especially, tariff incentives for non-baseload operation by private utilities are the key to maximising the flexible capacity.

Large-scale energy storage technologies are to be selected appropriately for grid situations. Commercially available pumped storage might have a cost advantage than BESS if local site condition suits.

In the case of flexible operation by a CFPP, additional investment for modification of mill, steam bypass, and operating software may be required. In this regard, a supporting program under the Resiliency Compliance Plan (DOE, 2018) or other suitable national plan is recommended.

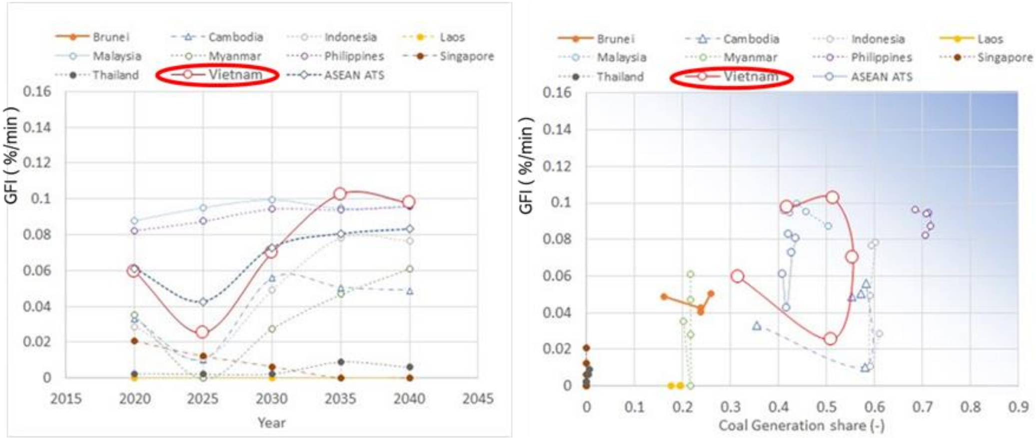
As facilitation of demand-side management, daytime operations are recommended for the power-intensive industry like electric arc furnace steel and electrolytic smelting. A necessary tariff mechanism to specify such daytime operation is also recommended.

4. Viet Nam

4.1. GFI of Viet Nam

The GFI of Viet Nam will stay relatively at a low level up to 2025, following which a sharp increase will be observed towards 2035. Installed capacity will continue to increase for the long term.

Figure 3.31. Future Grid Fluctuation of Viet Nam by GFI

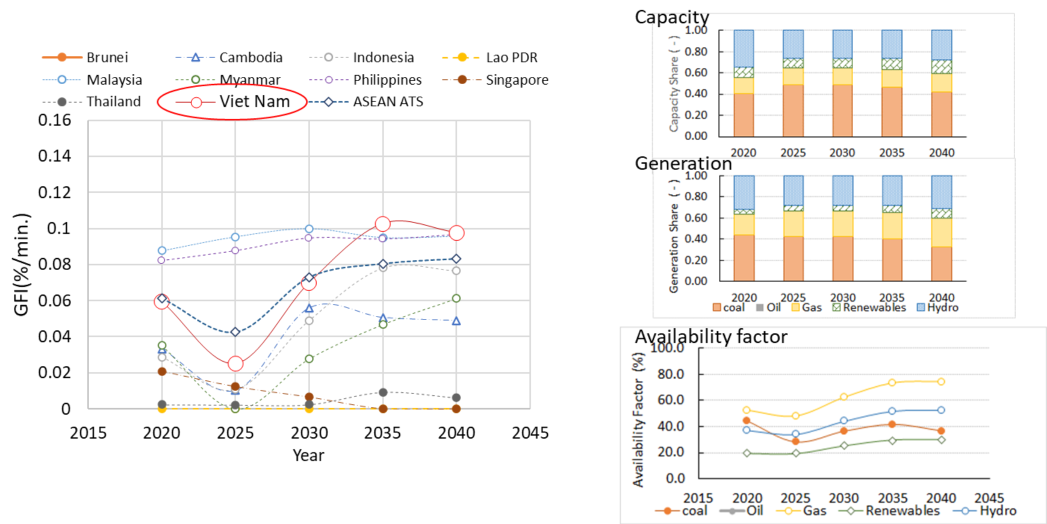


Source: Authors' calculation.

As of 2040, coal will account for less than 40% of the generation mix. The share of gas and hydro will increase, and so will the availability factor of these sources. As of 2040, renewable energy and coal will have an equal share of 40%.

Since domestic anthracite is not suitable for flexible operation, flexibilisation with imported coal will be a crucial key to successful grid stability.

Figure 3.32. GFI Analysis and Capacity, Generation, and Availability Factor of Viet Nam

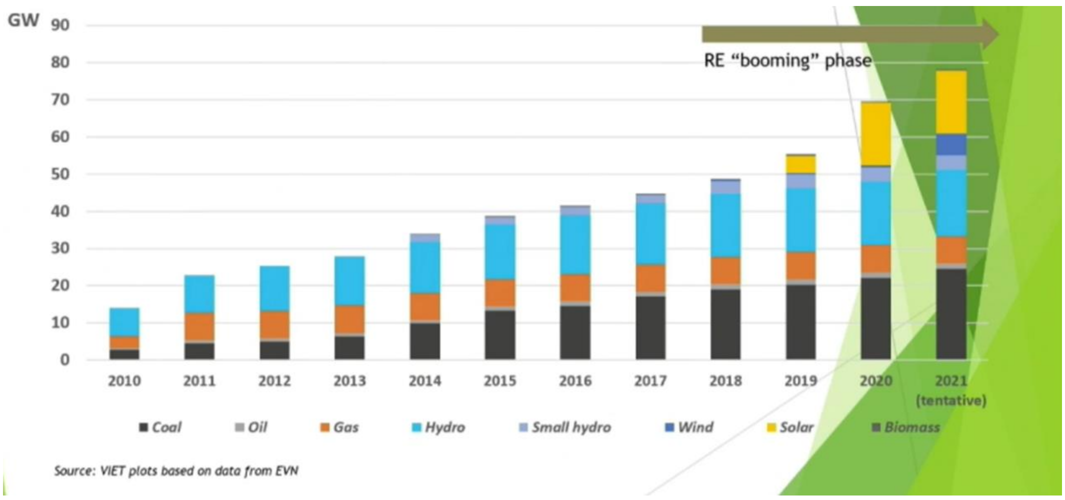


Source: Authors' calculation.

4.2. Power mix of Viet Nam's installed capacity

From here, we will explain the current situation of Viet Nam's power mix, the draft Power Development Plan 8, etc. Viet Nam has continued its economic growth steadily. Domestic energy sources are at their limits, and imported energy is increasing. Coal, gas, and hydro were the main power sources. But since 2018, renewable energy booms have led to increased small-scale hydro-, solar, and wind power.

Figure 3.33. Power Mix of Viet Nam's Installed Capacity

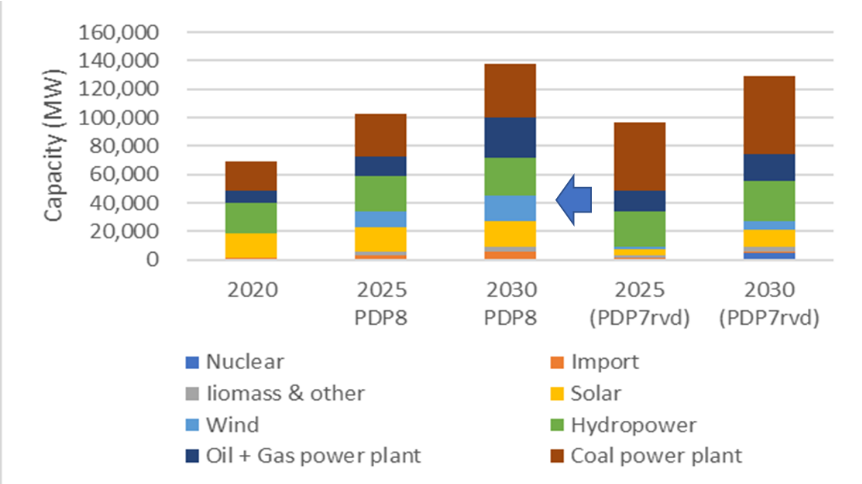


Source: MOIT (2021).

4.3. Power mix of Viet Nam's PDP8[3] draft up to 2030

A draft of PDP8 was published, indicating the direction of the energy transition. Figure 3.34 compares the present and the future power mix by the revised PDP7 and the draft PDP8, respectively. The important points of the PDP8 draft are as follows. The power supply configuration has been revised: conversion to clean energy, reduction of environmental impact, and suspension of new CFPPs.

Figure 3.34. PDP8: Power Mix up to 2030

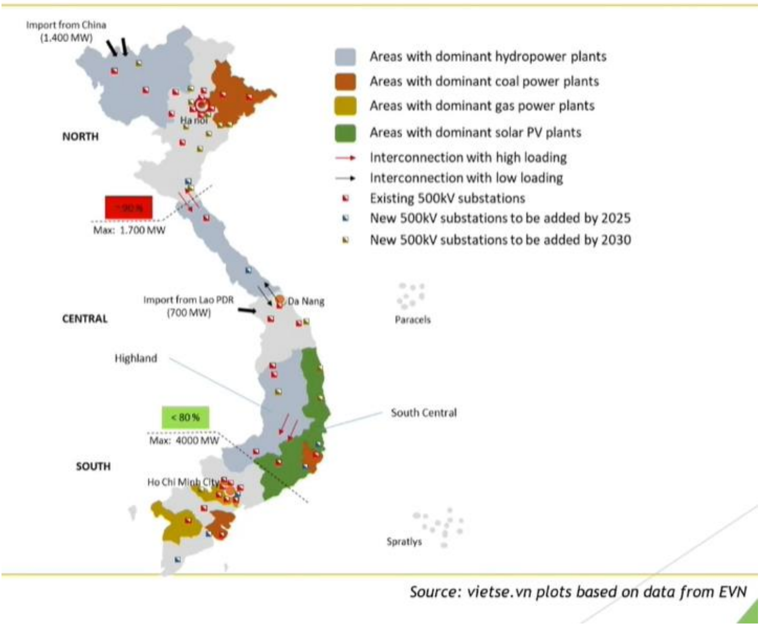


Source: MOIT (2021).

Figure 3.35 shows the grid system of Viet Nam up to 2030. High load demand is in the north and the south. Solar and wind projects are concentrated in south-central. It is essential to strengthen the power grid to support the transmission between north, central, and south.

[3] Draft PDP8, https://www.globalcompliancenews.com/2021/03/09/Viet Nam-key-highlights-of-new-draft-of-national-power-development-plan-draft-pdp8-04032021/ (accessed 7 June 2021); https://onevalue.jp/insight/Viet Nam-re/ (accessed15 October 2021).

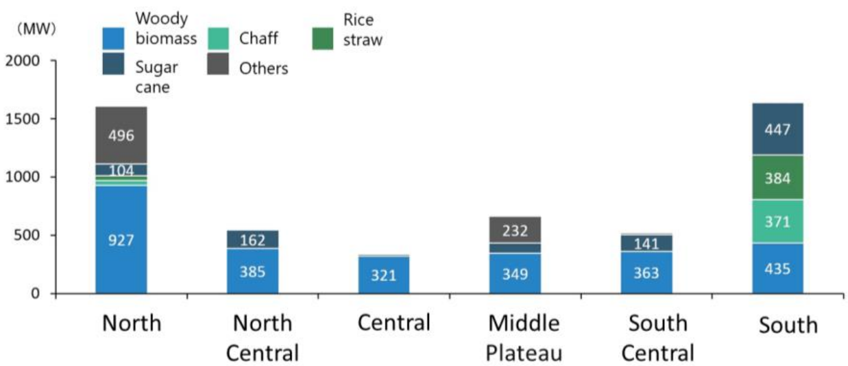
Figure 3.35. Grid System of Viet Nam up to 2030



Source: MOIT (2021).

The PDP8 draft shows the development potential of biomass power generation in 2030 (Figure 3.36). Since the distribution of plants as fuel is different, it is important to stably procure fuel according to the region in biomass power generation.

Figure 3.36. Development Potential of Biomass Power Generation, 2030



Source: Edited by JCOAL, original data: Onevalue.JP, October 2021. https://onevalue.jp/insight/Viet Nam-re/ (accessed 15 October 2021).

Strong incentives and mechanisms are needed to develop and strengthen renewable energy. Laws and regulations are also important. Feed-in-tariff mechanisms for renewable energy development are shown in Table 3.6. It is vital to continue and strengthen this mechanism.

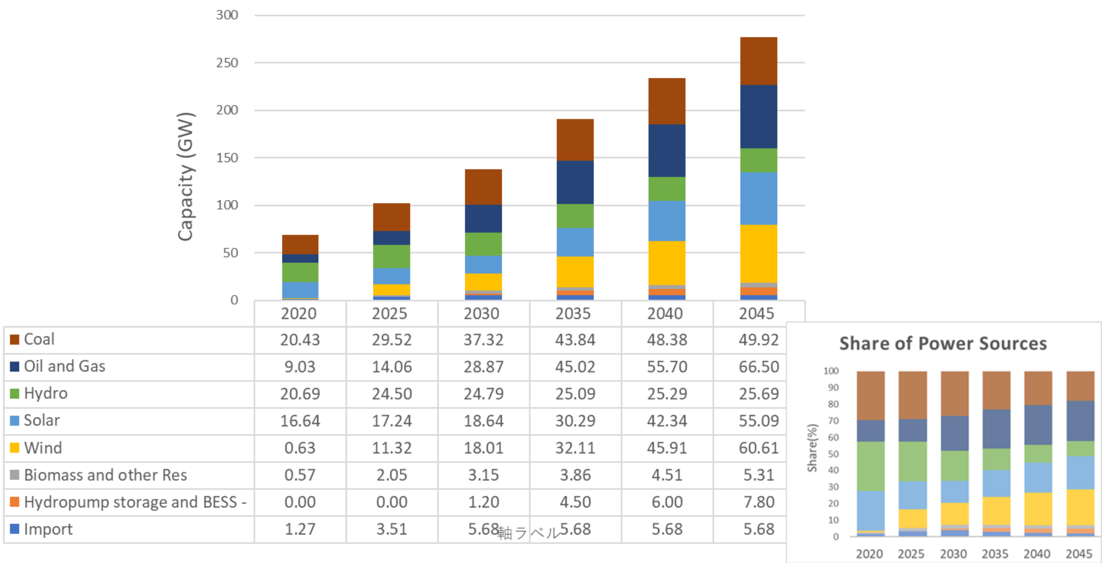
Table 3.6. Feed-in Tariff Mechanisms to Develop Renewable Energy

Type of RE	Status		FIT (US cent/kWh)	Note
	Current	On proposal		
Wind	FIT		Onshore wind projects: 8.5 Offshore wind projects: 9.8	COD before 31/10/2021
Biomass	FIT (CHP)		Cogeneration of power: 7.03 Non-cogeneration of power: 8.47	Decision No. 24/2014/QD-TTg dated on 24/3/2014 & Decision No. 08/2020/QD-TTg dated on 05/3/2020
Waste	FIT		Digged waste: 7.28 Direct-burned waste: 10.05	Decision No. 31/2014/QD-TTg dated on 05/5/2014
Solar	FIT	Auction	Floating solar: 7.69 Ground mounted solar: 7.09 Rooftop solar: 8.38	COD before 31/12/2020 On-grid solar with decision investment before 23/11/2019

Source: MOIT (2021).

Figure 3.37 shows the power mix of Viet Nam's PDP8 draft up to 2045. Steady economic growth is planned in the PDP8 draft. The development of renewable energy is remarkable. Coal and hydropower will remain flat, and share will decline. Renewable energy, excluding hydropower, will increase to 44% in 2045.

Figure 3.37. Viet Nam's Power Mix to 2045 according to Draft PDP8



	2020	2025	2030	2035	2040	2045
Coal	20.43	29.52	37.32	43.84	48.38	49.92
Oil and Gas	9.03	14.06	28.87	45.02	55.70	66.50
Hydro	20.69	24.50	24.79	25.09	25.29	25.69
Solar	16.64	17.24	18.64	30.29	42.34	55.09
Wind	0.63	11.32	18.01	32.11	45.91	60.61
Biomass and other Res	0.57	2.05	3.15	3.86	4.51	5.31
Hydropump storage and BESS -	0.00	0.00	1.20	4.50	6.00	7.80
Import	1.27	3.51	5.68	5.68	5.68	5.68

Source: Edited by JCOAL, original data: Viet Nam Initiative for Energy Transition, March 2021.

Viet Nam continues to grow steadily, focusing on the development of renewable energy. Renewable energy will increase to 44% in 2045 (without hydro). The country will not build new CFPPs but will continue using existing ones. Promoting energy conservation and efficiency improvement is essential.

4.3. Policy recommendations

Viet Nam promotes a balanced energy mix to ensure energy security and stabilise grid fluctuations. The feed-in tariff mechanism for expediting renewable energy development is continuously applied. With the introduction of renewable energy based on the PDP8, the power system of Viet Nam will transmit large amounts of renewable energy from the central and south-central to the northern and southern regions where demand is high (Figure 3.4-7). Therefore, the measures should be taken by dividing the region into demand and supply regions.

In the north and south regions, where existing and under-construction coal-fired power generation is the main power, it is recommended to address the maximum flexibilisation performance of coal-fired power generation and enable flexible operation of gas-fired power generation. Especially for coal-fired power generation, it is essential to introduce power generation technology that uses imported coal and has excellent load response and environmental performance.

On the other hand, in the central and south-central regions, as electricity-supplied regions, it is recommended to renovate conventional hydropower to pumped hydropower. Additionally, it is recommended to consider a flexibilisation policy for intermittent renewable energy for stable energy transmission to demand areas.

Moreover, although a bit of energy loss in AD-DA should be considered, it might be efficient for grid management to concentrate BESS in the north and south regions where many substations are located.

As facilitation of demand-side management, daytime operations are recommended for the power-intensive industry like electric arc furnace steel and electrolytic smelting. A necessary tariff mechanism to specify such daytime operation is also recommended.

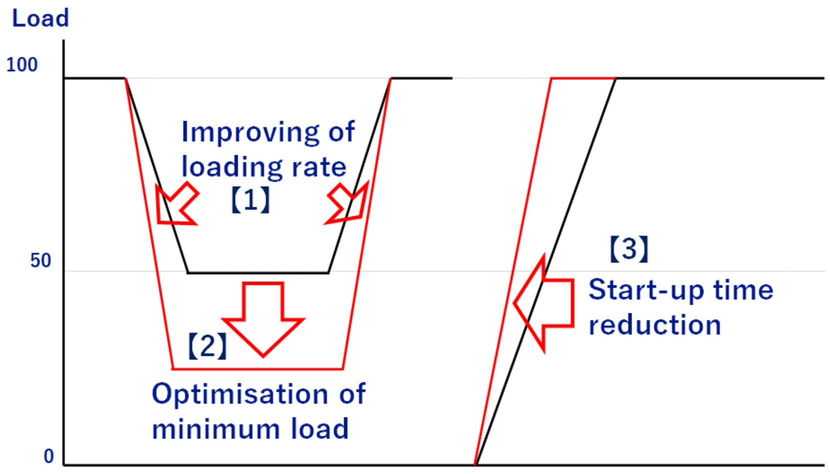
Chapter 4
Recommendations for the ASEAN Region

1. Available Technologies and Technical Solutions

Figure 4.1 shows the three key points of flexibilisation technology of CFPPs.

1) Improving loading rate
2) Optimising minimum load
3) Reducing start-up time

Figure 4.1. The Three Key Points of Flexibilisation Technology

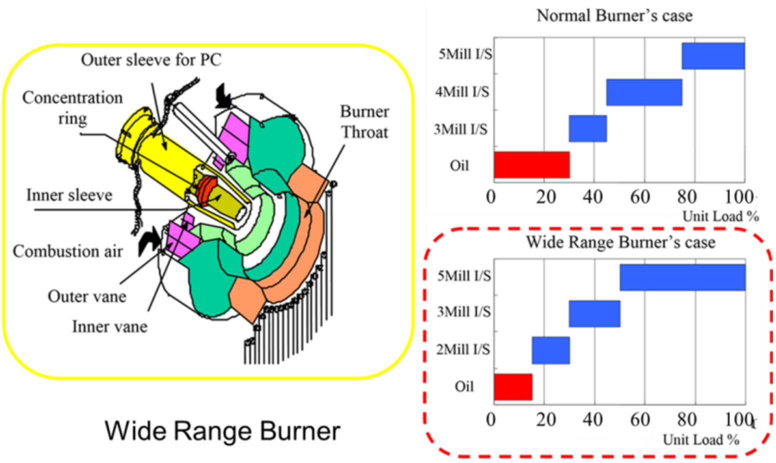


Source: Authors' calculation.

The most important factor in regulating the load of CFPPs is to improve the rate of load change. The first is the improvement of the burning characteristics of coal. The second is the improvement of steam temperature controllability. By introducing these, the load change rate can be improved to 3% to 5% per minute.

The next important point is the optimisation of minimum load. At the low load of the mill pulveriser, pulverised coal at the outlet of the mill pulveriser is in a lean condition with a high air and/or coal ratio of primary air, and oil support is required. Figure 4.2 shows an example of a WRB and burner turndown. The concentration ring is installed in the WRB. The figure on the right shows an example of a burner turndown. The above figure is for a normal burner, and the figure below is for a WRB. In the case of the WRB, the minimum load of coal firing without oil support is about 15% load.

Figure 4.2. Wide Range Burner and Burner Turndown



Source: Edited by JCOAL Original data from IHI.

The third important point is reducing the start-up time. Therefore, it is vital to quickly raise the turbine inlet steam temperature to shorten the start-up time. To that end, measures such as installing the following start-up bypass system, SH bypass system, and HP/LP turbine bypass system with RH cooling or turbine bypass system without RH cooling are essential. This start-up bypass system reduces the start-up time from ignition to full load from 120 minutes to 180 minutes.

To improve the load adjustment function, it is important to enhance equipment and systems and the control device, and optimise the adjustment. The operation ability improvement in the existing plant will be explained. In the case of existing plants, it is important to clarify the purpose of functional improvement and comprehensively examine and remodel two small areas: goals, effects, costs, and remodelling periods.

Table 4.1 summarises three main kinds of large energy storage technologies. A variety of electric energy conversion to potential, compressed, and electrochemical are currently available.

PSP is a kind of potential energy. Small hydro can be easily converted to this type by renovating the turbine and generator with an additional pump function.

The second one is compressed energy. The energy charge is done by an electric power–driven pump to the upper reservoir. Liquid air storage is an application of compressed energy. Charge–discharge is done by a simple mechanical operation of well-proven facilities and heat exchange without AD-DA conversion.

The application of electrochemical energy is normally known as BESS, a battery energy storage system. In this system, three kinds of technologies are suitable for large-scale energy storage: lithium-ion, sodium-sulphur (NAS), and redox flow batteries.

Table 4.1. Available Energy Storage Technologies

(same as Table 2.4)

Technologies	Features	
Potential energy Pumped-storage power	Pumped storage stores and generates energy by moving water between two reservoirs at different elevations. At times of low electricity demand, like at night or on weekends, excess energy is used to pump water to an upper reservoir.	
Compressed energy Liquid air energy storage	The liquified air is converted back into pressurised gas, which drives turbines to produce electricity. Cost-effective supply–demand balancing besides ancillary services, such as grid stability, inertia, and reactive power	
Electrochemical energy Lithium-ion	Lithium-ion batteries are suitable for storing high-capacity power. They are used in a wide range of applications, including consumer electronics such as smartphones and personal computers, industrial robots, production equipment, and automobiles.	
Electrochemical energy Sodium-sulphur (NAS)	NAS battery is a high-temperature battery. Full discharge (SOC 100% to 0%) is available without capacity degradation. No self-discharge. Best performed with long-duration application.	
Electrochemical energy Redox flow	Redox flow batteries are rechargeable batteries that are charged and discharged through the oxidation–reduction reaction of ions of vanadium or the like. The batteries are expected to serve as a technology to stabilise the power grids that will be needed to expand the introduction of renewable energy, including solar and wind power.	

Source: JCOAL.

2. Available Technologies and Technical Solutions: By-country Recommendations

2.1. Indonesia

Due to the COVID-19 pandemic, electricity growth during 2020 was below the target initially set out in RUPTL 2019. In the new RUPTL, the national generation mix is revised to maintain demand–supply balance as follows:

- No additional CFPP and sequential reduction of existing plants
- Increase the NRE to achieve the minimum target of 23% NRE mix starting in 2025.

Additionally, towards carbon neutrality in 2060, only NRE power plants will be added after 2031, and CFPPs will be phased out. Reducing CFPPs and increasing the NRE by reviewing oversupply are also effective from the carbon neutrality perspective.

As mentioned, the Indonesian government is considering the new electricity development plan:

1) A rapid increase in NRE from 2025, especially biomass, will enhance procurement in terms of fuel availability. In addition, due to its high cost, it is necessary to consider efficiency improvement and economic efficiency.

2) NRE will increase as a substitute for coal. Since hydropower, geothermal, and biomass are the main source for the time being, grid stabilisation and load adjustment are not necessary. However, in response to the abolition of CFPPs and the increase in NRE, especially solar power, towards carbon neutrality in 2060, a detailed study of securing base power sources, battery development, and grid stabilisation is needed.

2.2. Malaysia

Malaysia is steps ahead of other AMS in considering its energy transition pathway, as we understand from the past policies and legal frameworks in the power sector. According to the GSO, in expectation of the possible grid fluctuation, a study on renewable energy penetration is in progress. They envisage CFPPs to be cycled to minimum loading during solar peak time, possibly 50% to 70% during the weekdays, and the technical and power purchase agreement minimum during weekends or public holidays. In the case of high solar penetration, with which variation is considered to be higher, the range will be 30% to 70%. They also envisage the possible challenges in managing the three cycles of load variation in a day.

As we have seen, Malaysia is expected to experience grid fluctuation after 2030 even if the government will go for the new scenario, i.e. no more new CFPPs, regardless of greenfield or brownfield. Therefore, in the medium term, flexibilisation measures with thermal power, including coal-fired power and hydropower, would address grid requirements while renewable energy penetration proceeds. Storage technology will help ensure a non-intermittent power supply in the medium to long term. The Government of Malaysia is already planning to introduce energy storage facilities as part of power development.

Recommendations for ensuring grid stability in the period of energy transition

In the medium term, flexibilisation measures with thermal power, including coal-fired power and hydropower, will address the requirements of the grid while renewable energy penetration proceeds.

Storage technology will help ensure a non-intermittent power supply in the medium to long term. Consideration of policy initiatives from this stage to enable local manufacturing in the near future is recommended. It is also possible for Malaysia to make a hub supplying made-in-Malaysia storage facilities.

Consideration of policy initiatives by the federal government to enable local manufacturing in the near future is recommended.

According to the 12th Malaysia Plan, the federal government encourages local manufacturing in emerging industries, so such direction aligns with government policy. It is also possible for Malaysia to make a hub supplying made-in-Malaysia storage facilities.

Localisation of battery and manufacturing of some other key products is crucial, as these will enable Malaysia to maintain growth and development while maintaining system stability. It is important in energy economy and energy security through sustainable supply. Also, such an arrangement would benefit neighbouring countries and contribute to ensuring ASEAN's energy security.

2.3. Philippines

Based on DOE data, a detailed analysis was conducted to find the measures to be taken in the three grids, mainly from the viewpoint of the balance of the generation type. The flexibilisation measures to be taken in the power grid are as follows:

- Maximise the flexible operation by gas and hydro, which is normally operated as an intermediate mode;
- Install large-scale energy storage, such as BESS and pumped hydro; and
- Operate part of the coal-fired power flexibly, like partial load and/or 'daily start and stop' mode.

Implementation of the above-mentioned flexibilisation measures is recommended. Especially, private utilities' tariff incentives for non-baseload operation are key to maximising the flexible capacity.

Large-scale energy storage technologies are to be selected appropriately for grid situations. Commercially available pumped storage might have a cost advantage over BESS if local site condition suits.

In the case of flexible operation by a CFPP, additional investment for modification of mill, steam bypass, and operating software may be required. In this regard, a supporting programme under the Resiliency Compliance Plan (DOE, 2018) or other suitable national plan is recommended.

As facilitation of demand-side management, daytime operations are recommended for the power-intensive industry, like electric arc furnace steel and electrolytic smelting. A necessary tariff mechanism to specify such daytime operation is also recommended.

2.4. Viet Nam

Viet Nam has been trying to achieve a balanced energy mix to ensure energy security and grid stability. The feed-in tariff mechanism for expediting renewable energy development is continuously applied. PDP8 indicates that in parallel with the expected massive renewable energy introduction, the national power system will be further optimized by transmitting large amounts of renewable energy from the central and south-central "supply regions" to the northern and southern "demand regions" .

In the north and south regions, where existing and under-construction coal-fired power generation is the mainstay, it is recommended to address the maximum flexibilisation performance of coal-fired power generation and enable flexible operation of gas-fired power generation. As for coal-fired power generation, coal power with imported coal would provide flexible generation sources if appropriate technology and operation techniques are introduced for flexible and environmentally compliant plant operation.

On the other hand, in the central and south-central "supply regions", it is recommended to retrofit conventional hydropower into pumped hydropower. Pumped hydropower as a flexible generation source will be definitely contributing to the increasing requirements for grid stabilisation.

In addition, although a bit of energy loss in AD-DA should be considered, it might be efficient for grid management to concentrate BESS in the north and south regions where many substations are located.

Looking from the aspect of demand-side management, daytime operations are recommended for the power-intensive industry, like electric arc furnace steel and electrolytic smelting. A necessary tariff mechanism to specify such daytime operation is also recommended.

3. Policy Recommendations for ASEAN

3.1. For all-ASEAN and/or individual AMS recommendations on technical aspects

1) For AMS that will not have new CFPPs but will continue utilising existing ones up to the individual target period of the phasing out during the energy transition period – It is unconditional that environmental measures by clean coal technology will be taken as long as the existing CFPPs are continuously used. Then the following measures are recommended to ensure grid stabilisation while renewables are

introduced on a massive scale:

- Identify and ensure flexible sources of power generation
- Identify the optimal measures for flexible operation of CFPPs and ensure the implementation (Note: It is important to introduce the optimal measures from operational improvements to minor modifications while the plant economy is considered.)
- Identify the kinds, scale, and introduction timing of large energy storage facilities and ensure their introduction.

2) For AMS that will develop new CFPPs as per their current plan and will continue utilisation of the existing ones up to the individual target period of the phasing out during the energy transition period:

- Identify and ensure flexible sources of power generation
- Identify the optimal measures for flexible operation of CFPPs and ensure the implementation (Note: It is important to introduce the optimal measures from operational improvements to minor modifications while the plant economy is considered.)
- Identify the kinds, scale, and introduction timing of large energy storage facilities and ensure their introduction
- Ensure the flexibility of CFPPs that are to be newly introduced.

3) For AMS that will not utilise CFPPs at all or will utilise the existing ones to the minimum extent – In this case, the impact of coal power on the national energy transition pathway would be none or very little. Following are two recommended measures:

- Identify and ensure flexible sources of power generation
- Identify the kinds, scale, and introduction timing of large energy storage facilities and ensure their introduction.

3.2. For all-ASEAN and/or individual AMS recommendations on policy and institutional aspects

1) ASEAN regional policy for grid system integration has been in progress, and relevant bilateral and multilateral cooperation is in place. The initial main objective of the regional system integration was to ensure sustainable supply in respective AMS. In the context of the immense benefit that system integration would provide in terms of grid stabilisation, relevant cooperation would proceed while considering both the desired degree of grid flexibility and regional capability for coordinated measures.

2) Phased formulation of the regional and/or local value chain of energy storage facilities and relevant equipment to ensure the future production and procurement in time for the energy transition – AMS governments have been making strenuous efforts to increase local procurement in key industries. Enhancing regional coordination in this regard will help such individual policy facilitation and will be

conducive to support regional industry and energy security.

3) For AMS on steady growth pathways, it is essential to ensure sustainable electricity supply through grid stabilisation while sustaining the economy of power generation at respective power plants during the energy transition period when renewable energy introduction on a massive scale is expected. In this regard, not only policy, technical, and operational measures will be required but also policy arrangements and implementation of market and electricity tariff system formulation and reform.

3.3. Conclusion

Energy transition is the first-ever experience for ASEAN and all countries, however, the transition is a must pathway. At the same time, every country must consider its peculiar factors, such as global and national energy situation, existing and required system configuration, fuel availability, economy, growth, and culture. Each country should also stick to ASEAN's policy direction – that ASEAN and the AMS utilise all affordable and available fuels for power generation in the most environmentally compliant manner.

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Appendices

Appendix 1: Q&A of GFI Analysis

Quote from JCOAL @1st Working Group	Remark/Question	Answer
To forecast the GFI, the historical GFI is regressed with several variables. Each variable will have its own historic and forecast data.	What are examples of variables in this statement? If it refers to, let us say, total capacity or total renewable energy capacity, would it not result in multicollinearity? If it refers to the energy availability factor, how do we forecast the future values of this variable? Can gross domestic product (GDP) be one of the variables?	A validation check was done and so far optimised by the data obtained. => see validation graph
In several countries, the GFI is found to increase year by year with their economic growth.	Please clarify the statement. If one country has positive economic growth but with high efficiency (decouple GDP from electricity consumption), would the country have increased GFI value?	According to our analysis, the GFI will increase with rising solar and coal availability factors. The GFI should be considered with the quality of generation flexibility.
Countries with a high share of hydro and gas generation are supposed to have no future issues of grid flexibility.	Is there any rule of thumb that defines the relationship between the hydro or gas generation share and the GFI value? Or is it country specific?	Normally, gas thermal can be operated flexibly. Hydro, especially small and pumped hydro, is also positioned as a mid-merit generation.
	Would implementing other grid stability measures, for example, BESS or demand response, reduce the GFI of one country?	Although the stability measures cannot be reflected in calculating the GFI value itself, they might be practically effective and consider adding the proposed recommendations.

The GFI of many countries will be increasing from 2030, especially Indonesia, Malaysia, the Philippines, and Viet Nam.	What are the contributing factors of increased GFI in these countries: the MW of renewable energy, the MW of coal, the energy availability factor, or both?	The main factors are coal and solar availabilities.
	For Malaysia, the data behind this analysis refers to Peninsular Malaysia or Malaysia as a country (including Sarawak)? The grids are separated from each other.	Currently, whole country data were obtained.

Appendix 2: List of Members of the 1st Working Group for the ERIA Study

Country	Institution	
Indonesia	Ministry of Energy and Mineral Resources (MEMR)	Mr Senda Hurumzan Kanam, MSc. Deputy Director for Electricity Cooperation, Directorate of Programming (as a guest member)
		Mr Pramudya, ST, MT, Policy Analyst, Directorate of Programming
		Mr Hery Wahyudi Wibowo, ST, MT Electricity Inspector, Directorate of Electricity Engineering and Environment
		Mr Andi Hanif, ST, M.Eng. Electricity Inspector, Directorate of Electricity Engineering and Environment
	PT. PLN (Persero)	Mr Arief Sugiyanto Manager of System Planning for Java, Madura, and Bali
	PT. PLN (Persero)	Mr Herian Atma Engineer of System Planning for Java, Madura, and Bali.
Malaysia	Energy Commission (ST)	Ir Mohd Helmi bin Mohd Zaihan Assistant Director
	Grid System Operator (GSO)	Ms Rose Adila binti Bujal Senior Engineer
Philippines	Department of Energy (DOE)	Ms Melanie C. Papa Senior Science Research Specialist, Power Market and Development Division – EPIMB
		Mr Noriel Christopher R. Reyes Senior Science Research Specialist, Power Planning and Development Division – EPIMB
Viet Nam	Ministry of Trade and Industry (MOIT)	To be confirmed on Monday 14 June
	Viet Nam Electricity (EVN)	To be confirmed on Monday 14 June

Appendix 3: Minutes of the 1st Working Group Meeting on 'The ERIA Study on Enhanced Flexibilisation of Coal-fired Power Plants for Optimal Grid Stabilisation in the ASEAN Region'

Opening address by Dr Han Phoumin, ERIA

Carbon neutrality becomes a globally shared value and objective, given the imminent threat of climate change. Given the efforts by ASEAN towards renewable integration, the study comes at the right time when the region needs to see a range of measures for grid stabilisation, including the flexibility of coal power generation. I think coal would be resilient in power generation if it can really play a role in flexibilisation for grid stabilisation.

ASEAN still relies on fossil fuels in both the power and industry sectors. And coal will remain a reliable energy source in ASEAN, since the environment, affordability, and energy security are considered in the choice of energy sources. Coal is affordable and economically competitive. However, coal utilisation must be with clean coal technology, given the environmental requirements.

ERIA hopes to convey the recommendations, once provided under the study, to the relevant institutions and the power utilities in the region trying to identify their energy transition paths and the measures to be taken.

The MC expressed appreciation to Dr Phoumin and asked Mr Senda, Deputy Director for Electricity Corporation, Directorate of Programming, Directorate General of Electricity, Ministry of Energy and Mineral Resources (MEMR) of Indonesia, to deliver his keynote address.

Keynote address by Mr Senda Hurumzan Kanam, MEMR, Indonesia

The study on increasing flexibility of power plants needs to be carried out to improve the reliability and stability of the grid system. Due to the increased penetration of intermittent variable renewable energy sources, mainly wind and solar, the large penetration of PRA in the grid is not only due to the effort of various countries to achieve the target of the Paris Agreement and net zero emission. It also due to the lowering cost of PRA production and the development of energy storage technology that has been introduced into this system. The main approach to improving systems security and stability applies smart grid technology or grid modernisation.

One grid modernisation approach is to apply automatic generation control or AGC to respond actively to the fluctuations of PRA penetration on the system grid. In addition, the operation of a large system that works as a baseload is necessary to increase the ability to change the demand for a sudden increase, especially during the peak load in the afternoon, which forms a duck curve. Such situation is caused by the increased penetration of PRA, especially solar power plant which can only produce during daytime when household demand remains low and cannot supply during nighttime.

When demand increases with this heavily burdened coal plant that usually operates as a baseload, it is necessary to study and modify the operation of the coal plant so that it can respond to the changes in demand, following the duck curve, and changes in the supply of PRA that are intermittent. The ability to respond to the change in demand and supply to ensure stability depends on the (unclear) of each coal plant.

We have compiled a grid code regulating PRA intake in the system must be stable first before entering the system. In the future, our grid code has recommended wind power integration in Indonesia by utilising batteries to reduce its intermittency.

In Indonesia, to overcome the issue of location installer, we will implement a system with a floating solar power plant and a hydropower plant before introducing it into the grid, which we expect for reduced PRA appropriation. For example, in Lampung and [unclear], we plan to build a solar power plant system equipped with battery storage to supply the peak load at 18:00–20:00 to overcome the duck curve of increasing load before battery storage, and ancillary service (BA) introduces it into the grid.

In Europe, [unclear] demand occurs during the summer and the winter, where there is no demand in summer and high demand for heating in winter. However, the opposite occurs when there is a high solar energy supply in summer and a low supply in winter. To overcome this fluctuation of excess power during the summer season, the German government stores excess power produced from wind and is reused in the winter, which they call green hydrogen. From experience in Indonesia and Germany, we can learn the flexibility of coal power plants in the future by utilising storage technology, such as batteries and hydrogen.

In Indonesia, we tried to clean up our coal plants by introducing carbon capture and utilisation storage, or CCUS technology. Captured CO2 from coal-fired power plants will be injected into depleted oil gas fields nearby. Besides that, the excess power from the coal plant used in the operation of a large amount of PRA from solar will be stored in batteries or hydrogen storage. This energy storage will be utilised during the peak load. The hydrogen produced from this process is called blue hydrogen.

The next anticipated phase is to combine coal plant and hydrogen plant integrated with an ammonia production process so that the product can be exported as ammonia. With a strong commitment from both countries' governments and the industry sector, I am confident that this collaboration will inspire us further to join in relevant activities in the future and that innovation in the technology development of Indonesia and other ASEAN member states will progress.

The MC gave a briefing on the meeting agenda and the schedule.
The Working Group members introduced themselves and shared their thoughts on the study and the relevant issues.

Mr Pramudya, MEMR, Indonesia
I am in charge of the national electricity planning and evaluation. In the same context, we evaluate the plans of the PLN, RUPTL, the 10-year national power infrastructure development plan for power generation, transmission, distribution, and substation. I hope through this study, we can put together our knowledge to find a better solution for coal-fired power plants for a flexible and better grid. I joined another ERIA study on ASEAN interconnection, so it is my pleasure to participate again as a working group member.

Mr Hery Wahyudi, MEMR, Indonesia
My task is to support the government for technical proficiency and share the recognition of electrical safety with all relevant industry players and suppliers.

Mr Andi Hanif, MEMR, Indonesia
I am in the same team as Hery-san working as a national electrical inspector. I hope I can provide advice and support to the study team in the context of my daily work and duties.

Mr Arief Sugiyanto, PLN, Indonesia
I am in charge of the system branding for Jaffa, so I am working with the MEMR for RUPTL formulation. So, we – Mr Herian and I – are from the utility side, and Mr Pram is from the regulatory side. This is the first time I have joined this study on flexibility for coal-fired power plants, so I am interested in seeing the result and interim report of this study, especially regarding the technical capability of coal-fired power plants and the cost. Maybe later we can discuss this more. As Mr Senda said, in the future, we will have a lot of renewables coming into the system, and we need more flexibility from the existing power plants.

Mr Herian, PLN, Indonesia
I am working in the system planning division, which, together with the Directorate General of Electricity, drafts the RUPTL, the power development plan for Indonesia for the next 10 years. We hope that by working in this group, we can learn what technology is applicable to allow us to incorporate more renewable energy in the future.

Ir Mohd Helmi bin Mohd Zaihan, EC (ST), Malaysia
I am from the Energy Commission of Malaysia, currently in the electricity market operations unit. We are responsible for regulating the electricity supply industry – from generation, transmission, and distribution to retail.

Ms Rose Adila, GSO, Malaysia
I am from the grid management unit, coordinating the grid system for the power plant in Peninsular Malaysia. As the representative of GSO, I am looking forward to the study's outcome. Our main concern is system security. We hope that the technology or the recommendation from the study can benefit grid stability and power generation.

Ms Melanie Papa, DOE, Philippines

I am assigned to the unit that oversees the implementation of our wholesale electricity spot market. I am committed to participating and contributing to this study in whatever way I can.

Mr Noriel Christopher, DOE, Philippines

I am also from the Electric Power Industry Management Bureau of the Philippines, Department of Energy. But I am in a different division from our Power Planning and Development Division. My main task is more on generation planning of the power sector and mostly on crafting our power development plans.

Updates of each country's situation were presented according to the alphabetical order of the country names. Mr Pramudya, MEMR, Indonesia, made the first presentation for Indonesia.

Next, Ir Mohd Helmi bin Mohd Zaihan, EC (ST), Malaysia, did the country presentation. The floor was opened for questions as Dr Murakami requested time to ask Malaysia.

Dr Murakami, JCOAL Study Team

Thank you for your presentation. You mentioned 400 MW of BESS; 100 MW is relatively larger if BESS is connected with a standard solar plant or wind plant. So, which part of the grid are you planning to install BESS?

Ir Mohd Helmi bin Mohd Zaihan

Actually, we will ask the grid system operator to study this before deciding where to put BESS. We don't have any specific plan yet where to put BESS.

The Philippines also requested an opportunity to ask a question to Malaysia.

Ms Melanie Papa

Also, regarding the battery energy storage systems, may I ask how you treat or make transmission charges to those BESS? In the case of the Philippines, we don't have a policy yet when it comes to charging them for transmission. Whenever they draw power from the grid, they are being charged those transmission charges. How do you treat those systems in Malaysia?

Ir Mohd Helmi bin Mohd Zaihan

Similarly, currently, we don't have any charges in place in Malaysia. But we are conducting a study with a consultant to provide a framework for the charges. So, we are still unsure whether to park the BESS as part of the generation or part of the ancillary services and the charges. But we are still conducting studies, and we expect these to be completed by the end of this year.

Ms Melanie Papa
I see, so we have a similar dilemma. Yes, thank you.

Ir Mohd Helmi bin Mohd Zaihan
Yes, similar dilemma and the price is quite high for BESS. Maybe we can collaborate later to see how it goes in the Philippines as well.

Ms Melanie Papa
We will wait for the development in your country when it comes to those systems.

Indonesia was the third questioner about Malaysia's presentation.

Mr Hery Wahyudi
I have two questions for you. The first is how long is the time horizon for your PDP, and how often do you have to revise this document? For what reason? The second question is, I saw that you have a projection for a capacity mix for the next 20 years, if I'm not mistaken. Is there also a projection for the energy mix?

Ir Mohd Helmi bin Mohd Zaihan
Yes, we do have. For the power generation planning, we have a 10-year plan. The latest one that we published is from 2021 until 2030. There is no set timeline, but we usually conduct a study every year and maybe publish it in 5 or 10 years. But it depends on government policy. In any case, we do the studies every year. But currently, it is pretty difficult to make projections because the pricing and the demand are not yet stable due to the COVID-19 situation.

Mr Hery Wahyudi
And how does Malaysia set the target of a minimum share of renewables? In the case of Indonesia, it is 23% by 2025.

Ir Mohd Helmi bin Mohd Zaihan
We have a similar target, and it is about 35% something if my memory serves me.

The two representatives from the Philippines made their presentation.
Indonesia asked questions to the Philippines.

Mr Andi Hanif
I have three questions regarding your presentation. The first question is: so there are different corporations in your electricity business system, which involve different electricity sectors. Is that correct or not? The second question is, in the electricity generation sector, are there different corporations as well or none? For example, there are corporations, especially for our coal power plants, and other corporations for hydropower plants. Are all power plants under one corporation?

And then, the third question relates to what you said about the archipelago, which is very interesting. It is the same condition as our country Indonesia. So, there are different corporations on different islands, or is the corporation at the national level? Those are my three questions.

Ms Melanie Papa
The Philippines has multiple generation companies, and the government no longer owns them. When we had our electric power industry restructured in 2001, we sold the generation facilities owned by the government one by one. Now, private corporations own almost all generation companies. And it depends on those corporations what type of plant or fuel they will put up for their plants.

Mr Noriel Christopher
As mentioned by Ms Melanie, the Philippines' generation sector has been privatised. But regarding your third point on the Philippines being an archipelago, to help clarify that concern, let me differentiate that in the Philippines, there is what we call a grid area and an off-grid area. So, what we call a grid area refers to those areas in the main islands connected to the Philippines' national transmission lines or transmission highways.

In terms of the participation of the stakeholders in the grid areas, these are mainly private companies that put up these generating facilities and provide power to the grid. The transmission lines are owned by the government. But in terms of the operation and maintenance and the continuous improvement of these transmission facilities, the government signed a concession agreement with a private company, called the National Grid Corporation of the Philippines, to help the government extend the lines and be the one in charge of the system operations.

As for off-grid areas, at least for those areas where we currently have no private sector participation yet, the government is in charge of providing electricity to those islands not connected to the main grid. So, usually, these generating facilities are owned by the National Power Corporation. But, somehow, in terms of the participation of the private sector, we are also slowly opening these areas to private companies who might be interested in putting up generating facilities in those areas as well.

Mr Andi Hanif
I would like to know about the corporations you mentioned in your presentation. Which corporation is the largest in terms of the area it covers and the capital?

Mr Noriel Christopher
Okay, in terms of the share of these private companies in the generation sector, Ms Melanie can provide additional information. But in terms of our EPIRA Law, or the restructuring act of the power industry of the Philippines, we have a limit of 30% share of these companies in the total ownership base of our generating facilities. So, in terms of the specific companies that compose the largest shares in this mix, San Miguel

Corporation, Aboitiz Power Corporation, and First Gen Power Corporation are the major players in the Philippines' generation sector.

The other member from Indonesia asked a question to the Philippines.

Mr Hery Wahyudi

I would like to know about the Philippines' national target for greenhouse reduction in 10 years, 20 years. Also, what percentage of consumers have smart metres installed in place?

Mr Noriel Christopher

For the greenhouse gas emission reduction targets, I do not have the specifics of that information per sector. But in terms of our NDC commitment, we have submitted a 70% conditional target, depending on the support we will get from the international community in meeting the reduction target.

I currently do not have the numbers per sector, but I will try to get those and inform you after this meeting. But then, going to your next question, in terms of the number of smart metres currently installed, we also do not have the specific numbers now. But in terms of our shift to the smart grid framework policy, we still have a long way to go in terms of the number of end users. We only have a small number of end users already using smart metres, and these are coming in mostly from our private distribution utilities. So, the challenge now is to also increase the level of smart grid adoption, especially in our electric cooperatives. So far, the business sectors are the main areas of demand growth.

Dr Phoumin, ERIA was the next questioner.

Dr Phoumin

I would like to ask for a bit of clarification. In the Philippines' case, I think it's very interesting for the rest of ASEAN regarding the electricity market. The country has been moving from the vertically integrated electricity market towards more liberalisation.

I just want to know when it is moving, let's say, for power generation towards a private company. Does this private company remain with some long-term contracts with the grid operator as the off-taker, or is it based on demand and supply? If they are moving towards market liberalisation based on demand and supply, how can they ensure that they can attract investment in power generation if investors feel uncomfortable about how they're going to supply or sell their electricity without the long-term contract? Appreciate your clarification.

Ms Melanie Papa

The Philippines' electricity market is a gross pool market, meaning those who have bilateral contracts – the generation company with a contract with a distribution utility – still transact through that market. So, they will only have to pay the portion that is not contracted.

They will still set their obligations through the bilateral contract; then beyond that bilateral quantity, they will have to pay in the market. So, if ever the demand of the distribution utility goes up, that's the time they buy their quantity from the market.

So, it is sort of a shield. They are being shielded whenever the prices in the market go up because there are existing bilateral contracts, whether long term or short term. So, all transactions are seen and monitored through that market. Noriel, you may want to add?

Mr Noriel Christopher

I will make a supplementary clarification. It is a gross pool, and bilateral contracts are declared in the market on top of the spot declarations. For your information, most of our contracts are still under a bilateral agreement in terms of the share of bilateral contracts in the Philippines. Around 90% and 10% are transacted through the market as spot quantities. So, regarding the function of the market, in terms of dispatch, all generators, even if they already have bilateral contracts, still bid their output hourly. But as Ms Mel mentioned, we are shifting to a 5-minute interval market. After running, the market operator will provide a dispatch and a merit order table containing the dispatch of capacities after all the bids have been entered. This will be provided to our system operator. So, the system operator will be the one to follow this dispatch based on existing protocols.

So, regarding the dimension of encouraging more investments through this market, we are also trying to explore additional areas where we can encourage investments through our recently established renewable energy market for the transaction of renewable energy certificates and our reserve market. This is also to facilitate the reserve provision for an optimised energy and reserve provision within the market structure. Our current structure of providing reserves is just a one-on-one contract with the generator and the system operator. So, hopefully, by introducing the reserve market, we can encourage more generating companies to provide reserves and additional capacities, which the Philippines also needs. So, hopefully, we were able to provide clarification on the questions raised.

Before the presentation on the interim report, the JCOAL Study Team introduced themselves. Mr Oda, as Director of the International Collaboration Department, is the team leader. The by-country analytical reviews are handled by Mr Otaka for Indonesia, Ms Yamada for Malaysia, Dr Murakami for the Philippines, and Mr Ozawa for Viet Nam. Mr Teuchi handles the meeting organisation and will undertake a part in conducting surveys to support the elaboration of the study report.

The Study Team made the presentation.

Ms Yamada

The next slide shows the preliminarily provided questions and requests for clarification from the two representatives of Malaysia.

The first is quoting the JCOAL slide. To forecast GFI, the historical GFI is regressed with several variables. Each variable will have its own historic and forecast data. The remarks on questions are what are examples of variables in this statement? If it refers to, let us say, total capacity or total renewables capacity, would it result in multicollinearity?

If it refers to the energy availability factor, how do we forecast the future values of this variable? Can the gross domestic product be one of the variables? A validation check was done with the data obtained. Dr Murakami is asking you to see this validation graph on slide 14.

Dr Murakami made an additional clarification.

Dr Murakami
Horizontal is the data obtained from the duck curve, and vertical is estimated, that is the calculation data. So, the regression is very good. So far, this is the limitation of the regression. But we estimated this validation to be very good for establishing the multivariate regression.

Ir Mohd Helmi bin Mohd Zaihan
May I know what are the variables used?
And is it possible to include GDP in the GFI formula? Does GDP affect GFI?

Dr Murakami
As slide 14 says, I picked up four from the parameters: coal availability factor, renewable energy availability factor, nuclear availability factor, and solar availability factor. These four parameters are much related to the GFI. Then at the right bottom, the parameters are clarified as W1, W2, W3, and W4. You can see that W1 and W4 are much higher than W2 and W3. That means coal availability and solar availability factors constitute the main component of the GFI. That is the result of regression.

Including GDP in the GFI formula would probably be possible. GDP may affect GFI. However, GFI is calculated as the max ramp rate divided by the total installed capacity.

Ir Mohd Helmi bin Mohd Zaihan
I wonder if the same formula with W1, W2, W3, and W4 applies to all countries?

Dr Murakami
Yes, I use the same formula because I estimate this relation using the EIA data and the duck curve obtained from the public domain, which is the regression base. After that, we can get the regression formula to calculate each GFI from ASEAN.

Ms Yamada
The next question is that in several countries, this was what we say in our slides: the GFI is found to increase year by year with economic growth. Please clarify the statement. If one country has positive economic growth, but with high efficiency, decouples GDP from

electricity consumption, this is not happening I think or the country has increased the GFI value. And the recommendation, according to the team's analysis, is that the GFI will increase, mainly due to the increasing availability factors of solar and coal. The GFI should be considered with quality of generation flexibility.

The next is whether any rule of thumb defines the relationship between the share of hydro/gas generation with GFI values. Or is it country-specific? And our answer is that usually gas, thermal can be operated flexibly. Hydro, especially small hydro, and pumped hydro also positioned are deemed mid-merit generation.

And the next is about whether implementing other grid stability measures such as BESS, demand response would reduce the GFI of one country. And the answer is although the stability measures cannot be reflected in the calculation of the GFI value itself, they might be practically effective and will consider adding the proposed recommendations. So, this is what you have given as the remarks and questions on this part of the table. We will be trying to incorporate it in the forthcoming report.

As for 13, we have two questions; one is that the GFI of many countries will be increasing from 2030, especially Indonesia, Malaysia, the Philippines, and Viet Nam. And your question is what the contributing factors of increased GFI in these countries are: the megawatt of renewable energy, the megawatt of coal, energy availability factor, or both? The main factors are coal and solar availabilities and later, you can refer to the regression equation and coefficient.

The other is about slide 13, for Malaysia. The data behind this analysis refers to Peninsular Malaysia or Malaysia as a country, including Sarawak. The grids are separate from each other, and our answer is that we collected the data, the whole country data. So, it is not part of Malaysia but the national data. Do you have any comments? Is it all right?

Ir Mohd Helmi bin Mohd Zaihan
Later, we might like to have separate data for Peninsular Malaysia,

Ms Yamada
Well noted. We can work on that. But it is clear that we have this national data, and based on that, we have done this initial analysis. So, we have two for the rest: one is slide 16, about coal outcomes for less than 50% in the generation mix. And your comments about GFI (Note: see Appendix I) would help us appreciate the analysis and findings more. So, we will be addressing this request from you.

Ir Mohd Helmi bin Mohd Zaihan
Yeah, I think for the comment for slide 13, particularly for Peninsular Malaysia, I do not think you need to provide separate data. For example, Indonesia has thousands of islands, so I think the data can be used. We only have two main islands in addition to the Malay Peninsula.

Ms Yamada

Yeah, thank you for saving us. So, the last one is about slide 23, the chart: are the measures applicable to new coal plants through design or adapted to existing coal plants? Maybe we can list or differentiate between the two?

The other is whether the study team can include the problem or scenario that the machines will experience when in the cycle mode (Pmin-Pmax-Pmin). Also, what are the risks that the coal plant will face if they are run in the cycle mode without any modifications to the machine? So, that means you would like to have some kind of case-by-case analysis on this aspect of machinery and equipment and prevention or solution measures?

Ms Rose Adila

That is right. We also would like to know the impact on the machine we put on cycle mode: is there mechanical stress, or are there problems controlling the steam temperature?

Ms Yamada

Our team thinks we should first know exactly the specifications you have in mind when you ask this question.

So if we do this, it is not a case study because it is about this flexible operation of coal-fired power plants, for grid stabilisation. But then, if there are any contributing factors, it would be very good for us to do some case analytical work. For that, maybe we can ask any of your power plant specifications, and Ozawa-san can advise you; we can also make some recommendations on that. At this moment, that is our initial idea on this because how much mechanical stress on the equipment depends on the type and specification of such equipment. And it would be different from one to the other.

Ms Rose Adila

I also would like to know whether the technology you recommend on this slide can be implemented in both the conventional coal power plant and the super-critical coal power plant. Can it be used for both?

Ms Yamada

If you would like to discuss whether a particular technology can be introduced to the existing power plant, it is important to think about the technical applicability and economy of the plant, since in most cases some modifications will be required upon introducing additional equipment. So, it would be better to discuss such matters by looking into the conditions and requirements to find out if the envisaged introduction will benefit the overall operation of the power plant. Let us discuss this further with you later by email.

Ir Mohd Helmi bin Mohd Zaihan

You think that is a separate topic from this study.

Ms Yamada
No, it is not a separate topic. But it is within the context of enhancing the data results of this study. That is what we want, do you agree?

Ir Mohd Helmi bin Mohd Zaihan
Well noted and agreed to communicate later.

The following are the questions and requests for clarifications by Indonesia.

Mr Arief
I would like to know how flexible coal-fired power plants would be after modification. I think in your presentation, it is only 5%, that is the first question; the second question is about the cost required for such modification. And the third is a request to provide the successful case examples in Japan or any other country.

Ms Yamada
The 5% the slide mentions is how much we can change the rate per minute. It is a per-minute rate. The minimum loading value is in the next slide. Emerging economies have generally achieved between 30% and 50%. According to our experience in Japan, this can be lowered to 15%–25%. We will try to provide further details of the actual case example in Japan and other countries.

Mr Arief
So, the ramp rate is only up to 5% per minute with coal-fired power plants? With a gas turbine, we could ramp up/down at 20% per minute.

Ms Yamada
We know that the ramping rate usually varies between 1% and 2%, which can be technically possible without damaging the machine, between 3% and 5%. You are right, gas is definitely more flexible or easy to implement in flexible operation.

Mr Arief
I thought it could be more flexible; it could be more than 5%.

Ms Yamada
That is as long as we know what has been proven so far. However, we must pursue the possibility for further improvement.

Ms Yamada
The minimum load operation in the slides was already done in Japan, especially in the

Kyushu area, under similar climatic conditions as ASEAN countries. PV solar is at its peak; it can address over 90% of the demand.

Mr Arief

I would like to know what needs to be modified and how much it costs to modify to have more flexibility.

Ms Yamada

We do not have updated and detailed cost information. For practical purposes, you might like to ask manufacturers such as Mitsubishi Power directly. They will come up with very useful and accurate cost information if you provide them with the relevant specifications and conditions of the power plant. That said, as you indicated, we will try to cover general considerations and information about the cost of the study.

Malaysia asked the next question.

Ms Yamada

What will the coal plants face if they have been running the site [Unclear]. I think this is also the same as in the previous one: depends on what power plant and what kind of specifications you have in mind when you ask these questions. These will also be discussed later on.

For changing burners, it would take maybe 4 to 5 months. But that also depends on how many burners you would change.

Ms Rose

So, do they have to change all the burners or just a few?

Ms Yamada

That is actually optional; depending on how much flexibility you would like to achieve through the retrofit. I think it is 40%–50% usually. But 25% is very far from that. If you think 35% is okay, it's not too much. I think the modification will be less. But when you want to go to that extreme side, then it will take more time. In that case, I think it is better for you to give some case examples so we can study.

Ms Rose

One last question: For the HP (high pressure) bypass system, for example, the steam bypass spray, this can be installed to the existing coal power plant or the new one?

Ms Yamada

According to Ozawa-san, a bypass can be added to this existing power plant. That is very much possible.

Next and the final questioner was the Philippines.

Mr Noriel
Yes, just a question regarding the specific type or age of the coal plant on which these improvements can be applied. Is there a limit? Or, can you include these improvements within the system of old coal-fired power plants

Ms Yamada
Theoretically, from the team's point of view, that is also applicable to existing power plants. But let us look at this slide. There are roughly three key points. One is improving loading rate; two is optimising the minimum load; and three is reducing start-up time. This start-up time reduction is applicable to new power plants, while one and two can be for both existing and incoming power plants.

All presentations and Q & A sessions are over, and the tentative schedule was announced.

Ms Yamada
Let us clarify the upcoming study schedule just verbally. After this meeting, we will work on the respective parts of the report individually. Murakami-san will elaborate on this GFI thing. Some details and technical issues will be pursued by Ozawa-san as well.

During such work, we will interact collectively and/or individually with you for further advice, comments, and information. That will be done while we closely communicate with Dr Phoumin of ERIA. As I said, the second and last meeting will be in ERIA in October. Then the final report will come in mid-November 2021.

But if you are available and willing, we may have some by-country interactions, maybe for 20 minutes or so on MS Teams; that is, if email is not enough. All such options will be arranged if the relevant members agree.

Closing remarks by Toshiyuki Oda, JCOAL

Today we had a long and meaningful discussion. It was meaningful for us in the Study Team because we learned about the latest energy situation in Indonesia, Malaysia, and the Philippines through each presentation and advice. Such information will constitute part of the valuable data under the study.

I think we provided useful information to the Working Group members. We introduced the results of the initial analytical work on the GFI, relevant issues of load changes, and key technical points about potential flexibilisation through coal-fired power plants.
What would be required to materialise action towards flexibilisation implementation, we would need to hear from boiler manufacturers and relevant specialists while we share the outcomes of the initial and theoretical discussions like what we have done today.

I hope we can furnish an excellent final report in November 2021.
At the end of the session, a group photo was taken, and the meeting was closed.

Appendix 4: List of the 1st Working Group with Viet Nam, Working Group Members for the ERIA Study

Country	Institution	
Viet Nam	Vietnam Electricity (EVN)	Mr Minh Quang, Deputy Manager of Power System Analysis and Planning Department, National Load Dispatch Centre
	Vietnam Electricity (EVN)	Mr Nguyen Tuan Anh Senior Expert of Technical and Operational Department
	Vietnam Electricity (EVN)	Ms Nguyen Minh Hai Expert of International Relation Department

Appendix 5: Minutes of the Kick-off Meeting with Viet Nam on 'The ERIA Study on Enhanced Flexibilisation of Coal-fired Power Plants for Optimal Grid Stabilisation in the ASEAN Region'

(Meeting held virtually on 29 June 2021)

The meeting was started with greetings by EVN and JCOAL.

Welcome Address by Mr Toshiyuki Oda, Director of International Collaboration Department, JCOAL

The last couple of years saw an impressive global shift with all kinds of new and renewable energies as quite valuable and available options. JCOAL has been enhancing its efforts to engage in new fields and even changed its name to Japan Coal Frontier Organization. We will remain keen on working extensively for efficient, affordable, and sustainable energy for all, which is the shared spirit of SDG7.

Prevention of possible grid fluctuation is one of the most important actions we shall take while the massive introduction of renewables proceeds. Existing power plants with flexibility, including coal-fired power plants, are expected to address the issue collectively. At the same time, full attention is paid not to damage the equipment and efficiency to the extent such operation is no more economically viable.

As you might know, the essence of the final report will be incorporated into the comprehensive policy recommendations of ERIA that are to be submitted at the annual East Asia Summit. In this context. I am grateful for your participation today and would appreciate the forthcoming cooperation by EVN.

Keynote Address by Ms Luong Thi An, Deputy Director General of International Relations Department, EVN

Today we have Mr Nguyen Tuan Anh, Senior Expert of Technical and Operational Department; Mr Minh Quang, Deputy Manager of Power System Analysis and Planning Department, National Load Dispatch Centre; and Ms Nguyen Minh Hai, Expert of International Relations Department.

First of all, I would like to thank JCOAL for organising this meeting to better understand the study and participate in this interesting programme.

We believe that, through this study, we can get more outputs and understanding about how to improve the coal-fired power plant operation in Viet Nam. Then we hope to report to our EVN management to mobilise our resources to participate in this study and cooperate with you in our best efforts. We appreciate the continued collaboration between EVN and JCOAL. Thank you very much once again, and we look forward to seeing you in Viet Nam very soon after the COVID-19.

Now I would like to leave the floor to our colleagues from the national dispatch centre and engineers from the technical and operational departments for further discussion and presentation.

The MC asked everybody to turn on the video for a group photo before Ms An left the meeting.

Madam An
Thank you very much for the group photo. Please send us our photo after the meeting is over. Thank you.

Introduction of JCOAL team members

Dr Kazuyuki Murakami
My name is Kazuyuki Murakami. I have recently left the international collaboration department. My recent focus, amongst others, is bilateral cooperation with Viet Nam. I now belong to the R&D department, where I oversee technical studies on carbon neutrality as programme manager. In this study, I am in charge of grid fluctuation and analytical work for the Philippines.

Mr Masahiro Ozawa
Good afternoon, everybody. My name is Ozawa. I am an expert in thermal power plants, especially coal-fired boilers and environmental treatment. I worked with Mr Tang 3 years before. In this study, I will be in charge of Viet Nam.

Mr Shinjiro Teuchi
Good afternoon, I am Shinjiro Teuchi. Nice to meet you. I have been working at JCOAL for 10 years. I am a geologist. I belong to the international collaboration department. This is my first year to be in this project. I am very happy to be part of this scene.

Ms Yamada
Hi, everybody. I am Yamada, working for the international collaboration department of JCOAL. I am in charge of the part of Malaysia under this study. We have another colleague, Mr Otaka, who is working on the Indonesia part. Unfortunately, he has another meeting but will come to this meeting later on.

Today I will do the emceeing. Now, may I introduce the background of the study and what we will do under this study. This will be followed by your presentations on the current situation and updates on the relevant issues. Finally, the team will present the current progress by introducing the interim report summary using slides.

Introductory presentation by JCOAL

Ms Yamada clarified the slides on the study overview.

We know that all ASEAN countries made commitments not long after the international agreement had been in place. So, we very much appreciate it. That is why all AMS, not only Viet Nam, are trying hard to address emission reduction requirements mainly through renewable energy introduction.

As far as my memory serves me, a few years back, Viet Nam was committed to approximately 20%–21% renewable energy share target in the electricity mix as of 2030. And now Viet Nam revised it to 32%. That is the highest of all AMS targets. In fact, in 2019, it's done, you know, solar development from the previous 100 MW to almost 5,000 MW.

In the meantime, renewable energy is substantially variable and intermittent. And so that's why we have to do something about it. It's not only in Viet Nam; it is also in Japan. So, the ongoing massive introduction of renewables will enhance energy sustainability and resilience; we are sure about it. But that is if the existing fossil fuel power plants are appropriately controlled and operated with enough flexibilisation as per the requirements by the grid through the introduction of techniques, best practices, and technologies such as IoT and AI. But the situation may vary from one country to the other, even within ASEAN. As Oda-san said, gas power plants will be given the role.

However, some countries, where coal power is dominant over gas power, must do it with coal-fired power plants, as we have seen in the case of India. That is why we are here today.

And now. I would like to ask my junior colleague, Teuchi-san, to present the rest of the three slides about objectives, study methods, etc.

Taking the opportunity, let us clarify why we do this study and how ERIA will be utilising the outcome of the study. ERIA is an international research institute mandated to engage in joint study activities for policymaking in ASEAN. Their annual reporting and ultimate forum of discussion are the East Asia Summit (EAS), which is in the framework of ASEAN +6 member states (Australia, China, India, Japan, Korea, and New Zealand), to enhance the outcomes of the cooperation. Therefore, from any field of study, whether this is renewable or coal or whatever it is, ERIA will incorporate the outcomes of the respective studies into their report of recommendations at the EAS.

At the same time, every study will be reported to each target country. So, we will share all the reports and outcomes with the respective target countries: Viet Nam, Indonesia, Malaysia, and the Philippines. So that is my supplemental explanation.

Presentation by Viet Nam

Mr Minh Quang, National Load Dispatch Centre
Thank you very much for your introduction.

From our side, I will present the review of the grid system and the renewable energy development situation in Viet Nam. Firstly, some introduction about Viet Nam's installed system. This shows different types of power generation technology in Viet Nam.

So, you can see, we have a lot of volume in northwest Viet Nam; in this area, we have some big hydropower plants. This is the location where we have a lot of hydropower plants. We have many coal mines in the northeast and a thermal coal-fired power plant in this area. We have mostly the hydropower plants in the centre and the south. In the central and south, since 2019, we have had a lot of newly developed renewable energy power plants.

We primarily have solar power plants in central and south Viet Nam. In the south of Viet Nam, we also have some gas turbine power plants. So, as you can see in the slide, there is a mix of different types of technology. You can have the data in the slide. This is the share of energy production in 2020.

Under total demand, one size of our power system was nearly 250 million GWh in 2020. This is the simple map of Viet Nam's power network. You can see the shape of our country; we have a narrow country, and very long, from north to south. From the north to the centre, we have two 500 kV circuits of the advanced system; and from the centre to the south, we have four circuits in the power network. We plan to have our systems further extended and enhanced throughout the future. This is crucial, you see, in terms of the required energy production and the increasing peak load.

The rate of demand increase is nearly 10% per year. This is the data as of May 2021, when we had nearly 17,000 MW of wind and solar energy. It is about 25% of the national installed total capacity. In terms of different types, we have 142 power plants for the solar farm. The total installed capacity is 8,800 MW, and we have a lot of rooftop solar. So, we have more than 7,600 MW of solar, and we have more and more wind power plants in the system.

This is the data for the end of May. But now we have more than 700 MW of wind in the system. We plan to have about 5,000 MW of wind power plants in the system at the end of this year.

We have more and more wind energy power plants, and they just started in 2019. In 2 years, we have around 17,000 MW of renewable energy, which caused many problems to our power system, especially congestion. So, you can see that wind energy is very highly concentrated in some areas in the south and the centre of Viet Nam – about 17,000 MW. That is why we cannot catch up with the development of renewable energy power plants, and that is why we have congestion in some areas in the power system caused by renewable energy.

We also have the problem of surplus power generation because of wind energy. We had to transfer power from the centre and the south to the north. But we have cared for the limit in the connection from the north to the centre. So, we cannot transfer much power as much as we wanted from the centre to the north. That is why we had the problem of renewable energy surplus at some point last year, and we cannot transfer those power plants or energy to the north.

We have other issues caused by renewable energy power plants, such as system inertia. So, the more renewable energy power plants we have, the lower the system efficiency compared to the initial conditions of the power system. However, it is sometimes possible for us to improve the situation and get the system back to work at the near-initial efficiency.

In our case, we have an action plan for integrating renewable energy formulated through a project we did in 2018, assisted by international consultants from the US. They drew an action plan for different levels of renewable energy integration. That is why we have speedy integration of renewable energy power plants, and we can now manage the situation. Other than that, it is pretty good.

One solution to congestion issues: solar makes the power increase very fast during the day. As the discharge capability of the grid is very limited, a lot of solar power can cause congestion to the grid. In Viet Nam, we use the AGC system to manage that. With the AGC system, we can monitor the situation of the grid. When the transmission line is overloaded, we will signal our plants and ask them to reduce the reactive power automatically through the AGC system. Then as power plants' active power options are released, grid stability remains in the acceptable range, so the system is not overloaded. To control the renewable energy power plant, we also have many monitoring systems, such as the SCADA and WAMS systems. We have to wire our monitoring system as well. It is still under the power quality monitoring tools in the renewable energy power plant, which helps us control and monitor the renewable energy power plant quite well.

This year, we have a new PDP8. You can see that this is the preliminary share of the draft PDP8. In terms of installed capacity, we plan to have 28% in 2030 and, in 2045, 42% of installed capacity. Compared to the max, the peak demand in 2030, we may have 50% of the renewable energy compared to peak load. In 2045, in some situations, we may have 75% of the load covered by renewable energy. So, this is a brief introduction to Viet Nam's power system and the situation of renewable energy integration into the grid.

Q & A

Question by Dr Murakami

Thank you very much for the very informative presentation. I learned a lot. I have several questions, but I will ask about three. The first one is regarding rooftop solar. The capacity of rooftop solar is almost comparable to renewable solar. So, is it connected to grid utilisation? The second question is on a BESS solution. According to your plan, a BESS solution will be considered when the renewable share reaches about 40%. So, a large volume of BESS will be required. What do you think about that? The last one is on international cooperation. Your last slide implies that you have already cooperated with ADB and GE. If possible, may I know the drawing of that comparison? Thank you very much.

Mr Quang
For the first question on solar rooftop, as I explained in my slide, we now have more than 7,600 MW of solar rooftop in the power system. It is connected to the power system's medium and low voltage sides. On the question about BESS, we think that energy storage is one of the very good solutions to the situation in Viet Nam. However, the problem is that we do not have the mechanism to integrate BESS yet, so the regulation and issues with MOIT. The Ministry of Industry and Trade is not clear enough. If many investors want to invest in BESS, there is no guideline; they do not know how to do it. If we restore BESS into the system, they do not know how much we will get paid. For example, they do not know how much we will get paid for 1 day absorbed power during the daytime in the renewable energy power plant, and in the night time when they release the power from BESS.

We need to look at the policy from the government to provide investors with the incentive mechanism for them to invest in BESS. Regarding your third question on international cooperation, we did two projects in the past, one with GE. That project studied the integration of renewable energy into the system and how BESS can help release the congestion in the grid. The second study with ADB focused more on the frequency of regulations. Both projects were finished last year.

Question by Mr Masahiro Ozawa - When will the PDP 8 be issued?

Mr Anh
Okay. So normally, it should be issued at the beginning of the year, but now it is still under discussion.

Presentation by JCOAL

Mr Quang
We come from the national load dispatch centre. I would like to ask about the technical measures you explained in the slide. We are very interested in improving the performance of thermal coal-fired power plants, so as I presented, we have a lot of renewable energy power plants in our system. That is why we want to have flexibility in operating the various systems. Currently, our thermal coal-fired power plants are not feasible enough. So, for your information, the minimum load usually is about 70%.

In the slides you presented, the minimum load can be reduced from 30% to 50%, and it can be further reduced to about 15% or 25% of the total load. So, we would like to compare the load to what we have. We would like to know how to do this because our coal-fired power plants are quite old and the technology is not very good. How can we improve the existing power plants? Is there is a solution? This is our concern about the new power plants in the future. Thank you.

Ms Yamada

All right, I think Ozawa-san will address that. But I want to clarify that part of the answers is already summarised in the slides that Ozawa-san explained. So, regarding what you say, 30% to 50%, 50% is being achieved already by emerging countries with coal-fired power plants. So that 15% to 20% refers to what we are doing in Japan, and I think in some countries. So, now, Ozawa-san would be revisiting some of the points in his slides.

Mr Masahiro Ozawa

Coal in this slide is not anthracite but bituminous. We are aware that mainly bituminous coal is used in Japan, while anthracite is dominant in Viet Nam. With anthracite coal, it is very difficult to reduce the minimum load. It would be advisable that imported coal power plants be utilised for flexible operation in Viet Nam. So, if you reduce the minimum load by coal, it will yield. I recommend you reduce the minimum load by using imported coal. This key point of wide range burner is concentration adjustment ring. This divides the primary air into the main zone and weak zone. The high concentration zone is easy to fire, so that minimum load is reduced, but this is with bituminous coal. As I said, it is very difficult to fire.

Ms Yamada

I think Ozawa-san has already addressed your questions. As we understand, all the contents of this slide will be explored and developed into a more extensive analysis and recommendation in our forthcoming report. So, questions like what you have already asked and are going to ask will be very good inputs for us to have a more extensive range of solutions in the report. So, further questions or any request for clarification would be very much appreciated. Anybody else? Or you can ask as many as you want.

In the coming study period, we plan to have another meeting with all the target countries. Three other countries will be joining us. That will be in September when we provide the draft final report. We conduct the meeting in English because the report will be in English. We also have to report to ERIA in English. In summary, we like to do some direct interactions by email.

Ms Hai

Noted. The final report will be prepared by the end of the 2021 fiscal year, right?

Ms Yamada

This report will be furnished in November 2021, so in September 2021, we will have another meeting when all the four ASEAN countries are getting together to see our draft final report. Towards that meeting, we must work hard. As for the part of Viet Nam, we might be coming up with some questions, for which your help and advice are crucial.

Ms Hai

Thanks, yes, of course. You can send emails to the international relations department, where the coordinator will distribute them to relevant participants in this programme of EVN. Then we will get back to you by email as well.

Ms Yamada

Yes, thank you very much. Before closing this meeting, let me inform you that we would like to share your presentation with the Working Group members of Indonesia, Malaysia, and the Philippines. Before the meeting, we emailed you some of the presentations. We would appreciate your cooperation. The minutes of today's meeting and the last meeting will be shared with you.

Ms Hai

Yes, agreed and thank you.

The meeting was closed.

Appendix 6: List of the 2nd Working Group Members for the ERIA Study

Country	Institution	
Indonesia	Ministry of Energy and Mineral Resources (MEMR)	Mr Pramudya, ST, MT Policy Analyst, Directorate of Electricity Program Supervision
		Mr Hery Wahyudi Wibowo, ST, MT Electricity Inspector, Directorate of Electricity Engineering and Environment
		Mr Andi Hanif, ST, M.Eng Electricity Inspector, Directorate of Electricity Engineering and Environment
	PT. PLN (Persero)	Mr Arief Sugiyanto Manager of System Planning for Java, Madura, and Bali
	PT. PLN (Persero)	Ms Ira
Malaysia	Energy Commission (ST)	Ir Mohd Helmi bin Mohd Zaihan Assistant Director
	Grid System Operator (GSO)	Ms Rose Adila binti Bujal Senior Engineer
Philippines	Department of Energy (DOE)	Ms Melanie C. Papa Senior Science Research Specialist, Power Market and Development Division – EPIMB
		Mr Noriel Christopher R. Reyes Senior Science Research Specialist, Power Planning and Development Division – EPIMB
Vietnam	Vietnam Electricity (EVN)	Mr Nguyen Minh Quang Deputy Manager of Power System Analysis and Planning Department, National Load Dispatch Centre
	Vietnam Electricity (EVN)	Mr Nguyen Tuan Anh Senior Expert of Technical and Operational Department
	Vietnam Electricity (EVN)	Ms Nguyen Minh Hai Expert of International Relations Department

Appendix 7: Minutes of the 2nd Working Group Meeting on 'The ERIA Study on Enhanced Flexibilisation of Coal-fired Power Plants for Optimal Grid Stabilisation in the ASEAN Region'

(Virtual), 22 October 2021

The meeting was opened with the welcoming remarks by Dr Phoumin, Senior Energy Economist, ERIA

Dr Phoumin

The ASEAN member states (AMS) are now preparing for the near-future energy transition, which will require more flexibility in the grid. Accordingly, the flexibility of coal power plants will be crucial. With the information provided by this study, such energy transition will be going well. At the 1st Working Group meeting, we learned the optimum flexibility. For example, one of the study highlights is how grid fluctuation occurs and how we can control it.

Since coal power has been supporting the growth of the AMS and can play a role in flexibilisation in parallel with other flexible fuels, I hope this study will fit into ASEAN's policymaking. I hope this meeting will finalise the direction and conclusion of the study. I hope the result will be very interesting for all policymakers. I wish you a worthy discussion today. Thank you so much.

The Viet Nam representative made brief remarks as it was her first time to discuss with all other country representatives.

Ms Hai

Good afternoon, ladies and gentlemen. I am from the international relations department of EVN Viet Nam. Today we also invited a representative from the technical and operational department of EVN and the national load dispatch centre to join the meeting. Thank you for the final draft of the study.

The Team presented the background of the study, the GFI method and projected grid fluctuation by GFI, key technologies for flexible operation at the coal-fired power plant, and storage technologies, for which a Q & A session was conducted.

The Philippines asked a question about the GFI forecast for Thailand.

Mr Noriel

Okay. I have a question specifically on slide number 10, point number 2, regarding which you said that Thailand does not have grid fluctuation concerns. Can you explain a little bit more about that?

Dr Murakami

Thailand is shown in purple, and that means a low GFI. In this GFI calculation, the component of GFI, I mean dependence of GFI, is coal availability and solar availability. So, regarding Thailand, coal availability. Thailand has a gas-linked generation mix. Coal availability is rather small, which makes total GFI low. So, the tentative conclusion is that no major grid fluctuation will occur.

Indonesia asked a question about the presented storage technologies.

Arief

I would like to ask some questions about slide number 23. Are these not commercially available yet?

Dr Murakami

So far, the left-hand side is in Minami Soma. There are also other sites in Nishi Sendai, which are commercially operated. This is the example of the grid connecting substation. So, regarding industrial use, many smaller sizes of lithium-ion energy storage are being operated.

Arief

Are these types of batteries already available in the market?

Dr Murakami

Yes, sodium-sulphur is widely available, mainly in industrial areas, such as the automobile industry, since their production system may not allow the intermittent supply of electricity. So that is used for that the application of an uninterrupted power supply. Redox flow is most recently re-developed; now, it is being applied widely.

Arief

I suppose each type of battery has its characteristics, for example, high energy density, mass, lots of capacity, and so on. Which one is the best in your opinion? We would like to consider this kind of battery for implementation.

Dr Murakami

That is a very good question. Lithium-ion has an advantage for energy density, but the issue is cost. So, it uses very rare metals with a relatively shorter period compared to the other two technologies. Also, currently, the cost of lithium-ion is higher than the other two types, as we observe in the market in Japan. But it may depend on which country makes this BESS. China is now mass-producing good lithium-ion batteries at relatively affordable prices. That said, in terms of duration, sodium-sulphur has an advantage. So, these are the main factors you might like to consider.

Arief

Yes, of course, we have to consider the lifetime application cost.

Dr Murakami

My personal opinion is redox flow is very easy for operating. It requires only maintaining metal ion tanks. The reaction needs room temperature under NAS batteries; redox flow ones need about 300℃ operating temperature. In the case of lithium-ion, extra care should be exercised for safety. So, my tentative conclusion is: redox flow would be more advantageous. We can expand the capacity of the other metal ion tanks.

Arief

How about the impact on the environment?

Dr Murakami

Yes, basically, there is no concern about the surrounding environment because the material is circulating inside and will not go outside. Please visit the website links shown in the slide. Thank you.

The other Indonesian representative, also from PLN, asked about the cost implications of flexibilisation.

Ms Ira

About slide number 4, I missed some information about the flexibility of the cost involvement. For example, how many percent is the flexibility to be increased?

Dr Murakami

This slide shows the modification of coal-fired plants. The first one is improving the loading rate. The second one is optimising the minimum load. The third one is reducing the start-up time. Flexibility improvement depends on the grid situation. And if grid fluctuation is mild to the extent it can be followed by flexible operation, coal-fired power plants can contribute through such kind of modification and flexible operation with rapid rolling up and rolling down, operating at minimum load. In any case, it depends on the degree and volume of fluctuation.

Ms Ira

You mentioned grid flexibility. The capacity of the cost in the power plant itself in slide number 14 only increased slightly, maybe from 3% typically to under 5%? Can it be higher than that? Is it possible to be higher than 5%?

Ms Yamada

I think further load change rate might affect the mechanical part of the facility. It is impossible to increase the load change rate exceeding 5%. It is about the load change rate and is different from the minimum loading rate.

Malaysia asked a question.

Rose

On slide number 15, I would like to ask about your experience in Japan. In changing burners, is it only one row or two rows, and how long can we go for the lower load? Let's say, in a 100 MW coal-fired power plant, if we change only one- or two-row burners, how far can the load reach? For example, the loading rate can be controlled from 100 up to 10?

Mr Ozawa

In Japan, the wide range burner is used by one or two mills, the total mill is six or four, and change of burner is for one or two mills. What they usually do at coal-fired power plants in Japan is to replace just one or two out of six mills for a wide range burner. So, you asked us if it is possible, if it's being done in Japan or not, and the normal practice is that one or two out of six mills use wide range burners. Let me give you an example of a small plant, a 33 MW plant. That plant has two mills and four burners for one mill and four burners for the other mill. So, they just replace four burners for one mill for wide range burners. Then, they can bring down that minimum load by 20%. Another example is a 250 MW plant with 4 mills and 24 burners. Two mills and eight burners out of them were changed for wide range burner utilization.

The Team started with the subchapter on Indonesia, and another Q & A session took place. A JCOAL Team member asked a question to the Indonesian representatives.

Ms Yamada

I have a question about the situation in Indonesia. I have just seen the RUPTL and the working group members' presentation. You say that this biomass coal firing at about 30 out of 52 or 53 coal-fired power plants is mainly owned by PLN. Tests were conducted, if I'm not wrong, for the biomass cofiring rate of 5%.

And then your target is 20% to 30%. That is actually a lot; you might have CFB boilers in mind, but not all of them are CFBs; some of them are PC boilers. So, what is your perspective on conducting all these things up to the implementation stage in this context? Because your NRE target in 2025 is 23%, and most of that will be achieved by cofiring biomass on those coal boilers. The graph shows that the renewables share is about 17%–

18% in 2024, and in 2025, just 1 year later, it is 23%. So, I am wondering. What are your perspectives?

Arief

Okay, Ms Yamada, as we know, with the COVID-19 pandemic, our demand is not as initially projected. Lower electricity demand and then with the objective of 23% renewable energy in 2025. So, we don't need a new one with this existing power plant because we already have a power supply capacity. We use the existing coal-fired power plant and use biomass for coal firing. Yes, for now, we have already implemented a power project of 5% portion of biomass in the global power plant. As of now, we are yet to have a coal-fired power plant that cofires biomass. However, in 2025, all of PLN's coal-fired power plants will do cofiring. That is why from 2024 to 2025, we will have a very high rate of biomass and coal cofiring power plants in Indonesia. We also increase a lot of renewable energy, including solar and wind power, not only coal firing. So, as you see, maybe we can go further.

If you see here, from 2019 to 2021, we reduced coal, and then we increased renewable energy, which is solar power. So, we can say this will replace the outgoing capacity because we have 51.6% of renewable energy. We will develop further in the next 10 years, mostly from hydro, solar, and renewable energy.

The two representatives from Malaysia presented the subchapter on Malaysia, followed by their comments.

Ir Helmi

Yes, Ms Yamada, regarding the forecast for coal usage in the future, our prime minister has already announced in our 12th national plan that there will be no more nuclear power plants in Malaysia to achieve carbon neutrality by 2050. So, that forecast will be updated later, and if it is published, I will try to share it with you.

Ms Yamada

The 12th national plan says that Malaysia will have no more coal power plants, while in the 2021–2039 peninsular plan, 2,800 MW will be replacing the retiring plants though they are all in the brownfield. How shall we understand this?

Ir Helmi

I am not sure whether the government will allow us to install a new power plant to replace the old ones or there will be no new coal power plants. But I will try to find out for you. The 12th Malaysia Plan has been published already.

Ms Yamada

All right. So, how about the renewable energy transition roadmap?

Ir Helmi

SEDA, the sustainable energy authority, has not published the latest one. But I will try to find out when they will publish it.

Ms Yamada

Thank you very much, Helmi-san.

Rose-san, we have a question about the three cycles you mentioned in our email communication. My colleagues say that this is usually two cycles, not three. But you have three cycles of load variation in a day. In our understanding, it would be normally two cycles. So why three cycles?

Ms Rose

Okay, currently, we normally experience approximately 70% reduction in coal-fired power generation during difficult hours in the early morning . The flow is slow during that time; solar generation starts to rise around 9 a.m. and reaches our morning peak at around 11 a.m. At the peak time, that is, 0.30 pm to 1.00 pm, solar power generation reaches the maximum level. That is the severest period when we need to reduce even more. During that time, our load is lower due to lunchtime typically, so you have to reduce more. Then we can start increasing the load at around 4:00 p.m.

The two representatives from the Philippines presented the Philippines' subchapter, after which they spoke.

Mr Noriel

Good afternoon to everyone, participants, and the moderator for today's meeting. As a comment from the Department of Energy, Philippines and per the provided presentation material, yes, as of now, coal power generation is a big part of our generation mix. Based on our 2020 figures, it is around 57% of our total generation. The reference material for this study is the 2018–2040 Philippines energy plan. As stated earlier, what we did with our 2018–2040 energy plan, published a few weeks ago, the Philippines targeted 85% renewable energy mix by 2030 and 50% by 2040. These are recently published numbers, and one of the limitations, I guess, which JCOAL has also experienced, is the specific number of power plant units built since these are based on the different operational categories, such as baseload, mid-variable peaking, flexible, etc.

But one of the improvements we tried to work on is to itemise those new capacities based on their actual operation or actual technologies, which you can see in the recently published plan in the Philippines. But for now, based on what was presented, we take note of the flexibilisation measures recommended based on the study.

We note that to achieve our renewable energy targets, a major part of our generation mix will mostly come from our variable renewable energy sources, such as solar and wind, and the development of hydro facilities in the country. We note that there is a need to have a more flexible operation of systems, especially gas and hydro facilities, to help us mitigate the entry of VR and the consideration of energy storage, particularly battery energy storage systems.

There are also ongoing parallel studies on battery deployment conducted in the Philippines, which include looking into how much battery capacity the Philippines can put up to assess the system and make it more flexible. So, I guess, for now, these are our initial comments, which were presented. Thank you for providing these recommendations in the report. The 2020–2040 plan is already downloadable at the DOE site.

Ms Melanie

If I may add to his comment. I just want to put a positive comment on your recommendation, specifically on tariff, except incentives or exemptions for large-scale battery storage systems. During our first meeting, I recall I said that we are conducting a study on exempting battery storage systems from transmission charges during their loading operations. So, it is good to note that it is included in your recommendation. This study, once concluded, can support our study to make that policy possible in the Philippines. Once completed, we can share it with our principals, so they can support our study.

The Viet Nam representatives presented the Viet Nam subchapter, after which they spoke.

Ms Hai

Mr Hai and Mr Kwan, who have been following the projects for EVN since the first working group meeting, cannot attend the meeting today because they have another meeting at the same time. But we have another representative, Mr Tuan. Unfortunately, his mic is muted due to some urgent things coming up.

Ms Yamada

We know it is not possible to tell us. But everybody is wondering when PDP8 will be officialised.

Ms Hai

I will update this information by email.

Ms Yamada

That's not the major question. The major thing is you and your colleague members from EVN will comment on this presentation so that Ozawa-san can reflect everything in his subchapter. I will ask Dr Phoumin to wrap up the discussions and questions of our Working Group members. Also, please give us additional comments and instructions you might like to make.

Dr Phoumin, ERIA, commented on the presentation and discussion.

Dr Phoumin

I think the discussion was basically on the report already. I looked at the report, and it is really interesting. As we know, coal can be more flexible in accommodating renewables. I think this is a big message. I also think each country study is tailored to meet the needs of a particular energy mix of the country during the energy transition. I do not see any further comments from my side. I think this is sufficient.

Finally, Dr Han Phoumin, ERIA, thanked the Working Group members and the Team, expressing his expectation to work together continuously.

Dr Phoumin

Yamada-san, Dr Murakami-san, Otaka-san, Ozawa-san, and distinguished Working group members of this study, thank you so much for supporting this study. It will be very important for ASEAN's energy transition, particularly since each country will need to look into its energy mix. And seeing the whole energy system, I think we have a robust energy supply. At the same time, as we are getting pressure to shift the energy system, we still rely on coal. So, it is not practical to phase out coal power generation too early.

We still rely on coal during the energy transition and make the whole energy system more robust to respond to the increase in renewables, particularly solar. The study has highlighted the backup capacities from various build-ups – from hydro, battery storage, or hydrogen. We can say this is what we are looking for: to optimise energy and see how coal can play a critical role during the energy transition.

I would like to appreciate the contribution of these important members. Let me once again thank you all, and I hope to see you sometime. After this, the JCOAL team will properly finalise the report and submit it to ERIA.

We look forward to receiving the final report. Thank you.