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Study on the Applicability of Comprehensive and Optimal Carbon-neutral Solutions in ASEAN in Energy Transition

Edited by

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List of Abbreviations and Acronyms

AEDP	Alternative Energy Development Plan
AMS	ASEAN Member States
ASEAN	Association of Southeast Asian Nations
BCG	Bio-Circular-Green economy
BESS	battery energy storage system
BOI	Board of Investment
CCS	carbon capture and storage
CCUS	carbon capture, usage, and storage
CCPP	combined cycle power plant
CFPP	coal-fired power plant
CIPP	JETP Comprehensive Investment and Policy Plan
CO2	carbon dioxide
COP	Conference of the Parties
DEDE	Department of Alternative Energy Development and Efficiency, Ministry of Energy of Thailand
DMF	Department of Mineral Fuels, Ministry of Energy of Thailand
ENCON	Energy Conservation Promotion Fund of the Thailand's Ministry of Energy
ERIA	Economic Research Institute for ASEAN and East Asia
EUR	euro
EV	electric vehicle
EVN	Vietnam Electricity
FGD	flue gas desulphurisation system
FS	feasibility study
FiT	feed-in tariff
FT	Fischer-Tropsch
GDP	gross domestic product

GEF	Global Environment Facility
GHG	greenhouse gas
GW	gigawatt
GW·s	gigawatt second
Hz	hertz
H_2	hydrogen
IRR	internal rate of return
JETP	Just Energy Transition Partnership for Indonesia
JETRO	The Japan External Trade Organization
N_2	nitrogen
RoCoF	rate of change of frequency
MHI	Mitsubishi Heavy Industries, Ltd.
MW	megawatt
MEMR	Ministry of Energy and Mineral Resources of Indonesia
OCCTO	Organization for Cross-regional Coordination of Transmission Operators of Japan
PLN	PT Perusahaan Listrik Negara (Persero) State Electricity Company of Indonesia
RUKN	Rencana Umum Ketenagalistrikan Nasional National Electricity Master Plan of Indonesia
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik National Power Development Plan of Indonesia
t/d	tonne per day
THB	Thai baht
UFLS	underfrequency load shedding
UNIDO	United Nations Industrial Development Organization
VRE	variable renewable energy
WG	working group

Chapter 1
Background, Objectives, and Methodology of the Study

1. Background

The Association of Southeast Asian Nations (ASEAN) is one of the world's growth centres as the theme of 2023 ASEAN chairmanship of Indonesia 'ASEAN Matters: Epicentrum of Growth' indicates.

Looking back at 2021 when a series of global events were held in pursuit of urgent and well-coordinated actions against climate change, ASEAN Member States (AMS) also spontaneously tried to go along with its global partners. Taking the opportunity of the Conference of the Parties (COP) 26 or even before the conference, many AMS set carbon neutrality targets, while trying to decouple growth and emissions reduction.

Accordingly, the AMS have been intensifying their respective efforts in identifying the right and suitable decarbonisation technology and methods.

In the preceding study on 'Applicability of CCT for Comprehensive and Optimal Carbon-neutral Solution in ASEAN' conducted in November 2021–November 2022, technology to reduce carbon dioxide (CO2) emissions at the combustion stage such as biomass and ammonia cofiring, and CO2 removal/recovery/utilisation from post-combustion exhaust gas by the technologies such as carbon capture and storage (CCS) and carbon capture, usage, and storage (CCUS)/carbon recycling were studied, in pursuit of the possibility of introducing the optimum combination of technologies and comprehensive decarbonisation solutions that suit the regional circumstances in the ASEAN region.

The previous study had the following four AMS as different types of coal users:

1) Indonesia as the largest coal exporter of ASEAN and a heavy coal user

2) Malaysia as a coal importer and a coal user

3) Thailand as a local coal user and less dependent on coal but dependent on gas

4) Viet Nam as a local coal user, heavy coal user, and coal importer from Indonesia.

With their dependence on coal, energy transition measures and actions are deemed more crucial to their forthcoming energy policy and related initiatives leading to project implementation.

The previous study confirmed all four AMS had already launched various policy and policy programs, and consolidated available technology options. In addition to recommendations on the combination of technologies and the policy framework suitable to each country's situation, relevant issues, and problems to be addressed were sorted out and envisaged measures were indicated in the study.

Below summarises each country's situation around energy transition as of January–February 2023, when the Study Team discussed with the Economic Research Institute for ASEAN and East (ERIA) the selection of two target countries:

- Indonesia is expecting a massive introduction of variable renewable energy (VRE). As an archipelagic country, it has a varied scale of power grids from large to mini and micro, hence, balancing and flexibilisation for grid stabilisation are to be well managed. The government and the PT Perusahaan Listrik Negara (Persero) or the State Electricity Company of Indonesia (PLN) are trying to address possible grid fluctuation issues through inter-regional grid connection. However, interconnecting regional systems will take years and decades while VRE introduction will progress earlier and faster as the government and the power sector intensify their efforts. A preliminary study on how to ensure grid stability even during energy transition would provide key information not only to Indonesia but also to other AMS in planning balancing and flexibilisation measures required in energy transition.

- Malaysia is advanced in terms of policy formulation. Studies and projects are progressing in ammonia and biomass cofiring as well as CCS. The country is a potential role model in initiating energy transition.

- Emerging as a rising star in photovoltaic/solar and wind power development, Viet Nam just renewed its power development plan into a greener PDP8, through which the government is trying hard to tune up the existing power development plan and the new trend of surging renewables.

- '4D+E" is the principal component of Thailand's national energy policy, of which decarbonisation is a main pillar. Biomass utilisation is being highlighted as meaningful to the economic and social development in the context of bolstering utilisation of domestic biomass resources, given a large supply potential in the country. Currently, conventional utilisation technologies, such as dedicated biomass power generation, biogas, and biofuel from edible crops, have been well developed. Expanding the option of biomass utilisation technology is essential to maximise the value of domestic biomass resources.

In this regard, combining biomass gasification and fuel conversion was chosen as a sub-study topic. The outcome of the preliminary study would be an excellent reference to other AMS with a high potential of agricultural biomass utilisation that overarches the agricultural, industrial, and energy sectors.

2. Objectives

The study aims to identify two cases of technology application and measures to be taken as part of energy transition, based on the previous study outcomes.

While the two sub-studies will be each conducted for one country selected from the four AMS that participated in the previous study, the results and associated recommendations are intended to be utilised by other AMS as well. The study team will make utmost efforts in furnishing recommendations that all other AMS can consider.

3. Study process

1) Identification of two sub-studies technologies and measures with one target country, each selected from the four target AMS in the previous study.
2) Two sub-teams of JCOAL will conduct respective sub-studies in close collaboration with all working group members who will provide advice and information to the extent possible for the sub-teams to furnish better results of sub-studies.
3) Based on the outcomes of the sub-studies, the JCOAL Study Team will provide policy recommendations conducive to the energy transition efforts by ASEAN and respective AMS, apart from the individual recommendations to the two target countries.

4. Methodology

(1) Literature/desk study

The JCOAL Study Team conducts study activities, both for the sub-studies and the entire study, mainly through literature/desk study.

In addition, the study team and the two sub-teams individually communicate with the working group members for advice and information to ensure accuracy of the information the team uses for their analytical work.

(2) Working Group activities

A working group with representatives from the four AMS is to be organised to provide advice occasionally and at the two-time working group meetings. Based on the data and information provided by the members and the team, all participants will discuss the direction for further study by the team.

5. Identification of the Two Sub-studies

The JCOAL Study Team identified the following two sub-studies based on the previous study findings mentioned in section 1:

1) Grid stabilisation measures and technology from non-grid system end

2) Biomass utilisation by gasification and fuel conversion process

The following two chapters will clarify the concept, process, and outcomes of each sub-study.

Chapter 2
Indonesia

1. Energy, Climate Change, and Power Sector Overview

Indonesia, the world fourth largest in population, the largest in population in ASEAN, and the largest economy in ASEAN with the fifth largest per capita gross domestic product (GDP), is aiming to become a developed country and rank amongst the world's top-five largest economies by 2045.

GDP growth is forecast to be over 5% until 2027 and even thereafter will be steady at around 4%. Indonesia may attain top-10 economy status in the next decade and may reach the top 5 by 2040 from its current position of 14th.

Having been once one of the strongest leaders of the Organization of the Petroleum Exporting Countries (OPEC) up to the mid-2000s, Indonesia embarked on its 'de-oil fuel policy' in 2004 when the country became a net oil importer. Then in 2005, the country experienced a fuel and power crisis affected by the international fuel crisis.

In 2009, Indonesia surprised the world by its first and ambitious commitment for emissions reduction in Pittsburg Group of 20 by then-President Yudhoyono, 26% on its own and 41% with international support against a business-as-usual scenario by 2020.

During the same period, the power sector had been struggling to boost the long-stagnating national electrification rate for decades. The country saw outstanding growth of electrification rate according to the powerful economic growth between 1991 (48.9%) and 2001 (86.3%), followed by the next decade (2001–2011) that recorded an 8.5% growth to reach 94.8%. The government had been trying to address 'the last few miles' of yet-to-be electrified areas in villages in remote areas for years. As of 2021, the national electrification rate remains at 99.2%[1].

In May 2021, Indonesia made a net-zero commitment in 2060. In the same month, the government announced its first commitment of coal phaseout by 2056, which later became one of the main areas to be supported by the Energy Transition Mechanism and other international framework, such as the Just Energy Transition Partnership (JETP).

According to the initial coal phaseout program, in 2025, 1.1 GW of unabated coal and gas will be retired as initial actions under the program. By 2030, 1 GW subcritical coal retirement (first stage) was being planned. Finally, 2055 will see the remaining 5 GW

[1] All electrification rates were sourced from The World Bank (2023).

of the last ultra super critical retired. The 'Green RUPTL'[2], that is RUPTL 2021–2030, partially supports the coal phaseout national plan. Through RUPTL 2021–2030, also called the 'Green RUPTL', PLN focus on decarbonising fossil fuel–based power generation and developing renewable energy sources. Some notable actions include the cancellation of 13.3 GW of new coal-fired power plants previously planned in the 2019–2028 RUPTL, and of 1.3 GW of coal-fired power plants in the pipeline as well as the replacement of 1.1 GW of steam-fired power plants for renewable energy. Further, the next RUPTL is to incorporate what Presidential Regulation No. 112 of 2022, regarding Acceleration of the Development of Renewable Energy for the Supply of Electrical Power (PR 112/2022), stipulates. The forthcoming RUKN (*Rencana Umum Ketenagalistrikan Nasional* or the National Electricity Master Plan of Indonesia) that will be formalised earlier than the next RUPTL will also endorse such move by the RUPTL.

In November 2023, the JETP Working Group announced the JETP Comprehensive Investment and Policy Plan (CIPP). To date, it remains as a public consultation draft. The overview of the updated coal phaseout plan and the related expert views indicated in the CIPP suggest that the initially set and agreed coal phaseout plan may be modified to be more grounded in reality. The start of the actual coal phaseout will be delayed with the first target period from 2025 to 2035, while the phaseout target year is made earlier from 2055 to 2045. The CIPP also emphasises that Indonesia's coal phaseout plan will be implementable only if related laws and regulations to address the legal and regulatory issues around the retirement of 'young' coal-fired power plants (CFPPs) and the financial arrangement for early retirement are in place.

In the meantime, the CIPP reconfirms the country remains determined to add renewables on a massive scale and to phase down coal in parallel towards 2060.

2. Background

The previous subchapter showed that Indonesia will proceed to a coal phasedown and phaseout in the power sector and is planning to have over a 60% renewable share in the national electricity mix (on installed capacity basis). However, VRE solar and wind are clean but variable. Biomass is an immense help in accelerating clean transition but is small in terms of scale to fulfil the surging demand. Geothermal is anticipated to provide sufficient and invariable generation capacity but is yet to be smoothly developed. Ammonia and hydrogen are still midway towards future application and deployment as value chains are well established involving local industries. The 'all-with-gas solution' is not realistic given the scale of energy, electricity demand, related infrastructure availability, and the fact that gas is also transitional.

[2] RUPTL = *Rencana Usaha Penyediaan Tenaga Listrik* or the National Power Development Plan of Indonesia

In summary, coal will stay in the power generation mix of Indonesia for the near future and up to the latter part of its energy transition towards carbon neutrality or net zero. As the JETP CIPP mentioned while trying to face the issue of the positioning of CFPPs head-on for the first time in the last few years, CFPPs, if operated appropriately, can be a balancing source without a major impact on efficiency (ERIA and JCOAL, 2022). Indonesia can continue using the existing CFPPs for power supply and supporting grid system stabilisation. Flexibilisation can be ensured primarily through power plants that can perform as balancing sources, such as pumped storage, gas, and coal. Battery energy storage systems (BESSs) and synchronous phase modifiers will also help.

Another idea that deserves attention is on-grid and off-grid power generation choices to ensure the resilience of the power supply and grid system. Accelerating grid stabilisation requires urgency. Capacity addition for fulfilling the last miles of hard-to-electrify remote areas is also urgent. However, a grid connection is not necessary in some cases. Electrification plans with off-grid choices are worth considering, especially in remote island areas.

As shown, ensuring grid stability measures during the energy transition has become one of the most important issues in the power sector, regardless of the country. A sudden loss of input to the grid will cause the frequency to drop. Large rotating generators with inertial force in the system can prevent it and maintain the frequency at a constant level.

For this reason, there is a growing focus on inertia-specific supply, the role of suitable synchronous regulators, and the inertia power procurement market. This need for phase regulating has led to very high expectations for pumped hydropower generation.

In Indonesia, various studies for energy transition have been sped up to achieve carbon neutrality by 2060. However, there is a room for consideration for further actions concerning grid stabilisation, such as how to deal with generated solar power that is expected to see a sharp increase throughout energy transition.

In addition to the flexible operation of CFPPs, which will continue to operate for a few decades, it will be necessary to develop multifaceted initiatives, such as strengthening the phase-regulating function and forming an inertial power market.

The sub-study has tried to identify a simple method of grid system stability assessment focusing on frequency management and measures to be taken, technology choices, and a draft roadmap with recommendations, which we hope altogether will be conducive to policy formulation and planning for grid stabilisation in ASEAN and the AMS as well as in Indonesia.

【Study items】

- Main issues and potential problems around grid stabilisation, with focus on possible frequency fluctuation caused by massive VRE introduction
- Proposed method of grid system stability assessment
- Proposed technology measures and optimal combination of measures to address inertia deficits
- Draft roadmap of frequency stabilisation

3. Overview of the Issues about System Stability Arising from VRE Introduction

3.1. Trends in Power Supply Capacity in Indonesia

Figure 0.1 shows the net-zero emission scenario of the Indonesian power sector towards 2060.

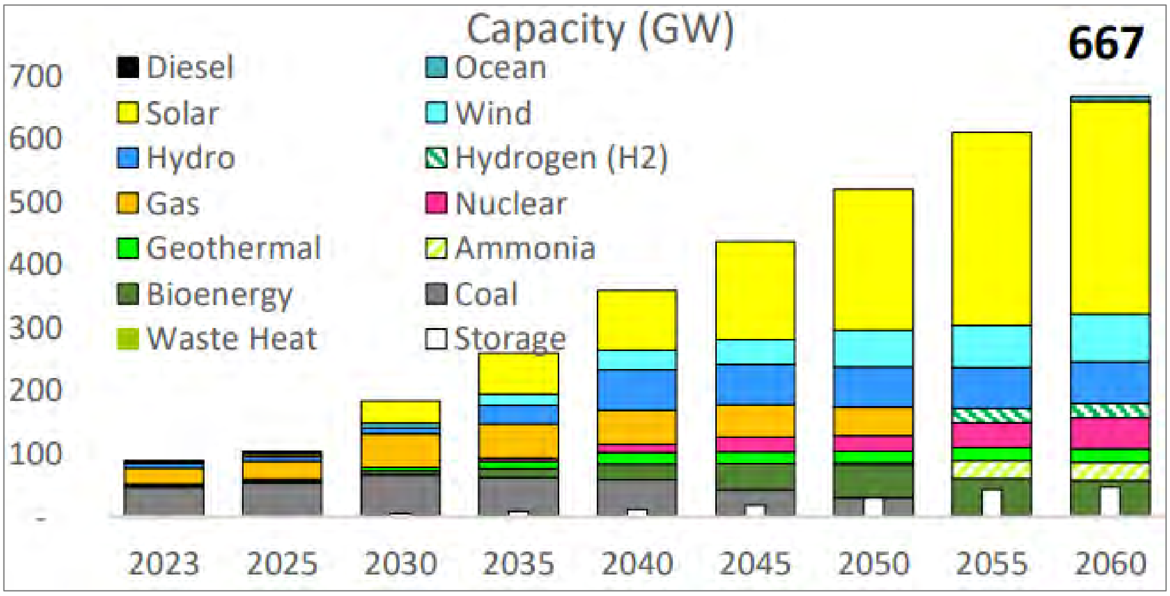
For the period 2021–2030, RUPTL 2021–2030 is applied. For 2031–2060 of the plan, the following conditions stated in Presidential Regulation No. 112 of 2022 and relevant documents are being considered:

- CFPP/combined cycle power plant (CCPP): No new CFPPs are planned, except those which are in the construction phase or have been financially committed. The existing CFPPs and CCPPs will be retired when they reach the end of residual life and/or their PPA expires. Less than 1 GW each of CFPPs and CCPPs will remain in operation in 2052 and 2050, respectively.
- New and renewable energy: Additional generation capacity after 2030 sources are only from NRE. It will be dominated by VRE, such as solar power, starting in 2035 and later by wind and ocean power plants.
- Geothermal: Maximised up to 88% of total potency
- Hydropower: Maximised, and the produced electricity is dispatched to load centres on other islands; hydropower functions as balancing sources to address possible fluctuation caused by VRE.
- Storage: Pumped storage, BESS, and hydrogen fuel cells will be massively utilised after 2035. From 2031 onwards, hydrogen utilisation will be gradually increased,

and 2051 will see massive utilisation of hydrogen.

- Nuclear power plants: to maintain system reliability, nuclear power plants will be introduced and operate around 2045. The total installed capacity of nuclear power in 2060 will reach 50 GW.

Figure 0.1. Power Plant Capacity and Electricity Production by 2060



Source: MEMR (2023).

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, these VRE plants must be balanced with hydropower as the base load power source.

As of 2060, total installed VRE capacity is to account for 421 GW (63%) out of the overall national installed capacity of 667 GW.

In view of the possible impact of the massive introduction of VRE, how to ensure grid stability during energy transition has become one of the most crucial issues in Indonesia's power sector.

3.2.4 3.2. Main issues and potential problems caused by massive VRE introduction and measures to be taken

Table 0.1 lists two major potential issues that massive introduction of renewable energy may cause to grid systems and standard measures to be taken, that is, power supply and demand imbalances and frequency fluctuations.

It is observed that in ASEAN, Cases 1, 2, and 3 have already been incorporated into the respective national power development plan and measures are being taken or are going to be taken. The sub-study accordingly was to focus on Case 4 as study subject.

Table 0.1. Main Issues and Troubles by Mass Introduction of VRE and Typical Measures

Issues	Troubles	Measures to be Taken
Supply and Demand Imbalances	CASE 1: VRE outputs decrease due to the weather conditions, etc. → Power supply deficit	- Securing of backup sources, e.g. thermal, hydro, electricity storage、thermal storage - Formulation of market such as capacity market, etc.
	CASE 2: VRE outputs surpass the demand → Power supply surplus	- Lowering of the minimum load at thermal power plants - Installation of electricity and thermal storage - Curtailment of VRE outputs - Surplus power utilisation for hydrogen production, etc.
Frequency Destabilisation	CASE 3: VRE outputs fluctuation causes frequency fluctuations under normal conditions → electricity quality is deteriorated, which affects consumers in both industries and communities.	Technical/technology improvement of frequency control
	CASE 4: Frequency sagging due to accidents at a large-scale power plant or grid, which may lead to exceed the maximum norm of RoCoF and/or maximum frequency deviation, then to chain of blackouts, which, in the worst case, causes massive blackouts affecting a broad range of consumers.	- Installation of equipment providing inertia installation. e.g., flywheel, thermal power, PSH, etc. - Inertia market formulation

RoCoF = rate of change of frequency
Source: JCOAL Study Team.

3.3. How Grid Frequency Fluctuation Progresses during an Accident

Figure 0.2 shows a schematic diagram of grid frequency fluctuations incurred by an accident. The horizontal axis indicates the elapsed time from the occurrence of the accident, and the vertical axis shows the frequency.

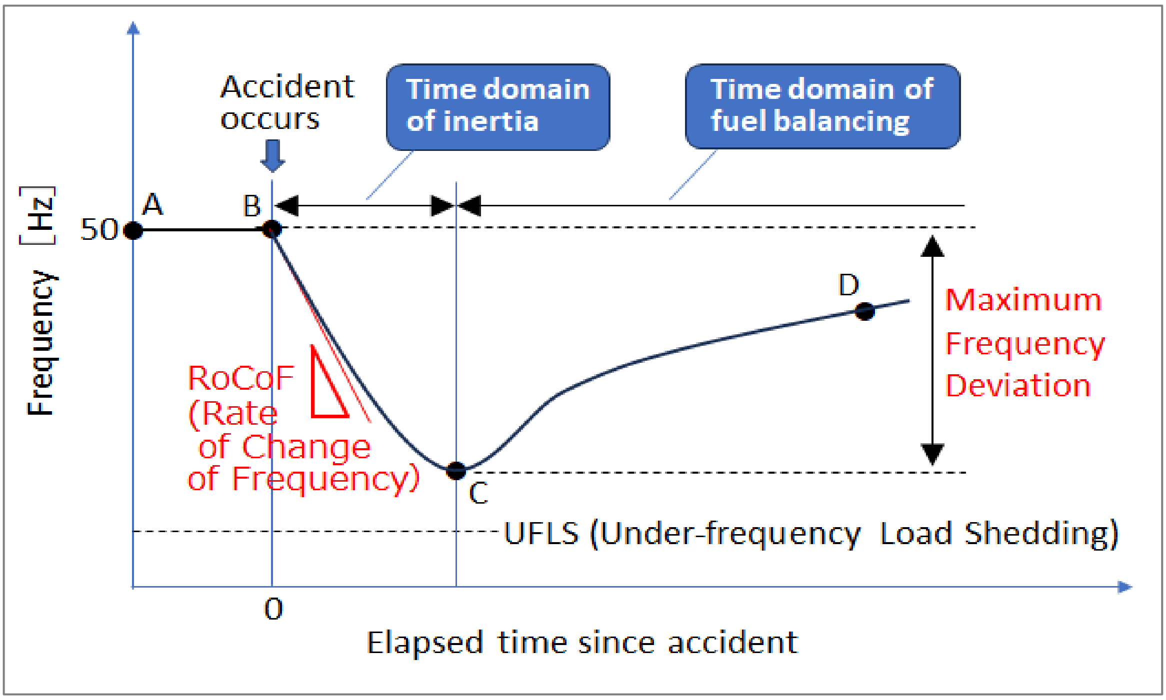
An accident occurs at point B, then the frequency drops sharply to point C. The frequency gradually recovers as balancing sources, such as thermal and hydro outputs, increase. To prevent blackouts, the two values indicated below must satisfy each criterion.

The first value is the rate of change of frequency (RoCoF. If the value of RoCoF exceeds the value of criterion, a dropout of inverter supply will occur.

The second is Maximum Frequency Deviation. If this value exceeds the value of criterion and point C reaches under-frequency load shedding (UFLS), dropouts of synchronous sources will occur.

The value of the frequency between points B and C is crucial, and the inertial force can help control the frequency in that time domain.

Figure 0.2. Schematic Diagram of Grid Frequency Fluctuation during an Accident



Source: JCOAL Study Team.

When frequency changes due to accidents, a force that tries to change the rotation speed acts on turbine-generators of synchronous sources. However, a turbine-generator rotor is very heavy and has a large inertial force, so it suppresses the change in the rotation speed. As such, when VRE increases and the proportion of synchronous sources decreases, RoCoF and Maximum Frequency Deviation increase and the dropping rate in frequency rises, further increasing the possibility of blackouts.

4. Proposed Method of Assessing Grid System Stability

Some softwares are available to assess grid stability and know about the future possibility of grid fluctuation. However, it would be beneficial for governments and policymakers to make a preliminary assessment so that they can well plan what and when measures are to be taken to enhance grid stability that is crucial to a smooth and successful energy transition.

In this sub-study, the team utilised the following grid system stability assessment method that is free and available to everybody.

STEP 1: Simple analysis (conducted in this study)

Estimation of grid system stability in terms of RoCoF and inertial forces and then plan measures for insufficient inertial forces.

STEP 2: Detailed analysis (to be conducted in the next study)

Estimation of grid system stability in terms of RoCoF and Maximum

Frequency Deviation by system simulations.

As mentioned, the above process is taken just as the first-hand assessment. Detailed assessment should be done separately as required.

STEP 1 uses criteria obtained from the simulation results of Japan's system, so it is positioned as a preliminary study for determining the policy for STEP 2. Therefore, to make a final decision, STEP 2 should be implemented based on the Indonesian system simulation.

STEP 1 of grid system stability assessment as follows:

STEP 1-1: Calculation of indicator α of the evaluation target

α = Msys/total installed capacity

Msys: the amount of power that can be generated by the total inertia force

[GW·s]

STEP 1-2: Determination of criterion α_{cr}

α_{cr} = $Msys_{cr}$/total installed capacity

$Msys_{cr}$: the value of Msys when RoCoF immediately after accidents (e.g. large power supply source trouble is 2 hertz (Hz)/s. It is derived through system simulation.

STEP 1-3: Grid system stability assessment by comparing indicator α and criterion α_{cr}

$\alpha \geqq \alpha_{cr}$: Sufficient inertia power, and so no issue about grid stability

$\alpha < \alpha_{cr}$: Insufficient inertia power, and so issues will arise around grid stability

In case of Msys value exceeding the threshold, a further drop of RoCoF by inverter supply dropout will occur to the point where synchronous sources get decoupled, which may lead to massive blackouts (OCCTO, 2023).

This study evaluated each system for the following reasons:

- Priorities and costs should be determined to consider plans for countermeasures against inertial force shortages. For this purpose, the degree of inertial force deficiency and the amount of inertial force deficiency in each system are required.
- When connecting various systems in Indonesia to the grid, DC power transmission is selected because the power transmission distance is long. However, current technology does not allow sharing of inertia between the connected systems. In that case, it is necessary to install equipment that supplies inertial force to each system, and the inertial force satisfaction of each system is required.

4.1. Calculation of Indicator α of the Evaluation Target

The proposed indicator α can be derived as follows:

α = Msys/total installed capacity

Msys: the amount of power that can be generated by the total inertia force [GW·s]

Msys of each synchronous source is calculated by the following equation.

Msys = installed capacity × energy availability factor × per-unit inertia constant

The per-unit inertia constant is time to generate rated output power due to inertia force.

Where

Installed capacity: Use the values in Figure 0.3

Energy availability factor (excluding nuclear):

Calculated from installed capacity and generation capacity in 2050 in the Baseline Scenario of AEO 7 (ACE, 2022)

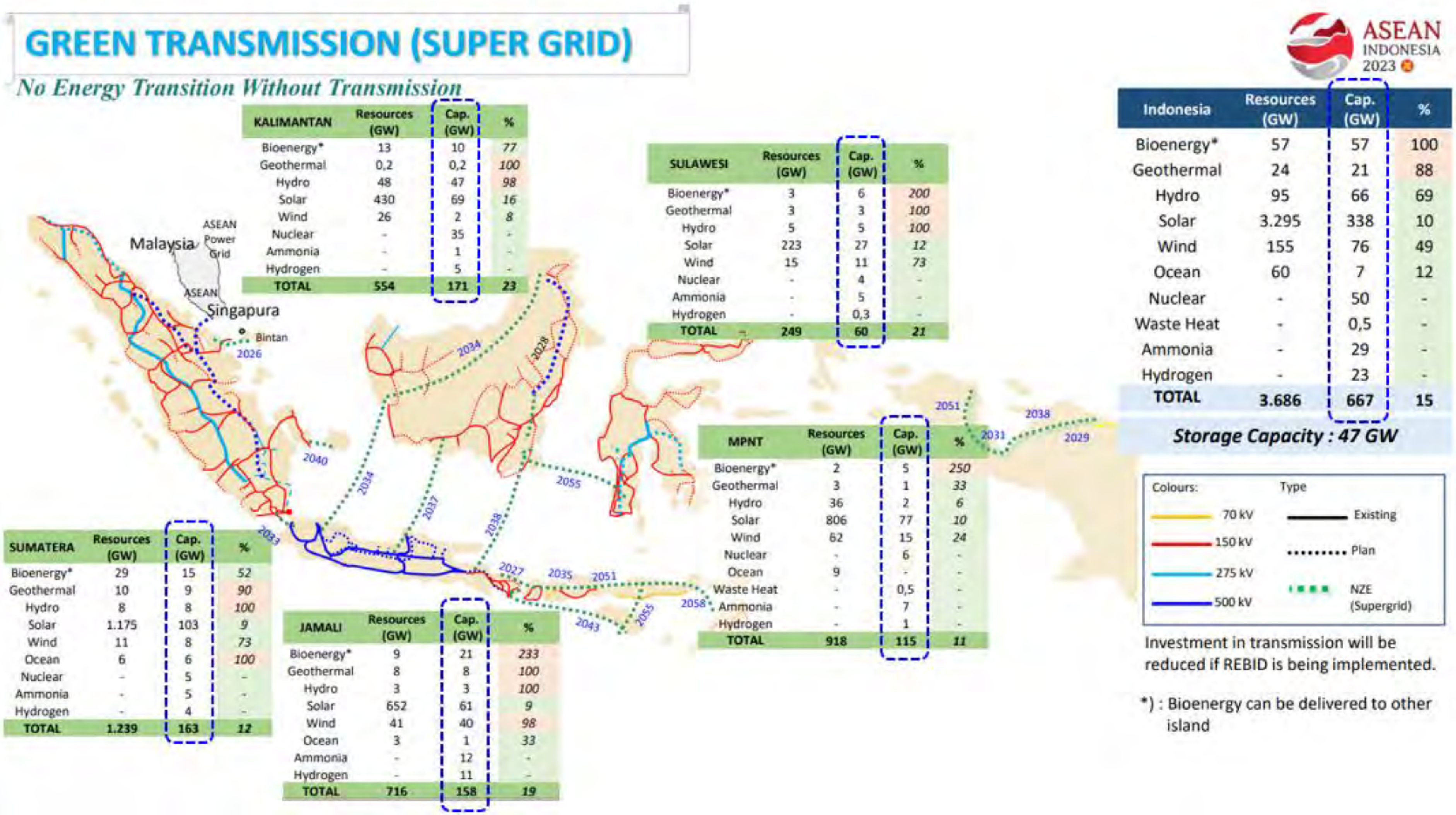
Energy availability factor (nuclear):

Average value from 2006 to 2010 of nuclear plant in Japan (Japan Atomic Industrial Forum, Inc., 2023)

Per-unit inertia constant: use the following values (OCCTO (2021a)

Thermal (ammonia, bioenergy, hydrogen), nuclear, and geothermal: 4s
hydro: 5s

Figure 0.3. Installed Capacity Used to Calculate α



KALIMANTAN	Resources (GW)	Cap. (GW)	%
Bioenergy*	13	10	77
Geothermal	0,2	0,2	100
Hydro	48	47	98
Solar	430	69	16
Wind	26	2	8
Nuclear	-	35	-
Ammonia	-	1	-
Hydrogen	-	5	-
TOTAL	554	171	23

SULAWESI	Resources (GW)	Cap. (GW)	%
Bioenergy*	3	6	200
Geothermal	3	3	100
Hydro	5	5	100
Solar	223	27	12
Wind	15	11	73
Nuclear	-	4	-
Ammonia	-	5	-
Hydrogen	-	0,3	-
TOTAL	249	60	21

Indonesia	Resources (GW)	Cap. (GW)	%
Bioenergy*	57	57	100
Geothermal	24	21	88
Hydro	95	66	69
Solar	3.295	338	10
Wind	155	76	49
Ocean	60	7	12
Nuclear	-	50	-
Waste Heat	-	0,5	-
Ammonia	-	29	-
Hydrogen	-	23	-
TOTAL	3.686	667	15

MPNT	Resources (GW)	Cap. (GW)	%
Bioenergy*	2	5	250
Geothermal	3	1	33
Hydro	36	2	6
Solar	806	77	10
Wind	62	15	24
Nuclear	-	6	-
Ocean	9	-	-
Waste Heat	-	0,5	-
Ammonia	-	7	-
Hydrogen	-	1	-
TOTAL	918	115	11

SUMATERA	Resources (GW)	Cap. (GW)	%
Bioenergy*	29	15	52
Geothermal	10	9	90
Hydro	8	8	100
Solar	1.175	103	9
Wind	11	8	73
Ocean	6	6	100
Nuclear	-	5	-
Ammonia	-	5	-
Hydrogen	-	4	-
TOTAL	1.239	163	12

JAMALI	Resources (GW)	Cap. (GW)	%
Bioenergy*	9	21	233
Geothermal	8	8	100
Hydro	3	3	100
Solar	652	61	9
Wind	41	40	98
Ocean	3	1	33
Ammonia	-	12	-
Hydrogen	-	11	-
TOTAL	716	158	19

Source: MEMR (2023).

4.2. Determination of Criterion α_{cr}

Due to resource constraints and for the sub-study team to conduct an analysis of Indonesia without relevant parameters, the analytical work was done with an assumption that the power systems in Indonesia was as reliable as those of Japan.

The proposed criterion α_{cr} can be derived as follows:

α_{cr} = $Msys_{cr}$/ total installed capacity

$Msys_{cr}$: the value of Msys when RoCoF immediately after accidents is 2Hz/s*. It is derived through system simulation.

In this study, $Msys_{cr}$ is the sum of $Msys_{cr}$ values of the three areas in Japan shown below (OCCTO, 2021a).

- 60 Hz band areas in Japan (except Okinawa Pref): 283 GW·s
- 50 Hz band areas in Japan (except Hokkaido Pref): 169 GW·s
- Hokkaido: 21 GW·s
- The total installed capacity is the sum of values of the three areas in Japan shown below (OCCTO, 2023).
- 60 Hz band areas in Japan (except Okinawa Pref): 311 GW
- 50 Hz band areas in Japan (except Hokkaido Pref):233 GW
- Hokkaido: 39 GW

This study used the following values obtained from the above Japan data.

A_{cr} = 0.81

It will be possible to apply the results of the Indonesian system's simulation once the same is conducted.

In addition, in the US state of Texas, Msys is used as an evaluation index of system stability. The value of Msys in Texas is ensured so that the time required to lower the frequency from 59.7Hz to 59.3Hz (at the start of UFLS) in the event of accidents is shorter than the UFLS operation time (OCCTO, 2021b).

Although the value of $Msys_{cr}$ in Texas state was not calculated based on RoCoF, the calculation results of α_{cr} are shown below for reference. The $Msys_{cr}$ used in Texas state and the total installed capacity of Texas state are as follows.

$Msys_{cr}$: 100 GW·s

Total installed capacity: 89 GW

Therefore, α_{cr} calculated from the above Texas state data is as follows.

A_{cr} = 1.12

5. Results of Assessing Grid System Stability

3.2.4 5.1. Grid System Stability Assessment Results

Figure 0.4 shows the by-system assessment based on the calculation results of **α**.

The level of criterion α_{cr}, which is the dividing point of sufficient and insufficient inertia, is shown by the blue line. Please note that the value of **α** for the whole Indonesia, shown at the most left, is for reference only, as it is on the assumption that the five systems are connected as one system.

Whole Indonesia:

- Sufficient inertia power, and so no issue about grid stability
- This is due to the large value of **α** in Kalimantan.

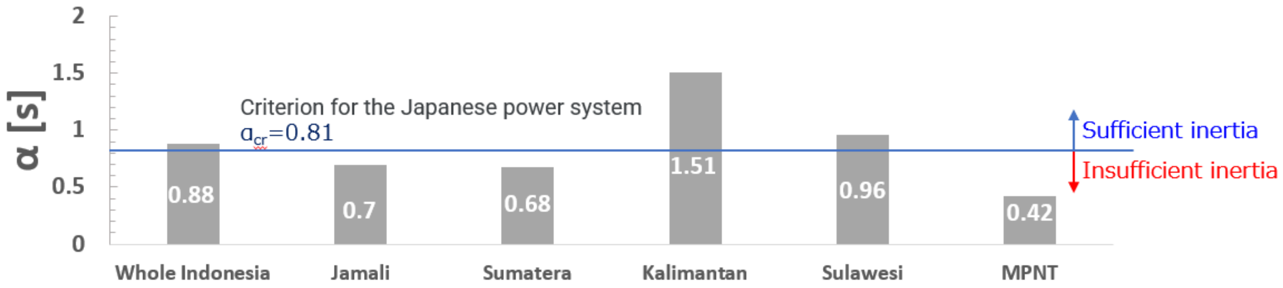
Kalimantan, Sulawesi:

- Sufficient inertia power, and so no issue about grid stability
- Kalimantan has a large amount of nuclear power and hydropower, so the value of **α** is large.

Jamali, Sumatera, Moluccas, Papua, and the Nusa Tenggara:

- Insufficient inertia power, and so issues will arise around grid stability
- Measures are needed to increase inertia.

Figure 0.4. The By-system Assessment Based on the Calculation Results of **α**



Source: JCOAL Study Team.

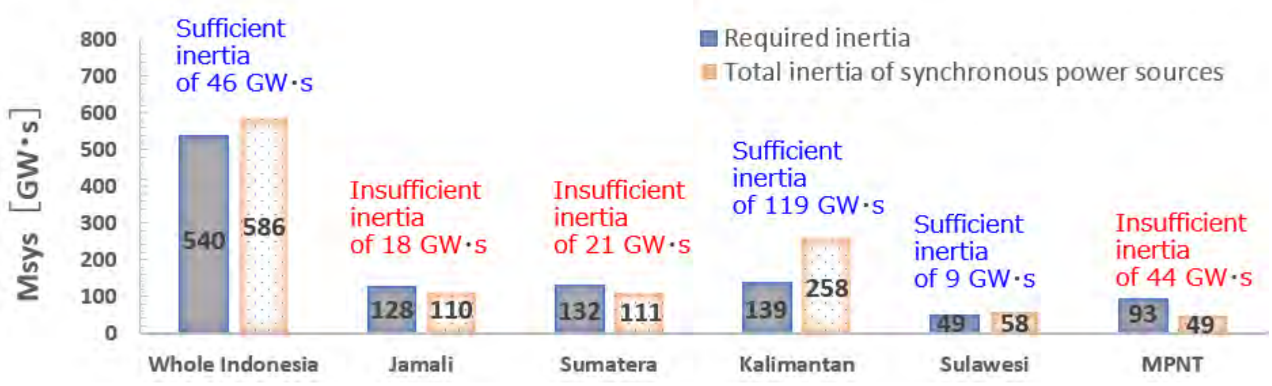
5.2. Calculation Results of Inertia Forces and Measures to Satisfy Required Inertia Force

Figure 0.5 shows the estimated Msys of each system. For each regional system, the grey bar graph on the left shows the required Msys, and the polka-dotted one on the right shows the total Msys of synchronous power sources.

The surplus in the Kalimantan system is 118 GW·s. On the other hand, the total deficits of the other three systems will reach 83 GW·s. Kalimantan's surplus exceeds the deficit in the three systems.

Installation of inertia supply equipment to systems lacking inertia will be required to be considered, planned, and implemented once the future deficits are confirmed.

Figure 0.5. The Estimated Msys of Each System



Source: JCOAL Study Team.

Figure 0.6 shows the result of calculating the effect of the increase in Msys in each sub-area in the 60 Hz area of Japan on the decrease in RoCoF when large power supply source troubles occur in the Kyushu sub-area.

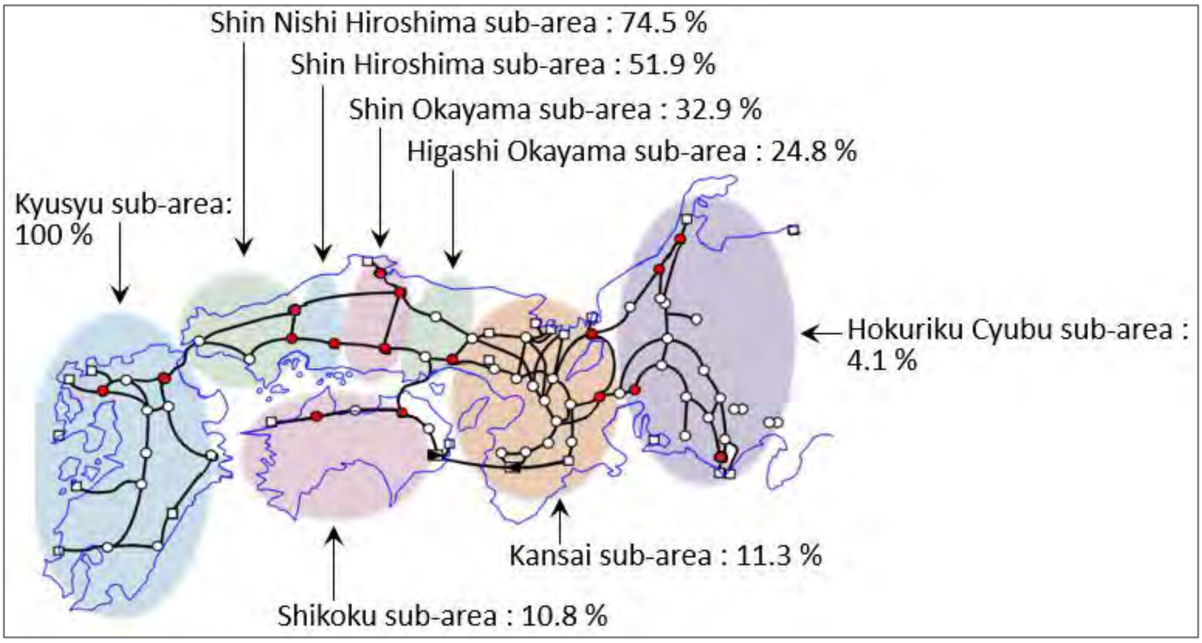
The values of each sub-area in Figure 0.6 were obtained using the following procedure.

- Calculating the amount of increase in Msys for each sub-area that will equal the amount of decrease in RoCoF when the Kyushu sub-area loses power.
- Calculating the ratio of the increase in Msys for the Kyushu sub-area to the calculated increase in Msys for each sub-area.
- The same graph indicates that the greater the distance between two sub-areas, the lesser the effect of reducing the RoCoF of one sub-area due to an increase in Msys in the other one, which may result in insufficient solution to the occurring

problem. For example, the effect of decreasing the RoCoF of the Kyushu sub-area due to an increase in Msys in the Kansai sub-area that is 400 km away is thought to be lessened to 11.3% compared to when the same amount of Msys was additionally provided to the Kyushu sub-area upon having troubles.

In summary, it would be advisable to consider the effect possibly caused by the distance between the expected accident location and the installation location of the inertia supply equipment on the expected effect of RoCoF reduction.

Figure 0.6. The Result of Calculating the Effect of the Increase in Msys in Each Sub-area in the 60 Hz Area of Japan on the Decrease in RoCoF during Large Power Supply Source Troubles: The Case of Kyushu Sub-area



Source: OCCTO (2022).

6. Measures to satisfy the required level of inertia

This study tried to identify all available measures of inertial force supply crucial to address the inertial deficit.

Table 0.2 lists the three options that are commercially available and the other two that are currently in-development status and expected for utilisation in the near future.

Table 0.2. Measures to Address the Requirements for Inertia Forces

Measures	Overview	Maximum Capacity of Inertia Force to be Supplied [GW･s]	Per-unit Inertia Constant [s]	Installation Cost [Million $ /GW･s]
Synchronous Condenser	- Installation of synchronous condenser, start-up motor, flywheel installation ✓ To supply output that addresses required inertia force	TBI	8	12.5
Synchronous Condenser (By conversion from synchronous generator)	- Remove steam turbine of the existing thermal power unit that is to be shut down - Additional installation of start-up motor and flywheels - Reuse of the existing synchronous generator as synchronous condenser ✓ To supply output that addresses required inertia force	Total installed capacity of the existing thermal power units available for conversion x 8s Inertia force of 325GW･s is expected in the case of Indonesia making all coal fired power units converse into synchronous condensers.	8	-
Pumped Storage Hydro Power	- Configuration of two water reservoirs at different elevations to generate power as water moves down, passing through a turbine - Requires power as it pumps water back into the upper reservoir for recharging - Acts as a giant battery, storing and releasing power as required	-	5	129
Grid-forming Inverter System	By combining a voltage source converter with built-in control equivalent to a synchronous generator and a power storage device, it supplies an output equivalent to inertia	TBI	TBI	Under development
Motor-Generator Set	A synchronous motor powered by renewable energy or storage batteries drives a synchronous generator.	TBI	5-9	Under development

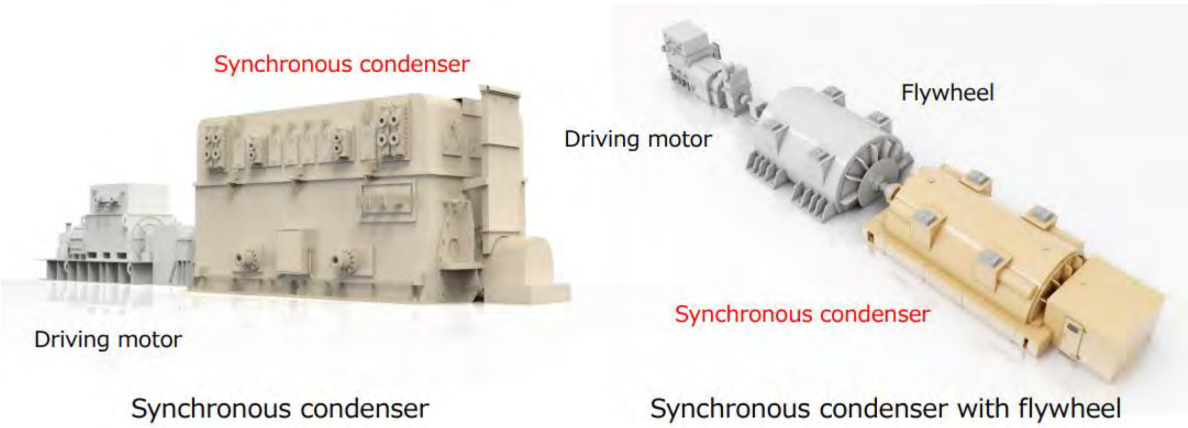
Sources: Ansaldoenergia (2023a), Asian Infrastructure Investment Bank (2022), Central Research Institute of Electric Power Industry (2023).

6.1. Synchronous Condenser

This system consists of a synchronous condenser and a driving motor (Figure 0). A flywheel may be optionally added for the requirement of additional inertia. The technology, structure, and operation and maintenance of a synchronous condenser are the same as those of a synchronous generator. The only difference is that a synchronous condenser can output power for a short duration of time equivalent to the inertial force of the rotor and flywheel.

A synchronous condenser supplies reactive power, short-circuit capacity, and inertia simultaneously.

Figure 0.7. Configuration of a Synchronous Condenser System



Source: MHI (2023).

Synchronous condensers are already an established technology and are connected to power grids in Europe and elsewhere. Figure 0.7 shows synchronous condensers connected to Italy's TERNA system in 2020, consisting of eight 250 megavolt-ampere reactive synchronous condensers with flywheels.

Assuming that the per-unit inertia constant is 8 s, the value of Msys that can be supplied by this equipment is 16 GW·s.

Figure 0.7. Synchronous Condenser Systems Installed in Italy

Source: Ansaldoenergia (2023b).

In 2020, three 250 megavolt-ampere synchronous condensers with flywheels were ordered for Italy's TERNA system, with an order value of more than EUR70 million (Ansaldoenergia, 2023a). Assuming an order amount of EUR70 million and per-unit inertia constant of 8 s, the cost per Msys will be EUR11.7 million ($12.5 million). If the lack of Msys in the three systems with insufficient inertia shown in Figure 0.5 is compensated for by these synchronous condensers with a flywheel, the cost will be as follows.

Jamali: $225 million

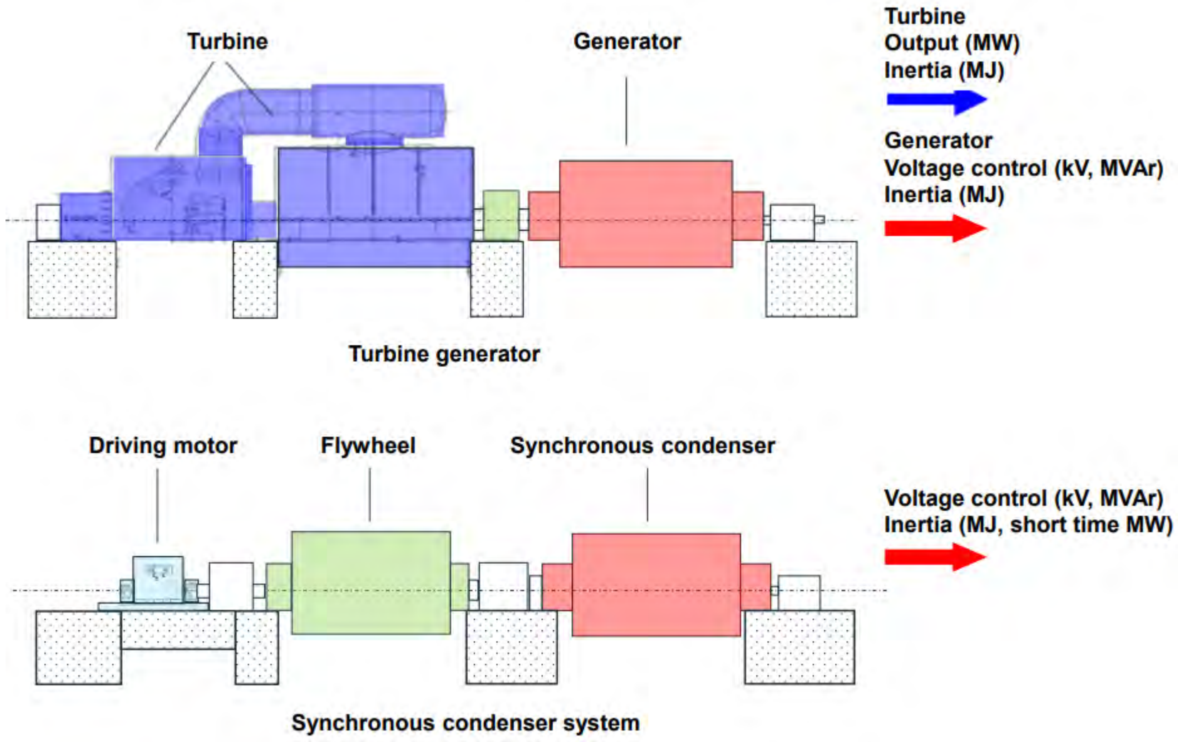
Sumatera: $263 million

Moluccas, Papua, and Nusa Tenggara: $550 million

Since the technology and structure of a synchronous condenser are the same as those of a synchronous generator, an existing generator can be converted into a synchronous condenser.

Figure 0.8 shows the configuration of an existing thermal power, and the post-conversion configuration of the synchronous condenser system. For this process, first, the turbine is removed and a driving motor and flywheel are installed. The generator can be repurposed as a synchronous condenser.

Figure 0.8. Configuration Before and After Conversion to a Synchronous Condenser System



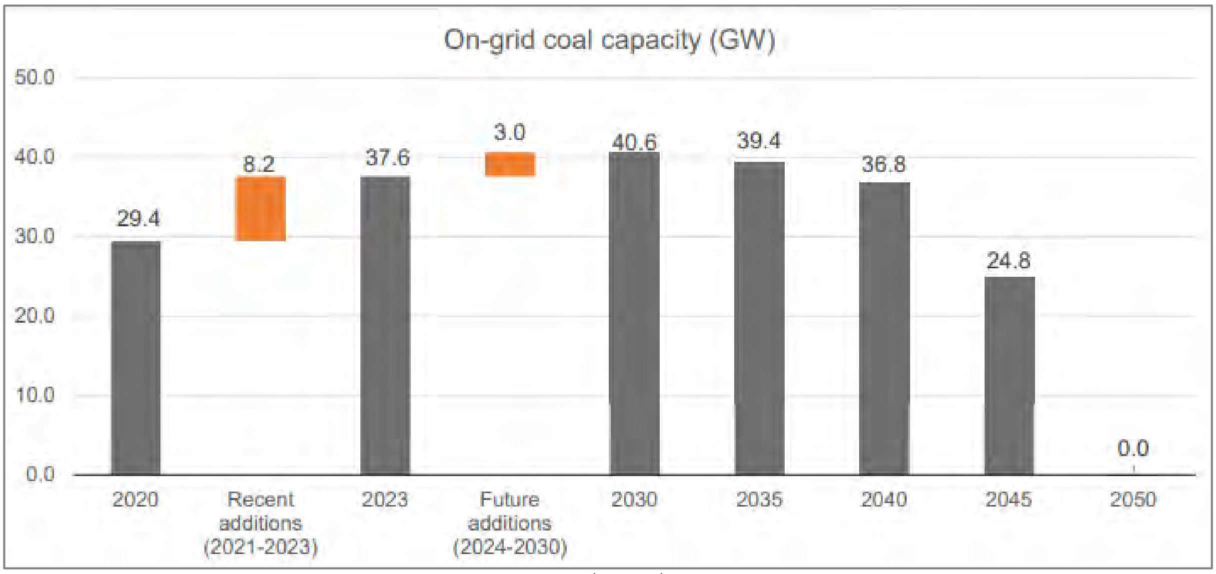
Source: MHI (2023).

Retrofitting an existing thermal power plant that have been shut down as per the phasing-down plan may provide an excellent option to utilise CFPPs that are to be retired.

Figure 0.9 shows the envisaged phaseout plan of the CFPPs, which will be gradually reduced from 2031 and abolished by 2056.

The total installed capacity of on-grid CFPPs scheduled to be shut down is 40.6 GW. If all those generators were converted into synchronous condensers, the inertia obtained would be 325 GW·s (= 40.6 GW x 8s). This value of Msys is 3.9 times the deficit value of Msys of the three systems with insufficient inertial force. Therefore, sufficient inertial force can be well supplied.

Figure 0.9. Coal-fired Power Capacity Trend and Phaseout under the JETP Scenario



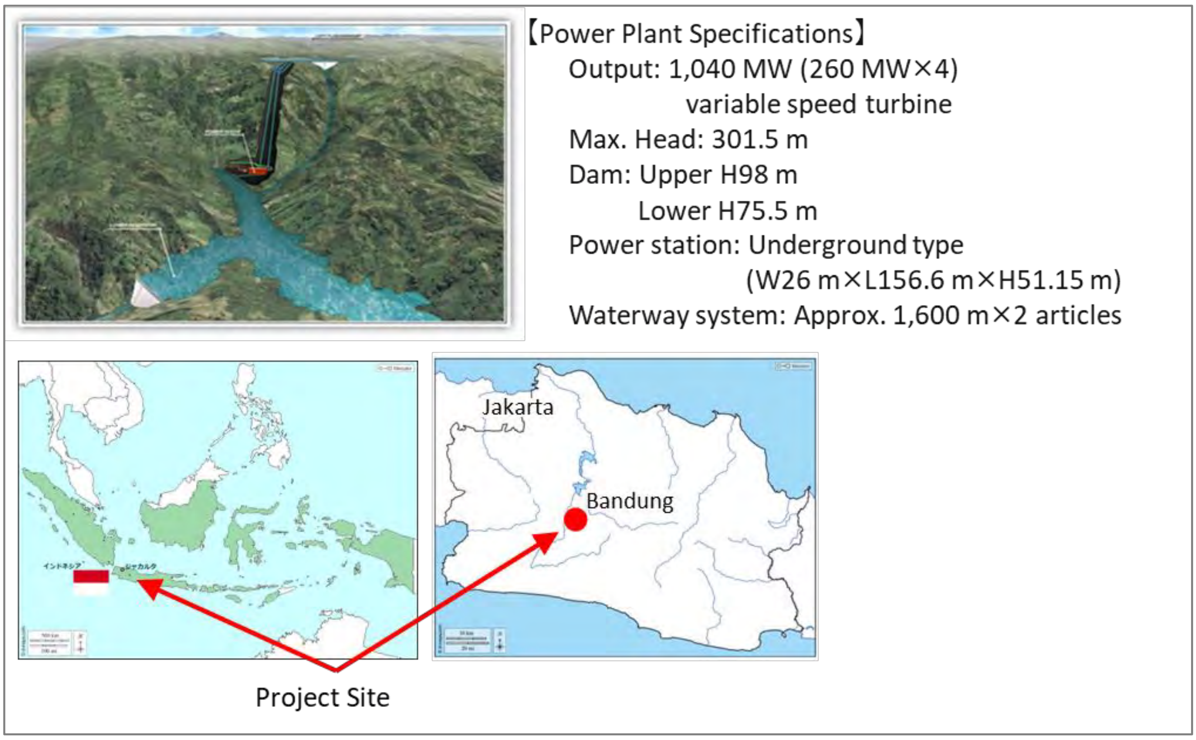
Source: JETP Secretariat and Working Groups (2023).

6.2. Pumped Storage Hydropower

The Upper Cisokan pumped storage power plant development, undertaken by the PLN with funding support from the World Bank, the Asian Infrastructure Investment Bank, and the Japan International Cooperation Agency, started in July 2023.

Figure 0.10 shows the overview of the plant. With an output of 1,040 megawatts (MW), it will be the first pumped-storage power plant in Indonesia.

Figure 0.10. Overview of Upper Cisokan Pumped Storage Power Plant

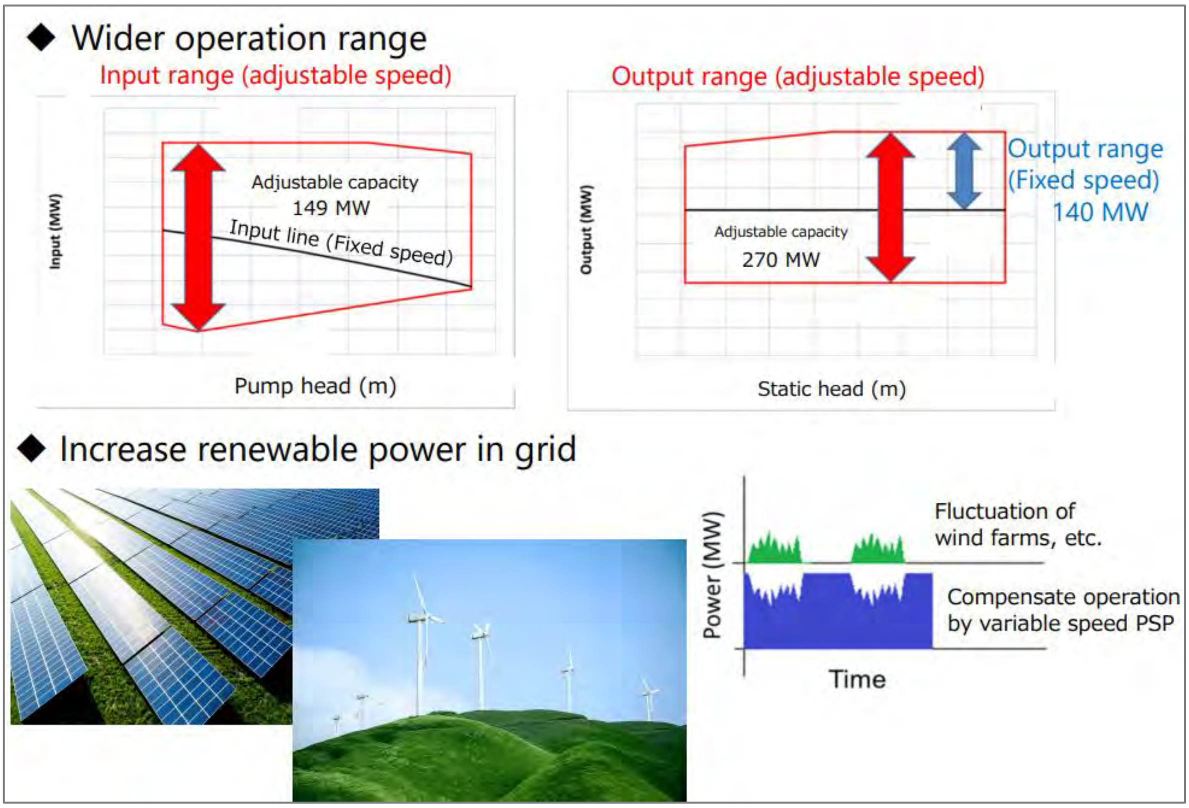


Source: Nippon Koei (2023).

Upper Cisokan uses an adjustable speed pumped storage system, which is featured by well controllable input power, controllable rotational speed of Upper Cisokan unit, etc.

The adjustable-speed pumped storage hydropower system has a wider operating range than conventional fixed-speed pumped storage hydropower system, allowing for greater flexibility. For example, the minimum load can be lowered (Figure 0.11).

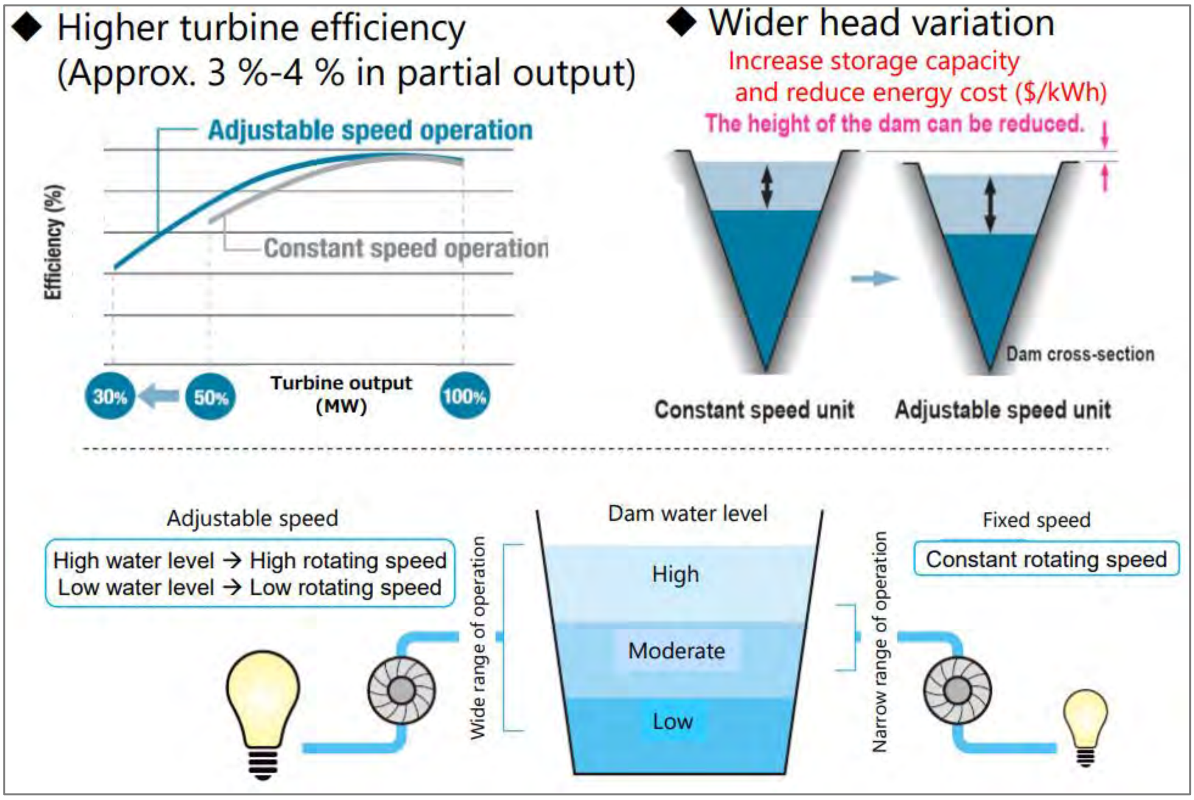
Figure 0.11. Operation Range of an Adjustable-speed Pumped Storage Hydropower System



Source: Toshiba Energy Systems & Solutions Corp (2023).

Figure 2.13 shows that turbine efficiency in partial output can be increased. As such, fluctuation incurred by VRE can be quite efficiently compensated by this adjustable speed pumped storage-hydropower.

Figure 0.12. Turbine Efficiency of Adjustable-speed Pumped Storage Hydropower System



Source: Toshiba Energy Systems & Solutions Corp (2023).

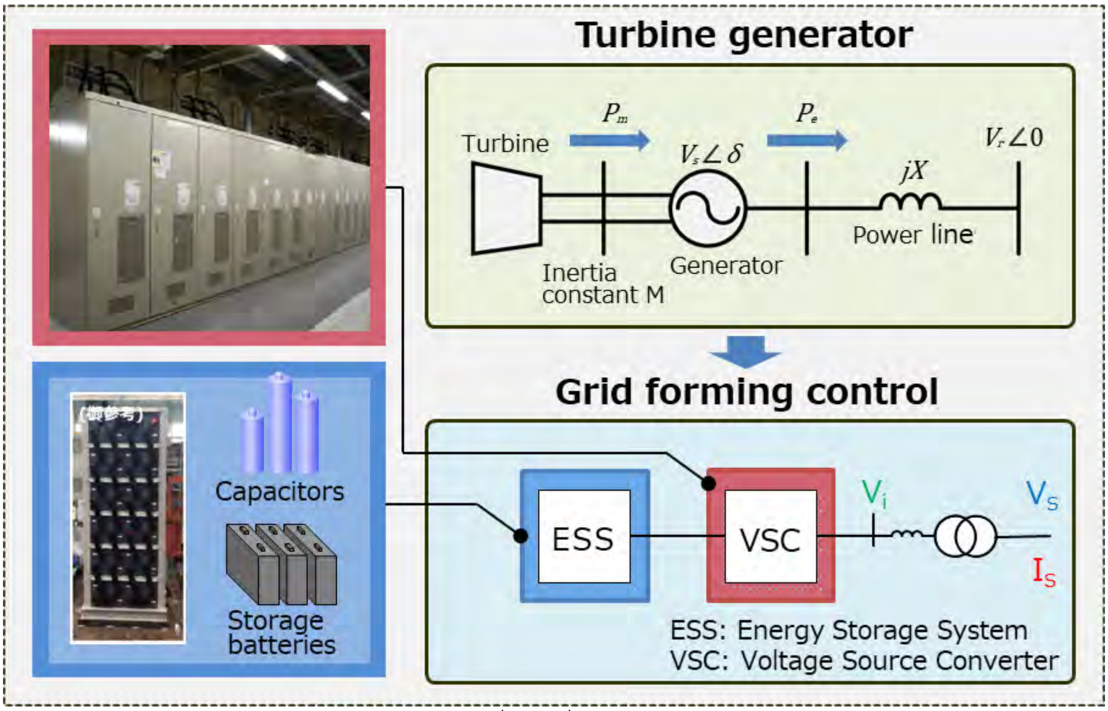
6.3. Grid-forming Inverter System

Conventional inverters cannot help addressing frequency fluctuations in the system, since they convert direct current output from VRE and other devices into alternating current.

Grid-forming inverters anticipated to be available sometime soon are conducive to frequency control in the system.

Figure 2.14 shows that combining a voltage source converter with built-in control equivalent to a synchronous generator and a power storage device supplies an output equivalent to inertia. Storage batteries and capacitors are used as energy storage devices.

Figure 0.13. Configuration of a Grid-forming Inverter System



Source: Mitsubishi Electric Corporation (2023).

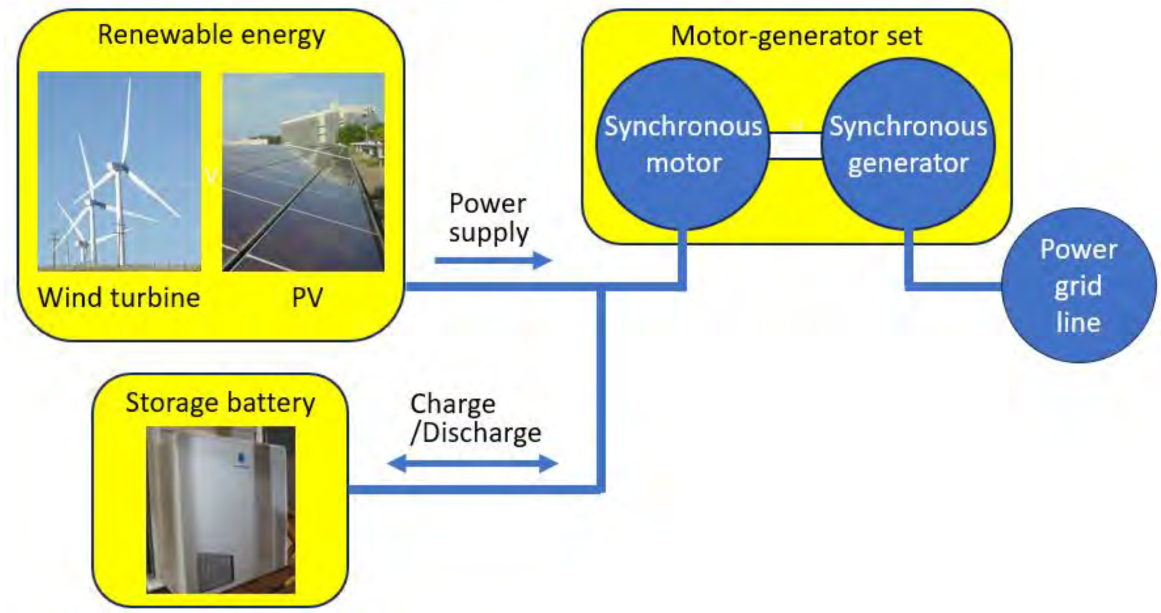
When connecting various systems in Indonesia to the grid, DC power transmission is selected because the power transmission distance is long. However, current technology does not allow sharing of inertia between the connected systems. In that case, it is necessary to install equipment that supplies inertial force to each system, and the inertial force satisfaction of each system is required. However, inertial force can be supplied by supplying the grid forming inverter system with DC power supplied by the grid line.

The grid forming inverter generating a voltage that simulates a synchronous generator does not need to be used in conjunction with a synchronous generator and can be used as a main power source (Meidensha Corporation, 2023). Therefore, grid forming inverters are effective in securing inertia in small-scale systems such as those in remote islands where synchronous generators are few.

6.4. Motor-generator Set

This system consists of a synchronous motor and a synchronous generator (Figure 0.14). A synchronous motor powered by renewable energy or storage batteries drives a synchronous generator. Since renewable energy is connected to the power grid via a synchronous generator, it is possible to supply electricity and inertia with renewable energy.

Figure 0.14. Configuration of a Motor-generator Set



Source: Edited by JCOAL Study Team based on data from the Central Research Institute of Electric Power Industry websites.

7. Roadmap for Grid Stabilisation

Figure 0.15 shows a roadmap for grid stabilisation. The outline is as follows.

STEP 1: Planning Measures

Evaluate system stability for power equipment plans that have been planned in consideration of the balance between demand and supply, and plan measures to ensure system stability.

STEP 2: Application of existing technology

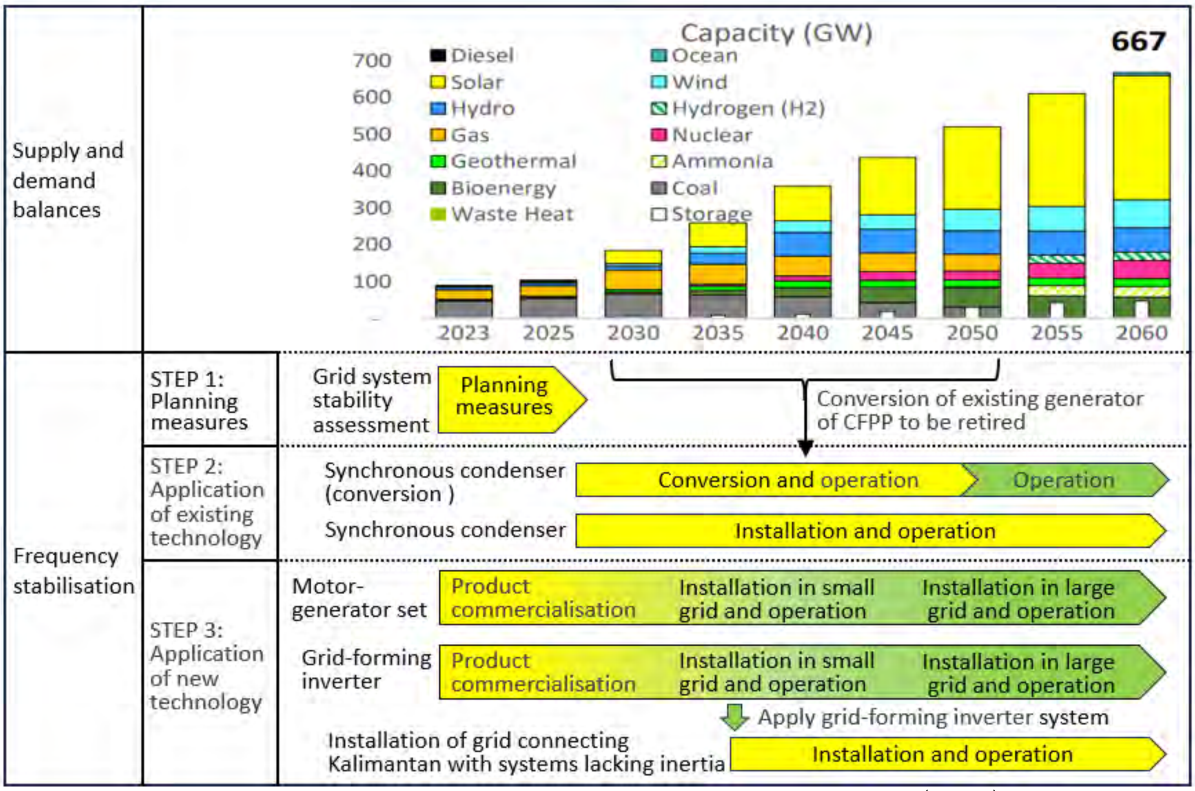
For systems that lack inertia, install new synchronous condensers, or convert existing thermal power plants into synchronous condensers.

STEP 3: Application of new technology

The applicability of grid forming inverter and motor-generator set are determined by comparing them with synchronous condensers. If applied, first apply it to the small grid, then apply it to the large grid.

When connecting Kalimantan with systems lacking inertia, DC power transmission is used, and inertial force cannot be shared. Thus, it is necessary to install grid forming inverters equivalent to the required inertial force.

Figure 0.15. Roadmap for Grid Stabilisation



Source: JCOAL Study Team, based on the sub-study outcomes and MEMR (2023).

Chapter 3

Thailand

1. Background

Thailand's energy policy, 4D+E, is indicated by five keywords: digitalisation, deregulation, decarbonisation, decentralisation, and electrification.

Table 3.1 outlines these five key concepts, and Thailand is proceeding under this energy policy. Biomass utilisation is clearly indicated as action items of decarbonisation in this policy.

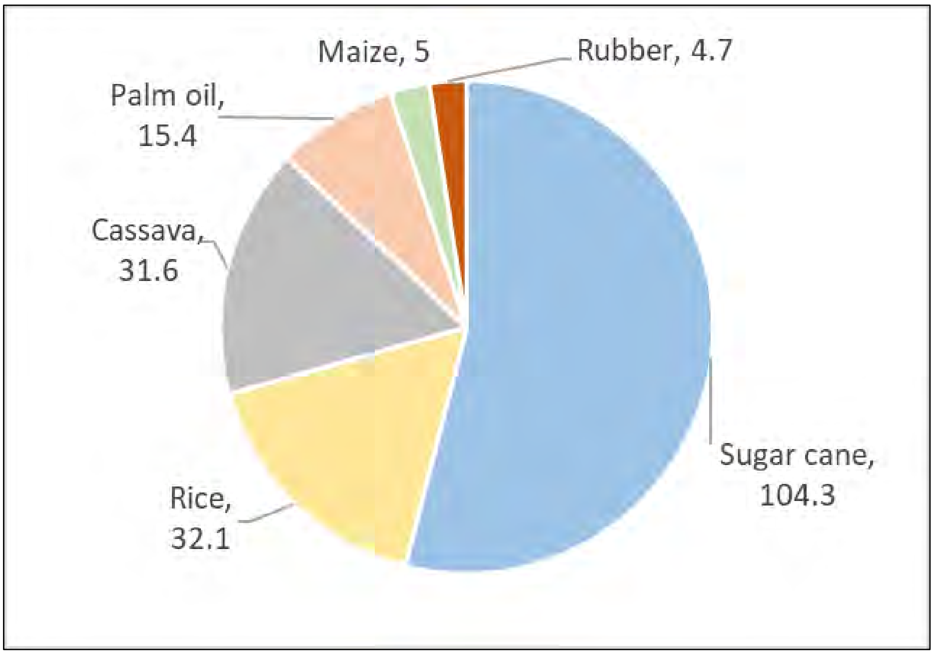
Table 3.1. Thailand's Energy Policy

Digitalisation	Enhance the transmission system to be 'Smart Grid'
	Support development of energy storage systems for increasing stability to community and large power plants
	Becoming ASEAN energy commercial centre
Deregulation	Originating the 'Sandbox' Project for energy innovation development
	Promote 'Energy Start-up' concept
	Conduct flexibility of ENCON fund utilisation to promote community energy business
	Increase opportunity for the public to purchase electricity ('Prosumer')
Decarbonisation	Promote production and utilisation of electricity from solar and bioenergy
	Absorb and increase the value of agricultural products (e.g. palm oil) by using as alternative fuels
Decentralisation	Promote P2P electricity trading by supporting electricity conveying through on-grid and off-grid systems
	Promote installation of community power plants
	Proceed with community power plant network mapping
	Support electricity balance in the southern area and the Eastern Economic Corridor
Electrification	Extend the EV network
	Promote EV utilisation

Source: DEDE (2020).

Under government initiatives, biomass dedicated power, biogas utilisation, and edible biomass fermentation type biofuel are spreading. Thailand has a large agricultural sector producing sugar cane, rice, cassava, palm oil, rubber, amongst others. Its total crop production is around 200 million tonnes per year. In this situation, biomass application technology to utilise agricultural residue should be widely developed towards Thailand's carbon neutrality.

Figure 3.1. Share of Crop Production in Thailand



Source: Edited by JCOAL.

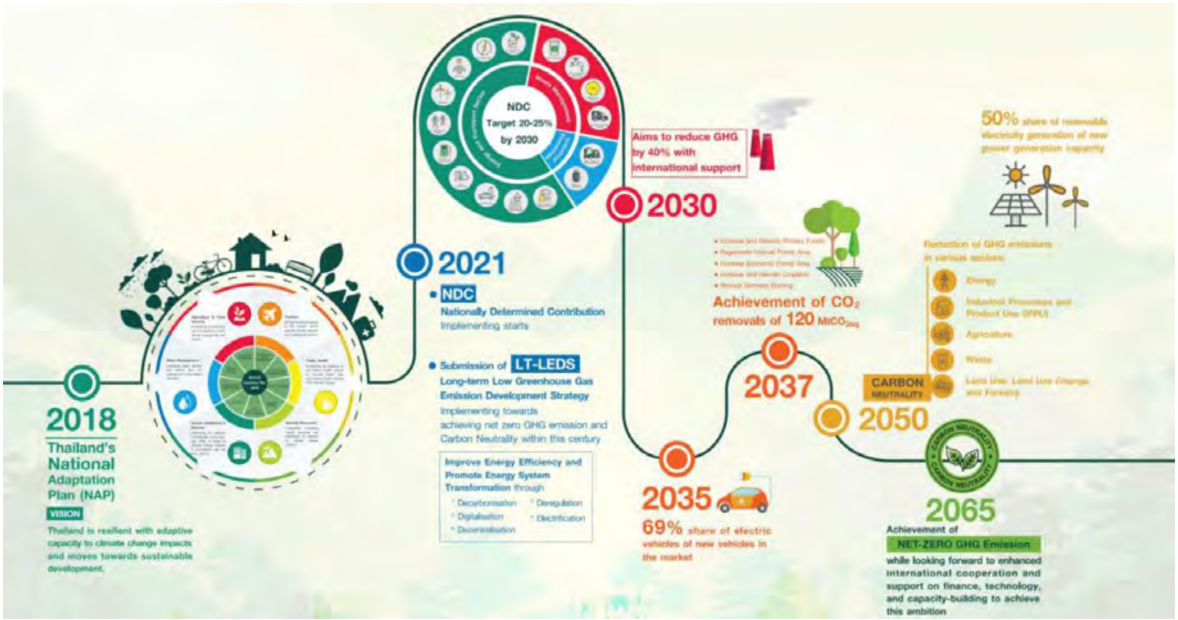
Table 3.1. Cultivated, Harvested, and Productive Areas of Thailand

Crop	Million Hectares
Rice	11.60
Maize	1.09
Cassava	1.59
Sugar cane	1.56
Para wood	3.51
Oil palm	0.98

Source: Office of Agricultural Economics (2022).

Figure 3.1 shows Thailand's long-term greenhouse gas (GHG) emission development strategy. In 2018, the country's National Adaptation Plan was announced. It aims towards resiliency with adaptive capacity to climate change impacts and moves towards sustainable development. In 2021, at COP26, Thailand pledged to enhance its nationally determined contribution or NDC to reduce GHG emissions by 30%–40% in 2030 from the previous target of 20%–25%, with international support. The country is committed to reaching carbon neutrality by 2050 and achieving net-zero GHG emissions by 2065. With these, the significant activities consist of an aspirational increase of EV share to the new vehicles in the market to be 60% by 2030.

Figure 3.1. Thailand's Long-term GHG Emission Development Strategy



Source: DEDE (2022).

In December 2020, Thailand unveiled the Thailand National Strategy (NSS 3.0) to achieve carbon neutrality by 2050. As part of this national strategy geared towards constructing a circular economy, the adoption of biomass energy is being expedited (JETRO, 2021a; DEDE, 2018).

Thailand has embraced the Bio-Circular-Green Economy (BCG) model to capitalise on its strength in agriculture and biotechnology, to nurture industries like food and agriculture, healthcare, as well as bioenergy, biomaterials, and biochemistry. BCG industries are forecasted to generate an added value equivalent to THB4.3 trillion (approximately 15.5 trillion yen), constituting 25% of gross domestic product in the upcoming 5 years.

To steer its energy landscape away from fossil fuels, Thailand's Ministry of Energy has set a goal of attaining a renewable energy generation ratio exceeding 30% within the next decade (2021–2030). In addition, the ministry targets to promote clean and renewable energy for power generation, which will be increased by not less than 50% in the new power plants by 2040. According to the facts, biomass in Thailand is used for direct combustion, whereas a little amount of biomass is used by fermentation.

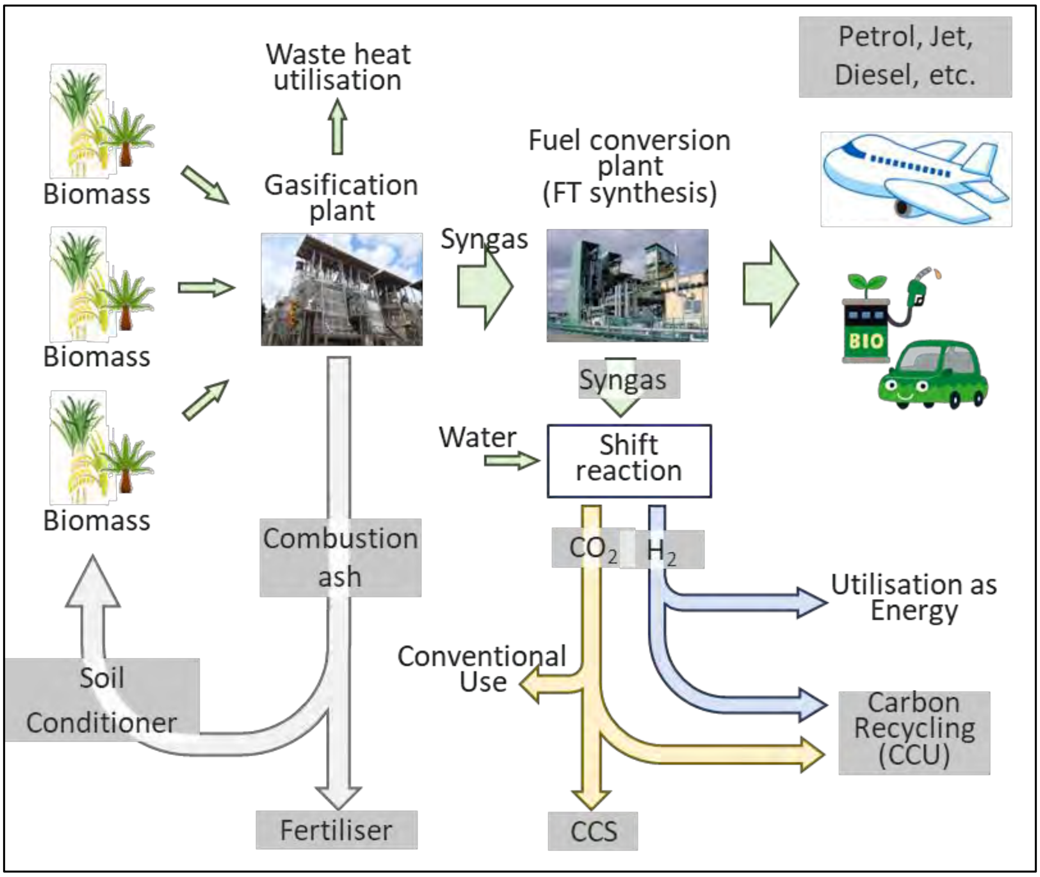
Within Thailand's array of renewable energy sources, biomass, waste processing, and biogas are deemed the most competitive in terms of cost and resource utilisation. Despite an annual availability of around 60 million tonnes of biomass resources for energy purposes, an estimated 40 million tonnes of biomass remain untapped each year.

2. Study Outline of Biomass Utilisation

2.1. Study Concept

In this study, a conceptual feasibility study of biomass gasification and fuel conversion process is conducted. It includes the utilisation of gasified by-products such as combustion ash and CO_2. The analysis for social implementation is also considered.

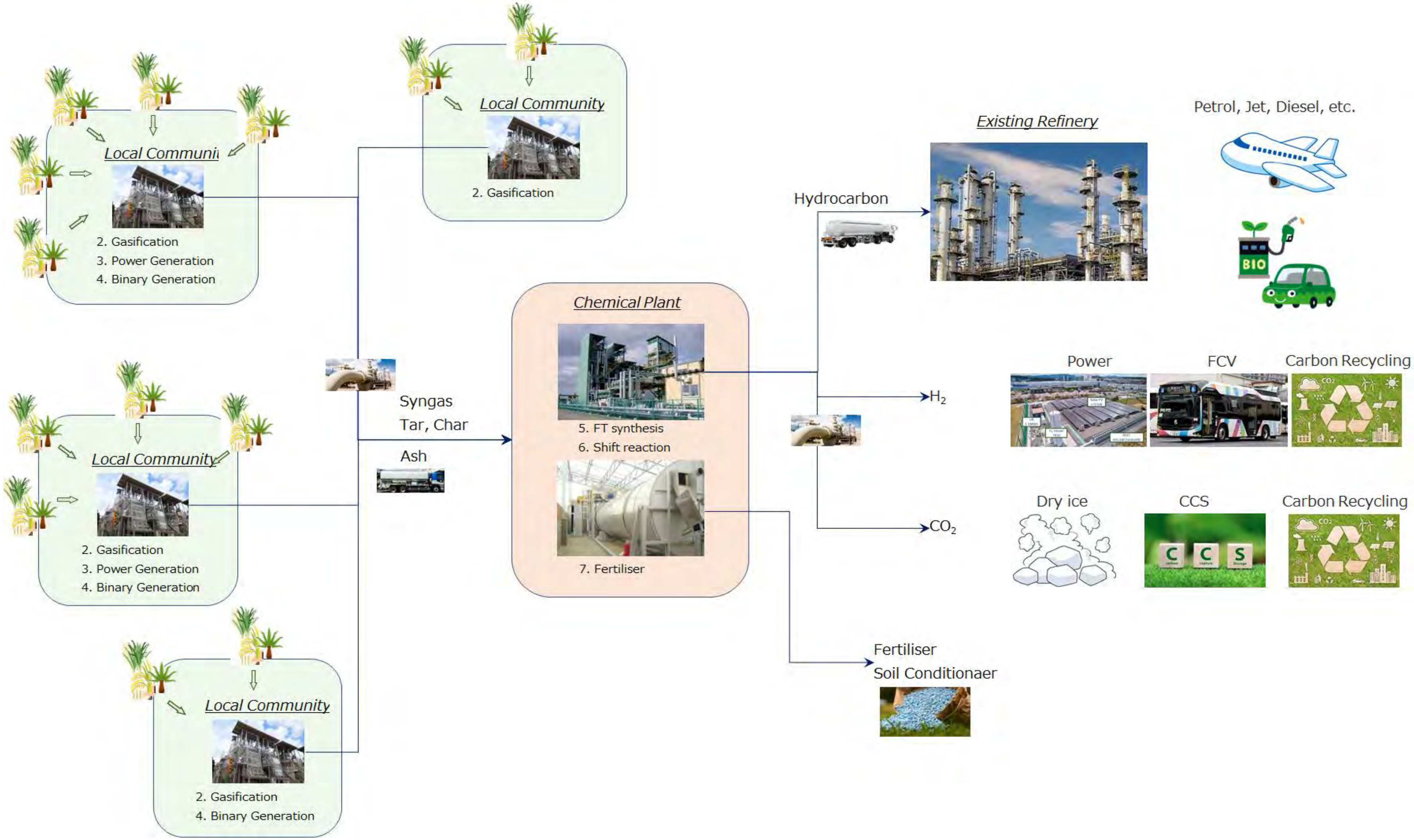
Figure 3.3. Conceptual Process Outline



Source: Edited by JCOAL.

Figure 3.4. Proposed Process Scheme of Biomass Utilisation 3.4 shows the cost–benefit analysis of each subprocess, i.e. gasification, power generation, Fischer-Tropsch (FT) synthesis, and shift reaction, will be conducted. Firstly, biomass is collected in each community base for converting to syngas. Syngas is converted to liquid hydrocarbon by FT synthesis process at a central larger chemical plant for further refining to fuel products such as petrol, kerosene, and diesel. Syngas is also converted to hydrogen (H_2) and CO_2 by shift reaction process. Ash is expected to be utilised as fertiliser and/or soil conditioner.

Figure 3.4. Proposed Process Scheme of Biomass Utilisation



Source: Edited by JCOAL.

2.2. Key Technologies

An updraft batch furnace type gasifier is selected for this study because of its simple operability and wide applicability of biomass species. This type can also be adapted for municipal waste and biomass co-gasification, partial oxidation.

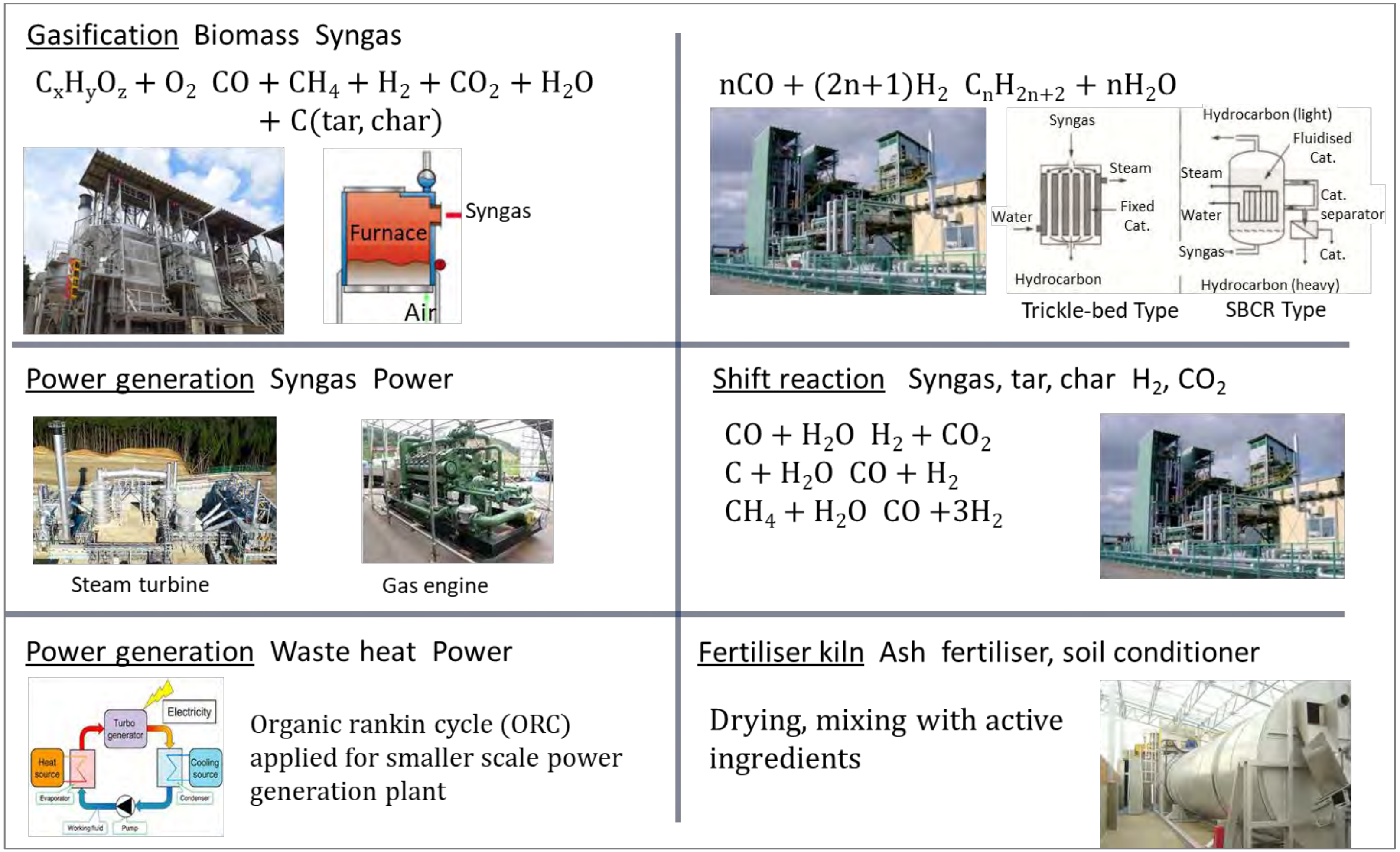
Two types of power generation were considered in this study: gas engine and organic Rankine cycle to use waste heat from gasifier.

As for gas-to-fuel conversion, the FT reaction is commercially available with trickle-bed type and slurry bubble column reactor type.

This reaction requires twice of hydrogen against carbon monoxide by molar ratio. If not enough hydrogen is contained in the syngas itself, another shift reactor is required for hydrogen supply. As pretreatment of the FT reactor and gas separation after the shift reactor, pressure swing absorption or PSA is commonly used.

Biomass ash is expected to be utilised for fertiliser application by mixing other effective components such as phosphate rock, magnesium lime, and urea in the dry and mixing process with a rotary kiln dryer.

Figure 3.2. Key Technologies for Biomass Utilisation



Source: JCOAL Study Team.

2.3. Specifications and Assumptions

The following parameters were used in this sub-study to estimate the financial feasibility of biomass utilisation in Thailand with mutual communication with the Thai working group members.

1) Biomass collection

    Analytical data: Production weighted average

    Supply: Collected at each site

    Cost of biomass: THB100–900/t as market price

2) Gasification

    Number of sites: 10

    Furnace: Updraft, batch type

    Scale: 5 t/d–500 t/d

    Availability: 30%

    Cold gas efficiency: 60%–65%

    Converted portion: Volatile matter (VM)

    Ash: To be utilised

    Char and tar: To be sold to the refinery

    Emission: Evaporated to air

3) Power generation

    Equipment: Gas engine, organic Rankine cycle

    Syngas rate: 10% of syngas

    Waste heat: 100% waste heat

4) FT synthesis

    PSA: 80% of N_2 separated from syngas

    N_2: To be sold to the market

    Swing rate: 2%–50% of syngas to shift reaction

    FT reactor: SCBR or trickle-bed type

    Conversion: 90%

    Input Energy: 15% of syngas calorie

    Product: Assumed as heavy naphtha (C8), to be sold to the refinery

    Vent gas: Evaporated to air

5) Shift Reaction

Shift reactor: Fixed-bed type

Conversion: 80%

Input Energy: 5% of syngas calorie

Product: H_2, N_2, CO_2 to be sold to the market

6) Fertiliser

Furnace: Rotary kiln

Input energy: Equivalent to mixing and drying @100^{0}C

Admixture: Urea, 100% of ash

Phosphate rock, 200% of ash

Magnesium Lime, 100% of ash

7) Product price

Power: 4.14 THB/kWh

N_2: 4.1 THB/m^3

H_2: 7.6 THB/m^3

CO_2:42 THB/m^3

Heavy Naphtha: 20,964 THB/kL

Fertiliser: 32,000 THB/t

8) Feasibility analysis

Project cost: EPC of each process, 10% added for connection

Maintenance: 1.5% annually, 10% every 10 years

Revenue: Sales of products and carbon offset, products price assumed to be constant

Cost: Operating cost of each process, interest rate, depreciation, corporate tax, variable unit cost to be constant

Financial parameters: Cash flow, net present value, internal rate of return (IRR)

Labour: 250,000 THB/M

Carbon credit: 107 THB/t

Interest rate: 6.5%

Pay back: 5 years (fix)

Depreciation: 20 years constant rate

Corporate tax: 20%

Discount rate: 10%

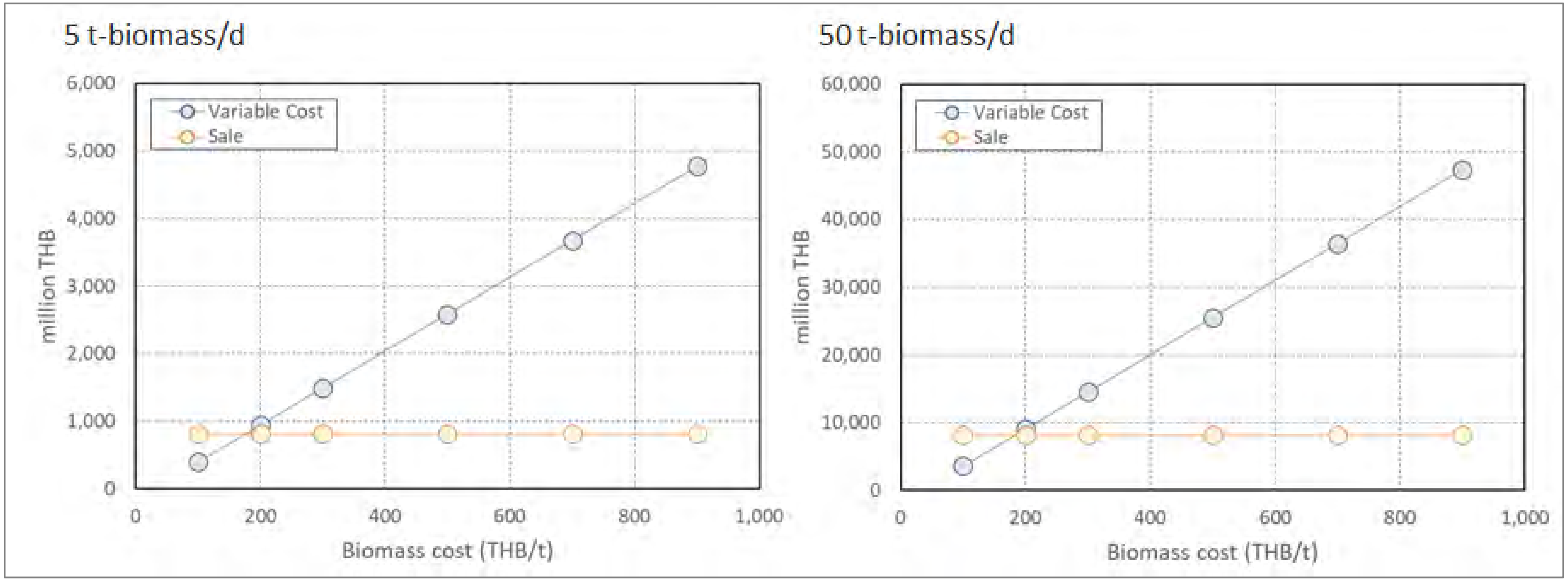
3. Analysis of Biomass Utilisation

Analysis was first done with variable cost-sales of each subprocess. Then a whole process feasibility was estimated with financial parameters of IRR with total project cost for a 20-year project.

3.1. Variable Cost Analysis of the Gasification Subprocess

The influence of biomass cost on the gasification subprocess operation was calculated and shown in Figure . It clearly indicates that the deficit between biomass cost and syngas sales is increased with an increase in biomass cost and its balancing point is around 200 THB/t-biomass.

Figure 3.6. Influence of Biomass Cost in the Gasification Subprocess

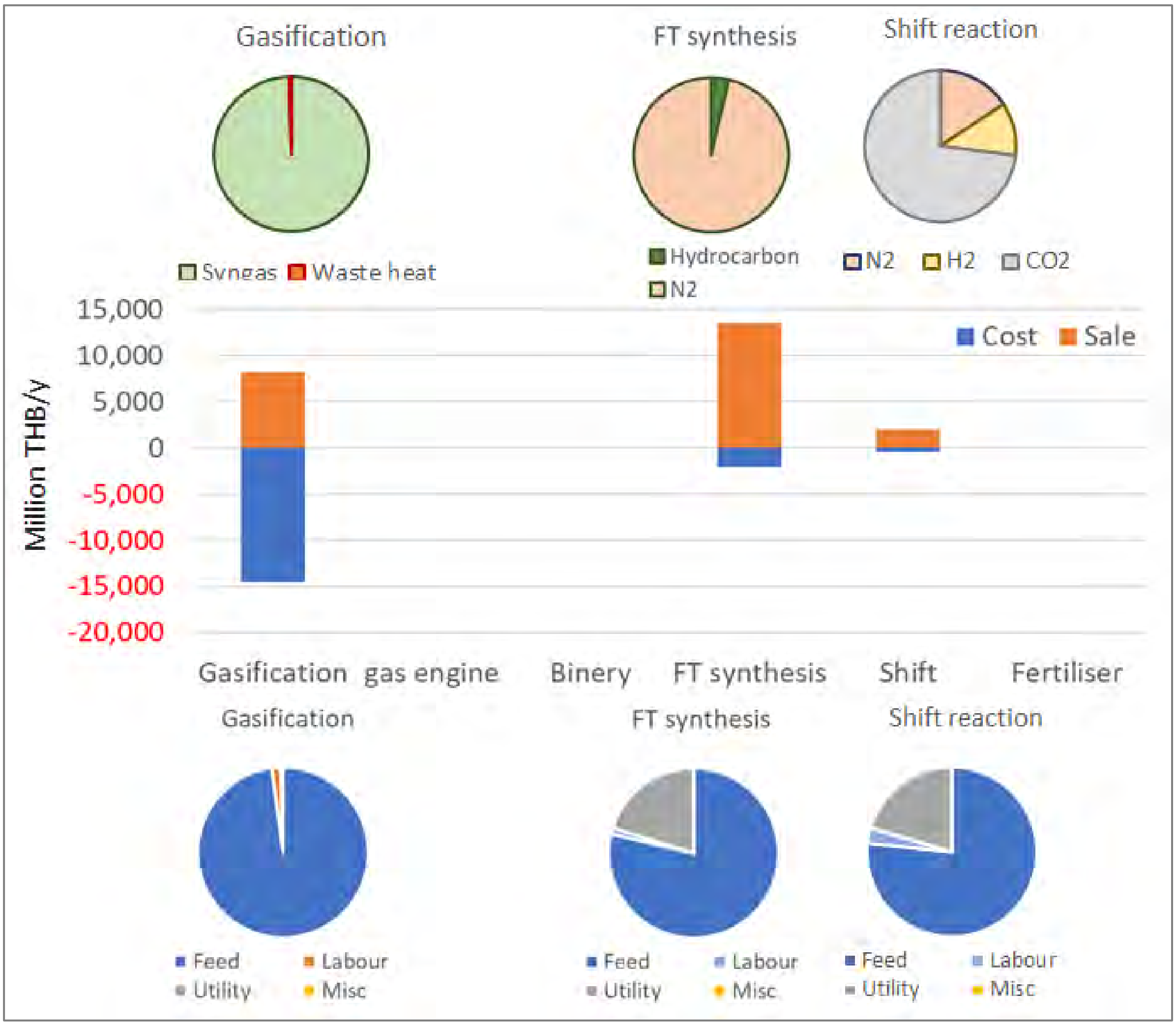


Source: Edited by JCOAL.

3.2. Cost Breakdown of Subprocess

Figure 3.7 shows a cost breakdown of each subprocess at the case of 5 t/d-biomass with 300 THB/t of biomass price case. Biomass price was found to be a dominant factor in determining project feasibility. Current biomass market price is around 900 THB/t, much higher than the critical point of this sub-study shown in Figure .

Figure 3.7. Breakdown of Running Costs



Source: Edited by JCOAL.

3.3. Financial Feasibility Analysis

The IRR financial parameter was calculated in the case of 5 t/d, 20 t/d, and 50 t/d. The example of the case of 50 t/d-biomass and 250 THB/t price is presented in Table . Since inflation rate might affect both cost and product prices and estimation becomes complicated, constant values were used for both biomass price, labour cost, and product price. The IRR, with 20 years' cash flow, was estimated using the parameter listed in the same table, such as corporate tax of 20%, current market interest rate of 6.5%, depreciation period of 20 years, carbon offset price of 107 THB/t-CO_2, etc.

In this analysis, the annual maintenance cost is assumed to be 1.5% of the whole project. Additional capital overhaul cost is 10% of the whole project at 10 years after commissioning. Carbon offset is assumed to become countable after 3 years of commissioning.

Table 3.3. Feasibility Analysis of 50 t/d Biomass Gasification and Biomass Cost Is Assumed to be 250 THB/t

Year	-1	0	1	2	3	4	5	6	7	8	9
Project	17,604,299,082										
Gasification	3,065,425,213	0	0	0	0	0	0	0	0	0	0
Power generation	0	0	0	0	0	0	0	0	0	0	0
Binary generation	0	0	0	0	0	0	0	0	0	0	0
FT synthesis	8,957,411,337	0	0	0	0	0	0	0	0	0	0
Shift reaction	3,981,071,706	0	0	0	0	0	0	0	0	0	0
Kiln	0	0	0	0	0	0	0	0	0	0	0
Connection,transportation	1,600,390,826	0	0	0	0	0	0	0	0	0	0
Revenue	0	0	15,509,725,638	15,509,725,638	15,509,725,638	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141
Gross Gen	0	0	0	0	0	0	0	0	0	0	0
Syngas	0	0	0	0	0	0	0	0	0	0	0
H_2	0	0	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814
N_2	0	0	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700
CO_2	0	0	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982
Hydrocarbon	0	0	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757
Fertiliser	0	0	0	0	0	0	0	0	0	0	0
Misc.	0	0	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384
Carbon credit	0	0	0	0	0	6,054,503	6,054,503	6,054,503	6,054,503	6,054,503	6,054,503
Cost	302,163,342	302,163,342	18,130,905,400	17,866,840,914	17,604,976,965	17,345,203,526	17,087,416,073	13,751,680,420	13,724,436,677	13,698,555,122	13,673,967,645
Feedstock	0	0	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000
Labour	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948
Utility	0	0	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108
Maitenance	0	0	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486
SGA	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395
Interest expense	0	0	1,100,268,693	880,214,954	660,161,216	440,107,477	220,053,739	0	0	0	0
Loan repayment			3,520,859,816	3,520,859,816	3,520,859,816	3,520,859,816	3,520,859,816	0	0	0	0
Depreciation	0	0	880,214,954	836,204,206	794,393,996	754,674,296	716,940,581	681,093,552	647,038,875	614,686,931	583,952,584
Corporate tax	0	0	0	0	0	0	0	441,024,930	447,835,866	454,306,255	460,453,124
Financial parameter											
Cash flow	-17,906,462,424	-302,163,342	1,779,895,009	1,999,948,747	2,220,002,486	2,446,110,727	2,666,164,466	2,445,193,274	2,438,382,338	2,431,911,950	2,425,765,080
NPV	-3,135,209,961										
IRR	7.4%										

Year	10	11	12	13	14	15	16	17	18	19	20
Project	1,760,429,908										
Gasification	306,542,521	0	0	0	0	0	0	0	0	0	0
Power generation	0	0	0	0	0	0	0	0	0	0	0
Binary generation	0	0	0	0	0	0	0	0	0	0	0
FT synthesis	895,741,134	0	0	0	0	0	0	0	0	0	0
Shift reaction	398,107,171	0	0	0	0	0	0	0	0	0	0
Kiln	0	0	0	0	0	0	0	0	0	0	0
Connection,transportation	160,039,083	0	0	0	0	0	0	0	0	0	0
Revenue	7,760,917,322	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141	15,515,780,141
Gross Gen	0	0	0	0	0	0	0	0	0	0	0
Syngas	0	0	0	0	0	0	0	0	0	0	0
H_2	115,076,407	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814	230,152,814
N_2	6,647,516,350	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700	13,295,032,700
CO_2	743,749,491	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982	1,487,498,982
Hydrocarbon	246,271,378	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757	492,542,757
Fertiliser	0	0	0	0	0	0	0	0	0	0	0
Misc.	2,249,192	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384	4,498,384
Carbon credit	6,054,503	6,054,503	6,054,503	6,054,503	6,054,503	6,054,503	6,054,503	6,054,503	6,054,503	6,054,503	6,054,503
Cost	13,184,316,892	13,698,836,540	13,674,234,992	13,650,863,521	13,628,660,624	13,607,567,872	13,587,529,757	13,568,493,548	13,550,409,149	13,533,228,971	13,206,805,578
Feedstock	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000	11,497,500,000
Labour	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948	274,693,948
Utility	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108	565,834,108
Maitenance	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486	264,064,486
SGA	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395	27,469,395
Interest expense	0	0	0	0	0	0	0	0	0	0	0
Loan repayment	0	0	0	0	0	0	0	0	0	0	0
Depreciation	554,754,955	615,038,703	584,286,768	555,072,429	527,318,808	500,952,868	475,905,224	452,109,963	429,504,465	408,029,242	0
Corporate tax	0	454,235,900	460,386,287	466,229,155	471,779,879	477,053,067	482,062,596	486,821,648	491,342,748	495,637,793	577,243,641
Financial parameter											
Cash flow	-6,629,074,523	2,431,982,304	2,425,831,917	2,419,989,049	2,414,438,325	2,409,165,137	2,404,155,608	2,399,396,556	2,394,875,456	2,390,580,412	2,308,974,563
NPV											
IRR											

Capital overhaul (%)	10	of Initial, every 10 years
Maintenance rate (%)	1.5	of Initial, annually
carbon Credit (THB/t)	107	
SGA:selling, general and administrative expenses (%)	10	
Interest rate (%)	6.25	
Pay back	5	
Depreciation (y)	20	constant rate
Corporate tax (%)	20	
NPV:Net Present Value		
Discount rate (%)	10	
IRR:Internal rate of return		

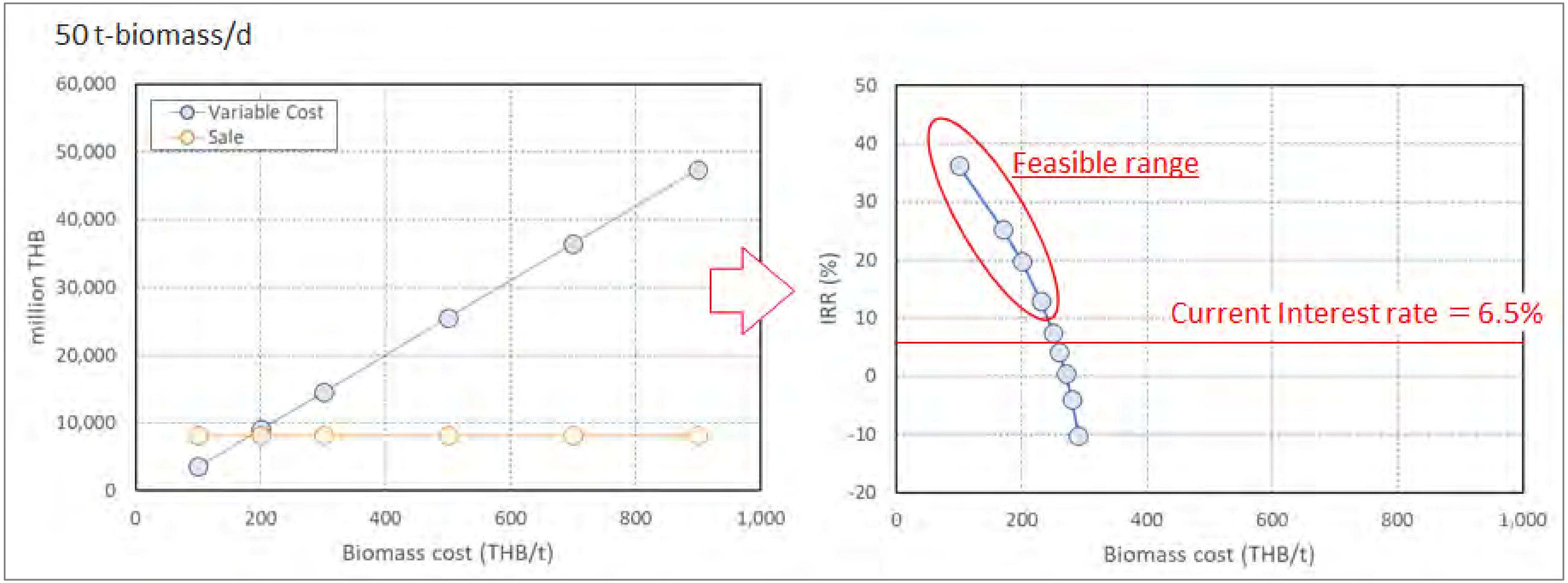
Source: Edited by JCOAL.

3.4. Influence of Biomass Cost

Various IRRs of 50 t/d-biomass case were calculated to find a feasible point of biomass price in this biomass utilisation process (Figure).

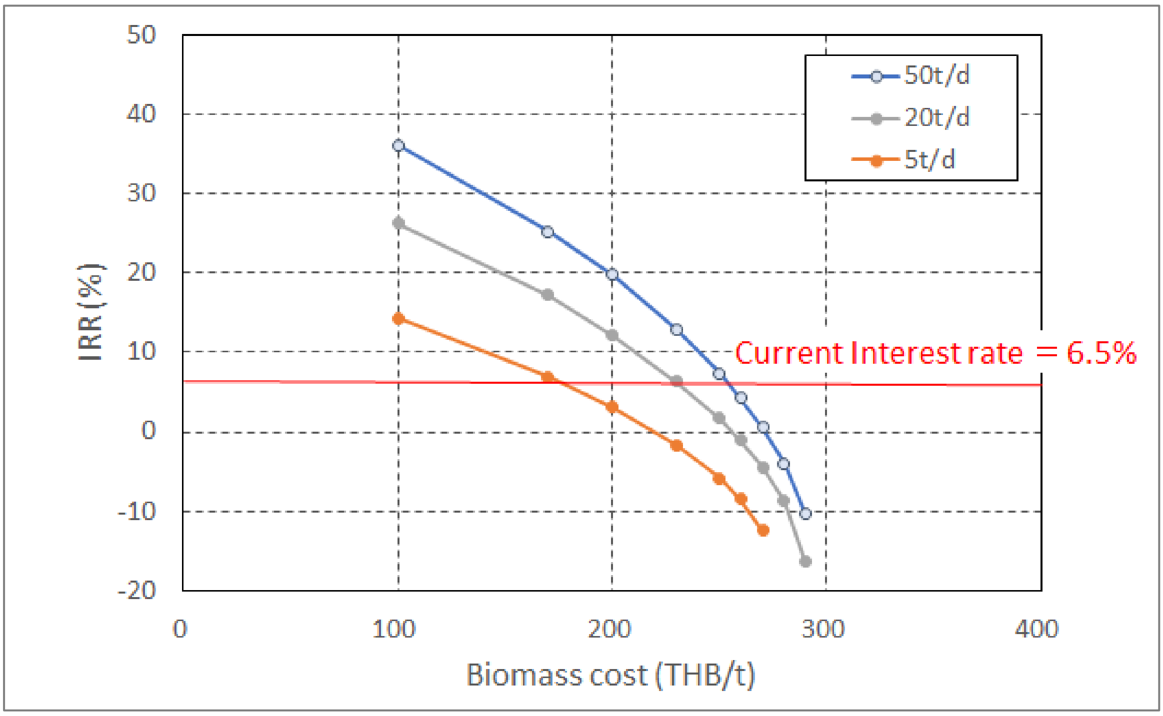
The IRR depends on process capacity and biomass cost. The feasible point in biomass price slightly improves with gasification capacity, but the absolute value is still much lower than the current market biomass price in Thailand. Compared to the current interest rate in Thailand, feasible biomass cost range of 50 t/d, 20 t/d, and 5 t/d cases are estimated to be <240 THB/t, <210 THB/t, and <140 THB/t, respectively.

Figure 3.8. Various IRRs of 50 t/d Biomass Case



Source: Edited by JCOAL.

Figure 3.9. Scale-up Effect of IRR with Various Biomass Costs



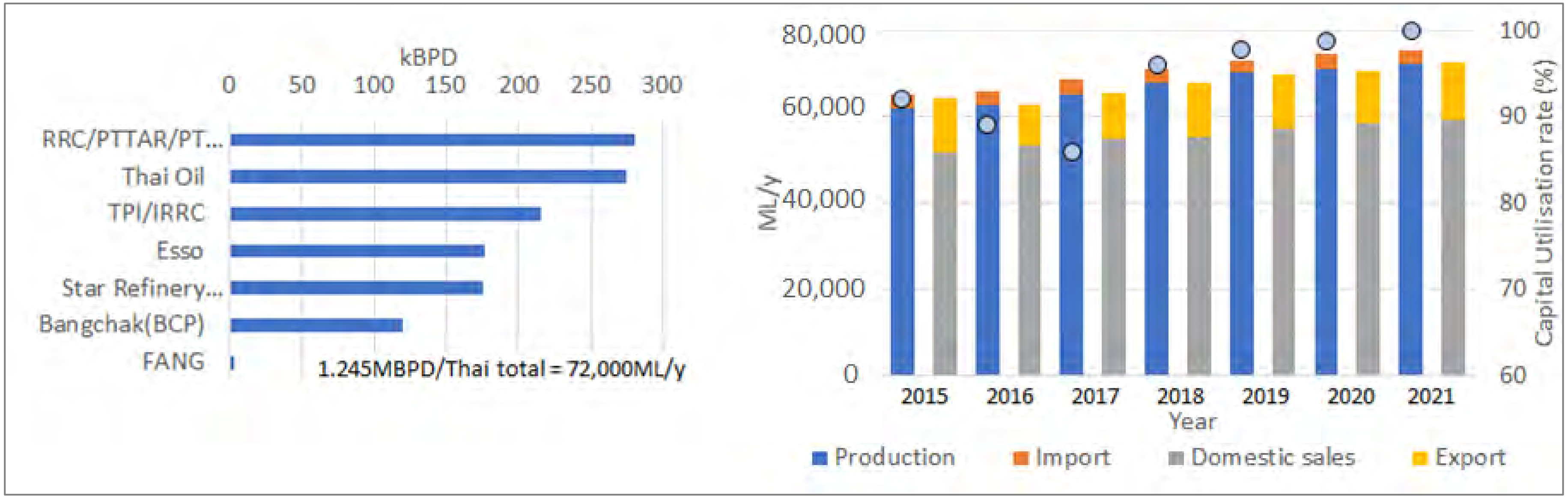
Source: Edited by JCOAL.

4. Market Situation of Products

4.1. Fuels

There are seven major refinery companies in Thailand with a total crude oil processing capacity of about 1.25 million barrels per day, or about 72 million kL per year (Statista, 2023). The production volume gradually increases year by year, and the capacity utilisation rate has recently exceeded 99%. Approximately 20% of the domestic production volume is exported within the ASEAN region. Although there is a small part of imports in terms of the product balance, the overall balance is high with a high operating rate (Krungsri Research, 2022). Eighty percent of production is consumed in the domestic market. Out of that, 80% is for transportation use, i.e. petrol, kerosene, and diesel. Its estimated volume is around 46,000 million litres per year.

Figure 3.10. Crude Refining Capacity (left) and Supply–Demand Balance (right)



Source: Edited by JCOAL with data from Krungsri Research.

On the other hand, the production volume expected in this feasibility study (FS) is 8 ML/y for 50t/d processing cases, which is sufficiently small than the existing processing capacity and can be included in the existing production and supply market.

4.2. Current and Future Gases

Hydrogen: Thailand has identified hydrogen as an important renewable energy source in the Alternative Energy Development Plan (AEDP) 2037, with a production target of 3,000 tonnes or 33 Mm^3 by 2036. Recently, Thai PTT invested in a green hydrogen plant with Saudi Arabia's ACWA Power with an annual capacity of 225,000 tonnes. As the demand for green hydrogen is expected to increase year by year, hydrogen production from biomass will positively contribute to this hydrogen strategy in Thailand. The production volume expected in this FS is 30 Mm^3/y for 50 t/d processing cases, respectively, which is sufficiently small compared to the existing processing capacity and can be included in the existing production and supply market.

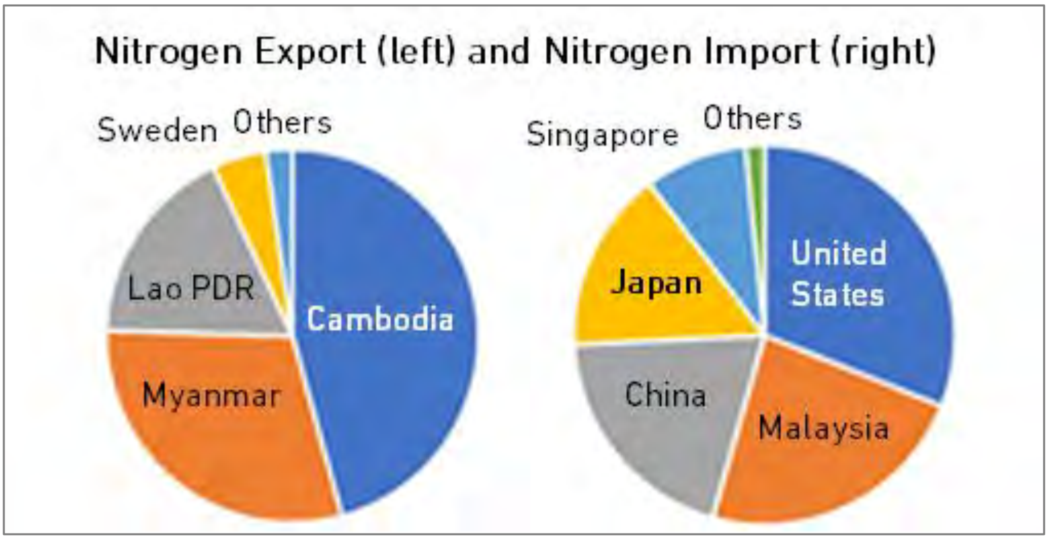
Figure 3.3. Image of a Future Green Hydrogen Plant

Source: INDEXBOX (2023).

Nitrogen: Nitrogen gas production in Thailand is increasing at an average annual rate of 2.7%. According to 2022 data, annual exports to Cambodia, Myanmar, Lao PDR, and Sweden are around 4.5 Mm^3. This volume cannot be covered by domestic production, and 1.26 Mm^3 was imported from the United States, Japan, Singapore, Malaysia.

The production volume expected in this FS is 77 Mm^3/y for 50 t/d processing cases, respectively, which is sufficiently small than the existing market volume and can be included in the existing market, since the demand for nitrogen in Thailand is expected to increase in the future.

Figure 3.12. Nitrogen Import Export Balance in Thailand



Source: INDEXBOX (2023).

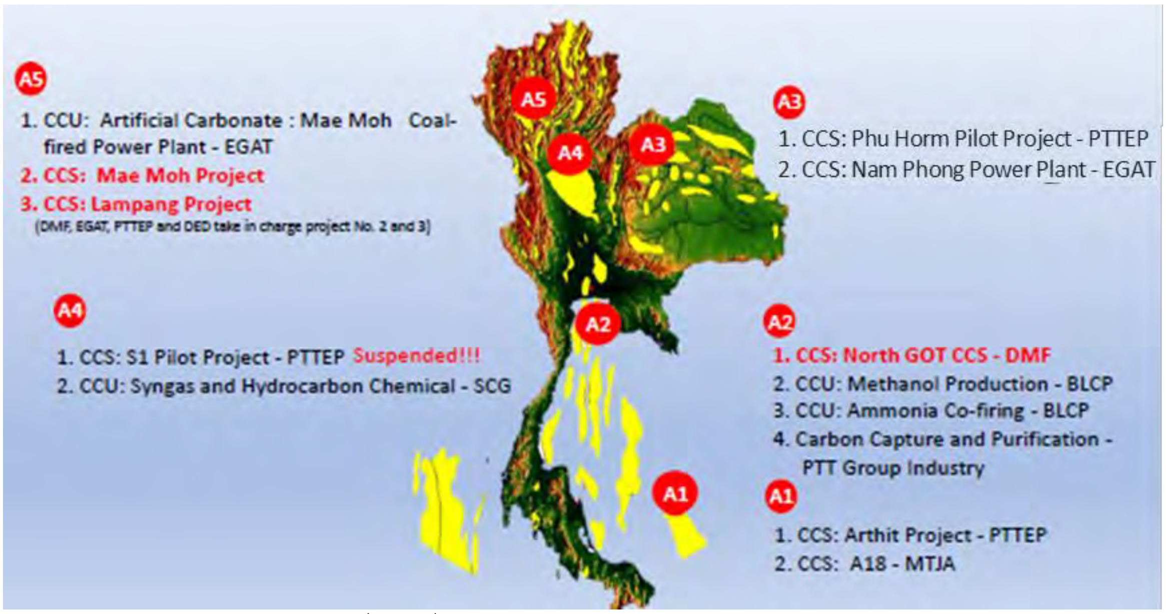
Carbon dioxide (CO_2): CO_2 is well recognised and is widely used in the industrial sector. The Asia and Pacific food grade CO_2 market size was valued at $407.6 million in 2021 and is expected to expand at a compound annual growth rate of 5.8% from 2022 to 2030. CO_2 application in Thailand is also expanding in proportion to the economic growth in various industrial sectors such as food, dry ice, fire extinguisher, and welding. CO_2 obtained in this project can be directly utilised for such applications, as its purity through the shift reaction is commonly recognised as high enough for food grade purposes.

Figure 3.4. Conventional Application of CO_2 in Current Industries

Source: Edited by JCOAL.

CO_2 for CCUS: CO_2 also can be utilised as a storage gas or reaction feedstock to the several CCUS projects ongoing in Thailand (Figure) without any recovery and purification cost.

Figure 3.14. CCUS Development Plan in Thailand



Source: ERIA Working Group (2022).

CO_2 can contribute to both industrial application and CCUS in Thailand.

5. Surrounding Situation of Project Implementation

5.1. Policies

Thailand's biomass policy landscape is characterised by comprehensive government initiatives and policy frameworks that aim to foster the growth of the biomass sector.

Alternative Energy Development Plan (AEDP): The AEDP, launched by the Ministry of Energy, serves as a roadmap for renewable energy development, including biomass. It sets specific targets for biomass energy production and outlines strategies for promoting biomass power plants, biogas production, and biomass utilisation in various sectors. The targets include increasing the biomass power capacity to 5.6 GW, ethanol production to 11.3 billion litres, and biodiesel production to 14 billion litres by 2037 (Ministry of Energy [Thailand], 2021a).

Feed-in Tariff (FiT) Scheme: Thailand's FiT scheme provides favourable electricity purchase rates for biomass power producers, incentivising investments in biomass projects. The FiT rates are structured based on the plant's capacity and technology, ensuring a stable and attractive revenue stream for project developers.

Power Development Plan (PDP): The PDP outlines Thailand's long-term energy strategy and includes provisions for promoting renewable energy, including biomass. The plan sets capacity targets for biomass power plants and emphasises the need for sustainable biomass sourcing and utilisation (Ministry of Energy [Thailand], 2021b).

Regulatory Framework: Thailand has established a supportive regulatory framework to facilitate the development of biomass projects. The Electricity Generating Authority of Thailand (EGAT) and the Office of the Energy Regulatory Commission play key roles in overseeing and regulating the biomass sector. These institutions ensure compliance with standards, facilitate project approvals, and promote FiT mechanisms to encourage biomass power generation.

5.2. Investment

Thailand has historically implemented various investment promotion measures to encourage domestic and foreign investments in the renewable energy sector, including biomass utilisation (ITA, 2021).

Thailand has adopted a new Five-Year Investment Promotion Strategy for 2023–2027, identifying bioenergy as one of the targeted industries for strategic development. The strategy aims to promote green and sustainable growth, enhance competitiveness and innovation, and support regional development and connectivity.

The Board of Investment (BOI) offers various incentives for bioenergy projects, such as tax exemptions, import duty reductions, land ownership rights, and visa and work permit facilitation. The BOI also offers special incentives for projects that align with the Bio-Circular-Green (BCG) Economy model, a new economic paradigm that aims to create value from biomass resources while reducing environmental impacts and enhancing social well-being (JETRO, 2021a).

Thailand has also implemented a project to promote small-scale biomass gasification plants in rural areas, with funding from the Global Environment Facility (GEF) and cooperation from the United Nations Industrial Development Organization (UNIDO). The project aims to reduce greenhouse gas emissions, increase energy autonomy, and encourage community participation in establishing and operating pilot plants that use local biomass residues to generate electricity (GEF, 2018).

As of December 2020, 107 biomass power plants were in operation, with a total installed capacity of 3,424 MW; 1,057 biogas plants in operation, with a total installed capacity of 600 MW; and 25 biofuel plants in operation, with a total production capacity of 9.7 million litres per day.

5.3. International Cooperation

Thailand has been working with various international organisations and partners to promote the development and utilisation of biomass energy, such as UNIDO, GEF, the World Bank, the Asian Development Bank (ADB), Japan International Cooperation Agency, and the German Agency for International Cooperation. These agreements could cover areas such as technology transfer, research collaboration, and policy development (UNDP, 2022).

The UNIDO-GEF project promotes small-scale biomass power plants in rural Thailand for sustainable renewable energy management and community involvement. The project aims to demonstrate the feasibility and benefits of biomass gasification technology and to build capacity for community-driven renewable energy management. The project received a grant of $4.5 million from GEF and mobilised $16.8 million from co-financing sources.

The World Bank project on biomass generation and cooperation. The project aimed to remove the barriers to the development of biomass power generation in Thailand, such as lack of awareness, technical expertise, financing, and regulatory support. The project received a loan of $40 million from the World Bank and mobilised $60 million from co-financing sources.

ADB has a project promoting renewable energy, clean fuels, and energy efficiency in the Greater Mekong Subregion (GMS). The project aims to enhance regional cooperation and integration amongst the GMS countries (Cambodia, China, Lao PDR, Myanmar, Thailand, and Viet Nam) in developing and utilising renewable energy sources, such as biomass. The project received a loan of $63 million from ADB and mobilised $97 million from co-financing sources.

6. Recommendations

As a comprehensive biomass utilisation in Thailand, the sub-study team conducted a conceptual feasibility study on the combination of biomass gasification and fuel conversion process as well as the utilisation of gasified by-products such as combustion ash and CO_2. As a result, process feasibility strongly depends on biomass cost, and cases are limited to less than 240 THB/t-biomass cost with the capacity of 50 t/d gasification.

6.1. Technical recommendations

The sub-study was not conducted at a specific site or specific equipment but it was based on a relevant policy situation in Thailand, average biomass analysis data, typical equipment configuration and their performance. Therefore, the accuracy of the analysis has some constraints. It is strongly recommended to implement an engineering study by the technology supplier or engineering firm for further detailed study. Biomass collection might be the primary issue to be considered in the feasible cases of 50 t/d at the community gasification plant. Also, syngas transport to a chemical plant is another point to be considered mostly in terms of safety concerns. There remains potential for improvement in the product mix leading to more beneficial combinations depending on domestic demand and product prices. On the other hand, it would not be economical to generate electricity at a community plant in parallel with syngas production. To improve this, it is necessary to consider increasing the scale of or separating the gas production and power generation for each community plant. Maximising by-products is recommended since H_2, N_2, and CO_2 production can contribute to the feasibility of the whole process.

6.2. Policy Recommendations

Government support for biomass collection would be beneficial in improving the gasification of plant operations and project economy for such a project to be profitable, thus contributing to local community development. Also, the syngas produced from biomass is deemed to be carbon neutral, making such a project advantageous in securing better price incentives for the produced syngas.

Incentives for biomass cost issue and/or financial support of facilities by the government for expediting biomass utilisation in Thailand are recommended. When implementing a specific project for the first time, the central government should lead cross-sectoral collaborations, involving local governments, local communities, equipment manufacturers, energy suppliers, and product off-takers. That way, wide dissemination is expected without individual efforts to formulate a project from scratch once a model case in a specific location is implemented with government support and initiatives. In that case, pursuing an optimal process tailored for individual conditions, such as the surrounding industrial structure, the type and amount of biomass to be collected, etc., is desirable.

The current proposal is a combination of existing technologies, and some of these technology suppliers would be overseas companies. It is then important that they be introduced within the framework of international cooperation. There are already various cooperation frameworks for biomass utilisation, focused on biomass power generation.

Chapter 4
Recommendations for the ASEAN Region

1. Available Technologies and Technical Solutions: Grid stabilisation

- Grid stabilisation measures and technology from non-grid system end is crucial.
- There are well-proven technologies such as synchronous condenser, flywheel, and pumped storage hydropower.
- There are also close-to-commercialisation technologies, such as grid-forming inverter system and motor-generator sets.
- Synchronous condensers have advantages in terms of a variety choices. They can be installed afresh, while synchronous generation facilities can be retrofitted and transformed to synchronous condensers as well. They can also be introduced in combination with flywheel, by which inertia supplying competency will be enhanced.
- Grid-forming to replace conventional grid-following is a new concept involving technology introduction, and regional, social, and/or community development. Grid-forming inverter systems will be useful by themselves and as part of an entire grid-forming activities that will be conducive to local independent grid system management, amongst others.
- It is crucial to conduct a system stability assessment on the latest power equipment plans and reflecting measures to ensure system stability based on the results of power equipment plans at an early stage.

2. Available Technologies and Technical Solutions

Biomass utilisation by gasification and fuel conversion process would be an excellent option in the future, if the following points will be well considered and addressed by the central government in collaboration with local authorities, local communities, and the private sector such as utilities and industries. This is especially when such carbon-neutral fuel can potentially contribute to the transport sector, which strongly depends on the development of EV for carbon neutrality.

- Sustainable supply of biomass
- Produced energy transport especially in terms of safety concerns
- Optimal product combination

- Central government to lead cross-sectoral collaborations, involving local governments, local communities, equipment manufacturers, energy suppliers, and product off-takers
- Central government and local governments to work together to provide appropriate incentives with flexible choices for those who try to participate in related projects to help expedite further biomass utilisation

3. Policy Recommendations for ASEAN

As the focus of the power sector is shifting towards VRE and grid systems are not always economically viable, the power sector is expected to introduce incentivising schemes and markets, such as inertia power market, capacity market, etc., tailored to the conditions of the country.

AMS with fully nationally controlled power sector will be required to take steps towards reformed and a reorganised power sector with competitive environment that helps expedite energy transition.

Since ASEAN countries have different but, to some extent, similar conditions, it would be highly recommended to learn from some advanced AMS that have taken a few steps forward in power sector reform.

The agricultural sector in the ASEAN region is one of the world's leading sectors that support their growing economy. Such various agricultural residues in ASEAN as biomass energy has a big potential in applying carbon-neutral energy not only for power but also for the industry and transport sectors. Therefore, maximising biomass energy utilisation is essential to achieving carbon neutrality in ASEAN in the future.

In ASEAN, the base of various support industries is expanding in the industrial and transportation fields, in the sense of achieving carbon neutrality by using existing engines and combustion technologies. Converting technology from biomass to gas or fuel is very meaningful.

It is worth working on the practical application and commercialisation of these technologies throughout ASEAN under the strong support by each AMS.

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Appendix I

Working Group Members

Country	Institution	Name and Designation
Indonesia	Ministry of Energy and Mineral Resources (MEMR)	Anandita Willy Kurniawan, Policy Analyst, Directorate of Electricity Supervision Program, Directorate General of Electricity
		Agung Sulistyo, Policy Analyst, Directorate of Electricity Supervision Program, Directorate General of Electricity
		Suryo Utomo Electricity Inspector, Directorate of Engineering and Environment, Directorate General of Electricity
	PLN	Arief Sugiyanto, Vice President of RUPTL Controlling, System Planning Division
		Tri Hardimasyar VP Technology Innovation and Business Incubation, Corporate Business Development and Investment
		Yenni Tarid Palimari VP System Planning of Jawa Madura Bali Division of System Planning
Malaysia	Energy Commission (ST)	Noorly Akmar BT Ramli Assistant Director
		Mohd Amirulazry Mohd Amin, Assistant Director
Thailand	Ministry of Energy	Yaowateera Achawangkul, Mechanical Engineer, Senior Professional Level of the Energy Research Division, Department of Alternative Energy Development and Efficiency (DEDE)
		Apiradee Suwannathong, Senior Professional Geologist, Department of Mineral Fuels (DMF)
Vietnam	Ministry of Industry and Trade	Hoang Thi Thu Ha, Power System Development Department IE(Institute of Energy)
		Nguyen Van Duong, Power System Development Department IE(Institute of Energy)

Appendix II

Report of the First Working Group Meeting

ERIA Research Project 2021/2022

First Working Group Meeting for the Study on the Applicability of CCT for Comprehensive and Optimal Carbon-neutral Solution in ASEAN (Hybrid), 5 July 2023

Attendance: Working Group Members, ERIA and JCOAL at the First Working Group Meeting

Country	Institution	Name and Designation
Indonesia	Ministry of Energy and Mineral Resources (MEMR)	Agung Sulistyo, Policy Analyst Directorate of Electricity Supervision Pro g ram, Directorate General of Electricity
		Suryo Utomo, Electricity Inspector, Directorate of Engineering and Environment, Directorate General of Electricity
	PLN	Arief Sugiyanto, Vice President of RUPTL Controlling, System Planning Division
Malaysia	Energy Commission (ST)	Mohd Amirulazry Mohd Amin, Assistant Director
Thailand	Ministry of Energy	Yaowateera Achawangkul, Mechanical Engineer, Senior Professional Level of the Energy Research Division, Department of Alternative Energy Development and Efficiency (DEDE)
		Apiradee Suwannathong, Senior Professional Geologist, Department of Mineral Fuels (DMF)
Vietnam	Ministry of Industry and Trade	Nguyen Van Duong, Power System Development Department IE(Institute of Energy)
ERIA		Toru Furuichi, Director General for Research and Policy Design Administration
		Han Phoumin, Energy Economist
		Rabindra Nepal, Associate Professor
		Ryan Wiratama Bhaskara, Energy Research Associate
		Citra Nur Endah Setyawati, Energy Research Associate
		Kei Sudo, Senior Policy Advisor for Energy
JCOAL		MURAKAMI Kazuyuki, Director, International Collaboration Department
		SAKATA Fumitoshi, International Partnership Coordination Group Leader, International Collaboration Department
		OZAWA Masahiro, Chief Engineer, International Collaboration Department
		YAMADA, Fumiko, Assistant Director, International Collaboration Department

At the outset, Ms Yamada of JCOAL as the Master of Ceremony (MC) announced the start of the meeting and that JCOAL has changed its formal name in full: Japan Carbon Frontier Organization. Then Furuichi Toru, Director General for Research and the Policy Design Administration of ERIA delivered the welcome address.

Welcome Address by ERIA

Furuichi: Thank you very much, the Working Group Members, ladies and gentlemen, good morning. I am very pleased to welcome you all to the first working group meeting on the applicability of comprehensive and optimal carbon-neutral solutions in ASEAN's energy transition, which is substantially phase II of the previous study. I would like to mention important studies in line with ERIA's recently published document on the technology list and the perspectives for the transition of finance in Asia (TFETA), which aims to support the smooth energy transitions in developing Asia, with realistic approaches that can facilitate many Asian countries in embarking on pathways to carbon neutrality while considering energy security, affordability, accessibility, and environmental protection simultaneously. It is very important to note that the combustion of coal-fired power generation with ammonia and hydrogen fuel amongst transitional technologies is highly recommended in ASEAN energy transition–related study.

The previous study report was just published on the ERIA website. The focus was on the choice of appropriate technologies. The second phase is more focused on technology introduction in terms of required institutional arrangements, stakeholder involvement for value chain formulation, and technology applicability.

Taking about technology, every technology has its own stage. CO_2 reduction at the combustion stage such as biomass cofiring and ammonia coring with coal-fired power generation. Then comes CO_2 removal, recovery, and utilisation from post combustion of exhaust gas by technologies such as CCS and CCUS as well as carbon recycling. The study will explore the possibility of introducing the optimum combination of technologies and comprehensive decarbonisation solutions that can be very suitable for regional circumstances in the ASEAN region and the national circumstances of each AMS.

I understand there are numerous opportunities for emissions reduction in the ASEAN region that are conducive to carbon neutrality. We should note, at the same time, that AMS' safeguarding of the energy supply is another crucial mandate under the current global and social constraints.

Ladies and gentlemen, last but not the least, I wish to take this opportunity to thank all the previous and current studies' working group members for your contribution to this study. I wish you will share your views, information, and insights during the discussion, which will make the meeting fruitful. Thank you very much.

Dr. MURAKAMI Kazuyuki, Director, International Collaboration Department, JCOAL, made brief remarks on behalf of the study team.

Murakami: Good morning. First of all, I would like to thank all working members from Indonesia, Malaysia, Thailand, and Viet Nam, and officials of ERIA for participating in this meeting. Thanks to your cooperation, we were able to undertake the current study as a continuation of the previous study. Let me emphasise that the point of the current study is that we pursue proposals for practical solutions. After continued communication with the working group members, desk study activities including analytical work in consultation with our partners in Japan and overseas, I hope we will be able to show the detailed results at the Second Working Group Meeting. I look forward to all your inputs to the discussion, as this meeting is important, being the first milestone of this study.

Each participant introduced himself or herself, followed by information about the meeting agenda.

Outcomes of the Previous Study and Outline of the Current Study

M. Yamada, on behalf of the Study Team, briefed on the outcomes of the previous study and outline of the current study.

Q & A Session:

Duong: I have a question to Thai members. Is there any banning of the export of domestic biomass resource from Thailand due to the national policy implementation?

Yaowateera: Thailand's Energy Ministry has the plan to promote renewable and alternative energy, called AEDP 2018, which is a revision plan before we launched National Energy Plan 2022. Initially, the newest national energy plan is scheduled to be published within this year. However, the direction of renewable energy promotion strategy will depend on the decision of the new Thai government. For biomass utilisation in Thailand, we plan to promote domestic agricultural wastes, regarded as the priority for power generation or heat generating, due to their availability and abundance.

In addition, some types of agricultural biomass, such as sugar cane or rice husk, have been completely utilised. Alternative biomass – such as rice straw, sugar cane top and trash, or rubber wood waste – are being considered for energy production.

For the second possibility, while Thailand is considered as a high potential renewable resource for energy production, if the implementation stage of syngas production from gasification process approaches, users may face high operating costs in terms of transportation and logistics. As a result, people are urged to gather and use biomass to generate power on-site or nearby to avoid the high transportation and logistics costs.

The morning session was closed with the announcement of lunch invitation.

Proposed study for Indonesia:

The outline of the study for Indonesia was presented by JCOAL's Indonesia sub-team.

Proposed study for Thailand:

The outline of the study for Thailand was presented by JCOAL's Thailand sub-team. Then the floor was opened for Q & A.

Q & A Session:

Yaowateera: I would like to clarify the definition of biofuel in Thailand. We generally emphasise the use of biofuel as a fuel for power generation, whereas other biofuel (e.g. bioethanol and biodiesel) is used as a transport fuel. We can go back to the question on page 28: we must discuss how we utilise biofuel in the industrial or state transportation sector.

Murakami: Biofuel may be for transportation, as petrol and diesel. Also, utilisation as jet fuel is quite promising.

Phoumin: When we talk about biomass power generation, we talk about electricity, with biomass for gasification and gas turbine or others. As for feedstock, do you have feedstock for bioethanol in Thailand? Bioethanol from feedstock like gas turbine and others, but for biofuel, they have palm oil from kennel. Now I am wondering what kind of feedstock we are focusing on through this study on biofuel in Thailand: whether it is normal feedstock like wood, waste wood, and other that normally go for power generation in Thailand.

Yaowateera: We used to discuss about biomass such as waste-to-energy power generation with fuel produced from wastewater and municipal waste. Recently, agricultural wastes are the dominant fuel, like rice husk, waste wood, sugar cane bagasse, while biogas is being used for both power and heat generation. If we consider deeply the utilisation status between power and heat, heat generation is considered the priority. In the previous study, gasification was mentioned as the suitable technology for advanced products, such as hydrogen, ammonia, or synthetic oil.

In the past, private companies installed a large amount of biomass gasification in the area that have high potential in the biomass fuel supply. However, it was accompanied by complicated operation in biomass gasification, for example, frequently a system clean-up. Eventually, biomass gasification is no longer popular; there are a lot of abandoned gasification sites. In my opinion, it is possible to modify or retrofit abandoned biomass gasification power plants through government support to execute the roadmap or the key policy, as well as technical support to the potential power plants.

Furthermore, the average installed capacity of biomass gasification power plant in Thailand is less than 5 MW per plant, and only a little amount of hydrogen and its derivative products seem to be obtained. In this regard, it is interesting to compare the feasibility between retrofitting of old gasification plants and construct new plants. Likewise, logistics between the producing facility and the utilisation unit should be included.

The promotion of the domestic use of hydrogen is considered in the further step. It is also important to conduct the study in more detail. If biomass will be aimed to generate electricity for reduction of grid extension, it is necessary to consider the methodology to transform raw biomass to the advanced biomass (e.g. torrefied biomass), which contains a higher calorific value, and can be fired with coal. According to the fact, many industries in Thailand – such as the cement and food industries – usually use imported coal for heat generation. Accordingly, adequate mixing ratio that will maintain the combustion efficiency with less modification to the system is a significant issue to be considered.

Besides the consideration of plant capacity and possible advanced products' generation, it is important to create the energy demand side, by allocating proper incentives or policies. Increasing energy (fuel) demand results in the suppliers' heightening.

Finally, we should consider the optimal price of fuel blending between biomass and coal, which should not be a burden to the energy user. Otherwise, the cost of the final product might rise, and the consumer will eventually bear the burden.

Murakami: Thank you, and that is a very important input for us. So, may I ask? You mentioned that the gasification generation plant is about less than 5 megawatts. In that case, how about the total volume of biomass at the gasification plant?

Yaowateera: Generally, it depends on the feedstock property, type of biomass, and reactions inside the gasifier. However, 1 kilogram biomass can generate approximately 1–2 kWh of electricity. (Yaowateera will investigate the precise figure in this regard.)

Phoumin: So, it depends on the calorific value of different types of the stuff. I would like to know the cost information and plant specification, if any existing plant for biomass gasification with expectation to future hydrogen production is in place. Information about the minimum scale for economic viability would help.

Then, if it turns out that it is not economically viable even with some envisaged incentives through policy measures, then solar PV would be a better option to produce the hydrogen if hydrogen is the end product. This is because we do have many cases of conversion from biomass, gasification, and hydrogen. The ASEAN region has advantages since feedstock can be cheaper compared to Japan and Korea and other or cheaper feedstock. Perhaps we can also lower the cost of hydrogen.

Murakami: We have started calculation of the fusion point. So far, in our estimation, a single calorie of biomass is much lower than that of natural gas because during the gasification process, syngas is directed by nitrogen. So we must add air for partial expansion. In this case, nitrogen is 80% of the air so that includes the syngas. We are seeking a separation process using PSA to make pure nitrogen, as it is currently carrying syngas and utilising it. And syngas if converted to liquid fuels. Estimation of liquid fuels so far indicates hydrogen is more precious than liquid fuels. I think liquid fuels should be compared to the current fuels.

So, we cannot add a higher price. But in hydrogen, we are sure. Of course, hydrogen is a derivative from biomass; it means green hydrogen. So far, in my calculation, only a small part of syngas is converted through shift reaction to make hydrogen. But if hydrogen is estimated to be more beneficial, all syngas should be shifted to hydrogen. In such a case, the FT synthesis might be excluded from the whole process.

Yaowateera: Theoretically, hydrogen content in the syngas is approximately 10% or 15% if it is the ordinary gasification reaction. However, if system modification is needed, we can use the water-gas shift reaction to increase the ratio of the hydrogen content in the syngas. My feeling is that the syngas and, eventually, the hydrogen cannot compete with available energy sources. For example, if hydrogen is to be used in the transport sector, Thailand is currently promoting the use of electric vehicles. When considering the fuel cost for electricity and comparing it to the cost of using hydrogen as a vehicle fuel, if hydrogen remains expensive, it may not be able to compete with other transport fuels or electricity.

Thailand is currently in the process of developing a roadmap to promote the use of hydrogen. Additionally, there is an urgent need to establish regulations for hydrogen transportation. In addition, hydrogen-related infrastructures such as fuel stations will be simultaneously introduced. However, installation of a hydrogen vehicle fuel station cost might be two to four times compared to a petrol station.

Murakami: Later, I will show you my general calculation by email. As per my estimation, the cost of liquid fuel is about more than half of the benefit. That means it is not commercial. But in case of hydrogen, the cost is about less than 50% against the benefit. I mean, hydrogen gas is basically pressured. That is why we must think about hydrogen. Syngas fuel hydrogen has more advantages than liquid fuels. In any case, we must study further. Thank you. We focused on biomass turbine intervention. Are there any other questions or comments for Thailand?

Yaowateera: The first scenario, proposes to promote the community gasification plant. However, due to the recent circumstance, biomass gasification plants are mostly abandoned. Thus, it is interesting to determine the method of modifying the gasification plants for other applications, such as pyrolysis oil production, or thermo-chemical hydrogen production.

Murakami: Yes, actually, I can choose between generation and gasification, so far any ratio. Currently, you are considering a gasification process that produces 5 tonnes per day, which is a relatively small scale. In that case, it would be better to go for gasification as biomass generation might be more costly. That being said, it depends on the type of biomass as well.

Yaowateera: For the third question, which corresponds to power tariff in Thailand. At present, Thailand mainly uses natural gas as the main fuel for power generation, whereas the renewable energy power ratio becomes approximately 25%.

Murakami: I find the rate on the website is about THB4.14. Is that relevant? I am not sure, but yes, we can choose the cheaper cost for industry use. It could be better.

Duong: May I suggest that we use the average cost? We do not care about the high price of the fuel, but we can refer to the over-generation cost per unit. What do you think about my idea? As I mentioned, if you use natural gas, the LCOE will be different from renewable energy.

Yaowateera: For power generation using biomass as fuel because it is a type of renewable energy, the government provides subsidy, called feed-in tariff (FiT), which depends on the installed capacity, type of fuel, location, and envisaged operation period.

Murakami: Thank you for the advice. So far, I have not specified the site. That means, I do not specify the type of biomass. Only in the typical ones, we can get from our website. So, your input for the monitoring would be quite welcome.

Phoumin: I remember that when we did the course study under asset collaboration, we had the AGEP program. At that time, maybe that was 5 years ago, they had a study involving renewable energy. You can refer to the labour costs and fuel costs from the study. However, please note you are supposed to obtain updated information as well.

Q & A session about the study outline was over.

Energy Transition Updates – Thailand

Thailand's by-country energy transition updates were initiated by Dr Yaowateera Achawangkul, Mechanical Engineer, Senior Professional Level, of the Energy Research Division, Department of Alternative Energy Development and Efficiency (DEDE).

Q & A

Phoumin: Thank you, Dr Murakami. Dr Yao, I think this is a very comprehensive presentation. I think it is very good for Thailand. I just want to know the subsidy, which you mentioned as 30%, in connection with equipment purchase. In the United States, we call tax credit. The investor can get a discount anywhere if that material is related, let's say, for biomass, EVs, or charging stations. Now, if we were to refer to the tax code that reduces inflation, we could consider it a form of subsidy. But how it can be done? If I am an investor, how can I get this subsidy? You mentioned a 30% discount when purchasing this equipment. Please clarify how this is applied? And who provides it?

Yaowateera: To ramp up renewable energy utilisation, the Energy Conservation Promotion Fund (ENCON Fund) is the potential government fund that the Ministry of Energy uses for renewable energy project implementation, in terms of partial investment subsidy. To apply the investment from the ENCON Fund, the project owner should prepare a proposal to explain the objective of the project, including the amount of investment capital cost.

Duong: So, fund revenue comes from the extra charges on the fossil fuel import, right?

Yaowateera: The ENCON Fund gathers money from petrol's levy**.** The fund objective is to use it for revolving capital and expenditure for subsidising the activities related to energy conservation.

Duong: In slide 8, I noted that you have FiT for solar grounds and solar plus BESS, and it is quite high. So, Do you have any specific requirements for integrating the BESS system with the solar energy capacity or volume? This solar plant needs to install BESS, for example, at least, 50% of the capacity of the solar plant, Will you get the higher price? What is the minimum requirement for BESS to get the FiT rate?

Yaowateera: The minimum requirement of BESS capacity to apply FiT is fixed in the criteria (The number needs to be rechecked.)

Ozawa: What is the non-firm contract and partial-firm contract?

Yaowateera: At present, the power purchasing contracts are divided into three tiers. The first contract is called 'firm contract', which requires the minimum amount of generated electricity from power plant to the utility. The electricity seller will benefit from a higher payment for the purchase of electricity than under other contracts.

The second is the 'non-firm contract', which has no minimum amount of electricity to be sold to the electricity authority. However, the electricity purchase price is lower than the firm contract. Therefore, this contract is seemingly suitable for low stability renewable energy sources, such as solar, wind, or some type of biomass.

'Partial-firm contract' allows the power seller to select the time to purchase generated electricity, which will be more flexible than a firm contract. This contract is suitable for a combined renewable energy system, for example, solar with biomass, or battery energy storage system.

Dr Apiradee Suwannathong, Senior Professional Geologist, Department of Mineral Fuels (DMF), made the second presentation on CCUS as part of the Thailand by-country updates.

Q & A

Phoumin: Yes, thank you, Dr Apiradee. I appreciate your very comprehensive presentation on CCUS in Thailand. I wonder if there is any idea already in terms of carbon credit in Thailand?

Apiradee: As for carbon credit, we are trying to study by TGO (Thailand Greenhouse Gas Management Organization) right now because it is still new to us. CCUS is quite new in Thailand; we try to escalate carbon prices and carbon credit. We study about what is called '45 Q type' that is from the US. In any case, we require another 1 to 2 years to determine the framework of a scheme suitable to Thailand.

Phoumin: That will be very good. Any other incentives to facilitate investment in CCUS, like

Dr Yao said, if you procure particular items, you will gain 30%?

Apiradee: We try to discuss with partners or stakeholders, like BOI, because right now, the CCUS is not involved in activities to get the incentives. Therefore, we discuss with them and input the CCUS as new activity; they can get incentive as well.

Phoumin: That is good. I think Thailand is already a fast mover.

Apiradee Suwannathong: No, no, you do not see fast move for Thailand.

Phoumin: Yes, thank you so much.

Murakami: Thank you. Any other questions or comments? Sorry, just one short question. I missed the first half of your presentation, but may I know the total potential of CCUS in Thailand?

Apiradee: Right now, we are focused on the initial phase of activity. We will try to identify the potential area and potential storage capacity as well as possible social impact including job creation, etc. It is still new to Thail society, though we have experts who are well versed in the field. We are trying to involve many parties to help us. Currently, we focus on the three areas, as I mentioned, Lumpa Memo and the northern part of Thailand, to solve CO2 emissions from coal-fired power plant and the eastern coastal area.

Murakami: Thank you for your nice presentation.

Duong: About the investment cost for the eastern zone CCS in the thermal pipeline. May I know the number of cases in Thailand?

Apiradee: We implement it in a phased manner. For the first phase, we try to evaluate the potential areas, which require a large amount of budget. So, Thailand is trying to secure funds from other countries. We proposed the project to the US, Japan, and then we hope we can get funding support from JBIC or METI. Right now, we assume that to be approximately THB7 million to THB1000 million. We are going to focus on the size skinning by using the subsurface data from the EIP Business. The area is about 25,000 square kilometres (km^2). We will scope down through site selection, then it will be 900 square km^2 to survey, to do 3D, 2D surveys. If the result is good, we will proceed to the next phase.

Duong: That is not just for Thailand. According to my knowledge, CCS is quite expensive now. We installed CCS in the existing power plant and it cost more than $2 million per megawatt. It is quite high.

Energy Transition Updates - Indonesia

Energy transition updates on Indonesia was made by Mr Agung Sulistyo, Policy Analyst, Directorate of Electricity Supervision Program, and Mr Suryo Utomo, Electricity Inspector, Directorate of Engineering and Environment, both from the Directorate General of Electricity, Ministry of Energy and Mineral Resources (MEMR). These were followed by the other presentations by Mr Arief Sugiyanto, Vice President of RUPTL Controlling, System Planning Division, PLN Indonesia.

Q & A

Phoumin: Thank you so much, Arief-san. I think Indonesia has a very comprehensive roadmap for the net zero pathway. There is some concern in terms of mobilising enough investment to decarbonise this system. In this context, I would like to know how you expect such investment and funding will be in place, as you lay out very clearly what and when a technology will be involved. You also involve nuclear, which might be the last option in terms of cost. I am wondering whether Indonesia is considering a new institution that oversees the overall progress to ensure the coherence of policy, including the progress of transforming the system. For example, retrofitting for coal combustion with biomass, ammonia, and other coals.

I also would like to know about the envisaged market structure side, requirements for carbon capture, as well as the monitoring and verification system. How about investment, particularly for coal? Many international banking institutions do not provide funding for coal. But under the area of framework, we are seeking for transition finance.

Arief: I think that is correct. So, for the implementation plan, we have challenges. That is why in our roadmap, new technology like nuclear and CCS will come after 2040 while we expect a lot to biomass cofiring in the short term. We have conducted biomass cofiring pilot projects to the ratio of 1%–5% of biomass at existing coal-fired power plants. With 5%, we do not need additional investment. But if we increase more than 5%, then we will need more investment for the modification of coal-fired power plants. Financing is still in progress. We will study first, if we increase biomass cofiring up to, for example, 30% or something and how much we need the investment, and then we will talk to the lender. Most lenders will not fund the coal-fired power plant, but for biomass, I think the World Bank has some repurposing scheme. But I am not sure yet if Japan also has this opportunity for funding to increase the biomass cofiring in the future for the new technology, I think that will be very helpful for us to implement biomass cofiring.

Agung: Okay. Thank you, Arief. Let me make a complementary explanation. We are currently exploring operation, one of which is with the energy transitional program, which provides funding in the key transition. Currently, we are looking for an appropriate mechanism that is mutually beneficial, that can be accepted by Indonesia and financial institutions such as Jafi. Thank you.

Yamada: I have a question for MEMR. As Dr Phoumin said, a roadmap is very much close to perfect. But I did not see really that, for instance. Also, you know, the point is the introduction of renewable energy because it is sustainable. At the same time, energy storage technology should be in place and should be affordable. Additionally, coal-fired power plants should be retired in a phased manner, running in parallel.

But I cannot see in your presentation and/or maybe in any other presentation or any other information I have seen on the internet how you will provide required balancing sources. Several partnerships have been agreed, including JETP, and they may help Indonesia in converting coal-fired power plants into synchronised condensers to support the introduction of renewable energy. What I would like to know is whether you will go for such power plant-conversed synchronous condensers and/or what kind of measures the government and the PLN have in mind. In summary, a combination of the technology you have in mind for supporting this grid stabilisation from the other end?

Agung: Thank you, but I think your question is very complex, so we will answer that question sometime later.

Yamada: Additionally, from the point of market formulation, it is not about near power market. But I think Malaysia is already thinking about things like capacity market; then how Indonesia will be working towards such market formulation. I think matters such as capacity market formulation are undertaken by your ministry. I would appreciate your feedback later on perspectives of near-future or future market formulation.

Agung: I will try to answer your question. I have in my mind to support the utilisation of PRA in Indonesia. I think we need power plants that have a higher rate like gas power plants. But maybe we can change the gas with gas from biomass. Maybe our colleagues in the renewable energy directorate can explain further about the utilisation of gas from biomass. Because if we utilise battery energy storage, as Arief mentioned, it is very expensive and maybe we need a very large space for the batteries. I think what is very affordable is to utilise the gas power plants that we have now, but we change the fuel with gas from biomass.

Duong: I would like to ask both the MEMR and the PLN. Thank you for the presentation. I would like to know if you have cofiring in the implementation stage. And the second question is, I see two cofiring hydrogens. If you will produce green hydrogen by yourself, is that for domestic use or are you also exporting the produced hydrogen? The third question is, did you consider electrical vehicles (EVs), or the modelling of EV, in power development planning. Thank you.

Arief Sugiyanto: Yes. Most of our efforts now are dedicated to hydrogen. We have a pilot project for hydrogen and ammonia. We use hydrogen for gas-fired power plants and ammonia, for gas and steam gas. In the future, we will implement cofiring with biomass for most of the existing coal-fired power plants mostly because it is possibly cheaper. If we produce hydrogen or ammonia domestically, it may be cheaper, while continuous dependence on import would make it more costly. So, this is also the point we need to study further, supply of hydrogen and ammonia. That is a challenge for us. And the second one is about EV. Yes, in the net zero emission roadmap, we consider transportation demand, the additional transportation demand from EV.

Duong: Thank you. About ammonia cofiring, I think Indonesia has conducted testing at existing power plants. So, could you please share the results of this pilot project testing?

Arief: For hydrogen, we have testing in Bali and ammonia; we have testing in East Java. So, I think it runs well, but the problem is the cost and the supply of the ammonia. The cost is currently still high. This is only for testing the pilot project. But if we want to implement further, we need to have cheaper cost for hydrogen and ammonia. I think the result is well.

Duong: I have a question. I see the capacity; you have three scenarios and I see the total installed capacity power system in retrofit scenarios for the Indonesia team here. I see the installed capacity in the retrofit scenarios is higher than the decommissioning scenarios. It does make sense because I think when you have more thermal capacity in the power system, you will need less wind and solar. So initial capacity tends to be lower, not higher. Is there any explanation for this? I mean, when you have thermal capacity in the power system, the total installed capacity should be lower. But here, it is higher. Is there something special here? Anyway, have you or your government chosen one scenario to use? Which scenario do you choose?

Agung: We have not decided on which one we will go for. That relies on how funding and financing and market mechanism will be developed.

Duong: Okay. Well noted. We would like to see which transitional pathway Indonesia will go and how things are to be worked out. One last question is about the super grid system you are planning to deploy. Will that be FDCs or the FVAC system? Thank you.

Agung: We will forward your question regarding the decision on the scenario. Maybe, we will confirm later by electronic communication if required. We cannot address your question right now.

Yamada: Thank you very much, Arief-san. We do not forget extending our appreciation to the two MEMR members attending here in person.

Now, we would like to ask Malaysia, Mr Amirulazry, to make his presentation.

Energy Transition Updates - Malaysia

The energy transition updates on Malaysia were presented by Mr Mohd Amirulazry Mohd, Assistant Director, Energy Commission Malaysia.

Q & A

Yamada: I have a few questions. Firstly, in this new scheme, you limit the total application in terms of power capacity up to 800 MW in total, and the scale of the solar power to be developed is between 5 MW and 30 MW, right? Is there any particular reason for that?

Amirulazry: Because of fairness, we do not want one company to take all the quotas, that is why we set the limit of 5–30 MW, and then we divide.

Yamada: How about the ceiling of 800 MW? You are planning to do it in a phased manner after looking at the status of the development of 800 MW. Then maybe 3, 4, or 5 years later, you plan to do the same thing?

Amirulazry: Actually, when this program was developed, it was originally only 600. When the announcement was made by our PFC, it was increased by more than 200 megawatts.

Yamada: Yes, it is understandable because in one-and-a-half months, since the beginning of April, you over 60 companies. So, I think that is a close base. Thank you very much.

And data is not directly related to your presentation. Maybe a month ago, I read in Malaysian media that your prime minister mentioned and verbally supported National Science Malaysia.to function as a focal point in the field of hydrogen, I think their roadmap is yet to be nationally approved, however, it is quite comprehensive. That is why I suppose the prime minister mentioned the roadmap as well. Are there any follow-up actions internally or between the relevant institutions?

Amirulazry: Okay. Since the announcement was made verbally by our prime minister during the Energy Asia event recently, maybe this is a good point. But I am not sure on this matter. I will try to find out the current action on hydrogen and we will update you.

Murakami: With energy-intensive industries such as steel making, electrification can be one decarbonisation measure. However, if a much higher temperature, say, more than 1,000^0 Celsius is required, which is often the case for such industries, with electrification it is hard to decarbonise. Hydrogen is the solution in those cases. My question is how you would apply CGPP to such industries.

Amirulazry: Actually, CGPP is focused on solar power, so the scheme is not for decarbonisation for such industries.

Energy Transition Updates – Vietnam

Energy transition updates on Viet Nam were made by Mr Nguyen Van Duong, Researcher, Power System Development Department, Institute of Energy, Ministry of Industry and Trade, Viet Nam.

Q & A

Ozawa: On the last sentence, why is renewable capacity concentrated in South Viet Nam?

Duong: Viet Nam stretches for a long distance from north to south. You know, in the north we have winter, so the solar radiance in the north is not good especially in winter. In the south, it is the same as in Indonesia; we have more sun light and that continues throughout the year. In the south, we have more wind, more solar, and more offshore wind potential. In the past, our load centre in the south was doing well. But now when the south is quiet, how to say, developed enough, we changed to the north. The problem is, in the north we do not have the potential of wind or solar or offshore wind. Now the hydro in the north has been fully exploited. We have also fully exploited coal. Now, we have to impose that we make use of every wind, solar, potential in north. But if not enough, we then have to focus on energy efficiency throughout the country.

Murakami: Coal phaseout is being planned in 2045, but the latest power plant is still under construction. That means the latest coal-fired power plants will operate for a maximum of 20 years, which means early retirement. Is that economically viable?

Duong: We have proposed a roadmap for coal. After 20 years, CFPP will start cofiring at least by 20%, and then, after 10 years, the existing CFPPs will fully run on biomass or ammonia. But with some new coal-fired power plants, such co-firing and switch to 100 % biomass or ammonia will happen earlier than stated in the roadmap, which we are proposing. We have six such power plants. We operate from now to 2030, and this power plant, maybe use steam, start covering after 20 years, or maybe higher, and by 2050 all the coal need to fully convert to the clean fuel.

Murakami: Yes. Thank you very much. Any other questions or comments?

Yaowateera: I have two questions on the presentation. The first question, I heard that Vietnam has the high potential for hydropower. However, it is not shown in Vietnam development plan towards 2050. The second question is that in the year 2050, the existing capacity of offshore wind is higher than onshore wind. Thus, more clarifications are needed for the issues mentioned.

Duong: Thank you. It is a very good question. Of course, we still have to develop hydro as it does not emit CO_2, and it has high flexibility. Now, the capacity of hydro is about 20 gigawatts (GW). You know, the total hydro potential of Viet Nam is about 40 GW. We have nearly more than 20 GW of big hydro. We have more than 10 GW of small hydro.

And we are planning to have nearly 10 GW of hydro expansion. So, in total, it is 40 GW and up to 2030. We will develop nearly 30 GW of hydro. Then until 2050, we will develop all hydro potential, which is nearly 40 GW.

On the second question: offshore wind is deemed to have a higher potential than wind onshore. I think there are two reasons for this. We want to focus on the investment cost of offshore wind, reduce the years. And I think we have challenges regarding offshore wind. However, in view of the limited availability of land for onshore wind projects and of the good potential and advantages offshore wind has, we have little choice but go for the latter. So, in the future, offshore wind would be more competitive in the market.

Wrap-up for Takeaways

Murakami: Thank you very much to all who participated in this important meeting. I would like to wrap up today's meeting. First, on the proposal by the study team regarding the case. It shows us some categories of the issues of grid stabilisation. So, all of you are kindly requested to let us know what further comment and question we should focus on detailed studies in the future. So, regarding Thailand, we propose biomass utilisation to make biofuels, but we have learned about the issues in Thailand for biomass utilisation apart from power generation.

On the second half of the meeting about country updates, we learned much from Indonesia, Malaysia, Thailand, and Viet Nam. Regarding Malaysia, we learned about several scenarios towards emission futures. We learned about the Corporate Green Power Program that is newly started towards carbon neutrality. Regarding Viet Nam, we learned that PDP8 is approved this year. I know that they use much fossil power, fossil energy, such as coal. Viet Nam's government's position in achieving carbon neutrality in 2050 is very important, and therefore very aggressive for their target.

Following the group photo session, the meeting was closed with a vote of thanks.

Appendix III

Report of the Second Working Group Meeting

ERIA Research Project 2022/2023

Second Working Group Meeting for the Study on the Applicability of Comprehensive and Optimal Carbon-neutral Solutions in ASEAN

Meeting held in Bangkok, Thailand and on MS Teams on 11 October 2022

Attendance: Working Group Members, ERIA and JCOAL at the Second Working Group Meeting

Country	Institution	Name and Designation
Indonesia	Ministry of Energy and Mineral Resources (MEMR)	Anandita Willy Kurniawan, Policy Analyst, Directorate of Electricity Supervision Program, Directorate General of Electricity
		Suryo Utomo Electricity Inspector, Directorate of Engineering and Environment, Directorate General of Electricity
	PLN	Tri Hardimasyar VP Technology Innovation and Business Incubation, Corporate Business Development and Investment
		Yenni Tarid Palimari VP, System Planning of Jawa Madura Bali Division of System Planning
Malaysia	Energy Commission (ST)	Noorly Akmar BT Ramli Assistant Director
		Nur Diyana binti Othman Assistant Director
Thailand	Ministry of Energy	Yaowateera Achawangkul Mechanical Engineer, Senior Professional Level of the Energy Research Division, Department of Alternative Energy Development and Efficiency (DEDE)
		K. Wuttipong Geologist, Senior Professional Level Unconventional Fuels Group, Mineral Fuels Management Division, Department of Mineral Fuels (DMF)
		Apiradee Suwannathong Senior Professional Geologist, Department of Mineral Fuels (DMF)
Vietnam	Ministry of Industry and Trade	Hoang Thi Thu Ha, Power System Development Department IE(Institute of Energy)
ERIA		Han Phoumin, Senior Energy Economist
		Tri Muliani Manik, Officer
JCOAL		MURAKAMI Kazuyuki, Director, International Collaboration Department
		SAKATA Fumitoshi, International Partnership Coordination Group Leader, International Collaboration Department
		OZAWA Masahiro, Chief Engineer, International Collaboration Department
		YAMADA Fumiko, Assistant Director, International Collaboration Department

At the outset, the MC, Ms Yamada, welcomed all participants and announced the start of the meeting.

Welcome Address by Dr Phoumin, ERIA:

First of all, a very good morning to you all, and my great respect to the JCOAL team, particularly Dr Murakami, Yamada-san, Sakata-san, and Ozawa-san for their hard work for today's presentation and for preparing for the whole day meeting. This is the second working group meeting on the applicability of comprehensive and optimal carbon-neutral solutions in ASEAN. As you may be aware, each AMS is developing a carbon-neutral pathway. We are facing great challenges on how we are moving away from fossil fuel dependency, since our infrastructure have been based on fossil fuels for decades. To make the shift away from fossil fuels, the first step that is envisaged is the phased retirement of coal-fired power plants, which is not easy as most of them are young compared to other regions and countries. For the upstream sector, probably it is possible to work on the coal infrastructure improvement to some extent by introducing CCUS and/or introducing renewable energy projects to the existing coal project site.

I think JCOAL has done a great job in conducting the study on behalf of ERIA in consultation with ASEAN member countries. Moving forward to carbon neutrality, we cannot overlook what we have done in our history of development and what we have now as a result.

Talking about pathways to carbon neutrality, European countries are actually in a better position than us. Why? Because they have transformed their system while they further developed their grid systems. So, their systems were able to incorporate clean technology, renewable, more easily. The AMS have invested heavily in coal, natural gas, and others. So, we need to work based on whatever infrastructure we have now. Otherwise, the energy cost in financing the value chain will be much more expensive than Europe. Why am I saying that? To retire the coal power plants early, you need new capital to finance such activities.

Now, it matters where the money comes from. It is not possible from only one source – either it is from government subsidies or by raising electricity tariff. Then, you must do new investment of renewable and clean technology. So, this way might not be feasible and suitable for ASEAN countries. We need to work around technology that makes coal cleaner. I think we have the technology – by blending coal with biomass, or with ammonia and combining with technology like CCUS would be the way to get it done.

Remarks by Dr Murakami, JCOAL:

A very good morning. First all, I would like to thank all the members for participating in this important meeting. All working members from Indonesia, Malaysia, Thailand, and Viet Nam and the working members and close friends of ERIA for this study. We will explain the essence of the draft report for comments, advice, and information from the working group members and ERIA.

We have two sub-studies under this ERIA study: grid stabilisation in Indonesia and biomass utilisation in Thailand. However, these sub-studies are not for the concerned countries only. The main objective of our study as well as that of other studies being conducted under ERIA is to provide recommendations as a part of ERIA's policy recommendations to be submitted at the annual East Asia Summit. So, we hope the outcomes of the two sub-studies will be conducive to the policy efforts by Malaysia, Viet Nam who are participating in this working group, as well as the rest of the AMS who did not join this meeting.

Updates On CCUS in Thailand

Dr Apiradee Suwannathong, Department of Mineral Fuels, Ministry of Energy Thailand, provided updates on the overall CCUS situation in Thailand under the initiative of the Government of Thailand, including Arthit Upstream CCS Project (in the E&P area), the Northern Gulf of Thailand (beyond the E&P area), EGAT MAE MOH MINE (beyond E&P area), and the CCS regulatory framework formulation in Thailand.

The Q&A session started with a question from PLN Indonesia.

Tri: May I know whether you have projects that are for the capturing side?

Apiradee: In Thailand, we are yet to have an umbrella authority that can oversee all CCS activities. The government is discussing developing regulations and propose the establishment of such an authority, for which a certain length of time is required. While waiting for that, we are working on CO2 utilisation for E&P (exploration and production). If a sufficient number of projects were implemented, then the government will better understand the importance of establishing such an authority. That said, it is not that we just wait and see. In the Gulf of Thailand project, we assess the geological formation first. In the next phase, we will have CO2 from power plants and the industry sector stored. And for all these things, we require assessment by the Cabinet.

Phoumin: Thailand is now moving really fast in the CCUS pilot project, particularly for arctic island projects. I would like to know whether particular subsidies are ready, or if this is solely based on PTT (a key government corporation) investment alone. Any availability of a carbon credit scheme?

Apiradee: The government is trying to help accelerate the Arthit project through subsidy and other measures. We as the ministry in charge are trying to provide the best-possible support toward implementation.

Self-Introduction:

Participants, including ERIA and JCOAL members introduced themselves. Taking the opportunity, the JCOAL Team expressed appreciation to the Government of Malaysia and the Energy Commission to voluntarily finance Ms Nur Diyana's participation in this meeting.

Some also made their remarks as it was the only occasion to express their thoughts prior to discussion on the draft report.

Phoumin: Looking towards 2025, the year when Malaysia will be ASEAN Chair, I believe we can do something together. Let us know if there is anything ERIA can do to support that. In this context, the Energy Commission might request JCOAL to work on a study conducive to your chairmanship.

Yenni: I would like to know how the team reached the topic of grid stabilisation with measures from non-grid end. I was not at the First Working Group Meeting, and the PLN member who attended the first meeting was not really aware of this topic.

My other concern is how our names will be mentioned in the report and whether the members have to undertake any kind of responsibilities for the report. I think I cannot take such responsibility since we have no particular agreement in writing. I understand we are here as resource persons.

Yamada: We agree with you. We do not mean to ask you to take responsibility in any form. That we refer to the names of the working group members is for us to acknowledge and express our appreciation to all the people who have cooperated in the report making. However, we can keep a name off from the list in the report.

Phoumin: Thank you for expressing your concern. I understand invitations were appropriately sent to each institution and nominations were made. So, with regard to your concern, just tell JCOAL how your names with designations are to be shown in the report.

A disclaimer expressing working group members are not responsible for the report and its contents and so are the individuals of ERIA or JCOAL or any individuals who participate in this exercise. So, I think that will cover your concern and you should not worry regarding your participation. But we might just add a disclaimer.

Suryo: I think we are in a different position from PLN. For MEMR members, it does not matter since the MEMR has processed the request from JCOAL appropriately. As a result, we were appointed by our superior to join this working group. In that context, it is our responsibility.

Willy: I just want to ask one question. The MEMR working group member who attended the first meeting was a different person and now I am attending the second meeting.

You choose one of us or all of our names will be there on the list?

Yamada: Yes, the names of all the members who attended the first and/or second meeting will be shown to acknowledge our appreciation to them. Whether a member has attended once or twice does not matter.

Phoumin: I would like to suggest that you communicate with ERIA and JCOAL for any continuation of or development from the current study, because it is important for us to obtain project ideas that are well-sourced from the actual situation of each AMS and of the whole ASEAN. As you are aware and have known from JCOAL, the study on grid flexibilisation strongly indicated the potential support by coal-fired power plants of grid stabilisation through flexible operations. In the current study, they try to provide information about non-grid end technology that will be a part of measures to be taken for grid stabilisation.

Tentative Outcomes of the Study on Thailand by the JCOAL Team:

JCOAL presented the tentative outcomes of the sub-study on biofuel utilisation in Thailand, followed by a Q&A.

Tri: From the 30th slide, the picture from chemical plant outcomes can be hydrocarbon, hydrogen, and CO2. I refer to your slide here. Which one is more economical to produce hydrogen from this chemical plant or from electrolytes? In your case, is hydrogen green? In economic aspects, which is more feasible, chemical plant or electrolyser?

Murakami: In this case, we can utilize syngas to produce hydrogen by shift reaction. So far, I do not compare the feasibility of the process of producing hydrogen. The advantage of this process is to utilise internal energy for hydrogen production. I can analyse the process from syngas production. Of course, biomass is already carbon neutral and the energy to produce hydrogen is syngas itself. So, we do not utilise any fossil energy through the process. That means this hydrogen will be green.

Noorly: On gasification, the scale 5–500 tonnes per day seems to be too large in terms of logistics. In the case of Malaysia, we have challenges in securing biomass because the biomass plant is different from the farmer miller. That is why I asked you about logistics issues and others.

Yaowateera: I have a similar question regarding this. The first question is about the cost of biomass per tonne; you would consider biomass and the agricultural material as residues. I think you should consider the agricultural area and the quality, including the cost for the gasification plant.

Murakami: I started the study with 5 tonnes but I must expand this process actually by 200 tonnes to make the process feasible. In these cases, the availability of biomass can be monitored. I agree with you about logistics. If we do shift to the more detailed study, we have to think about that question in detail. Thank you very much for your recommendation.

Phoumin: I think they involve labour, so that will be involved in the cost of biomass. The cost of biomass itself may be very low, but transportation may be costly.. Perhaps Dr Yao may have to provide a cost–benefit analysis for all kinds of biomass such as agricultural waste, etc. Can you explain the carbon credit per tonne?

Murakami: I found the data in a website of Thailand. Also, carbon credit 35 THB/t has already started.

Noorly: How come is it touched on just lightly? To conduct an analysis involved in carbon credit in this study is important

Murakami: In this case, it is about 500 tonnes per day capacity for hydrocarbon production; is annually 19,000 tonnes of biomass per year. That means 158 tonnes of hydrogen per year. This liquid fuel can be converted to be carbon neutral, but this is of the carbon credit option. After 4 years of commissioning, we add the carbon credit. But it varies because the price estimated here is very low, so the plant may not provide large benefit.

Yaowateera: If you calculate biomass syngas at 500 tonnes/ day, the total biomass generation is equal to 20 megawatts for the gasification plant installed capacity, especially, the community-scale biomass gasification plant. However, I think 20 megawatts for a community power plant is quite large in terms of biomass availability in the local area.

Murakami: Yes, the maximum capacity must be around 100 tonnes/day. I will recalculate as per your recommendation. Thank you.

Tri: Thank you, I have questions. On slide 45, the presentation stated that the product price of hydrogen is THB411/cubic metre. Per my calculation, it would be roughly $132/kg. It is very expensive. Could you clarify it? THB411/cubic metre is equivalent to $132/kg, which is very expensive for hydrogen plants.

Murakami: You are right, the hydrogen price shown in the other slide is to be revised. Thank you very much. As I mentioned, nobody has the price. It is not so high, and in the future, we need to shift to being a hydrogen society. Hydrogen price should be much less than the current price. In our government, ¥30/cubic metre is the target in 2030 and ¥20/cubic metre in 2050 is the overall target. So, we should be able to rearrange these prices. But so far, we have changed the price, but we cannot find it in the websites.

Tri: It looks too expensive. Hydrogen at $122/kg would not be considered for utilisation. Nobody would buy hydrogen at such a high price. You would say you are willing to buy hydrogen at $132/kg, but nobody else would be.

Phoumin: Regarding power generation, the hydrogen to be combusted for electricity would probably be 1%. So, biomass, hydrogen from biomass will be good as it is not be used costly. However for hydrogen, it is better to use for different purposes, for power generation.

Murakami: If most of the syngas is combusted to power, I must think about the other process. Biomass gasification and power are already ongoing. So, I changed the idea that biomass gasification syngas will convert to hydrogen and other materials. That is the idea.

Phoumin: So, the whole idea is not for power?

Murakami: No, regarding power, I think about utilisation of just excess heat, or some small part of syngas should be combined for power generation. In this case, the contribution is very low.

Phoumin: I think the whole idea Dr Murakami-san brought in is very interesting. But some of the assumptions, like on the price, need to be changed to be consistent.

One more thing, Dr Murakami, on slide 47. I think we cannot do this because why we calculate, you need to make sure that kind of escalated then any discount rate. Basically, if you look at the cost structures and then revenue, then cost you see the feed stock. Because of the feed stock, you assumed almost zero for biomass. But you put this stock, that is agricultural waste, it is a huge amount of money.

I wonder why that is the cost of feedstock. Because if it is stocked on the assumption of 0.15, almost zero, this feed stock costs more than the utility cost. Yes, very high. I am afraid that could make this project less attractive.

Murakami: Please see this one. Admixture for fertiliser is about equal the amount of urea, 200% of phosphate rock, and 100% of magnesia lime. This is mostly the total feedstock cost.

Phoumin: Murakami-san, if surplus ammonia will go with coal cofiring, because biomass itself is zero emission content. If in the case that ammonia from biomass gasification process you are going to synthesize by syngas and hydrogen, I think if you add ammonia for coal combustion, this project is not attractive. But from biomass, with the low cost of feedstock biomass, biomass alone converted to syngas and syngas to hydrogen would perhaps be very attractive. I can see why feedstock is very costly because the cost is mixed with ammonia's cost. That is why the cost is very high.

Murakami: Thank you, I noted. Are there any comments or advice for this study?

Noorly: Perhaps you can include the source of data, for example, you mention in the report that the assumed price as 0.1 THB. We want to appreciate your thoughts so that we can understand whether biomass consists of rubber wood? Or what is biomass utilisation?

Murakami: Yes, I will show the actual data. So far, the assumed cost of biomass as 0.1 THB is ,on presumption that the biomass to be utilised is wastes . In any case, I have to rearrange the data from Dr Yao's input.

Yaowateera: May I once again know the indicated timeline?

Yamada: I think it would be 27 November until 14 December. You will have more than 2 weeks to comment on the draft.

Tentative Outcomes of the Study on Indonesia by the JCOAL Team:

JCOAL presented the tentative outcomes of the sub-study on non-grid end technology for grid stabilisation in Indonesia, followed by a Q&A.

Noorly: As for slide 17, why have you taken up Case 4 and neither of Case 1-3 was selected?

Sakata: According to our observation, Cases 1, 2, and 3 have been conducted in Indonesia and other AMS to a certain extent. The massive introduction of VRE for energy transition is new for any country. In that context, measures to address Case 4 will also be important.

The point here is, we are coming up with a simple and periodic grid system stability assessment method that does not require either time or extra cost.

First, we estimate the stability of the grid system in terms of RoCoF and inertial forces, and then plan measures for insufficient inertial forces. Step two is detailed analysis. We estimate the stability of the grid system in terms of global and maximum frequency deviation. As you are aware, this is the firsthand assessment; a detailed study should be conducted if required.

Yenni: If the target period of the study spanning towards 2060, I do not fully agree with you in suggesting these non-grid end technology and equipment. Indonesia is already planning to have all regional systems interconnected by 2060, when grid stabilisation is envisaged to be sustained. So, trying to identify measures on by-system basis would not be useful. And please clarify why a particular technology you mentioned is judged as applicable and appropriate.

Yamada: I do not mean to make any kind of intervention. but in my personal observation, if you talk about your own grid development plan including interconnections, it is generally a rolling plan. And interconnecting all your major islands is not an easy task. So, fully depending on that plan of ensuring grid flexibility and stabilisation would be a little too risky. Why not consider other good options while you see how your interconnection plan goes. That is what we think would help you to some extent.

And the other point that will affect your plan to ensure grid flexibility and stabilisation is that funding of grid enhancement is not as easy as power development since grid development by itself is in general not really profit-making. So, special incentives and market formulation, in addition to public finance, would be required to make things more workable in a sustainable manner.

Sakata: Well noted and thank you for your comments. We will try to reflect them.

Tri: Your introduction of synchronous condenser and some storage technology, etc. is informative. However, please note that cost information is crucial. If all 83 GW we envisage would be covered by synchronous condenser, it will be quite costly. And you have to think about how big the impact on our NCUE would be.

Yamada: I suppose the price of conversion from existing thermal power plant to synchronous condenser may vary depending on each plant situation. That said, we will try to indicate reference prices.

Noorly: My question is about slide 27. You mention that inertia constant with synchronous condenser is 8 sec. However, in the other part of the presentation, it is 4 sec. Why are they different?

Sakata: The 8 seconds includes response time of the synchronous condenser in combination with flywheel.

Yenni: As for the process of identifying alpha, I wonder whether it would be possible for you to make the study outcomes more relevant by using some other countries other than Japan for benchmarking.

Yamada: We are not a national team, and we undertake the study under supervision by ERIA, so we cannot choose one country in an arbitrary manner. The only reason we did so with reference to Japanese cases is we were able to obtain sufficient data about Japan's grid systems. As you might know, it is generally not disclosed to a third party without some previous arrangement. In consideration of time constraints, we have chosen Japan as reference. However, using the Texas case is possible as data is available.

Willy: Thank you. Regarding slide 27, per unit inertia constant, five is mentioned, which may depend on the scale of capacity. How about in the pump storage hydro? Does it depend on the scale?

Yamada: Your question is whether this per unit inertia constant, that is 5 sec, can be different as per the unit scale, right? According to Sakata-san, there will be no difference.

Tri: On the second point, I would like to mention that insufficient inertia will be addressed through interconnection in the ASEAN region, which is called APG. Under the plan, the North Kalimantan System will be connected with Sabah System and so will Sumatra and Peninsular Malaysia. So, your study should reflect those interconnections that will be in place later.

Yamada: We will consider your points.

Energy Transition Updates – Malaysia

Ms Noorly of the Energy Commission, Malaysia presented an overview of the newly announced National Energy Transition Roadmap (NETR) that is deemed to be a steering shift from transitional fossil fuels–based economy to a high value green economy energy transition.

Noorly: The NETR is divided into two parts: we have on the left side EE, RE, hydrogen, bioenergy, green mobility, CCUS, covering all. The next pillar is the 10 flagship catalyst projects by the government, identifying several projects for each component. And the next, part two is just to say that it has a fast-tracking enabler. The ones shown below are financing and investment, human capital, capabilities, policy and regulation, technology, infrastructure and governance, and investment opportunities. I just wanted to highlight renewable energy, that is 27 GW solar PV will be in place by 2037, then solar PV will reach 57 GW and 70% of the national installed capacity by 2050. And funding is the tough part in energy transition.

Phoumin: I understand Malaysia is moving quite fast on the energy transition policy. I want to congratulate Malaysia. And I am wondering how such energy transition policy formulation is going with Indonesia.

Willy: The basic plans in the power sector in Indonesia are RUPTL and RUKN. The so-called Green RUPTL, RUPTL 2021–2030 is already in place and the next version is under preparation. The RUKN will be issued hopefully quite soon. So, we can refer to RUKN for any updates once it is available.

Phoumin: So, in Thailand?

Yaowateera: For the energy transition, Thai government has established the 4D and 1E: digitalisation, decarbonisation, decentralisation, deregulation, and electrification, including the update on the renewable policy, because the new government and the new energy minister also keep the same energy policy to increase the share of renewable energy to 50% of the new power installed capacity by year 2040, as well as achieve carbon neutrality by the year 2050 and net-zero greenhouse gas emission by 2065, respectively. In addition, to promote the use of electric vehicles, at least 30% of electric vehicle share should be increased by the year 2030. Hopefully, the new national energy plan will be completed by the middle of next year.

Phoumin: I think we can have different packages, like 2050 is carbon neutrality, 2065 is net zero, so the difference of the two I understand that the former allows you to offset emissions by incorporating carbon sink and that the latter will require you to make the plant purely with net-zero emissions by 2065.

Tri: I think all the countries have comments here regarding funding.

Yamada: You are right. I have a question. Could you go back to slide of the Energy Commission, slide no. 2? Okay, so in potential investment opportunities and the impact of this roadmap, towards 2030, you mention the establishment of one hydrogen hub. In my understanding, you have already done it because you already have green energy. That is this one huge hydro power and two more hydro power will be coming. They already started producing hydrogen a few years back. And they are conducting further studies in collaboration with Korean companies. So, I think that is already done.

Noorly: I need to check that one because yes, we have a hydrogen production at Sarawak , But I need to check because for each pillar, for each level, there is a ministry involved. So, the Energy Commission, our ministry, is involved only in renewable energy, energy efficiency. I think hydrogen is under the Ministry of Economy or Ministry of Science; technology innovation is under a different ministry. But I can check and get back to you.

Phoumin: You mentioned earlier that hydrogen will be used to generate power. Local green hydrogen production is 2.5 million tonnes per year. It is all to be used to generate power or utilised for other sectors as well?

Noorly: Let us check it after we go back to the office. The Energy Commission focuses on renewable energy. My department focuses on transmission distribution, funding and financial. For each component, there is a ministry in charge. There is a person in charge for each. So, regarding your question, I need to check again because I think it is mentioned in the roadmap. I will send you the comments.

Phoumin: The other is about green mobility. The roadmap mentions only for electrifying transportation. How about using hydrogen? You are not planning to provide hydrogen or green hydrogen for transportation because this roadmap is all about electrifying transportation using electricity.

Noorly: I need to confirm that one also.

Yamada: May we know where we can obtain the roadmap?

Noorly: It is with the Ministry of Economy, so it is available at the ministry's website.

Phoumin: The roadmap is very interesting; you can look into EVs – whether two-wheels or four wheels. We would appreciate further details from you.

The ERIA study focuses on Indonesia, Malaysia, Thailand, and Viet Nam, Southeast Asian countries. But we also want to know regarding the energy transition in your country, Japan. Do you have any information? Maybe we from Southeast Asia can have knowledge from you, the most advanced world country in Asia? Yes, China also. But regarding technology, we can learn from China, Japan, and South Korea.

In response to ERIA's request regarding energy transition initiatives in Japan, JCOAL provided overviewing slides.

Murakami: Japan's carbon neutral target year is 2050 and our government has identified 14 major sectors for growth through energy transition activities. The reference year is 2013 as that was the peak of CO2 emissions. After that, our CO2 emissions getting have been decreasing because of the economic situation and the enhanced technology development. So, the CO2 emission reduction target by our government in 2030 has become 46% from 2013, and 0% in 2050. But in 2050, around 200 million tonnes of CO2 will still be actually emitted. So, to address CO2 emissions, our government targets around 200 million tonnes of CO2 by CCS and CR technologies. This is the carbon neutrality roadmap.

In the power sector, renewables will be installed to the full extent, while gas and coal should also remain as they are synchronous and can contribute to grid stabilisation through flexible operation. For your information, 15% as the minimum operating load of thermal power plant has been achieved.

The technology roadmap for carbon recycling is with all kinds of technology for future carbon recycling. At around 2030, our government targets to commercialize technology not using hydrogen. For example, fixation by carbonate production. This also involves the direct absorption by rocks and other inorganic materials. After 2040, some of the technology using hydrogen like conversion of CO2 to methanol and other hydrocarbon will be used.

Wrap-up

Phoumin: My appreciation to all the working group members. I enjoyed the whole day of conversation and exchange of knowledge. I think this is a very incredible input to the study. I found your comments very insightful and useful for improving the report. I found your inputs to be not only technical but also very practical to the extent that they are applicable to each country. So, I am looking forward to a very good report, after your inputs are incorporated by the JCOAL team.

I also want to thank the JCOAL team; they have worked hard to collect and analyse information, aiming to furnish excellent recommendations for the AMS. We hope that you will provide more comments to ensure that this report can be useful to your country. So, I want to say thank you so much, and have a wonderful evening.

Murakami: Thank you very much indeed for important input during this working group meeting. I appreciate all your comments and the country updates by Thailand and Malaysia very much.

Wuttipong: Thank you, Dr Phoumin, ERIA, all working group members, and the JCOAL team. First of all, I would like to thank you for inviting me to attend this meeting. Due to climate change, the hottest issue right now, every country is trying its utmost efforts. But just using conventional technology, we may not be able to achieve the target. That is why CCS has come to be one of the central issues in the past few years. That is a private chain mitigation plan and new business in the region. I believe that the CCUS technology is one of the solutions to achieve our goal for decarbonisation as long as the technology becomes commercially available in the future. I hope this study will be beneficial for ASEAN Member States, especially on CCUS.

Participants were reminded of the time schedule for the visit to Mahachai Green Power Plant the following day. The meeting was closed with thanks to all participants.