Appendices

Appendix I. Overview of the Power Sector in ASEAN

Current Situation of the Power Sector

- Corporate structure of the power business
  The power generation business of each country is shown in Table 1A. The Philippines and Malaysia are privatised. However, in Indonesia, Thailand, Viet Nam, and Myanmar, their respective state power companies conduct the countries' electricity business. The Lao PDR and Cambodia have mixed state-owned and private companies, but independent power producers (IPPs) account for most of them (Table 1A).

Table 1A. Corporate Form of the Electric Power Business

	Government Organisation	National Company	Private Company
Cambodia	Ministry Mine and Energy (MME)	Electricité du Cambodge (EDC)	Independent Power Producer (IPP) Rural Electricity Enterprise (REE） Provincial Electricity Company (PEC） Provincial Electricity Utility
Indonesia	Ministry of Energy and Mineral Resources (MEMR） Directorate General of Electricity (DGE）	Perusahaan Listrik Negara (PLN)	PT. Indonesia Power (IP） PT. Pembangkitan Jawa Bali (PJB）
Lao PDR	Ministry of Energy and Mines (MEM）	Electricité Du Laos (EDL)	IPP Domestic IPP International EDL Generation Public Company (EDL-Gen)
Malaysia	Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC)	Tenaga Nasional Berhad (TNB)） Sabah Electricity Sdn Bhd.(SESB） Sarawak Energy Bhd. (SEB)	IPP Small Power Producer (SPP）
Myanmar	Ministry of Electricity and Energy (MOEE)	Electric Power Generation Enterprise (EPGE) Department of Power Transmission and System Control (DPTSC)	Yangon Electricity Supply Cooperation (YESC） Mandalay Electricity Supply Cooperation (MESC） Electricity Supply Enterprise (ESE）
Philippines	Department of Energy (DOE) Electric Power Industry	National Power Corporation (NPC)	Manila Electric Company (MERALCO)

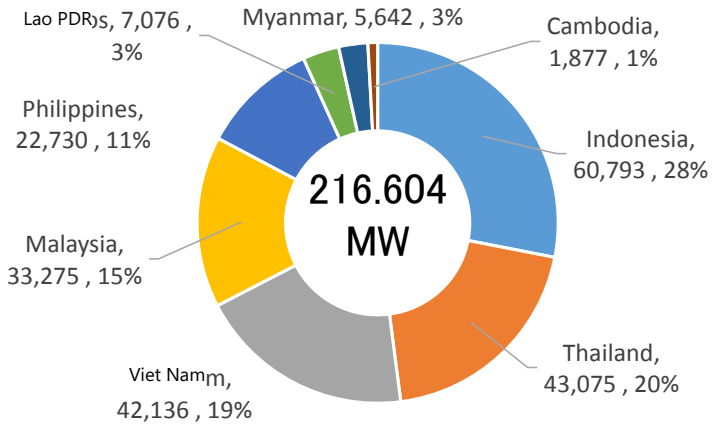
	Management Bureau Director of Energy Policy and Planning Bureau		Visayan Electric Company (VECO) Davao Light and Power Company, Inc. (DLPC)
Thailand	Ministry of Energy (MOE)	Electricity Generating Authority of Thailand (EGAT)	IPP SPP Very Small Producer (VSPP)
Viet Nam	Ministry of Industry and Trade (MOIT) Electricity and Renewable Energy Authority (EREA)	Electricity of Viet Nam (EVN)	IPP Vinacomin EVN

Source: Created by each government website.

- Power generation capacity in each country

  The total capacity of the power generation facilities of the eight countries in 2017 was 216,604 MW. The share of each country is 28% for Indonesia, 20% for Thailand, 19% for Viet Nam, 15% for Malaysia, 11% for the Philippines, 3% for the Lao PDR, 3% for Myanmar, and 1% for Cambodia (Figure 1A).

Figure 1A. Capacity of Power Generation in Each AMS (MW)

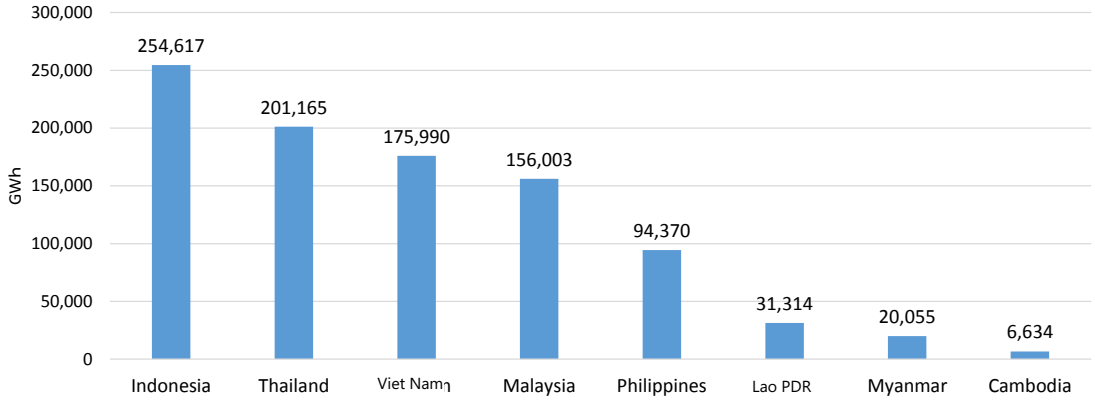


AMS = ASEAN member state.
Source : Created by Home Page in each country.

Figure 1B hows the amount of electricity generated in 2017[1] by country. Indonesia is the largest with 254,617 GWh. The smallest is 6.634 GWh by Cambodia. The Lao PDR uses only 4,697 GWh (15%) of the total 31.314 GWh for domestic consumption, and the remaining 85% of the electricity is exported to neighbouring countries. Thailand, Viet Nam, and Cambodia buy electricity from the Lao PDR.

[1] Thailand and Myanmar in 2018, Viet Nam and Malaysia in 2016.

Figure 1B. Power Generation in Each AMS (GWh)

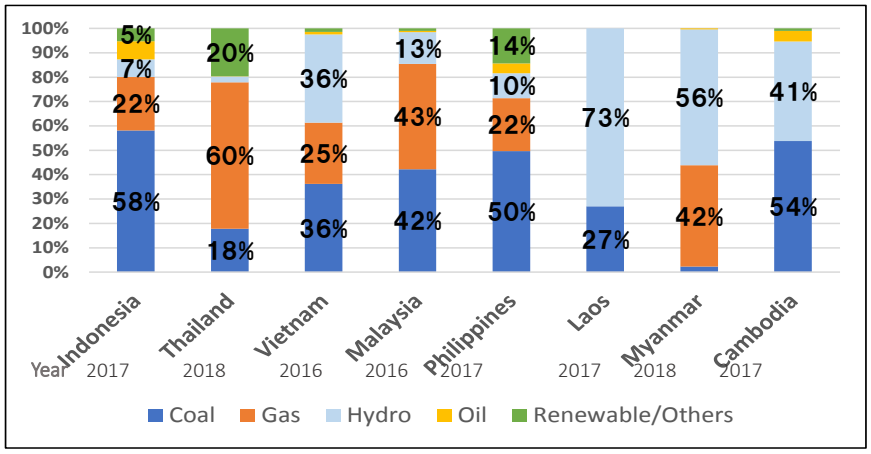


AMS = ASEAN Member State.
Source：Created by Home Page in each country.

Current situation of the coal-fired power plant

The following graph shows the ratio of electricity generation by source in each AMS in 2017. Indonesia (58%), Cambodia (54%), Philippines (50%), Malaysia (42%), Viet Nam (36%) are the countries with the highest ratio of coal. High ratio of gas is in Thailand and hydropower is in the Lao PDR, hydropower and gas are in Myanmar. In Thailand and the Philippines, the ratio of renewable energy is high. Especially in the Philippines, geothermal power generation is thriving.

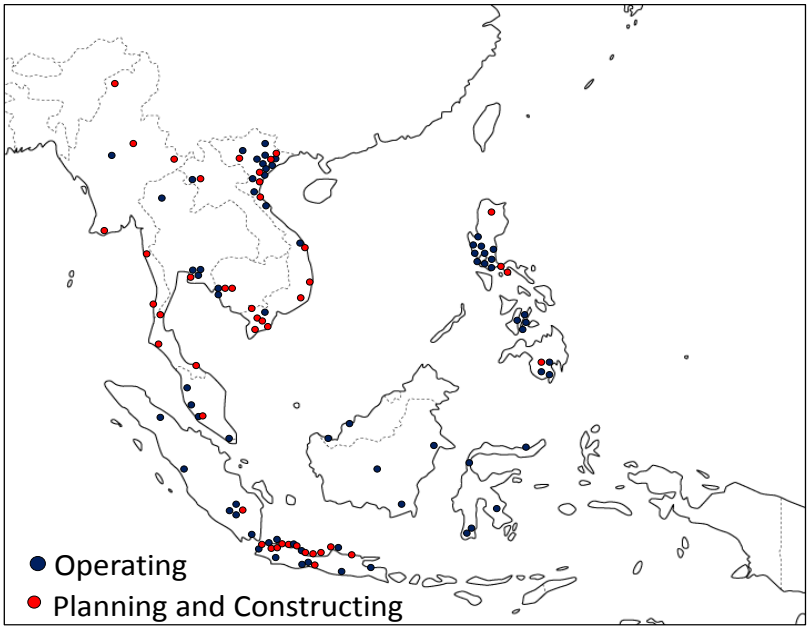
Figure 1C. Electricity Generation by Source, %



Note: The Government of Indonesia categorises hydropower as renewable energy. This graph separates hydro from renewable only for the sake of comparison.
Source: Created by Home Page in each country.

Figure 1D hows the location of coal-fired power plants currently in operation and being planned and under construction. Indonesia, Malaysia, Philippines, and Viet Nam are being installed by coal-fired power.

Figure 1D. Coal-fired Power Plants that Are Operating, Being Planned, and Under Construction



Source: Created by Home Page in each country.

Future power generation plan

In the power planning of the eight countries, coal plays a major role in the future as its consumption will steadily increase with the operation of new coal power plants. In Indonesia, coal consumption is predicted to be 192 Mt (electricity 163 Mt) in 2027. Viet Nam is expected to consume 157 Mt (electric power 131 Mt) in 2030. Coal consumption of Malaysia, Thailand, the Philippines, Lao PDR, and Cambodia is also predicted to increase to millions of tons. The current 264.23 Mt of coal consumption, including industries other than electric power, will further increase and is predicted to exceed 400 Mt tons after 10 years.

Cambodia

The transition of power generation from 2007 to 2017 in Cambodia increases at an annual rate of 17.3%. At this rate, power generation will be 23,774 GWh in 2025, 3.6 times of 6,634 GWh in 2017. The power plan is expected to add 720 MW of coal-fired power plants.

Indonesia

Indonesia's power generation will be 501,917 GWh in 2027, which is about 2.5 times compared to the current quantity. Coal generated is 293,902 GWh, accounting for 58% of the total generation. In addition, the total capacity of power generation facilities to be built between 2018 and 2027 is 56 GW, 27 GW of which is coal power, which is 48% of the total generation.

Lao PDR

The power plan of the Lao PDR is driven mainly by hydropower and coal. Hydropower

generation will be 17,486 MW in 2030, increasing three times compared with 2017. The coal generation will be expanded to 3,378 MW in 2025 because of the expansion of the Hongsa Power Plant and two new coal power plants. Hydropower growth is overwhelming that of coal. The ratio of coal in the electricity mix will fall to 15% in 2035 from 27% in 2017.

Malaysia

The 11th Malaysia Plan (2016–2020) has been announced. Among the power plans, that of 2020 (191,937 GWh) will be 1.9 times more than the 2010 (101,727 GWh); the ratio of coal is planned to increase from 42% in 2010 to 53% in 2020. However, the actual for 2015 was 135,450 GWh, which is behind the planned 158,843 GWh.

Myanmar

According to Myanmar's electricity plan, electricity demand will increase to 8,121 MW by 2025. Myanmar's power generation capacity is large because power supply loss is as large as 30% due to the poor grid. The total electricity capacity in 2030 is planned to be 16,112 MW, 2.9 times that of 2017. Hydropower accounts for 55% of the overall installed capacity, followed by 16% coal, 15% gas, and 14% renewable energy. As of 2016, six coal-fired power plants were in the government's power development plan.

The Philippines

According to the Philippine power plan, power demand will be 16,325 MW in 2020; 28,185 MW in 2030; and 49,287 MW in 2040. It will increase 1.3 times, 2.3 times, 4.0 times, respectively, compared with 2015.

Thailand

The power plan of Thailand is to construct a new 57,460 MW power plant by 2036, when power generation will be about 320,000 GWh. The amount of power generated is 1.6 times of the current quantity. The composition rate of 2036 is 18% renewable energy, 2% (domestic) hydropower, 15% (imported) hydropower, 37% natural gas, 17% imported coal, 6% lignite coal, and 5% nuclear power. Coal, with indigenous lignite and imported all together, accounts for 23%.

Viet Nam

According to the power plan of Viet Nam, the amount of power generation is 572,000 GWh in 2030, 3.2 times of the current quantity. Coal accounts for 53%.

Appendix II. Working Group Members and the Meeting at ERIA Headquarters on 6 February 2019

(1) Working group members

No	Country	Name	Affiliation	Designation
1	Cambodia	Mr Chheang Bunthy	Generation, Transmission and Sub-Transmission Department, Electricity Authority of Cambodia (EAC)	Deputy Director
2	Cambodia	Mr Sok Chandareth	Ministry of Mines and Energy	Chief of Energy Statistic Office
3	Cambodia	Mr Han Vanra	Independent Power Producers Operation Office, Generation Department Electricite du Cambodge (EDC)	Deputy Chief
4	Indonesia	Ms Elis Heviati	Directorate of Bioenergy, Directorate General of New, Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources	Deputy Director for Investment and Cooperation of Bioenergy
5	Philippines	Mr Jensen M. Alvarez	Biomass Energy Management Division, Renewable Energy Management Bureau, Department of Energy	Senior Science Research Specialist
6	Philippines	Ms Litz M. Manuel-Santana	External Affairs, MERALCO PowerGen Corporation	Vice President & Head
7	Thailand	Mr Chawit Chongwilaiwan	Hydro Power Plant Planning and Feasibility Study Department, Power Plant Development Planning Division, Electricity Generating Authority of Thailand (EGAT)	Head of Hydro Power Project Feasibility Study Section
8	Thailand	Dr Yaowateera Achawangkul	Department of Alternative Energy Development and Efficiency, Ministry of Energy	Mechanical Engineer, Senior Professional Level

(2) Summary of the Meeting: Attendance List

No	Country	Name	Affiliation	Designation
1	Cambodia	Mr Chheang Bunthy	Generation, Transmission and Sub-Transmission Department, Electricity Authority of Cambodia (EAC)	Deputy Director
2	Cambodia	Mr Sok Chandareth	Ministry of Mines and Energy	Chief of Energy Statistics Office
3	Cambodia	Mr Han Vanra	Independent Power Producers Operation Office, Generation Department Electricite du Cambodge (EDC)	Deputy Chief
4	Indonesia	Ms Elis Heviati	Directorate of Bioenergy, Directorate General of New Energy, Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources	Deputy Director for Investment and Cooperation of Bioenergy
5	Thailand	Mr Chawit Chongwilaiwan	Hydro Power Plant Planning and Feasibility Study Department, Power Plant Development Planning Division, Electricity Generating Authority of Thailand (EGAT)	Head of Hydro Power Project Feasibility Study Section
6	Thailand	Dr Yaowateera Achawangkul	Department of Alternative Energy Development and Efficiency, Ministry of Energy	Mechanical Engineer, Senior Professional Level
7	Japan	Dr Kazuyuki Murakami	Business Development Department, Japan Coal Energy Center	Principal Deputy Director
8	Japan	Ms Yamada Fumiko	Business Development Department, Japan Coal Energy Center	Assistant Director
9	Japan	Mr Yasuo Otaka	Business Development Department, Japan Coal Energy Center	Deputy Director
10	Japan	Mr Itsuki Watanabe	Jakarta Representative Office, Sumitomo Heavy Industries, Ltd	Chief Representative
11	Japan (Indonesia)	Mr Irul Khoiruddin	Jakarta Representative Office, Sumitomo Heavy Industries, Ltd	
12	Japan (Indonesia)	Mr Yoga Iriansyah Unthailawal	Jakarta Representative Office, Sumitomo Heavy Industries, Ltd	
13	ERIA	Dr Han Phoumin	ERIA	Energy Economist
14	ERIA	Mr Shigeki Kamiyama	ERIA	Director General for Research Administration

(3) Summary of the Meeting: Minutes

Date and time : 6 February 2019, 9:30–15:20

Location : Meeting Room 5-6, ERIA

Attendance : Dr Phoumin, Mr Kamiyama, six delegates from Cambodia, Indonesia, and Thailand, Dr Murakami, Mr Otaka, and Ms Yamada of JCOAL Study Team

Morning Session

Members of the JCOAL team expressed their appreciation to delegates who came all the way to Jakarta during their busiest time of the year. Two delegates from the Department of Energy (DOE) and MERALCO PowerGen of the Philippines could not be physically present but were willing to provide their inputs through electronic communication.

Mr Kamiyama of ERIA, in his brief welcome address, indicated that ERIA handles about 20 studies annually, some of which are requested by the AMSs and others are proposed by relevant organisations. In any case, the point is that the study concept and its objectives are in line with the East Asia Summit (EAS) Energy Study Roadmap. Four pillars constitute the roadmap and these are always on the agenda of the EAS Energy Ministers' Meeting. He closed his address by expressing his expectation of a fruitful discussion.

Dr Murakami of the JCOAL Study Team served as the chair. The self-introduction of participants was followed by a photo session.

Cambodia's delegates Mr Sok Chandreath of MME and Mr Han Vanra of EDC made the first presentation. They described the structure of the relevant institutions with the Ministry of Mines and Energy (MME) functioning as the policymaker, the Electricity Authority of Cambodia as the regulator, and the Electricité Du Cambodge (EDC) as the central utility/operator/retailer/single buyer from the independent power producer (IPP). Current renewable energy is contributing both to the national and the isolated grids. Comprising Cambodia's power strategy is the development of diversified energy sources, transmission lines – national/Greater Mekong Subregion/ASEAN – and rural grid as well as upgrading HV/MV/LV lines. It also includes the development of rural electrification through enhancement of supply from the national grid and stand-alone systems.

Looking at the overall situation, the annual electricity demand per capita increased from 416 kWh in 2017 to 490 kWh in 2018. The peak capacity supply increased from 1,100 MW in 2016 to 1,269 MW in 2017. At the same time, the peak demand in Phnom Penh was about 735 MW. In 2018, the national electrification rate increased to 81.58%, while the electrified households in urban areas were almost 100%, and those in rural areas about 70%. Cambodia has a good potential of hydropower of about 10,000 MW. At present, about 13% of its potential is constructed. In 2018, the total electricity supply increased to 7,954 GWh within the installed capacity of about 2,215 MW while imported electricity accounted for 17%.

As for the primary energy supply mix, coal accounted for 16% as of 2017, which means a massive increase from 0% in 2010, according to the country's strategy for energy diversification.

During the presentation, general specifications of coal-fired power plants were indicated. They used 6,210 GCV/kg of bituminous coal imported from Indonesia.

The environmental regulatory values for air quality control are SO_2 500, NOx 1,000, PM 400. Ash removal is done by the ESP. The SO_2 control system is part of the standard equipment for environmental control.

The installed capacity of biomass power generation reaches 51.27 MW with eight IPPs. Fuels vary from firewood to bagasse to paddy husk.

Dr Phoumin mentioned that coal and woodchip co-combustion has been demonstrated already in Thailand, which would be a good reference to the other AMS.

Indonesia, represented by the Ministry of Energy and Mineral Resources, was the second presenter in the working group meeting. Indonesia is highly dependent on fossil fuel; more than 90% of national energy consumption is derived from oil, gas, and coal. The government is shifting its energy policy priorities towards renewable energy in view of the limited remaining reserves of fossil fuel as well as the global and national environmental concerns.

However, the situation of current utilisation is that the total generation by renewable energy is 9.525 GW only against the potential 441.7 GW.

As of 2018, renewables accounted for 7.3% and coal accounted for 30.1%. Renewable energy will considerably increase up to 23% of the primary energy mix in 2025, while coal will be steady; it will remain at 30%.

During the last decade, Indonesia's national electrification ratio has impressively improved. By Q3 2018, it had reached 98.30%; in the same quarter in 2010, it was 67.2%.

Overviewing national policy priorities, the National Energy Plan emphasises the following: (i) maximising the use of renewable energy, (ii) minimising the use of petroleum, (iii) using coal as a reliable national energy supply, (iv) optimising the use of natural gas and new energy, and (v) using nuclear as a last resort.

The government also sets out bioenergy development goals consisting of six main pillars, including the commitment to reduce GHG emissions to 29% below the Business-As-Usual scenario by 2030.

A regulatory framework, including electricity tariff to facilitate renewable energy, is also in place.

Under government initiative, various programmes are progressing. Biomass potential for electricity is highest in Sumatra (15,588 MWe). National potential is as much as 32,654 MWe. As of today, the installed capacity of biomass power is 1,858.5 MW with on-grid at 214.6 MW and off-grid at 1,643.9 MW. The target capacity in 2025 is 5.5 GW.

The latter part of the presentation discussed coal resources, such as quality, reserves, production, price mechanism, and domestic market obligation.

Finally, challenges in bioenergy development and the government's efforts to overcome them were introduced.

The Department of Energy (DOE) and MERALCO PowerGen were not able to send delegates, so the third presenter was Thailand. The first part of the presentation was undertaken by the Department of Alternative Energy Development and Efficiency. As of now, Thailand is also dependent on fossil fuel, which accounts for 75.63% of the national energy consumption. The major fossil fuels used are oil and gas. Coal's share is relatively small in its energy mix. Renewable energy accounts for 15.28%. The installed capacity of biomass power accounts for 30%, 3,276.88 MW out of 10,797.50 MW.

Three main pillars constitute the fundamental energy policy of the Government of Thailand: (i) secure the country's energy supply, (ii) implement fair pricing for energy, and (iii) conserve energy. The government is committed to reduce GHG emissions by 20%–25% by 2030.

The government has embarked on the Alternative Energy Development Plan (AEDP) 2015–2036, which sets out an integrated and by-fuel strategy towards the target of 30% renewables in total energy consumption by 2036. Biomass use is no doubt an important part of the AEDP. The government has been continuously endeavouring to reform relevant strategies that support renewable energy development.

The potential type of biomass in Thailand varies, such as rice straw, sugar cane top and trash, corn trunk, cassava rhizome, cassava trunk, oil palm frond, para-wood root, etc.

Ongoing major activities consist of encouraging (i) biomass use, promotion, and support; and (ii) research and development (R&D). To increase the use of unutilised biomass and improve energy efficiency in agro-industry, the government is facilitating development of off-grid 300 MW biomass power plants mainly with residual para wood in three southern border provinces. The programme is to be implemented under a public–government partnership.

The government is also trying to promote and support biomass utilisation through updating and revising biomass potential and collection factors, providing financial support and knowledge sharing with the community. R&D activities are also enthusiastically pursued. Pelletization, torrefaction, biocoal, and innovative biomass energy monitoring are among the R&D themes.

The second part of Thailand presentation's was undertaken by the Electricity Generation Authority of Thailand (EGAT).

Firstly, the structure of Thailand's electricity sector was shown. The contracted capacity is 46,090 MW as of December 2017. The 2018 Power Development Plan forecasts that the overall installed capacity will reach 77,210 MW with capacity addition of 56,431 MW and capacity retirement of 25,310 MW. Renewable energy is envisaged to account for 32.5% (25,086 MW). Thermal power will account for 6.8% (5,213 MW). Biomass is anticipated to be 17% in the renewable electricity mix in 2037.

Thailand is well on its way towards biomass use in the power sector. As of 2017, 688 biomass projects submitted a request for power purchasing agreement (PPA). However, 58% (5,053 MW in 432 projects) were cancelled, while 33% (2,910 MW in 194 projects) had seen a commercial operation date and 9% (790 MW in 62 projects) had their PPAs done. While Thailand is endowed with a wide variety of biomass, the envisaged most potential agricultural biomass is bagasse (56%, equivalent to 2,053 MW), woodchip (22%, 800 MW), rice husk (11%, 407 MW), and palm (3%, 111 MW). These major biomass resources have been developed in connection with a particular industry sector and/or regions and are featured accordingly.

The latter part of EGAT's presentation was dedicated to a biomass and coal co-firing research at the EGAT Mae Moh Thermal Power Plant. The purpose of the research that continued on 40 tons/day biomass (total biomass mix: 1,000 tons) and pulverised coal is to pursue a possibility of co-combustion of biomass at the existing coal-fired power plant. The anticipated research outcomes in terms of emission reduction and technical effect on the existing equipment are to be evaluated in the research.

The envisaged solution is co-firing of (i) bio-coal pellets of 5,700 kcal/kg; (ii) biomass (woodchip) pellets of 3,700 kcal/kg and woodchips of 2,000 kcal/kg; and (iii) lignite coal of 2,790 kcal/kg.

The tentative outcomes of the research indicate two scenarios: (i) without modification of the power plant and (ii) with modification of the power plant. The former is advantageous only in terms of lowest initial cost; however, it is less flexible with the highest mixture ratio at 2%–3%. Also, poor mixing could risk a mill fire. In the meantime, the second scenario no doubt requires a higher investment cost in installation of new biomass mill and burner. That said, the second scenario will realise more flexibility with the highest ratio over 10% and high throughput.

Thailand has its own biomass tariff and it would be possible to earn the +5% premium tariff through biomass power generation. However, it is still at the experimental stage, and how the government will ensure that +5% is important.

Feed-in tariff for biomass power generation in Thailand was allocated by B4.00–5.50/kWh corresponding to its existing capacity. Furthermore, power plant project owners can obtain the premium rate if their project is located in the three southern border provinces throughout the power purchasing contract period.

At the end of the morning session, Dr Murakami mentioned that in case of Japan, 3% is deemed to be the mix limit. A wide range of biomass fuels is also used for co-combustion.

Dr Phoumin commented that coal itself is sustainable in terms of energy security, so it would be beneficial to pursue the optimal use of biomass through co-combustion with coal.

Afternoon Session

The representatives of JCOAL and Sumitomo Heavy Industries (SHI), both as part of the JCOAL study team, presented the overview of the study and technological considerations, respectively, based on their own experiences.

Q&A, Discussion

- The circulating fluidised bed (CFB) may provide the same level and scope of advantages in terms of CO_2 emission reduction and other environmental mitigation. Then how about the cost? I would also like to know required volume of biomass and levelized tariff.
- What is the optimal size of biomass?
- Demolition wood waste utilisation might have potential.
- CAPEX and OPEX are the most crucial.
  → In Thailand, stoker boilers are used for co-combustion, so the situation might be a little different.（SHI）
- Biomass–coal co-combustion is beneficial as it reduces CO_2 emissions and coal consumption. Also, possible emissions of methane from dumped agricultural waste will be prevented.
- As of now, Indonesia has not seen a policy framework for co-firing power plants (including the pricing policy) in place. This is partly because they are yet to find an effective way to monitor the use of the feedstocks. However, PT PLN (Persero), the national utility company, will soon conduct a co-firing trial in one of its power plants.
- In Thailand, public campaigns against coal caused coal-fired power plant plans to be cancelled. However, coal share is increasing in the latest PDP. Coal used is sub-bituminous or bituminous.
- To maximise biomass use, gasification is thought to be suitable for smaller power generation.
- JCOAL conducted a demonstration of biomass gasification in rural areas. That was on small scale, 2 MW, and efficiency is not as high as a large-scale USC. However, it is possible where a smaller scale plant is suitable. The JCOAL team will later provide details.
- Identification of a possible biomass–coal co-combustion and the desired composition is important. The most crucial is whether it is feasible in ASEAN.
- Talking about safety, what type of technology is required to ensure safety? In Thailand, where people are more concerned about environmental impacts and safety of power generation, it is to be much clearer.

- Indonesia's price policy is US ¢ 4–5/kWh for coal and US ¢ 10/kWh for biomass.
- As for plant scale, the biggest in Indonesia is 10 MW; that is in palm oil plantations.
- There are concerns about big differences in skills and economic feasibility.
- A unit of 50–100 MW is considered appropriate. Plant location is important for increasing feasibility with plantation, etc. （SHI）
- There are five important points: (i) feasibility, (ii) biomass potential, (iii) public acceptance, (iv) price policy, and (v) recommendations for policy support.
- People in Thailand have impressions that biomass does not require much labour and time.
- Policy barriers are to be identified and addressed. (SHI)
- In summary, the Mae Moh mine mouth power plant is running out of cheap coal.
- Power plants that use co-combustion of biomass with coal of any mix ratio may not be allowed to register under Republic Act No. 9513.
- A co-combustion power plant may be registered under Republic Act No. 9513 until such time that the plant is 100% fired by biomass.
- Considering the volume of biomass needed to replace coal in power plants of big capacity, it would be very difficult to identify the source of biomass feedstock, and the collection/consolidation and logistical requirement needed. A typical 12 MW biomass power plant requires 13 tons/hour or about 103,000 Mt of pure rice hull per year.

To conclude, the working group summarised the importance of biomass utilisation as follows: (i) use of domestic biomass resources, especially waste materials; (ii) GHG reduction; and (iii) mitigation of regional environmental impact for replacing coal.

For further materialisation and facilitation, policy recommendations for government support, such as tariff incentive, demonstration, and research and development, are the most important outcomes of the study.

Through the discussion, the scope and schedule of the biomass study were agreed on by working group members. JCOAL will provide the draft report by the middle of May for further feedback by the working group members.