Chapter 3

Potential of Ammonia Co-firing in ASEAN Countries

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Chapter 3

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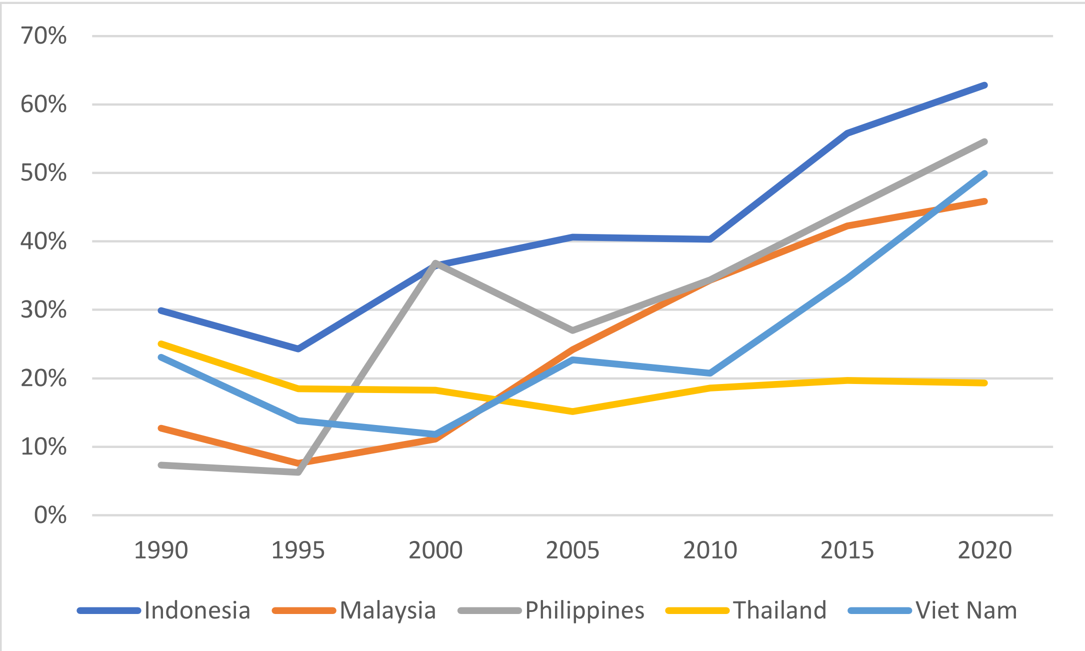
1. The Necessity for Coal–Ammonia Co-firing

Coal power is facing difficulties under the climate mitigation requirements. COP26 referred to the phasedown of unabated coal power, and the voluntary group comprising over 190 countries and businesses has committed to the phaseout of unabated coal power. However, coal power is currently one of the essential sources of electricity in ASEAN (Figure 3.1). Therefore, reducing emissions from existing coal power is an important step to decarbonising ASEAN pragmatically. This work evaluates the potential of coal–ammonia co-firing in ASEAN 5 countries – Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam.

Figure 3.1. Share of Coal Power Generation in ASEAN 5 Countries



Source: IEA (2021c).

2. Precondition for the Calculation

The coal power unit database developed by Enerdata[37] and other country-specific and technology-specific data were used to estimate the potential of coal ammonia co-firing (Figure 3.2).

Coal power capacity

Two scenarios were assumed for additional coal power capacity in the future (Table 3.1). In the 'low' scenario, all capacity under the construction phase will be operational by 2030. In the 'high' scenario, all capacity under the construction and project phases will be operational by 2030. No additional capacity was assumed after 2031 for both scenarios. Although database information, such as commissioning and decommissioning years, was used to judge the operation status of the unit in the target year, the default lifetime of 40 years was also used in case of lack of such information.

Table 3.1. Scenario for Additional Coal Power Capacity

Scenario	Additional Capacity
Low	~2030: All capacity under construction phase 2031~: No additional capacity
High	~2030: All capacity under construction and project phase 2031~: No additional capacity

Source: Author.

Ammonia co-firing ratio

All coal power units with over 10 years of residual life are assumed to have a co-firing ratio of 20% after 2035[38] and 50% after 2045. In this work, no technological or geographical constraints were considered for introducing ammonia.

[37] https://www.enerdata.net/research/power-plant-database.html

[38] 5 years later than Japan's target shown in the Green Growth Strategy.

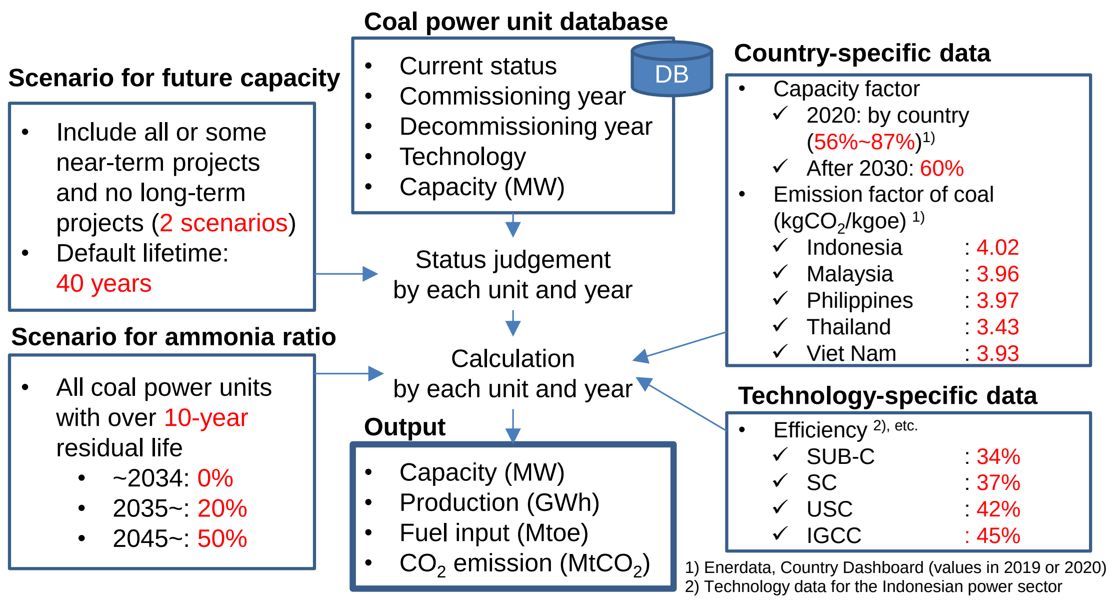
Capacity factor

The future capacity factor of power plants is highly uncertain. Here, 60% was simply assumed for all five countries after 2030. Note that the actual capacity factor of coal power was used for each country in 2020.

Efficiency

Technology data for the Indonesian power sector (Danish Energy Agency, 2021) was used for the efficiency of each technology. In case of lack of technology information in the database, subcritical and ultra-supercritical (USC) were assumed for existing and planned power plants, respectively. A study (CRIEPI, 2019) showed that the efficiency of coal power plants could be lowered by 3.7% point (HHV) by mixing ammonia at 20%. However, it also pointed out that efficiency can be improved by additional plant refurbishment or optimisation of various combustion parameters. Therefore, this study does not assume any drop in efficiency by mixing ammonia in the future.

Figure 3.2. Overview of Methodology

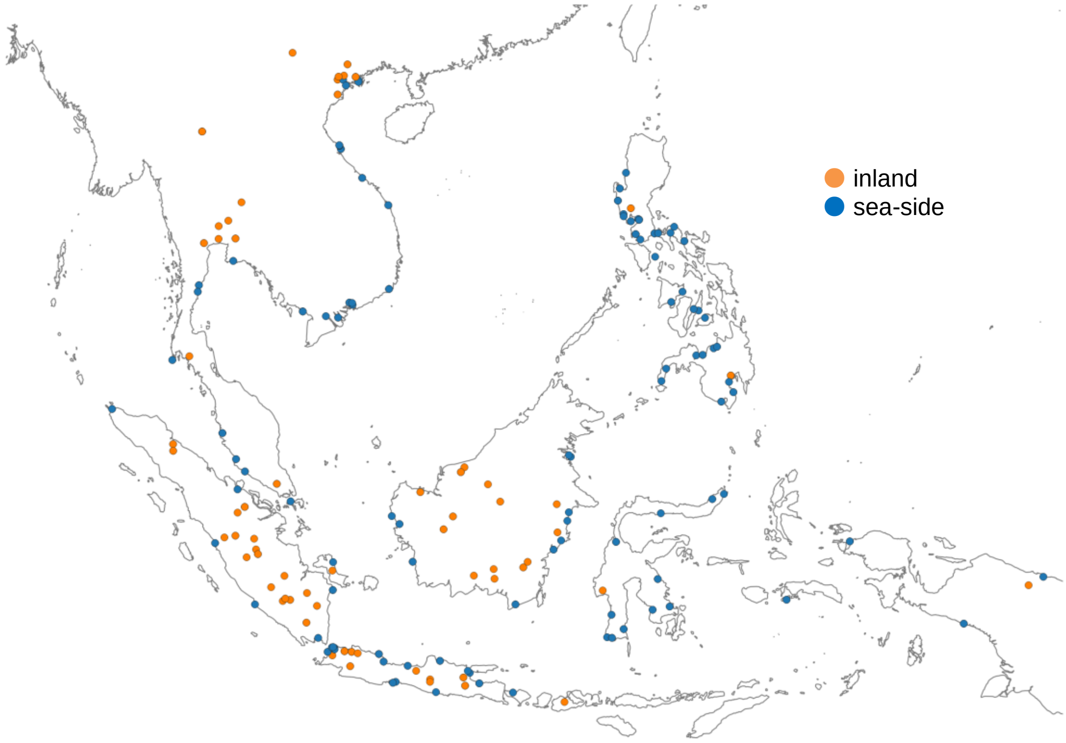


IGCC = integrated gasification combined cycle, SC = supercritical, SUB-C = subcritical, USC = ultra-supercritical.

Source: Author.

Since the database also includes the latitude and longitude of the power plants, they can be plotted on the map with Geographical Information System (Figure 3.3). Considering importing ammonia by ship, sea-side plants might be suitable for co-firing. However, as already stated, the geographic constraints were not considered in this analysis.

Figure 3.3. Location of Coal Power Plants in Five Countries



Note: Plants under construction or development are also included.

Source: Author, based on Enerdata.

3. Estimation of Coal–Ammonia Co-firing Potential

3.1. Coal power capacity

Figure 3.4 shows the coal power capacity by 2050. In short, the capacity would increase dramatically by 2030 in Indonesia, the Philippines, and Viet Nam if all projects were successfully developed, while it would decrease significantly by 2040 in Malaysia and Thailand. Note that our estimation with Enerdata's database is not necessarily consistent with government plans. In addition, some countries are currently developing their new power development plans (PDPs), including the outlook of coal power.

For Indonesia, coal capacity would be doubled by 2030 in the high scenario. Although the government plan is close to the low scenario in 2030, the plan seems to assume a more aggressive retirement of coal towards 2050. With technology, the proportion of high-efficiency plants is expected to increase. However, the technology types of many planned power plants are unknown, and they are assumed to be USC in this analysis.

The Philippines also has a lot of additional capacity by 2030 in the high scenario. But this might be overestimated, considering DOE's declaration of coal moratorium. The predicted capacity by the government would be 13.6 GW in 2030 and 2040, between the low and high scenarios. By technology, subcritical would increase towards 2030 in the high scenario. As a result, the average efficiency would not improve very much.

Viet Nam would experience increased coal capacity more than any of the other four countries in the high scenario. The capacity would be 56 GW by 2030 in the high scenario, 10 GW of which is already being constructed. The government plan is estimated to be around 40 GW[39] by 2030. Much of the additional capacity would be supercritical rather USC.

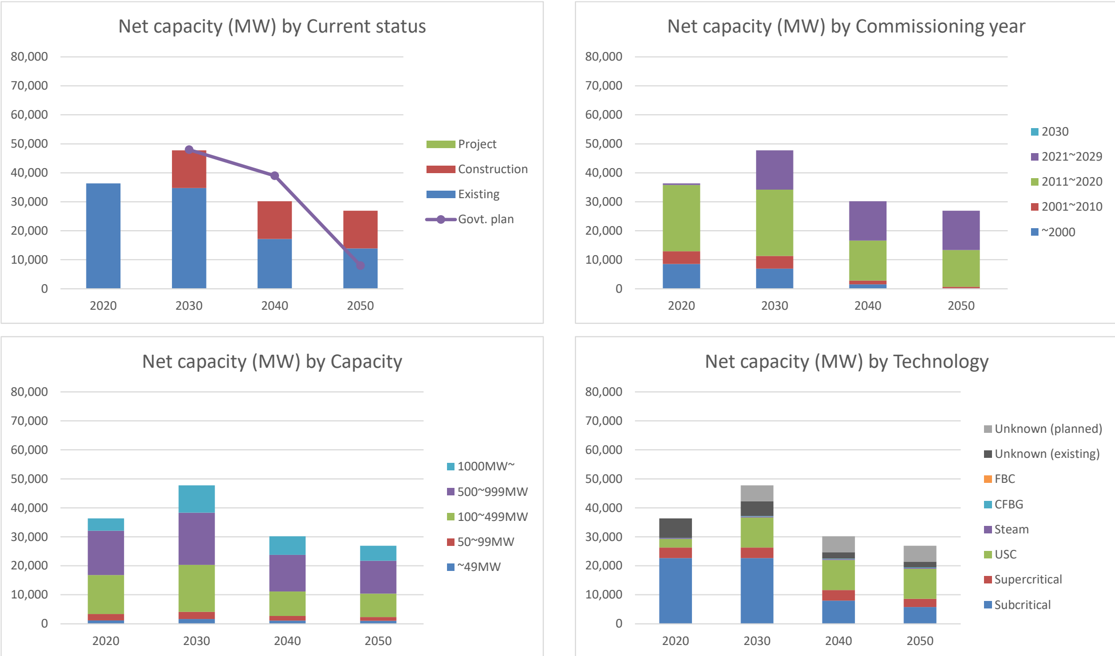
In Malaysia and Thailand, on the other hand, the limited additional capacity would be operational by 2030, according to the database. As a result, coal capacity in these two countries would significantly decrease by 2040 without any long-term projects or lifetime extensions for existing plants. Note that the governments predict more capacity than our estimation by 2040, implying that some additional plants are not included in the database[40] and/or lifetime extension.

[39] Coal power accounts for 28.3% to 31.2% in the total capacity of 130 GW to 144 GW in 2030.

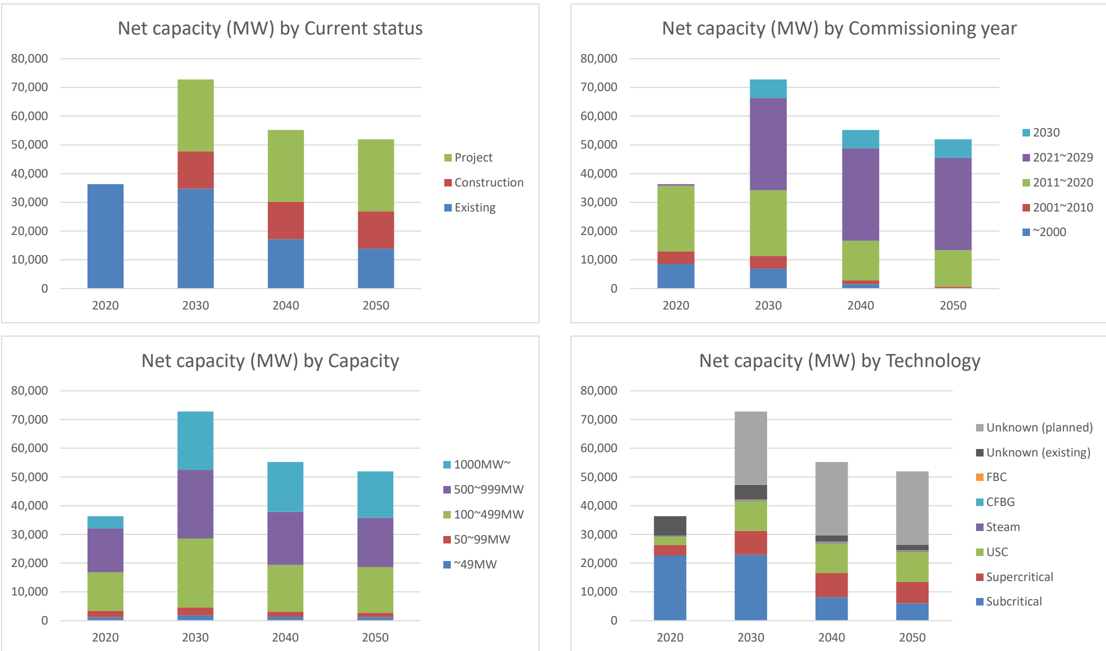
[40] In Thailand, the replacement of Mae Moh 4-7 is not included in the database.

Figure 3.4. Coal Power Capacity by 2050 (Indonesia)

[Low scenario]



[High scenario]



Source: Author.

Figure 3.5. Coal Power Capacity by 2050 (Malaysia)

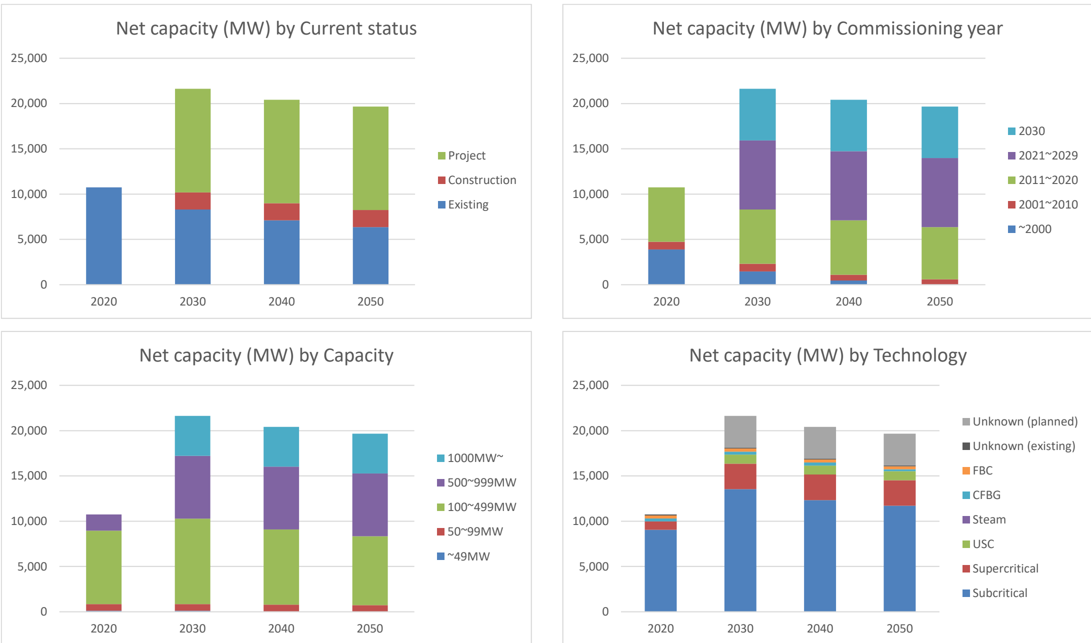
[Low / High scenario]

Source: Author.

Figure 3.6. Coal Power Capacity by 2050 (Philippines)

[Low scenario]

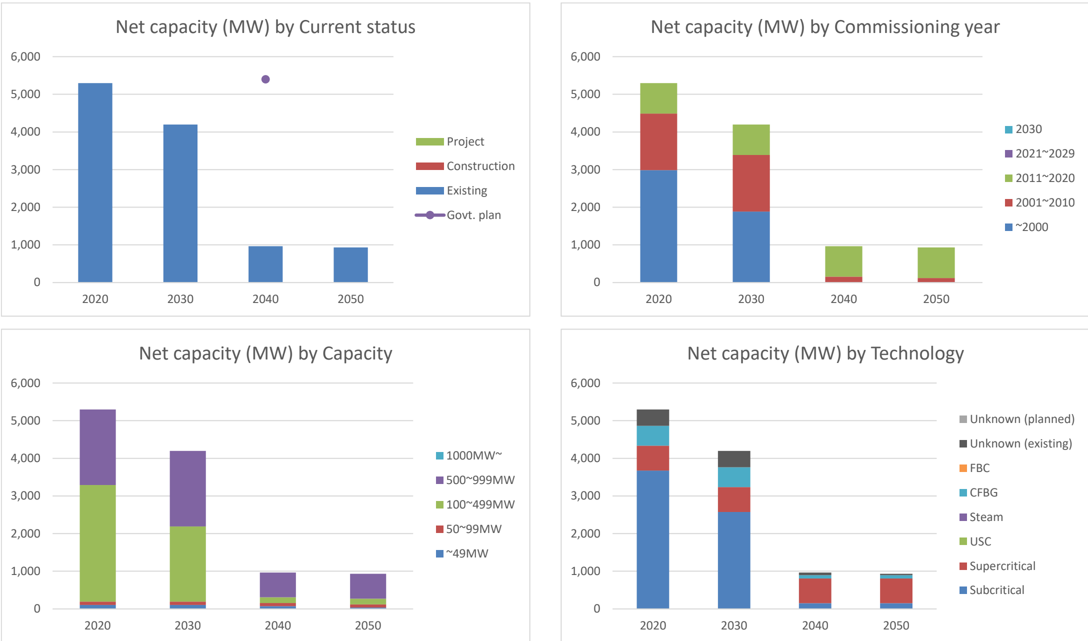
[High scenario]



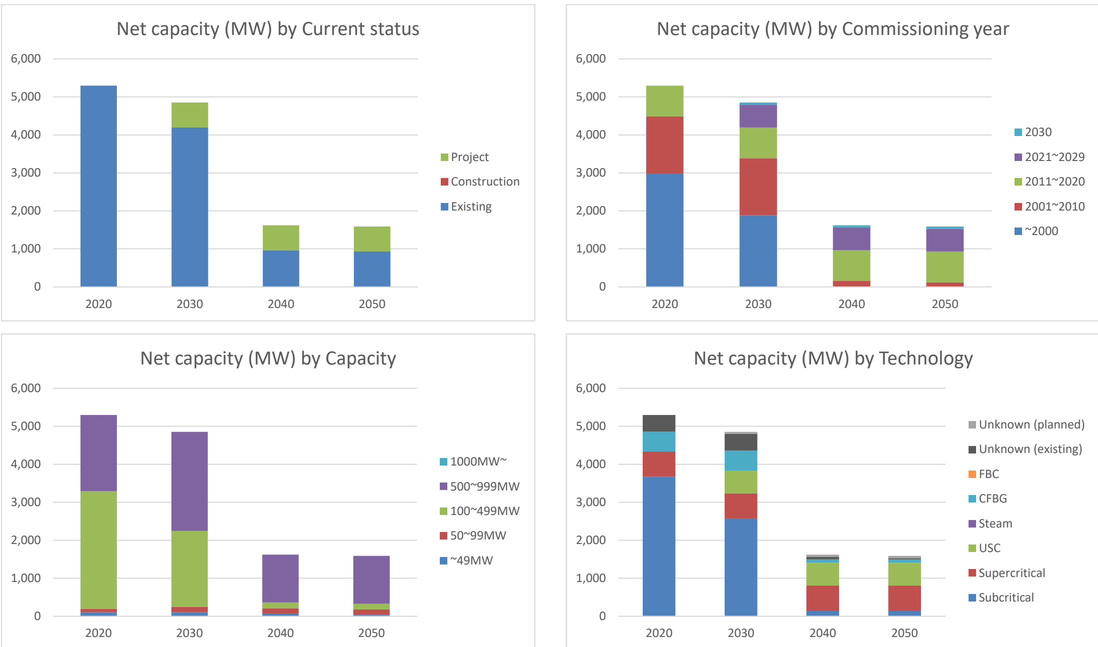
Source: Author.

Figure 3.7. Coal Power Capacity by 2050 (Thailand)

[Low scenario]



[High scenario]

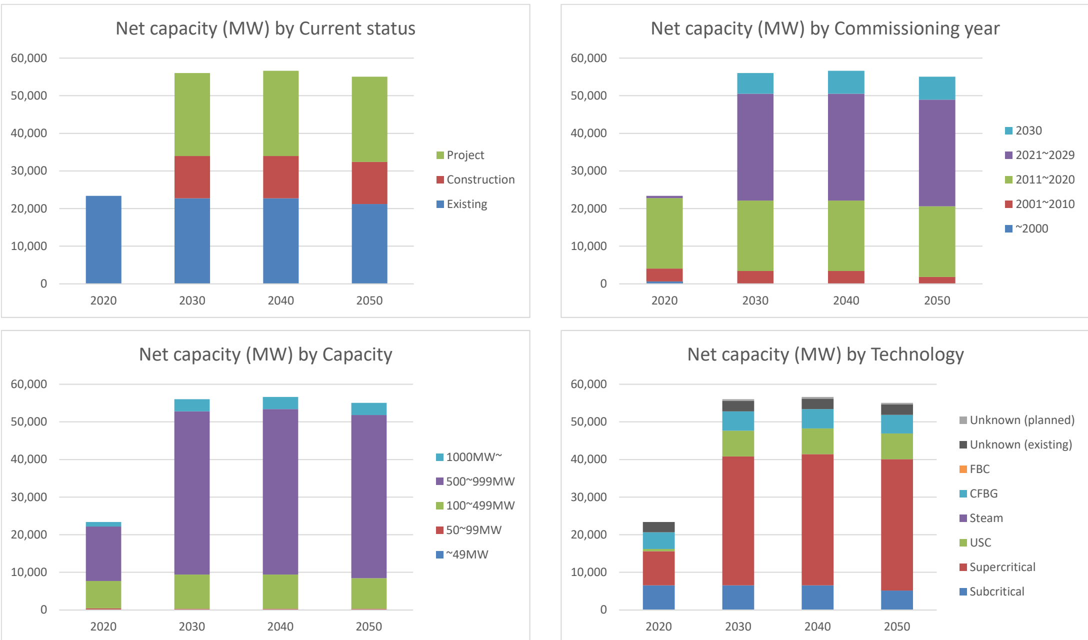


Source: Author.

Figure 3.8. Coal Power Capacity by 2050 (Viet Nam)

[Low scenario]

[High scenario]



Source: Author.

3.2. Fuel input and CO_2 emission

In addition to the low and high scenarios, the PDP scenario, which reflects each country's government plan, was added here for reference. Note that bottom-up estimation using the database was not conducted for the PDP scenario, so the average efficiency and ammonia ratio under the PDP were simply assumed at 40% and 50%, respectively.

In ASEAN 5 countries in 2050, as much as 147 $MtCO_2$ to 283 $MtCO_2$ emissions could be avoided from coal power plants by making the most of ammonia co-firing potential (Table 3.2 and Figure 3.9). These figures are equivalent to 10%–18% of total energy-related CO_2 emissions in 2019. The ammonia demand would be 83 Mt to 160 Mt (37 Mtoe to 71 Mtoe) in 2050, which is a considerable volume compared with the current global ammonia demand of 200 Mt (mainly for fertiliser). How to supply this amount of blue or green ammonia is the key.

Table 3.2. Reduced CO_2 and NH_3 Demand by Coal Ammonia Co-firing in 2050

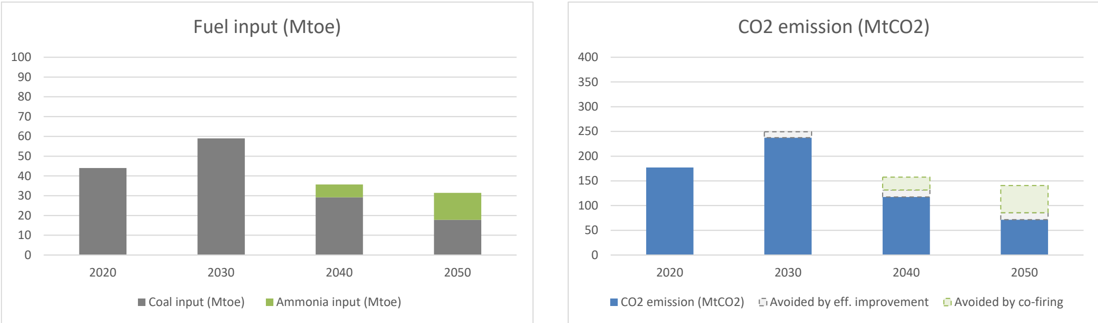
Scenario	Item	IDN	MYS	PHL	THA	VNM	Total
Low	Capacity [GW]	27	3	8	1	32	71
	CO_2 reduced [Mt]	55	6	19	1	67	147
	NH_3 demand [Mt]	31	3	11	1	38	83
PDP (ref.)	Capacity [GW]	8 (2050)	8 (2040)	14 (2040)	5 (2037)	41 (2030)	76
	CO_2 reduced [Mt]	18	18	30	10	91	168
	NH_3 demand [Mt]	10	10	17	7	52	96
High	Capacity [GW]	52	3	20	2	55	131
	CO_2 reduced [Mt]	110	6	46	2	119	283
	NH_3 demand [Mt]	61	3	26	1	68	160

Note: A 40% efficiency and ammonia ratio of 50% are assumed for calculating the PDP scenario.

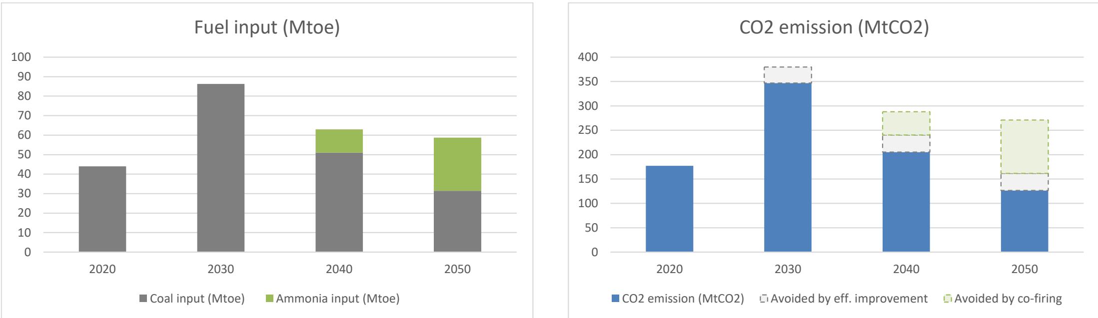
Source: Author (Capacity in the PDP is based on information from each country).

Figure 3.9. Fuel Input and CO_2 Emission by 2050 (Indonesia)

[Low scenario]



[High scenario]

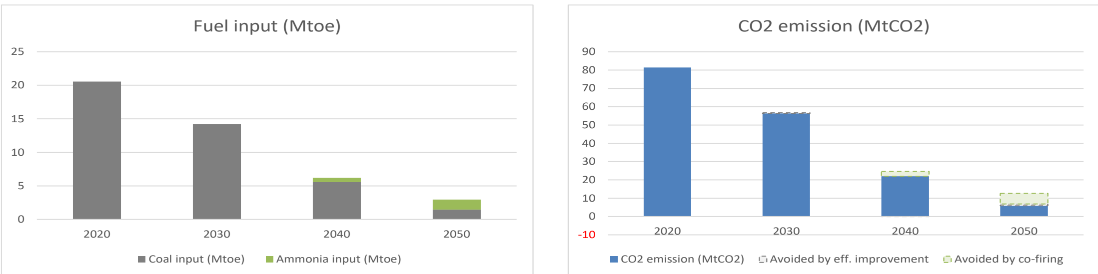


Note: Avoided by efficiency. Improvement shows the comparison with efficiency in 2020.

Source: Author.

Figure 3.10. Fuel Input and CO_2 Emission by 2050 (Malaysia)

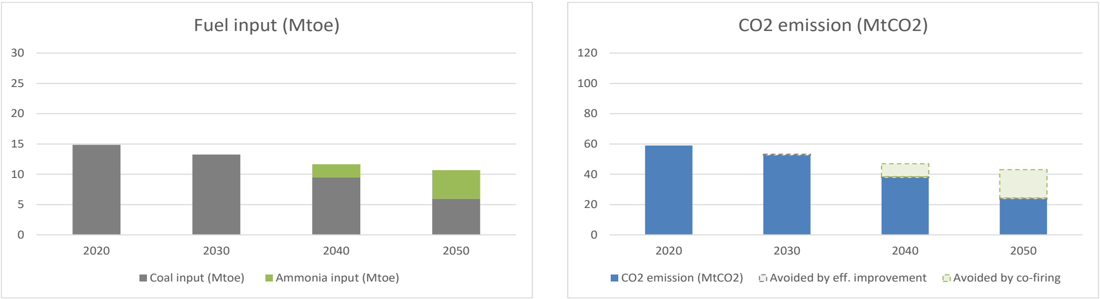
[Low / High scenario]



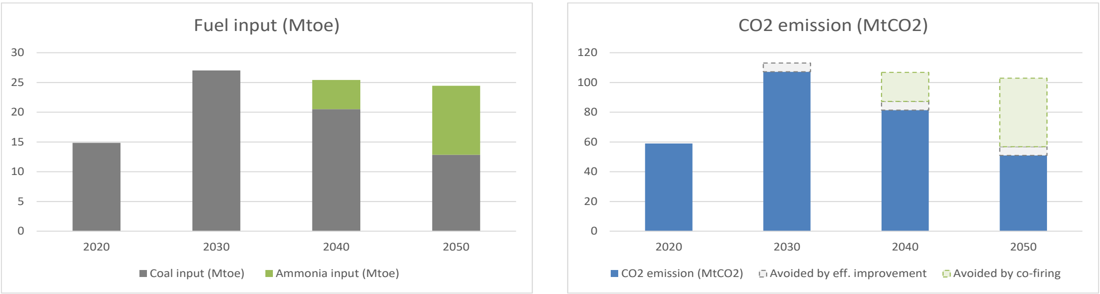
Source: Author.

Figure 3.11. Fuel Input and CO_2 Emission by 2050 (Philippines)

[Low scenario]



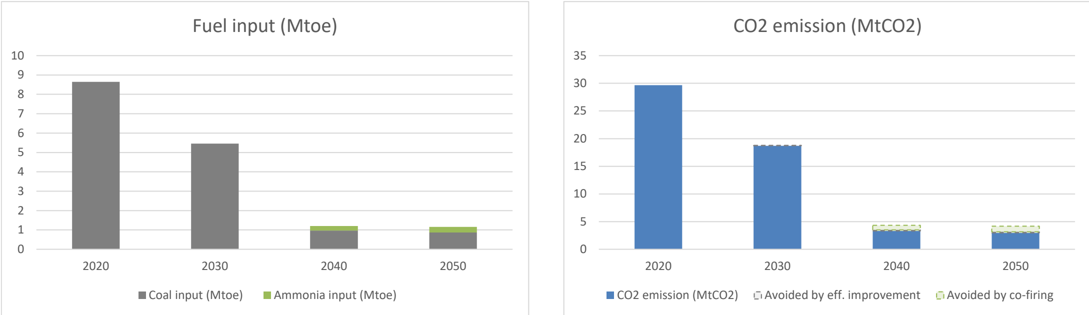
[High scenario]



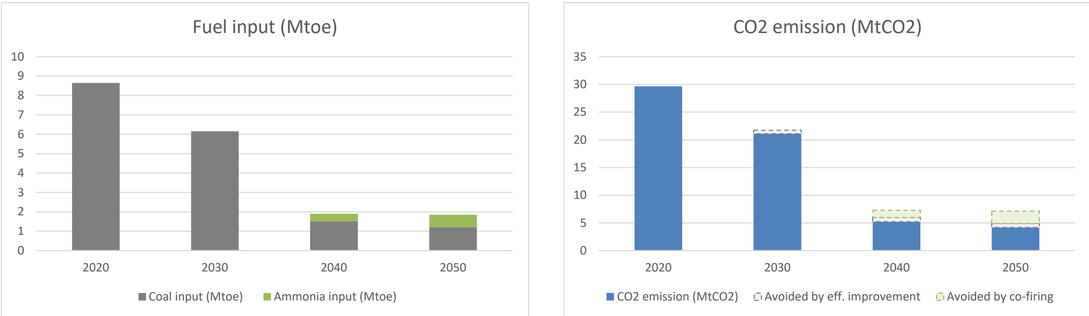
Source: Author.

Figure 3.12. Fuel Input and CO_2 Emission by 2050 (Thailand)

[Low scenario]



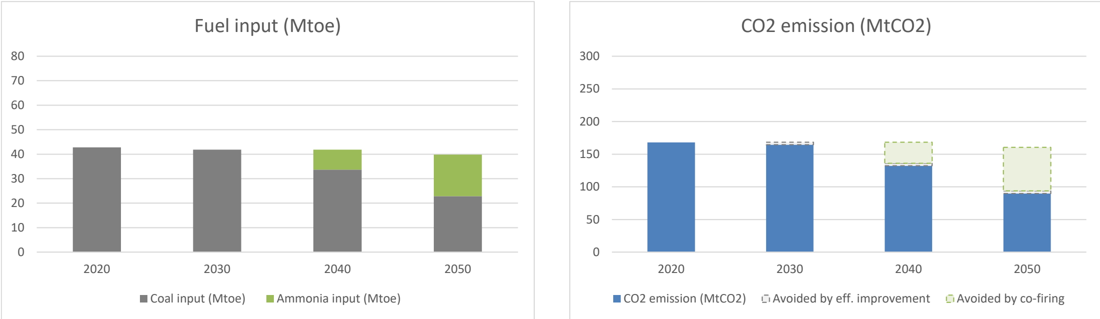
[High scenario]



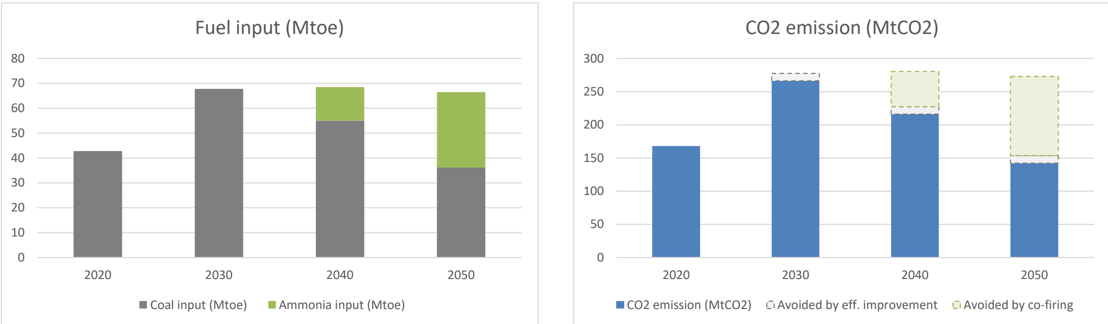
Source: Author.

Figure 3.13. Fuel Input and CO_2 Emission by 2050 (Viet Nam)

[Low scenario]



[High scenario]



Source: Author.

4. Issues for Ammonia Co-firing (Policy/Technology/Cost/Logistics)

Malaysia has a proven track record in ammonia production but does not have sufficient technology for ammonia co-firing. Therefore, it announced that the technical study of ammonia co-firing would be carried out with the cooperation of Japanese companies at the International Conference on Fuel Ammonia held in October 2021.

In the Philippines, since the electricity price is relatively high compared to other ASEAN countries, it is difficult to refurbish power generation facilities which lead to higher electricity prices. Therefore, like other decarbonisation technologies, raising funds for equipment refurbishment is challenging for ammonia co-firing. However, a Japanese private company has invested in a major electric power company in the Philippines and is considering the introduction of a power plant using green fuel, such as ammonia. Also, where energy resources are scarce, forming a supply chain that stably procures ammonia is also a challenge.

Viet Nam plans to promote renewable energy towards the realisation of carbon neutrality. On the other hand, since the number of coal-fired power generation units is large during the transition period, the cost of refurbishment for ammonia co-firing will be high. Moreover, stable and low-priced procurement is required to supply ammonia to many power plants. So far, ENV and Japan (METI, NEDO, JCOAL) have agreed to promote the sharing of technical information and cooperation.