Chapter 3

By-country Situation and Perspectives

June 2023

This chapter should be cited as
ERIA study team (2023), ‘By-country Situation and Perspectives, in Yamada, F., K. Murakami, H. Phoumin (eds.), *Study on the Applicability of CCT for a Comprehensive and Optimal Carbon-neutral Solution in ASEAN*. ERIA Research Project Report FY2023 No. 04, Jakarta: ERIA, pp.22-96.

Chapter 3

By-country Situation and Perspectives

1. Indonesia

1.1. Energy and Power Sector Overview

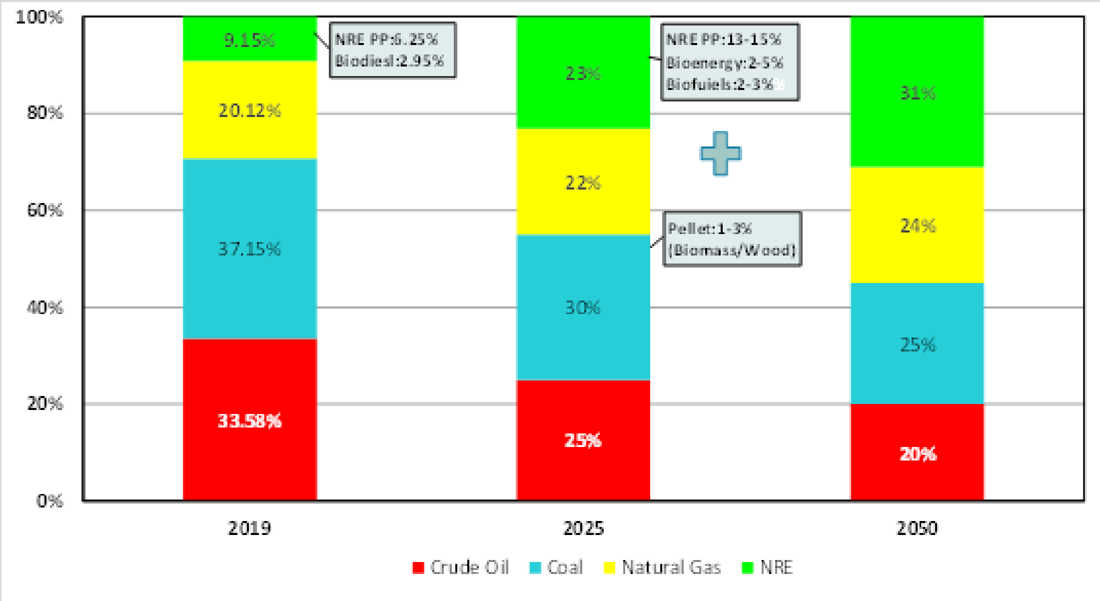
Endowed with fossil fuel resources such as crude oil, natural gas, and coal, Indonesia has been using these as its primary energy sources and a source of state revenue. However, as the reserves of fossil fuels are declining and depleting, and as a global call for emission reduction is intensifying, Indonesia has started to shift its energy policy towards a massive introduction of new and renewable energy (NRE) sources, in the hope of diversifying energy sources and curtailing the use of fossil energy.

1) Energy mix

Figure 3.1 shows the realisation and future target of the latest National Energy Plan (RUEN) formulated in 2017. NRE share in the total energy mix will increase from 9.15% in 2019 to 23% in 2025, and 31% in 2050, the largest in the energy mix in 2050.

In 2019, NRE contributed 9.15% of the total energy mix, comprising 6.2% of the NRE power plant and 2.95% of biodiesel. To achieve a 23% target of NRE share in 2025, the Indonesian government will increase the NRE power plant and boost bioenergy utilisation. Bioenergy power plants will contribute around 2%–5%, while biodiesel utilisation will contribute around 2%-3%. In addition to pursuing the target, the government will implement biomass cofiring with coal-fired power plants (CFPPs), which is expected to increase the NRE portion by 1%–3%. Currently, biomass used for cofiring in the CFPPs is not included in the NRE and is classified as coal by Indonesian government rules.

Figure 3.1. The Realisation and Target of National Energy Mix



Source: Working Group presentation for the Study on Biomass and Coal Co-combustion in the ASEAN Region (II).

2) National power development plan and key directions

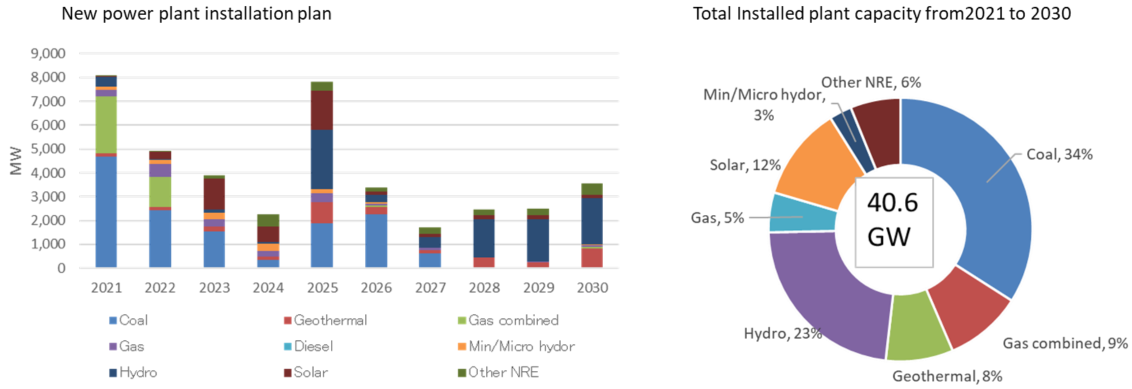
Indonesia's electricity supply business plan, known as RUPTL (*Rencana Usaha Penyediaan Tenaga Listrik*), is prepared by the Perusahaan Listrik Negara (PLN), the state-owned power company. The RUPTL is published annually to review the detailed electricity supply plan for 10 years.

It took more than a year from the issuance of the RUPTL in 2019 until the RUPTL in 2020 was released because the PLN had to observe the unusually slugging electricity demand growth due to the COVID-19 pandemic. The PLN also tried to identify how and to what extent it would have to reflect the impact of the pandemic and energy transition requirements to formulate the new RUPTL. The government also shifted to RE due to Indonesia's commitments under the Paris Agreement and its recently declared carbon neutrality objectives. The new RUPTL was released on 5 October 2021 after a review and revision of the power supply configuration as follows:

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

Figure 3.2 shows the installed generation capacity of Indonesia in 2020 and 2030. The installed capacity in 2020 is 63.3 GW, and the expansion in RUPTL 2021–2030 is 40.6 GW. The total power plant capacity will be 99.2 GW in 2030. By substituting CFPPs with NRE power plants, the share of coal power in the projected installed capacity mix in 2030 will be less than half, and the NRE share will be 29%.

Figure 3.2. New Power Plant Installation Plan

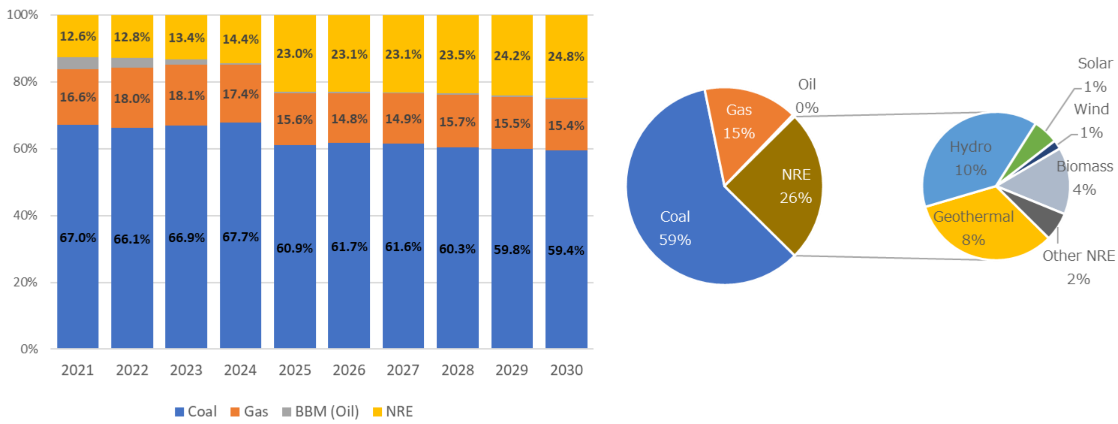


Source: PLN (2021).

3) Power generation energy mix

Figure 3.3 illustrates the electricity production and energy mix of power generation in 2030 based on RUPTL 2021. Total electricity production in 2030 will be 445 TWh. In 2025, NRE will significantly increase due to a policy response of 23% NRE generation. The main NRE are hydro, geothermal, and biomass, which are baseload power sources. But coal still accounts for 60% of electricity generation.

Figure 3.3. Electricity Production and Power Generation Energy Mix in 2030



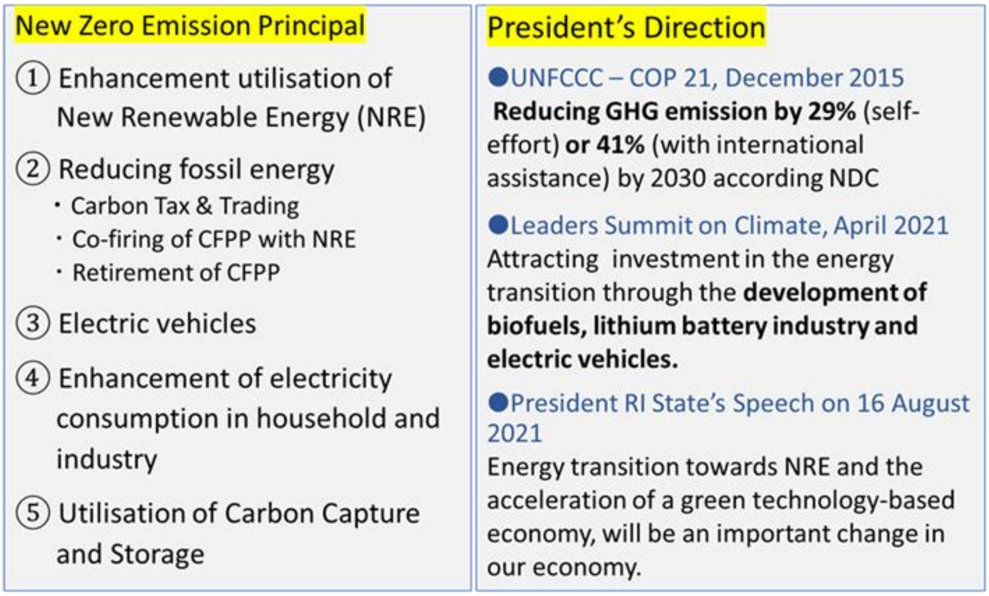
Source: PLN (2021).

1.2. Policy Towards Carbon Neutrality and Other Related Policies

Figure 3.4 shows the statement and basic principles of the Indonesian President for CO_2 emission reductions. The basic principles are mainly the promotion of NRE use, the reduction of fossil fuels, especially coal, and the promotion of EVs.

Finally, President Joko Widodo declared at COP26 the promotion of RE and achievement of carbon neutrality (CN) by 2060 on the premise of accepting international support.

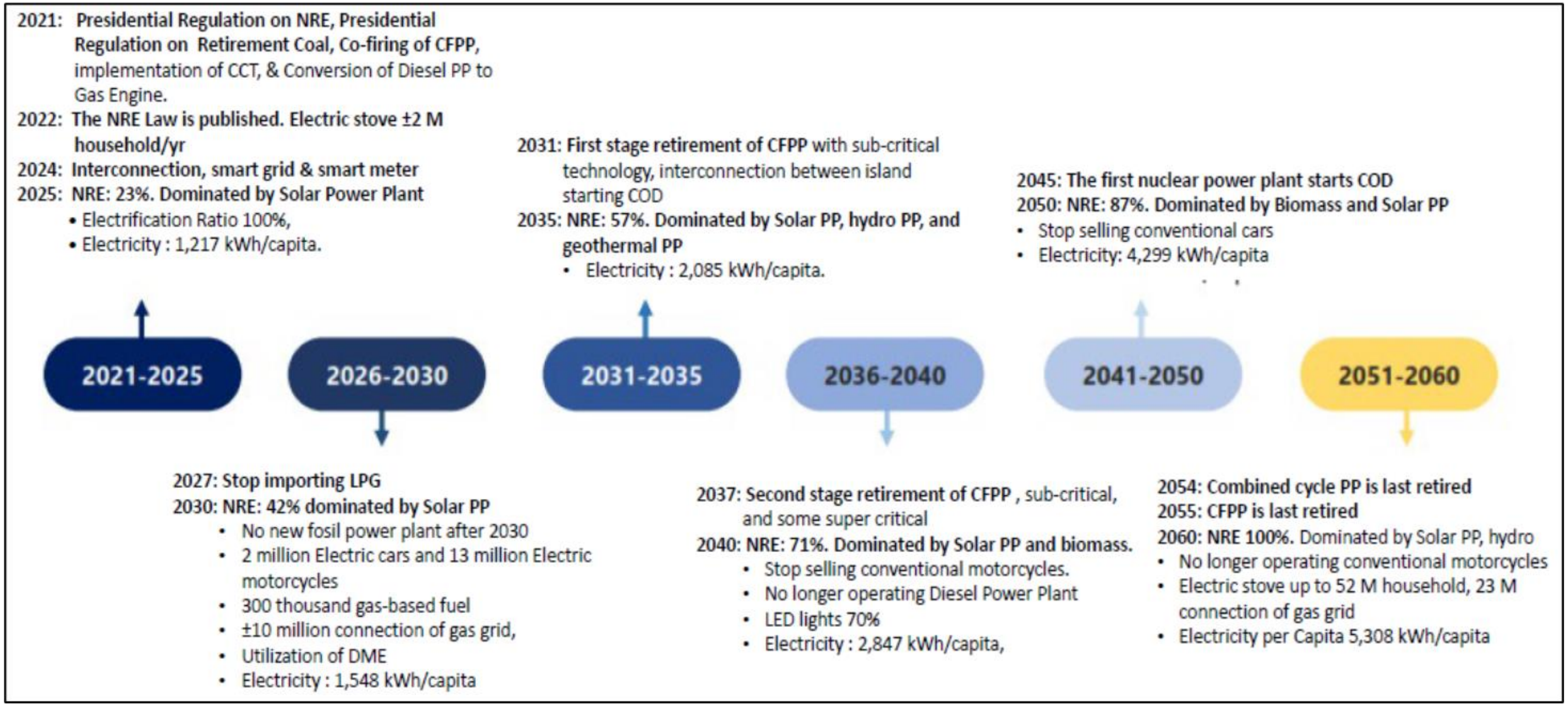
Figure 3.4. Main Pillars of Policy and President's Directions for Carbon Neutrality



Source: Directorate General of Electricity, MEMR (2021).

Figure 3.5 shows the prepared roadmap based on this CN in 2060, and the items to be implemented are set annually.

Figure 3.5. Roadmap for Carbon Neutrality in 2060



Source: Directorate General of Electricity, MEMR (2021).

In addition, a new presidential regulation was enacted on September 2022 to achieve CN. The outline of this Presidential Regulation No. 112 of 2022 is as follows:

- Banning the development of new CFPPs with certain exceptions (including CFPPs already included in PLN’s development plan [RUPTL])
- Reducing CFPPs by authorising the MEMR to accelerate the termination of CFPPs operated by the PLN and/or independent power producers (IPPs)
- Replacing the basis of the NRE tariff from the average electricity generation basic cost to a ceiling price based on the type of energy sources and locations
- Streamlining the procurement process of NRE projects through a direct appointment and selection and providing a time limit to conclude the entire process
- Providing incentives for geothermal power plants.

1.3. Ongoing and Planned Measures for Carbon Neutrality

The key CN measures by the Government of Indonesia are as follows:

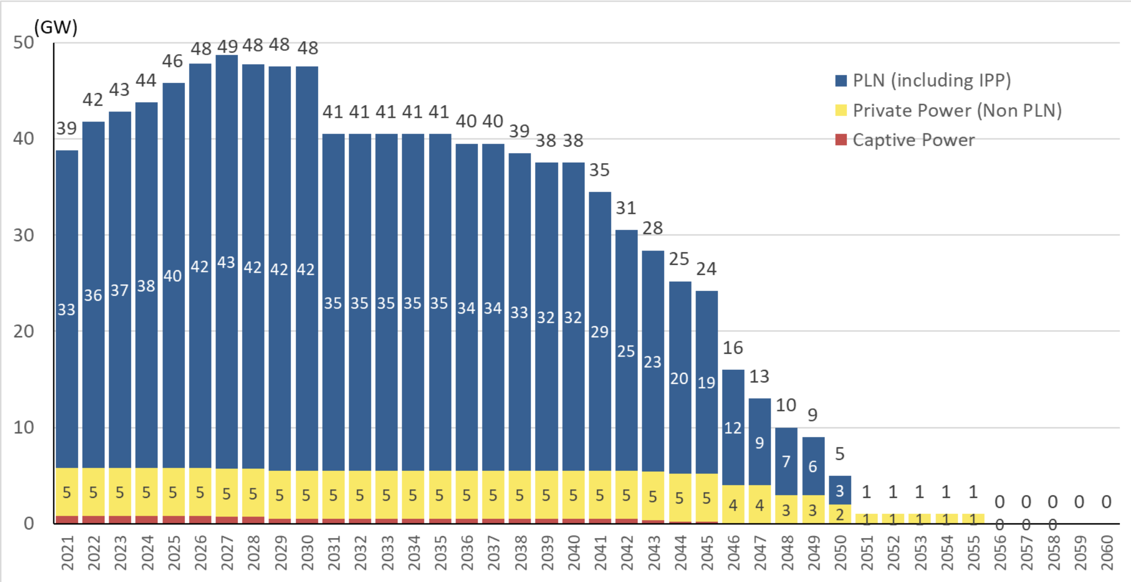
1) Decreasing CFPPs

Figure 3.6 shows the phaseout plan of the CFPPs, which will be gradually reduced from 2031 and abolished by 2056.

The basic principles are as follows:

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

Figure 3.6. Phaseout Plan of Coal-fired Power Plants

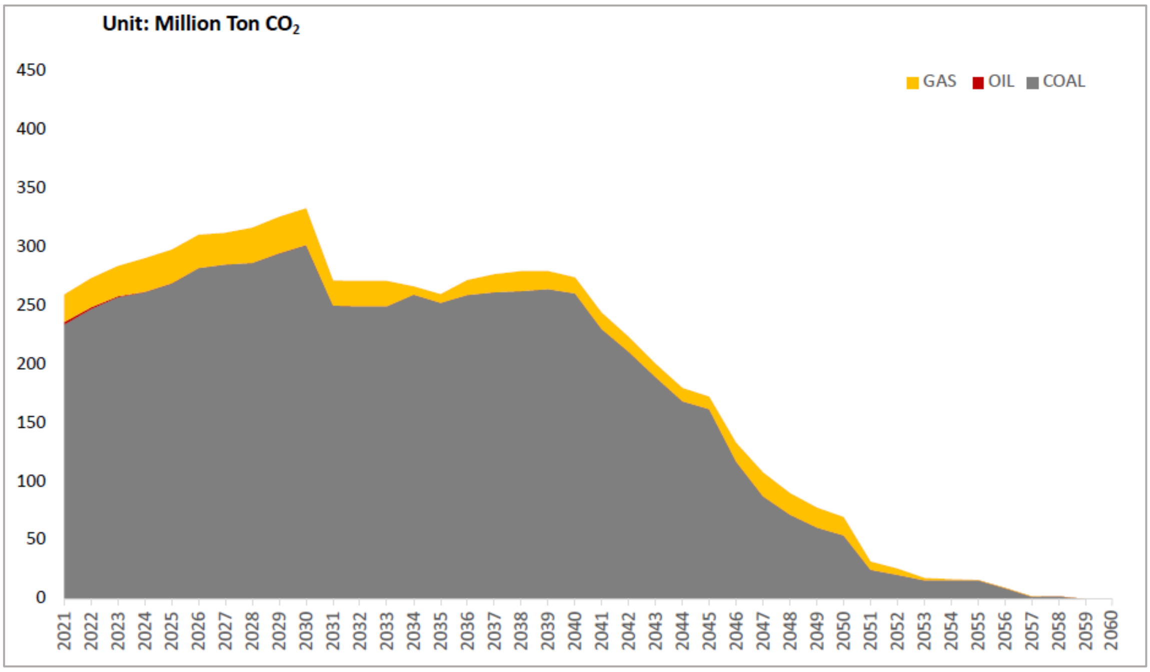


Source: The First Working Group Presentation for the Study on Net-zero Emission Scenario in Indonesia's Power Sector.

Figure Figure 3.7 shows the change in CO_2 emissions based on this reduction plan. The main changes are as follows.

- Total emissions from the power generation sector in 2021 were 60 million tonnes of CO_2-e.
- Towards 2030, power plant emissions will peak at 333 million tonnes CO_2-e.
- Emissions will sharply decrease by 2031 as coal and combined cycle power plants peak.
- Emissions will significantly go down after 2040, following the completion of fossil plant
- contracts.
- Emissions of power plants will be close to zero by 2057.

Figure 3.7. Projection of Power Generation Emission



Source: The First Working Group Presentation for the Study on Net-zero Emission Scenario in Indonesia's Power Sector.

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

Table 3.1. Plan of Biomass Cofiring with Coal

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

Source: PLN (2021).

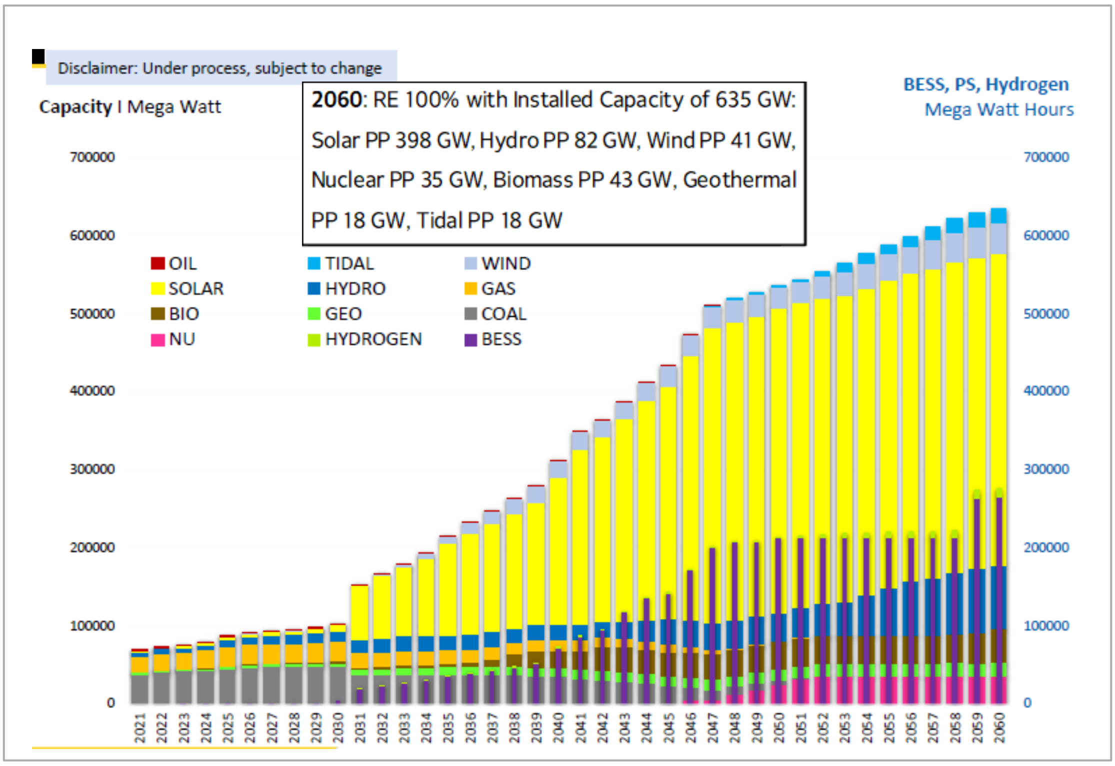
2) Promoting and increasing NRE

Error! Reference source not found. Figure 3.8 shows the power supply plan until 2060 that is under consideration based on the CFPP phaseout plan.

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

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

Figure 3.8. Power Plant Capacity and Electricity Production by 2060



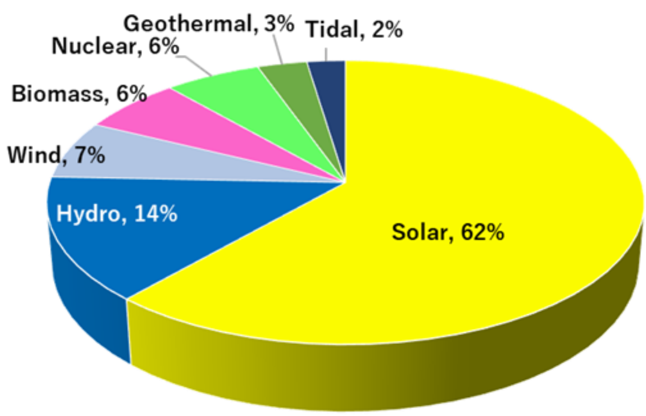
Source: The First Working Group Presentation for the Study on Net-zero Emission Scenario on Indonesia's Power Sector, MEMR (July 2022).

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, which is the baseload power source.

NRE targets in 2060 are as follows.

- The goal is to build a fully decarbonised power sector with an installed capacity of 587 GW by 2060.
- As shown in Figure 3.9, the generation energy mix in 2060 is solar = 361 GW, hydropower = 83 GW, wind = 39 GW, bioenergy = 37 GW, nuclear = 35 GW, geothermal = 18 GW, and tidal power = 13.4 GW.
- Pumped-storage power generation: operation in 2025; 4,200 MW in 2060
- Storage batteries: Large-scale introduction starting in 2031, 140 GW in 2060
- Green hydrogen: Start in 2031, 520 MW in 2060

Figure 3.9. Power Energy Mix in 2060



Source: The First Working Group Presentation for the Study on Net-zero Emission Scenario in Indonesia's Power Sector, MEMR (July 2022).

Table 3.2 shows the NRE potential in Indonesia. Indonesia has abundant and various NRE resources. But currently, only 0.3% of the total potential has been utilised. The NRE potential is distributed as follows:

Table 3.2. NRE Potential

Energy Sources	Old (GW)	Updated (GW)
Solar	400.0	3,295
Hydro	90.0	99
Bioenergy	45.0	57
Wind	60.6	155
Geothermal	24,0	24
Ocean	18	60
Total	**637**	**3,686**

Source: The First Working Group Presentation for the Study on Net-zero Emission Scenario in Indonesia's Power Sector, MEMR (July 2022).

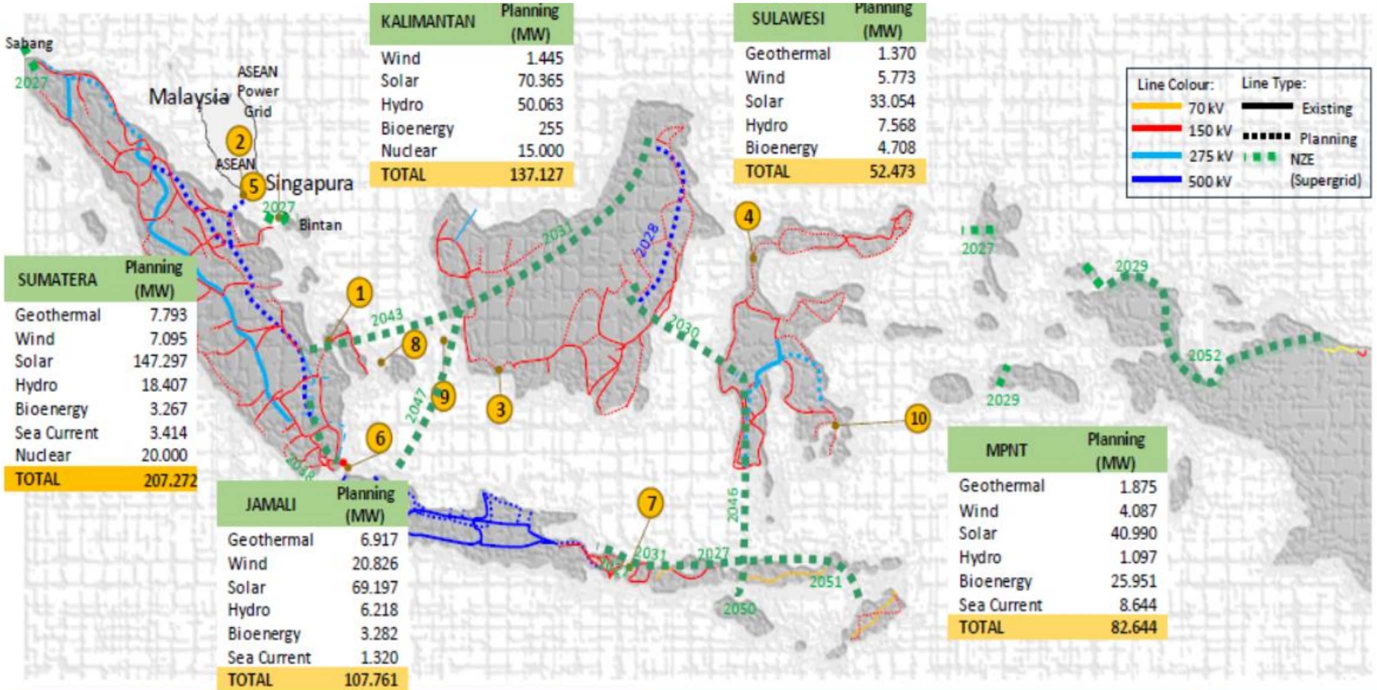
- Hydro potential spreads all over Indonesia
- Solar potential spreads all over Indonesia
- Wind potential (> 6 m/s) is particularly located in East Nusa Tenggara, South Kalimantan, West Java, Nanggroe Aceh Darussalam (NAD), and Papua
- Tidal energy potential, particularly in Maluku, East Nusa Tenggara, West Nusa Tenggara, and Bali
- Geothermal potential spreads in the ring of fire areas, including Sumatra, Java, Bali, Nusa Tenggara, Sulawesi, and Maluku.

Figure 3.10 shows a super grid plan for re-sharing resources.

NRE will increase as a substitute for coal. Since solar, wind, and tidal power are variable renewable energy (VRE), balancing these VRE plants with the base load power, such as hydropower, is necessary. However, the potential of each energy source is different in each region. Establishing the grid to achieve a balance across Indonesia is essential.

It is worth considering that microgrids may benefit some low electricity demand areas than getting connected to a larger network.

Figure 3.10. Super Grid Plan for Re-sharing Resources



National	Planning (MW)
Geothermal	17.955
Wind	39.226
Solar	360.902
Hydro	83.354
Bioenergy	37.463
Sea Current	13.378
Nuclear	35.000
TOTAL	**587.278**

A. Listed in *RUPTL*:

1. 150 kV Interconnection Sumatera-Bangka (2022);
2. 500 kV Interconnection Sumatera-Malaysia (2030), Supporting ASEAN Power Grid;
3. 150 kV Interconnection Kalimantan (2023);
4. 150 kV Interconnection Sulbagut-Sulbagsel (Tambu-Bangkir COD 2024).

B. Stated in RUPTL and need further study:

5. Interconnection Sumatera-Singapore (include Interconnection Sumatera-Bintan), supporting ASEAN Power Grid;
6. 500 kV Interconnection Sumatera-Jawa;
7. 150 kV Interconnection Bali-Lombok (require further study for Interconnection Jawa-Nusa Tenggara);
8. 150 kV Interconnection Bangka-Belitung (require further study for the Interconnection of Sumatera-Kalimantan);
9. Interconnection Belitung-Kalimantan (require further study for the Supergrid Nusantara program);
10. 150 kV Interconnection Baubau-Sulbagsel (require further study for the Bau-Bau Sulbagsel Interconnection System Reliability).

Source: The Second Working Group Presentation for the Study on Net-zero Emission Scenario in Indonesia's Power Sector (October 2022).

1.4. Applicable Technologies for Carbon Neutrality in Indonesia

Table 3.3 shows applicable technologies for CO_2 reduction and capture, utilisation, and storage of CO_2.

Based on Indonesia's CN plan, described in the previous section, applicable technologies for coal power generation, cofiring, storage, and NRE were reviewed. The results are reflected in the table.

1) CCT

Coal, Indonesia's most abundant and major indigenous energy source, has been supporting the national revenue until today. However, coal is the biggest emitter of CO_2. As mentioned, no more CFPPs will be constructed; they will be phased out. This direction was confirmed at the G20 hosted by Indonesia in November 2022. The 'no more new CFPP' policy is conditional, except for financially closed ones and those under construction. Also, those under any specific national development plan can be exempted from the directive, according to the newly legislated Presidential Regulation No. 112 of 2022. With the little possibility for new CFPPs, the introduction of CCTs such as IGCC and A-USC cannot be envisaged as they are not technology for existing CFPPs.

However, as those existing CFPPs shall continuously contribute to the power supply and as balancing resources for grid stabilisation in parallel with progressing massive RE introduction and emerging new energy development, CCT and the accompanying appropriate environmental compliance and efficiency techniques remain crucial.

Table 3.3. Applicable Technologies for Carbon Neutrality in Indonesia (1)

Road Map towards Carbon Neutrality						Indonesia
Reduction	Thermal Power	High Efficiency	IGCC			Not applicable
			IGFC			Not applicable
			A-USC			Not applicable
	Fuel	Biomass	Combustion	CFBC biomass firing		Applicable
				PC coal cofiring		Highly applicable
			Manufacturing	Material	Agricultural waste pellet	
					fast-growing tree	
				Pre-treatment	Torrefied pellet	Not applicable
					Washing	Not applicable
		Ammonia	Utilization	Ammonia gas turbine		Applicable
				Ammonia industrial furnace		Not applicable
				Ammonia-coal cofiring		Applicable
			Manufacturing	Ammonia process	Coventional process + CCS	Not applicable
					New&Innnovative process	Not applicable
				R&D base, Supply chain		
		Hydrogen	Utilisation	Hydrogen gas turbine		Applicable
			Manufacturing	Hydrogen process	water electrolysis by RE	Applicable
					Turquoise hydrogen	Applicable
				R&D base, Supply chain		
	Renewables	Wind, Solar, Geothermal	Offshore wind			Highly applicable
			Perovskite PV			Highly applicable
			Next generation geothermal			Highly applicable
		BESS	large Li-ion, NaS, Redoxflow			Highly applicable
	Manufacturing process	Steel	Coke reduction	Energy saving, LRC	ferrodoke	
				Direct reduction		
				Hydrogen reduction COURSE50	Super-COURSE50	
				carbon recycling BF		
		Cement				

LRC = low-rank coal.

Source: JCOAL Study Team.

Table 3.4. Applicable Technologies for Carbon Neutrality in Indonesia (2)

Road Map towards Carbon Neutrality						Indonesia
Capture	Capture/ Recovery	Capture/ Recovery	Recovery/generatri on	Oxyfuel IGCC		Not applicable
				Supercritical CO2 cycle generation		Not applicable
				Chemical looping combustion		Not applicable
			chemical absorption			Optional
			solid absorbent material method			Optional
			physical absorption			Optional
			membrane separation			Optional
			physical adsorption			Optional
Utilization	Chemicals	Chemicals	Core materials	Methanol		
				SOEC process	CO	
					Methyl Cycrohexane	
				Artificial photosynthesis	Olefin	
			Derivatives	Formic acid	Boron-doped diamond electrode	
				Polyurethane intermediate		
				Para-xylene		
				Polycarbonate		
				Polyurethane		
				Ethylene urea		
	Fuel	Fuel Synthesis	Gas fuel	Methane	Sabatier process	
					SOEC process	
					Biomass photosynthesis	
			Liquid fuel	Diesel	Biomass photosynthesis	
				Jet fuel	Biomass photosynthesis	
					Biomass gasification FT synthesis	
				Olefin, kerosene		
	Mineralization	Cement/conc rete	Concrete	CO2 absorption type		
				Carbonate type		
			Admixture	CO2 absorption type		
				Carbonate type		
	Others	Others	Sector Coupling	Industrial complex carbon recycling		
Storage	Storage	CCS, DACCS, BECCS	Forest absorption/afforest ation	afforestation		Applicable
				Blue carbon		Applicable
			CCS			Keenly pursued

Source: JCOAL Study Team.

2) Cofiring

CFPPs will increase until 2030 and will be phased out after 2031. However, coal is expected to remain a power generation source until 2057 as CO_2 emissions from CFPPs continue. Given the importance of enhanced environmental measures, especially in reducing CO_2 emissions, cofiring coal with biomass or ammonia, acknowledged as carbon-neutral, is effective. Currently, ammonia supply sufficiency and its value chain are yet to be secured. That the Government of Indonesia has been pursuing biomass cofiring implementation is the just and the most realistic measure to further reduce emissions from CFPPs towards 2030. During this period, Indonesia can explore possibilities for ammonia cofiring through studies and demonstrations, including cross-sectoral studies for the value chain formulation.

3) CCS/CCUS

CCS/CCUS is also effective in reducing CO_2 emissions from CFPPs. Many old oil wells in Indonesia are likely applicable for CO_2 storage. There is also potential for oil recovery as enhanced oil recovery.

4) NRE

NRE is expected to provide alternative power capacity as the capacity fulfilled by CFPPs decreases during its phasing down. Increased generation from RE is ongoing already. However, after 2031, the country will see the full-fledged development of various renewables. During its energy transition towards 2060, Indonesia has committed to developing 587 GW of clean energy–sourced power, of which 361 GW is solar, 83 GW is hydroelectric, and 39 GW is wind power. As CFPPs are phased down, VRE will take the overwhelming share of power generation. However, the issue of impacts on the grid will possibly emerge even in the early phase of the transition path. Then coal power can function as a balancing source while energy storage and other flexible sources like geothermal power are in place. Once-issued government initiative on rooftop solar power generation initially planned to be grid-connected is now pending following the concerns expressed by the PLN about the possible severe impact on the grid system.

In summary, NRE is no doubt anticipated to be the main force to support the power supply towards CN. And measures for grid stabilisation with flexible sources, including CFPPs, will be taken for sustainable power supply and energy transition.

5) Hydrogen

So far, Indonesia seems comparatively reserved about developing and utilising hydrogen. However, looking at the planned generation mix in 2060 in which solar dominance is outstanding and considering Indonesia is endowed with gas and coal, Indonesia will benefit from pursuing possibilities for both blue and green hydrogen.

1.5. Policy Recommendations with Key Considerations

President Joko Widodo declared at COP26 in 2021 to accelerate RE development and achieve CN with international support by 2060. Therefore, to ensure CN in 2060, RE will be gradually but steadily introduced and developed towards 2031, when the first planned retirement of CFPPs happens. NRE power plants will be massively added from thereon, while CFPPs will be phased down and then out.

1) Measures for grid system stabilisation

Grid system stability is probably the most crucial key to the energy transition.

In the case of Indonesia, like other AMSs, the situation could be more severe than in developed economies as VRE's introduction will proceed speedily to address the growing economy and power demand.

Indonesia has been trying hard to improve grid capacity and system management and will enhance its efforts in the coming years. Also, as part of ASEAN, Indonesia has an advantage from the ASEAN Power Grid; it will help the country with sustainable power supply and with requirements for grid flexibility. In addition to enhancing the grid system, flexibilisation can be ensured primarily through power plants that can perform flexible operations, such as pumped storage, gas, and coal. BESS 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 a must. Electrification plans with off-grid choices are worth considering, especially in island areas.

2) Coal-fired power plants can continue to contribute to the energy transition

Indonesia foresees a coal phase-down and phaseout in the power sector. However, as we have seen, VRE-solar and wind are clean but variable. Biomass is a big help in accelerating clean transition but is small to fulfil demand. Geothermal is anticipated to provide sufficient and invariable generation capacity but has yet to be smoothly developed. Ammonia and hydrogen are still midway through future application and deployment. 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.

In summary, coal will stay in the power generation mix of Indonesia for the foreseeable future and up to the latter part of the energy transition. Coal-fired power can be a flexible source if operated appropriately. So, Indonesia can continue using the existing CFPPs for power supply and supporting grid system stabilisation.

Even after retirement, CFPPs can be repurposed through conversion to synchronous phase modifiers, a proven and commercially available technology for grid stabilisation, or whatever purpose conducive to energy transformation.

We must note that environmental measures shall be continuously enhanced as long as CFPPs are utilised.

3) Shift of domestic coal use to the industrial sector

Coal is an important indigenous natural resource for Indonesia.

Forward-looking discussions by the government involving private sector players require urgency on shifting domestic coal use to the industrial sector for further clean and effective use suitable to the energy transition era. Its outcome will be conducive to the policy and policy instruments that will ensure appropriate and sustainable coal utilisation while the coal phase-down is progressing in the power sector.

4) Technology deployment to help with key knowledge and experience sharing with other AMSs

CCS, hydrogen, and ammonia utilisation is crucial technology requiring a grand design of cross-sectoral and internationally coordinated value chain based on sharing key knowledge and experiences between countries. In this context, collaboration with other AMSs will be beneficial.

5) The next national energy plan should be equipped with decarbonisation plans and perspectives

The last basic energy plan (RUEN) was enacted in 2017. An official supporting plan or policy is yet to be in place. The next RUEN is anticipated to be equipped with decarbonisation plans and perspectives that have been committed and mentioned on occasions, such as COP26 and 27 and G20 hosted by Indonesia.

2. Malaysia

2.1. Energy policy and power sector overview

1) National growth, energy, and climate change policy

Malaysia had been on a steady economic growth path until the COVID-19 global pandemic affected the country, like most economies worldwide. GDP growth in 2010-2019 was 4.3%–7.4%. The year 2020 saw a sharp decline to -5.6%; however, the country has seen a steady and early recovery from the pandemic. As of December 2022, the GDP growth rate was expected to reach 14.2%.

Malaysia has oil, gas, and RE, holding a large share of Southeast Asia's fossil fuel resources. The country has always been conscious of the importance of energy security and has had clear energy policies addressing various energy supply and utilisation elements. Malaysia strategically incorporated coal as part of its energy mix. Such was in line with the country's energy policy evolving to facilitate energy security, sustainability, and clean energy, which now constitute a major part of the globally shared concerns about energy.

At the same time, the country is environment-conscious; we see this in its introduction of USC power plants at an early stage. Currently, the standard specification of CFPPs in Malaysia is USC, with all required environmental equipment.

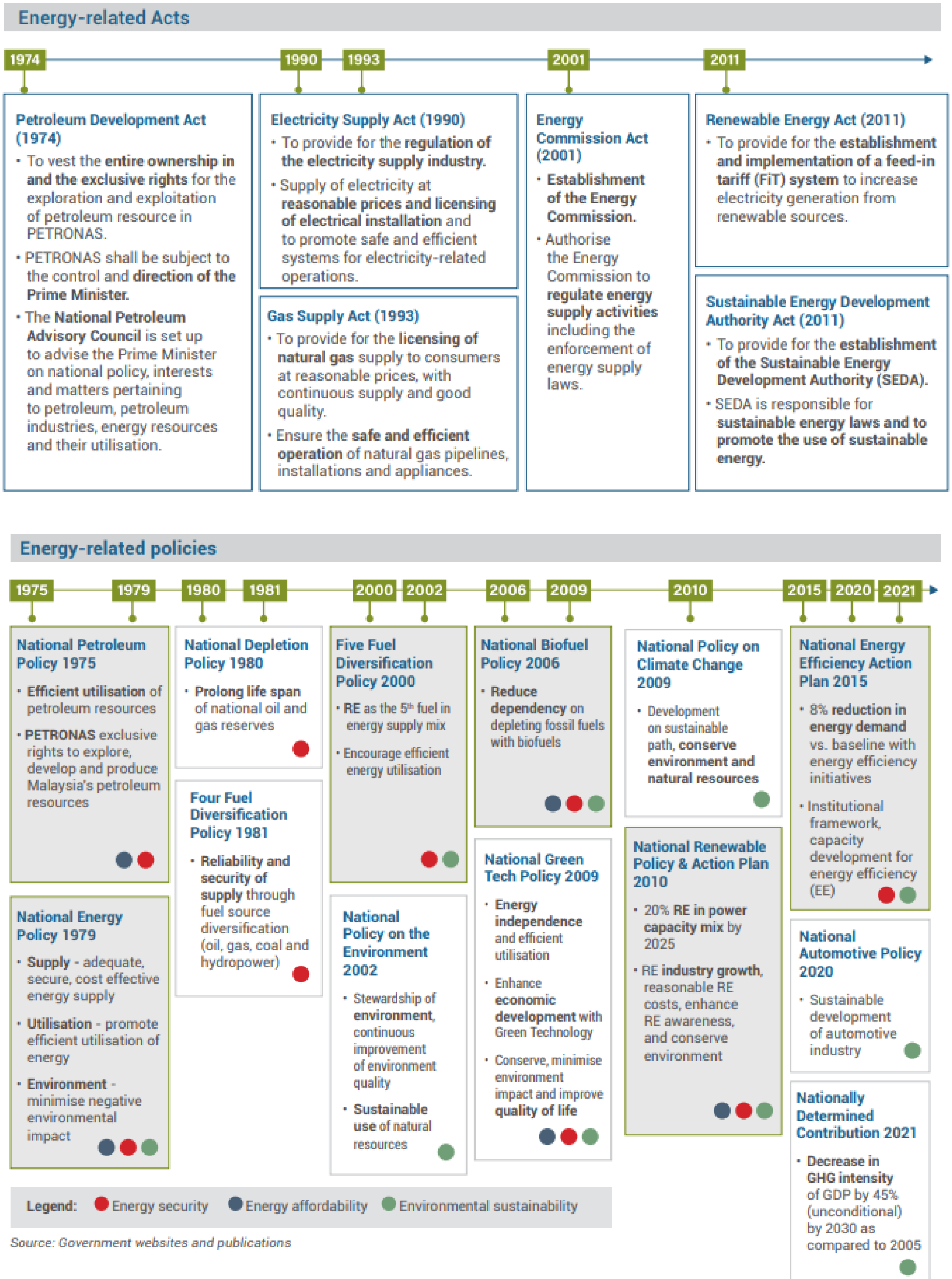
In the meantime, looking at the climate change policy, the country is committed to the unconditional CN target in 2050, the earliest announced in ASEAN, together with Brunei, Cambodia, the Lao PDR, and Viet Nam.

National targets to note are 31% RE share by 2025, reduction of coal capacity by 4.2 GW by 2029, coal phase-down expected to be completed by 2045, and energy intensity to be reduced by 45% by 2030.

Figure 3.11 reviews the major related energy laws and policies to date.

The following section outlines the organisation of Malaysia's power sector, which is unique in that it is integrated in parallel with independent operations across its regions.

Figure 3.11. Major National Energy-related Acts and Policies



Source: Economic Planning Unit, Prime Minister's Department (2022)

2) Organisation of Malaysia's power sector

The Ministry of Energy and Natural Resources (Ketsa), the line ministry that took over from the then Ministry of Energy, Science, Technology, Environment, and Climate Change in March 2020, has jurisdiction over the energy and electricity sector. The Economic Planning Unit (EPU) oversees the sector as the secretariat institution in charge of economic development policy. EPU has authorised the National Energy Policy 2022–2040 (NEP or DTN in the Malaysian language).

The Sustainable Energy Development Authority, a new wing for RE development established in 2011, is the implementing institution of the RE policy and has taken a central part in policy formulation as the author of Malaysia's Renewable Energy Roadmap (MyRER). The Energy Commission regulates and facilitates clean and sustainable energy utilisation nationally. In addition, the commission often undertakes a central role in the national delegation at international meetings.

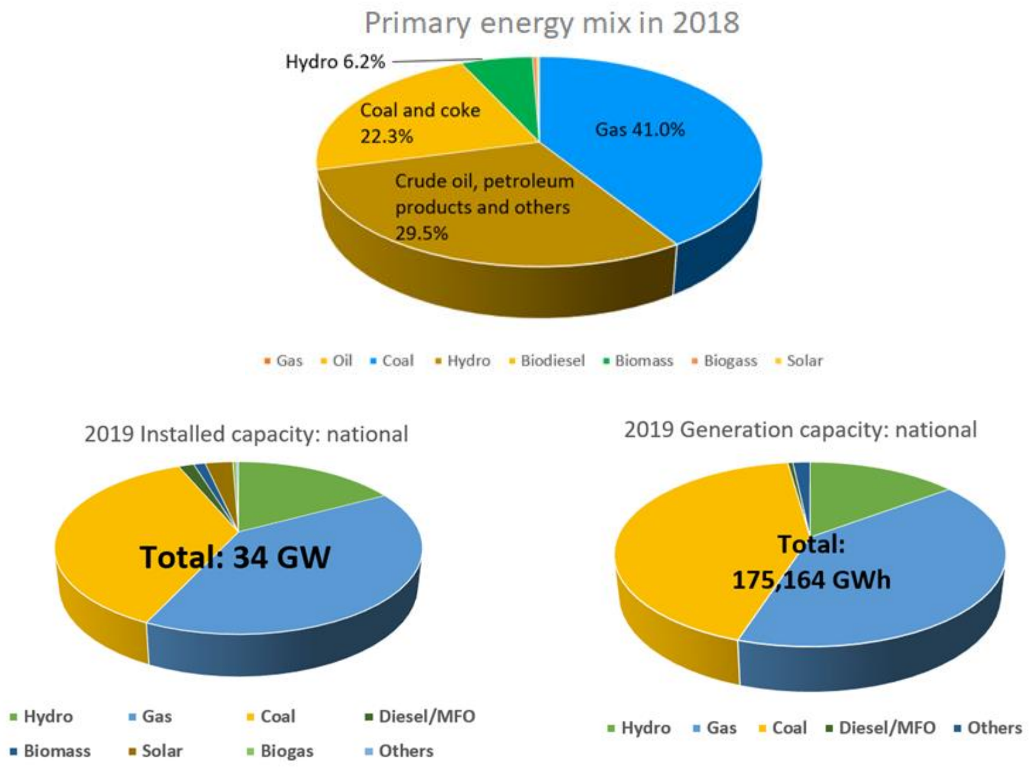
While the federal government formulates national policy and facilitates implementation, different institutions handle each region's day-to-day power sector management. For example, power generation, transmission, and distribution in Peninsular Malaysia are under the Tenaga Nasional Berhad (TNB) and the Grid System Operator; the same for Sabah is handled by the Sabah Electricity Corporation under the provincial government. The Electrical Inspectorate Unit under the Ministry of Utility Sarawak oversees the power sector in Sarawak. Sarawak Energy, the fully privatised and power sector leader in Sarawak, is active throughout the value chain generation, transmission, and distribution.

3) National electricity situation with diverse generation portfolio in the three regions

Figure 3.12 shows Malaysia's primary energy, installed capacity, and generation mix.

Fossil fuel and its products take the lion's share, 92.8% of the national primary energy mix. Coal and gas account for 36.7% and 39.8% of the national installed capacity and 42.8% and 40.2% of the national generation capacity in 2019. Overall, Malaysia is still fossil fuel dependent.

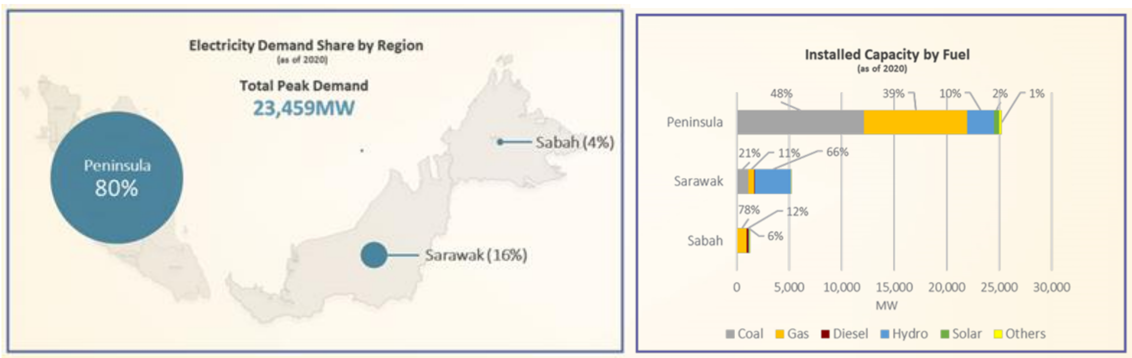
Figure 3.12. Malaysia's National Installed Capacity and Generation Capacity



Source: Energy Commission (2020).

Per by-region shares of electricity demand and by-fuel installed capacity in each region, the most populous peninsula, with 82% of the national population, holds 80% of the national power demand. It is the most dependent on fossil fuels, especially coal.

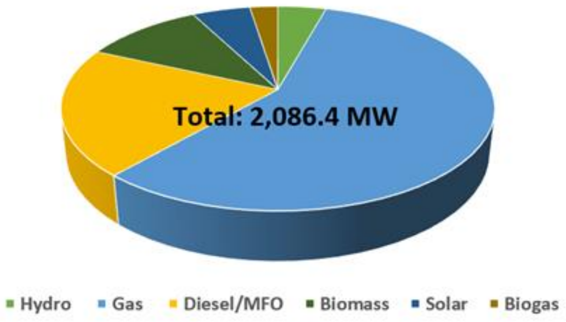
Figure 3.13. Electricity Demand Share by Region



Source: Malaysia country presentation at the First Working Group Meeting on 13 July 2022.

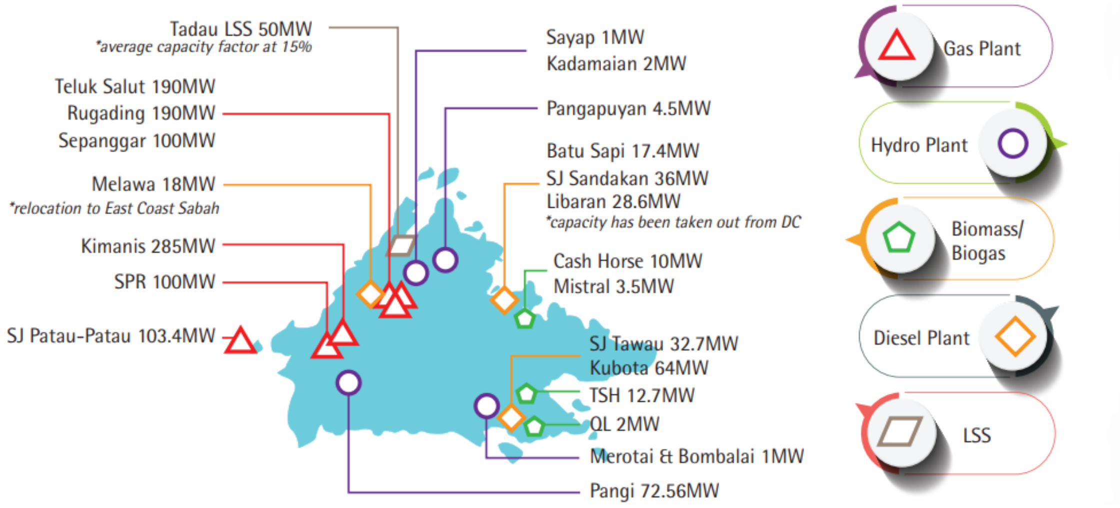
Sabah has several micro- to mid-scale power plants, mostly located on the region's west side. It also heavily depends on fossil fuels. However, it has no coal power and is primarily dependent on gas and diesel. The Sabah government desires to import electricity from Sarawak, with less population and surplus power to export, for which Syarikat Sesco Berhad (Sesco) and Sabah Electricity Sdn Bhd (SESB) signed a memorandum of understanding (MoU) on 6 August 2022. Their target is to trade 30 MW for 15 years by the end of 2023 through the Sarawak–Sabah interconnection via a 31 km 275 kV double circuit transmission line planned to be installed between Lawas substation in Sarawak to Mengalong substation in Sabah.[1]

Figure 3.14. Installed Capacity in Sabah, 2019



Source: Energy Commission (2020).

Figure 3.15. Power Plants in Sabah



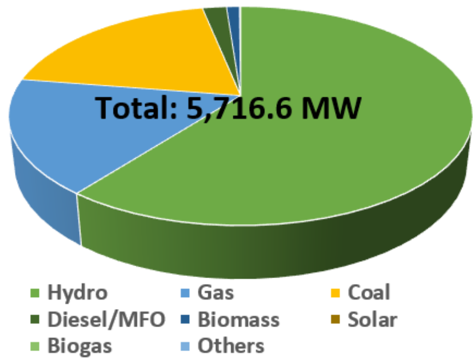
LSS = large-scale solar.
Source: Energy Commission (2020).

The Electrical Inspectorate Unit under the Ministry of Utility Sarawak government oversees the power sector. Sarawak Energy is the sole implementer from generation, transmission, and

[1] 'Sarawak to Export 30 MW Electricity for 15 Years to Sabah by the End of 2023', *Dayak Daily*, 6 August 2021, https://dayakdaily.com/sarawak-to-export-30mw-electricity-for-15-years-to-sabah-by-end-of-2023/

distribution to retail.

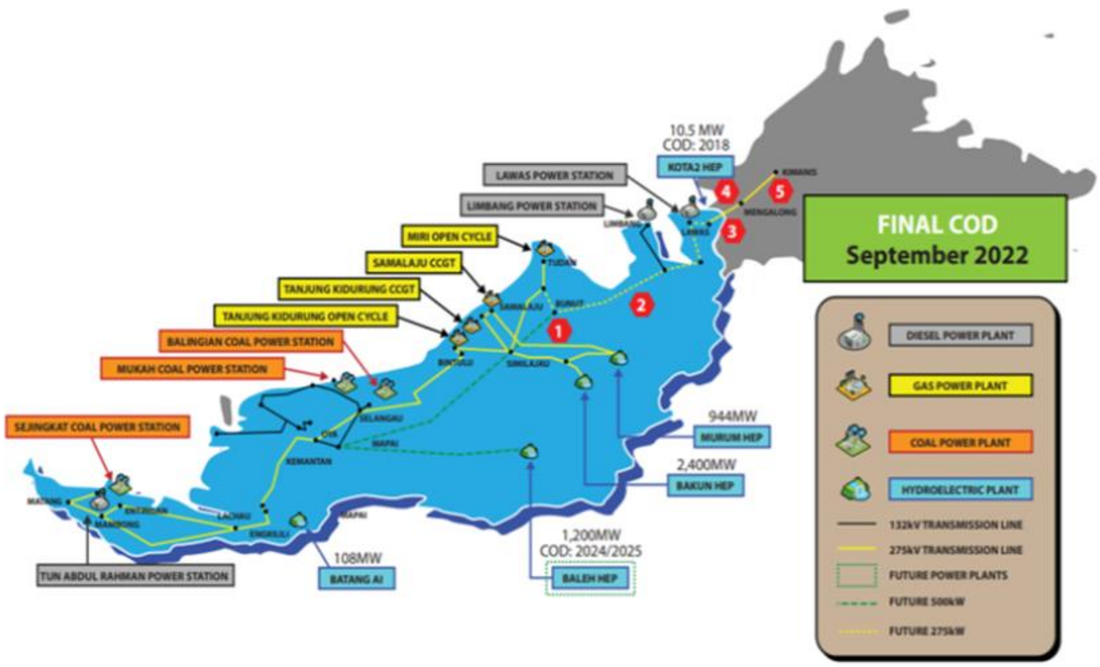
Figure 3.16. Installed Capacity in Sarawak, 2019



Source: Energy Commission (2020).

Endowed with abundant natural resources, Sarawak has a well-balanced electricity mix emphasising hydropower as the mainstay of its power generation (Figure 3.16). Thanks to its large- and mid-scale hydro projects (Figure 3.17), which boost the region's total supply capacity with the smallest population of all three regions in Malaysia.

Figure 3.17. Power Plants in Sarawak



Source: Energy Commission (2020).

Sarawak began to export electricity to West Kalimantan, Indonesia, in January 2016 through a 275 kV interconnection operated by Sarawak Energy. This project is Malaysia's first successful power trading project for Malaysia and has pushed up the position of Sarawak Energy as a green electricity exporter with its abundant hydropower resources.

During the 4 decades since the Four Fuel Policy in 1980, which diversified fuels for energy security, Malaysia switched to coal to generate power and has let CFPPs operate without having major opposition from its people. This was mainly because the environmental requirements for CFPPs have been well addressed. In the early stage, Malaysia shifted to super-critical and USC power plants during the last decade. After the latest introduction of the Jimah East Power Plant in 2019, USC accounted for 40% of all coal-fired power national installed capacity.

Table 3.5. List of Coal-fired Power Plants in Malaysia

No.	Plant	Capacity	Tech	Coal Type
1	TNB Janamanjung	2,070 MW	SC	Sub-Bituminous
	TNB Janamanjung U4	1,010 MW	**USC**	Sub-Bituminous
	TNB Manjung Five	1,000 MW	**USC**	Sub-Bituminous
2	Kapar Energy Ventures	1,486 MW	SC	Bituminous
3	Jimah Energy Ventures :	1,400 MW	SC	70% Bituminous 30% Sub-bituminous
4	Tanjung Bin Power	2,100 MW	SC	70% Bituminous 30% Sub-bituminous
	Tanjung Bin Energy	1,000 MW	**USC**	Sub-Bituminous
5	Mukah Power Generation	270 MW	SC	Sub-Bituminous
6	Sejingkat Power Corporation	210 MW	SC	Sub-Bituminous
7	Jimah East Power	2,000 MW	USC	Sub-Bituminous

Source: Malaysia country presentation at the First Working Group Meeting on 8 July 2022.

However, from the other aspect, the smooth introduction of coal-fired power generation has made Malaysia build up its coal dependency. Today, the country ranks 18th among the top 40 countries with the highest share of coal in electricity generation.[2]

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[2] 'Share of Coal in Electricity Generation and Coal Policies', Figure 2.4 on p. 58, "Coal in Net Zero Transition", IEA, November 2022, https://iea.blob.core.windows.net/assets/4192696b-6518-4cfc-bb34-acc9312bf4b2/CoalinNetZeroTransitions.pdf.

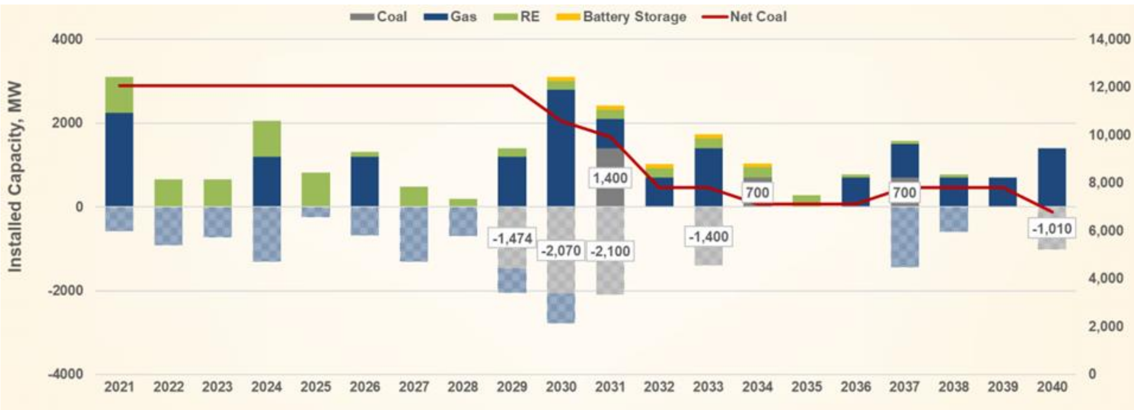
Figure 3.18. Map of Coal-fired Power Plants in Malaysia

Source: Malaysia country presentation at the First Working Group Meeting on 8 July 2022.

So, it is natural for Malaysia to consider coal phase-down by retiring long-serving plants in the Peninsula in a phased manner in parallel with accelerated RE development and energy efficiency efforts. The total capacity of 8,054 MW of retired CFPPS is projected to be replaced by only 2,800 MW of coal capacity towards 2040, according to the currently available plan for Peninsular Malaysia (Figure 3.18).

Further, the government recently mentioned that over 7,000 MW CFPPs will expire by 2033. No new CFPPs will be constructed. In Malaysia's power sector, coal may be phased down gradually and then out even earlier than by 2040.

Figure 3.19. Capacity Additions and Retirements of Peninsular Malaysia



Source: Country presentation at the First Working Group (2022).

2.2. Long-term Policy Towards a Greener Future

1) Energy sector under the 12th Malaysia Plan

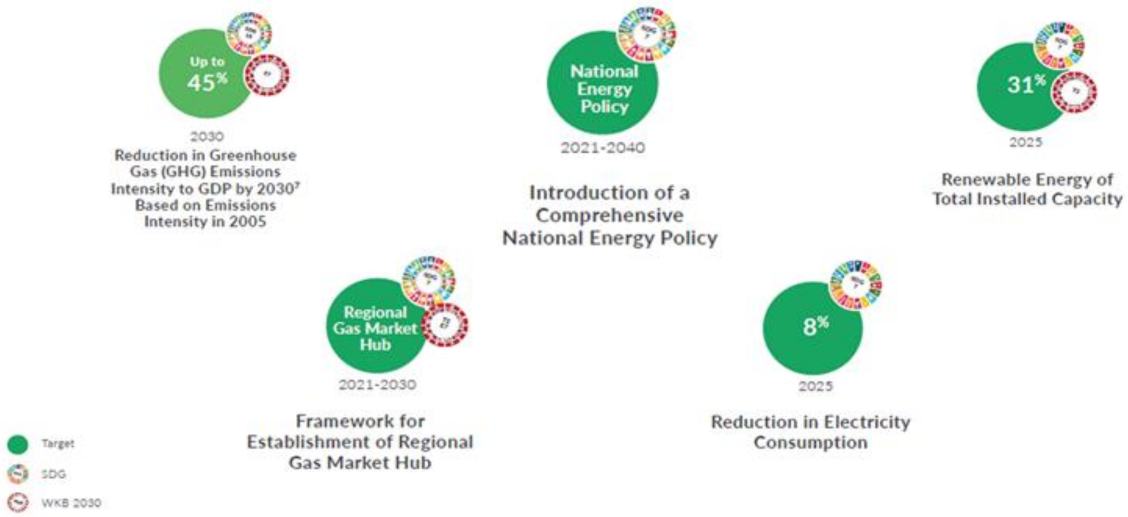
The 12th Malaysia Plan (the 12th Plan) is the 5-year national plan for 2021–2025, providing a major agenda for national recovery to restore economic stability and enhance national economic growth. It was announced in September 2021 and deemed the most ambitious and transformational-ever national plan.

The 12th Plan is anchored on Theme 1 – resetting the economy; Theme 2 – strengthening security, well-being, and inclusivity; and Theme 3 – advancing sustainability.

Developing future talent, accelerating technology adoption and innovation, enhancing connectivity and transport infrastructure, and strengthening the public service are catalytic enablers to support the achievement of the key themes.

The energy sector is well linked and interrelated to Theme 3, which focuses on advancing green growth, enhancing energy sustainability, and transforming the water sector. The energy sector is well linked and interrelated to Theme 2, and an immense contribution of energy transformation to the 12th Plan is anticipated while the country is transitioning.

Figure 3.20. Energy Sector Targets under the 12th Malaysia Plan



Source: EPU (2022).

The 12th Plan stipulates by-sector key economic growth activities called 'KEGA'. The energy sector has five KEGAs.

KEGA 5: ASEAN Hub – Establish ASEAN hubs in 12 activities, including the gas trading market

KEGA 7: Malaysian Commodities 2.0 – Move downstream products to generate higher returns and growth of new industries

KEGA 8: Logistics, Transportation, and Sustainable Mobility – Use green technology, low-carbon, and strategic traffic management

KEGA 11: Renewable Energy – Use new technologies, providing pilot localities, and offer to fund RE generation

KEGA12: Green Economy – Emphasise low-carbon activities, including green buildings, sustainable transportation, circular economy, etc.

2) National Energy Policy 2022–2040

The National Energy Policy 2022–2040 (NEP), a long-awaited national energy policy in line with national plans such as the 12th Malaysia Plan, has enlightened challenges and opportunities in the coming years of the energy transition. NEP tells us how Malaysia will overcome relevant challenges and use future opportunities while involving a broad range of stakeholders over multiple sectors and the people of Malaysia.

NEP shows the national ambition for a dynamic shift and a transition towards the competitive and future-proof energy, industrial, transportation, and relevant sectors, by which the country's future growth and development is anticipated to accelerate and enhance.

Figure 3.20 shows selected target areas and Low Carbon Nation Aspiration 2040 targets compared to the values in 2018. As shown in

Figure 3.21, by achieving the 2040 targets, many positive impacts on emission reduction and massive job creation are anticipated. This means all that work for energy transition is understood more as opportunities than challenges.

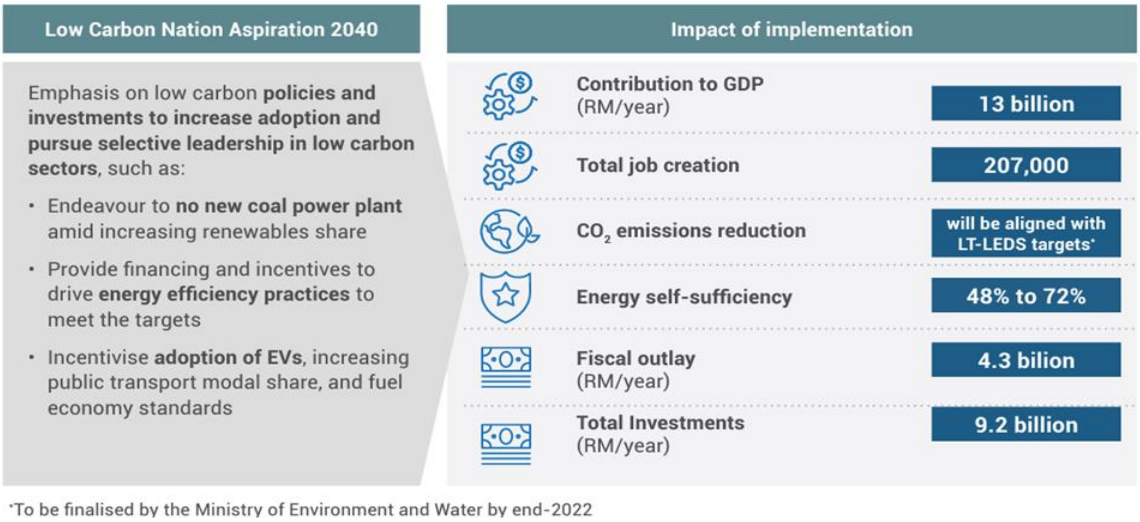
Figure 3.21. Selected Target Areas for Low-carbon National Aspiration

Selected Targets	2018	Low Carbon Nation Aspiration 2040
1. Percentage of urban public transport modal share	20%	50%
2. Percentage of electric vehicle (EV) share	<1%	38%
3. Alternative fuel standard for heavy transport	B5	B30
4. Percentage of Liquefied Natural Gas (LNG) as alternative fuel for marine transport	0%	25%
5. Percentage of industrial and commercial energy efficiency savings	<1%	11%
6. Percentage of residential energy efficiency savings	<1%	10%
7. Total installed capacity of RE	7,597 MW	18,431 MW
8. Percentage of coal in installed capacity	31.4%	18.6%
9. Percentage of RE in TPES	7.2%	17%

Legend: Energy security Energy affordability Environmental sustainability

Source: EPU (2022).

Figure 3.22. Low-carbon National Aspiration 2040 and Expected Impacts (Draft)



Source: EPU (2022).

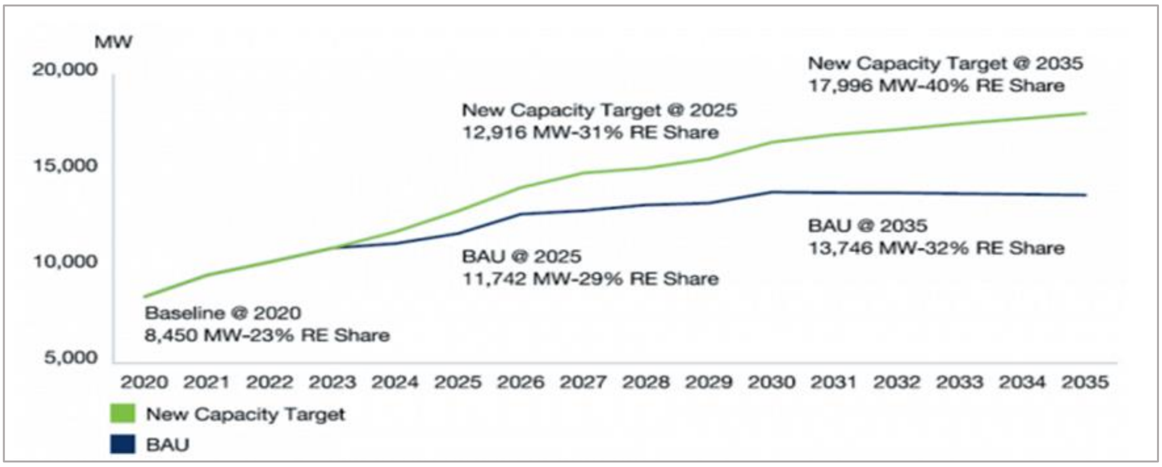
3) Malaysia Renewable Energy Roadmap (MyRER)

MyRER by SEDA is a 2022–2035 long-term RE roadmap and the first of its kind for Malaysia. MyRER constitutes national policy and policy rationale for CN by 2035, and its trajectory is to:

- achieve Malaysia's net-zero GHG emissions by 2050
- contribute to the national commitment to the Paris Agreement
- invest RM20 billion for 2025 and RM35 billion for 2035
- create, directly and indirectly in the RE sector, up to 46,636 jobs.

MyRER indicates RE, which currently accounts for 23% (8,450 MW) of the national electricity mix in 2020, will be increased to 31% (12,916 MW) in 2025 and 40% (17,996 MW) in 2035, through which energy intensity will decrease by 60% in 2035 (Figure 3.23).

Figure 3.23. Summary of RE Capacity Evolution and RE Share



Source: MyRER (2021).

2.3. By-technology Initiatives and Projects

1) Hydrogen Economy Position Paper

Hydrogen is deemed to be a key pillar of decarbonisation, and it is said to enable many more applications than those common today. However, most technologies that can contribute significantly are still nascent. The formulation of global and local value chains is also a major challenge.

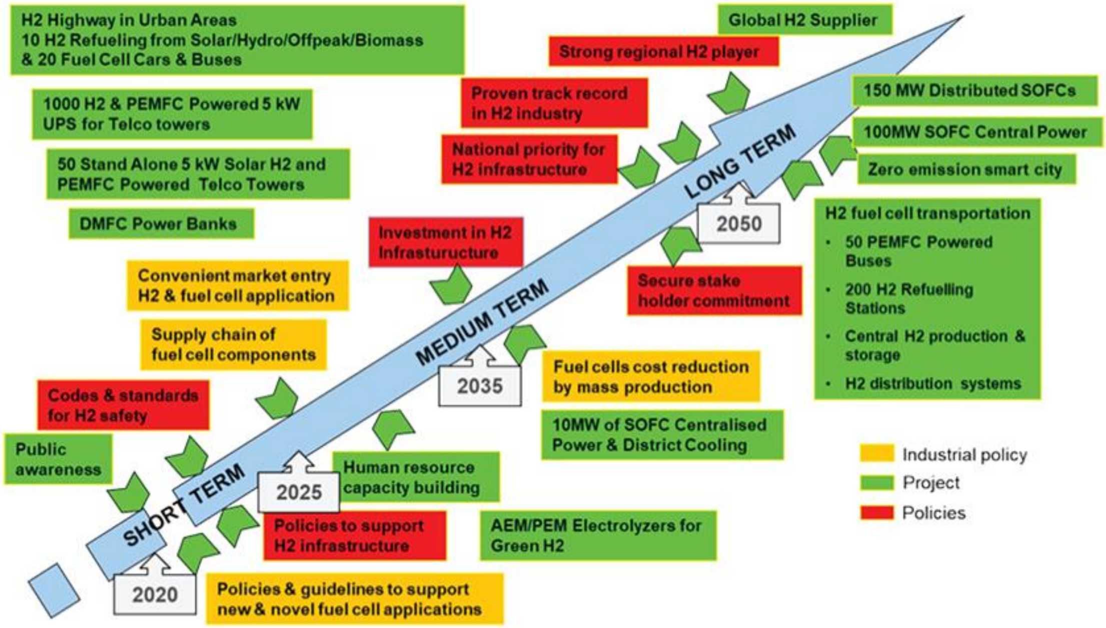
As of today, a fundamental policy on hydrogen is yet to be formulated in Malaysia.

However, in 2020, the Academy of Sciences Malaysia (Akademi Sains Malaysia) issued a Hydrogen Economy Position Paper to pursue possibilities to position hydrogen technology development and hydrogen utilisation as future key energy and industrial areas. The position paper clarifies that hydrogen must be defined as the sixth fuel for Malaysia and urges the government to accelerate policy and regulatory framework arrangements for technology development and near-future application. The position paper further implies that Malaysia can be a regional leader in hydrogen technology, focusing on hydrogen infrastructure, fuel cell applications, and emerging technology.

What the position paper and the document tell are yet to be authorised by the federal government. However, given the forward-looking observation of the possible challenges and opportunities under the 12th–18th Malaysia Plans (2021–2050). the paper deserves attention. The position paper also comprises all related sectors through recommendations for implementing by-group programmes and projects. The concerns described in the position paper may form the basis for further government consideration of hydrogen potential.

The Hydrogen Roadmap in 2020 in the position paper (Figure 3.24) foresees beyond 2050, when Malaysia will be a global hydrogen supplier. It indicates that policies and guidelines will be formulated, and safety codes and standards will be established by 2025.

Figure 3.24. Hydrogen Roadmap in 2020



Source: Akademi Sains Malaysia (2022).

The position paper mainly focuses on hydrogen for electricity in the energy and transportation sectors. Hydrogen also has a wide range of potential in industries, many of which would apply to Malaysia.

2) Nano Malaysia Energy Storage Technology Initiative (NESTI) Programme

The Nano Malaysia Energy Storage Technology Initiative (NESTI) Programme, launched in November 2021, is focused more on e-mobility and fuel cell development. Led by the Ministry of Science, Technology, and Innovation with Nano Malaysia Berhad as the implementing agency, it serves as a national-level platform to develop and commercialise energy storage systems.

The programme's primary goal is for Malaysia to produce high-technology energy storage components and systems for energy storage technology applications for both domestic consumption and export markets. The country is envisaged to be a major exporter of EV components in the ASEAN region.

3) CCS-related Initiative

Petroliam Nasional Berhad (PETRONAS) has expressed at an early stage its intention to make decarbonisation its business opportunity and contribution to the global target for climate change.

During the last few years, PETRONAS has been enhancing its international collaboration with various domestic and international players in pursuit of decarbonisation contribution through CCS. In March 2022, PETRONAS inked an MoU with the New York–listed energy services giant Schlumberge. The Carbon Capture and Storage (CCS) Centre of Excellence is planned under the

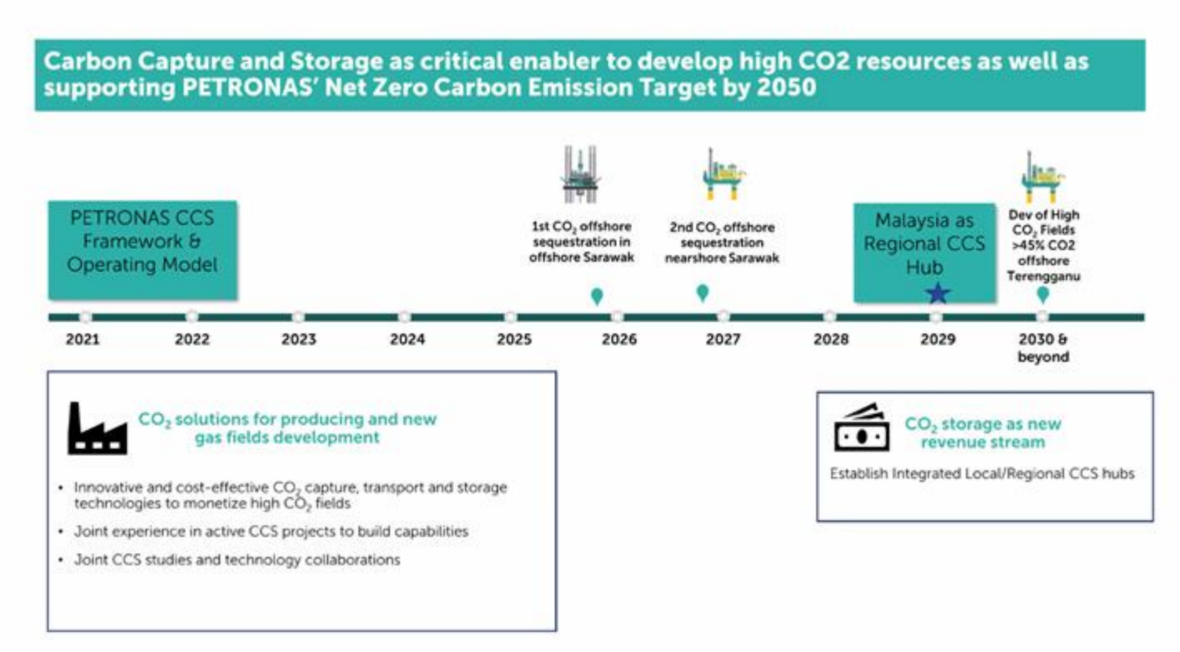
MoU, encompassing a cloud-based data repository for carbon storage, CO_2 separation technologies and capacity development, and emissions management.

PETRONAS signed a series of agreements on CCS studies and programmes with global technology and consulting companies such as DNV, Shell, JAPEX, JGC, etc., in 2022.

In September 2022, PETRONAS signed another MoU with the Japan Bank for International Cooperation (JBIC) for financing several decarbonisation technology areas, including CCS.

The year 2050 is the national target for net zero emissions and PETRONAS.

Figure 3.25. CCUS in NEZ Target of PETRONAS



Source: PETRONAS, https://www.petronas.com/flow/technology/getting-know-ccus-petronas.

2.4. Ongoing Projects and Projects in the Pipeline

1) TNB Genco-PETRONAS Gas and New Energy-IHI Project

A techno-economic evaluation study was conducted on the green and blue ammonia production supply chain through the partnership of the two Malaysian key players: Petronas and TNB GENCO, and Japanese Chugoku Electric, Mitsui, and IHI. The study, funded by METI, was completed in February 2022.

The techno-economic evaluation focused on the following:

- technology applicability of ammonia cofiring at USC power plant
- production supply chain, including the production of green ammonia from RE and blue ammonia from natural gas
- a CO_2 emissions reduction business model

- the possibility of the business model dissemination in the region with by-country tailored modification

2) Ammonia Cofiring Feasibility Study

TNB Research conducted a joint feasibility study of ammonia cofiring with sub-bituminous coal using its in-house combustion test rig. This study found that a significant CO_2 emissions reduction from flue gas was observed after ammonia had been injected.

Phase I of the study in 2021 is a desktop study on technical and economic aspects. It is being developed into the pilot phase and will be commercially implemented if the outcomes are good.

3) Biomass Cofiring Pilot Project

Kapar Energy Ventures has been collaborating with IHI Power System Malaysia. The project began in 2019, and pilot tests were conducted in July 2022.

4) Study for Commercial Conversion of Hydrogen to MCH (methylcyclohexane) in Trenganu

Malaysian PETRONAS Hydrogen and Japanese ENEOS partnered to conduct the study.

A joint feasibility study agreement, which constitutes a part of the MoU on clean hydrogen supply value chain development executed in August 2021, was signed in March 2022 (Phnom Penh Post, 2022).

The project aims to achieve the following by 2027:

- Max. 50,000 tonnes (50 KTPA) per year of hydrogen production and conversion to MCH, transportation of MCH to Japan, provision of clean hydrogen in Japan through ENEOS refineries
- If the project materialises, it will be the world's first commercial hydrogen-to-MCH project.

The investment decision is expected to be made by the end of 2023.

Figure 3.26. ENEOS Yokohama Tsunashima Hydrogen Station

Source: Phnom Penh Post (2022).

5) Kasawari 2 CCS Project

PETRONAS Carigali International Sdn, a subsidiary of PETRONAS, is engaging in the Kasawari 2 CCS Project. Oslo-listed Xodus is undertaking a feasibility study and conceptual design.

The CCS project is about capturing flared gas from the gas field in Kasawari, offshore Sarawak, and compressing it to inject it into the depleted reservoir. It is

expected to reduce CO_2 volume that is otherwise emitted via flaring by 76 million

tonnes over the expected field life, with an annual average saving of 3.7 million tonnes per year. Kasawari will be on stream in 2023, and CCS will follow as the second phase.

As for infrastructure, the following are additionally required:

- A new CO_2 sequestration platform, including facilities to recover hydrocarbons from the permeate stream before the CO_2 is compressed/pumped to the desired export pressure
- A new 135 km carbon steel pipeline to transport the CO_2 to the M1 field
- Three new injection wells.

Figure 3.27. Kasawari CCS Project Site

Source: The Energy Year (2021).

6) Sarawak H_2 Biscus Green Hydrogen and Ammonia Project and Power Supply Project

Sarawak Energy launched the first green hydrogen integrated production in ASEAN in 2019.

Figure 3.28. Sarawak Energy's Hydrogen Production Plant and Hydrogen Bus Terminal

Source: Presentation by Sarawak Energy for the ASEAN Energy Business Forum 2022

That initial project now has been developed into an international collaboration project involving Samsung Engineering, SEDC Energy, LOTTE Chemical, and POSOCO Holdings as project partners.

The production plant can produce 130 kg of hydrogen per day at a purity of 99.999% (five 9s) and is capable of supporting and fully refuelling up to 5 fuel cell buses and 10 fuel cell cars per day.[3]

Supported by the expanding hydropower potentials, the green hydrogen project is expected to see further development conducive to Malaysia's decarbonisation efforts.

2.5. Enabling Schemes in the Power Sector

The following are enabling schemes in Malaysia's energy and electricity sector, backed by government policies, for pushing the country forward to a green energy transition.

1) Green Electricity Tariff

Green Electricity Tariff (GET) is a government initiative to provide green electricity from RE supply to any electricity consumer to reduce their carbon footprint in electricity use. The GET programme is a part of the nation's initiatives to achieve net-zero GHG emissions by 2050.

[3] Sarawak Energy presentation at the ASEAN Energy Business Forum 2022 (virtual).

GET subscribers will be supplied with green electricity from solar power and hydropower. The envisaged major source is solar power through large-scale solar (LSS). In other words, it is available to the extent the capacity supplied by the LSS is available.

Under this programme, the Malaysia Renewable Energy Certificate (mREC) that complies with international REC standards can be obtained.

2) Malaysia Renewable Energy Certificates

The mREC represents the delivery of 1 MWh of RE to the grid and all associated environmental benefits of displacing 1 MWh of conventional power in Malaysia.

While mREC is not tradeable in Malaysia and is to be redeemed/retired to end customers directly, the owner of the redeemed/retired mREC can claim the rights to the generated RE.

The government expects mREC implementation to increase market demand for RE. Every purchase of mREC will increase funds for RE developers to build even more RE generators, making more RECs available in the market. Overall, it will reduce brown energy utilisation and increase clean energy utilisation.

For a company committed to a sustainability target despite inaccessible green energy for the time being, mREC is the easiest and most cost-effective way to achieve sustainability goals.

3) Carbon Trading Scheme

The carbon trading scheme constitutes a part of supporting schemes for energy transition since cost barriers bar shifting to clean energy. Currently, no carbon trading scheme, such as a domestic emission trading scheme (ETS), is in place in Malaysia. However, in September 2021, the Ministry of Environment and Water published the *National Guidance on International Voluntary Market Mechanisms* to guide any entity in Malaysia that intends to participate in international voluntary carbon markets.

While the national carbon trading scheme is being awaited, in September 2022, the state government of Sarawak announced that it would start a local carbon trading scheme in 2023. A national ETS or any other trading scheme will be considered and established based on the observed outcomes of the forthcoming implementation of Sarawak's carbon trading scheme, which is expected to help make such a scheme nationally available.

2.6. Policy Recommendations

Malaysia is endowed with oil, gas, and RE and has strategically incorporated coal into its energy mix. In addition, the country is recognised as one of the most proactively planning and responding AMSs to the requirements of energy transition through a series of long-term plans and policy initiatives. In summary, considering its energy transition pathway, it is steps ahead of other AMSs.

In 2021–2022, a major national plan, energy policy, and several energy transition initiatives towards 2050 and beyond were publicised. Many of those initiatives are plausibly formulated to align with the 12th Malaysia Plan and the expected future 5-year national plans so that they are organised in a way involving all relevant institutions and companies to play their roles in a concerted manner.

Tables 3.6 and 3.7 overview the decarbonisation technology from reduction, capture, utilisation, and storage, indicating high potential and/or applicable technology solutions for Malaysia.

Table 3.6. Applicable Technology Solutions for Malaysia: Reduction

Road Map towards Carbon Neutrality						Status	Policy/Programs/Projects
Reduction	Thermal Power	High Efficiency	IGCC			Not applicable	
			IGFC			Not applicable	
			A-USC			Not applicable	
	Fuel	Biomass	Combustion	CFBC biomass firing		Keenly pursued	
				PC coal cofiring		Keenly pursued	Pilot and demonstration progressing
			Manufacturing	Material	Agricultural waste pellet	Keenly pursued	
					Fast-growing tree	Not applicable	
				Pre-treatment	Torrefied pellet	Applicable	
					Washing	Not applicable	
		Ammonia	Utilisation	Ammonia gas turbine		Keenly pursued	Pilot and demonstration progressing
				Ammonia industrial furnace		Keenly pursued	
				Ammonia-coal cofiring		Keenly pursued	Study progressing
			Manufacturing	Ammonia process	Coventional process + CCS	Applicable	
					New & Innnovative process	Applicable	
				R&D base, Supply chain		Applicable	
		Hydrogen	Utilization	Hydrogen gas turbine		Not applicable	
			Manufacturing	Hydrogen process	Water electrolysis by RE	Keenly pursued	Hydrogen Economy Position Paper as a reference; Green hydrogen production from hydro power has been progressing and anticipated to scale up
					Turquoise	Keenly pursued	
				R&D base, Supply chain		Keenly pursued	Hydrogen Economy Position Paper as a reference; studies are progressing
	Renewables	Wind, Solar, Geothermal	Offshore wind			Not applicable	
			Perovskite PV			Keenly pursued	PV are being agressively developed with help of LSS, etc. In GET scheme for consumers, green electricity is mainly sourced from LSS projects
			Next generation geothermal			Not applicable	
		BESS	Large Li-ion, NaS, Redoxflow			Keenly pursued	12th Malaysia Plan & NEP
	Manufacturing process	Steel	Coke reduction	Energy saving, LRC	Ferrodoke	Not applicable	
				Direct reduction		Not applicable	
				Hydrogen reduction		Not applicable	
				COURSE50	Super-COURSE50	Not applicable	
				Carbon recycling BF		Not applicable	
		Cement					

Source: JCOAL Study Team.

Table 3.7. Applicable Technology Solutions for Malaysia: Reduction (2)

Road Map toward Carbon Neutrality						Status	Policy/Programs/Projects
Capture	Capture/ Recovery	Capture/ Recovery	Recovery/ generation	Oxyfuel IGCC		Not available	
				Supercritical CO_2 cycle generation			
				Chemical looping combustion			
			Chemical absorption				
			Solid absorbent material				
			Physical absorption				
			Membrane separation				
			Physical adsorption				
Utilisation	Chemicals	Chemicals	Core materials	Methanol		Currently not available	
				SOEC process	CO		
					Methyl Cycrohexane		
				Artificial photosynthesis	Olefin		
			Derivatives	Formic acid	Boron-doped diamond electrode		
				Polyurethane intermediate			
				Para-xylene			
				Polycarbonate			
				Polyurethane			
				Ethylene urea			
	Fuel	Fuel Synthesis	Gas fuel	Methane	Sabatier process		
					SOEC process		
					Biomass photosynthesis		
			Liquid fuel	Diesel	Biomass photosynthesis		
				Jet fuel	Biomass photosynthesis		
					Biomass gasification FT synthesis		
				Olefin, kerosene			
	Mineralisation	Cement/ concrete	Concrete	CO2 absorption			
				Carbonate type			
			Admixture	CO2 absorption			
				Carbonate type			
	Others	Others	Sector Coupling	Industrial complex carbon recycling		Highly applicable	
Storage	Storage	CCS, DACCS, BECCS	Forest absorption/ afforestation	Afforestation		Highly applicable	
				Blue carbon		Applicable	
			CCS			Keenly pursued	PETRONAS CCS roadmap; Kasawari CCS

Source: JCOAL Study Team.

1) Highly Potential Technology Areas

Highly potential technology areas in the context of policy directions and applicability are highlighted below.

Technology area 1: Hydrogen

Malaysia is outstanding in its determination to promote hydrogen development and utilisation. In 2019, a few years before the Hydrogen Economy Position Paper was published, Sarawak Energy started producing and refuelling hydrogen. It partnered with PETRONAS, Samsung Engineering, LOTTE Chemical, and POSCO Holdings.

The Hydrogen Economy Position Paper claims Malaysia could become on par with the United States and Australia in leading global hydrogen technology development and utilisation.

Both the position paper and Sarawak Energy coincidentally focus on green hydrogen, especially given the recent situation where hydrogen prices have skyrocketed with natural gas prices. Green hydrogen is gradually taking the primary position for massive production in the future.

Also, since it matters how much carbon footprint can be reduced throughout the hydrogen value chain to be formulated, Malaysia is on the right track in trying to focus on green hydrogen.

A few points for further consideration are:

- Currently, so much attention is paid to fuel cells and electricity when it comes to hydrogen. However, there are various areas, such as chemical and industrial processes, for which hydrogen can be utilised. So, it would be advisable that hydrogen development and utilisation policy be multisectoral and with a clear picture of value chains to be established.
- As the Hydrogen Position Paper clarifies, safety is a major concern in considering hydrogen use. Accordingly, safety considerations shall be a part of the basic policy that will be formulated.

Also, as with most industrial activities, hydrogen production entails carbon emissions, though the massive introduction of hydrogen is primarily for reducing emissions. Accordingly, the government is supposed to facilitate and oversee development and utilisation efforts by national and private companies while paying extra attention to how carbon footprint can be reduced during the process.

Technology area 2: Solar and hydro

Solar power and hydropower are undoubtedly important for clean and sustainable electricity supply and bolstering the anticipated green hydrogen development.

Technology area 3: CCS

CCS is crucial for the energy transition. However, only some projects have reached the commercial phase due to cost barriers and unforeseeable technology-related factors. Most commercial projects are at oil and gas development sites using CO_2 injections for enhanced recovery. For applying the technology to a power plant, incorporating CO_2 utilisation to make it CCUS for the increased economy of the project is required.

As the preceding part has clarified, PETRONAS is geared to engage in the Kasawari CCS project with domestic and international players, with a roadmap ready to back up the relevant activities. Thai government-owned PTT’s subsidiary PTTEP is also considering going for a CCS project at its Lang Lebah field in Malaysia. The company has been developing a CCS project in Thailand already.

Kasawari CCS attracts such attention from ASEAN, the rest of Asia, and the world. Developing a sour gas field will be common throughout all incoming gas development projects in ASEAN. Since sour gas contains a high H2S and CO_2 content, its development entails technical difficulties and requires extra deliberation and measures in exploration, and so does the CCS project.

Considering that CCS-potential depleted fields in Malaysia will have the same conditions and requirements as others in Indonesia, Thailand will experience a similar situation. In collaboration with other AMSs, Malaysia would benefit from establishing a knowledge and data-sharing scheme among AMSs.

That way, the huge cost otherwise incurred at the initial stage can be avoided, and well-informed decisions on project implementation will be possible.

Other potential technology areas

In addition to the above areas, biofuel, energy storage, and biomass and ammonia cofiring at CFPPs are highly potential.

These existing and new energy areas and technologies are highly anticipated to open up opportunities for industry development, job creation, and social development as per the 12th Plan and beyond, for which cross-sectoral planning, coordination, and collaboration with more focus on industry areas are crucial.

Also, safety, economy, and energy security, in addition to energy transformation, shall be ensured.

2) Institutional Support

Institutional support and incentives will be required to facilitate the application of decarbonisation technology. And policymakers must note that such institutional support may also be transitional and must be followed up for modifications or further institutional changes. For instance, a feed-in tariff (FiT) is effective in supporting the introduction of renewables. However, preceding cases have shown that unbundling the power sector for a competitive market is crucial to accelerating RE introduction. RE will no longer depend on FiT since it must be incorporated into the competitive market. So, the power market in Malaysia on a single-buyer scheme will be changed during the power sector transformation. That way, Malaysia can materialise RE development and massive production of green hydrogen.

3) Coal phase-down Path

Malaysia has 12,546 MW of CFPPs, of which 2,000 MW commenced operations only in 2019. Given Malaysia's standard residual life and the economy of power plants, it is a little too early to retire the most recent ones before 2040.

However, it would work if those retired power plants were not just retired but appropriately reutilised through conversion to synchronous condensers, a proven and commercially available technology for grid stablisation,[4] or whatever purpose conducive to energy transformation.

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[4] Several retired thermal power plants were repurposed as synchronous condensers. The World Bank conducted a very useful study indicating that repurposing thermal power plants as synchronous condensers will be one of the options to address the issue of 'too young to retire' CFPPs in ASEAN (https://documents1.worldbank.org/curated/en/144181629878602689/pdf/Coal-Plant-Repurposing-for-Ageing-Coal-Fleets-in-Developing-Countries-Technical-Report.pdf).

The following and some websites show the technology and actual cases: http://pe.org.pl/articles/2015/10/12.pdf,

https://www.eaton.com/content/dam/eaton/services/eess/eess-documents/eaton-case-study-iou-synchronous-condenser-conversion-cs027014en.pdf;

https://energiforskmedia.blob.core.windows.net/media/22669/decommissioned-nuclear-power-plant-as-system-services-providers-energiforskrapport-2017-348.pdf

A coal-fired power phase-down and phaseout roadmap, as part of a national energy transition roadmap, shall be formulated. All necessary measures should be taken since coal-fired power, as a major part of the electricity mix, will continue to support energy security through sustainable electricity supply for at least the first half to the middle of the energy transition period. During that time, efforts to reduce emissions and environmental measures must continue, and operations shall be conducted in a way that contributes to preventing grid fluctuation.

4) Malaysia's position to support ASEAN's energy transition

Malaysia has an advantage since the country, as a member of the ASEAN community, has been involved in most areas of the energy sector – from fossil fuel production, power generation, clean utilisation of coal, renewable energy, and new energy development to regional grid integration. Moreover, as being ahead in terms of readiness for policy and standards formulation and legislation, Malaysia is highly anticipated to initiate government-to-government sharing of knowledge, experience, and information, as well as cooperation for regional value chain formulation and establishment. Such will benefit the country as the energy transition will be very costly, especially at its initial stage. Well-informed decisions are the key to the successful application of decarbonisation technology.

5) National Decarbonisation Roadmap

With NEP, the long-term energy policy, in place and MyRER, the national RE roadmap, the next anticipated is formulating a national decarbonisation roadmap that shows a cross-sectoral and inclusive energy transition pathway. Again, Malaysia can contribute to formulating an integrated roadmap of ASEAN decarbonisation and roadmaps of other AMSs by initiating the national roadmap formulation.

3. Thailand

3.1. Energy/Electricity Situation and Policies

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

Table outlines these five keywords, and Thailand is proceeding under this energy policy.

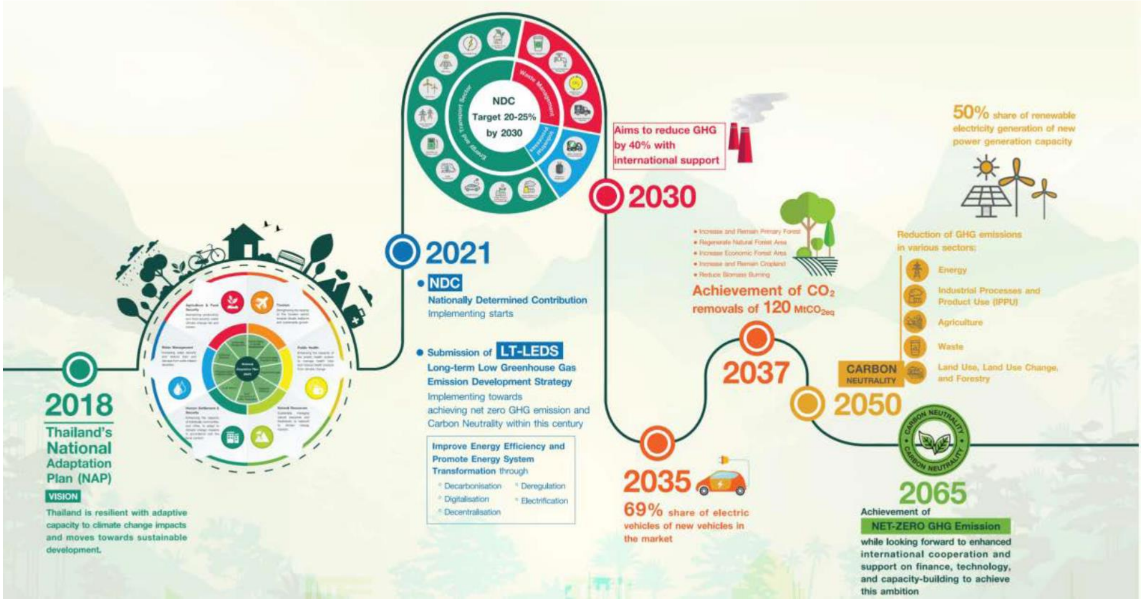
Table 3.8. Thailand's Energy Policy

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

Source: Working Group presentation for the Study on Biomass and Coal Co-combustion in the ASEAN Region (II), DEDE (June 2020).

Figure 3.29 shows Thailand's long-term 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 the 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 CN by 2050 and 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 69% by 2035. Likewise, a 50% share of renewable electricity generation of new power generation capacity is strategically planned by 2040.

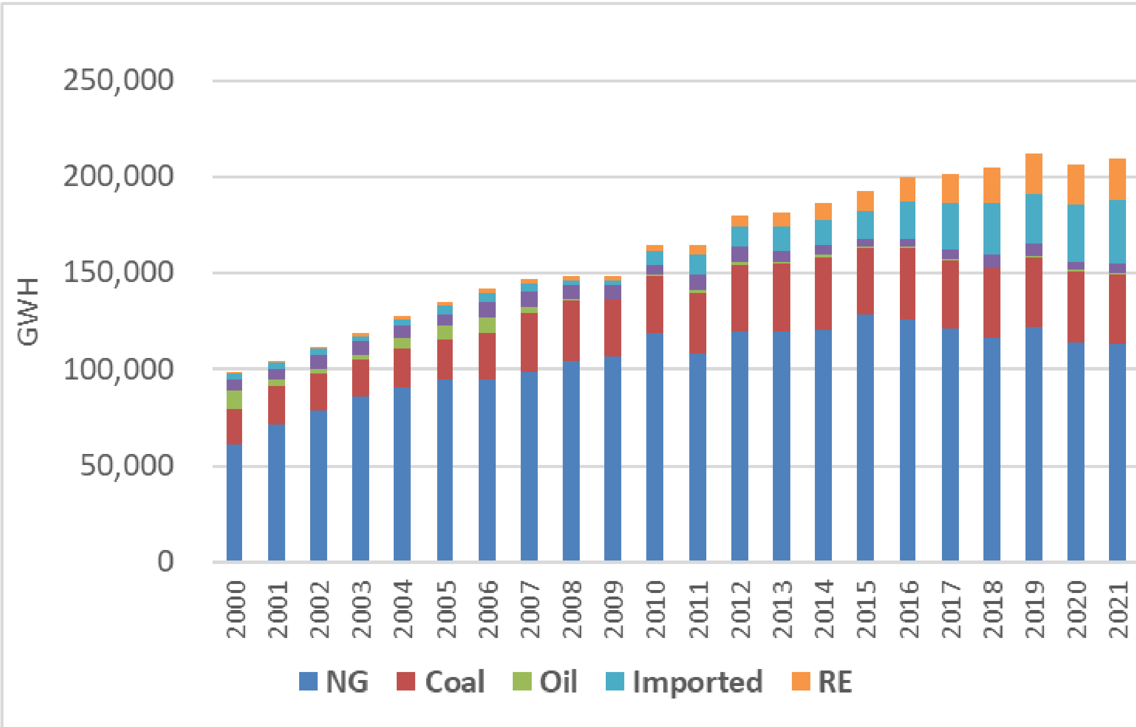
Figure 3.29. Thailand's Long-term GHG Emission Development Strategy



Source: The First Working Group Presentation for the Study on Thailand's Renewable Energy Promotion Policies, DEDE (July 2022).

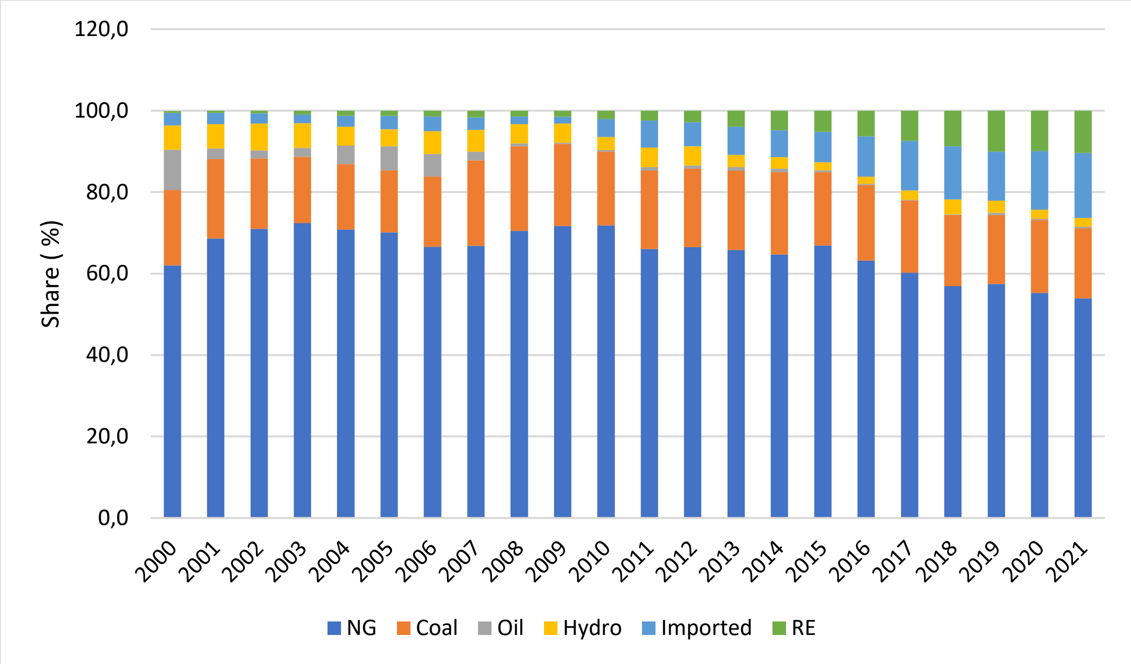
Figure 3.30 shows Thailand's recent power generation, and Figure 3.31 shows its recent power generation share of fuel. In the last 10 years, natural gas and coal had not grown, but imported fuels and RE did.

Figure 3.30. Power Generation by Fuel



Source: Edited by JCOAL Study Team based on data from EPPO, https://www.eppo.go.th/index.php/en/.

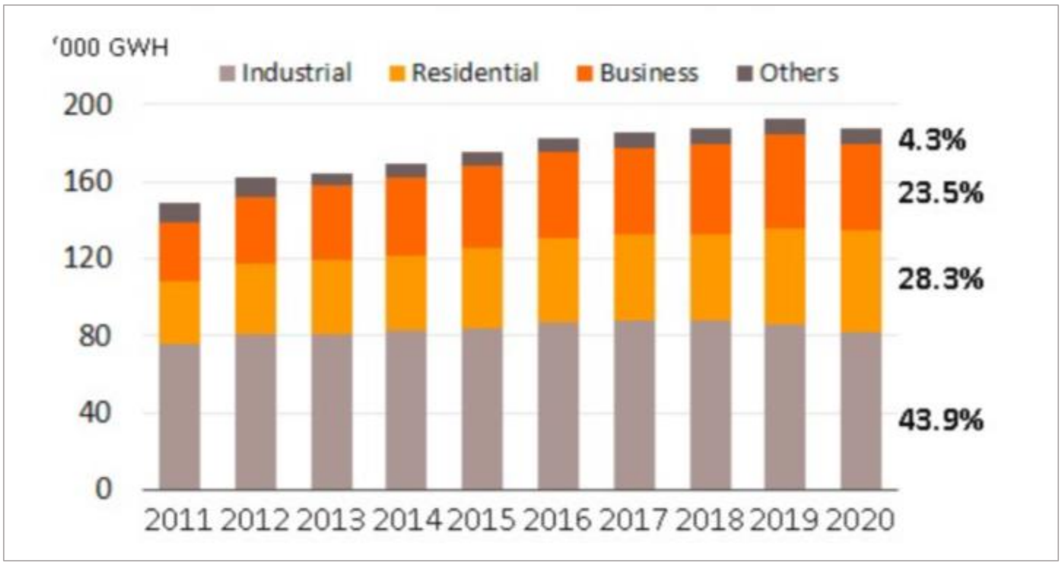
Figure 3.31. Power Generation Share by Fuel



Source: Edited by JCOAL Study Team based on data from EPPO (2022), https://www.eppo.go.th/index.php/en/.

In 2020, the major sources of demand were the industrial, household, and business sectors, which accounted for 43.9%, 28.3%, and 23.5% of national electricity consumption, and others at 4.3%.

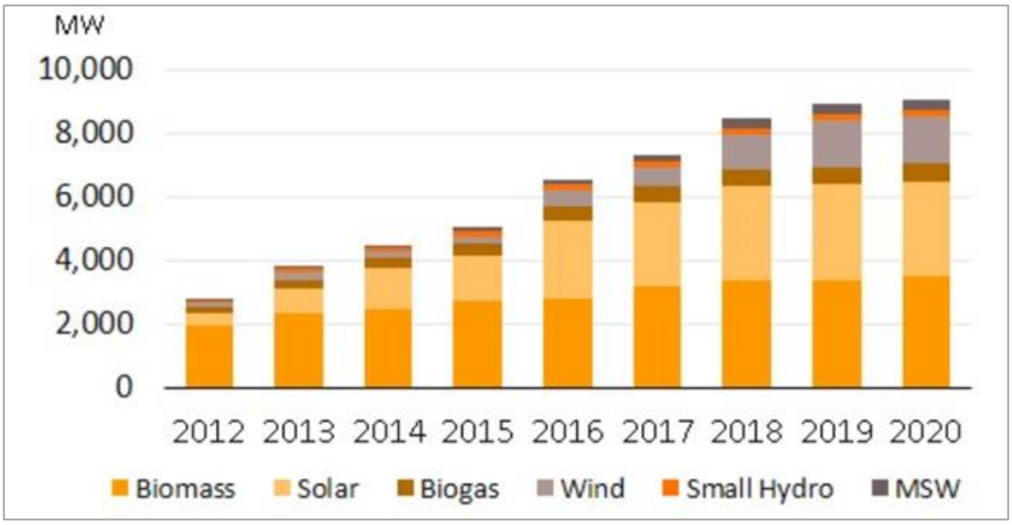
Figure 3.32. Electricity Consumption by Segment



Source: Energy Policy Planning Office, https://www.eppo.go.th/index.php/en/.

In 2020, natural gas fuelled 55.3% of the electricity produced in Thailand. Recently, the country's natural gas production has been declining, and imports are increasing, whereas RE sources contributed 10.0% of national electricity consumption in 2020 compared to only 2.1% in 2010.

Figure 3.33. Installed Capacity of Renewable Energy



Source: DEDE, https://www.dede.go.th/webmax.

The revision of the Power Development Plan (2018–2037) targets more than 56 GW of installed capacity by 2037. Actual electricity generation is only 53% towards meeting the target laid out in the Alternative Energy Development Plan (AEDP) 2015 of having 17 GW of renewable-powered supply by 2036. By segment, biomass generation has performed best, and supply is now 63% of the target, followed by waste-to-energy (59% of target supply), small hydro (51%), solar (50%), wind (50%), and biogas (43%).

Table 3.9. Total Capacity under PDP2018 Revision 1

Power capacity	PDP2015 (MW)	Power capacity	PDP2018 (MW)
Installed capacity as of 2014	37,612	Installed capacity as of 2018	46,090
Retired capacity (2015-2036)	-24,736	Retired capacity (2018-2037)	-25,310
New capacity (2015-2036)	57,459	New capacity (2018-2037)	56,431
Total capacity as of 2036	**70,335**	**Total capacity as of 2037**	**77,211**

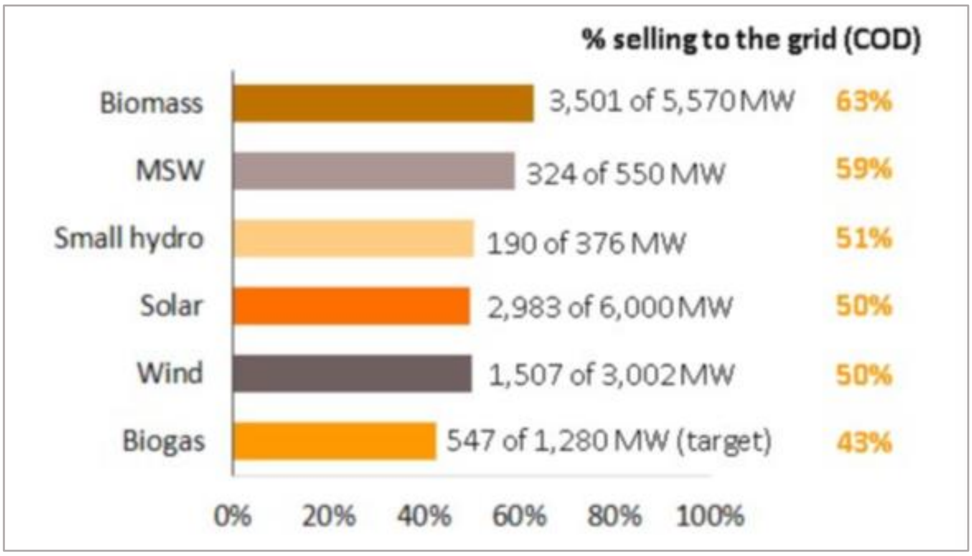
Source: EPPO (2020).

Table 3.10. Share of Fuel Used in Power Generation (%)

Fuel type	PDP2015	PDP2018	PDP2018 rev.1
Natural gas	37	53	53
Coal	23	12	11
Imported hydro	15	9	9
Renewable energy	20	20	21
Nuclear	5	0	0
Energy saving	0	6	6

Source: EPPO (2020).

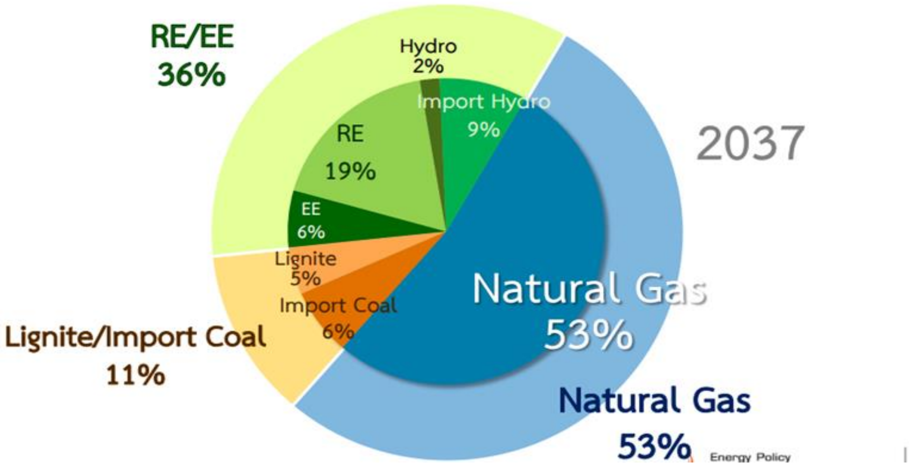
Figure 3.34. Renewable Energy Generation Capacity and AEDP Target (as of 2020)



Source: DEDE (2022).

A power plant, under the new AEDP 2018, consists of solar (54%), biomass (17%), hydro-floating solar hybrid (17%), and wind (9%). Of the 56 GW of new power generation from 2018 to 2037, RE accounted for 37% and combined cycle 27%, accounting for more than 60%. As a result, by 2037, natural gas will account for 53%, RE for 36%, and coal for 11%.

Figure 3.35. Power Plant under the New AEDP



Source: EPPO (2020).

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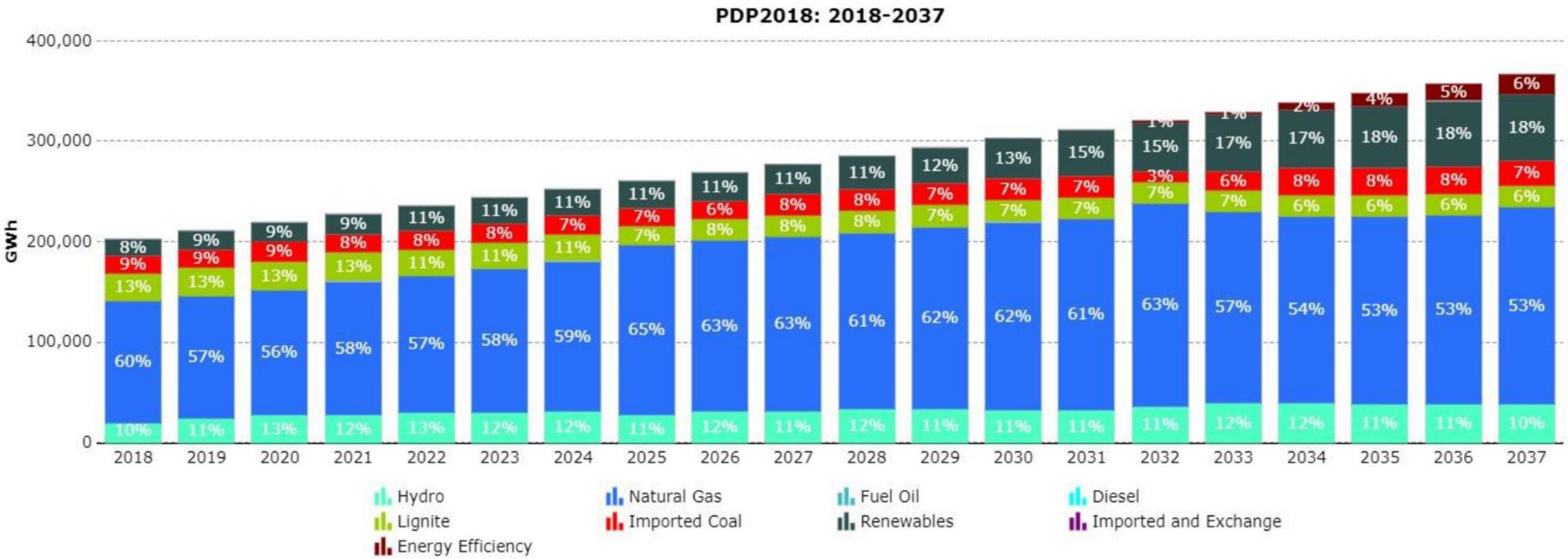
Figure 3.36 shows the power development plans for PDP 2018–2037 by type of power generation facilities.

Figure 3.36. Thailand's Power Development Plan 2018–2037 Revision 1



Source: Presentation of Thailand at the First Working Group Meeting, 8 July 2022.

3.2. Policy Towards Carbon Neutrality and Other Related Policies

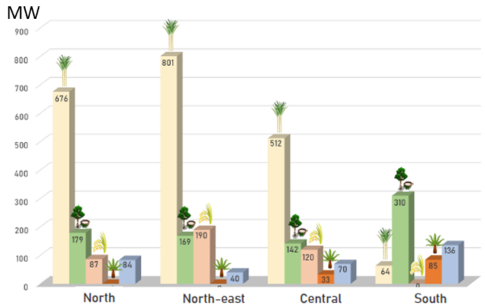
1) Biomass

This figure shows the biomass potential and current biomass power plant.

The Government of Thailand aims to utilise its domestic agricultural waste as a biomass energy source by adapting the ‘community power plant project’ concept, which needs smaller and distributed generation technologies. Bagasse and leaves are the largest biomass source in Thailand. The total capacity of the domestic biomass power plant is 3,700 MW. Out of this, 2,052 MW is of bagasse and leaves. Other major sources are rubberwood waste, rice husk, and palm cluster. In operation under a PPA are 256 biomass power plants.

Figure 3.37. Biomass Potential and Current Biomass Power Plant

	Potential (Mt/y)	Biomass power plant (MW)
Rice husk	1.38	400
Bagasse & Leaves	6.87	2052
Palm Cluster	0.99	118
Rubber wood waste	0.29	800
Others		330
total		3700

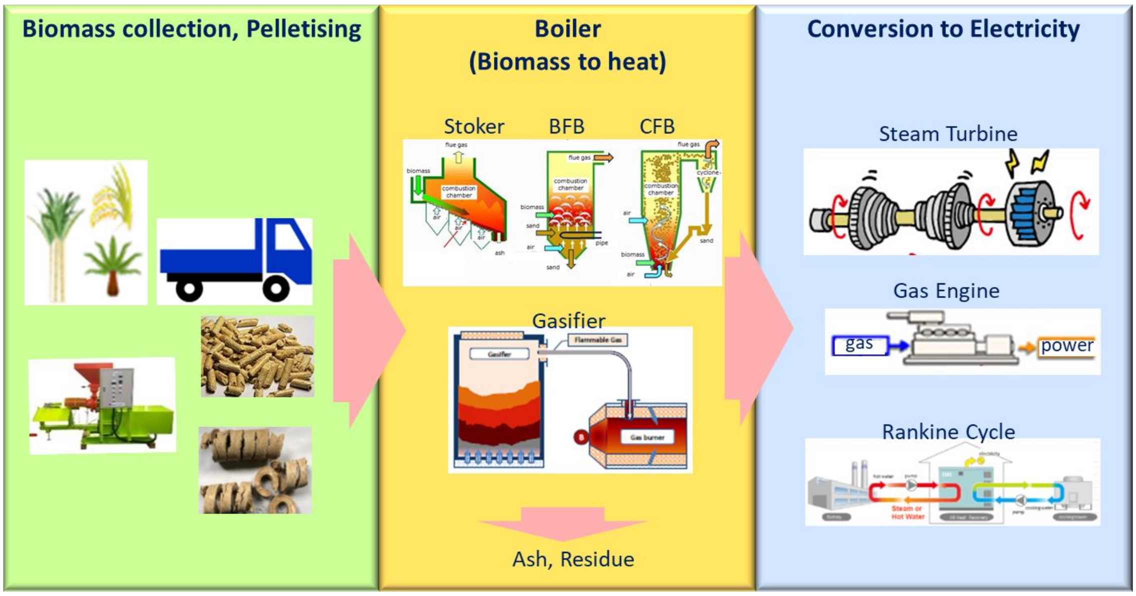


Biomass fuels in Thailand, categorized by type of biomass

Source: Working Group Presentation for the Study on Biomass and Coal Co-combustion in the ASEAN Region. EGAT (Feb. 2019).

Figure 3.38 shows adaptable technologies for biomass to energy in three portions: (i) biomass collection, (ii) biomass-to-heat conversion, and (iii) heat-to-power conversion. The technique must be properly selected for each portion. The technology chosen should be considered the electricity demand of nearby communities, suitable biomass type, volume, seasonal variation, and the economics of equipment costs.

Figure 3.38. Adaptable Technologies for Biomass to Energy



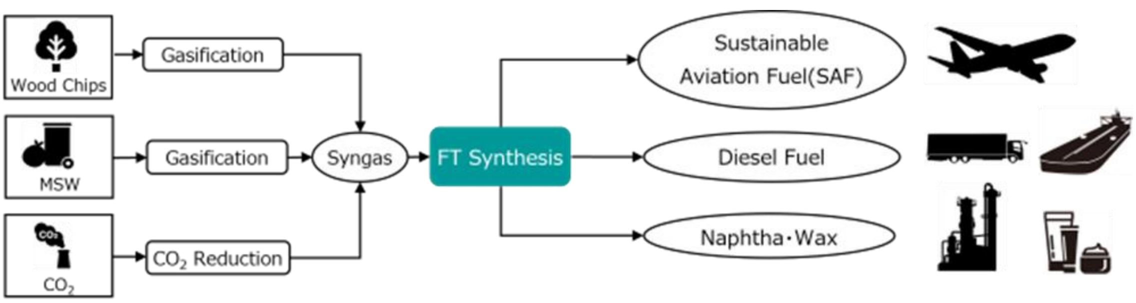
Source: ERIA & JCOAL (2020).

2) Synthetic Fuel

Synthetic fuels using carbon-neutral biomass as a carbon source consist of (i) gasification of biomass and (ii) synthesis of hydrocarbons by Fischer-Tropsch reaction of syngas. In Japan, several companies are in the pilot stage for commercialisation.

The reaction of synthesizing hydrocarbons from the cracked gas generated by pyrolyzing biomass in the first stage of the process has also been put to practical use in the world's industrial sector. In particular, the shift reaction that generates CO_2 and hydrogen through the reaction of carbon monoxide in the biomass decomposition gas with water is to be focused. Since the hydrogen required for the Fischer-Tropsch reaction is produced from CO and water by the shift reaction, the CO_2 produced as a by-product is of high purity. Therefore, if CO_2 can be stored, it can be used as a negative emission, contributing to CN.

Figure 3.39. Synthetic Fuel Process from Biomass (Ref. 1)



Sources: Toyo Engineering website, https://www.toyo-eng.com/jp/en/solution/e-fuel/;

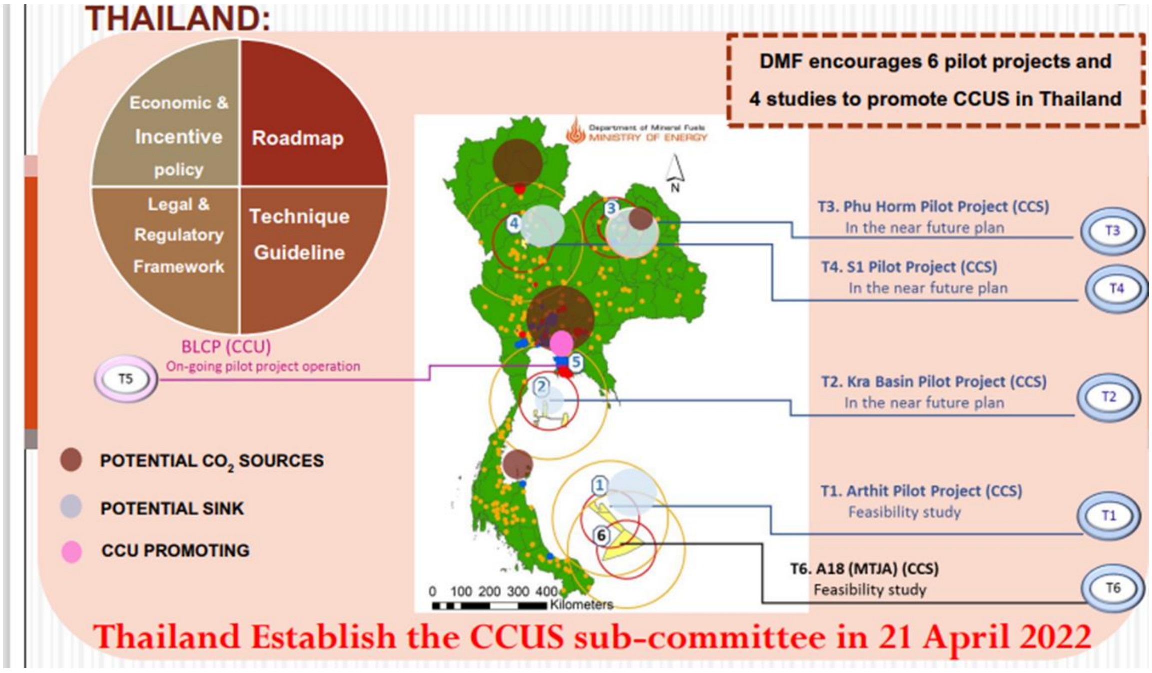
Figure 3.40. Synthetic Fuel Process from Biomass (Ref. 2)

Sources: News web, https://www.nikkei.com/article/DGXLRSP612791_Y1A610C2000000/.

3.3. Ongoing and Planned Measures for Carbon Neutrality

Figure 3.41 shows the current CCUS development in Thailand. The Thai Ministry of Energy established the CCUS sub-committee in April 2022. The ministry's Department of Mineral Fuels (DMF) has been facilitating six pilot projects and four studies on CCUS in the country.

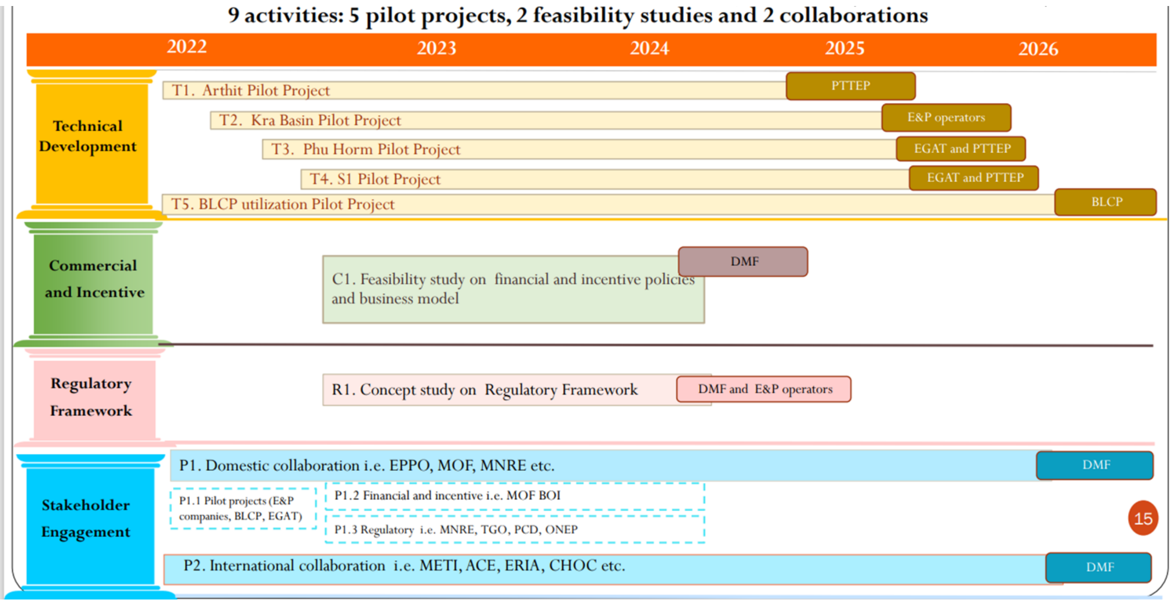
Figure 3.41. Current CCUS Development in Thailand



Source: Presentation of Thailand at the First Working Group Meeting on 8 July 2022.

Figure 3.42 shows Thailand's CCUS development work plan in 5 years from 2022 to 2026. There are five technical development projects, two feasibility studies, and two collaboration projects. They are also participating in the international collaboration projects shown at the end of the period.

Figure 3.42. CCUS Development Work Plan (2022–2026)



Source: Presentation of Thailand at the First Working Group Meeting on 8 July 2022.

Table 3.11 shows the applicable technologies for CO_2 reduction and for capture, utilisation, and storage of CO_2. It is important to describe each item to the extent that it can be technically applied according to the situation and needs of each country. In addition, it is important to review it according to economic feasibility and future changes in the situation.

Table 3.11. Applicable Technologies for Carbon Neutrality (1)

Road Map towards Carbon Neutrality						Thailand
Reduction	Thermal Power	High Efficiency	IGCC			Not applicable
			IGFC			
			A-USC			
	Fuel	Biomass	Combustion	CFBC biomass firing		Applicable
				PC coal cofiring		
			Manufacturing	Material	Agricultural waste pellet	Applicable
					Fast-growing tree	
				Pri-treatment	Torrefied pellet	Optional
					Washing	
		Ammonia	Utilisation	Ammonia gas turbine		Applicable
				Ammonia industrial furnace		
				Ammonia-coal cofiring		
			Manufacturing	Ammonia process	Coventional process + CCS	Optional
					New&Innnovative process	
				R&D base, Supply chain		
		Hydrogen	Utilisation	Hydrogen gas turbine		Applicable
			Manufacturing	Hydrogen process	Water electrolysis by RE	Applicable
					Turquoise hydrogen	
				R&D base, Supply chain		Optional
	Renewables	Wind, Solar, Geothermal	Offshore wind			Applicable
			Perovskite PV			
			Next generation geothermal			
		BESS	large Li-ion, NaS, Redoxflow			
	Manufacturing process	Steel	Coke reduction	Energy saving, LRC	Ferrodoke	Optional
				Direct reduction		
				Hydrogen reduction		
				COURSE50	Super-COURSE50	
				Carbon recycling BF		
		Cement				Applicable

Source: JCOAL.

Table 3.12 Applicable Technologies for Carbon Neutrality (2)

Road Map towards Carbon Neutrality						Thailand
Capture	Capture/ Recovery	Capture/ Recovery	Recovery/generatrion	Oxyfuel IGCC		Not applicable
				Supercritical CO_2 cycle generation		
				Chemical looping combustion		
			Chemical absorption			Applicable
			Solid absorbent material method			
			Physical absorption			
			Membrane separation			
			Physical adsorption			
Utilisation	Chemicals	Chemicals	Core materials	Methanol		Applicable
				SOEC process	CO	
					Methyl Cycrohexane	
				Artificial photosynthesis	Olefin	
			Derivatives	Formic acid	Boron-doped diamond electrode	
				Polyurethane intermediate		
				Para-xylene		
				Polycarbonate		
				Polyurethane		
				Ethylene urea		
	Fuel	Fuel Synthesis	Gas fuel	Methane	Sabatier process	Applicable
					SOEC process	
					Biomass photosynthesis	
			Liquid fuel	Diesel	Biomass photosynthesis	
				Jet fuel	Biomass photosynthesis	
					Biomass gasification FT synthesis	
				Olefin, kerosene		
	Mineralisation	Cement/ Concrete	Concrete	CO2 absorption type		Applicable
				Carbonate type		
			Admixture	CO2 absorption type		
				Carbonate type		
	Others	Others	Sector Coupling	Industrial complex carbon recycling		Applicable
Storage	Storage	CCS、DACCS、BECCS	Forest absorption/afforestation	Afforestation		Applicable
				Blue carbon		
			CCS			

Source: JCOAL Study Team.

3.4. Policy recommendations

The applicability of CCT for a carbon-neutral solution is as follows. According to the Thai government's energy policy 4D+E, the comprehensive utilisation of biomass is important, along with conventional RE, such as hydropower, and relatively new RE, such as solar and wind power.

1) On biomass utilisation in the power sector, the Thai government's policy to promote community power plant is the right choice as it accelerates the decentralisation of power sources and utilisation of domestic resources. Biomass combustion can be combined with many other technologies according to the type of biomass and plant scale to enhance the outcomes of the overall community power plant for further dissemination. In this context, individual optimisation is desirable.

2) Developing synthetic fuel from biomass gasification and fuel synthesis is desirable for biomass utilisation in the transport sector. Since the purity level of CO_2 produced as a by-product is quite high, substantial CO_2 reduction can be expected by replacing conventional fuels with synthetic fuels and storing them.

3) Hydrogen derived through a shift reaction of CO to CO_2 is expected to utilise combustion as carbon-free fuel, fuel cell, and key material for several carbon-recycling reaction pathways. In this connection, a study on the overall utilisation chain of biomass, hydrogen, and CO_2 will be recommended.

4) The Thai government is actively promoting CCS projects. There are various CO_2 sources and their concentration. Among them, the recovery of CO_2 from flue gas is particularly important. In this regard, government support will be very effective.

4. Viet Nam

Viet Nam is a dynamic, emerging economy with approximately 100 million people. Before the COVID-19 pandemic, the country recorded an annual GDP growth rate of 6%–7%, dramatically increasing energy demand and greenhouse gas (GHG) emissions. With high economic growth expected to continue, the country could face severe electricity shortages in 2030 if energy demand growth is unchecked.

According to the APEC Energy Working Group's Expert Group on Energy Data and Analysis, hydropower has been Viet Nam's clean, stable, and reliable energy source. But saturation has shrank hydropower's share in the country's electricity mix (from 37% in 2019 to 30% in 2020). Due to constraints in dam reservoir capacity, hydropower cannot meet the growing demand. Fossil fuels (coal, gas, and oil) account for about half of the electricity generation mix. Coal has been the cheapest and most readily available source, but Viet Nam increasingly depends on imports. Meanwhile, renewables such as small hydropower, solar, wind, and biomass account for only 16% of electricity generation.

In 2015, the government announced its first national development strategy on renewables, aiming to increase the share of renewables in total primary supply and electricity generation to about 32% by 2030.

4.1. Energy/Electricity Situation and Policies

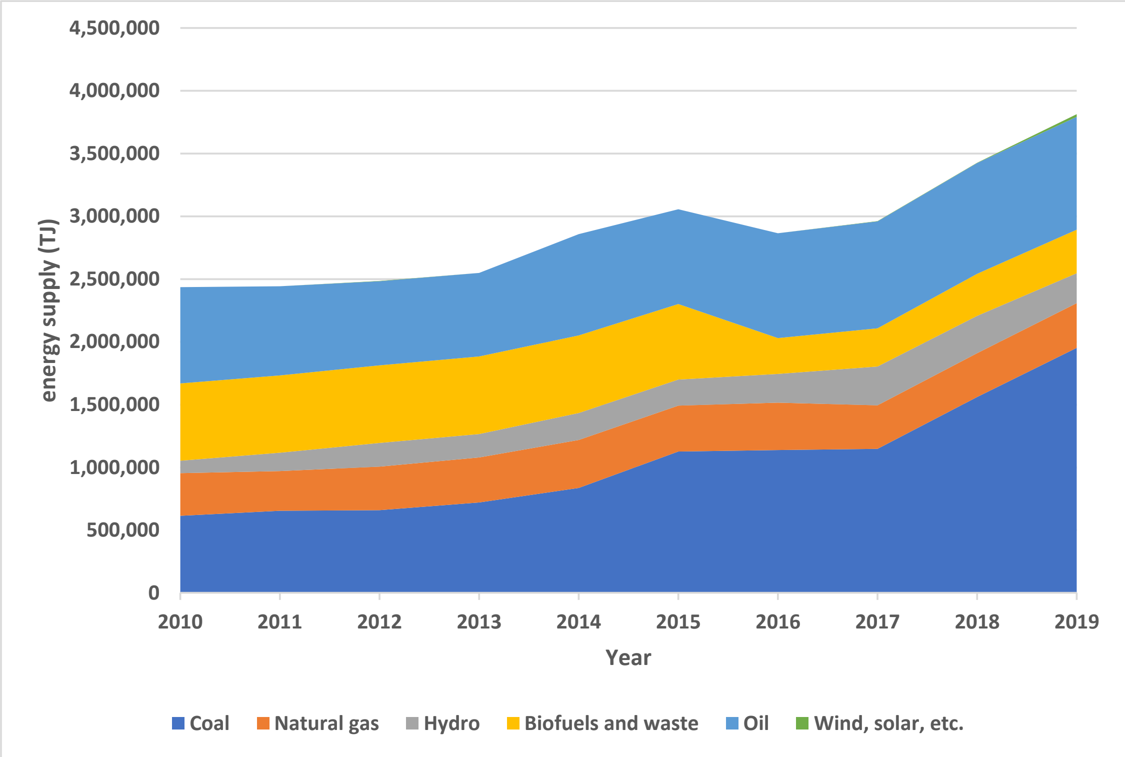
1) Current Energy Supply and Demand

Figure 3.43 shows the evolution of the energy supply from 2010 to 2019. Coal (blue) and oil (light blue) represent a large share of the energy supply sources.

In terms of the rate of increase, petroleum increased by 17% from 2010 to 2019, while coal increased by over 300%. So, it is no exaggeration to say that coal accounts for most of the increase in Viet Nam's energy supply.

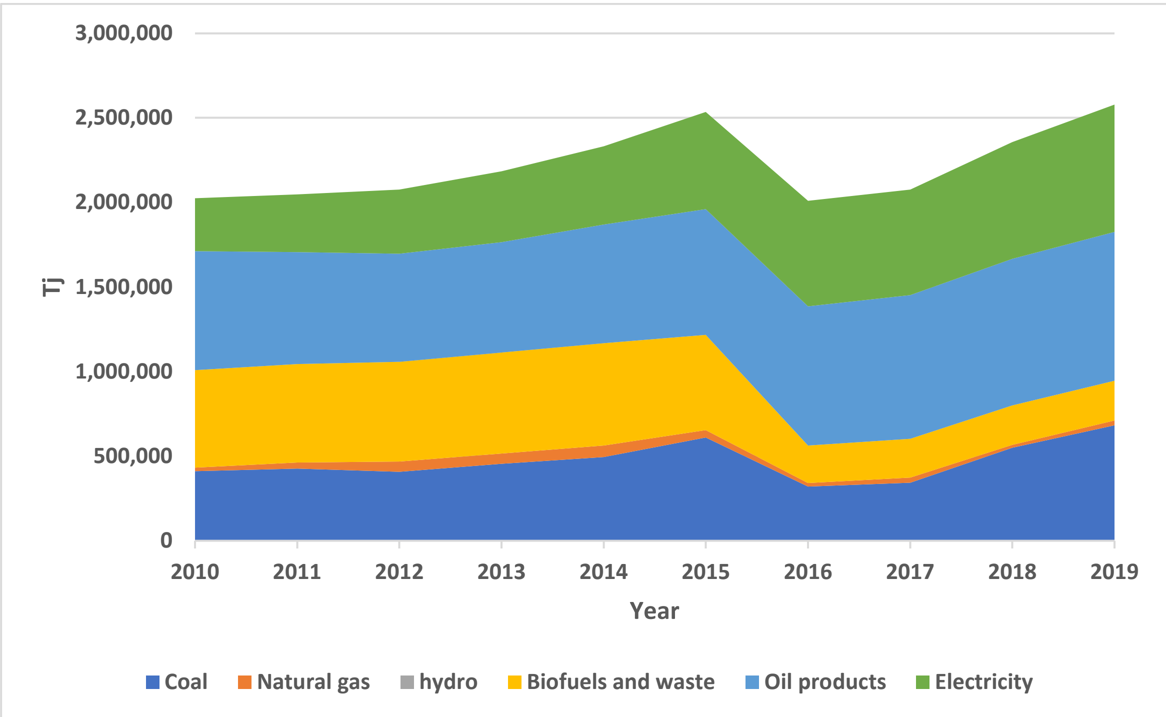
The evolution of energy consumption from 2010 to 2019 is also shown in Figure 3.44. The largest increases over this period have been in coal (66%) and electricity (240%). Regarding electricity consumption, Viet Nam ranks second in ASEAN, after Indonesia.

Figure 3.43. Total Energy Supply by Source in Viet Nam



Source: IEA (2021c).

Figure 3.44. Total Energy Consumption by Source in Viet Nam

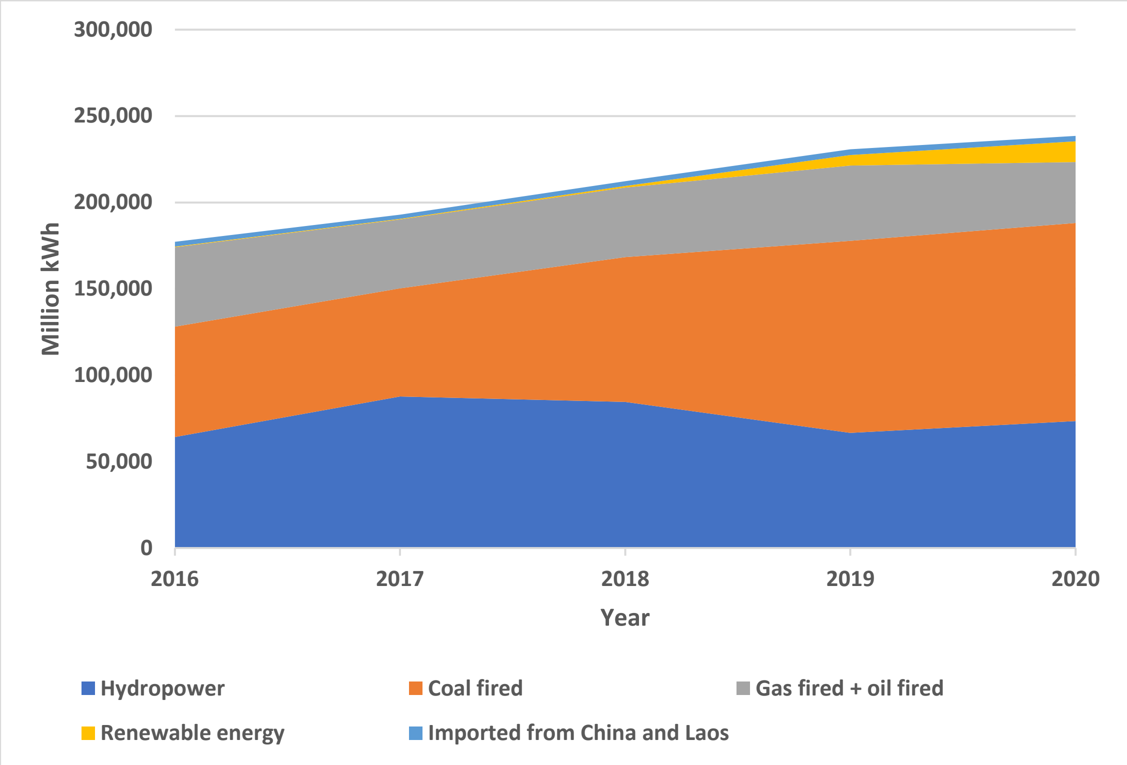


Source: IEA (2021c).

2) Power Production and Purchase by Sector

Figure 3.45 from the Vietnam Electricity (EVN) Annual Report (2021) shows the change in electricity generation between 2016 and 2020 by fuel type. The highest rate of increase in power generation is in coal-fired power, which increased by 1.8 times in 2020 compared to 2016.

Figure 3.45. Power Production and Purchase

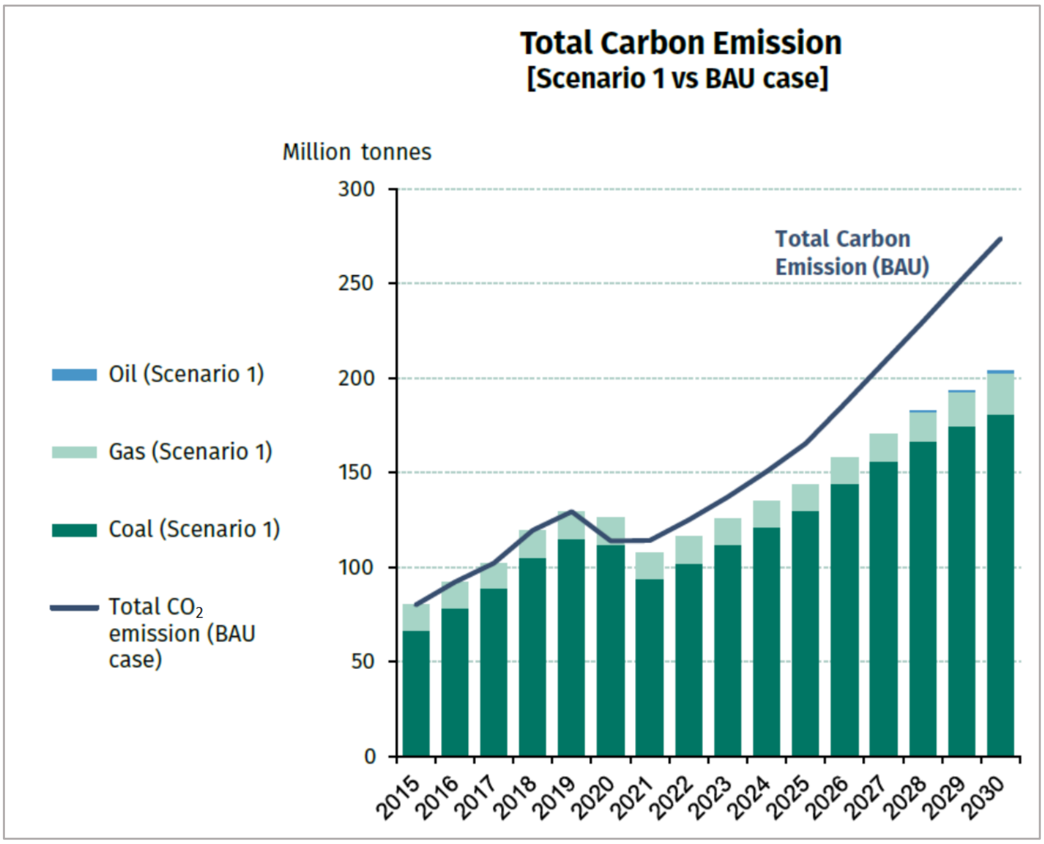


Source: EVN (2021).

3) Total Carbon Emission in Viet Nam

The projected CO_2 emissions up to 2030 are shown in Figure 3.46. CO_2 emissions will increase from 130 Mt in 2019 to 204 Mt in 2030, as existing and 9 GW of new committed coal facilities operate at a high capacity to meet strong demand growth over the next decade. Due to the increased share of non-fossil fuel generation, total carbon emissions in this scenario are 26% lower than in the business-as-usual scenario in 2030.

Figure 3.46. Total Carbon Emissions



BAU = business-as-usual scenario.

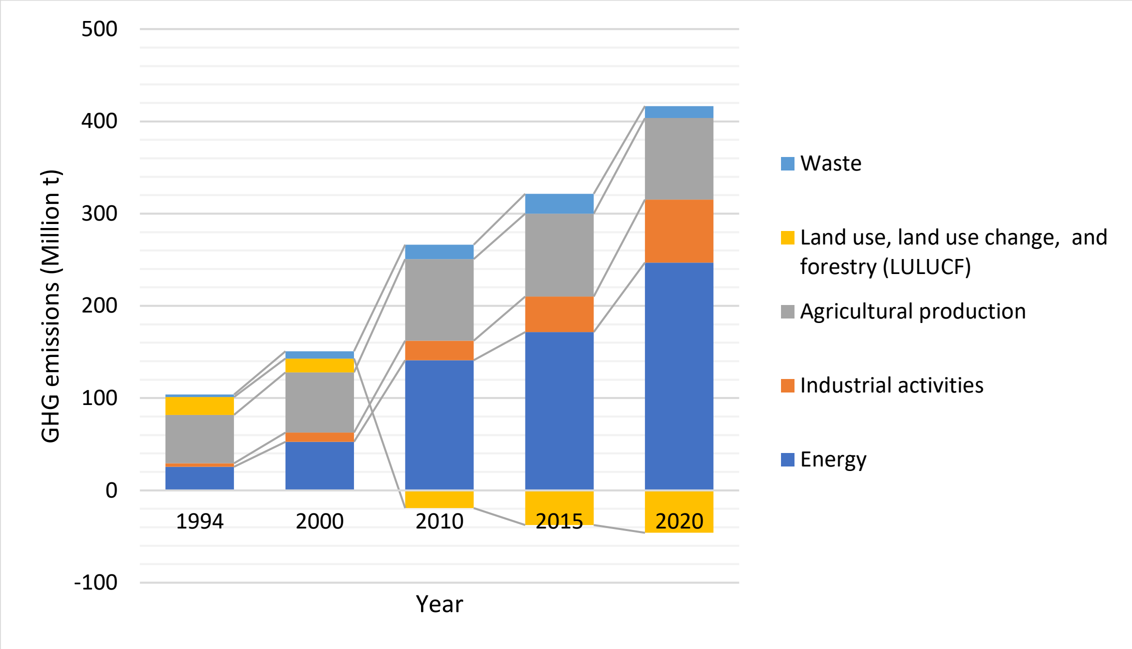
Source: Liutong and Alvarez (2021).

Figure 3.47 shows the change in CO_2 emissions by industry in Viet Nam between 1994 and 2020, as reported at the 19th ASEAN Energy Security Forum on 16 June 2022.

CO_2 emissions have increased from 104 million tonnes in 1994 to 3.7 million tonnes in 2020, an increase of about 3.5 times. The largest share of the growth is in the energy sector, which accounted for 67% of CO_2 emissions in 2020.

GHG emissions from energy use and development increased from 141.2 million tonnes (CO_2) equivalent in 2010 to 247 million tonnes (CO_2) equivalent in 2020, 45% of which was related to electricity production in 2020.

Figure 3.47. Current Status of GHG Emissions in Viet Nam



Source: Edited by JCOAL Study Team based on data from MOIT (2022).

4.2. Review of PDP8 for 2030 and 2045 in Viet Nam

In 2021, Viet Nam's Ministry of Industry and Trade (MOIT) published the National Electricity Development Plan (PDP8) for 2021-2030. This included a vision to 2045, proposal number 1682/TTr-BCT.

The draft PDP8 was mainly concerned with RE introduction, and the results were presented in October 2021 and April 2022. It is currently awaiting approval by the Prime Minister.

The installed generation capacity by energy source for PDP8 is shown in Table 3.13. In the table, reference is made to EVN's annual report for actual data at the end of 2020. For the 2030 generation installed capacity plan, the March 2021 announcement and the October 2021 review are for the base scenario, while the April 2022 review is for the high scenario. A stacking graph based on these data is shown in Figure 3.48**.** MOIT proposes the following for the draft PDP8 (announced in March 2021) and the new PDP8 (reviewed in October 2021).

Coal-fired power generation capacity will reach approximately 29,429 MW in 2025 (base scenario) and grow to 40,649 MW in 2030 (base scenario), increasing from approximately 27.96% of total installed capacity in 2025 to about 28.3% of total installed capacity in 2030. No new CFPPs will be developed during this period (except those under construction between 2021 and 2025 and under investment promotion to start operation). Projects approved under the revised PDP7 but opposed by local communities or failed to meet development criteria (e.g. where the project is not feasible) are recommended to be suspended. However, 19,266 MW will be added until 2030, and PDP8 will take over coal-fired projects in PDP7. In the April 2022 review, CFPPs will no longer receive any increase in installed generating capacity.

Gas-fired power, including LNG, will increase to 27,471 MW by 2030 (base scenario). The share of gas-fired power, including LNG, is expected to grow from about 13.54% in 2025 to about 21.1% in 2030. However, of the approximately 17,900 MW of projects added in October 2021, only about 10,300 MW of gas-to-power projects will be developed by 2030 under the draft PDP8, while other projects will be deferred until after 2030. In the Northern Region, an additional 2,250 MW of gas-to-power projects were proposed for regional energy security reasons and to minimise inter-regional transmission, in addition to the recently approved approximately 1.5 GW. In the April 2022 review, the installed capacity of gas turbine–based thermal power generation approximately doubled.

Hydropower capacity (including large, medium, and small hydropower and pumped storage) would gradually increase from about 25,323 MW by 2025 (base scenario) to 26,684 MW by 2030 (base scenario). The share of hydropower is projected to decrease from about 24% in 2025 to about 19.39% in 2030. In the April 2022 review, it would increase to 30,946 MW (high scenario), but the share would increase slightly to about 20.14%.

Onshore and offshore wind capacity is expected to increase from about 11,320 MW in 2025 (base scenario) to 18,010 MW in 2030 (base scenario). However, given that more than 10 GW has been approved under the revised PDP7, the addition does not appear as large as expected from the private sector. In Letter No. 4219/EVN-TTD dated 22 July 2021, 144 wind power projects have signed PPAs for about 8,145 MW. The PPAs are for 8,145 MW. Only up to 2,000 MW can be generated for offshore wind power by 2030. The draft PDP8 has removed the list of large offshore power projects. The draft PDP8 states that they will represent about 11% of total installed capacity by 2025, decreasing to about 9% by 2030. The April 2022 review reinstated offshore power projects at 23,121 MW (high scenario).

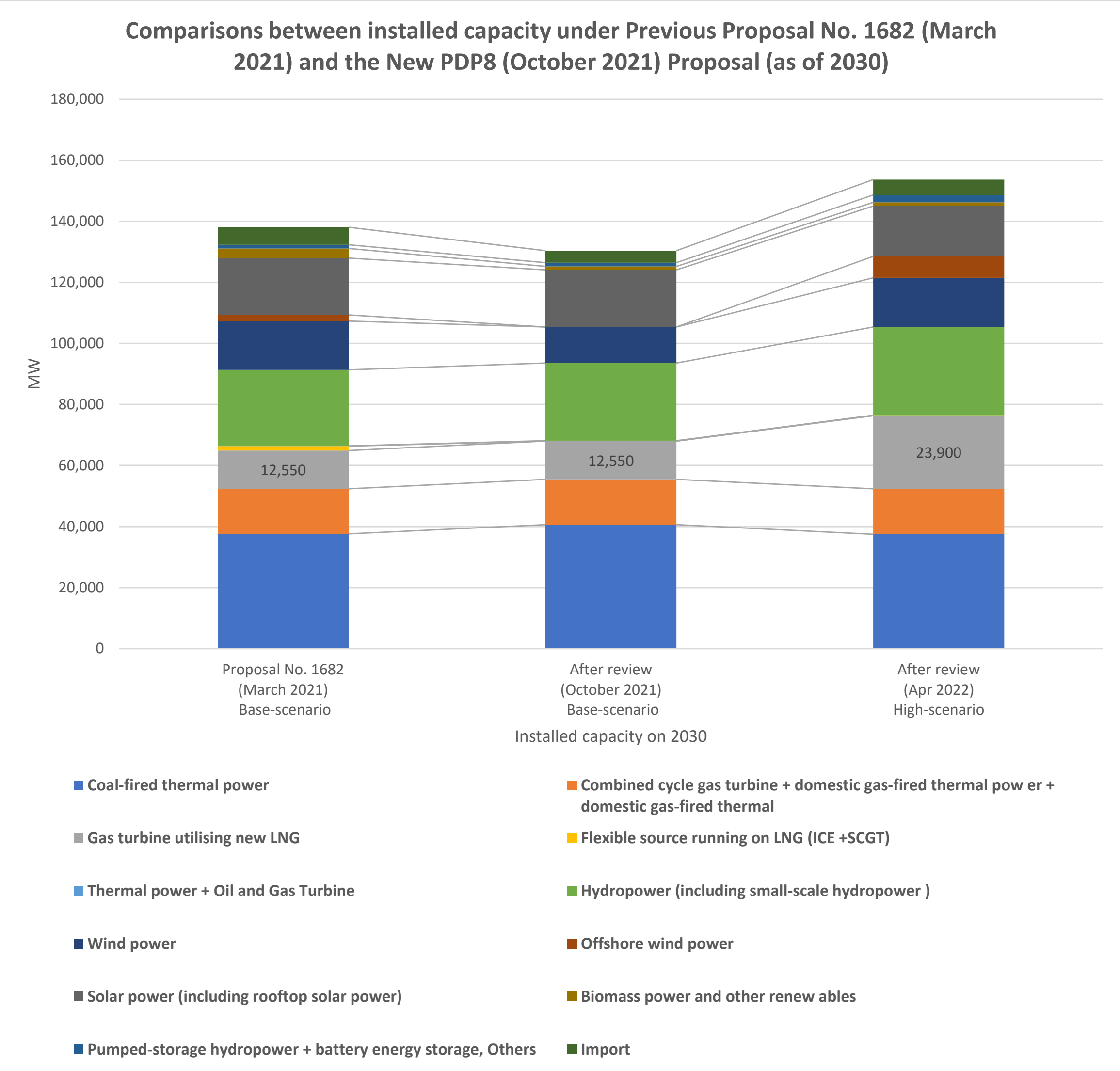
Table 3.13. Installed Generation Capacity by Energy Source for PDP8 (as of 2030)

Year / Item	2020	2030		
		Installed Capacity		
	End of 2020	Proposal no. 1682 (March 2021) Base scenario	After review (October 2021) Base scenario	After review (Apr 2022) High scenario
Coal-fired thermal power	21,838	37,573	40,649	37,467
Combined cycle gas turbine +domestic gas-fired thermal power + domestic gas-fired thermal		14,783	14,783	14,930
Gas turbine utilising new LNG	9,025	12,550	12,550	23,900
Flexible source running on LNG (ICE +SCGT)		1,400	0	150
Thermal power+oil and gas turbine		138	138	0
Hydropower (including small-scale hydropower)	20,993	24,872	25,484	28,946
Wind power	538	16,010	11,820	16,121
Offshore wind power		2,000	0	7,000
Solar power (including rooftop solar power)	16,506	18,640	18,640	16,491
Biomass power and other renew ables		3,150	1,170	1,230
Pumped-storage hydropower + battery energy storage, Others	325	1,200	1,200	2,450
Import	572	5,743	3,937	5,000
Total installed capacity (MW)	69,797	138,059	130,371	153,685

Source: Baker and McKenzie (2021).

For photovoltaics (PVs), the total capacity would reach about 17,240 MW in 2025 (base scenario) and 18,640 MW in 2030 (base scenario). Solar PV would account for approximately 16.79% of the total installed capacity in 2025 and about 14.3% in 2030. However, with 8,751 MW of solar PV plants in operation by the end of 2020 and a further 7,755 MW of rooftop PV systems in commercial operation, this does not appear to be as large an addition as the private sector might expect. The April 2022 review shows 16,491 MW (high scenario) and 2,149 MW less, likely due to the postponement of new solar PV projects.

Figure 3.48. Installed Generation Capacity by Energy Source for PDP8 (as of 2030)



Source: Edited by JCOAL Study Team based on data from Baker & McKenzie (2021, 2022).

The installed capacity of electricity generation by energy source in 2045 is shown in Table 3.14. A graph built up from this data is shown in Figure 3.49. By energy source, coal-fired power will reach a generation capacity of 50,699 MW (high scenario) in 2045. The share of coal-fired power will decrease to about 15.4% in 2045. Between 2030 and 2045, there is no change in the installed capacity of coal-fired power generation, but the share of coal-fired power in the total installed capacity decreases significantly. The decrease amounts to 13,232 MW.

Gas generation capacity gradually increases to 53,883 MW in 2045 (61,900 MW including base scenario and LNG flexible sources), or approximately 20.6% of total installed capacity (23.64% including LNG flexible sources). In the April 2022 review, it is reduced to 46,330 MW. But LNG flexible sources will increase by approximately 28,000 MW, bringing the combined total to 74,530 MW.

Table 3.14. Installed Generation Capacity by Energy Source for PDP8 (as of 2045)

Year / Item	2045 Installed Capacity		
	Proposal no. 1682 (March 2021) Base scenario	After review (October 2021) Base scenario	After review (Apr 2022) High scenario
Coal-fired thermal power	50,168	50,699	37,467
Combined cycle gas turbine + domestic gas-fired thermal power + domestic gas-fired thermal	12,754	14,783	14,930
Gas turbine utilising new LNG	38,150	39,050	31,400
Flexible source running on LNG (ICE +SCGT)	15,600	8,100	28,200
Thermal power + oil and gas turbine	0	0	0
Hydropower (including small-scale hydropower)	25,772	29,077	35,139
Wind power	39,610	27,110	55,950
Offshore wind power	21,000	21,000	66,500
Solar power (including rooftop solar power)	55,090	51,540	96,666
Biomass power and other renew ables	5,310	5,250	5,210
Pumped-storage hydropower +battery energy storage	7,800	6,600	29,250
Import	5,743	8,743	11,042
Total installed capacity (MW)	276,997	261,952	411,754

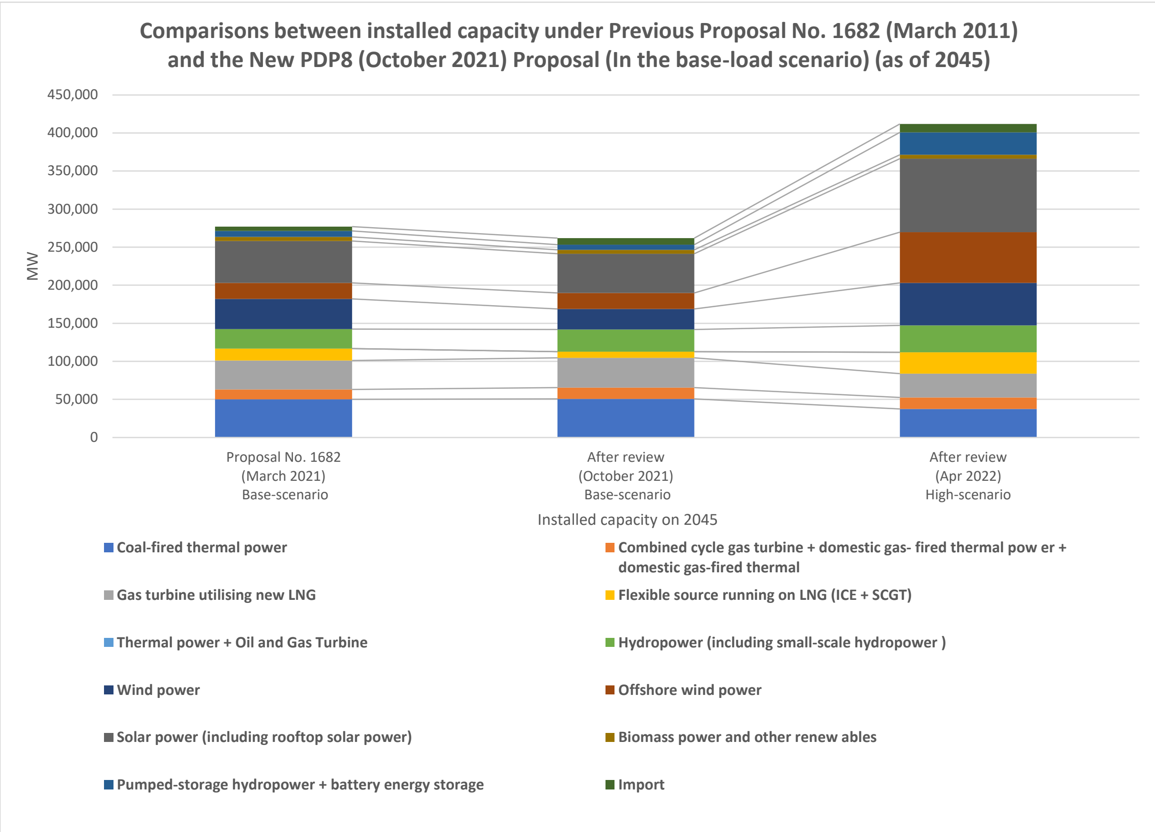
Source: Baker & McKenzie (2021, 2022).

Hydropower capacity (including large, medium, and small hydropower and pumped storage) will gradually increase, reaching approximately 29,077 MW in 2045 (base scenario). The share of hydropower will continue to decline (as hydropower potential is almost exhausted). In particular, the share of large, medium, and small hydropower and pumped storage will amount to about 12.58% of the total installed capacity in 2045. In the April 2022 review, hydropower installed capacity increased again to 35,139 MW (high scenario).

Wind power generation (onshore and near-shore wind capacity) will increase significantly to about 27,110 MW by 2045. For offshore wind power, the draft PDP8 proposes a significant increase in capacity to about 21,000 MW by 2045: in the April 2022 review, 28,840 MW more onshore wind and 45,500 MW more offshore wind under the high scenario, bringing the total to 122,450 MW.

Solar PV capacity will increase significantly to around 51,540 MW by 2045, accounting for about 19.3% of total installed capacity. The April 2022 review further increases installed capacity by 45,128 MW to 96,666 MW on a high scenario.

Figure 3.49. Installed Generation Capacity by Energy Source for PDP8 (as of 2045)



Source: Edited by JCOAL Study Team based on data from Baker & McKenzie (2021, 2022).

4.3. Policy Directions and Related Basic Policies for Decarbonisation

At COP26 in Glasgow in 2021, Prime Minister Pham Minh Chinh announced that the country would phase out coal power generation by the 2040s and achieve net-zero carbon emissions by 2050. In its National Strategy on Climate Change, Viet Nam has recently announced a 43.5% emission reduction target by 2030, sectoral emission targets for 2030 and 2050, and qualitative proposals for achieving the targets.

As in other countries, Viet Nam's emissions come from various energy and land-use systems. Approximately 30% of total GHG emissions come from the power sector, 30% from the industrial sector, and 10% from the transport sector.

Within the Vietnamese government, several agencies have announced specific CO_2 reduction policies. For example, the Electricity Development Programme 8 (PDP8) of the Ministry of Industry and Trade aims to switch approximately 75% of electricity generation capacity to renewables by 2045. Around 100 GW will come from solar power and 120 GW from wind power (a higher target for solar power is being considered). The ministry also announced using hydrogen and ammonia in thermal power generation schemes, paving the way for green hydrogen to replace fossil fuels partially.

In the transport sector, the Prime Minister encouraged the introduction of electric vehicles (EVs), EV charging infrastructure and the electrification of public transport. Public stakeholders acted accordingly. The Ministry of Finance reduced the registration fee for EVs.

Other government agencies have also made commitments. The Ministry of Agriculture and Rural Development has committed to halt deforestation by 2030, while the Ministry of Construction has set requirements to promote green building.

Outside of central government agencies, several ministries are also committed to decarbonisation.

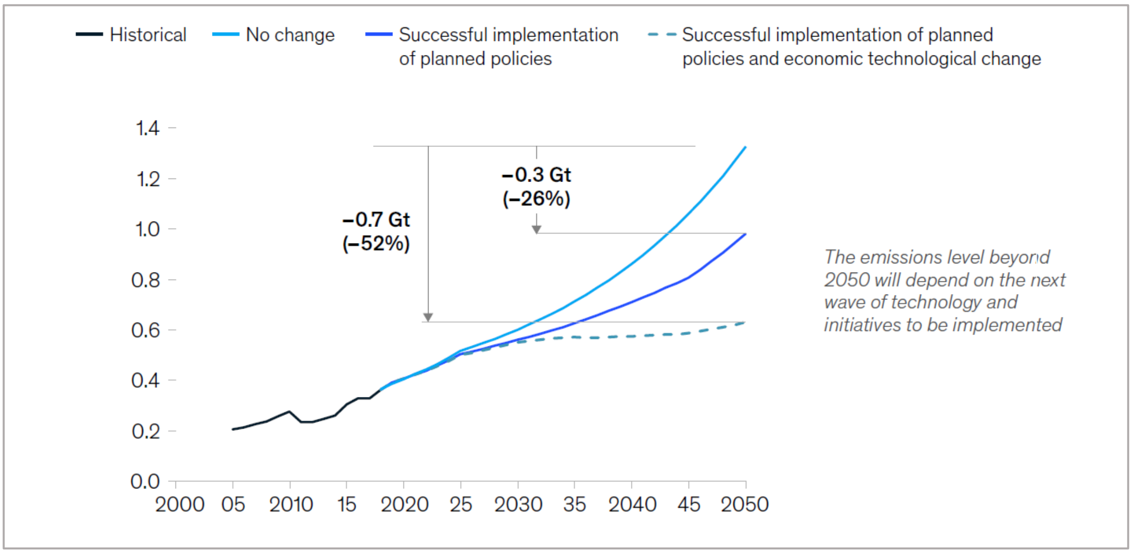
Quang Nam Province is working with the World Wide Fund for Nature (WWF) on forest conservation and is a pioneer in carbon sink projects in Viet Nam.

If the Government successfully implements these policies, emissions will likely be reduced, but not to the extent needed to achieve zero emissions by 2050.

Figure 3.50 illustrates this gap in three scenarios. The least desirable scenario is the one described earlier, where the industry continues to grow at the planned rate without technological change and the planned policies being successfully implemented. The scenario in the middle of the chart shows the case where the planned policy updates are successfully implemented. In the best scenario combining the latest plans with economically viable technological innovations, such as the conversion of passenger cars, motorcycles, and tricycles to EVs, more efficient agriculture, and a shift to advanced manufacturing, the emissions curve falls further. Under this scenario, emissions in Viet Nam could level off around 2035.

By 2050, they are almost at the same level as in 2025, at 0.6 gigatonnes.

Figure 3.50. Pathways of Viet Nam CO_2 Emissions, Gigatonnes of CO_2 Equivalent ($GtCO_2e$)



Source: Agarwal, et al. (2022).

4.4. Examples of Planned or Ongoing Initiatives, Related Measures, etc.

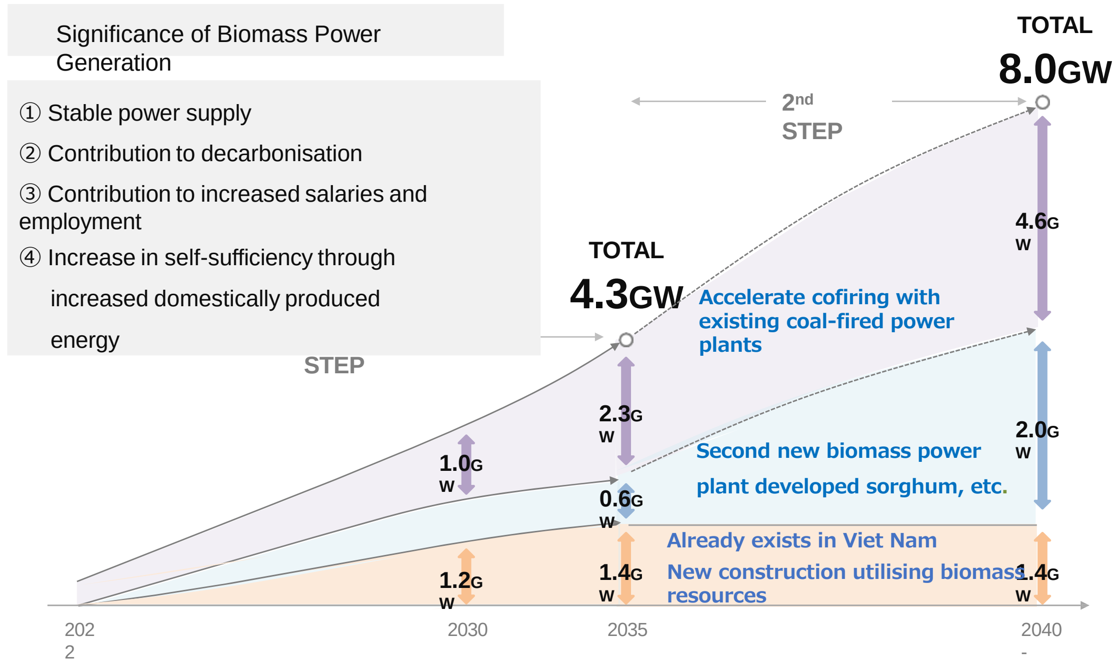
This section reports on the state of RE development in Viet Nam.

1) Power Generation using Biomass

A major concern for biomass power generation is the availability of fuel. But Viet Nam has a thriving agricultural and forestry industry, and a wide variety of biomass fuels are abundant. Although it is not widely known, Viet Nam is one of the world's leading agricultural countries, with many agricultural and forestry products boasting the top share of the international market. Viet Nam is also rich in forestry resources. It has a land area of approximately 33 million hectares (ha), of which forests cover about 14 million ha. Of this, about 70% is natural forests, and 30% is planted forests, although logging of natural forests was banned under a 2014 Prime Ministerial Decision. As of November 2018, the area of planted forests for commercial use, excluding security forests for protection and disaster prevention, was approximately 2.93 million ha.

As an example of biomass cofiring power generation in Viet Nam, the project being undertaken by the Japanese company erex is described. The company's power generation plan is shown in Figure 3.51: 1.4 GW of new biomass power plant using existing unused biomass; 0.6 GW of new biomass power plant using new biomass fuels including sorghum, by 2035; and 2.3 GW of bio-cofiring power generation at existing CFPPs, for a total of 4.3 GW. This plan could reduce CO_2 emissions by approximately 27 million tonnes per year, a reduction of roughly 10% compared to 2020. The company has already submitted a grand proposal to MOIT Viet Nam. The significance of working on biomass power generation includes stable electricity supply, contribution to decarbonisation, increased salaries and employment contribution for farmers, and increased self-sufficiency through increased domestic energy production.

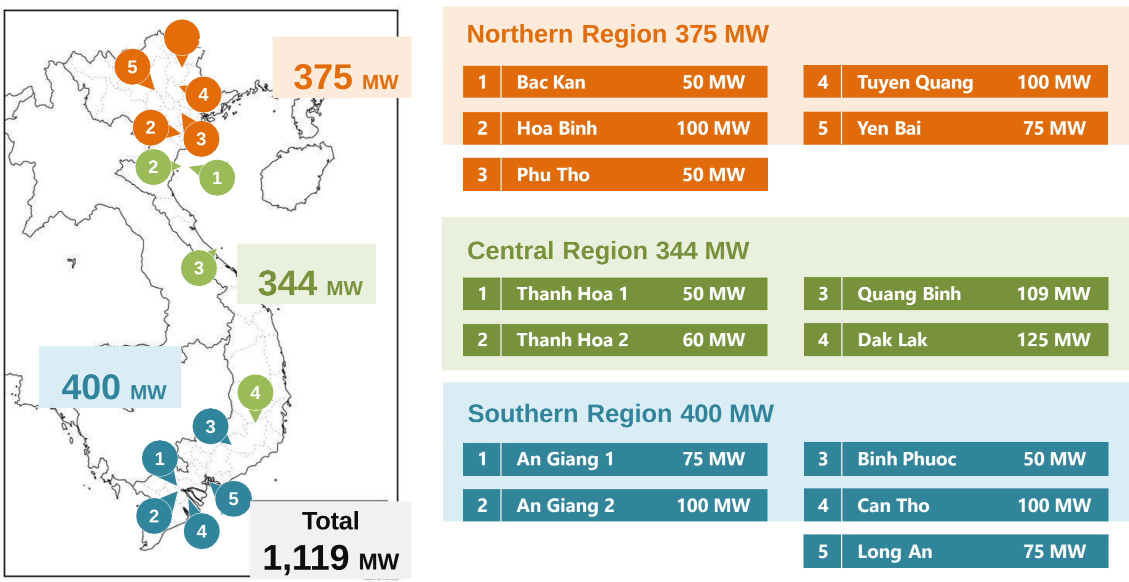
Figure 3.51. Erex's Power Generation Plan in Viet Nam



Source: Erex (2022a).

The locations of the power plants that erex is considering targetting for 2035 and their installed generation capacity are shown in Figure 3.52. In the diagram on the left, the potential in biomass power generation is shown in different colours – the darker the colour, the higher the potential. In addition, the power generation installed capacity is larger in the central and northern regions.

Figure 3.52. Biomass Power Plant Potential by Region in Viet Nam



Source: Erex (2022a).

Erex was invited to participate in the conference on 27 August 2022 in Lao Cai Province, Viet Nam, under the theme 'Potential – Opportunity – Cooperation for Development' in the presence of Prime Minister Pham Minh Chinh. An MoU was signed between five Vietnamese provinces (Yang Bai, Tinh Quang, Bac Kan, Lai Chau, and Ha Giang) on the study of development projects using agriculture and forestry as raw materials and the construction of biomass power plants. Figure 3.53 shows the documents used at that time. For constructing new biomass power plants in PDP8, 14 new biomass power plants in 12 provinces with a total capacity of 1.2 MW are planned, and a shift of existing CFPPs to biomass cofiring and single combustion by 2030, with a total capacity of 100 MW. The drawing on the left shows potential sites for new biomass power plants.

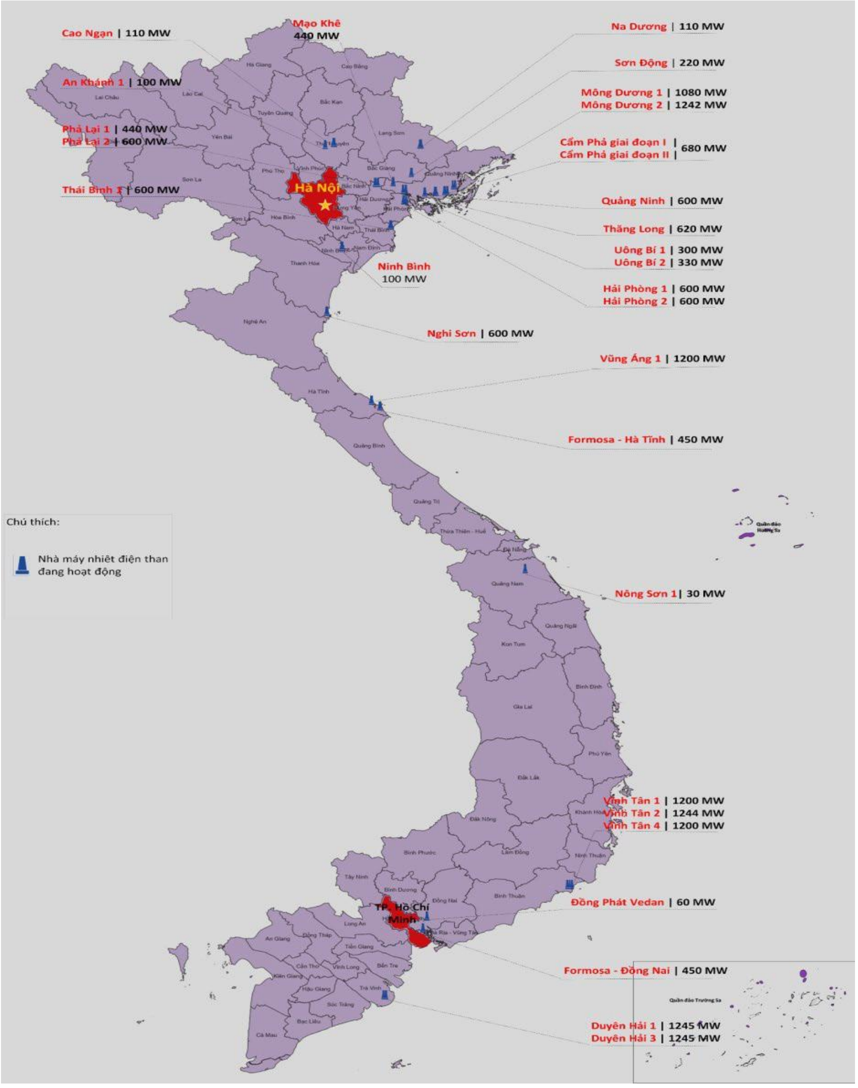
Figure 3.53. Candidate Sites for Newly Constructed Biomass Power Plants

		Project Name	Capacity
North	1	Yen Bai	75 MW
	2	Tuyen Quang	100 MW
	3	Hoa Binh	100 MW
	4	Phu Tho	50 MW
	5	Bac Kan	50 MW
Central	6	Thanh Hoa 2	60 MW
	7	Thanh Hoa 1	50 MW
	8	Quang Binh	109 MW
	9	Dak Lak	125 MW
South	10	Can Tho	100 MW
	11	An Giang 1	75 MW
	12	An Giang 2	100 MW
	13	Long An	75 MW
	14	Binh Phuoc	50 MW
		14 Projects in 12 Provinces	**1,119 MW**

Source: Erex (2022a).

The location of CFPPs and the specifications of each CFPP as of January 2022 are shown in Figure 3.54. Circulating fluidised bed-type boilers are suitable for biomass cofiring, with a total installed capacity of 4,600 MW or 22% of the total installed capacity as of January 2022.

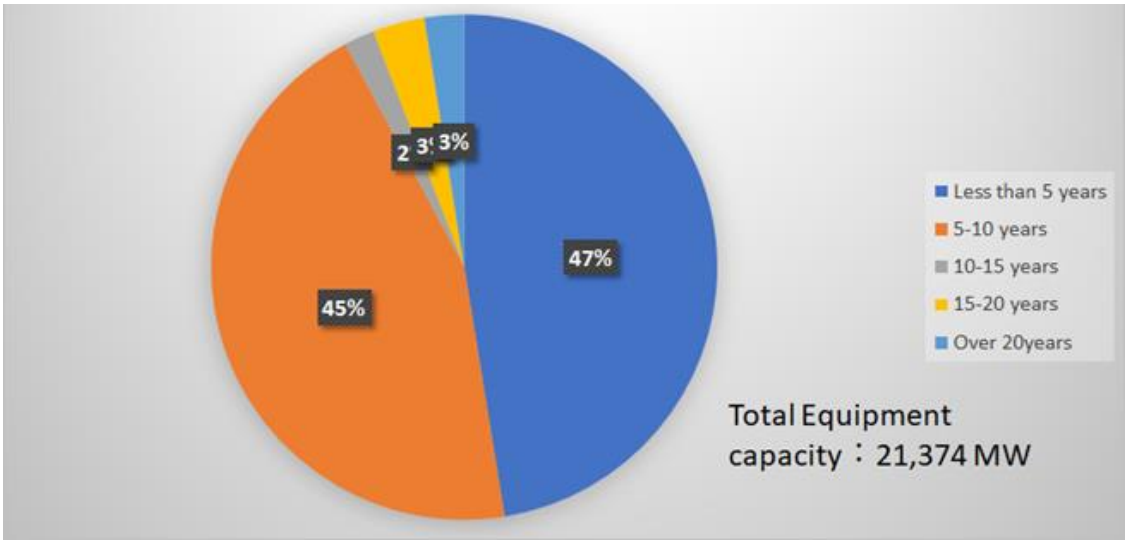
Figure 3.54. Current Status of Coal-fired Power in Viet Nam (as of January 2022)



Source: Erex (2022b).

A pie chart from the previous list of CFPPs by the number of years in operation is shown in Figure 3.55. Those operating for less than 5 years account for 47%. Those operating for 5–10 years account for 45%; those in operation for less than 10 years account for 92%.

Figure 3.55. Coal-fired Power Plants by Years Since the Start of Operation



Source: Edited by JCOAL Study Team based on data from erex (2022a).

2) Ammonia Cofiring with Coal

Ammonia supply is a challenge. However, Federal International has entered into an MoU with the Green Solutions Group to install a 200 MW electrolysis plant in Tra Vinh province, Viet Nam, which will produce 150,000–180,000 tonnes of ammonia and 30,000 tonnes of green hydrogen per year and is expected to be operational in 2024. The plant aims to reduce CO_2 emissions by cofiring ammonia and coal.

3) Solar Power Generation

Viet Nam's solar power generation has seen a significant increase in installed capacity since 2018, when the FiT policy was introduced, until the end of 2020, when the FiT price expires.

As of January 2021, approximately 19.4 MW of solar power generation had been installed. In a PDP8 review, MOIT and EVN have expressed continued support for commercial and industrial (C&I) rooftop solar power generation systems, despite the suspension of policy for utility-scale solar power generation projects. Developers provide electricity to customers at lower tariffs than the EVN, and these tariffs are guaranteed for up to 20 years.

Table 3.15 shows some C&I rooftop solar developers in Viet Nam.

Several well-known investors have entered this market. French utility EDF Renewables and its local partner, VinaCapital, have committed to invest US$100 million in a pipeline of 200 MW peak (MWp) C&I rooftop solar power generation systems over the next 3 years. Korean conglomerate SK Group and its local partner Nami Energy have committed US$200 million over the next few years, with an installation target of 250 MWp.

Table 3.15. Viet Nam's C&I Rooftop Solar Developers

Local Investor	Foreign Investor	Name of Company/ Joint Venture (if any)	Target C&I Rooftop Solar Capacity
Vina Capital	EDF Renewables	SkyX Solar	200 MWp by 2023-2024
REE	-	REE Solar Energy	500 MWp by 2025. Operating capacity 93 MWp (2021)
TTC Group	-	TTC Energy	EnergyUndisclosed. Operating capacity 50 MWp (2022).
Bamboo Capital Group	SP Group	BCG Energy	500 MWp by 2025.
Nami Energy	SK Group	-	250 MWp, no timeline specified.
-	Shire Oak International	Shire Oak International	250 MW in development. Operating capacity 52 MW (2021).
-	TotalEnergies	TotalEnergies	30-50 MWp per year.
-	Sojitz, Osaka Gas, LooopSOL	SOL Energy	10 MWp, no timeline specified.
-	GreenYellow	GreenYellow	Undisclosed. Operating capacity 70 MWp (2022)
	Norsk Solar	Norsk Solar	Undisclosed. Operating capacity 11 MWp (2021).
Copper Mountain Energy	Oman Investment Authority	CME	1000 MWp by 2024.

Source: Thu (2022).

4) Wind Power Generation

A recent study by the World Bank concluded that Viet Nam could increase its offshore wind power capacity by 11 GW to 25 GW by 2035. This is only if the government successfully develops and implements policies to grow this industry.

According to a World Bank study, 25 GW of wind power capacity by 2035 could meet 12% of Viet Nam's electricity demand and, in the process, stimulate the growth of a robust local supply chain, create thousands of skilled jobs, and potentially offshore wind-related exports to other global markets. So, it could add at least US$50 billion to the country's economy.

Currently, 18 offshore wind power projects operate in Viet Nam, all located offshore in relatively shallow waters.

Viet Nam has significant offshore wind power (OWP) potential, with an estimated technical potential of 475 GW within 200 km of the coast. This is the largest potential in Southeast Asia and corresponds to about six times Viet Nam's total installed capacity as of 2021. The windiest OWP areas, with average wind speeds exceeding 8 m/s, are located off the south-central coast near major demand centres, such as Ho Chi Minh.

This situation is shown in Figure 3.56. Large offshore wind resources also exist in the north.

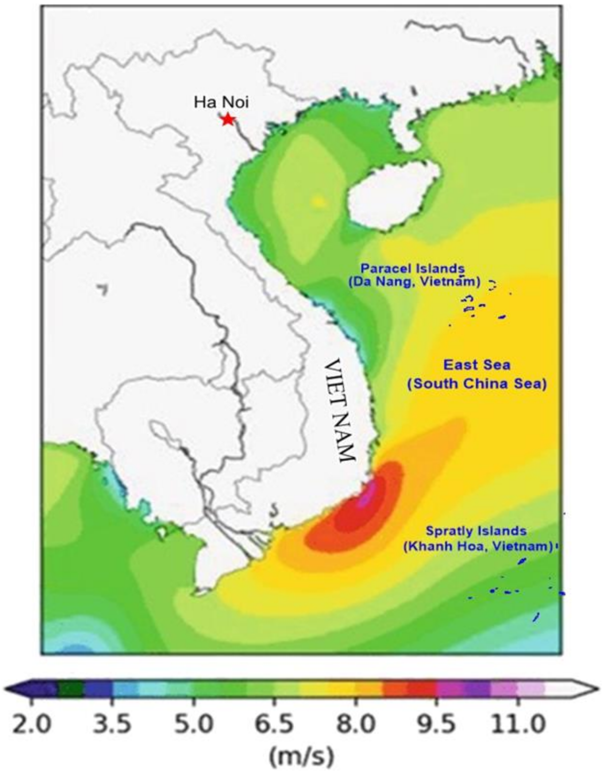
The rapid decline in technology costs has made offshore wind power an increasingly promising energy source.

OWP projects in Viet Nam first became eligible for FITs in 2011, and rates were revised in 2018. At the start of 2021, Viet Nam had one existing OWP plant of 99 MW in Bac Lieu province. In 2021, 20 new plants with a total capacity of 779 MW OWP projects will operate commercially, making Viet Nam the third-largest market for OWP capacity deployment after China and the

United Kingdom. Around 50 projects are in the preparation and construction phases, including the large Lagan (3.5 GW) and Thang Long (3.4 GW) projects.

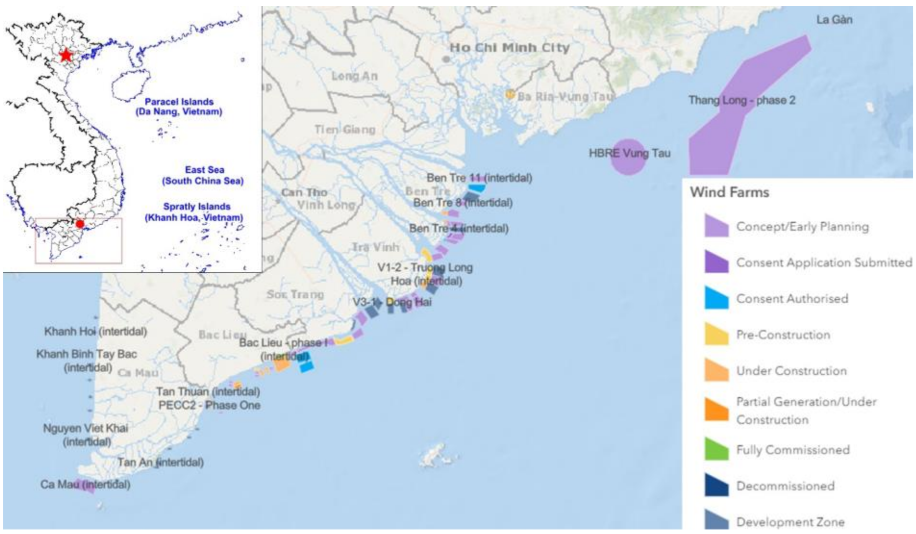
Figure 3.57 shows the status of these projects.

Figure 3.56. Offshore Wind Power Potential in Viet Nam and Nearby Areas



Source: Thang et al. (2022).

Figure 3.57. Viet Nam's OWP Projects, Southern Zone



Source: Thang et al. (2022).

Several challenges need to be overcome to ensure the success of large-scale offshore wind power projects.

One well-known challenge is the form of the PPA. The new public–private partnership (PPP) Law and the new Investment Law on Independent Power Producers (IPPs) removed the automatic qualification of government guarantees. The next challenge is transitioning to a tariff-bidding system. Now that FiT has ended, the Prime Minister stated that tariffs would be changed to an auction system, with competitive bidding for each wind power project to determine tariffs. However, critics predict that introducing a competitive tendering system could slow down the country's solar and wind power projects.

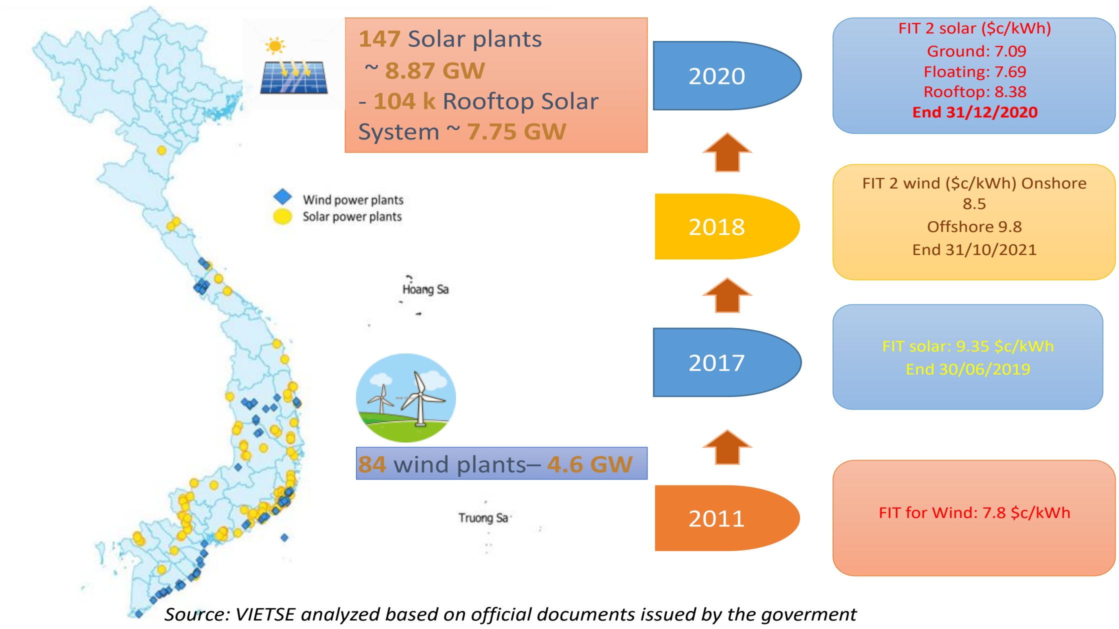
Grid network issues are also a major challenge. Most offshore wind power is located in southern Viet Nam, far from the main demand areas in the northern region, including Ha Noi where electricity demand is tight.

5) Position of solar power and wind power generation, FITs, the unit cost of electricity-generated power

The location of solar power generation and hydropower plants and FiT prices in Viet Nam are shown in Figure 3.58. The installed capacity of solar power generation is 8.87 GW for regular panels, 7.75 GW for roof-mounted types, and 4.6 GW for wind power.

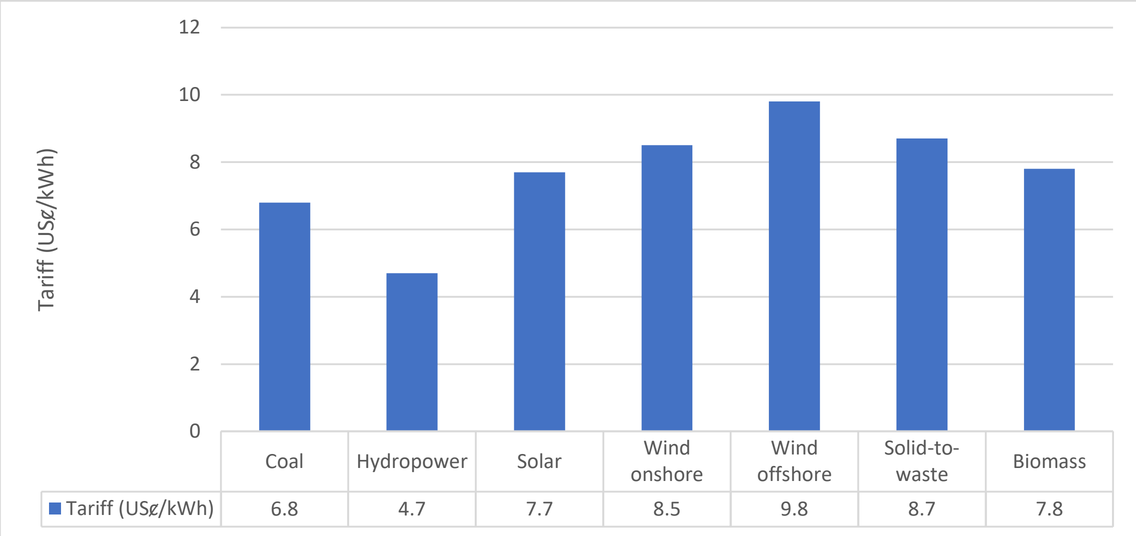
Figure 3.59 shows the unit cost of electricity by type of generation. From left to right: coal-fired, hydropower, solar, onshore wind, offshore wind, waste, and biomass power generation. Coal-fired and hydroelectric power is sold at the price of electricity sold, while the rest is at the FiT price. The setting of the FiT price is an issue for the future.

Figure 3.58. Location of Solar Power Generation and Hydropower Plants and FiT Prices in Viet Nam



Source: Ngo To Nhien (2022).

Figure 3.59. The Unit Cost of Electricity by Type of Generation in Viet Nam



Source: Edited by JCOAL Study Team based on data from ADB (2021).

4.5. Policy Recommendations

In its keynote speech, Viet Nam, who chaired the 38th ASEAN Energy Ministers' Meeting (AMEM), stated that the country aims to achieve 50% RE by 2030/2050.[5] The draft PDP8 was mainly concerned with introducing RE, and the results were presented in October 2021 and April 2022. It is currently awaiting approval by the Prime Minister.

1) Summary of the Related Policies in Technological aspects

Technology area 1: Biomass-coal cofiring power generation

According to the EVN report, coal-fired power generation in Viet Nam in 2020 accounted for about half of the total power generation and about 30% of the capacity. Most CFPPs in Viet Nam have been operating for less than 10 years. So, using these facilities effectively to reduce CO_2 emissions would be more effective, and the feasibility of coal and biomass cofiring is high.

Technology area 2: Dedicated biomass-fired power generation

In Viet Nam, rice husks, rice straws, and sugarcane pomace from the vicinity of power stations can be compressed and transported to power stations and used directly as fuel, thus, eliminating the need to process them into solid fuel wood pellets. In addition, biomass called sorghum can be grown quickly and has a high potential for dedicated biomass firing.

[5] ASEAN Energy Business Form (AEBF) (virtual) 2020 held in November 2020.

Technical area 3: Ammonia cofiring with coal

Ammonia cofiring is a key measure to directly mitigate CO_2 emission from CFPPs in Viet Nam. In this regard, MOIT and the EVN are pursuing technical information and experience from the countries in its demonstration stage.

Technology area 4: PV power generation

There is no room for new PV projects under the draft PDP8, as the power source is unstable and affects grid stability. But the policy of no upper limit on the scale of development and capacity for rooftop PVs, provided they are not connected to the grid and are for private consumption, will enable development to proceed.

Technology area 5: Wind power

Viet Nam has areas with a high potential for offshore wind power, particularly in the south, and future development is expected.

Technology area 6: Carbon capture and storage

It will be necessary to introduce technology to capture and store CO_2 from coal-fired power flue gas to use coal-fired power effectively.

2) Technology areas with High Potential

Table 3.16 shows the technology areas for CN in Viet Nam. Technology areas with high potential regarding policy direction and applicability are circled with red lines. Many technologies that can be proposed are CO_2 reduction technologies.

Solar and wind power, introduced worldwide as variable RE, are promising power generation technologies that can take advantage of Viet Nam's geographical characteristics and should be actively introduced. Of course, it is necessary to introduce power storage technology, such as BESS, that can compensate for these fluctuations and load adjustment by other power sources, such as gas and coal-fired power. A development plan that considers the grid balance is necessary. In addition, we believe that the rooftop solar power described in the previous section is valuable as an off-grid power source and a power source that constitutes a virtual power plant in the future.

Since many CFPPs and the current power generation greatly depend on coal-fired power, biomass co-combustion, biomass dedicated firing, and ammonia cofiring, which can be used in existing infrastructure, are the main measures to reduce CO_2 in thermal power generation. In particular, Viet Nam is a promising country regarding fuel supply potential, so actively promoting domestic use is highly desirable.

Table 3.16. Carbon-neutral Technology with High Applicability in Viet Nam

Road Map towards Carbon Neutrality						Viet Nam
Reduction	Thermal Power	High Efficiency	IGCC			Optional
			IGFC			Optional
			A-USC			Optional
Reduction	Fuel	Biomass	Combustion	CFBC biomass firing		Keenly pursued
				PC coal cofiring		highly applicable
			Manufacturing	Material	Agricultural waste pellet	Keenly pursued
					Fast-growing tree	Keenly pursued
				Pre-treatment	Torrefied pellet	highly applicable
					Washing	Optional
		Ammonia	Utilisation	Ammonia gas turbine		Applicable
				Ammonia industrial furnace		Not applicable
				Ammonia-coal cofiring		highly applicable
			Manufacturing	Ammonia process	Conventional process + CCS	Optional
					New&Innnovative process	Optional
				R&D base, Supply chain		Applicable
		Hydrogen	Utilisation	Hydrogen gas turbine		Optional
			Manufacturing	Hydrogen process	Water electrolysis by RE	Applicable
					Turquoise hydrogen	Optional
				R&D base, Supply chain		Optional
	Renewables	Wind, Solar, Geothermal	Offshore wind			highly applicable
			Perovskite PV			Keenly pursued
			Next generation geothermal			Optional
		BESS	large Li-ion, NaS, Redoxflow			Applicable
Reduction	Manufacturing process	Steel	Coke reduction	Energy saving, LRC	Ferrocoke	Optional
				Direct reduction		Optional
				Hydrogen reduction		Optional
				COURSE50	Super-COURSE50	Optional
				Carbon recycling BF		Optional
		Cement				Optional
Capture	Capture/ Recovery	Capture/ Recovery	Recovery/generation	Oxyfuel IGCC		Optional
				Supercritical CO2 cycle generation		Optional
				Chemical looping combustion		Optional
			Chemical absorption			Optional
			Solid absorbent material method			Optional
			Physical absorption			Optional
			Membrane separation			Optional
			Physical adsorption			Optional

Source: JCOAL Study Team.

Similarly, cofiring with ammonia, which can be used by modifying existing power plants, has already begun in Japan at a 1,000 MW class USC plant. Therefore, we can expect to proceed with discussions with companies that have the technology.

Since CO_2 reduction alone cannot achieve CN, the negative emission CCS is also a technology that should be introduced. CO_2 recovery technology from thermal power generation exhaust gas is essential to introduce CCS or CCUS. We believe that early support from the government for its introduction is necessary.

3) Institutional Support

Financial support is needed to effectively utilise many CFPPs in Viet Nam, as the cost of capturing the flue gas from CFPPs is a bottleneck.

For solar and wind power generation, setting the FiT price at an appropriate level is necessary. But in the future, making the electricity market competitive and developing the electricity system for this purpose are necessary.