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Southeast Asia's Clean Energy Transition:
A Role for Nuclear Power?

EDITED BY
DAVID SANTORO & CARL BAKER

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Executive Summary

David Santoro & Carl Baker

Like the rest of the world, the energy landscape in Southeast Asia is undergoing dramatic and rapid change. This change is driven by two dynamics: climate change and changing perceptions regarding energy security.

Many countries are moving to a lower-carbon energy mix to fight climate change. Leading up to the 2021 United Nations Climate Change Conference, for instance, 64 countries pledged or legislated a commitment to achieving net-zero emissions in the coming decades.[1] While much of the initial focus has been on renewable energy, there is a growing recognition that countries need options that also provide a new source of baseload energy as they begin replacing large fossil fuel power plants. The transition to a cleaner energy system is expected to continue in the foreseeable future with most countries in Southeast Asia anticipating being able to reach their clean energy goals by mid-century at the earliest.

Energy security concerns driven by inflationary pressures in the post COVID-19 commodity markets and supply dislocations created by the military conflict in Ukraine have also forced many countries to reconsider their energy options. Significantly, many countries are convinced that these problems will remain even if the Ukraine conflict ended rapidly because US-China rivalry is entrenched and even intensifying, and such rivalry will likely keep the geopolitical environment (and the global economy) dangerously volatile.

The need to reduce carbon emissions and strengthen energy security is thus reshaping the global energy landscape fundamentally. This "reshaping" is taking many forms. According to McKinsey & Company's report on *Global Energy Perspective 2022*, electrification and renewables show accelerated growth: the global energy mix is shifting fast toward power, synfuels, and hydrogen, representing 32% by 2035 and 50% by 2050.[2] Meanwhile, demand for fossil fuels is projected to peak between 2023-2025, making up 43% of the global energy mix by 2050.

In that new emerging mix, nuclear power has a role to play as well, albeit a minor one. The projections of the International Energy Agency's report on *World Energy Outlook 2022* show that the share of nuclear is set to remain broadly where it is today – around 10% – regardless of what happens.[3] Still, per the Agency's report on *Nuclear Power and Secure Energy Transitions*, "Nuclear energy could play an important role in ensuring that the energy sector's journey to net zero emissions is rapid and secure."[4] The report adds that "the policy landscape has shifted in ways that favour nuclear energy."[5] Because small modular reactors (SMRs) are cheaper, small, mobile, flexible, have user-centric characteristics, and are empowered by advanced (and safer) Generation IV technologies, the report also notes that these reactors may "play a meaningful part in energy transitions."[6]

These developments are global but especially salient in Southeast Asia, where economic growth is strong, demand for a clean-energy transition high, and concern about energy security is soaring in an increasingly tense strategic environment.

About the Volume

To bring clarity on these developments and their implications in Southeast Asia, the Pacific Forum commissioned several Southeast Asian scholars to write analytical papers on the energy transition that is underway in the region, which are compiled in this volume.

Each chapter looks at the current and possible future energy landscape of a specific Southeast Asian country and focuses especially on the place and role of nuclear power in it. This "nuclear focus" is important because, for decades, most Southeast Asian countries have expressed on-and-off interest in nuclear power but never brought it online. Interest is now picking up again, especially for SMRs, so if this time one or several Southeast Asian countries successfully went nuclear, it would be a first.[7] It is good timing, therefore, to devote attention to how Southeast Asian countries are thinking about nuclear power in today's context, for multiple reasons, including those related to safety, security, and safeguards.

[1] For more information, visit https://www.un.org/en/climatechange/cop26
[2] *Global Energy Perspective 2022* (New York: McKinsey & Company, April 2022), p. 32.
[3] World Energy Outlook 2022 (Paris: International Energy Agency, November 2022), p. 47.
[4] *Nuclear Power and Secure Energy Transitions – From Today's Challenges to Tomorrow's Clean Energy Systems* (Paris: International Energy Agency, September 2022), p. 13.
[5] Ibid., p. 13.
[6] Ibid., p. 11.
[7] For background information on nuclear energy related to ASEAN, visit https://aseanenergy.org/work/asean-nuclear-portal/

The volume has seven chapters. It opens with a chapter on Indonesia. Written by Elrika Hamdi, the chapter explains that Indonesia's current power generation mix is still dominated by fossil fuels and that despite its potential with renewables, the country has taken its time to invest in these technologies. Yet due to cost and pressure to decarbonize, Jakarta recently committed to reaching net zero by 2060. Implementation has yet to begin, but preliminary work reserves a role for nuclear power. There is resistance to it, yet also enthusiasm, notably for SMR technologies. Significantly, a small US venture, Thorcon International, plans to deploy an SMR in Indonesia.

The chapter on Malaysia, penned by Sabar Md Hashim, shows that Kuala Lumpur is still heavily dependent on fossil fuels but is working hard to balance a perceived need for energy security, energy affordability, and energy sustainability. Nuclear power has long been a secondary consideration for Malaysia and previous efforts to bring it to the fore have failed, including as recently as in the late 2010s. There are proponents of nuclear power in Malaysia, however, and addressing the complex "energy trilemma" of security, affordability, and sustainability may help Kuala Lumpur overcome its reluctance to invest in nuclear power and consider SMR options.

In her chapter, Shwe Yee Oo shows that Myanmar, too, has relied primarily on fossil fuels to power its development and that it is unlikely to change under the military regime that took power in 2021. Since then, there has been uncertainty about Myanmar's energy diversification plans. Meanwhile, although nuclear power could become an option as part of its energy mix, Myanmar does not appear to have a plan to invest in it in the near term, especially given the international concerns that emerged in the late 2000s, when Naypyitaw was suspected of harboring nuclear-weapon ambitions and maintained a relationship with North Korea. Still, Naypyitaw seems to have a relationship with Moscow in this domain.

Julius Cesar Trajano's chapter on the Philippines explains that Manila has been overdependent on coal and imported fossil fuels. He stresses that Manila has also long been interested in nuclear power, and that interest is rising due to rising energy costs as well as concerns about energy security and sustainability. That's why the new president, Ferdinand "Bongbong" Marcos Jr., declared that his administration would revive the nuclear power plant that was built decades ago and build at least one new plant using SMR technology. Doing so will not be easy, however, as Manila will need to overcome numerous challenges, ranging from drafting regulations and providing expert training to engaging in public education.

Denise Cheong and Victor Nian's chapter on Singapore points out that the small island state imports much for its basic needs, including in the energy sector. Singapore's energy policy is driven primarily by energy security and affordability, yet also by energy sustainability. Given its limited potential to deploy renewables, Singapore is exploring low-carbon alternatives, including nuclear power, to reduce its reliance on fossil fuels. Nuclear power (notably SMRs) could thus play a role in Singapore's future energy landscape, though concerns about safety and waste management abound.

The chapter on Thailand, authored by Doonyapong Wongsawaeng, shows that Bangkok has similar preoccupations in terms of energy affordability, energy security, and energy sustainability. Thailand, too, relies primarily on fossil fuels but is trying to diversify its energy sources. It has had an interest in nuclear energy but efforts to bring it to fruition never paid off, most recently in the final years of the 2010s. Going forward, however, SMRs could potentially break the wall of resistance to nuclear power development in Thailand.

Written by Nguyen Nhi Dien, the chapter on Vietnam shows that Hanoi's energy outlook is not vastly different from its Southeast Asian counterparts, though it appears more advanced in the development of renewables. Once committed to developing nuclear energy (and on track to becoming the first Southeast Asian country to deploy nuclear power plants), Vietnam however decided to postpone its projects in 2016. Those projects could be revived, however, especially given growing demands for energy and concerns about energy security and sustainability. Significantly, some in Vietnam consider SMRs to be potentially viable options.

The general trend in all the assessments is thus a growing recognition in Southeast Asia that continued reliance on fossil fuels cannot continue. Governments in the region have shown serious commitment to reducing their carbon footprint and seeking ways to find alternative sources for electricity generation. While there is still a great deal of skepticism

regarding the introduction of nuclear power, there does seem to be growing interest in the possibility that SMRs, and especially floating nuclear power plants, could offer an alternative for replacing fossil fuel power plants for the purpose of providing stable baseload electricity demands. Still, there is also a recognition among energy planners that nuclear power comes with many new requirements to ensure that these facilities are managed in a safe and secure manner. The attraction of the smaller scale of SMRs has certainly changed the discourse regarding the feasibility of introducing nuclear power in Southeast Asia. Looking ahead, the big question is whether SMR manufacturers can deliver products that address the region's energy priorities.

Of note, the volume does not include chapters on Brunei Darussalam, Cambodia, and Laos because none of these three countries is on track to develop nuclear power, although Phnom Penh and Vientiane have both taken (tiny baby) steps in that direction.[8]

[8] For Cambodia, see Michael Firn, "Government signs nuclear power agreement with China and Russia," *Khmer Times*, July 27, 2021. For Laos, see "Russia and Laos plan nuclear cooperation," *World Nuclear News*, April 15, 2016.

1

Indonesia Power Sector

Elrika Hamdi

Indonesia's Energy Market Profile – A Brief Background

Indonesia has long been known as a country endowed with natural resources, both fossil fuel and renewables. Prior to the 1990s Indonesia was one of the world's largest oil exporters, though since 2004 it has become a net importer of oil due to declining production and domestic demand exceeding production. On its natural gas reserve, the country is fairly self-sufficient for its own domestic use, except for LPG where it still imports 75% of its consumption.

Indonesia is also endowed with a coal reserve. As the second largest coal exporter (or the largest thermal coal exporter) globally, this island nation is highly dependent on income from coal exports. Together with other mining industry, coal and other minerals (iron, nickel, etc.) contributed 22.7% of Indonesia's export value in June 2022[1]. The surging global coal and crude palm oil (CPO) prices, two of Indonesia's main export commodities, have contributed to the country's positive trade balance and helped the government manage the looming inflation risk felt by other countries globally.

However, the combination of being a net exporter of coal and net importer of oil & LPG actually creates a zero-sum game for the Indonesian macro-economic condition due to the government's decision to heavily subsidize oil & LPG. The government also subsidizes electricity for select customers, and from 2017 until now, still provides compensation payment to the State Utility Company (PLN) for implementing a tariff freeze. In short, many Indonesians are still shielded from global market energy prices and have long enjoyed an artificially low energy price.

Current generation mix and demand profile

Indonesia's current power generation mix is still dominated by coal and gas. Around 85.4% or 62.9 gigawatts (GW) of Indonesia's installed capacities are fossil fuel engines, with coal-fired power plants dominating the mix at 50.2%, gas 28.4%, and diesel 6.8%. Despite the large renewables' potential, development of power plants using renewables has been slow, and has contributed less than 15% as of early 2022.[2]

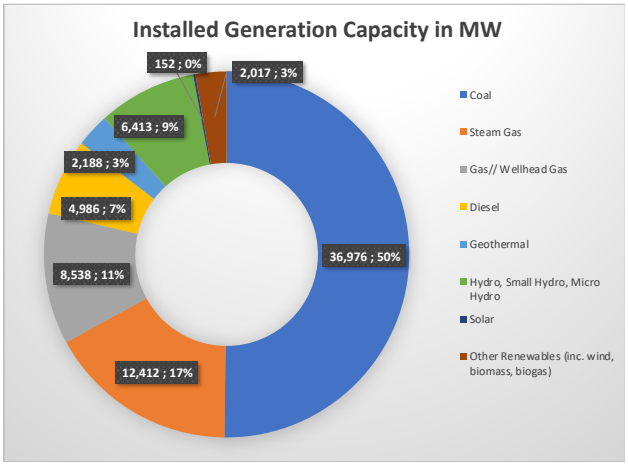


Figure 1 Indonesia's Power Mix in early 2022 (including captive power and private power utility) [3] *Source: Ministry of Energy and Mineral Resources Directorate General of Electricity Press Release. January 2022*

More than 60% of Indonesia's total installed capacity of 73.7 GW is located in the demand center of Java Island. Yet, coal remains the dominant form of generation in all of the regional systems, followed by gas power plants.

The growth of coal-fired power plants had been prominent over the last 15 years mostly as a result of government special programs to accelerate power generation capacities through the Fast Track 1 and 2 Program during President Susilo Bambang Yudhoyono's administration and the 35GW Program initiated by President Joko Widodo. Renewables remained at a disadvantage to thermal plants due to policy interventions such as capped coal and gas prices (Domestic Price Obligation and Domestic Market Obligation), which do not reflect the global market prices. This policy was taken with the intention to lower the state utility's (Perusahaan Listrik Negara – PLN) production cost, but in the end created an artificially low price for fossil fuel generation which translated to renewables being noncompetitive with coal and gas-powered plants. The fact that the ecosystem of domestic renewable industry is still pretty nascent and underdeveloped has also hindered growth in the sector.

[1] Badan Pusat Statistik. Berita Resmi Statistik. July 15, 2022.
[2] MEMR Dirjen Ketenagalistrikan. Ministry of Energy and Mineral Resources Directorate General of Electricity Press Release. January 2022
[3] The power mix includes power plants not connected to PLN grids, these are usually power plants in certain industrial area or special economic zones, or power plants that are for owned-used. PLN-connected installed capacities are around 64.3 GW or 87.3% of total power mix.

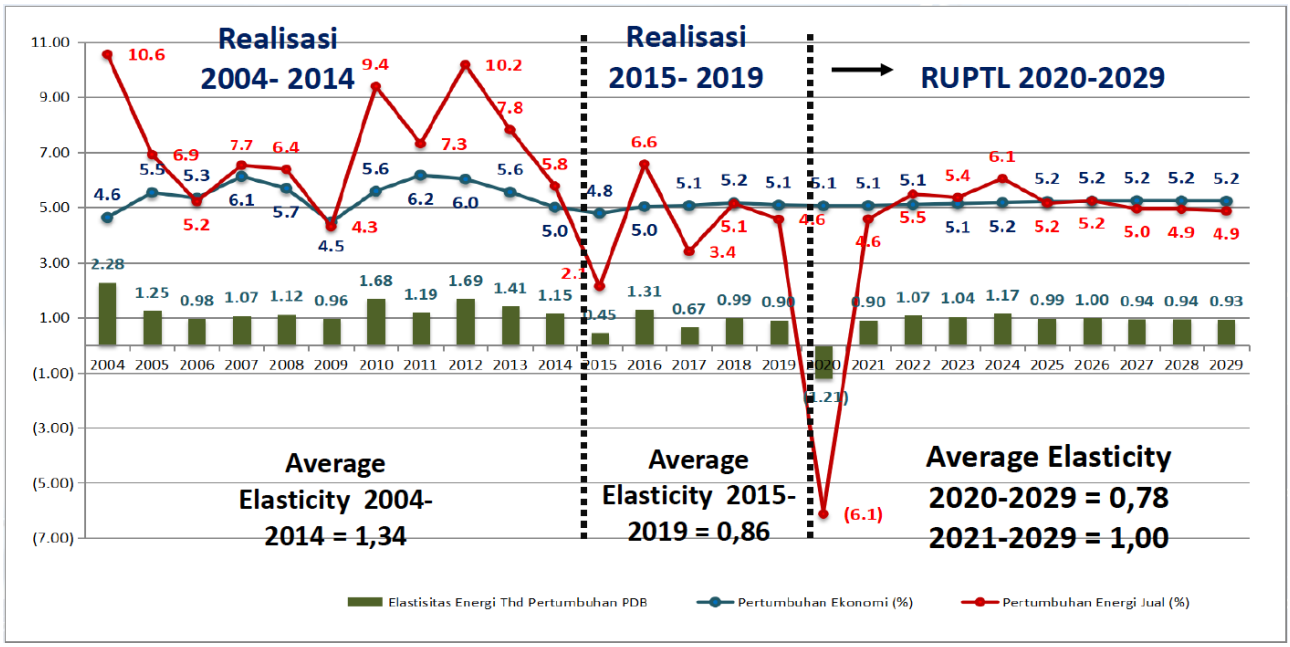


Figure 2 PLN's Demand Profile
Source: PLN Presentation

Meanwhile Indonesia's power demand profile is still growing at a healthy rate, though much lower than the government's expectation. The constant misalignment of system planning and policy with the reality of the demand profile has led to an overinvestment in generation capacity over the last few years. This has trapped PLN in a financial straitjacket that leaves few easy options for the utility company.[3]

Current grid capacity – PLN data

Indonesia's grid development had previously been concentrated on two of its biggest and most populous islands, Java-Bali and Sumatera. As of mid-2020, Indonesia's electricity systems were mainly managed by PLN and spread among 22 isolated main systems. The largest systems, the Java-Bali system is currently the only network that has a 500 kV backbone with net capacity of 32 GW; Sumatera has 150 kV and 275 kV interconnections with net capacity of 7 GW (a 500 kV super high voltage transmission for Sumatera interconnection is currently on plan).

In total, Indonesia's transmission network spanned 61,234 kms and distribution lines covered 1,006,265 kms as at December 2020. PLN reported relatively healthy transmission losses of around 2.1% but much higher distribution losses of 5.61%, bringing the total T&D losses to 7-8%.[4]

Transmissions (kms)	end of 2020	Distribution (kms)	end of 20202
500 kV	5,250	Medium Voltage	414,800
275 kV	3,648	Low Voltage	591,465
150 kV	46,680		
70 kV	5,656		
Total transmission lines (kms)	**61,234**	**Total distribution lines (kms)**	**1,006,265**

Table 1 PLN Transmissions & Distributions Lines (end of 2020)
Source: PLN RUPTL 2021-2030

[3] For further analysis please see IEEFA. Indonesia wants to go greener but PLN Is stuck with excess capacity from coal-fired power plants. November 2021.

[4] PLN RUPTL 2021-2030, p. IV-26

PLN's Main Electricity System	Net Max. Generation Capacity (MW)	Peak Load (MW)
Nias	73.6	30.4
Sumatera	7,029	5,467
Batam-Bintan	519	354
Bangka	173	138
Belitung	61.4	38.8
Jawa-Bali	32,170	24,132
Khatulistiwa	457	316
Kalimantan Interconnection	1,635	1,129
Sumbawa-Bima	140	101
Lombok	315	231
West Flores	37.4	30.8
Isolated NTT	114	73.9
Kupang	119	86.2
North Sulawesi/Gorontalo	463	368
Southern Sulawesi	1,810	1,206
Bau-Bau	53.5	32.0
Ternate-Tidore	41.0	34.9
Isolated Maluku	118	69.7
Ambon	99.3	46.2
Manokwari	45.9	24.3
Sorong + Isolated Papua	276	147
Jayapura	132	73

Generation capacities of each system are summarized in the table above.

Demand Forecast and The New Net Zero Goal by 2060

Over the years, PLN and the Ministry of Energy and Mineral Resources (MEMR) have finally learned from their mistake of overestimating demand and overinvestment in generation capacities, which had worsened PLN's financial condition. In the new Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik or RUPTL) 2021-2030, the utility company finally revised significantly its demand forecast, taking into account more granular considerations in creating scenarios including the projection of economic recovery after the pandemic, changes in technology adoption, awareness on energy efficiency and conservation efforts, and the global push for decarbonization of the power sector. The new demand forecast is now lowered to an average of 4.91% in 2021-2030 compared to 6.42% in the previous RUPTL.

Meanwhile the long-term power demand forecast stated in several long-term planning documents is estimated to reach 1,885 TWh by 2060.

Figure 4 Long-term power demand projection 2060
Source: MEMR. Inception Report: Peta Jalan NZE Sektor Energi. 22 January 2022

Depleting the source of finance for coal, as well as the global push to accelerate decarbonization of the energy sector due to increasing concern on climate

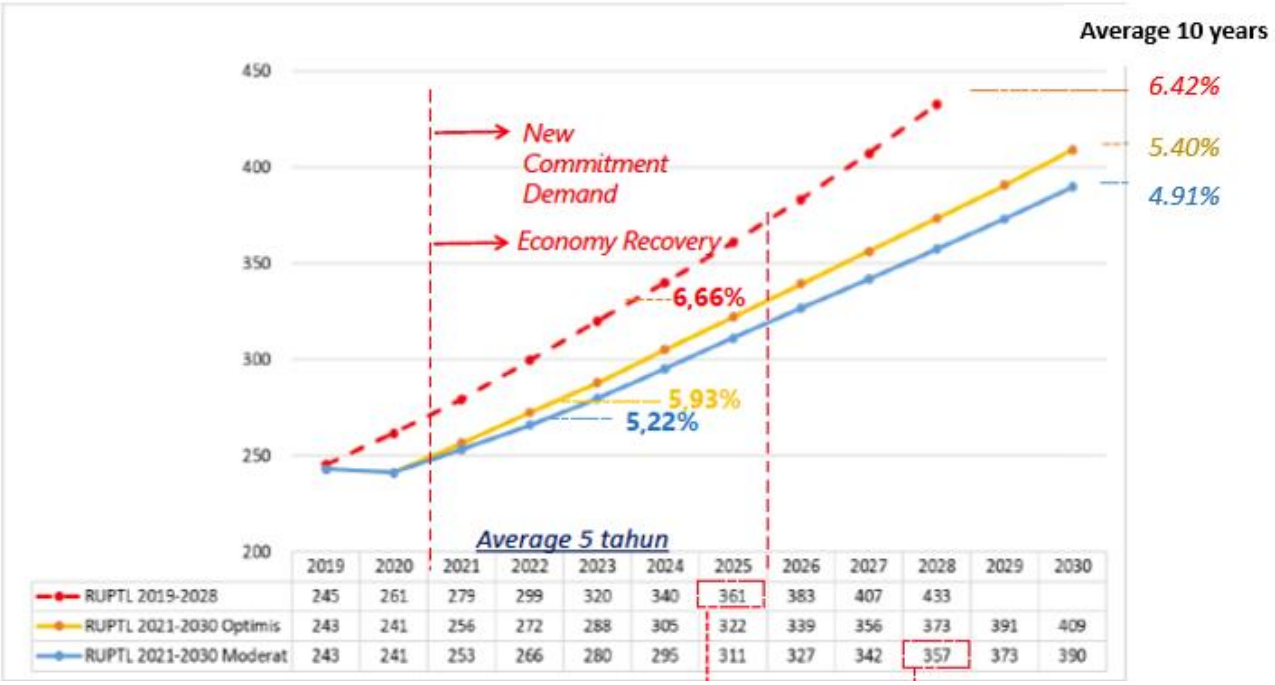


Figure 3 New Demand Projection 2021-2030 is Lowered to Reflect Growth Reality
Source: PLN RUPTL 2021-2030 Press Release. 5 October 2021.

crisis and extreme weather event, was genuinely felt by the Indonesian government. As of 2021, both the government and PLN announced a commitment to reach net zero by 2060. This commitment is not yet implanted in any formal Indonesian government document, though it has been expressed to the global community during COP, which is understandable since the country is still trying to determine the best possible way to achieve that goal, while currently being heavily dependent on fossil fuel.

Of the many scenarios often orchestrated by either the Ministry of Energy and Mineral Resources (MEMR) or by PLN themselves, they all entail a plan to stop building new coal plants (except for ones that are already under contract and/or constructions) from 2025 onward and focus on accelerating renewable energy development thereafter. But considering the overcapacity problem currently faced by PLN in two of its largest systems, the increased uptake of renewable will mostly be seen after 2030.

The NZE 2060 scenarios are still changing mildly, depending on who is presenting them, so the targeted numbers could differ slightly. The below chart shows an example of the grand design by the MEMR to reach the net zero goal by 2060. It is worth noting however that interestingly nuclear energy is often found in the ministerial planning documents but not so much mentioned in PLN's.

The MEMR in particular is planning to ramp up generation from solar energy, banking on Indonesia's strategic location near the equator. The ministry and PLN are also planning to maximize all other potential renewables, such as hydro and geothermal, which should be the best replacement for baseload coal power. In addition, the ministry is exploring new sources of energy which includes, nuclear, ocean current, and hydrogen to fulfill the forecasted demand until 2060.

Meanwhile, PLN 10-year plan for generation capacities has also been toned down compared to previous planning. The so-called 'Green RUPTL' now accounts for 52% of renewable additions, and 48% of fossil until 2030. For the next 5 years, the majority of power plants coming online will still be dominated by coal and gas-fired as these are plants that have either started construction or have signed strict Power Purchase Agreements (PPAs) with capacity payment contracts.

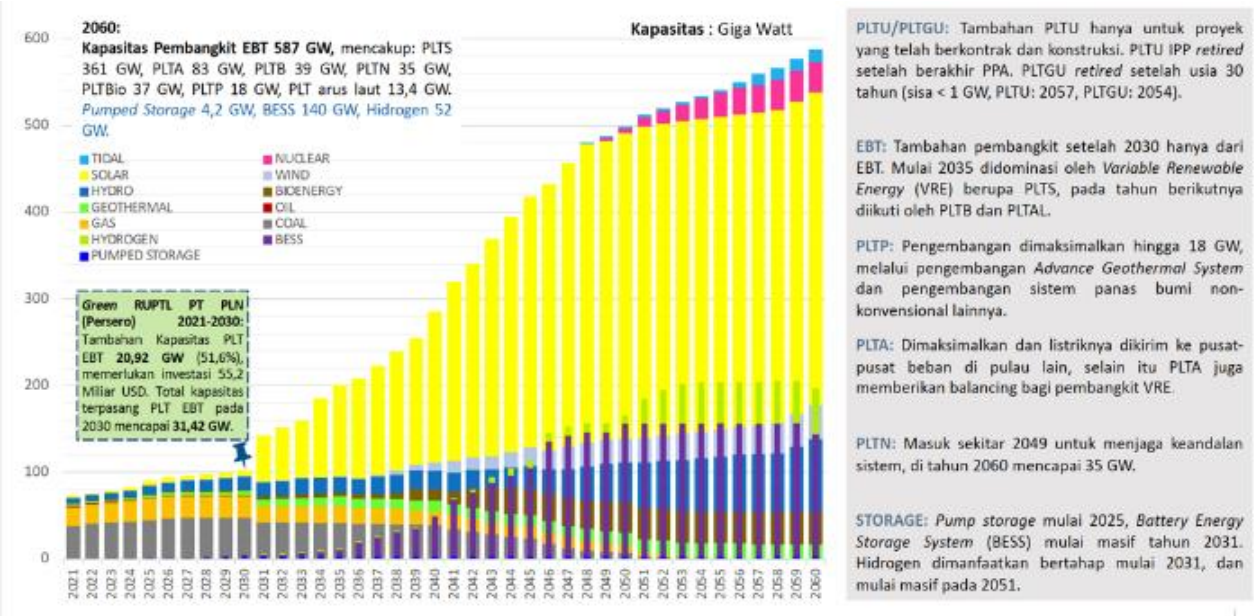


Figure 5 Indonesia's Power Sector Planning to Reach Net Zero Emission by 2060 – the MEMR version. Source: Dadan Kusdiana, Director General of New and Renewable Energy, MEMR. Business Indonesia Green Economy Outlook 2022. 23 Feb 2022

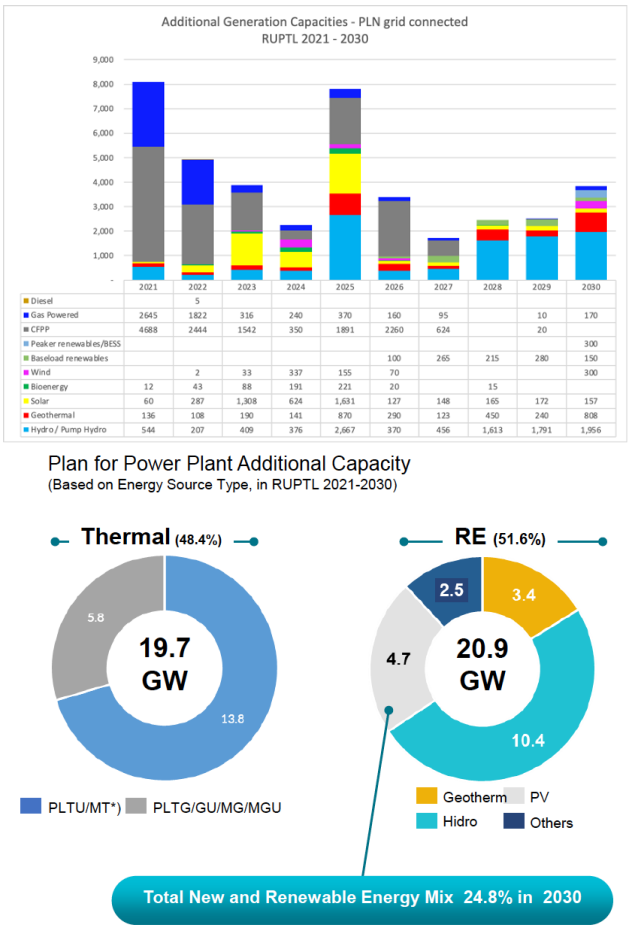


Figure 6 PLN Generation Capacity Planning 2021-2030
Source: PLN RUPTL 2021-2030

Investment outlook for Indonesia's power sector

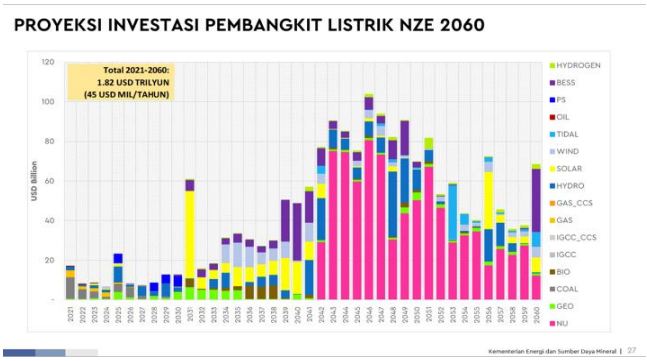


Figure 7 Investment Required to Reach Net Zero by 2060
Source: ESDM. Inception Report: Peta Jalan NZE Sektor Energy. 22 January 2022

To achieve the Net Zero by 2060 goal, the MEMR projects a need of USD 1.82 trillion from 2021 to 2060 or about USD 45 billion/year as set out in the chart below. It is interesting to see that after 2040, the largest investment needed is for nuclear power plants, although when comparing its value, nuclear is only forecasted to contribute 35 GW of 587 GW of installed capacities by 2060 (see Figure 5). This confirms the government's understanding that nuclear will not be a cheap $/kWh option for Indonesia.

Electrical energy policy framework

As stipulated by Indonesian Constitutional Law, the power sector is considered as strategic assets in Indonesia and therefore should be controlled by the government. The power sector is highly regulated with a vertically integrated state utility (Perusahaan Listrik Negara – PLN) monopolizing across the whole sector. The power market cannot and should not be unbundled according to the Law, but private players (Independent Power Producers – IPPs) are allowed to enter the generation side. In general, PLN is the only off-taker for any power producers, with the mandate to electrify all of Indonesia and holding the fully integrated business permit area across the Indonesian islands. Aside from PLN, there are currently only 53 other business permit holders, most of which are special industrial or special economic zones[5].

The Ministry of Energy and Mineral Resources (MEMR) is the ultimate policy maker for energy and power sector. Having said that, being a fully owned government enterprise, PLN also needs to answer to the Ministry of State-Owned Enterprises (MSOE). At the same time, considering that PLN is still highly dependent on subsidies and incentives from the government for its operational expenses, PLN must also answer to the Ministry of Finance (MoF). The three line-ministries are considered as key players in determining prominent policies in Indonesia's energy sector.

[5] MEMR Directorate General Electricity. Business Permit Holders (2019).

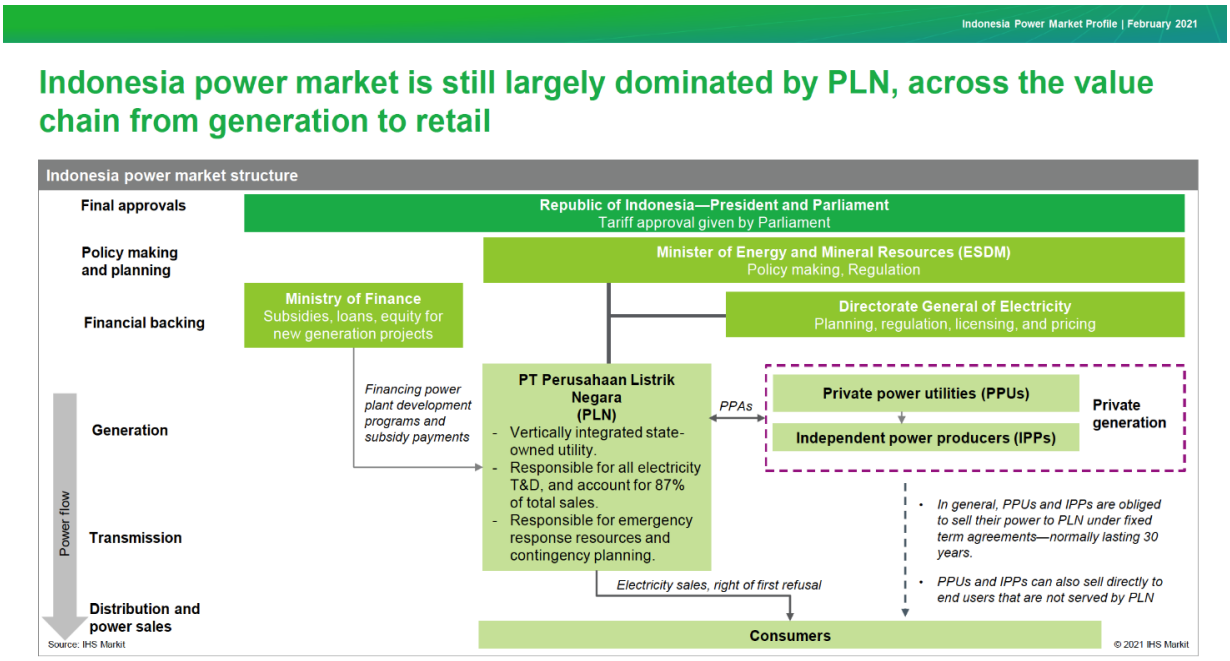


Figure 8 Indonesia's Power Market Structure
Source: IHS Markit. Indonesia Power Market Profile. February 2021

Energy policy

Energy policies in Indonesia are mainly regulated under two big regulatory umbrellas, the Energy Bill No. 30/2007 and the Electricity Bill No. 30/2009. Both laws provide a general overview and guidance on how the power and energy sector should be governed. The laws are then followed up by implementing regulations such as government regulations, presidential regulations, ministerial regulations and local government regulations. A simplified chart of the energy policy framework that exists and currently under discussion are presented below.

Energy improvement plans

As briefly explained above, the roadmap for Indonesia to improve its energy plans and reach the Net Zero by 2060 ambition is still very much a dynamic process, heavy with push and pull factors from different stakeholder interests. One of the most talked about roadmaps that has been publicly

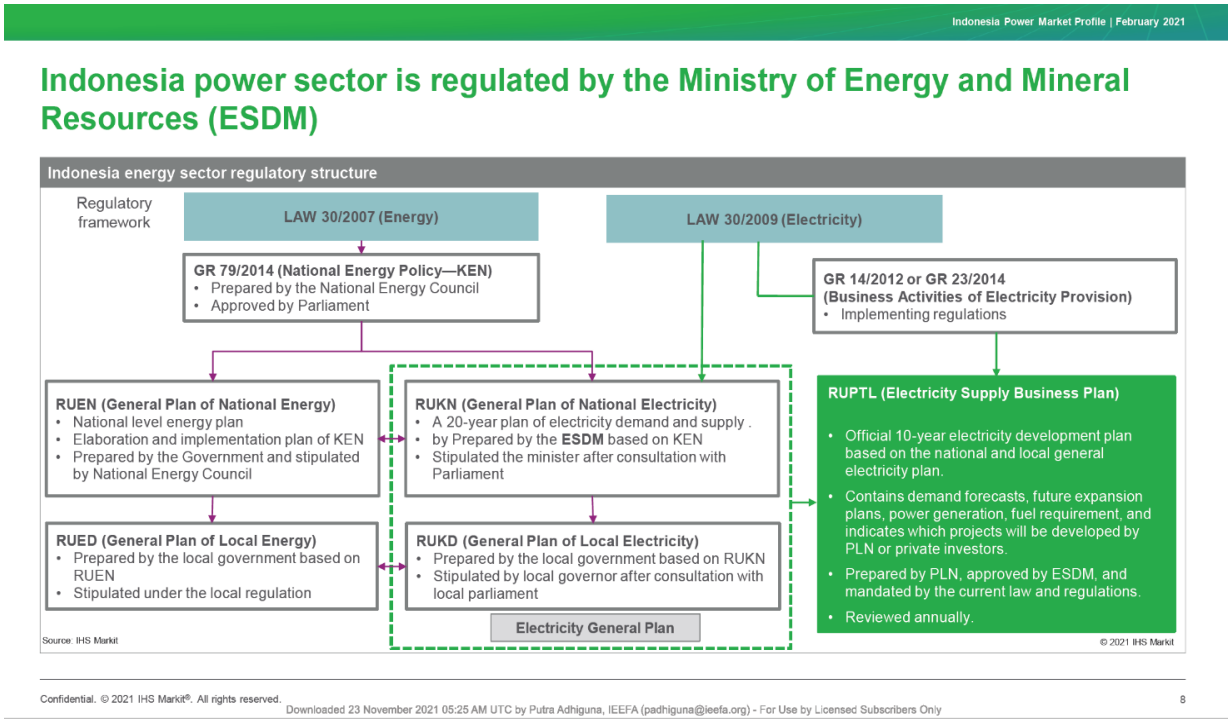


Figure 9 Indonesia's Energy and Electricity Policy Framework
Source: IHS Markit. IHS Markit. Indonesia Power Market Profile. February 2021

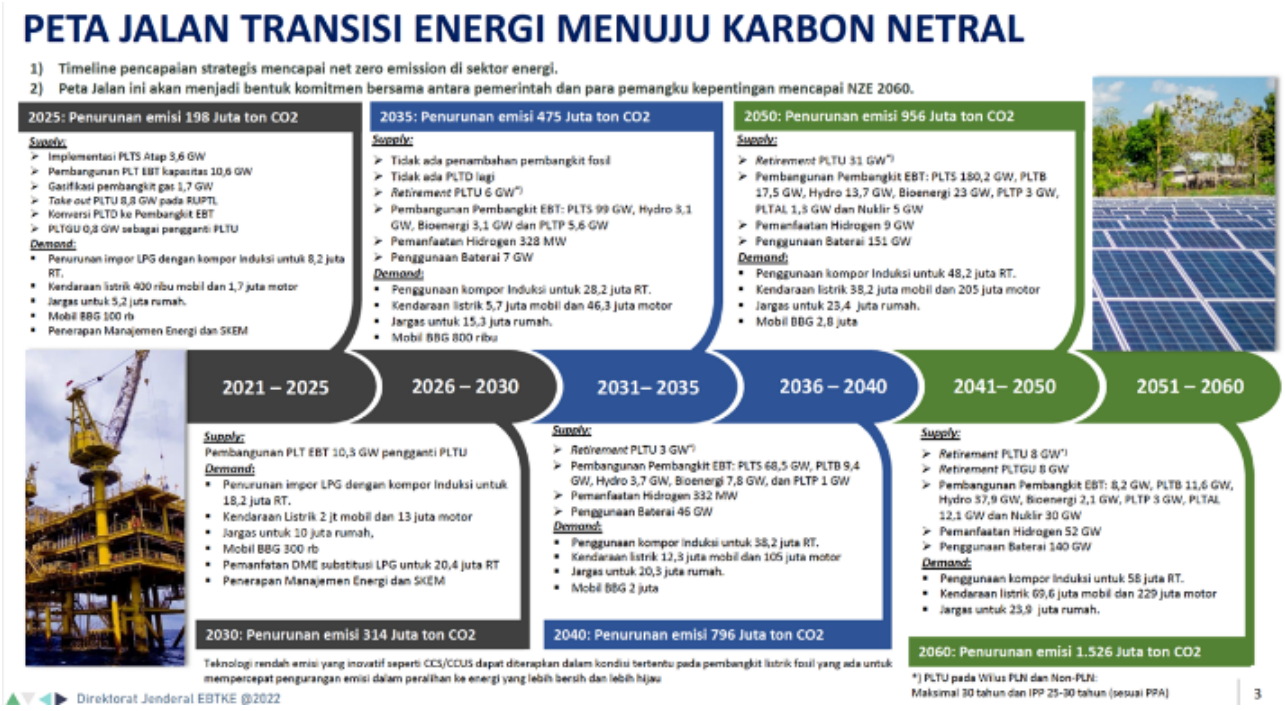


Figure 10 Energy Transition Roadmap to Net Zero Carbon
Source: Dadan Kusdiana, Director General of New and Renewable Energy of MEMR. Energy Summit 2022 (Metro News). 31 May 2022.

presented by the MEMR is shown in the chart below. The roadmap presented by the government looks promising and quite ambitious. The plan covers many objectives from early coal plant retirements and diesel engine phase outs by 2025, to accelerated renewable energy, replacement of LPG stoves with electric stoves, to speeding up transitions to EVs, and deployment of new technologies in energy generation including hydrogen and nuclear by 2050. The challenges however are not only in planning, but more in implementation and governance of each of these ambitions. Inconsistencies in policies and regulations and lack of political will are something that analysts found difficult to convince many investors who actually have long been looking to enter the Indonesian energy market.

Despite all the challenges, the Indonesian government and Indonesian public are well aware that clean energy transition is no longer just an option, but a necessity for the country. The risks of global climate change to the Indonesian people, coupled with economic and financial risks of being a laggard in the renewable energy sector have been seen as a major impediment to a country whose long-term goal is to raise itself to become a develop nations by 2045.

Nuclear energy in the Indonesian energy context

Regulatory Framework

Law No. 10/1997 on nuclear energy sets high-level precedents for how nuclear energy should be governed within Indonesia. In general, there are four key concepts that should be included.

1. **Safety:** Physical safety on nuclear both in the installations and the raw materials from mining to energy production. Safety of all radioactive materials in mining, installation and physics, employees and workers of the nuclear industry, and most importantly, the public and environment's safety (including safety on waste disposal).
2. **Security**: Preventive measures, detection, response to sabotage actions, thefts, illegal transfer or access to radioactive materials, radiation and other illegal actions in nuclear facilities must be kept under maximum supervision. Nuclear threats can come from both inside and outside of nuclear installations.
3. **Safeguard**: the action to encourage non-proliferation efforts or an action to prevent the deviation of the use of nuclear power from peaceful purposes to the purpose of

producing nuclear weapons or other nuclear explosive devices.

4. **Nuclear liability**: liability for losses caused by nuclear incidents that are detrimental to life and the environment, including incidents that occur during nuclear transportation. The principle adopted is strict liability.

As a non-nuclear state, Indonesia has ratified some of the global nuclear treaties as well as enacted a law and its implementing regulations pertaining to nuclear materials. A summary of the regulation framework is given below.

Safety	Security	Safeguard	Nuclear Liability
Presidential Reg No 81/1993: Ratification of Convention on Early Notification of a Nuclear Accident	Law No 10/2014: Ratification of International Convention for the Suppression of Acts of Nuclear Terrorism	Law No 8/1978: Ratification of Non-Proliferation of Nuclear Weapons	The Vienna Convention on Civil Liability for Nuclear Damage of May 21, 1963
Presidential Reg No 106/2001: Ratification of Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	Presidential Reg No 49/1986: Ratification of Convention on the Physical Protection of Nuclear Material and Amendment to the Convention on the Physical Protection of Nuclear Material	Law No 9/1997: Ratification of Treaty on The Southeast Asian Nuclear Weapon Free Zone	Protocol to Amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage 1997 and revised through the Convention on Supplementary Compensation for Nuclear Damage 1997
Presidential Reg No 106/2001: Ratification of Convention Nuclear Safety	Presidential Reg No 46/2009: Ratification on the Amendment on the Physical Protection of Nuclear Material	Law No 1/2012: Ratification of Comprehensive Nuclear-Test-Ban-Treaty	Presidential Reg No 74/2012 about Nuclear Liability
Presidential Reg No 84/2010: Ratification on Joint Convention of the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management		Comprehensive Safeguards Agreement (CSA)	
		Additional Protocol Pursuant to Comprehensive Safeguard Agreement	

Table 2 Laws and Regulations Ratified by Indonesia
Source: Intan Soeparna. Legal Perspectives on Nuclear Development in New and Renewable Energy. Airlangga University, Centre for Nuclear Regulations and Management. October 2020.

nuclear in the draft of the New and Renewable Energy Bill.

With all the new regulations currently under discussion, it remains to be seen if there will be stricter and tighter oversight for nuclear energy development and domestic capacities and capabilities, and if stronger oversight can be built in the short period of time. This has resulted in an awkward dynamic. Understandably, many Indonesian policymakers lack the complicated technical and financial knowledge for nuclear power. As a result, they have struggled to provide the kind of oversight that is required to evaluate complex nuclear project proposals. To date, the discussion has been framed solely in terms of opportunities, with little attention paid to the need of disciplined governance habits that must be addressed before proceeding with any nuclear installation.

Particularly for the power sector, nuclear energy should remain as "the last option" as stipulated in the last National Energy Policy document.[6] That said, there has been a lot of heated discussion lately to revise this statement in the draft of the new document as well as an effort by nuclear advocates to include

[6] Government Regulation No 79/2014

Nuclear liability issues

Law No. 10/1997 stipulates that each nuclear operator in Indonesia would be liable to a maximum of IDR 900 billion (USD 64 million) for any nuclear accident occurring on site or during fuel or waste transportation. This amount was updated by Government Regulation No. 46/2009 to IDR 4 trillion (USD 276 million).[7] There is, however, a caveat within the regulations. One of the clauses states that nuclear owners are not liable for any nuclear accident that occurs as a direct result of international or non-international armed conflict or natural disasters of extraordinary magnitude beyond the required safety design limits set by the supervisory agency. In the explanation chapter of the Law, the 'extraordinary natural disasters' include earthquakes of seismic category S1 and S2. Considering the unstable geographical location of Indonesia, this clause presents a high risk for taxpayers when so-called 'natural disasters' inevitably take place.

A follow-up regulation issued by President Susilo Bambang Yudhoyono through Presidential Regulation No. 74/2012 confirmed the liability limit increase up to IDR 4 trillion. This regulation further breaks down the liability limit into types of reactors. Apparently, the IDR 4 trillion is the upper limit for commercial reactors with more than 2000 MWe energy. Those having installed capacity of 1500-2000 MWe are capped at IDR 2 trillion (USD$142.8 million); 1000 – 1500 MWe capped at IDR 1 trillion (USD$71.4); 500 – 1000 MWe capped at IDR 500 billion (USD$35.7 million), and any commercial reactor below 500 MWe will have their liability capped at IDR 250 billion (USD$17.8 million).[8]

The segregation of liability limit favors the use of small modular reactors (SMR) as they would be liable for a much smaller amount in comparison to traditional large-scale units. Although when it comes to unforeseen catastrophic event, a small reactor's accident with core melt down would still cause a significant impact to people and the environment.

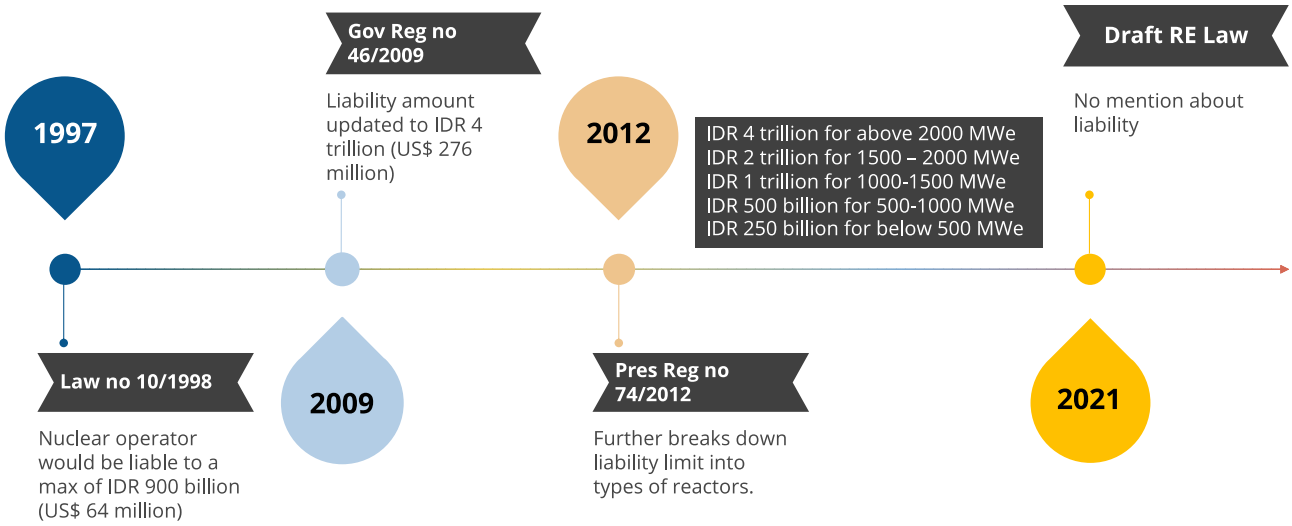


Figure 11 Indonesia's Regulation on Nuclear Accident Liability Framework
Source: IEEFA. Tackling Indonesia's Nuclear Power Euphoria. June 2021.

Infrastructure and ecosystem for nuclear power development in Indonesia

Although the Indonesian government has been contemplating the addition of nuclear energy to the country's energy mix since the 80's, the infrastructure and ecosystem for nuclear power is not yet fully developed. Except for the 2.1 MW capacity of BATAN research reactors, the country still lacks a lot of supporting infrastructure that would be crucial for safety, security, and safeguard issues associated with nuclear technology.

Historically, nuclear accidents have occurred despite the fact that the industry has been subject to high levels of regulation and oversight at both the country and international level. This regulatory imperative reflects the open-ended and catastrophic nature of the potential risks associated with nuclear technology. Nonetheless, governance remedies have not always proven effective due to bureaucratic failures, a

[7] BAPETEN. Peraturan Pemerintah no 46/2009.

[8] MEMR. Presidential Regulation no 74/2012.

history of cover-ups, and the potential for unmanaged liabilities.

Indonesia currently does not have enough governance capacity for managing new commitments to the nuclear industry. As rigorous oversight is absent from a credible and independent energy commissioner, Indonesia may face challenges in developing the safety and safeguard guidelines that are required for safe operations of commercial nuclear power. History has shown that it is precisely this type of robust oversight that becomes an important precondition for commitments to long-lived nuclear power assets.

Financial visibility

A study by the Institute for Energy Economics and Financial Analysis (IEEFA) found that there is an apparent mismatch between what nuclear power advocates want to achieve and what PLN will be able to offer. At the moment and for the foreseeable future, Indonesia does not need more baseload power, especially for islands with grid systems that are already experiencing overcapacity.[9]

According to IEEFA, Indonesia's vertically integrated market structure and the complex nature of PPA contracts gave little room for PLN to renegotiate contractual agreements with IPPs. Although the COVID-19 crisis is not the fundamental cause of PLN's financial problems, it has shown how overoptimistic planning and stringent contracts could lock-in the utility with obligation to pay for unneeded power. It is therefore very understandable if PLN, at this stage of the game, is not looking into the possibility of adding another inflexible high-cost power source into the energy generation mix.

Meanwhile, all nuclear power plant owners, be it the traditional large scale pressurized water reactor (PWR) or the SMR, would understandably ask for such fixed capacity payment contracts. Technically there may be ways to enable nuclear power plants to be flexible, but plant owners would inevitably choose to dispatch nuclear plant energy as baseload, so that the required steady stream of cash flow needed by the plant owner to repay debt is guaranteed.

The recent pledge announced by PLN to become carbon neutral by 2050 actually paints a clear picture of how PLN sees the role of nuclear power in Indonesia's energy transition scenario.[10] It looks like PLN sees nuclear as a viable option to decarbonize PLN's grid systems, a view that is in line with the plans of other utilities in other countries. However, it is worth noting that in all of PLN's net zero scenarios—be it the 2045, 2050, or 2060 version—nuclear is planned to start only in the year of 2040, not earlier in this decade like most SMR nuclear advocates would have preferred. The unexpected announcement reflects PLN's realistic expectation on nuclear power development in Indonesia, and its ability to cover any cost overruns that have occurred in almost all of nuclear power development globally.

Another impending hurdle that would challenge financial feasibility of nuclear energy in Indonesia relates to insurance and warranty issues. The complex nature of nuclear power projects always drives upside cost risks, which often become the driver in delayed construction time, resulting in project cost overruns. Recent research indicates that an estimated 97% (175 out of 180 projects studied) of nuclear power projects exceed their initial budgets, with an average US$ 1.3 billion cost overrun per project, and 64% more time than projected.[11] The median construction time for nuclear reactors in 2019 was 117 months,[12] while solar took a maximum of 24 months, and wind 36 months to deploy.[13]

In places with a longstanding nuclear footprint such as the US, the UK, and Europe, insurance for nuclear facilities is pooled under one mutual insurance associations such as Overseas Nuclear Electric Insurance Limited (NEIL) in the US; EMANI and ELINI[14] in Europe, or the UK's Nuclear Risk Insurers Limited. Without a proper warranty on technology and no insurance platform existing in Indonesia, it would be difficult to mitigate any risks pertaining to cost overruns or safety issues. It would be strongly advised that policy makers ensure the needed underlying insurance framework is prepared well in advance.

[9] IEEFA. Tackling Indonesia's Nuclear Power Euphoria. June 2021.
[10] Mongabay. Indonesia Says No New Coal Plants from 2023 (After the Next 100 or so). May 12, 2021.
[11] Ramana, M.V. 2020. Op.cit. p. 11.
[12] World Nuclear Association. World Nuclear Performance Report 2020. August 2020.
[13] European Commission. PV Status Report 2019. 2019.
[14] European Mutual Insurance for Nuclear Installations (EMANI), focused on physical damage, and European Liability Insurance Mutual (ELINI), focused on liability, respectively.

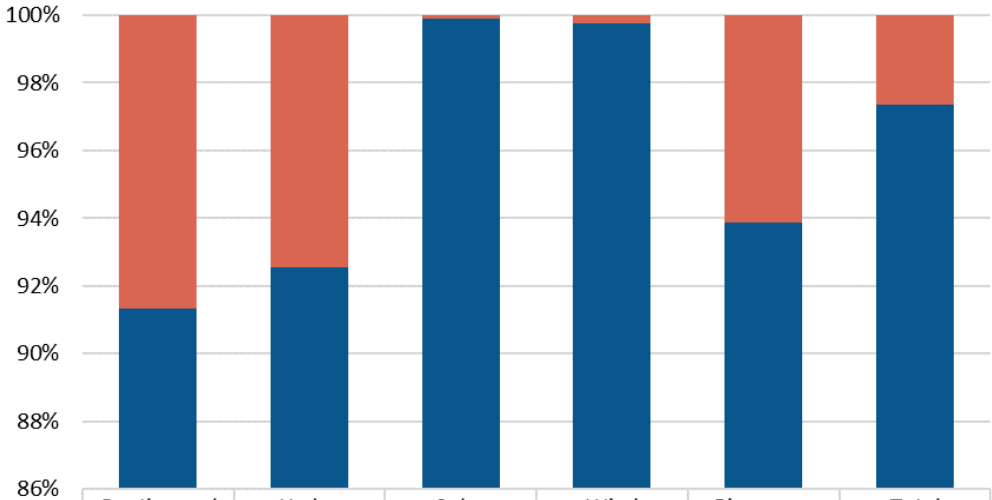
Technology options

Despite being endowed with a huge renewable energy potential, Indonesia has only managed to utilize less than 2% of its renewable sources so far. The untapped potential is the result of a combination of past mistakes including coal-fired power plants being overbuilt, overly optimistic demand projections, and lack of preparedness for a renewable industry ecosystem including the lack of domestic financing for renewable projects. These, however, have slowly changed over the last two years, as the Indonesian government has geared up to reach their new net zero commitment. Hypothetically, these resources alone can easily fill the demand trajectory for Indonesia's power sector which is forecast to reach 118-127 GW in 2025, and 205-267 GW in 2038.[15]

battery storage cost should also give PLN plenty of choices to increase intermittent renewable energy sources into its system.

It would arguably make more sense for the utility company to find a way to optimize system operations and enhance the cost effectiveness of projects with known technology. Given the ongoing improvements in renewable technology cost curves, a new focus on providing a conducive business environment for the renewable energy industry in Indonesia would be more consistent with PLN's medium-term financial priorities.

When we talk about nuclear energy, historically its economy of scale wins the competition for cheaper baseload power as compared to coal or gas power



	Geothermal	Hydro	Solar	Wind	Bioenergy	Total
Current Installed Capacity (MW)	2,271	6,051	232	154	2,132	10,839
Potential (MW)	23,966	75,091	207,898	60,647	32,654	400,256

Table 3 Untapped Renewable Energy Potentials in Indonesia
Source: Installed capacity is taken from MEMR Infographic 2021. RE potential is taken from DEN. Bauran Energi Nasional 2020.

What is important to note here is that PLN already has proven and reliable technology options available to meet the 2025 or 2030 Paris Agreement target. The already mature hydro technology and civil construction knowledge for hydro power is long known and proven in Indonesia. Some optimum hydro sites are even able to produce power at very low cost and are competitive with coal. The new government-backed geothermal exploration program is meant to help lower the project's risk which will lower production costs. The global trend of annual double-digit deflation of solar, wind, and

plants. However, with the geographical and geological conditions of Indonesia, big scale nuclear technology might not be the best fit for an island nation with very dispersed demand centers. As of today, there is no real plan from big nuclear players like EDF France, to enter the Indonesian market.

A new option that has generated a lot of enthusiasm from nuclear experts and technocrats recently is the SMR. This new technology offers fast construction using modular designs that can be scaled up or down as needed, and in theory should significantly

[15] Forecast is based on the National Electricity General Plan 2019-2038, with the lower target includes energy efficiency measures.

improve construction time and efficiency, and hence reduce initial capital costs. Proponents of the technology would also say that it is safer, with some reactor designs being self-contained and theoretically having the ability to shut itself down and remain cool for an unlimited time. Critics of the technology would argue otherwise though with claims about SMRs suffering the same problems as large reactors, notably on the safety issues and the unresolved problem of long-lived radioactive waste.

In Indonesia, there is currently an SMR technology being planned, carried out by a new small venture company called Thorcon International (a US based SMR startup). The company managed to sign a memorandum of intent to develop a study and pilot project together with the Indonesian Defense Ministry for a preliminary 50 MW Thorium Molten Salt Reactor (MSR) power plant. Their goal is to build a first phase of 500 MW thorium-fueled MSR, which would escalate up to 3 GW in the future.

A major problem for the technology though is that gaining design certification from an experienced nuclear authority will be difficult due to the untested technology. It would also be difficult to assess the likelihood that Thorcon can see this project to completion. Their lack of financial backing, from a strong parent company such as what Nu Scale Technology received from Fluor Corporation in the US, also presents a risk that the dream might not be easy to realize, especially without subsidy or financial incentives from the government.

Indonesian public acceptance of nuclear power

In general, Indonesian public awareness and perception about the benefit of nuclear energy have improved from 26.7% in 2011 to 59.7% in 2013 according to surveys conducted by Batan. However, it is worth noting that public perceptions of 'nuclear' still relates strongly to weapons and military activities. Public support for Indonesia's nuclear energy program was also found quite high, with 60.1% of support in 2013. Many people perceived that nuclear energy could contribute to energy security and independence.

But there are two remaining concerns that cannot be shaken and have so far deterred the Indonesian government from speeding up its nuclear energy programs. First is the perception about nuclear accidents and liabilities which remains a big question for Indonesian society, especially after the Fukushima accident. Second is the radioactive waste issue, which is still unresolved by nuclear experts and advocates. The questions are always about the uncertainty of who is going to cover what, for how long, and at what public cost?

The type of an unresolved event, such as what had happened in early 2020, where a radioactive Cesium-137 nuclear waste site was found in an empty field near a BATAN housing complex in Serpong, Indonesia brought these questions to reality. Though the level of radiation found from the radioactive metal was considered low at 140 microsievert per hour,[16] the Indonesian Nuclear Energy Regulatory Agency (Bapeten) could not answer how this nuclear waste ended up in an open field near a housing complex.

For many countries in Southeast Asia, these technical challenges and governance burden have been a barrier to the acceptance of nuclear.

Grid expansion plan

PLN and the Indonesian government have an ambitious plan to develop more transmissions and distribution capacities to almost double the current capacity in the next few years. A number of network interconnections and even super grid ideas are being studied, including the long-sought after ASEAN super grid. A brief of the system plan is explained in the picture below.

The ASEAN nations have also been developing plans to interconnect some member countries. The initiative started since 2014 but has not yet been successfully implemented. The gestation period shown in a pilot project to bring up to 100 MW of renewable hydropower from Laos to Singapore (the LTMS project) took eight years. Meanwhile, the ASEAN super grid plan has been in discussion for more than 20 years. This highlights the challenges ASEAN nations face to scale such plan into reality.

[16] Tempo. Pemerintah sebut temuan radioaktif di Serpong sebatas pencemaran. February 19, 2020.

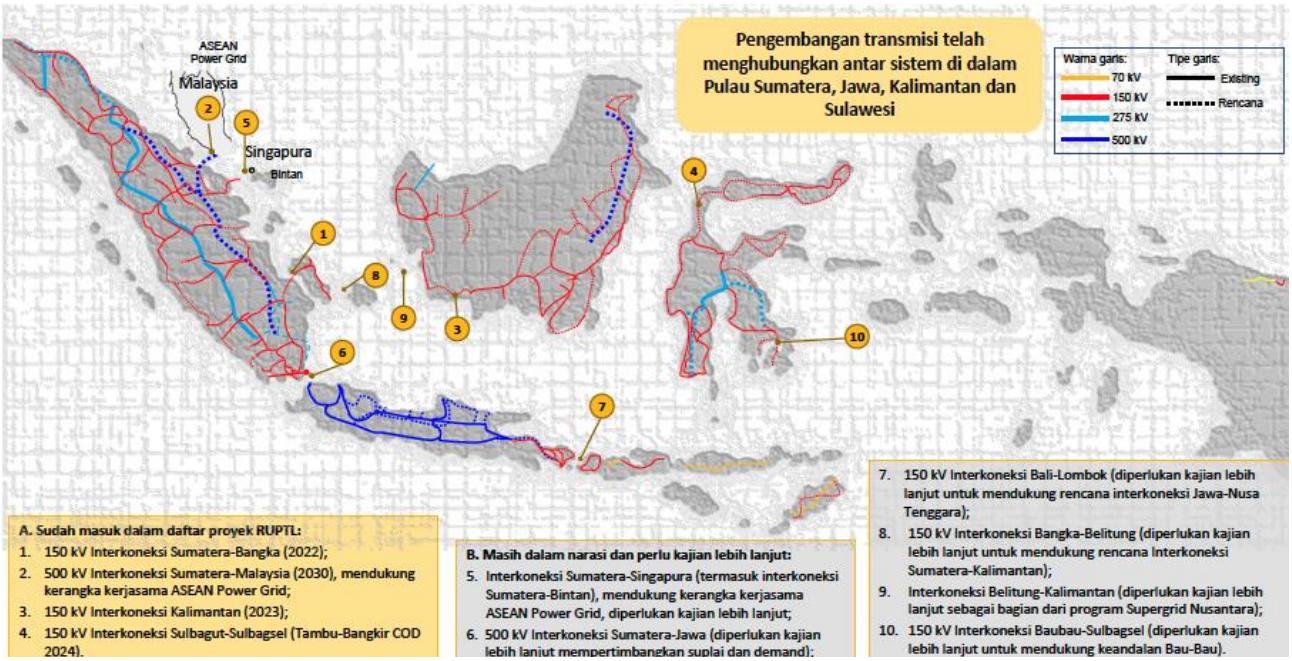


Figure 12 Indonesia's Grid Expansion Plan
Source: Ministry of Energy and Mineral Resources Directorate General of Electricity Press Release. Oct. 5, 2021

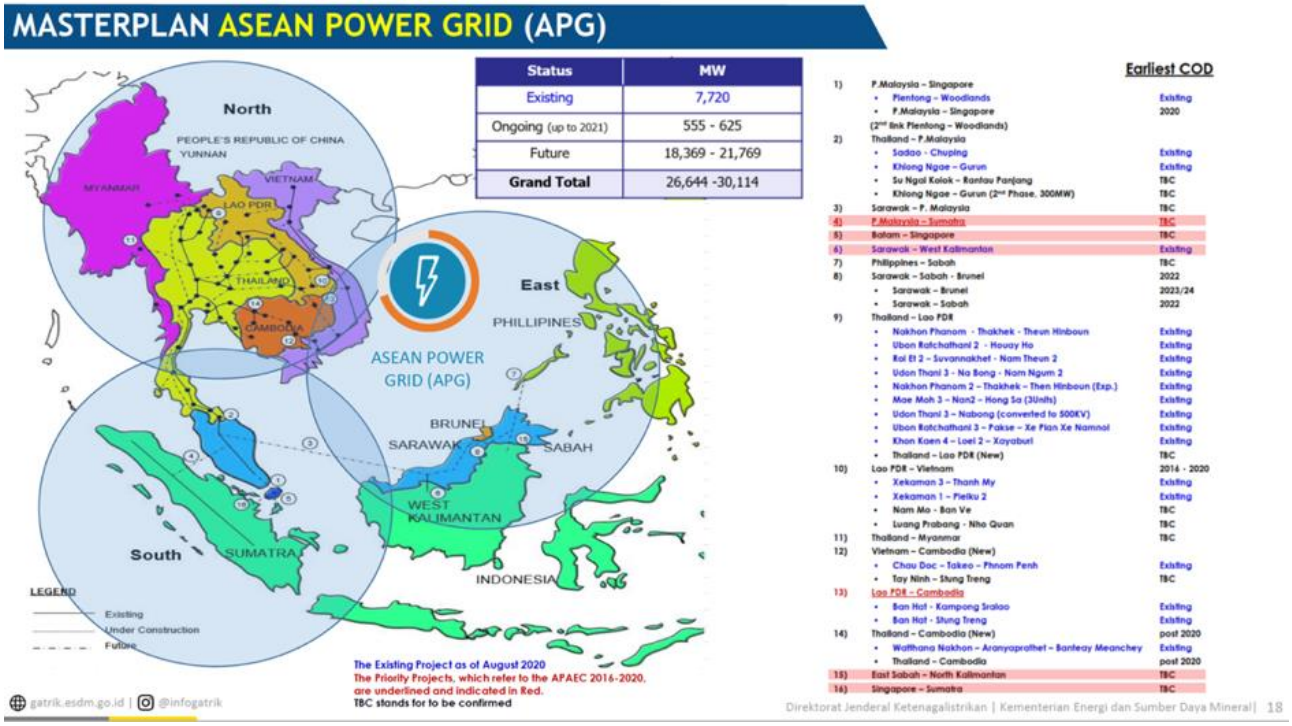


Figure 13 ASEAN Super Grid Plan
Source: MEMR

2

Malaysia Energy Landscape and Requirements 2022-2050

Sabar Hashim

Introduction

Malaysia has significant indigenous energy resources and is capable of importing those it is lacking. Energy has helped sustain economic growth in Malaysia, however approximately 61% of its energy fuels are imported, notably coal and liquefied natural gas (LNG). Thus, there is a need to ensure energy security, which acts as a key lever in the energy trilemma—finding a balance between security, affordability, and sustainability in accessing and using energy. The other energy trilemma levers, affordability and sustainability, have always been at the top of every energy planner's mind.

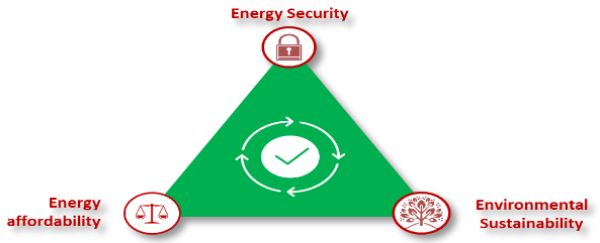


Figure 1 The Energy Trilemma

Environmental sustainability is also important, as the energy-environment nexus has affected climate patterns and population movements more than ever before, warranting a response from countries including Malaysia. Affordability is essential to ensure access energy especially electricity for both commercial and residential purposes. Energy security has received considerable attention since the conflict in Ukraine began in February 2022, as countries have sought alternative sources and energy prices have soared.

Balancing the three levers of the trilemma is pivotal to energy planners. In Malaysia, there is a need to revisit how the electricity generation mix has been planned and operated. Energy planners need to be agile in responding to supply-demand issues and geopolitics. As Malaysia grapples with conventional and renewable options, it needs to examine security issues when considering options that are feasible and proven. Planners might need to explore the fundamentals of inertia and base load capabilities. In this context, the potential of nuclear energy could be re-examined not only for base-load operation and electricity system resilience, but also for effective decarbonization.

Electrical energy analysis framework

The electricity sector in Malaysia includes generation, transmission, distribution, and retail with different utilities managing jurisdictions in Peninsular Malaysia, Sabah, and Sarawak.

Figure 2 Map of Malaysia: Peninsula, Sabah and Sarawak[1]

Grid Capacity

Malaysia's combined grid capacity—defined as total maximum power outputs (nameplate capacity) of the generators under conditions designated by the manufacturer—is approximately 38,000 Megawatts (MW). Peninsular Malaysia's installed capacity was 31,094 MW in 2021 [27,500 MW (without solar)] with Sarawak and Sabah at 5,307 MW and 1,468 MW respectively.[2] Thus, the Peninsula's installed capacity is almost 82% of total capacity. Peninsular Malaysia's installed capacity has been dominated by fossil fuels, i.e., gas and coal, which comprise 90% of its total. However, it does not necessarily mean gas is used more as coal is favored due to its relatively cheaper price.

From Sabah's installed capacity of 1,468 MW, only 1,223 MW is dependable due to aging and derated capacity with the dominant fuel being gas at 80% of the generation mix, defined as the percentage distribution by technology (thermal, large hydro, renewables) of the capacity of operational generation plants.

Most of Sarawak's electricity is generated from two major types of plants: hydroelectric and thermal,

1 Source: https://constitutionnet.org/

[2] 2021 Suruhanjaya Tenaga – report by the regulator.

	Peninsula	Sarawak	Sabah
Installed Capacity 2021	31,094 MW	5,307 MW	1,468 MW
Maximum demand 2021	18,858 MW 19,183 MW (2022)	3,664 MW 4,100 MW est. 2022	1,003 MW
Fuel for installed capacity 2020 & 2021	46% coal and 38% gas. 50% coal and 40% gas: 9% RE	70% hydro with 3,452 MW from large hydro	80% gas

Table 1 Installed generating capacity & demand of Malaysia (Peninsular, Sarawak and Sabah)

with hydro being approximately 68% of its generation mix. The utility harnesses the state's abundant indigenous natural resources to generate predominantly renewable hydropower, complemented by thermal (gas and coal) for energy security and diversity. Sarawak Energy, the utility, has also developed small hydropower plants that support off-grid communities and rural electrification in the state's many remote villages. It plans to add 5% solar energy into its generation mix by 2030. Sarawak's energy demand was 3,664 MW in 2021 with projections rising to 4,100 MW by 2022 and 5,600 MW by 2026. Total electricity demand is expected to rise to 6,000 MW by 2030 as the state's GDP expands five-fold, with approximately 1.6 million new jobs created when the Sarawak Corridor of Renewable Energy (SCORE), is fully operational. There has been some degree of success in decarbonizing the power system in Sarawak due to the almost 70% contribution of hydropower.

Current generation mix

Generation mix entails a combination of the various fuels used to generate electricity in a given state or country. The annual generation mix is made up of mostly thermal fossil fuels (gas and coal), with almost an equal proportion making up nearly 80% of the installed capacity in Peninsular Malaysia, with gas and hydro dominant in Sabah and Sarawak respectively. Gas and coal, with their inherent nature or inertia – energy stored in large rotating generators – gives them the tendency to respond well during emergencies. That is why the energy planners designate these gas and coal-fired plants on base load to restore stability in the event of any major system perturbation. These grid inertias are still unmatched by solar photovoltaic or many non-hydro renewable plants. Renewable energy (RE), including large hydros, is at 16-23% of capacity-mix based on the 2020 figure. However, the generation mix reflects a combination of merit order operation and embedded

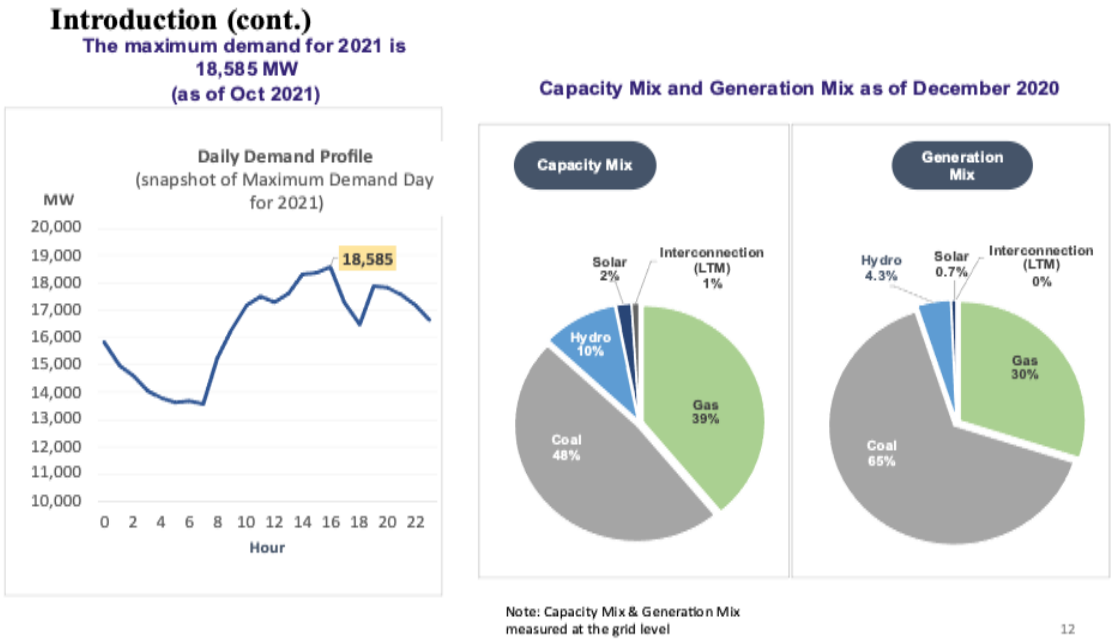


Figure 3 Gen Mix and Installed Capacity 2020

The gen mix for Malaysia in 2021 is dominated by fossil fuels i.e., coal at 59.07% and gas at 34.43% with RE taking the other shares (hydro and solar at 5.49% and 0.88% respectively).

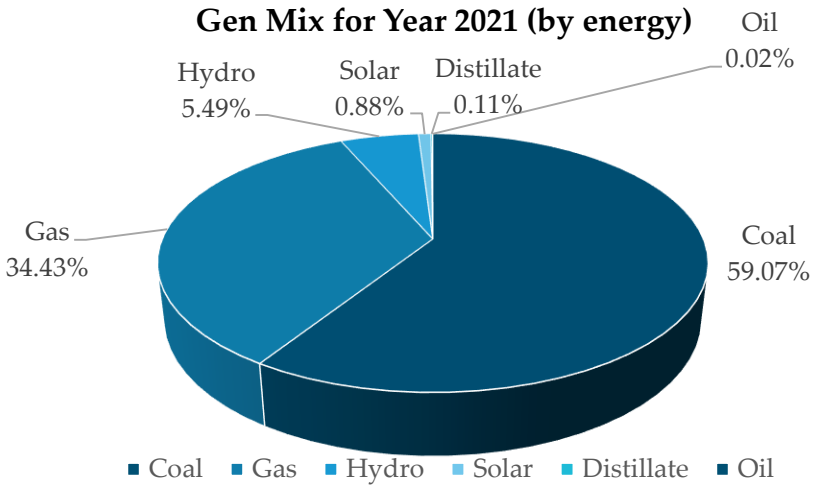


Figure 4 Gen Mix for 2021

energy security features as dictated by the power grids that allow reliable power flows and minimize loading problems on the transmission circuits.

Currently there are surplus generation quantum, which allows adequate generation reserve margin. For Malaysia, the reserve generating capacity, also called spinning reserve (stored in the flywheel) or operational reserve is quite healthy at approximately 40% but could be further reduced for optimization. The reserve allows an approximately 10-minute recovery of the base load when the stored energy in the flywheel kicks in.

In managing the energy trilemma, the government has set several policies and planning criteria. Energy security is managed through the diversification of fuel mix with a target to maintain a Herfindahl-Hirschman Index (HHI) of below 0.5 by 2025 and provide enough reserve margin and spinning reserve for the day-today generation and system balancing.

Utilities and independent power producers (IPPs) in Malaysia have been accorded – by market design – almost equal proportion of generation amount as in Peninsular Malaysia with the power utility Tenaga Nasional Berhad (TNB) sharing the capacity with IPPs.

The current generation mix provides economic buffer to lower income groups and very affordable tariff and position Malaysia among the countries with low electricity tariff.

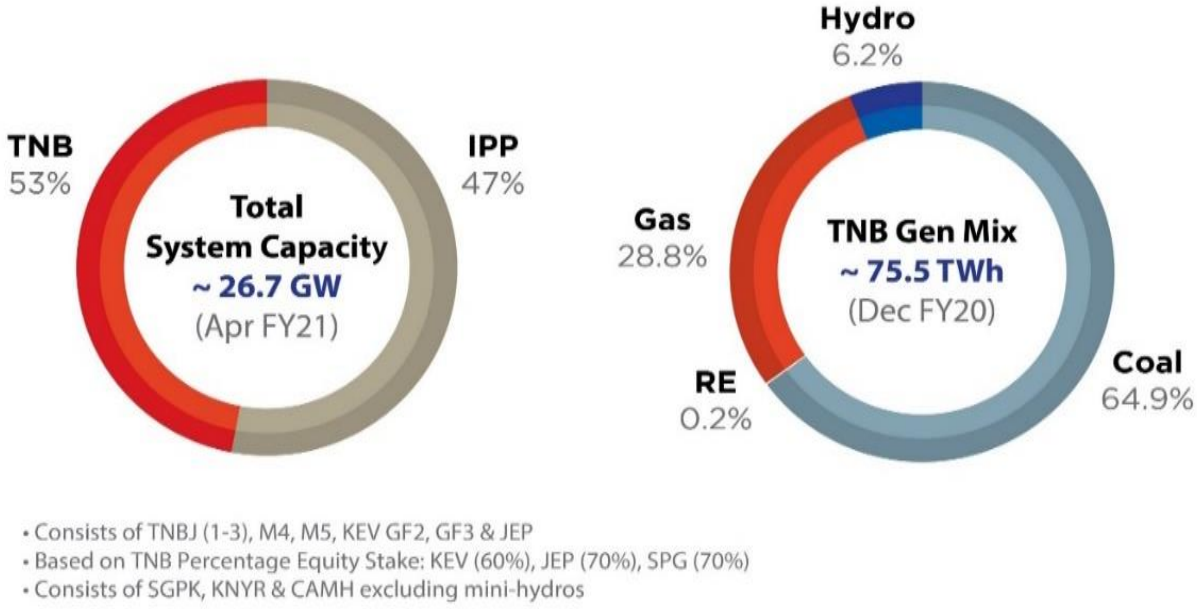
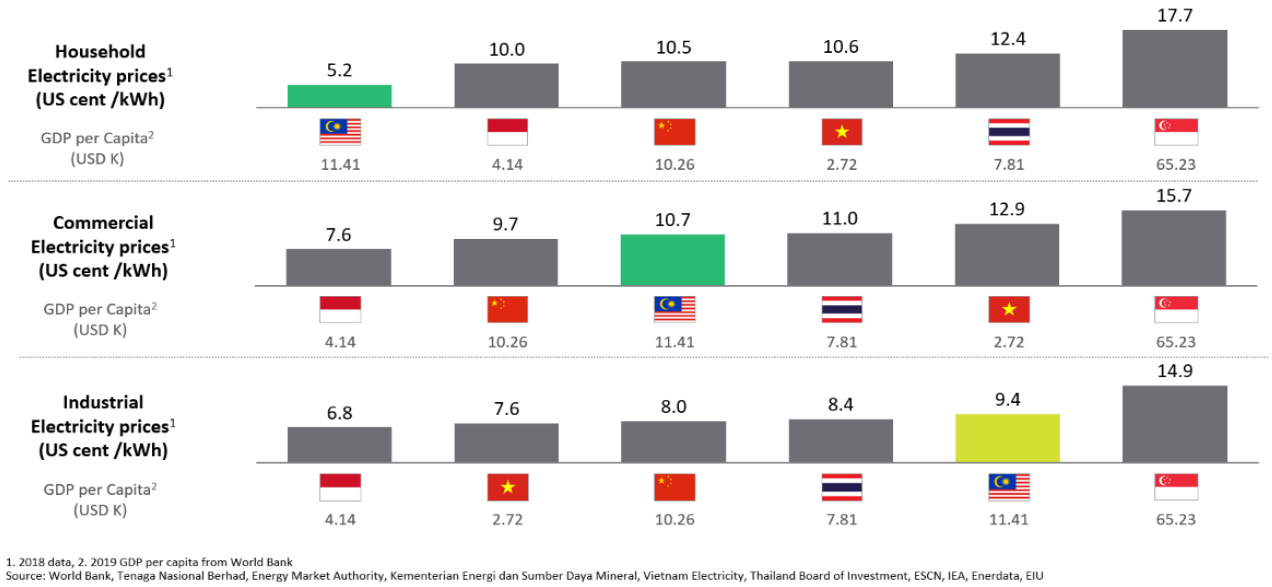


Figure 5 Share of TNB and IPP Power Plants in Peninsular Malaysia.[3]



1. 2018 data, 2. 2019 GDP per capita from World Bank
Source: World Bank, Tenaga Nasional Berhad, Energy Market Authority, Kementerian Energi dan Sumber Daya Mineral, Vietnam Electricity, Thailand Board of Investment, ESCN, IEA, Enerdata, EIU

Figure 6 Comparison of Electricity Tariff in ASEAN and others

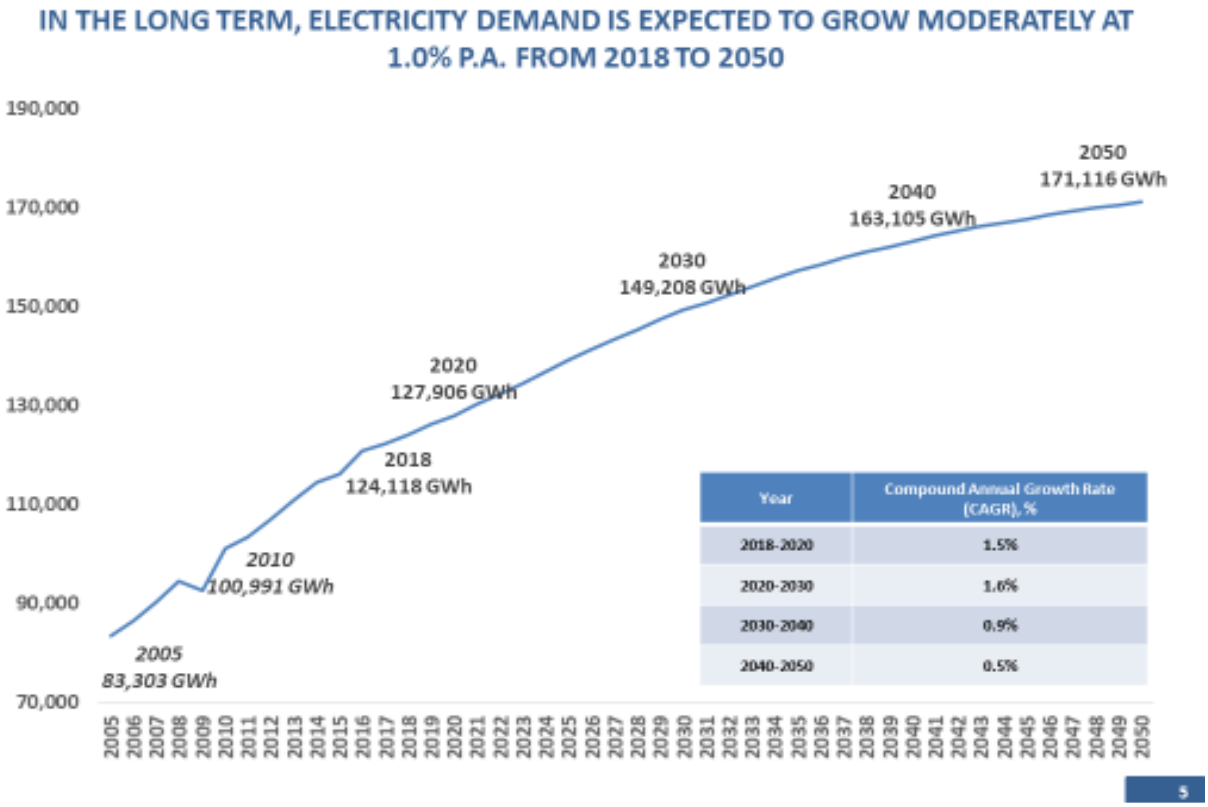


Figure 7 Energy Projection as per 1% p.a. Rise in Electricity Demand
Source: Single Buyer

Demand outlook

Peak demand, also referred to as peak load, is the maximum electricity usage during a specified period of time typically from 11 am to 4 pm on weekdays especially from Tuesday until Thursday.

The demand in Peninsular Malaysia in 2021 was 18,858 MW (**Table 1**). The COVID-19 pandemic significantly reduced the overall demand in 2020 but demand has bounced back since 2021 and projected to fully normalize in line with the economic recovery by 2023. For the year 2021-2030 and 2030-2039, demand is projected to grow by 0.9% per year and 1.7% per year respectively. After deducting the projected resources at the distribution network (Dx), the net demand is projected to grow by 0.6% per year for 2021-2030 and 1.8% per year for 2030-2039.

Sarawak has a demand of 3,664 MW while Sabah is at 1,003 MW according to the 2021 regulators' report.

Supply sources

The government has been careful in studying the impact of rising energy demand and is providing measures to ensure the continuity of supply and stability of the grid for overall system security. The generation supplies to the power plants come from indigenous (natural gas, hydro, etc.) as well as imports (coal and LNG).

Gas and LNG are sourced from PETRONAS, the national oil company (NOC). Malaysia has been reaping the benefits of exploring oil and gas fields since the 1970s with the establishment of the NOC, which has grabbed most oil and gas exploration from competitors such as Shell, BP, and Caltex. PETRONAS has been expanding globally and has made major in-roads in explorations. There is also a regional ASEAN gas network called Trans Asian Gas Pipelines (TAGP), which has been interconnected among various ASEAN countries. In addition, there are also regasification gas terminals (RGTs) in Melaka and Pengerang Johor to administer the gasification of liquefied natural gas (LNG) imports to natural gas for power plants and other industrial uses.

Coal is largely used for base load but is imported and its procurement has been centralized by TNB Fuel, a wholesale buyer. Coal is cheaper than gas and is abundant in many countries such as Indonesia, Australia, and South Africa.

There has been increased emphasis on introducing more RE and a doubling down on solar power. In support to Malaysia's commitment toward sustainable energy, the supply capacity mix in Peninsular Malaysia is projected to see an increase in RE share from 17-23% to 31% by 2025, while the thermal capacity share will be reduced from 82% to 69%. As a result, carbon emission intensity per GDP for the Peninsular Malaysia power sector is projected to be on a downward trend with a 45% reduction by 2030 compared to 2005 level, in line with Malaysia's commitment in COP21.

The RE capacity mix is projected to increase from 31% to 40% by 2035 through the Malaysia Renewable Energy Roadmap (MyRER). The RE capacity is projected to increase from 8,450 MW in 2020 to 12,916 MW by 2025, with a further increase to 17,996 MW by 2035, thus reducing the intensity of carbon emissions in the electrical supply sector by 45% by 2030 and 60% by 2035. An additional 2,414 MW of RE capacity would be developed in Peninsular Malaysia from 2026 to 2035 to support the country's national commitment. The economic multiplier effects are apparent since the program is targeted to generate economic spillover of about RM20 billion by 2025 and RM33 billion by 2035 and create an estimated 47,000 employment opportunities in the RE field.

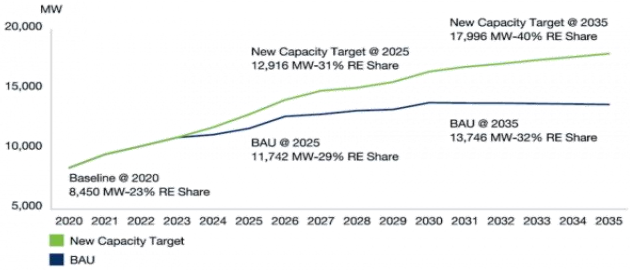


Figure 8 RE advocacy on the overdrive

Grid stability is embedded in the development scheme. The grid infrastructure would be further strengthened and enhanced with much-needed technical enablers such as energy storage systems. With variable RE (vRE) i.e., solar, being the dominant source of RE in the system, it is important to ensure that intermittent generation from solar PV will not jeopardize the overall electricity supply system in providing an undisrupted and continuous power supply. This necessitates the introduction of a battery energy storage system (BESS). The new RE capacity requirement is projected to further increase and require 500 MW of BESS for the 2031-2039 period, while reserve margin is expected to reduce further—but be optimized—to 21% by 2039.

Connectivity

Grid connection between generating stations and the transmission system or distribution system for the purpose of enabling electricity to be transferred is critical. Electricity supply is provided throughout Peninsular Malaysia as well as the populated pockets in Sabah and Sarawak.

The voltage levels for the transmission networks are (in kV): 500, 275, 132, 66, while those in distribution networks are 33, 22, 11, 0.415, 0.120.

Voltage levels	Peninsular	Sabah	Sarawak
500kV	784		
275kV	9,518	598	1,331
132kV	12,175	2,076	388
66kV		119	

Table 2 Transmission Network in Circuit, kilometers[3]

	Peninsular	Sabah	Sarawak
Overhead Lines	532, 403	9,394	10,906
U/ground Cables	697,159	1,374	4,908

Table 3 Distribution Network in Circuit, kilometers

ASEAN interconnection

Malaysia is one of the original advocates for an ASEAN Power Grid, which sees itself connected to Thailand and Singapore. ASEAN member states such as Malaysia have been leveraging interconnected power grids, known as the ASEAN Power Grid (APG), to derive benefits from sustainable and cross-border power trade as well as leveraging gas supply, from both piped gas and LNG. Cross-border interconnection allows for use of power from a neighboring utility/country to be factored into the generation mix. In the spirit of reserve resource sharing, ASEAN member states could explore enhancing cross-border energy transactions, particularly electricity. An interconnection facility bodes well for an energy transition that is affordable, sustainable, clean, and safe.

Beyond the existing Malaysia-Thailand, Malaysia-Singapore and Sarawak-Kalimantan, Indonesia interconnections, the Lao, Thai, Malaysian and Singaporean governments have launched the Laos-Thailand-Malaysia-Singapore (LTMS) power integration project (PIP) in support of the ASEAN ambition to enhance power system stability in the region. The PIP currently stands at 300 MW from Laos to Malaysia; the connection to Singapore was realized in June 2022.

Electrification: a success story

The government of Malaysia, through Malaysia Plans and massive agency work by Ministry of Rural Development and Ministry of Energy and Natural Resources, has ensured high electricity access to the population at approximately 97%, targeting a higher penetration level of 99% by 2025.Such electricity access has enabled the country to reduce the urban-rural economic divide.

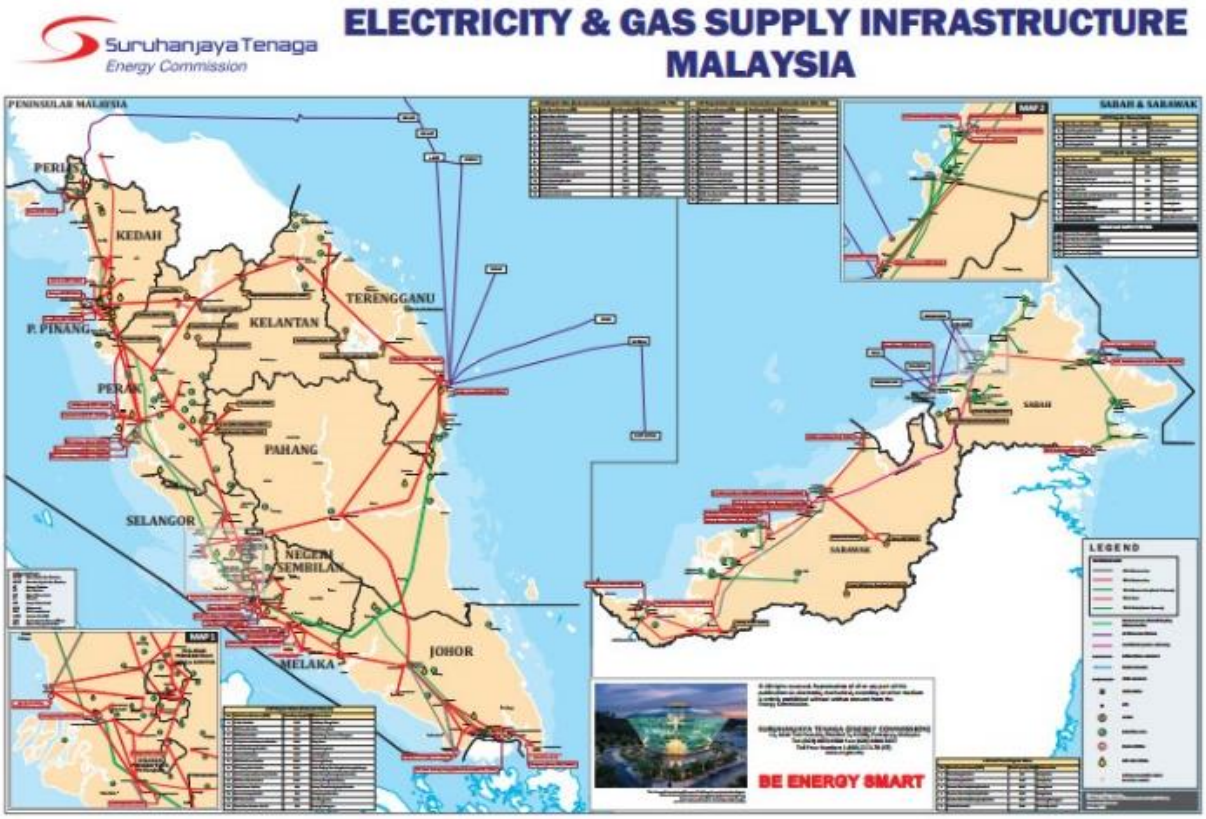


Figure 9 Electricity and Gas Supply Infrastructures

[3] Department of Statistics Malaysia (DOSM), 2018

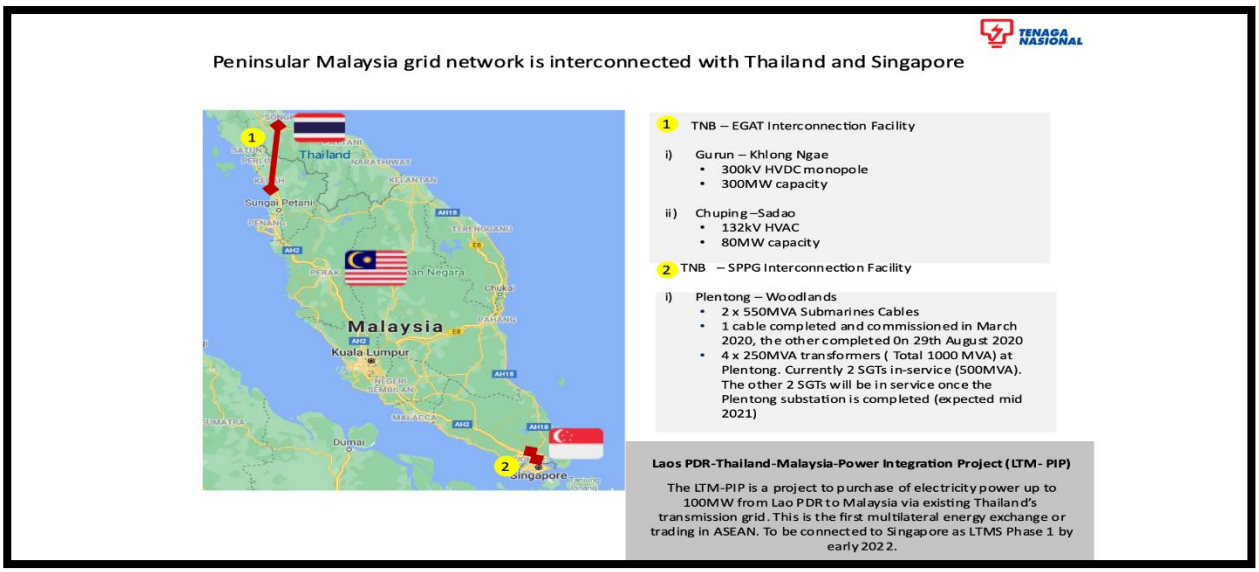


Figure 10 Peninsular Malaysia and interconnection to Thailand and Singapore

Figure 11 Sarawak and interconnection to Kalimantan
Source: Sawarakenergy.com

Electricity and utilities

Malaysia inherited the electricity infrastructure based on British designs and standards from the early 20th century and has managed it since independence in 1957. Malaysia has been endowed with substantial indigenous resources such as hydro and natural gas, which it discovered offshore Trengganu in the 1970s and used since early 1980s. Large hydro resources are important in the East Malaysian state of Sarawak, and they form 70% of the generation capacity while hydro resources in Peninsular Malaysia have been fully explored and form 7-9% of the generation mix. Malaysia also imports LNG, which complements indigenous natural gas and coal as they form the bulk of the generation mix in Peninsular Malaysia due to price attractiveness. Oil was widely used in 1960-1970s, but it has been decoupled from the generation mix arising from the risk associated with importing from the Middle East and the bitter lessons from the oil embargo in 1973. Non-hydro renewables, especially solar photovoltaic (solar PV), has been gaining momentum as the country tries to wean itself fossil fuels, especially coal.

The electricity systems in Peninsular Malaysia, managed by Tenaga Nasional Berhad (TNB), and East Malaysia, via Sarawak Energy Berhad (SEB) and Sabah Electricity Sendirian Berhad (SESB), have not been connected and are independently operated, although there have been various feasibility studies favoring a fully interconnected national system.

Investment outlook

Post pandemic recovery has been hampered by spiraling energy prices notably gas and coal since early 2022, which has been partly due to the Ukraine crisis. But the continuous rise in demand should augur well for the future. Investors are impressed with greater regulation in some areas and greater market liberalization in others. Malaysia's energy policy making is transparent and competitive, and a well-managed and viable industry signals further development and helps mobilise investments. A clear agenda is to decarbonize and jettison coal power plants in favor of cleaner fuels. However, there are still lively debates on whether it is prudent to accelerate phasing down of coal in light of spiralling energy prices that affect base load plants in the generation mix.

Electrical energy policy framework

Roles and responsibilities

The electricity industry in Peninsular Malaysia and Sabah is regulated under the Energy Commission, while Sarawak is regulated under the state government. The Energy Commission governs the electricity landscape where it bases its operations on the optimal generation expansion plan along with the least cost dispatch simulation upon optimal grid system planning. The regulator's Generation Development Plan is reviewed annually to take into account the latest economic conditions, electricity demand, emerging technologies, and development status of the planned projects. The Commission is also responsible for managing the competitive bidding mechanism for new power plants. TNB and IPPs are the main generation players in Peninsular Malaysia.

To ensure greater transparency, two TNB functional departments, in charge of production scheduling and grid control and generation dispatching, were ring-fenced from TNB in 2011 and made a Single Buyer Grid System Operator, reporting to the Energy Commission.

Energy policy and policymaking

The energy sector is a critical growth engine for the Malaysian economy as it contributes significantly to the GDP, creates jobs, enhances trade, and is connected to major sectors such as transportation, industry, commercial, and residential consumption. As the energy-climate nexus is also of primary focus, more efforts are to be channeled toward Sustainability Development Goal 7 (SDG7) affordable and clean energy.

Energy policymaking has become more complex and asymmetrical due to overarching energy

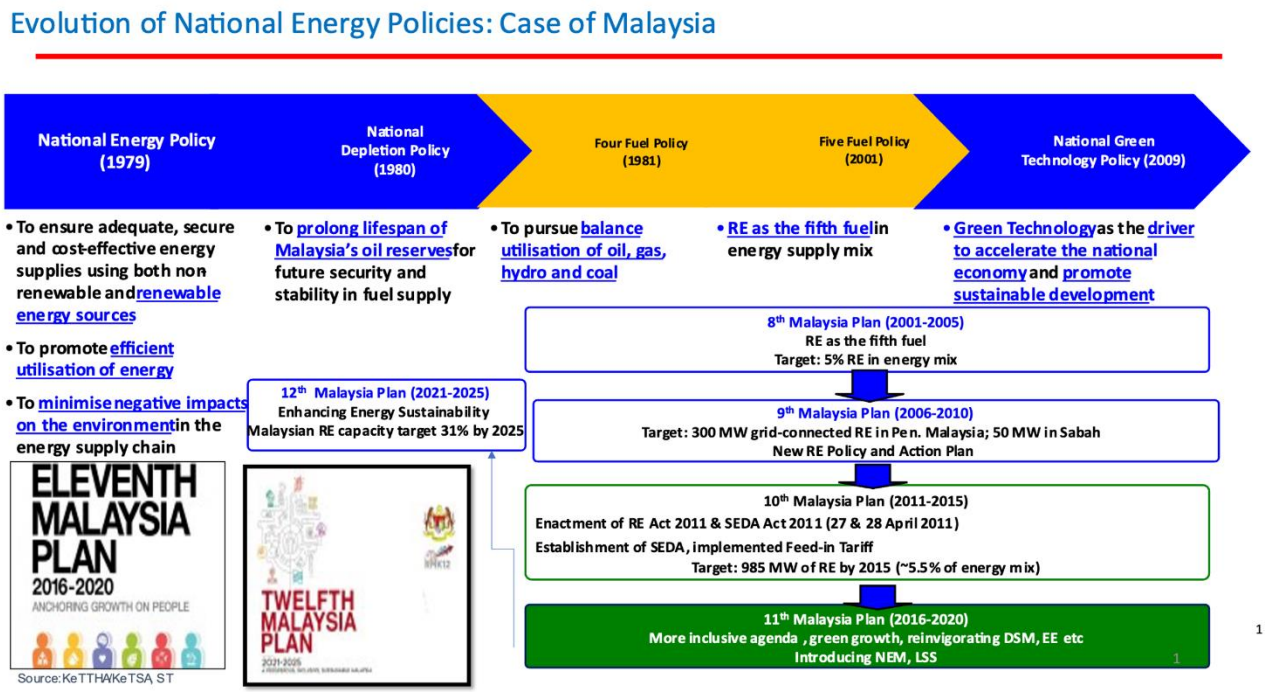


Figure 12 Evolution of national energy policies in Malaysia
Source: Author's own in unpublished internal sharing in EPU, 2021

requirements, legacy issues, and exogenous commitments, especially climate change. Energy is an essential element in any national economy and in the Malaysian case, it has been a crucial enabler due to its multiplier effects. In 2019, the energy sector, for instance, contributed approximately 28% of the national GDP and was responsible for a quarter of the total workforce. Currently, more than 8 million households have daily access to electricity. [4] Numerous measures have been undertaken to ensure the security of the energy supply since independence, and most recently laid out in Malaysia's 11th (2016-2020) and 12th (2021-2025) Energy Plans.

Managing paradoxes

Malaysia's Energy Policy 2021-2040 (Dasar Tenaga Negara 2021-2040) will be launched by 3rd quarter 2022. It has been designed to repurpose Malaysia's energy sector as the country transitions toward a **low-carbon future**. Energy planners should revisit the energy trilemma with greater advocacy for environmental sustainability, *viz* clean energy and fulfilling the aspirations as a low carbon nation by 2040 and zero emission greenhouse gas (GHG) by 2050. These aspirations will surely reinvigorate more conversation on greater clean energy and sustainability advocacy.

TNB has announced its sustainability pathway with an aspiration to achieve net zero emissions by 2050, in a pronounced move toward decarbonization and renewable energy (RE). The TNB aspiration is underpinned by a commitment to reduce 35% of its emissions intensity as well as 50% of its coal generation capacity by 2035. In addition, TNB has pledged to ensure revenue from coal generation plants does not exceed 25% of its total revenue. TNB will continue to improve efficiency at existing thermal plants, and build up scale in the renewable generation portfolio, targeting 8,300MW of RE by 2025.[5]

The general strategy has been to ensure affordable energy and electricity. Energy affordability is mostly embedded in energy conservation as it addresses the individual user or consumer. But there is a need to revisit energy security for uninterrupted fuel resources and supplies. Energy security correlates national security and availability of natural resources for energy consumption, but in the Malaysian context it is further defined as the provision of reasonably priced, reliable, and environmentally friendly energy. [6] Inadequate and uneven distribution of energy would lead to significant disadvantages and vulnerabilities. Connecting the decarbonization process to energy security, is not that straightforward and may not be stabilizing as a sufficiently high volume of base load plants for system stability is still required.

Energy improvement plans

The Peninsular Malaysia Generation Development Plan 2021-2039 is one the most important documents regarding energy planning, especially electricity. The key consideration is not limited to projection of demand and generation capacity, but also to monitor the progress on transmission project implementation and to support the government's policies in achieving 31% RE capacity by 2025.

Improvements are initiated via the Ministry of Energy (KeTSA) and the Energy Commission (ST) in the form of grid enhancement, energy efficiency, digitalization, and other initiatives. Both entities are entrusted to manage the industry as well as ensure a stable and affordable tariff as fuel prices constitute 65% of tariff. The regulator expects electricity demand of 24,050 MW in 2039, which can be trimmed by almost 1,000 MW by integrating demand side renewable sources at the distribution end.[7]

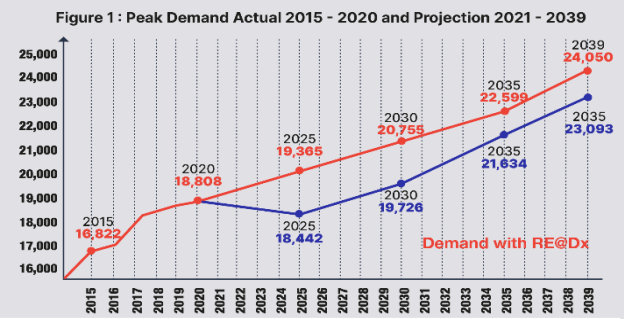


Figure 13 System demand 2015-2020 (actual) and projection 2021-2039
Source: ST

Measurement and monitoring

Nationally, the Energy Commission is tasked with regulatory measurement and surveillance. Energy items have also been regularly shared with Cabinet

[4] Department of Statistics Malaysia, 2019.
[5] Ibid.
[6] Halisah Ashari" Energy Security, Energy Efficiency, and Energy Dialogue" for Parliament of Malaysia 2013
[7] Report by Energy Commission (ST), March 2021

ministers if the issues require high-level decisions and intervention. Regionally, Malaysia is also a party to update developments under ASEAN Ministerial Energy Meeting (AMEM) and Senior Officials Energy Meeting (SOME) platforms using the ASEAN Plan of Action for Energy Cooperation (APAEC) technical working group modality.

Challenges and opportunities

Malaysia embarked on a sustainable and clean energy journey in the early 2000s but has since been reinvigorated to reflect a whole-of-nation approach due to its holistic and impactful planning approach. Along the way, numerous initiatives have taken place, some appeared to be duplicative, some parallel. Planners need to carefully ponder the complexities involved and yet bring out the essential elements of sustainability without losing sight of energy security and affordability. Every decision should reflect bold and 'no regret' position as there are economic benefits.

Clean energy transition

Rapid evolution in global megatrends such as energy transition will create a range of challenges and an array of opportunities for the energy sector as well as the broader economy. The vision of a decarbonized world offers a strong correlation between role of energy industry in climate mitigation as well as giving options for a decarbonization framework. Proponents of the new vision have called for countries to increase their stakes in decarbonization beginning with pledges—later becoming commitments—in the energy transition that would propel them to the next decades. Malaysia is not alone in this journey and needs to select its own path in navigating the challenges.

Planners need to be cognizant of global best practices and find the best elements in generation and grid planning. Resources might be selective, but planners should focus on indigenous resources first and on imported resources that are closer to Malaysia.

Clarity in the energy agenda

Malaysia's energy transition needs to be carefully navigated. Planners need to balance options and look for strategic midpoints and a favorable endpoint. Knowing that the pillars of the energy trilemma have always been demanding due to changing narratives, planners must address diverse and shifting priorities for the period 2022-2040 where there will be interplays or couplings among green growth, energy security, and affordability.

The conflict in Ukraine has had wide-reaching effects such as soaring energy fuel prices, which have put a strain on consumers around the world. Mobility of energy sources have been constrained, and energy prices have increased. Countries have to reorient toward or reinvigorate measures to achieve energy security.

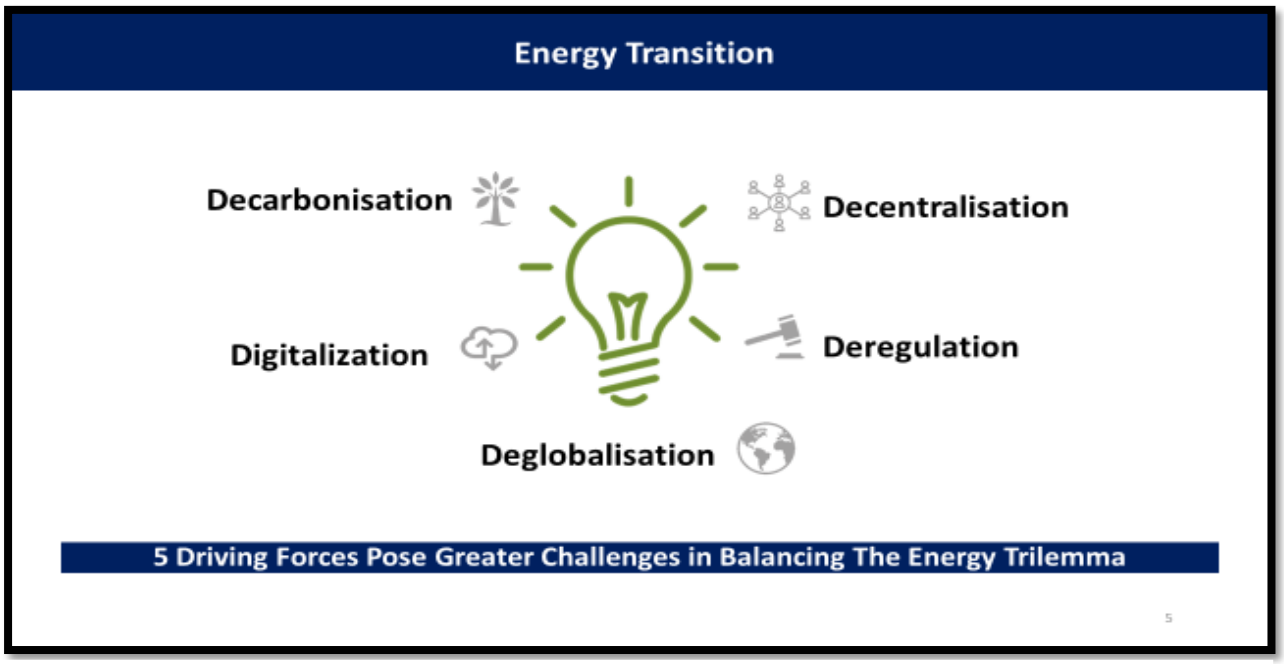


Figure 14 Elements of Energy Transition

These changes have also led to new opportunities to accelerate economic recovery with new energy and emerging technologies such as battery storage systems, hydrogen and digitalization, and in some cases harnessing indigenous resources such as hydro. Energy planners need to focus on technology selection. It is imperative to identify roles different technologies can play in meeting Malaysia's future energy needs. New technologies can have different multiplier effects, job-creating potential, and may require different skills. Innovative arrangements such as regulatory easing may be necessary.

Planners also need to pay attention to the financial details. There will be costs—both disruptive and planned. Some might be risky, and de-risking also means that costs need to be embedded. ESG-compliant and innovative Islamic/*shariah*[8]-compliant requirements must be included whenever possible. Consideration should be given to coexistence of different energy sources. Investment signals for energy infrastructure—FDI and even internal investment could come in various forms either more investments for conventional thermal (gas and even coal if required for energy security), RE (e.g., solar farms), green building requirement) etc. Fiscal policies may have to be adjusted and structural changes implemented to reflect contemporary needs.

New challenges have also emerged: spiraling energy prices and threats to energy security in various forms. Malaysia has been experiencing high costs for energy imports since the start of 2021. For instance, the price of coal, which typically makes up half of Malaysia's generation mix, has risen by an average of 76% every six months. The average price of natural gas rose to RM30/MMBtu in 1Q2022 from RM26.81/MMBtu in 4Q2021. There are calls for reduced dependence on fuel imports as well as greater scaling up and availability of smart and clean energy technologies. Planners need to address all these demands, but they must navigate carefully. The option to periodically revisit future generation scenarios in line with energy best practices should be kept open.

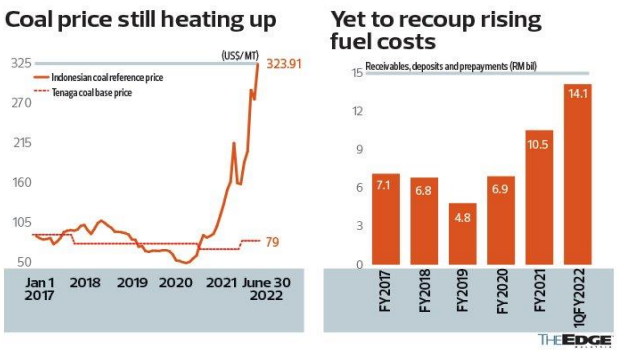


Figure 15 Prices of imported energy fuel. Source: The Edge 2022

Soaring energy prices have forced Malaysian planners to revisit their **base-load operations** and the short- medium- and long-term energy roadmap. The energy sector needs credible solutions and reliability. Yet, there are no short cuts or foreseeable solutions to high dependence on gas and coal. Geopolitical uncertainties could shave segments reserved for 'secured' imports (LNG and coal) and planners will have to respond. One might ask the following question: Would the Ukraine crisis prompt a return to ex-ante in the form of primacy of energy security over affordability and sustainability?

The nuclear energy option

The Non-Proliferation Treaty (NPT) Article IV acknowledges the right of all parties to develop nuclear power/energy for peaceful and civilian purposes. Therefore, civilian nuclear power plant (NPP) development is an option and Malaysia could benefit from international cooperation in this area, in conformity with its nonproliferation obligations. Nuclear energy could contribute to clean energy and environmental preservation. Some ASEAN member states have considered nuclear power as an option to meet energy requirements in certain phases of their energy journey.

Civilian nuclear energy in Malaysia has always been a secondary consideration. Mostly for non-technical reasons, nuclear energy has been repeatedly cast away from the main electricity supply picture. There was some seriousness in nuclear energy sporadically in the 1960s, 1970s, 1980s. Between 2005-2018 there were discussions and a commitment to ensure proper capacity planning that included sending students to study nuclear engineering in established institutions in Europe and the US. However, in 2018 the new government decided to de-emphasize nuclear power. As a result, the Nuclear Energy Program Implementing Organization (NEPIO) Malaysian Nuclear Power Corporation (MNPC), which was established as a vehicle to study the introduction of nuclear energy in the country, was disbanded. Although Malaysia is drafting a National Nuclear Technology Policy 2021-2030, the government has maintained its position of no nuclear power in the

[8] Islamic financial framework that is nondiscriminatory, non-profiteering.

country. Nevertheless, Malaysia has supported an action plan involving capacity building and cooperation with established international bodies such as IAEA.

Nuclear energy benefits

Introduction of nuclear energy in the generation mix would bring numerous benefits. First, it would bolster energy security. Proponents of nuclear energy claim that utility companies could use conventional nuclear power plants. In remote areas, small modular reactors (SMRs) could be used since nuclear plants are very reliable and have a high load factor. Second, nuclear energy offers energy/fuel diversification where the combination of nuclear with RE plus energy efficiency could effectively address the demand-supply gap. Strategically, nuclear could replace coal and even gas in the long-term (2040 onward as in the Malaysia energy landscape). Nuclear plants are also designed for lengthy life—at least 60 years, which may be extended after appropriate enhancement. This augurs well for its acceptance when compared to other conventional power plants. Third, the comparatively stable uranium price will ensure low and affordable electricity tariff in the grid. Uranium is also abundant as apparent from many energy resource estimations.

Fourth, nuclear power plants help mitigate climate change as they produce virtually no greenhouse gas emissions or air pollutants during their operation. Ultimately, any generation mix that incorporates nuclear power can help reduce greenhouse gas emissions while delivering energy to the grid in increasingly large quantities. Another advantage of nuclear is that it could blend with other clean fuels. It offers a feasible clean option with proven technology that could be used in conjunction with RE and natural gas/LNG to eventually replace coal.[9]

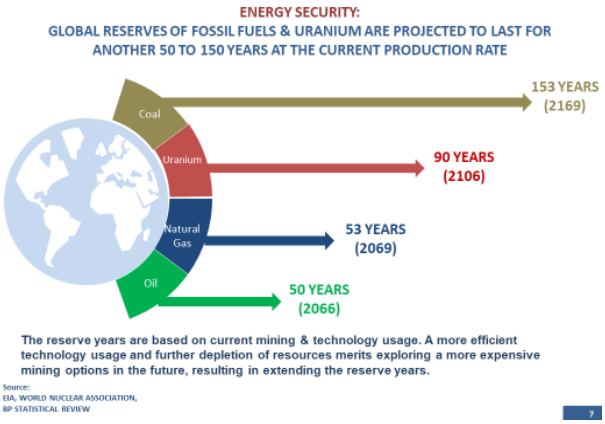


Figure 16 Global reserves of major fuel commodities

Energy planners could carefully lay out a dedicated exit strategy for fossil fuels via nuclear. Existing fossil fuel power plant sites, especially coal, could be repurposed with SMRs to facilitate clean energy transition. The advantage of SMRs is that they are small in size (50-300 MW), which is about one-third of the generating capacity of conventional nuclear reactors. Since they are modular, they would fit in nicely with any marginal requirement in the generation capacity mix. SMRs, as either a permanent or temporary solution, could also be utilized in addressing geopolitical and resource nationalism threats as these modular units require less time to install, i.e., three to five years, as compared to conventionally large size nuclear plants, which may take more than 10 years to build. Currently, according to IAEA, four SMRs are in advanced stages of construction in Argentina, China, and Russia. These SMRs are expected to be fully commissioned and operational within a year or two. Other countries, including newcomer nuclear energy countries, are conducting research and development on the technology.

Economically, nuclear energy would create multiplier effects that are potentially inclusive in nature by producing a high engineering base and knowledge workers in any country. It would also create a base to leapfrog into world-class safety culture, governance, placing Malaysia as a leading-edge technically competent nation, and a head start in knowledge economy.

Malaysian energy planners are very familiar with nuclear energy. There have been various attempts to introduce nuclear energy in the past and as recently as 2011-2018 via the NEPIO MNPC. The project team was involved in comprehensive feasibility studies including engineering, legal, and regulatory capacity

[9] It generates power through fission, which is the process of splitting uranium atoms to produce energy. The heat released by fission is used to create steam that spins a turbine to generate electricity without the harmful byproducts emitted by fossil fuels.

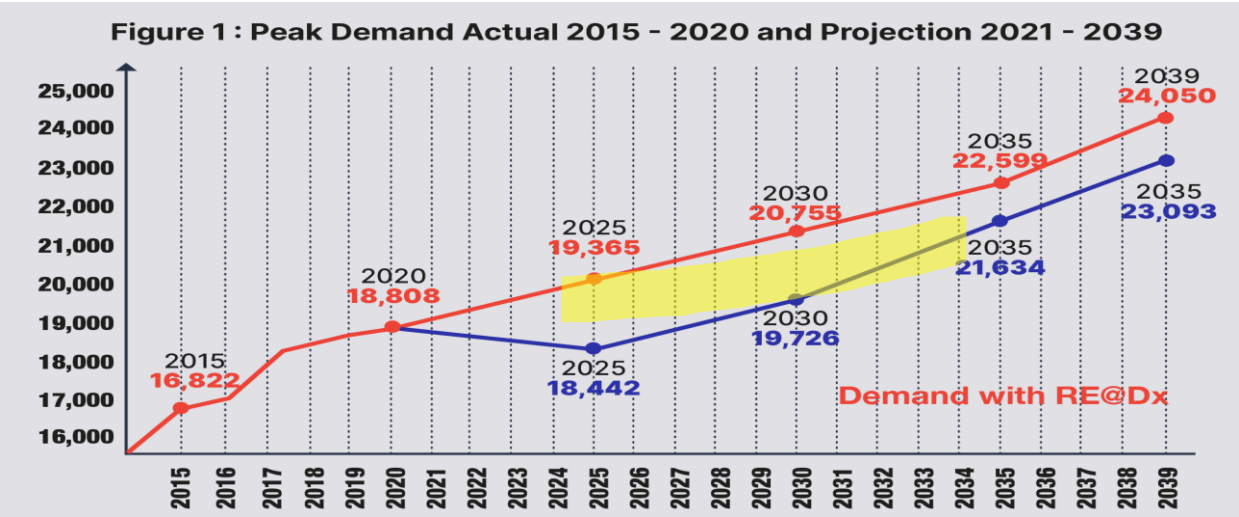


Figure 17 Meeting peak demand with substitutes

building, as well as public acceptance advocacy. The technical team developed a comprehensive engineering project design, technical testing methods, and even operations with US-based manufacturers. The legal and regulatory framework team was being trained and was developing the national nuclear energy bill. The Malaysian government has sent highly qualified engineering students to study nuclear energy abroad and created local nuclear engineering faculties.

Malaysia's foray into nuclear energy also included close cooperation with the International Atomic Energy Agency (IAEA) since 1969. Malaysia has been a long-time affiliate and has sent officials to work at the IAEA, including holding tops posts such as deputy director general as in the case of Dr. Noramly Muslim, the former director-general of the Malaysia Nuclear Agency. There has also been close collaboration and interdependence of agencies and stakeholders in managing nuclear security, safety and safeguards (3S), as well as environmental

Peaceful use /Technology			**Est of NDT Lab 1980; Est Dep of Nuclear Science UKM 1982**	**Est NAA Lab in 1983; Secondary Standard Dosimetry Lab (SSDL) 1982; National Radioactive Waste Mgt Centre 1984; Est of radioisotope production facility 1984; Atomic Energy LicensingAct1984**	**SINAGAMA 1989 est**	**ALURTRON 1989 est**	**Gamma Greenhouse 2005**	**IAEA Collaborating Centre (ICC) in radiation processing of natural polymer 2006-09; + nanomaterials 2010-2014; Cyclotron Putrajaya Hospital 2006;**	**IAEA ICC in radiation processing of natural polymer &nanomaterial 2016-2020; IAEA ICC for NDT 2015-2019**
1897 First X-Ray used in Malaya		**1969 Malaysia became member of IAEA**	**1972 Malaysia established PUSPATI – now Malaysia Nuclear Agency**	1MW TRIGA Research Reactor commissioned 1982 .					
	1964 Malaysia ratified PTBT	**1970 Malaysia ratified NPT**				1998 Malaysia signed CTBT		2008 Malaysia ratifed CTBT	2017 Msia signed TPNW; 2020 Malaysia ratified TPNW **Malaysia might not yet sign Convention on Nuclear Safety (CNS) but it has collaboration with Asian Nuclear Safety Network (ANSN)**
Non-Peaceful use									

Figure 18 Nuclear development incorporating both non-power and power.

protection. Malaysia has also established strong relationship with international nuclear fraternity (e.g., United States, China, Canada, Russia, Japan, South Korea, ERIA, etc.) In studying the nuclear energy option, Malaysia has also been involved in the subsector network of nuclear energy in the ASEAN Ministerial Energy Meetings (AMEM).

Malaysia has had a high regard for global efforts in nonproliferation, nuclear security, and nuclear disarmament, as demonstrated by signing and ratifying many agreements and nuclear protocols. Malaysia has signed and ratified the Nuclear Nonproliferation Treaty (1970), the Comprehensive Test Ban Treaty (1998), and the Treaty on the Prohibition of Nuclear Weapons (2017). The country also signed the Convention of Early Notification of a Nuclear Accident [INFCIRC/335] (1987), the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency [INFCIRC/336] (1987), the International Convention for the Suppression of Acts of Nuclear Terrorism (2005), Arms Trade Treaty (2013), the International Convention for the Suppression of Acts of Nuclear Terrorism (2005), and the IAEA Safeguards Additional Protocol (2005).

In addition, Malaysia was one of the ASEAN member states that introduced the Bangkok Treaty (or Southeast Asia Nuclear-Weapon-Free Zone (SEANWFZ)) in November 1971. This nuclear weapons moratorium treaty between 10 Southeast Asian member states under the auspices of the ASEAN was ratified 1996. Five of the original ASEAN members (Indonesia, Malaysia, Philippines, Singapore, and Thailand) met in Kuala Lumpur in 1971 and signed the declaration on ASEAN's Zone of Peace, Freedom and Neutrality (ZOPFAN) in 1971.

Nuclear Energy Disadvantages

Notwithstanding the benefits, Malaysia has also recognized of some negative issues associated with nuclear energy, including public acceptance, high investment costs, high technology dependence, the lack of a track record for SMRs, and strong lobbying by RE advocates.

First, public confidence was shaken by the Fukushima nuclear disaster in 2011. The spectre of a meltdown triggered debate and led to the closure of nuclear power plants and abandonment of new projects around the world. It also led to the resurgence of other plants especially gas and coal. The Fukushima incident also led to discussion on liability where the very existence of generation companies, utilities and even governments that have nuclear plants may be at stake due to the huge financial penalties for nuclear disasters.

Second, nuclear power plants, especially the conventional designs, are prohibitively expensive as they could cost twice as much as conventional fossil fuel power plants. This aspect could be a huge deterrent to any aspiring nuclear energy newcomer. The costs have been ballooning since there have been demands for additional design requirement in the aftermath of the Fukushima disaster. Although proponents of nuclear power may argue that the costs can be amortized to more than 60 years or beyond, huge working capital needs to be disbursed upfront for civil and structural work.

Third, there would also be huge technology dependence on nuclear plant manufacturers and suppliers since the knowledge and intellectual property associated with the engineering and design belong to them. The lack of capacity for newcomer countries to learn and master the engineering and design of these plants will deter –and even stifle – nuclear knowledge mastery.

Fourth, while SMRs' may mitigate some the current impediments, the lack of a track record may hinder their acceptance among energy planners. As part of best practices, any new technology should be established before large-scale deployment.

Fifth, RE advocacy and lobbying for it could dampen the rise of other conventional and new technologies. While the intent behind programs such as Malaysia Renewable Energy Roadmap (MyReR) 2020-2030 could see an astounding rise in RE in the generation capacity mix, they will gain traction among stakeholders and authorities at the expense of other technologies. Extreme lobbying by RE advocates have side-lined coal and even nuclear as they have gained momentum after 2016 Paris Agreement. The energy-climate nexus has exacerbated the debate on energy, but RE has been favored. A variety of advocates have been investing a lot of money in the push for more RE, which has narrowed the options to natural gas and nuclear with the exit of coal. The lobbying has clearly overshadowed some prevailing logic such as the need for reliability, resilience, and proven technologies.

Challenges for nuclear energy

The major challenge for energy planners is how to get the nuclear agenda back on track. First, nuclear advocates should make an effort to gain greater public buy-in and confidence. There should be a persistent initiative to monitor public opinion by carrying out surveys. Second, advocates need a strong government commitment. Third, there must be a mandate to revisit and solidify the legal and regulatory framework for nuclear energy. In Malaysia, energy planners and nuclear regulators may need to resuscitate the nuclear power segment in the original Atomic Energy Licensing Act.

Proponents should also highlight the compelling factors that make nuclear energy competitive as a clean energy alternative. The image of nuclear power plants as being too big and costly needs to eradicated by rebranding nuclear power as proven, scalable, clean source of energy and climate friendly. Energy planners need to be more imaginative in extolling the positive facets of nuclear plants including smaller and modular packages, i.e., SMRs.

Nuclear capacity building (HR, technology, knowledge etc.) is also importnat. The initiative to produce local nuclear engineering graduates and experts to complement those sent abroad should be pursued. In addition, authorities need to overcome technical/implementation challenges by reinstating the NEPIO-like body. The NEPIO is comprehensive, and it has the oversight of IAEA.

Another important task is to manage new threats to nuclear resurgence such as cyber security and proliferation. Planners should be well-versed with saboteur elements and other threats by keeping themselves abreast with international development as well as energy geopolitics. Authorities need to join internationally established groups to understand and appreciate the magnitude and gravity of the threats.

The regional energy masterplan in the form of ASEAN Plan of Action for Energy Cooperation (APAEC) Phase II: 2021-2025 was cast with aims to accelerate its energy transition and enhance energy resilience, while also ensuring its energy security. The heart of the plan is to seek a clear pathway to diversify its energy mix by introducing clean and reliable energy. In this context, nuclear could stand-alone and complement – as well as compete- with gas/LNG and RE.

Infrastructure

Malaysia is aware of the various facets of the infrastructure planning of a NPP as numerous exercises were carried out during the feasibility study of nuclear energy from 2011 to 2018. A technical, financial, and regulatory feasibility study, for the introduction of two 1,000 MW civilian NPPs by 2030, had commenced in 2011 by MNPC, the NEPIO. The nearly completed study was terminated in 2018.

Familiarization with nuclear infrastructure could be obtained via and training in nuclear power facilities. There are groups that cater to the mutual interest of nuclear control engineers as they may encounter trouble-shooting issues in daily work. However, there are IAEA guidelines for siting NPPs. Some best practices always include requiring local authorities to reserve certain land for future nuclear plant sites. Organizationally, a task force should be shaped after a NEPIO-like framework. The team should be empowered to liaise with all relevant authorities pertaining to nuclear project requirements.

Regulatory framework

Regulatory development is feasible in Malaysia since authorities are familiar with existing protocols – some of which are already signed. Malaysia was nearly finished revising the Atomic Energy Licensing Act 1984 (Act 304), including nuclear liability, when the nuclear energy portion was taken out and the bill was abandoned. Reintroducing this comprehensive act would catalyze tabling of other protocols and provisions of the International Atomic Energy Agency (IAEA) Convention on Physical Protection of Nuclear Material (CPPNM), and its 2005 Amendment Protocol, the International Convention for the Suppression of Acts of Nuclear Terrorism (ICSANT), the Additional Protocol to the IAEA Comprehensive Safeguards Agreement, and various IAEA Codes of Conduct.

Therefore, it is imperative for the government to follow through with signing the required protocols to avoid miscues and unwarranted objections to its nuclear power ambition.

Financial

Financial requirements are a customary exercise for any power plant project. As an NPP requires heavy investment, it would have to be government-sponsored and owned. The business model would

likely have to accommodate a lengthy loan-payment period or even an amortization scheme and a nuclear liability insurance scheme. The challenge is to ensure political will is present to introduce an NPP project into the power generation portfolio.

Technology

Nuclear plants have a long record of success and are transformational. Nuclear newcomer countries should be cognizant of various technologies that are available. While traditional fission technologies continue to dominate, new technologies are emerging such as SMRs, floating NPPs, and thorium. The world is also waiting for the commercial availability of fusion/fast breeder reactors. The biggest challenge with SMRs and other novel technologies is that while they might have great potential, many of them are in the infancy stages of development.

Public acceptance

Public outreach activities need to be persistent and consistent as gaining acceptance of nuclear power, especially if it involves new technology, may pose a problem among energy agencies and stakeholders. The message for nuclear energy as a clean option needs to be consistent and clear.

For Malaysia, the nuclear power agenda has remained in the background since 2018 but events in the energy landscape could force energy planners and other stakeholders to do some serious rethinking and keep the option open for nuclear post 2040. The challenge is to overcome the inertia of being inactive for the past several years and regain the momentum in driving a clear message that nuclear power is an attractive option for Malaysia. Energy planners and stakeholders could benefit by promoting energy literacy programs and extolling the value proposition of nuclear technologies.

Looking ahead

The ever-changing economic and energy dynamics require a flexible approach in managing short-, medium- and long-term scenarios. A new approach for energy planning is to strike a **balance between energy security, economic affordability and environmental sustainability**. While energy planners may be comfortable with conventional technologies, they also need to embrace new technologies in the electricity generation mix and resource options such as nuclear. The options have to be reliable, dependable and proven. Keeping options open and periodically revisiting future scenarios are necessary as the energy transition and crises are real and demand a timely response.

A prudent policy approach entails a **detailed collaboration framework with support from stakeholders, regulators, industries and consumers**. Newcomer countries like Malaysia, should acknowledge the support from well-established nuclear nations and entities especially those available in the ASEAN region notably ASEAN Network of Regulatory Bodies on Atomic Energy (ASEANTOM), and ASEAN Nuclear Energy Cooperation Sub-Sector Network (NEC-SSN) in the ASEAN Ministers on Energy Meeting (AMEM) framework.

Energy options, especially new technologies in power industry, need to be part of each country's energy literacy program. Public support for improving the country's energy profile will be a crucial element in moving ahead with energy infrastructure development.

Opportunities for regional cooperation abound. Interest in constructing more power plants may be buoyed by global and regional economic recovery. From Malaysia's perspective, the regional energy landscape has been subdued following the Covid-19 pandemic and economic slowdown. However, in anticipation of a gradual recovery in demand; the supply side is also hopeful of new development.

In the longer term (2050), we should anticipate a **reinvigorated ASEAN's appetite demand for energy**. The energy landscape is looking for a bright spark that may come from a major power investment in ASEAN. That would spur other players or stakeholders to ride the wave. Singapore has announced a potential foray into nuclear energy by 2050 to ensure it meets its zero emission target.[10] Other ASEAN member states may also follow suit if indicators in Philippines are accurate.[11]

Demand for energy within ASEAN is as good as trade. With ASEAN targeting a sizeable global economic share by 2030, i.e. from third to fourth largest, overtaking EU and Japan in the process,

[10] Energy 2050 Committee report, Energy Market Authority, Singapore, March 2022.

[11] Various chronicles during Government of President Duterte and as recent as public discussions in 2021.

several indicators are worth mentioning. According to the World Economic Forum (WEF), ASEAN will see an additional 140 million consumers, representing 16% of the world's new consumers.[12] Rapid growth in digitalization by 2030, with a recent estimate of 575 million internet users,[13] will also spur massive power consumption. In addition, the number of high- and upper-middle income households is expected to rise from 30 million in 2019 to 57 million in 2030.[14] A more staggering forecast is the remarkable rise in domestic consumption, which represents around 60% of ASEAN's gross domestic product (GDP) today, as it is expected to double to US$4 trillion.[15]

In this context, energy consumption will likely be a major focus. The projection of installed generation capacity should easily double by 2040 as compared to 2015[16]. Energy planners and analysts need to plan future infrastructure comprehensively.

With the spirit that no one is to be left behind, ASEAN member states will certainly aim for maximum electrification and reliability. Remote island states and regions such as those in Indonesia and the Philippines ought to be targeted as they need power as much as those in established capital areas and subregions. Countries that target rapid industrialization such as Vietnam will certainly aim for reliable power resources.

The energy crisis precipitated by the war in Ukraine could create demand for diverse energy resources. Energy planners may be desperate to obtain energy resources such as gas, coal, and RE. Nuclear power may still be a feasible option to pursue in medium-to-long term hastened by the needs to reduce coal use for the clean energy transition.

However, ASEAN countries are at risk of losing over 35% of its GDP by 2050 due to climate change and environmental disasters.[17] The overreliance on coal needs to end within the planning horizon. While accelerating the exit of coal could be a catalyst to hasten nuclear entry, there will always be questions regarding nuclear power scalability and right-sizing.

Enter SMRs, which could offer lower initial capital investment, greater scalability, and siting flexibility for locations unable to accommodate more traditional larger reactors. They also have the potential for enhanced safety and security. Having SMRs could also offer lower market risks as manufacturers could optimize designs and cut design costs.

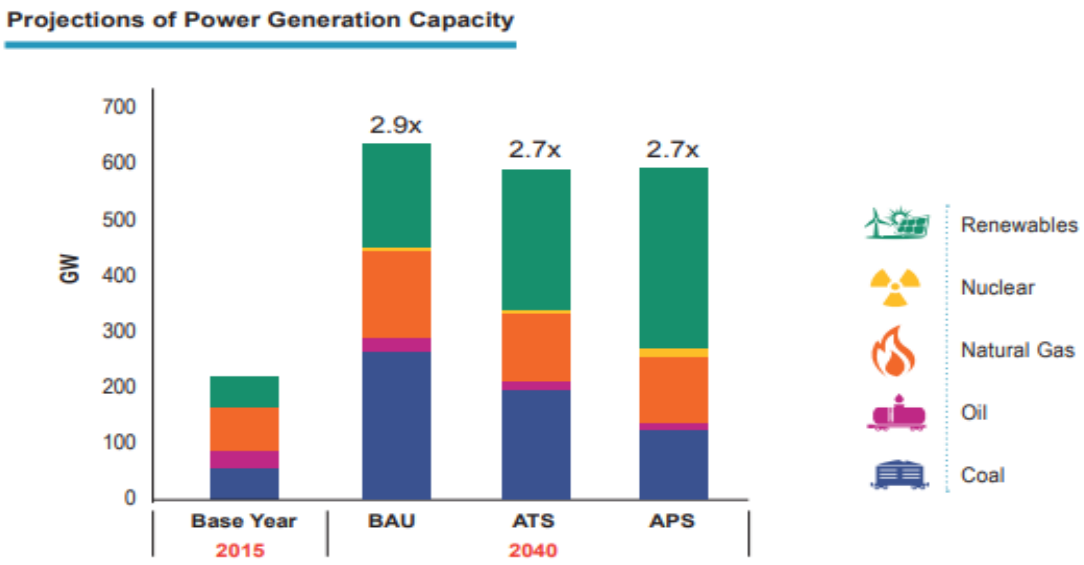


Figure 19 Projection of generation installed capacity.
Source: 5th ASEAN Energy Outlook (AEO5) 2015-2040

[12] WEF "Future of Consumption in Fast-Growth Consumer Markets: ASEAN". 2020
[13] https://theaseanpost.com/article/future-consumption-asean, November 2020.
[14] Ibid.
[15] Ibid
[16] 5th ASEAN Energy Outlook (AEO5) 2015-2040, ASEAN Centre for Energy (ACE) 2017
[17] ASEAN risks losing 35% GDP by 2050 from climate change (openaccessgovernment.org)

Grid expansion

Recognizing that the grid connection plan is equally important to the generation development plan, authorities need to assess and enhance the strength of national power grid or network on periodic basis. Mitigation plans and network reinforcement ensures the power system remains strong and resilient. Malaysia's energy sector also needs to pay attention to grid expansion to include modernization. Aging components such as switchgears and tower footings need to be replaced, refurbished and maybe upgraded.

the resilience and robustness of each grid and naturally augment cross border interconnection.

However, financial valuation and management of the grid remains a challenge. Since the utility companies are tasked with reinforcing the grid, it is costly and requires financial compensation from the regulators. The grid has a long return on investment period and is not routinely scrutinized for optimization. Similar issues will also rise for the interconnections where each participating party needs to apportion some budget for network maintenance and upgrades.

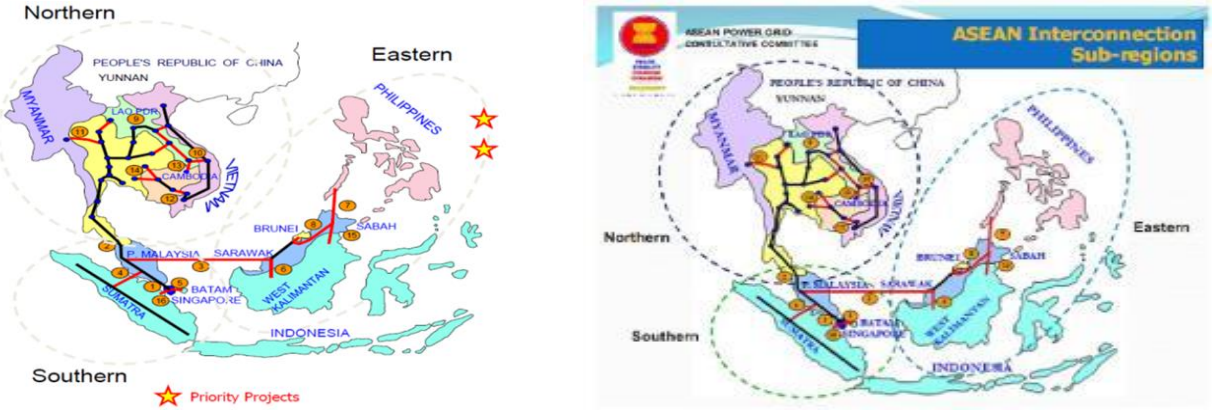


Figure 20 ASEAN Power Grid – existing and proposed interconnections including subregional development.

Malaysia needs to have the grid of the future i.e., smart grid with digital facilities. The digital facilities will ensure superior supply performance, while preventing intermittent supply interruption. In addition, consumers could be equipped with prior knowledge of consumption using the apps that the utility provides.

Malaysia also aspires to enhance regional interconnection through the ASEAN Power Grid. Although Malaysia is currently only connected to Thailand, Singapore and part of Kalimantan, Indonesia, the prospect of commissioning additional interconnections to Sumatera and Brunei looks promising in years to come. Network upgrades at the interconnection points at the borders of Thailand and Malaysia are feasible and these will augment the recently upgraded segments at the border of Malaysia and Singapore. These upgrades will facilitate greater involvement in the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS PIP), which is currently at the first phase of operations. As each national grid experiences organic growth in their transmission assets and system control facilities, they will increase

The future for energy planners is exciting as they have many options. First, the planners could go with existing energy resources. Second, they could embrace emerging energy resources and technologies. In both situations, planners know they have already begun their journey in the clean energy transition as the planning horizon reaches out to 2040, 2050 and beyond), aiming for the most sustainability-friendly options that navigate around energy security issues. The verdict is not in, but there are plenty of technology and energy resource options, and nuclear, with all its advancement in coming decades, is feasible and within the reach of most countries.

3

Myanmar's Energy Landscape

Shwe Yee Oo

Introduction

Myanmar is one of the least developed countries in the ASEAN region and has been struggling with economic deficits, underdevelopment, illiteracy, and various health and social issues. Insufficient power supply and power shortages in both rural and urban areas are no exception and a daily routine. Myanmar was regarded at its worst under the military regime from the early 1980s to 2010, as the country deteriorated in every aspect. There was new hope when the democratic transition began in 2011, and the population experienced freedom and a modest improvement in their daily life—until 2020. Electricity consumption increased during that period and the industrial sector progressed due to foreign direct investments, which facilitated a slight improvement in the country's economy.

In 2020, the country's GDP was US$78.93 billion and GDP per capita (Purchasing Power Parity) was $5,123.41, according to the World Bank.[1] Myanmar's economy mainly relied on agriculture and fishing (23.1%), industry (36.7%), and service (40.2%) in 2019[2], and its important industries include agricultural processing, wood and wood products, mining and minerals, tourism, and oil and gas. Although oil and gas are part of Myanmar's major industries, the country's current installed power generation mix consists mainly of hydropower (54%), natural gas (41%), coal (2%), oil (2%), and solar (1%).[3] The sectors consuming most of final energy in Myanmar are: industry (39%), residential (27%), transport (16%), and commercial (18%) as of 2020.[4] To understand more about Myanmar's energy/electricity sector, the paper will look at the country's energy supply and demand, energy policies, and challenges and/or opportunities.

Energy consumption in Myanmar

Energy consumption in Myanmar has increased tremendously since 2005. Before that, the country's consumption was at a slow elevation. The

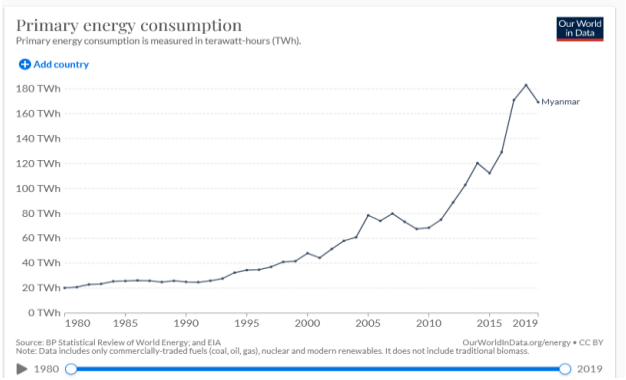


Figure 1 Primary energy consumption in Myanmar from 1980 to 2019

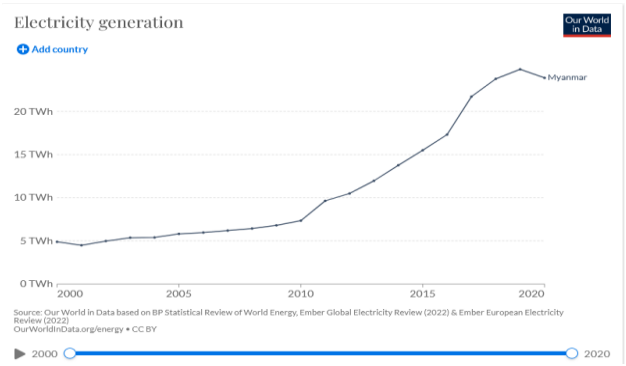


Figure 2 Electricity generation in Myanmar from 2000 to 2020

consumption in 1980s and 1990s went around 20 Terawatt hours (TWh) to 50 TWh. Starting from 2005, the energy consumption jumped, and it reached 180 TWh in 2018.

Despite the increase in energy consumption since 2005, electricity generation and consumption dramatically increased only after 2010.

The demand for energy and electricity is definitely rising. According to the Ministry of Electricity and Energy (MOEE), the annual demand for power consumption in Burma is increasing by 15% to 17%.[5] In the country's energy mix as of 2020, hydropower made up 52% of the total power generation (1,990 MW), natural gas made up 45% (1,722 MW), coal contributed 2% (76 MW), and solar generated 1% of

[1] Trading Economics, Myanmar GDP https://tradingeconomics.com/myanmar/gdp
[2] Myanmar Market Profile, HKDTC Research, 15 October 2021 https://research.hktdc.com/en/article/MzU4MDI4MzMz
[3] "Myanmar still losing billions of Kyats in power generation despite the increase in the price of electricity" (translated), Htet Naing Zaw, The Irrawaddy, 8 June 2020 https://burma.irrawaddy.com/news/2020/06/08/224249.html
[4] Economic Research Institute for ASEAN and East Asia (ERIA) and Myanmar Ministry of Electricity and Energy, Myanmar Energy Outlook 2020: Assessment of Future Simulation Results, ERIA Research Project Report FY2020 no.01, Jakarta: pp.33-48 https://www.eria.org/uploads/media/Research-Project-Report/RPR---Myanmar---2020/12_Chapter-6.pdf

[5] Burma - Country Commercial Guide, International Trade Administration, Department of Commerce https://www.trade.gov/country-commercial-guides/burma-energy

Source of supply	Hydro	Natural Gas	Coal	Diesel	Solar	Total
Installed capacity	3.262 MW (54%)	2,496 MW (41%)	120 MW (2%)	116 MW (2%)	40 MW (1%)	6,034 MW
Total generation	1,990 MW (52%)	1,722 MW (45%)	76 MW (2%)	-	40 MW (1%)	3,929 MW

Table 1 Total Installed Capacity and Total Generation Mix (2020)
Source: MOEE, International Trade Administration

total electricity (40 MW). The total power supply in 2020 was 3,828 MW.

Electricity supply and Myanmar's power plants

As for power supply, according to the MOEE, there were a total of 28 hydropower stations, 15 gas-fired stations, and three steam turbine stations generating electricity in Myanmar in 2019. In addition to the main power stations, there are sub-stations distributing power, including 29 hydropower sub-stations and 47 gas-fired power sub-stations.[6] Among the five steam turbine stations, one in Tikyit in Shan State is a coal-fired station.[7] The first commercial solar energy project, which launched the first phase in 2019 in Minbu, was aimed to produce 40 MW of power and add to the national grid system. The project was introduced by a Belgium-based organization, and it was part of Myanmar's long-term goal to achieve 100% electrification in 2030.[8] The solar project was also the pioneer project for the country's ambition to increase the share of renewable energy in the energy mix by 12% by 2025.

Besides the current running power plants, there are also a good quantity of proposed power projects. According to the country commercial guide from the International Trade Administration[9], the proposed power projects and their generation capacity are as below.

	Hydropower plants	Coal-fired power plants	Gas-fired power plants
Proposed plants	51	10	1
Proposed capacity	46,000 MW	7,994 MW	270 MW

Table 2 List of proposed hydropower plants in Myanmar

No	Commissioning year	Hydropower plants	Installed capacity (in MW)	Annual generation (in MW)
1	1974	Baluchaung 2	168	1,190
2	1989	Sedawgyi	25	134
3	1990	Kinda	56	165
4	1992	Baluchaung 1	28	200
5	1995	Zawgyi 1	18	35
6	2000	Zaungtu	20	76
7	2002	Thaphanzeik	30	117.2
8	2004	Monechaung	75	330
9	2005	Paung Laung	280	911
10	2007	Yenwe	25	123
11	2008	Kabaung	30	120
12	2009	Shweli 1	600	4,022
13	2009	Kengtawng	54	377.6
14	2010	Yeywa	790	3550
15	2011	Dapein	240	1,065
16	2011	Zawgyi 2	12	30
17	2011	Shwekyin	75	262
18	2012	Kyeeohn Kyeewa	74	370
19	2012	Kunchaung	60	190
20	2013	Chipwe Nge	99	433
21	2013	Nancho	40	152
22	2014	Baluchaung 3	52	334
23	2014	Thaukyekhet 2	120	604
24	2015	Myogyi	30	135.7
25	2015	Upper Paung Laung	140	454
26	2015	Phyuchaung	40	120
27	2017	Myittha	40	170
28	2019	Yarzagyo	4	N/A

Table 3 List of hydropower plants in Myanmar (2019)
Source: Myanmar Ministry of Electricity and Energy

No.	Hydropower plants under-construction	Installed capacity (in MW)
1	Shweli (3)	1050
2	Upper Yeywa	280
3	Deedoke	60
4	Upper Kengtawng	51
5	Upper Baluchaung	30.4
6	Middle Paung Laung	158
7	Thahtay Chaung	111

Table 4 List of hydropower plants under construction in Myanmar (2019)
Source: MOEE

[6] Myanmar Ministry of Electricity and Energy https://www.moee.gov.mm/mm/ignite/page/649
[7] https://ejatlas.org/conflict/tigyit-coal-power-plant-shan-state-myanmar
[8] The ASEAN POST Team, "Solar Power Use in Myanmar", The ASEAN Post, 10 January 2021 https://theaseanpost.com/article/solar-power-use-myanmar
[9] Burma - Country Commercial Guide, International Trade Administration, Department of Commerce https://www.trade.gov/country-commercial-guides/burma-energy

No	Commissioning year	Gas-power plants	Installed capacity** (in MW)	Annual generation*** (in MW)	Remark
1	2018	Myingyan	225	1500	
2	2015	Kyaukse	102	NA	
3	1974	Kyungchaung	54	12	
4	1980	Mann (Minbu)	36.9	0	
5	1985	Shwetaung	55.35	12	
6*	2016	Kyaukphyu	90	NA	
7	1975	Myan Aung	34.7	12	
8	2019	Thahton	169.95	NA	50.95 MW installed capacity in 1975
9	2014	Mawlamyaing	230	NA	
10	2022	Ywama	300.9	NA	70 MW installed capacity in 1980
11	NA	Thilawa	350	50	proposed to upgrade up to 1,250 MW in 2024
12	1995	Ahlone	154.3	50	
13	2020	Thaketa	477.1	400	Halted in 2021 due to financial problems
14	1996	Hlawga	154	40	
15	2015	Kanbauk	12	5	Initial capacity was of the plant was 6 MW

**Kyauk Phyu gas-fired power plant project consists of two gas power plants with generating capacities of 135 MW and 150 MW. The one that is expected to be fully operational in 2022 is the one with 135 MW generation capacity. The other plant with 150 MW generation capacity currently is producing 60 MW electricity, which is expected to generate at its full capacity after the construction of the gas kit that would supply gas to the power plant. In total, the Kyauk Phyu power plants are expected to produce a combined capacity of 285 MW.*

*** Installed capacity of each power plant varies according to the sources in different years. The capacity data in the table are taken from recent sources.*

**** Generation capacity from 2016*

Table 5 Gas-fired power plants according to the latest grid map of MOEE
Source: MOEE

Moreover, there are power stations and sub-stations under construction. Hydropower stations being constructed are listed as Table 4.

In May 2021, the Myanmar Investment Commission appointed by the military regime approved the US$2.5 billion Mee Lin Gyaing natural gas power project. The project is to be developed jointly by three Chinese companies - Yunnan Provincial Energy Investment Group Company Limited (39%), Union Resource and Energy Company Limited (41%), Zhefu Holding Group Company Limited (1%), and Myanmar's Supreme Group of Companies (19%). The project was initially expected to be completed by 2023 providing 35% of the electricity produced to the Ayayarwaddy region and the rest to Yangon.[10] The

[10] Myanmar Junta Approves 15 Investments, including US$2.5-billion Power Project, The Irrawaddy, 8 May 2021
https://www.irrawaddy.com/news/burma/162007.html

installed capacity of the Mee Lin Gyaing power project is 1,390 MW and the power produced is projected to be transmitted via 500 kV transmission lines, which are to be constructed in the Ayeyarwaddy region and in the Yangon division. Other facilities that are projected for the Ayeyarwaddy region include an LNG-fired power plant, an LNG terminal, and gas pipelines to Yangon. The project is currently in its early stages of design and construction and is expected to begin commercial operation in 2027.[11]

No.	Gas-fired power plants under-construction	Installed capacity (in MW)
1	Kyauk Phyu	135
2	Mee Linn Gyaing	1,390
3	Kanbauk	1,230

Table 6 List of gas-fired power plants under construction
Source: Ministry of Electricity and Energy

No.	Commissioning date	Coal-fired power plant	Installed capacity	Available capacity
1	2005	Tygit (Tikyit)	120 MW	27 MW

Table 7 Coal-fired power plant in Myanmar
Source: Myanmar Energy Sector Assessment, Strategy and Roadmap, Asian Development Bank https://www.adb.org/documents/myanmar-energy-assessment-strategy-road-map

According to the MOEE's power grid map, there are steam turbines in addition to the above-mentioned coal-fired, gas-fired and hydropower plants. Three are marked on the map in the Yangon division around Thakayta, Innsein, and Shwepyithar townships.
(See https://www.moee.gov.mm/en/ignite/page/641)

Regarding power lines, those that are currently connected to the national grid system include 230 kV, 132 kV, and 66 kV transmission lines. The new grid line with a 500 kV capacity carrying electric power from the Mee Lin Gyaing hydropower plant is under construction according to the MOEE. Though, the projected timeline to accomplish the construction of transmission lines cannot be determined due to the pandemic and political instabilities in the country.

The first commercial solar power plant in Minnbuu, which was launched in 2019, is expected to add 170 MW of electricity to the existing national grid. According to the project developer, Thailand's META Corporation, the plant is built on over 836 acres of land, aiming to be the largest solar plant in ASEAN. The plant is projected to be constructed in four phases - the first three phases producing 40 MW electricity and the last phase 50 MW - capable of producing a total of 350 million kWh annually, which can electrify about 210,000 households.[12] According to local media reports, the MOEE floated a tender for 29 solar power plants targeting a total of 1,030 MW of power generation.

In Myanmar, biomass is only used in rural areas for cooking and heating, and it is still difficult to see economic profits from them.[13] Myanmar's first rice-husk power plant with 0.5 MW production capacity[14] was launched in March 2017 near Nay Pyi Taw with the help of the Ministry of Environment of Japan the Yanmar Company, a Japanese agricultural machinery manufacturer.[15] The electricity produced by the power plant is used in the rice mill, which is next to the plant. Surplus electricity would be distributed to nearby villages. The corporation also mentioned that it aimed to launch a 2.2 MW rice-husk power generation factory in Kyaiklat, and a 1.6 MW factory in Myaungmya, both in Ayeyarwaddy region but no further information could not be gathered on the development of the two projects.

Access to electricity, power demand and supply

The electricity demand in the country was growing by 15% each year according to The ASEAN POST in 2019.[16] Recent estimates by the World Bank indicate that electricity consumption in the country will grow at 11% annually until 2030 with peak demand expected to reach 12.6 GW by 2030. To capture the

[11] Peter Carlisle, "Myanmar proposes to include $2.5-bn Mee Lin Gyaing project in early projects of China-Myanmar Economic Corridor", Thailand Construction News, 28 April 2022 https://thailand-construction.com/myanmar-proposes-to-include-2-5-bn-mee-lin-gyaing-project-in-early-projects-of-china-myanmar-economic-corridor/
[12] The ASEAN Post Team, "Solar Power shines in Myanmar", The ASEAN Post, 28 July 2019 https://theaseanpost.com/article/solar-power-shines-myanmar
[13] Maw Maw Tun, Dagmar Juchelkova, "Biomass Sources and Energy Potential for Energy Sector in Myanmar: An Outlook", Resources, 28 May 2019 https://www.mdpi.com/2079-9276/8/2/102/htm
[14] Thiha, Myanmar opens first biomass power plant, Consult-Myanmar for fruitful investment in Myanmar, 3 April 2017 https://www.consult-myanmar.com/2017/04/03/myanmar-opens-first-biomass-power-plant/
[15] Htoo Thant, "Rice husk power plant opens in Myanmar", Myanmar Times, 28 March 2017 https://www.mmtimes.com/national-news/nay-pyi-taw/25477-rice-husk-power-plant-opens-in-myanmar.html
[16] The ASEAN POST Team, "Solar Power Use in Myanmar", The ASEAN Post, 10 January 2021 https://theaseanpost.com/article/solar-power-use-myanmar

growing demand, the country will need to invest US$ 2 billion per year.[17] The country's electricity production in 2019 was around 3.6 GW[18] and 54% of the country was electrified, which means at least 23.5 million people do not yet have reliable electricity (that can be interpreted to mean that approximately 5 million households were in need of electricity).[19]

The World Bank's Energy Access Diagnostic Report published in 2019 noted that 86.5% of households have access to at least one source of electricity—through the national grid or through off-grid solutions.[20] The off-grid solutions include solar home system (SHS), which can power a television or a fan; solar lighting system (SLS), which can provide lighting or charging mobile phones; rechargeable batteries; and mini-grids. Off-grid solutions are crucial as they provide access to electricity for rural households that are rarely connected to the national grid. Only 22% of rural households have access to the national grid while 85.3% of urban households are connected to it. As a result, rural households (up to 61% of households from the rural area) adopt off-grid solutions, while 11% of urban households use them. For cooking, 33.8% of urban households use electric stoves exclusively, 22.4% use electric stoves in combination with biomass stoves (either one as a primary stove or a supplementary stove). In rural areas, firewood is very common and 58% of households use three-stone stoves, 15.9% traditional stoves, 13.2% use improved stoves, 7.5% use electric stoves and biomass stoves in combination, and only 4.5% use electric stoves exclusively.

Regarding prospective electricity consumption, according to an Economic and Research Institute for ASEAN and East Asia (ERIA) report on Myanmar Energy Outlook 2020[21], the consumption of electricity in industry will increase by 7.7%, in the residential sector by 6.4%, and in the commercial sector by 7.3% per year. The demand for electricity will increase by 7% per year and it will reach 6.7 Mtoe (million tons of oil equivalent) in 2040. Regarding the power supply, the power generation in 2016 was 20.3 TWh of which hydropower made up 59.9%, natural gas made up 39.7%, and coal, oil, and solar made up the rest. ERIA estimated that the power generation in 2040 would reach 89.4 TWh with a growth rate of 6.4% per year. It is projected that hydropower will be playing a major role but its share in the power generation mix will be declining. Power production from natural gas is estimated to increase to 51% and hydropower to decrease to 47%. The growth of power generation from renewable energy is estimated to be the fastest at an average rate of 22.3% per year due to the national plan to increase renewable energy shares in the power generation mix.[22]

However, the electricity supply figures changed significantly after the February 2021 coup: power generation decreased notably in 2022 resulting in extreme load shedding throughout the country. In March 2022, merely over 2100MW (about 50% reduction from the pre-coup average daily peak generation of 4200MW) was supplied to the national grid. Monthly electricity generation has been declining about 30% since October 2021. The decrease in power generation mainly is due to the closure of LNG power plants (400MW LNG power plant in Thakata and 350MW plant in Thilawa SEZ Thanlyin) because of surging LNG price and the depreciating Kyat, damages of power infrastructures and delayed repair because of human resources constraints, and low water level in hydropower reservoirs. Many townships connected to national grid as well as mini grid are experiencing power shortages.[23]

[17] World Bank Group, Myanmar Economic Monitor, Building Reform Momentum, June 2019 https://openknowledge.worldbank.org/bitstream/handle/10986/31934/Building-Reform-Momentum.pdf?sequence=1&isAllowed=y pg.12.

[18] Idem

[19] Richard Harrison, Matthew Arnold, « The Challenge of Electrifying Myanmar's Households », Myanmar Times, 13 November 2020 https://www.mmtimes.com/news/challenge-electrifying-myanmars-households.html

[20] Bryan Bonsul Koo, Han Kyul Yoo, Sandra Keller, Dana Rysankova, Elisa Portale, Myanmar Beyond Connections, Energy Access Diagnostic Report based on the Multi-Tier Framework, World Bank Group, May 2019 https://openknowledge.worldbank.org/bitstream/handle/10986/32381/Myanmar-Beyond-Connections-Energy-Access-Diagnostic-Report-Based-on-the-Multi-Tier-Framework.pdf?sequence=1&isAllowed=y

[21] Myanmar Energy Outlook 2020, ERIA Research Project Report 2020, No.1, Prepared by Oil and Gas Planning Department and Ministry of Electricity and Energy, Supported by Economic Research Institute for ASEAN and East Asia, May 2020 https://think-asia.org/bitstream/handle/11540/12331/Myanmar-Energy-Outlook-2020-Full-Report.pdf?sequence=1

[22] Economic Research Institute for ASEAN and East Asia (ERIA) and Myanmar Ministry of Electricity and Energy, Myanmar Energy Outlook 2020: Assessment of Future Simulation Results, ERIA Research Project Report FY2020 no.01, Jakarta: pp.33-48 https://www.eria.org/uploads/media/Research-Project-Report/RPR---Myanmar---2020/12_Chapter-6.pdf

[23] World Bank Group, Myanmar Economic Monitor, Reform Reversed, July 2022 https://pubdocs.worldbank.org/en/597471658359366101/July-MEM-2022-Final.pdf pg. 12-13

Tier 0	Electricity is not available or available less than four hours a day. Households use candles, lamps, or battery-powered devices.
Tier 1 (3W – 49W)	Electricity is available for four hours a day, including at least one hour in the evening. The electric capacity is enough to power lighting and charging phones or a radio.
Tier 2 (50W – 199W)	Electricity is available for at least four hours a day, including two hours in the evening. The electric capacity is sufficient to power low-load appliances (such as television, fans, and multiple lights, etc.).
Tier 3 (200W – 799W)	Electricity is available for at least eight hours a day, including three hours in the evening. The electric capacity is sufficient to power medium-load appliances (such as refrigerator, air cooler, rice cooker, etc.).
Tier 4 (800W – 1999W)	Electricity is available for at least 16 hours a day, including four hours in the evening. The electric capacity is sufficient to power high-load appliances (such as microwave, washing machine, iron, etc.). At this stage, the grid connection is legal and there is no long unscheduled interruption.
Tier 5 (2,000W – more)	Electricity is available for at least 23 hours a day, including four hours in the evening. The electric capacity is sufficient to power very high-load appliances (such as air conditioner, electric stove, vacuum cleaner, etc.) as needed.

Table 8 World Bank Multi-Tier Framework
Source: The World Bank

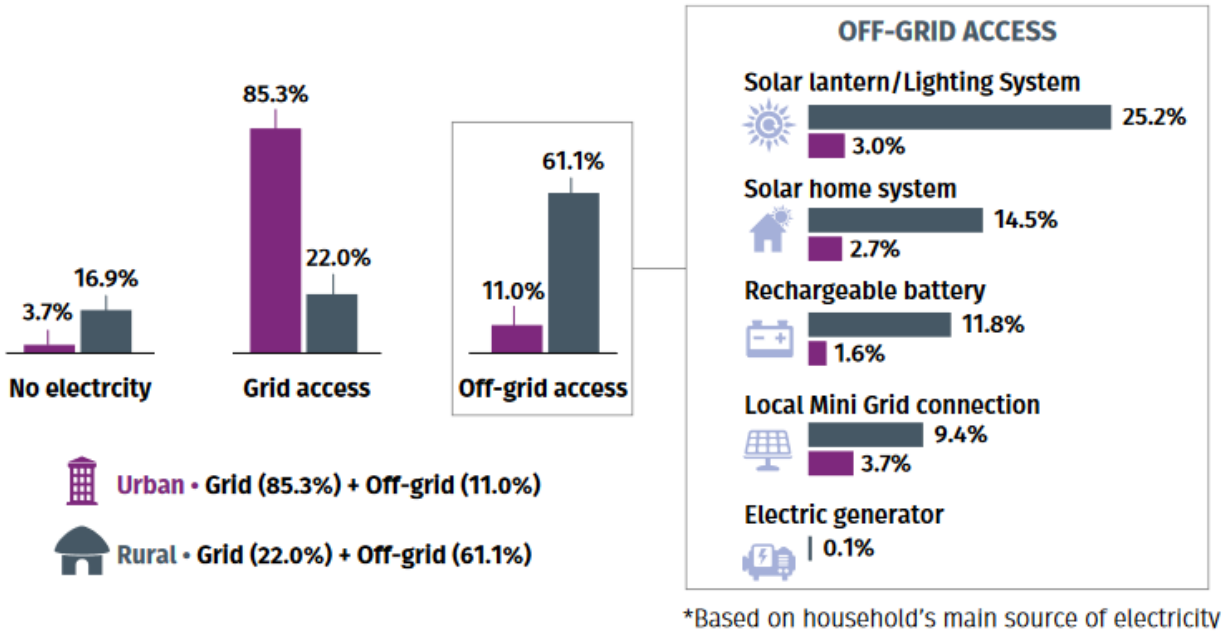


Figure 1 Urban/rural access to electricity by technology
Source: Myanmar Beyond Connection, WB Group

World Bank's Multi-Tier Framework survey

The World Bank conducted a survey[24] on the access to electricity for the implementation of its Multi-Tier Framework in Myanmar in 2017. The survey was done in an equal ratio of electrified and non-electrified households in an equal allocation of urban and rural areas. The Multi-Tier Framework is a form of measuring access to energy by the households according to the different tiers.

While 86.6% of households have access to at least one source of electricity, 38.6% get access through the national grid and 48% via off-grid solutions. Off-grid solutions include solar home system (11.4%), solar lantern or solar lighting system (19.4%), rechargeable batteries (9.2%), communal or isolated mini-grid system (7.9%). The electricity access in urban and rural households according to different systems is reported in the diagram by the World Bank below.

Nationwide access to electricity through different systems can be found in the diagram below. The average tier among urban households for electricity access is Tier 3.6 while the average tier among rural households is Tier 1.6.

Electrical energy policy framework and energy improvement plans

The MOEE is the key actor in implementing policies and regulations regarding electrification, foreign direct investments, oil and gas development, and establishing the National Electrification Plan (NEP) and the Myanmar Energy Master Plan (MEMP). Concerning the electricity and electrification, there are seven departments working under MOEE co-operating on projects and plans – 1) the Department of Electric Power and Planning (DEPP), the Department of Hydropower Implementation (DHPI), the Department of Power Transmission and System Control (DPTSC), the Department of Electric Power Generation Enterprise (EPGE), the Department of Electricity Supply Enterprise (ESE), the Yangon City Electricity Supply Corporation (YESC), and the Mandalay Electricity Supply Corporation (MESC). The Ministry of Planning, Finance and Industry (MOPFI), the Myanmar Investment Commission (MIC), the Ministry of Natural Resources and Environmental Conservation (MoNREC), and the National Commission for Environmental Affairs (NCEA) also play a significant role in the electricity and energy sector in Myanmar.

The MEMP was launched in December 2015. The study was done mainly with the help of the government of Japan and the Asian Development Bank. The plan provides forecasts and the estimation of energy consumption and rate of electrification,

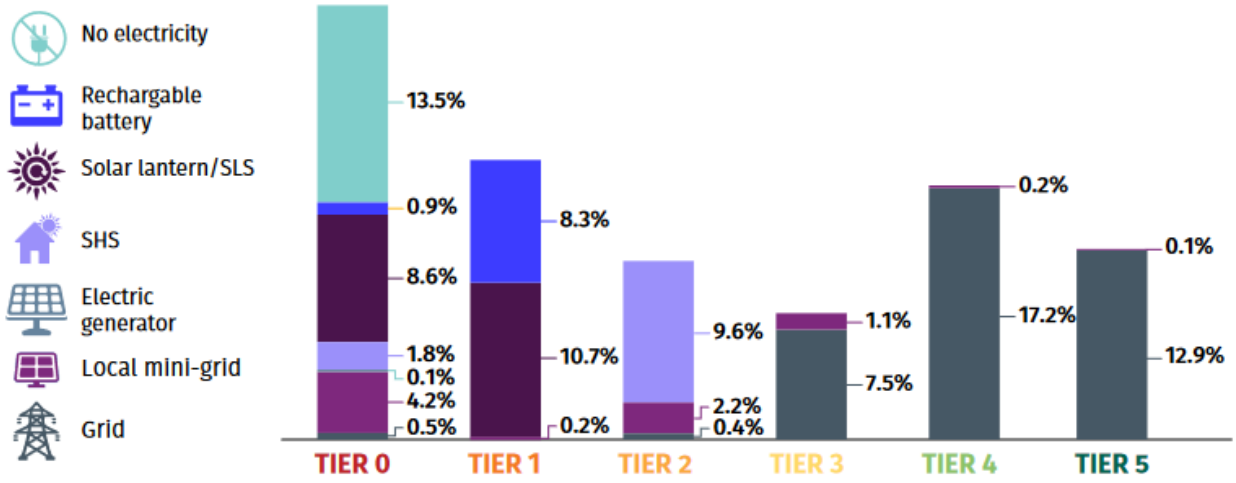


Figure 2 Nationwide access to electricity by technology
Source: Myanmar Beyond Connection, World Bank Group

[24] Bryan Bonsul Koo, Han Kyul Yoo, Sandra Keller, Dana Rysankova, Elisa Portale, Myanmar Beyond Connections, Energy Access Diagnostic Report based on the Multi-Tier Framework, World Bank Group, May 2019 https://openknowledge.worldbank.org/bitstream/handle/10986/32381/Myanmar-Beyond-Connections-Energy-Access-Diagnostic-Report-Based-on-the-Multi-Tier-Framework.pdf?sequence=1&isAllowed=y

Location of candidate coal-fired power plant projects	Planned Capacity	MOU signed on
Htan Ta Bin Township	270 MW (phase 1), 270 MW (phase 2), 300 MW (phase 3)	2010
Kyun Gyan Gon Township	300 MW (phase 1) & 600 MW (phase 2), 600 MW (phase 3	2012
Thilawa Industrial Zone	1,200MW (phase 1), 2,000MW (phase 2), 3,000 MW (phase 3)	2013
Kyauk Tan Township	500 MW	2013
Shwe Lin Ban Industrial Zone	1050 MW	Proposal stage
Kale District	270 MW (phase 1) & 270 MW (phase 2)	2010
Myeik Township	50 MW	2012
Kawthaung Township	250 MW (phase 1) & 250 MW (phase 2)	2012
Dawei Special Economic Zone	400 MW (phase 1) & 3,600 MW (phase 2)	Proposal stage
Ngayok Kaung Township	540 MW or 600 MW	2013
Keng Tong Township	25 MW	2013

Table 9 List of candidate coal-fired power plant projects
Source: MEMP

supply strategies for a secure and reliable energy mix, energy efficiency in different case scenarios, establishment of an effective investment environment, employment of innovative technologies, and minimization of the social and environmental impacts. Myanmar, interestingly, has been attempting to develop greener energy throughout the years compared to its neighboring countries. The MEMP states that the country will attempt to achieve 100% electrification by 2030, mainly through hydropower, renewable, natural gas, and coal.

Hydropower, being the major source of electricity, is projected to grow its share in the energy mix by 2030. It is stated in the MEMP that about 46 GW of new hydropower capacities are planned by 2030 and beyond. Despite the ambitious plan for hydropower development, private hydropower projects became subject to public scrutiny due to the social and environmental impacts. The China-backed Myit Sone Dam Project (which is now postponed) is the case in point of people's increasing resistance to private hydropower projects.

Solar power plant projects are regarded as a complementary electricity resource during the dry season when there is less water in reservoirs. Solar energy is targeted to reach 12% by 2025. With the initial phase of the first solar power plant having been launched, the renewable energy share in the mix is progressing. The MEMP mentions that a memorandum of understanding was signed with the investors from the US for a solar power project in Myanmar including two facilities—one in Nabuai and one in Wundwin—both in the Mandalay region. There are no reported updates for the project. The first completed solar project in Minbu was funded and developed by a Chinese company and launched the initial 50 MW phase in 2019.[25] (In May 2022, the junta canceled the tenders offered under the former civilian government for 26 solar projects. [26] Developing solar and hydropower plants are shown above in the table as well as in the final report of MEMP. There may be a difference in the number of projects due to the latest changes throughout the year on the ground before and after the coup in Myanmar.)

Myanmar's natural gas plays a significant role in power generation. Proven gas reserves are believed to be insufficient for the demands from various sectors of the country's economy, including the power generation sector. Considering the current gas-based power plants and those under construction/development, the consumption of gas

[25] Max Hall, « Myanmar connects its first utility scale PV project », PV Magazine, 2 July 2019 https://www.pv-magazine.com/2019/07/02/myanmar-connects-its-first-utility-scale-pv-project/

[26] « Myanmar Junta Cancels Chinese-Backed Solar Powered Projects », The Irrawaddy, May 2022 https://www.irrawaddy.com/news/burma/myanmar-junta-cancels-chinese-backed-solar-power-projects.html

by the power plants can reach 300 million cubic feet per day when they are in operation simultaneously. If this capacity-need continues, the consumption of gas will reach 1,000 million cubic feet per day by 2030. This requirement can only be met by importing LNG. Due to increasing long-term costs, LNG can be an expensive option. Thus, the country is willing and planning other options for power generation.

Coal is obviously an option and there is one coal-fired power plant in the country. According to the MEMP, there are 11 candidate projects for coal-fired power plants in Yangon, Sagaiang, Tanintharyi, Ayeyarwaddy, and Shan State.

Location of candidate coal-fired power plant projects	Planned Capacity	MOU signed on
Htan Ta Bin Township	270 MW (phase 1), 270 MW (phase 2), 300 MW (phase 3)	2010
Kyun Gyan Gon Township	300 MW (phase 1) & 600 MW (phase 2), 600 MW (phase 3	2012
Thilawa Industrial Zone	1,200MW (phase 1), 2,000MW (phase 2), 3,000 MW (phase 3)	2013
Kyauk Tan Township	500 MW	2013
Shwe Lin Ban Industrial Zone	1050 MW	Proposal stage
Kale District	270 MW (phase 1) & 270 MW (phase 2)	2010
Myeik Township	50 MW	2012
Kawthaung Township	250 MW (phase 1) & 250 MW (phase 2)	2012
Dawei Special Economic Zone	400 MW (phase 1) & 3,600 MW (phase 2)	Proposal stage
Ngayok Kaung Township	540 MW or 600 MW	2013
Keng Tong Township	25 MW	2013

Table 10 List of candidate coal-fired power plant projects

The country has selected three types of coal-fired power units – 1) 600 MW supercritical, 150 MW circulating fluidized bed, and 50 MW pulverized coal-fired unit for further expansion planning. As there are environmental and social impacts of coal, the MEMP suggests that the projects should be implemented with much attention. The availability of coal for the above planned coal-fired power plants is also a critical matter. The estimated annual consumption of coal by a 300 MW coal-fired power unit is around 1.3 million tons and over the lifespan of the power plant, the consumption would go up to 39 million tons. For the above-mentioned candidate coal-fired power plant projects, the domestic supply of coal would not be sufficient in the long term. The largest coal reserve in Myanmar is in Shan State with 118 million tons. The largest deposit of sub-bituminous coal is in Sagaing region with the capacity of 87 million tons. Compared to the prospective need of coal supply to the coal-fired power projects, the current domestic reserves alone cannot fulfill the consumption need.[27] The master plan recommends carrying out the projects in conjunction with mining development so the supply to power plants could be sustained.

State/Region	Capacity (MW)
Kachin State	42
Kayah State	10
Karen	139
Chin State	41
Mon State	94
Rakhine State	357
Shan State	184
Yangon Region	76
Mandalay Region	264
Ayeyarwaddy Region	395
Bago Region	251
Magway Region	296
Sagaing Region	332
Tanintharyi Region	119
Naypyitaw	36

Table 11 Residential need for electricity generation Source: NEP (2014)

Myanmar's Electrification Plan or National Electrification Project (NEP)[28] was developed to achieve nationwide access to electricity by 2030. The World Bank Group funded and closely engaged with the MOEE, and the Ministry of Agriculture, Livestock and Irrigation (former Ministry of Livestock, Fisheries and Rural Development) in preparation and implementation of the NEP. Plan preparation began in 2013, the draft was launched in 2014, the World Bank approved it in 2015, and implementation started in 2016. The plan contains two components: 1) Geospatial Least-Cost Electrification Rollout Plan, and 2) Roadmap and Investment Prospectus. The Geospatial Rollout Plan is comprised of 1) systematic grid network rollout connection plan, 2) complementary spatial plans for mini-grids and, 3) individual Solar Home Systems. The plan's approach is to make the grid extension reach out to the States—especially to the densely populated areas first, remote areas later, and mountainous areas (such as Chin, Kachin, Kayah and Shan States that will have the

[27] Myanmar Energy Master Plan, Asian Development Bank, Intelligent Energy System, Myanmar International Consultants, December 2015 https://policy.asiapacificenergy.org/node/2923 pg. 590-591

[28] Myanmar National Electrification Program (NEP), Roadmap and Investment Prospectus, Castalia Strategic Advisors, September 2014 https://www.seforall.org/sites/default/files/Myanmar_IP_EN_Released.pdf

highest cost per connection) in the final phase. For the areas where the grid extension will reach later, the NEP projects the development an off-grid system in the short- and medium-term as a pre-electrification option.

According to the NEP (2014), the new electricity-generation-capacity needed to reach the modest residential need shown in Table 11.

The table reflects only residential demand; the generation capacity would go higher for further commercial and industrial demands. Regarding the pre-electrification option, the NEP proposes mini-grids system for large villages and solar home systems for small villages. For the first five-year phase (2016-2020) of project, the NEP forecasts that US$700 million would be needed for the project ($670 million for capital investment and $30 million for technical assistance). For the poorer of the poor, the NEP recommends subsidies (the smallest with the highest percentage of subsidies) for the basic needs of lighting and ICT. Regarding communities participating in the off-grid system, the villages would have to form a Village Electrification Committee, which will be provided guidelines by the Department of Rural Development (DRD). The World Bank approved US$400 million in September 2015 for the National Electrification Project.

The grid expansion includes expansion of existing medium voltage substations and new substations, construction of 12,900 miles of medium and low voltage lines, 772 MVA of medium and low voltage transformers and 11,600 community connections, 750,000 household connections, and 132,000 public lights. The off-grid electrification plan (mini-grid and individual home solar systems) is projected to be based mainly on technologies such as solar photovoltaic (PV), mini-hydropower, wind, biomass, and hybrid. It would also deploy home solar systems in households as well as in public institutions. The NEP also calls for strengthening capacity building, improving the policy and regulatory framework, developing a GIS (Geographic Information System) platform, securing technology assessment, technical advice, financial analysis, and environmental and social impact management. The NEP includes a component called "Contingent Emergency Response", which allows for rapid allocation of credit for the expansion plans as well as emergency recovery and reconstruction support.

The World Bank also conducted a safeguard assessment[29] of the National Electrification Plan and identified the following - 1) environment, 2) natural habitats, 3) physical cultural resource, 4) indigenous people, 5) involuntary resettlement of people, and 6) safety of dams triggered due to the construction of power substations, establishing of power lines, and installing power systems based on solar, hybrid solar-diesel generators, wind turbines, biomass and small-scale hydropower. The environmental and social impacts of the projects are presumed to be manageable as the prospective benefits from the project are expected to outweigh the negative impacts. The Law for Environmental Conservation[30] (2012) grants the mandate of cooperation between relevant government organizations for the conservation of natural and cultural heritage sites, and cultural monuments. Myanmar Electricity Law[31] (2014) also states that all electrification projects shall comply with social and environmental assessment work, impact mitigation work, compensation on affected losses, and that the regional governments shall establish environmental conservation funds. Regarding ethnic minorities, the World Bank recommended establishing an Environmental and Social Management Framework (ESMF) that includes Indigenous People Framework and Resettlement Policy Framework as the off-grid expansion projects in peripheral ethnic areas can have land acquisition impacts. Concerning the safety of dams, the assessment report suggested not to accept dam projects that would have a height or water drop of 10m or more.

In addition to the national energy and electrification policies, the Multi-Tier Framework Survey [32] conducted by the World Bank suggested some policy

[29] Myanmar National Electrification Project, Environmental and Social Management Framework, 27 June 2018 https://documents1.worldbank.org/curated/en/630691468322766145/SFG1097-REVISED-V1-IPP-P158303-PUBLIC-Disclosed-7-17-2018.pdf

[30] Environmental Conservation Law https://www.myanmar-law-library.org/law-library/laws-and-regulations/laws/myanmar-laws-1988-until-now/union-solidarity-and-development-party-laws-2012-2016/myanmar-laws-2012/pyidaungsu-hluttaw-law-no-9-2012-environmental-conservation-law-english.html

[31] Electricity Law (Draft) https://www.burmalibrary.org/docs18/2013-Electricity_Bill-en.pdf https://policy.asiapacificenergy.org/sites/default/files/2014-11-03-Electricity_Law-44-bu-red.pdf

[32] Bryan Bonsul Koo, Han Kyul Yoo, Sandra Keller, Dana Rysankova, Elisa Portale, Myanmar Beyond Connections, Energy Access Diagnostic Report based on the Multi-Tier Framework, World Bank Group, May 2019 https://openknowledge.worldbank.org/bitstream/handle/10986/32381/Myanmar-Beyond-Connections-Energy-Access-Diagnostic-Report-Based-on-the-Multi-Tier-Framework.pdf?sequence=1&isAllowed=y pg. 35.

recommendations for better and extended access of electricity in the country, especially in rural areas, to improve the quality and reliability of electricity supply by addressing voltage issues, outages, and limitations to move both grid-connected and off-grid households to a higher tier as well as to provide a solution (grid or off-grid) to households without any source of electricity. The World Bank's policy recommendations are:

1. To formulate optimal energy solutions at the lowest cost based on the population density, distance from the grid network, potential electricity demand, and socioeconomic environment.
2. To expand grid infrastructure and create financing options to lift the financial barriers of households in connecting the grid and creating grid densification.
3. To strengthen quality control systems on solar devices and microfinance programs to integrate off-grid solar products to villages where the national grid system cannot reach.
4. To improve the mini-grid regulatory framework to foster private investments for the expansion of new mini-grids to enhance the availability of electricity.

The Economic Research Institute for ASEAN and East Asia report, "Energy Outlook 2040[33]", made for the Oil and Gas Planning Department of Myanmar's MOEE, proposed policies based on the country's prospective energy landscape in 2040. The outlook predicted that the total final energy consumption will increase at an average rate of 3% per year in 2016-2040. The consumption will grow in the industrial sector the fastest (4.2%), followed by the transport sector (4%), the residential sector (1.8%), and the commercial (1.5%). Electricity production will increase from 20.3 TWh in 2016 to 89.4 TWh in 2040 at an average rate of 6.4% per year.

In the production of electricity, the share of hydropower will decline from 60% in 2016 to 47% in 2040 while the share of natural gas will be increasing from 40% in 2016 to 51% in 2040. The contribution of coal and solar in the electricity production was predicted to be 1% each by 2040. Total primary energy supply will increase at an average rate of 3.5% per year and it will reach 40 Mtoe in 2040. As the changes in GDP affect energy demand, Myanmar's energy demand will increase according to the economic growth it achieves. The report estimated that the energy demand can increase or decrease by 5% to 7% on average.

Sector	Strategies	Activities
Residential	-setting up energy performance standards -raising awareness of energy efficiency	Labelling the appliances, certification facilities for appliances, introducing incentives for energy efficiency performance, phasing out energy inefficient appliances from the market, organizing training programs targeting educational institutions, and conduction awareness campaigns
Commercial	-implementation of energy efficiency technologies -energy efficiency measures in new building design -promotion of renewable energy -Capacity building for energy efficiency practices	Establishing energy efficiency building codes, promoting energy efficient equipment and supporting the local manufacturing of energy efficient appliances, conducting energy audits, preparing energy efficiency guidelines, providing incentives, and training engineers/architects
Industry	-Adoption of energy efficient technologies -Awareness raising among industry owners, managers and engineers -Capacity building for energy efficiency practices	Organizing trainings, establishing or data collection procedures and energy audits programs, introducing energy management practices in industries, creating incentives, supporting the development of energy service companies, and preparing energy efficiency guidelines

Table 12 Applicable energy efficiency strategies and activities in the residential, commercial, and industrial sectors
Source: National Energy Efficiency and Conservation Policy, ADB

[33] Myanmar Energy Outlook 2040, ERIA Research Project Report 2019, No.1, Prepared by Oil and Gas Planning Department and Ministry of Electricity and Energy, Supported by Economic Research Institute for ASEAN and East Asia, May 2020 https://www.eria.org/uploads/media/Research-Project-Report/RPR---Myanmar---2020/Myanmar-Energy-Oulook-2020-Full-Report.pdf

Sector	Strategies	Activities
Residential	-setting up energy performance standards -raising awareness of energy efficiency	Labelling the appliances, certification facilities for appliances, introducing incentives for energy efficiency performance, phasing out energy inefficient appliances from the market, organizing training programs targeting educational institutions, and conduction awareness campaigns
Commercial	-implementation of energy efficiency technologies -energy efficiency measures in new building design -promotion of renewable energy -Capacity building for energy efficiency practices	Establishing energy efficiency building codes, promoting energy efficient equipment and supporting the local manufacturing of energy efficient appliances, conducting energy audits, preparing energy efficiency guidelines, providing incentives, and training engineers/architects
Industry	-Adoption of energy efficient technologies -Awareness raising among industry owners, managers and engineers -Capacity building for energy efficiency practices	Organizing trainings, establishing or data collection procedures and energy audits programs, introducing energy management practices in industries, creating incentives, supporting the development of energy service companies, and preparing energy efficiency guidelines

Table 13 Suggested energy efficiency strategies and activities for the residential, commercial, and industrial sectors

According to the prediction, the supply from hydropower will increase at an average rate of 6.3%, gas supply by 5.7%, and oil by 4.9% per year. The report also predicted that the import dependency of energy will be also increasing from 14% in 2016 to 49% in 2040 due to a potential increase in oil imports for transport and natural gas imports for power generation.

The policy recommendations made are: 1) promote energy efficiency policies to reduce total primary energy supply, total final energy consumption, and carbon emission, 2) increase domestic energy to maintain energy supply security, and 3) encourage continuous use of biomass to curb fossil fuels.

Beside the frameworks mentioned above, there are national energy efficiency policies that were suggested to cope with rising demand. The ADB's report of National Energy Efficiency and Conservation Policy [34] for Myanmar described applicable energy efficiency strategies and activities in the residential, commercial, and industrial sectors.

Roles and responsibilities

The Ministry of Electricity and Energy [35] is the key actor in Myanmar's electrification and energy development projects. The Ministry is responsible for the implementation of policies, rules and regulations, and the promotion of investments. MOEE is composed of the following departments.

1. **Electric Power Planning Department** is responsible for formulating the Master Plan for power generation, transmission, and distribution, formulating and assessing power projects, evaluating the contracts and agreements, assisting bilateral cooperation, technical exchange and regional/international co-operation, accommodating power trading and interconnections, and establishing training centers and training programs.
2. **Energy Supply Enterprise** is responsible for sustainable power supply and power distribution, implantation and maintenance of hydropower plants, gas turbines, and other power plants outside of the power grid.
3. **Electric Power Generation Department** is responsible for setting up goals for power generation and electricity sales, contracting and negotiating sales of electric power, conducting mechanical and electrical maintenance of hydropower plants, supervising power generation and consumption, supplying operation and maintenance training to the employees, and preparing plans for project implementation.
4. **Oil and Gas Planning Department** is responsible for establishing energy policies

[34] Republic of Union of Myanmar: Institutional Strengthening of National Energy Management Committee in Energy Policy and Planning, Final Report, Technical Assistant Consultant's Report, Asian Development Bank, 2015 https://policy.asiapacificenergy.org/sites/default/files/National%20Energy%20Efficiency%20and%20Conservation%20Policy%20%28NEECP%29%2C%20Strategy%20and%20Roadmap%20%28Draft%29.pdf

[35] Ministry of Electricity and Energy https://moee.gov.mm/en/ignite/index

and the legal framework for the oil and gas sector, scrutinizing exploration, monitoring oil and gas contracts and projects, cooperating in drafting the statement of income, expenditure and budget allocation with enterprises, implementing plans for the development of energy sector and the promotion of private sector, implementing programs for environmental and social development, supervising tender processes and coordinating with international organizations and companies, establishing energy statistical data, and estimation of future energy supply and demand.

5. **Department Power Transmission and System Control** is responsible for the managing materials and equipment needed for power projects, evaluating estimated project costs, calculating power system data (such as power system load flow, short circuit analysis, and transient stability), establishing technical specifications for transmission lines and substations, reporting on construction progress, performing quality control of the constructed transmission lines, maintaining transmission lines to reduce the duration of power outages, studying system improvement and extension, conducting research and development for national grid extension, managing a steady and reliable supply of electricity, collaborating with regional authorities for land acquisition in project areas, and reporting environmental and social impacts of projects.
6. **Department of Hydropower Implementation** is responsible for conducting feasibility study reports for new projects, planning and designing new projects, conducting detailed investigation and data collection, cooperating with consultants for projects, updating the progress of the projects, organizing capacity building training, managing technical issues such as calculating dam regulation and reservoir operation, maintaining existing reservoirs, dams, canals, structures and penstocks, establishing standards and specifications for power generation equipment, supervising control and data acquisition systems.
7. **Petroleum Products Regulatory Department** is responsible for receiving, storing, vending, and distributing petroleum products, regulating the price and managing the tender processes, administering petrol stations, maintaining quality control, and issuing distribution permits and sales license to investors and retailers.
8. **Myanmar Oil and Gas Enterprise** is responsible for managing and controlling the performance of oil and gas fields, collaborating with local and foreign oil and gas companies/organizations in 51 offshore blocks, consolidating the statistical data, supervising oil and gas operations such as exploration, drilling, production, and distribution, assisting in obtaining approval for land use permission and leases for foreign oil companies from Myanmar Investment Committee, participating in onshore and offshore blocks tenders, formulating national energy policy, and amending the petroleum law.
9. **Myanmar Petrochemical Enterprise** is responsible for managing three refineries (Thanlyin, Chuck, Thanbayarkan), five fertilizer factories (in Kyunchaung, Kyawzwa, Myaung Daga, Kangyidaunt, and Sala), and three liquefied petroleum gas plants (in Minbu, Nyaung Don, and Kyunchaung), supervising the production of petroleum and petrochemical products, urea fertilizers, liquefied petroleum gas from crude oil and natural gas, transporting crude oil and petroleum products, and distributing and selling fertilizers, LPG, gasoline, and diesel.
10. **Yangon Electricity Corporation Department** is responsible for distributing electric power to domestic and commercial consumers in the Yangon region, monitoring system development plans, providing reliable and sufficient power, and establishing measures for the development of private sector investment in electricity generation and distribution.
11. **Mandalay Electricity Corporation Department** is responsible for providing electricity to the Mandalay region, conducting system development plans, operation and maintenance, ensuring sufficient electricity supply and reducing electricity loss in the region, and encouraging private sector to invest in electricity distribution.

In addition to MOEE, there are other ministries and organizations involved in the country's energy and electricity projects such as the Ministry of Agriculture, Livestock and Irrigation, Ministry of Planning, Finance and Industry, Ministry of Investment and Foreign Economic Relations, Ministry of Natural Resources and Environmental Conservation, Myanmar Investment Commission, and National Commission for Environmental Affairs.

The Ministry of Agriculture, Livestock and Irrigation was formed in 2016 to combine three former Ministries – Ministry of Livestock, Fisheries and Rural Development, Ministry of Agriculture and Irrigation, and Ministry of Cooperatives. In 2021, the Ministry of Cooperatives and the Department of Rural Development were reorganized as the Ministry of Cooperatives and Rural Development. By the time the NEP was drafted, and the World Bank approved the loan, it was the Ministry of Agriculture, Livestock, and Irrigation that was assigned the task of implementing the rural electrification plan. Later, the plan went under the Department of Rural Development of the Ministry of Cooperatives.

The Ministry of Planning, Finance and Industry is fundamentally responsible for strengthening Myanmar's insurance sector, promoting public-private partnership, sharing information between financial institutions and regulators, promoting foreign direct investment from multinational corporations, securing technical assistance from international organizations, and collaborating with UNDP. In the Ministry of Investment and Foreign Economic Relations, the Directorate of Investment and Company Administration (DICA) functions as a regulator of investments and companies, a company registrar, an investment promoting agency, and the secretariat of the Myanmar Investment Commission. DICA is also responsible for encouraging and facilitating foreign and local investors by providing information (documents and materials), fostering coordination between investors, drafting, negotiating, and approving bilateral investments, and agreements. One of the key roles of DICA is that it serves as the focal department for all affairs related to ASEAN-based investments.

The Myanmar Investment Commission (MIC) is the key body responsible for investment development, protection of investors and investments, development of the national economic environment through investments in accordance with Myanmar Investment Law of 2016. It also issues permits or endorsements to investors, and notifications including the stipulation of investment promotion and restricted investment activities.

The Ministry of Natural Resources and Environmental Conservation was established in 2016 by combining the Ministry of Mining and the Ministry of Environmental Conservation and Forestry. Ministry of Mining was responsible for the formulation of mining policies, exploration of minerals and gems, granting of mineral permits, and coordination of mining sector.

The National Commission for Environmental Affairs was established in 1990 to act as a coordinating body for environmental affairs, to promote sustainable development, and to advise the government on environmental policies. It was reorganized as National Environmental Conservation Committee (NECC) in 2016. NECC is responsible for guiding national activities related to climate change and developing policies and strategies. The overarching responsibilities include facilitating and negotiating with government agencies and institutions to formulate solutions to the environmental problems, supervising rehabilitation activities based on impacts caused by the government/commercial projects and activities, promoting international collaboration for environmental conservation, and approving activities on urban management planning.

Investment and budgeting plan

Funding for the National Electrification Plan is supposed to flow from the Union budget, donor financing, and tariffs from electricity sales. The NEP implementation started with US$400 million approved by the World Bank in 2015. The NEP also partnered with Japan International Cooperation Agency (JICA), Asian Development Bank (ADB), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Kreditanstalt fur Wiederaufbau (KfW), Italy, and Norway to support national electrification. Moreover, the NEP encouraged the private sector to become involved in the financing scheme through public-private partnership corporations, and community enterprises.

In the short- to medium-term, the Yangon Electricity Supply Board was planned to be incorporated into the International Finance Corporation, the Union budget, banking sector, subsidies and customers'

payments, and wheeling payments (for private transmission asset owners/operators). However, there were barriers in implementing the project: the lack of institutional capacity both in public and private sectors, lack of knowledge of the use of goods and the maintenance of the system, lack of participation of private sector in the remote areas, lack of willingness to pay for the system before seeing the product, limited time and limited feasible data for mini-grids, and budget allotment.

In 2019, Italy extended an interest-free €30-million loan to Myanmar National Electrification Project (NEP). The loan, approved in the Parliament in 2018, came with the grace period of 18 years and then would need to be paid back in 10 years. The German state-owned development bank, Kreditanstalt fur Wiederaufbau (KfW), also extended a €9-million loan for the electrification of Shan State. According to *Myanmar Times*, US$310 million of the US$400 million approved by the World Bank was allocated to the Ministry of Electricity and Energy and the rest to the Department of Rural Development under Ministry of Cooperative and Rural Development.[36] In December 2020, the Asian Development Bank approved a US$171.27 million loan for the construction of 44 medium-voltage substations and distribution lines in Kayin State, Ayeyarwaddy, Bago, and Magway regions. ADB has provided more than US$500 million in loans and technical assistance to support Myanmar's energy sector, including policy reform and infrastructure development since 2012.[37]

Basically, the budget for the electrification plan flows from international loans, especially from organizations such as the World Bank and Asian Development Bank even though the NEP projected the creation of various channels to get funds by including the private sector and community enterprises.

Myanmar's nuclear story

Although nuclear energy can become an option for the electricity supply, Myanmar currently does not have any plan to insert nuclear power into its energy mix. There is no regulatory framework or roadmap for nuclear energy development even though there was some training for the use of nuclear energy in the industrial and healthcare sectors.

In 2010, there were allegations that the Burmese military was attempting to acquire nuclear weapons and developing the technology with the help of Russia. Norway-based Democratic Voice of Burma (DVB) concluded after a five-year investigation that while Myanmar had attempted to acquire the technology and expertise, it was a long way from producing nuclear weapons.[38] The conclusion was based on files and photographs provided by a defected Burmese defense engineer trained in Russia, the purchase of machinery or uranium enrichment from Germany and Switzerland, and illicit cooperation with North Korea.[39] Many experts were skeptical of DVB's allegation and the Institute for Science and International Security stated that the equipment under investigation could also be used for producing materials such as titanium or vanadium.[40]

"Although nuclear can become an option for the electricity supply for the increasing demand, Myanmar does not have any plan to insert nuclear power into its energy mix so far."

[36] Htoo Thant, Chan Mya Thwe, "Italian loan to facilitate electrification project", Myanmar Times, 28 May 2019 Italian loan to facilitate electrification process | The Myanmar Times (mmtimes.com)
[37] "$171 Million ADB loan to help expand electricity access in Myanmar", Asian Development Bank, 5 December 2020 $171 Million ADB Loan to Help Expand Electricity Access in Myanmar | Asian Development Bank
[38] Martin Petty, "Myanmar seeking to develop nuclear weapons – report", Reuters, 4 June 2020 https://www.reuters.com/article/idINIndia-49046620100604
[39] Jerome Taylor, "Burmese Junta 'is developing a nuclear threat", *The Independent*, 4 June 2010 https://www.independent.co.uk/news/world/asia/burmese-junta-is-developing-a-nuclear-threat-1991009.html
[40] David Albright and Christina Walrond, "Technical Note: Revisiting Bomb Reactors in Burma and an Alleged Burmese Nuclear Weapons Program", Institute for Science and International Security, 11 April 2011, https://isis-online.org/uploads/isis-reports/documents/Burma_Analysis_Bomb_Reactors_11April2011.pdf

Economic Sector	Sub-Sectors	Sub-Sectors Included	Energy Carriers Considered
Manufacturing	Iron & Steel	Iron, Steel	Electricity, Coal, Natural Gas
	Non-Ferrous metals	Copper , (Tin and Zinc not significant in energy use)	Electricity, Coal, Natural Gas
	Non-Metallic minerals	Bricks, Glass, Cement	Electricity, Coal, Natural Gas
	Pulp & Paper		Electricity, Gas
	Food Processing	Sugar	Electricity, Gas
	Other manufacturing	Chemicals, Food processing, Electronics, Plastics, Machinery, Textiles, Wood and Wood Products, Transport Equipment & Repair	Electricity, Coal, Natural Gas, Diesel
Mining & Quarrying	N/A	N/A	
Construction	N/A	N/A	
Power & Gas	N/A	N/A	

Table 14 List of energy intensive industries
Source: Myanmar Energy Master Plan

In June 2010, Myanmar's envoy to the International Atomic Energy Agency (IAEA) dismissed the allegations in a letter sent to the IAEA. The Foreign Ministry also issued a denial and reassured that there were no activities related to uranium conversion, enrichment, reactor construction or operation carried out in the past, ongoing, or planned for the future in Myanmar.[41] Again in 2011, Myanmar's vice president said to a visiting US delegation that Myanmar had halted its nuclear research program because the international community misunderstood Myanmar over the issue. [42] Myanmar leaders (after the democratic transition) communicated with the IAEA and confirmed that Myanmar was in no position to consider the production and use of nuclear weapons, and did not have enough economic strength to do so.[43] However in July 2014, Myanmar announced that it was developing human resources and had plans to build reactors when required infrastructure had been built.[44]

In fact, Myanmar has showed interests in the peaceful use of nuclear energy since 1955 when it established its Atomic Energy Center. It joined the IAEA in 1957. In 1997, the Department of Atomic Energy was established under the Ministry of Science and Technology. Myanmar asked Russia for assistance in starting a nuclear research program in the 2000s and they signed a contract in 2001 to design a 10 MW research reactor for radioisotope production. The negotiations fell through because the two countries

[41] Myanmar denies allegations it is seeking nukes, Taiwan News, 19 June 2010 https://www.taiwannews.com.tw/en/news/1293530
[42] David Albright and Andrea Stricker, "Myanmar Says Halted Nuclear Research Program: Verification Critical", *ISIS Reports*, 3 June 2011, https://isis-online.org/isis-reports/detail/myanmar-says-halted-nuclear-research-program-verification-critical/33
[43] International Atomic Energy Agency, "Statement by the Leader of Myanmar Delegation H.E. U Tin Win to the 55th Annual Regular Session of the IAEA General Conference", Vienna, 19-23 September 2011 www.iaea.org https://www.nti.org/analysis/articles/myanmar-overview/
[44] Joshua Carroll, "Report: Myanmar plans to build nuke reactor for research", Anadolu Agency, 22 July 2014 https://www.aa.com.tr/en/world/report-myanmar-plans-to-build-nuke-reactor-for-research/139018

could not agree on the payment.[45] In 2007, Rosatom and Myanmar's Ministry of Science and Technology signed another agreement for the establishment of a nuclear research center with a 10 MW light water reactor with low-enriched uranium. [46] They also agreed to train Myanmar scientists and to produce radioisotopes.

In 2015, Rosatom met again with the minister of Science and Technology at the International Economic Forum in St. Petersburg. The Rosatom CEO and the then Minister Ko Ko Oo signed a memorandum and agreed to create favorable conditions for interaction in the use of advanced nuclear technologies including the strengthening of the legal framework and personal training. There has been no follow-up on later progress regarding cooperation on nuclear power between Russia and Myanmar.

It seems that Myanmar is not yet ready for the development of the civilian use of nuclear energy even though it showed interest over the years. Adding nuclear energy to the energy mix still seems unrealistic as the country has struggled with its nuclear research plans. There is no regulatory framework or nuclear policy, and Myanmar is not actively working to incorporate nuclear energy in its electricity production plans. The funding for nuclear projects is another challenge that is holding back Myanmar's capacity for developing a nuclear energy program. A survey on public opinion toward nuclear energy is yet to be done.

Possibility for an SMR market

The most likely sector for SMR utilization would be energy intensive industries, which basically includes mining, construction, manufacturing, and power and gas production. The GDP contribution of industries was increasing until 2021 as the government made efforts to industrialize the country to promote economic development. The energy consumption of the industrial sector had also been increasing, especially in the heavy industries as well as in energy intensive industries.

Mining in Myanmar is mainly focused on the extraction of ferrous and non-ferrous metals, jade and gems, industrial minerals, and precious metals. According to the Ministry of Mines, there were 1,297 small scale mines and 148 large scale mines in 2012.[47] The number of small-scale mines increased six-fold during the previous decade and mining activities are expected to grow according to the domestic market needs.

In the heavy industries and energy intensive industries mentioned above, due to the disturbances and intermittence in electricity supply and also the growing demand of power supply. SMRs could play a role in resolving these shortages since the current/forthcoming Myanmar government cannot set plans to fulfill the needs. As SMRs are designed to produce 50 MW to 300 MW of electricity, the sector of heavy industries (either private or public) is suitable to focus on as the first attempt.

In addition to heavy industries, luxury hotels within the service sector would be another area that SMRs can play a significant role. Not limited to hotels, amusement/theme parks that consume an impressive amount of electricity can also be considered not only in Myanmar but also in other ASEAN countries.

As Myanmar is the least electrified country in the ASEAN region, especially because the remote and rural areas of the country are still under-electrified, the electrification of those areas, either on-grid or off-grid, is a priority and urgent. Villages or community-wide electrification plans using SMRs would be an interesting proposal for Myanmar as it works on its goal of 100% electrification by 2030.

Even though Myanmar is not yet ready to develop nuclear energy and does not yet have plans to add nuclear to its energy mix, the country's electricity need will be increasing. As Myanmar currently does not have an interest in nuclear power plants due to both the safety and security reasons, it would probably take more time to convince the authorities and get any SMR projects approved.

Conclusion

Myanmar's current political situation is deteriorating. The junta and the resistance groups seem to be in a deadlock. Given the significant popular distrust of the State Administration Council (SAC), negotiations

[45] Myanmar Overview, Nuclear Threat Initiative (NTI), 28 May 2015 https://live-nuclear-threat-initiative.pantheonsite.io/analysis/articles/myanmar-overview/

[46] "Russia, Myanmar reaffirm nuclear cooperation", World Nuclear News, 26 March 2015 https://www.world-nuclear-news.org/Articles/Russia,-Myanmar-reaffirm-nuclear-cooperation

[47] Myanmar Energy Master Plan, Asian Development Bank, Intelligent Energy System, Myanmar International Consultants, December 2015 https://policy.asiapacificenergy.org/sites/default/files/1_2015-12-Myanmar_Energy_Master_Plan_red-2.pdf p.g.291

and discussions to resolve the current conflict seem still far away. Moreover, the changing rules and regulations by the SAC in the trade sector as well as in the export and import sectors are making it difficult for businesses.

Regarding the energy sector, it seems unlikely that Myanmar will move forward after the coup. Burmese people's Civil Disobedient Movement—a campaign advocating not to work under the junta, not to go to schools and universities run by the junta, and not to pay tax and electricity bills—severely affects the junta in maintaining human resources, capacities, and their administrative mechanism. The replacement of experienced officials and experts in ministries, including the MOEE, with military personnel has led to significant mismanagement. Together with sanctions and isolation from the international community, the junta is also struggling with economic hardship and diplomatic nonperformance.

The World bank halted the payment requests since the military took power and put a hold on disbursement of the operations. The electricity master plan, and the electrification projects and goals that were set by the former civilian government are being neglected by the ruling junta. Blackouts are now frequent in cities such as Yangon and Mandalay as well as in small towns and villages that are connected to the national grid. Even though efforts to increase the power supply were made, the deteriorating investment climate poses challenges. Due to political precariousness and poor foreign currency convertibility, several large multinational energy companies such as Total, Petronas, Electricité de France, withdrew from the power projects as well as from the country. Local industries are now trying to secure reliable energy by investing in off-grid renewable energy, but the high upfront capital needs and supply chain disruptions are making it difficult. The instability around the country is another challenging factor. There are daily battles in the ethnic areas especially in Kachin, Karen, Kayah, Chin States and also in the Bamar-majority middle parts of the country. In big cities like Yangon and Mandalay, sudden attacks and bombing are taking place on a daily basis. This has paralyzed all types of electrification and energy development planning. Clearly, this situation makes the implementation of any SMR projects impossible. Nevertheless, SMRs for electricity production would be interesting in the post-conflict Myanmar.

For the US concerns over Russia's nuclear cooperation in the region, Myanmar is totally a different case study. Russia is not the real rival of the US for developing Myanmar's nuclear energy market. For Myanmar, China is a close friend and a loyal trade partner that the US should monitor closely. Currently, China is investing enormously in hydropower, oil, and gas. If the country changes its mind and attempts to initiate nuclear power projects for electrification, China would be the first to invest in it.

Moreover, Myanmar's mining sector is largely overwhelmed by Chinese investors. For the US SMRs, to promote a market among Chinese investors would not be a good tactic although it is not impossible. For other heavy industries, the US has to deal with the Myanmar government or the military junta depending on when the project would be starting. In both cases, there would surely be delays. Besides, corruptions by the military generals who would be in charge of the projects, permits cannot be avoided. Nonetheless, there would be hope in the next civilian government (if any) for SMRs to get a market there as the government will have to work hard on both completing the 100% electrification project and to catch-up on what the country will have missed in its energy diversification program during the crisis.

Predicting the final outcome of Myanmar's current crisis is hard to predict. The military is the oldest, the strongest and the most experienced institution in the country. However, the anti-military sentiment of Burmese people has reached its peak after 2021 coup. People have been resisting the junta for nearly two years and it seems that the crisis would go on until one counterpart is totally defeated. In such case, time is the only matter.

Although the lack of financial assistance, mismanagement, human resource shortages, and the junta's inconsistent policies and regulations are reversing the progress the country achieved in energy sector in the previous decade, one should not forget that there is an opportunity in every crisis. In the case of Myanmar, the crisis itself will create a lot of opportunities in the country's post-conflict era.

4

Re-energizing the Philippines' Nuclear Power Program: Opportunities and Challenges

Julius Cesar Trajano

Introduction

The Philippines has been recently demonstrating its interest in tapping into nuclear energy as a long-term option for power generation. The need for additional reliable power sources has increased with the projected growth of the Philippine economy and its population. Additionally, worsening environmental problems, associated with overreliance on fossil fuel and other traditional sources of energy in the country, is generating a strong demand for cleaner and more sustainable alternative sources. Nuclear power has been proposed as one of the clean power sources by key government officials, primarily from the country's Department of Energy (DOE) and the Philippine Nuclear Research Institute (PNRI), which serves as an agency that promotes and regulates peaceful uses of nuclear technology.

The Philippines' new president, Ferdinand "Bongbong" Marcos Jr., declared that his administration would be looking into reviving the mothballed nuclear power plant built during his late father's administration. The Philippines needs to be ready with higher power supply "if we are going to industrialize post-pandemic."[1]

During the election campaign, the tandem of Marcos and the new vice president, Sara Duterte, issued a pledge to install at least one nuclear power plant and to consider the revival of the mothballed Bataan Nuclear Power Plant (BNPP). Marcos' pledge would certainly be a continuance of the Duterte administration's adoption of a national position favoring the exploration of peaceful uses of nuclear energy and science. An executive order signed by Duterte to promote nuclear power generation is "a good springboard for the next administration to pursue its nuclear energy objectives," they said in a joint statement issued in March 2022.[2] The country has a two-pronged approach to introducing nuclear power: first to open the BNPP and second to use SMRs and build new NPPs.[3]

This chapter discusses the Philippines' power demand and supply outlook. It then identifies key reasons why the Philippines is exploring nuclear energy as a potential power generation source in the context of climate change mitigation and energy security concerns. It enumerates key actors and mechanisms in the country's nuclear energy program preparations. It also highlights the current status of the BNPP and the pre-feasibility study on possible deployment of SMRs in the country. Key challenges that include amending legal and regulatory frameworks, enhancing the nuclear security regime, ratifying significant nuclear conventions, and intensifying public education are also discussed. This chapter is partly informed by research interviews conducted by the author in the Philippines in May 2022.[4]

Philippine power consumption and supply outlook: overdependence on dirty coal and imported fossil fuels

The Philippines has one of the fastest growing economies in Asia. The rapidly growing population and accompanying economic growth are expected to increase domestic demand for energy and electricity. However, the Philippines faces four energy insecurity problems: (1) electricity demand is growing fast; (2) the supply of electricity is inadequate to meet the rising demand; (3) the discrepancy in electrification rate between cities and rural areas is wide; and (4) the country has one of the world's most expensive electricity costs. Due to its limited indigenous energy reserves, the country has become heavily reliant on imported fossil fuels (oil, gas and coal), but has nonetheless expanding its own local renewable resources. Continuous economic growth has been hampered due to poor energy security and high power prices, requiring a radical shift in the energy sector, particularly in electricity sector, that can generate sustainable, reliable power at an affordable cost. Its expensive electricity puts the investment climate at risk. The problems of the power sector include the inefficient generation, transmission, and distribution of electricity.[5]

[1] Katrina Domingo. "Marcos reviewing South Korea recommendations on nuclear plant revival." ABSCBN News, May 23, 2022. https://news.abs-cbn.com/news/05/23/22/marcos-mulls-bataan-nuclear-plant-revival

[2] Yuichi Shiga. "Marcos vows to bring nuclear power to the Philippines." *Nikkei* Asia, April 17, 2022. https://asia.nikkei.com/Politics/Philippine-elections/Marcos-vows-to-bring-nuclear-power-to-the-Philippines

[3] Interview with Lorenz Fernando, Strategic Trade Management Office, Department of Trade and Industry, Makati City, Philippines, May 27, 2022.

[4] Conducting these interviews was approved by the Institutional Review Board of Nanyang Technological University (NTU-IRB Reference: IRB-2020-06-044) and was part of the research project supported by the Singapore Ministry of Education (MOE) Academic Research Fund Tier 1 Grant.

[5] Taniguchi, S. 2019. Securing Access to Electricity with Variable Renewable Energy in the Philippines: Learning from the Nordic Model. *ADBI Working Paper 1009*. Tokyo: Asian Development Bank Institute. Available: https://www.adb.org/publications/securing-accesselectricity-variable-renewable-energy-philippines; https://www.sciencedirect.com/science/article/pii/S0301421522000064#bib35

The power sector relies largely on dirty, imported fossil fuels with a majority 77% share. and has expanded coal-based generation through construction of coal-fired power plants in the past 10 years to meet future energy demand. Coal consumption rose from 7 million tons in 2006 to 33.2 million tons in 2020.[6] As a result, greenhouse gas (GHG) emissions are expected to grow rapidly, with CO2 emissions projected to grow from 26 to 92 million tons annually if all planned coal plants are installed. Hence, one significant energy-environmental challenge is an expected rise in GHG emissions levels in the Philippines (Mondal et al., 2018).[7] It must be noted that the Philippines is a party to the Paris Climate Agreement and has codified its national commitments to reduce its GHG emissions.

In 2021, the amount of CO2 emissions from energy consumption in the Philippines amounted to approximately 136.8 million tons of carbon dioxide. This reflects an increase from the previous year's total of 127.2 million tons.[8] While all energy-related sectors heightened the country's GHG emissions, the top two contributors were electricity generation and the transportation sector. Electricity generation contributed more than half (51.7%) of the total GHG emissions in 2018, while the transportation sector added 27.9%. The unabated growth in GHG emissions is primarily fueled by burning coal for electricity generation and oil in the transportation sector.[9]

The Philippines is located within the typhoon belt and Pacific Ring of Fire. It is therefore vulnerable to extreme weather events such as typhoons, floods, and rising sea levels. The 2017 Global Climate Risk Index ranked the Philippines as the most affected country by extreme weather and other natural disasters. In the previous decade, the Philippines had been hit by devastating storms such as Typhoon Yolanda (International name: Haiyan), resulting in the loss of life, property, and national productivity. The Philippines cannot ignore climate change even amidst its economic development aspirations. Decarbonizing its energy sector has therefore been part of the country's commitments to reduce GHG emissions.[10]

The Philippines is largely a coal consuming country. A rash of approvals for coal-fired power plants in recent years has boosted coal's dominance in the country's power mix.[11] Coal provided about half (52%) of the country's power generation supply, while natural gas contributed 21.4% and geothermal with 10.5% share of the total power generation.[12]

The Philippines relies heavily on coal combustion to meet its energy demand. Coal's prominence as a primary fuel source in the Philippines is evidenced by its meteoric rise from 28% of the energy mix in 2003 to almost double that amount in 2019. By December 2020, 59 coal-fired power plants with a total installed capacity of 10.9 GW operated in the country. On October 27, 2020, Secretary Alfonso Cusi of the Philippines' Department of Energy (DOE), however, announced a moratorium on endorsements for new coal power plants, signaling a halt in coal's prominence. Before the moratorium, coal-based development was held in high regard in the country's energy policy, making coal the predominant sociotechnical imaginary of Philippine energy. To shore up domestic supply, the Philippines imports coal mainly from Indonesia and Australia, which the Philippine government regarded as energy projects of national significance. Although coal is king, its inadequate domestic coal supply means that 75% of these requirements are imported. Given the significant number of coal-fired power plant projects approved before the coal moratorium, the Philippine energy system can expect an extended coal dependency.

Rising power demand

Peak demand, the highest electricity consumption occurring in a given day or year, depicts the trend of electricity sales forecast with a uniform load factor. Based on the Philippine Energy Plan 2018-2040, the country's peak demand will increase almost four-fold with 6.6% annual increments for the 20-year period, from 15,282 megawatts (MW) in 2020 to 54,655 MW in 2040. With greater economic growth prospects based on the projected gross regional domestic product (GRDP), Mindanao will exhibit the highest

[6] https://www.statista.com/statistics/1267170/philippines-volume-of-coal-consumed/
[7] https://www.sciencedirect.com/science/article/pii/S0301421522000064
[8] https://www.statista.com/statistics/1083210/philippines-carbon-dioxide-co2-emissions/#:~:text=In%202021%2C%20the%20amount%20of,million%20tons%20of%20carbon%20dioxide.
[9] Department of Energy, *Philippine Energy Plan.*
[10] A. G. La Viña, J. M. Tan, T. I. M. Guanzon, M. J. Caleda, L. Ang, "Navigating a trilemma: Energy security, equity, and sustainability in the Philippines' low-carbon transition." Energy Research and Social Sciences. Vol. 35, 37–47 (2018)
[11] Reuters. "Philippines shuts door on new coal power proposals." November 4, 2020. https://www.reuters.com/article/philippines-energy-idUSL4N2HQ1Z9
[12] Department of Energy. *Philippine Energy Plan*.

annual growth at 7.9%, followed by Visayas at 7.3% and Luzon at 6.2%.[13]

Similarly, electricity sales will also increase almost four-fold, equivalent to nearly 7.0% per year, which stood at 335,691 gigawatt-hour (GWh) by 2040 from 91,369 GWh in 2020. By 2040, on a per grid basis, Luzon still will get about two-thirds of the total electricity sales, while the remaining will be shared by Visayas with 16.9% and Mindanao with 16%. Gross generation will increase three-fold reaching 364.4 terawatt-hour (TWh) in 2040 with a 6.6% a year growth rate from 101.8 TWh in 2020. Coal's share of total power generation will fall by about half from a high of 57.0% in 2020 to 24.6% in 2040. Generation from coal will only increase at 2.2% annually as only committed projects will be added over the planning period. The aggregate share of renewables in the generation mix will reach 35% by 2030 until end of the planning period to meet the required share of renewable energy (RE) for the mandated renewable portfolio standard (RPS). Solar will contribute 15% to the total power generation. Hydro will provide 14.0%, while geothermal would provide 4.4%, wind 1.4% and biomass less than 1.0% share of the total.

"The Philippine Department of Energy has indicated in the *Philippine Energy Plan 2018-2040* that there is a need to encourage the facilitate new and emerging energy generation options"

The total installed capacity from all generation sources will rise by about four times from 26.2 GW to 95.7 GW in 2040, coming from existing, committed, and new build capacities. Solar, having the lowest capacity factor, will expand to more than 34% total by 2040 because of a declining capital cost from $750/kilowatt (KW) to $650/KW. As such, solar has the cheapest levelized cost of electricity (LCOE) among renewable technologies. Natural gas and hydro will also contribute significantly to the total installed capacity with 25.4% and 16.1% share, respectively. Coal's share will drop to 14.2% in 2040 from 41.7% in 2020 due to the coal moratorium for greenfield coal power plants. Other technologies, such as oil, geothermal, biomass and wind will contribute 1 to 5% of the total.[14]

Natural gas will overtake coal as the major fuel for power generation with its share increasing significantly to 40% of the total from nearly 20% in 2020. This is attributed to the flexibility of its fuel to support the higher penetration of renewables in the generation mix, specifically solar and wind.

However, with the depletion of natural gas from the Malampaya gas field, the country needs to import liquefied natural gas (LNG) to meet its fuel requirements. Operating since 2001, the Malampaya project is the only local producer of indigenous natural gas. It currently supplies fuel to around 40% of gas-fired plants in Luzon, powering around 3,457 MW of power plants that provide power supply to the Luzon grid. Major urban centers (including Metro Manila) are part of the Luzon grid. Hence, this grid needs a reliable supply of electricity. In total, Malampaya supplies up to 20% of the country's energy requirements. [15] The gas field is located offshore Northwest Palawan, within the country's exclusive economic zone, facing the disputed South China Sea.[16]

To address both energy and climate change challenges, the Philippine Department of Energy has indicated in the *Philippine Energy Plan 2018–2040* that there is a need to encourage and facilitate new and emerging power generation options such as nuclear energy, energy storage, fuel cells, and ocean thermal energy conversion in the medium to long term. Peak electricity demand is forecasted to increase from 12,213 MW in 2015 to 49,287 MW in 2040 under a high GDP growth scenario, translating into a 6% annual average growth rate for that period.[17]

[13] Department of Energy, Philippines. *Philippine Energy Plan 2018-2040*. Taguig City, Philippines: DOE, 2018. https://www.doe.gov.ph/sites/default/files/pdf/pep/Philippine%20Plan%202018-2040.pdf?withshield=1

[14] Department of Energy. *Philippine Energy Plan.*

[15] Shell Philippines. Overview of Malampaya. https://malampaya.com/about/ (accessed July 8, 2022); Danesa Rivera. "Cusi lauds Razon investment in Malampaya natural gas project." *The Philippine Star*, June 4, 2022. https://www.philstar.com/business/2022/06/04/2185856/cusi-lauds-razon-investment-malampaya-natural-gas-project

[16] Shell Philippines. Overview.

[17]https://www.sciencedirect.com/science/article/pii/S0301421522000064#bib35

DOE reported that the total primary energy supply in 2021 reached 60.3 million tonnes of oil equivalent (MTOE), from 56.4 MTOE in 2020, indicating an increase in energy demand. Energy self-sufficiency, on the other hand, decreased from 52.6% in 2020 to 48.9% in 2021. According to DOE, coal remains as the dominant source of electricity generation at 58.2% in 2021, while renewable comprises 22.0%. [18] The decreasing energy self-sufficiency indicates the growing reliance of the country's energy sector on imported fossil fuels (oil, gas and coal) while reducing share of indigenous sources of energy.

According to the *Philippine Energy Plan 2018-2040*, which includes energy mix scenarios until 2050, a sustainable scenario option that introduces nuclear power by 2030 draws a more diversified energy mix as compared to business-as-usual scenarios that exclude nuclear energy. Without nuclear power, there will be higher LNG importation and increased dependence on imported fossil fuel sources impacting the country's energy security. The study also shows that nuclear power can be introduced by 2027. A DOE official asserted that nuclear energy will form part of the country's energy transition under the Plan's Clean Energy Scenario.[19] The country's goal of realizing the Clean Energy Scenario (CES) for the Filipinos by 2040 entails radical shift from business-as-usual scenario through rapidly expanding the use of renewable energy and other energy technologies (such as nuclear power), strengthening energy efficiency and conservation, implementing appropriate information and communication technologies (ICT) in the energy chain, and building up energy resiliency.[20]

Under the Clean Energy Scenario, the projected peak demand stands at 57,303 MW. To meet the peak demand, the Clean Energy Scenario requires more total installed power generating capacity of 93,482 MW, or an additional dependable capacity of 75,325 MW by 2040 to satisfy a lower peak demand. The high requirement for additional capacity in the Clean Energy Scenario is attributed to having more renewables in the system, specifically solar and wind that are considered variable capacity. The additional capacity would need to be supplied by more dependable base-load energy sources. Hence, additional capacities from natural gas and other low carbon and highly efficient technologies such as nuclear power are essential. In the Clean Energy Scenario, base-load nuclear power can effectively complement the variable capacity provided by renewables in the next decades.[21]

The Luzon grid's peak demand will rise to 39,987 MW by 2040, four times higher than the 2018 level. The electricity consumption growth will have to be met with a total additional capacity of 45,740 MW by the end of 2040, comprising 15,220 MW of baseload capacity, 8,400 MW of intermediate capacity, 18,500 of variable capacity (mostly renewables), 3,200 MW of flexible capacity, and 420 MW of peaking capacity. The Visayas (central Philippines) grid's peak demand will rise by more than 400% from its 2018 level to 9,774 MW in 2040. Added electricity supply for Visayas will have to be powered by 8,564 MW of additional capacity – 5,000 MW of baseload capacity, 700 MW of intermediate capacity, 1,324 MW of variable capacity, 1,340 MW of flexible capacity, and 200 MW of peaking capacity. In the Mindanao (southern Philippines) grid, peak demand expands by about five times, reaching 10,273 MW in 2040. A total 13,041 MW is needed by the end of 2040 to meet the demand growth, broken down as 6,553 MW of baseload capacity, 200 MW of intermediate capacity, 5148 MW of variable capacity, 1,100 MW of flexible capacity, and 40 MW of peaking capacity.[22]

Nuclear energy as a future power source

Proponents of nuclear power, even those within the government, cite one major reason in favor of nuclear power: the need to find a new energy source as the Malampaya natural gas field will be depleted by 2025. The field supplies about 23% of the country's power supply, supplying the main island of Luzon. [23] The absence of a replacement base-load power source could lead to possible rotational power interruptions. Nuclear proponents have pointed out that with the country's pledge to the Paris Agreement, including the moratorium on building new coal-fired power plants, [24] and the limitation of renewables, despite

[18] Department of Science and Technology, Philippines, "Press Release: Make nuclear power a part of the solution to meet energy demand, expert urged," Taguig City, the Philippines, August 9, 2022.
[19] Interview with Patrick Aquino, Undersecretary of the Department of Energy, Taguig City, Philippines, May 2022.
[20] Department of Science and Technology, "Press Release."
[21] Department of Energy, Philippines, *Philippine Energy Plan*.
[22] Ibid.
[23] Department of Energy, Philippines. Power Generation Mix. 2015. https://www.doe.gov.ph/energy-statistics?q=energy-resources/powermix&withshield=1.
[24] Climate Home News. Philippines declares moratorium on new coal power plants. October 28, 2020. https://www.climatechangenews.com/2020/10/28/philippines-declares-moratorium-new-coalpower-plants/.

recent attempts to expand their share, nuclear energy can fill the need for a reliable, base-load power source.[25] Carlo Arcilla, a proponent of nuclear power and the director of the nuclear regulatory agency (PNRI), pointed out that potential alternatives to Malampaya, such as nuclear and renewables, are not contradictory, as nuclear energy is clean with no greenhouse gas emissions and complements renewable sources such as wind and solar.[26]

Meanwhile, former DOE Secretary Alfonso Cusi argued that while the Philippines strongly supports clean energy transition, instead of imposing a carbon tax, the country is exploring nuclear power as a new energy source.[27] Energy and climate security experts in the Philippines strongly recommend that to simultaneously address the issues of energy security and carbon emissions, the country has to reduce its overdependence on a single, imported resource (coal), and pursue energy diversification by enlarging the share of low-carbon, clean energy sources.[28] From the perspective of the DOE, addressing both energy security and climate change provides an opportunity for a sustainable transition to clean energy, which includes nuclear power.

"The Philippines might be able to deploy nuclear projects in five years if the new Marcos administration prioritizes the inclusion of nuclear in the power mix"

In addition, proponents contend that nuclear energy can decrease the high cost of electricity in the country. The Philippines has the most expensive electricity in all of Asia due its heavy reliance on imported fossil fuels while power generation remains limited to a few big power companies. With the privatization of the power sector under the Electric Power Industry Reform Act (EPIRA), the government could not enter power generation, which meant the state-owned National Power Corporation had to sell its power plants to the private sector and has been prohibited from building new power plants.[29]

A median Filipino family pays more than 10% of its monthly income for electricity. Arcilla claimed that "[n]uclear power will especially spare the poorest among the Filipinos who are the ones actually allotting the lion's share of their income just for electric bills."[30] DOE Secretary Cusi claimed that for the Philippines to bring down the cost of electricity, nuclear power is the best option.[31] However, the impact of nuclear energy on the actual cost of electricity for Filipino consumers is not clear. According to a DOE official, "the extent of reduction in electricity rates will depend on the share of nuclear energy in the power generation mix. To provide for a meaningful reduction in electricity rates, the share of nuclear should ideally be at least 20 percent to 30 percent and displace the more expensive generation in the power generation mix."[32] More importantly, it remains uncertain if the government can own and operate nuclear power plants, given the limitation imposed by EPIRA, or if the private sector will run these plants and determine the cost of nuclear-generated electricity.

Nuclear energy preparations: key actors and mechanisms

The Philippines might be able to deploy nuclear projects in five years if the new Marcos administration prioritizes the inclusion of nuclear in the power mix, among others, according to two DOE officials. The Philippine Energy Plan envisions nuclear energy to come in by 2030, but that it may come in as early as 2027. The newly elected president has been very vocal in tapping nuclear power, partly owing to the fact that his late father, former President Ferdinand Marcos Sr., ordered the construction of the

[25] Interview with a Philippine regulatory official, Zoom, July 2020.
[26] Carlo Arcilla. Debunking Nuclear Myths, Presented at the NU-CLEAR: Webinar Series on Nuclear Power - Webinar 1, October 23, 2020.
[27] Philippine News Agency. Carbon tax makes PH energy sector uncompetitive: DOE chief. March 9, 2021, https://www.pna.gov.ph/articles/1133078 (accessed February 21, 2022).
[28] Antonio GM La Vina, et al. Navigating a trilemma: Energy security, equity, and sustainability in the Philippines' low-carbon transition. *Energy Research & Social Science*, 35 (2018) 37-47. https://doi.org/10.1016/j.erss.2017.10.039
[29] Interview with a Philippine regulatory official, Zoom, July 2020.
[30] Philippine Nuclear Research Institute. "DOST backs revisit of nuclear energy policy to address rising power cost," August 24, 2020. https://www.pnri.dost.gov.ph/index.php/2-uncategorised/670-dost-backs-revisit-of-nuclear-energy-policy-to-address-rising-power-cost (accessed February 21, 2022).
[31] Philippine News Agency. "Carbon tax makes PH energy sector uncompetitive: DOE chief," March 9, 2021. https://www.pna.gov.ph/articles/1133078 (accessed February 21, 2022).
[32] Interview with Patrick Aquino, Undersecretary of the Department of Energy, Taguig City, Philippines, May 2022.

country's first and only nuclear power plant, the BNPP. President Marcos Jr., who assumed office on June 30, 2022, pledged to build "at least one nuclear power plant so we can finally produce cheap energy and for us to lower our electricity rates."[33]

But the resumption of the Philippines' journey toward nuclear power actually began under President Rodrigo Duterte (2016-2022). It was in 2016 when the Philippine government started exploring the possibility of nuclear power and the revival of BNPP. The DOE co-organized, together with PNRI and the IAEA, an international conference on "Prospects of Nuclear Power in the Asia Pacific Region" in Manila in August 2016. Immediately after, the DOE, in partnership with the PNRI, availed technical assistance from the IAEA to assess infrastructure needs for the possible introduction of nuclear power in the country under a technical cooperation project (IAEA TCP-PHI2011) titled, "Assessing the Development of Nuclear Power Program in the Philippines (Phase I)."[34]

To spearhead preparations for the possible use of nuclear power, the DOE created the Philippine Nuclear Energy Program Implementing Organization (NEPIO) in October 2016. NEPIO's main task is to coordinate the necessary steps and preparatory measures pertaining to nuclear power. Crucial achievements of NEPIO and DOE are (1) the successful peer review mission by the IAEA in 2018 to assess the 19 nuclear infrastructure issues that the country needs to address before embarking on a nuclear energy project; (2) the Integrated Work Plan that serves as a guiding document to systematically organize cooperation activities with IAEA on nuclear infrastructure development; (3) a pre-feasibility study on Small Modular Reactor deployment in an industrial zone in northern Philippines; and (4) the conclusion of Energy Planning Studies (EPS) and Pre-Feasibility Studies 2017 of Nuclear Infrastructure Issues (PFS 2017), which contain the assessment of the 19 infrastructure issues necessary for drafting the country's national position to embark on nuclear energy program.[35]

The EPS, in particular, strongly recommends the use of nuclear power, given the rising energy demand in the country and the lack of cleaner energy sources. The study finds that natural gas and renewables, as clean energy options, actually compete with each other. Hence, there will be a need for other low carbon sources to replace coal's share in the power mix. For DOE-NEPIO, nuclear power can help decrease the country's GHG emissions and is complementary to natural gas and renewables in power generation. It therefore concludes that the entry of nuclear power is feasible as a mitigation option. Based on NEPIO's study, DOE submitted the recommendation for a "National Position to Embark on a Nuclear Power Program" to the Office of the President in April 2018. A national position, if approved by the president, signals the country's official pro-nuclear energy stance.[36]

In December 2018, upon the request of the Philippines, the IAEA sent an international peer review mission, comprising of 13 experts from various countries. The experts evaluated the preparatory steps being undertaken by the Philippines, including an assessment of the 19 nuclear infrastructure issues that the country needs to address. In October 2019, DOE received the Report of the INIR Mission, which provides evaluations and recommendations that would further help the Philippines address the 19 infrastructure requirements needed before embarking on a full nuclear energy program.[37]

The report identifies key areas that require further actions:

1. Engage a wider range of stakeholders in finalizing the work needed to come up with a national position;
2. Revise the country's legal and regulatory framework that enhances national commitment to safety, security, and non-proliferation;
3. Strengthen the country's capacity to implement and enhance its approaches to several issues related to a future nuclear power project.[38]

[33] Yuichi Shiga. "Marcos vows."
[34] Department of Energy, Philippines. *Philippine Energy Plan.*
[35] Ibid.; Department of Foreign Affairs of the Philippines. "PH, IAEA Discusses Integrated Work Plan for Nuclear Infrastructure." December 13, 2019. https://dfa.gov.ph/dfa-news/news-from-our-foreign-service-postsupdate/25268-ph-iaea-discusses-integrated-work-plan-for-nuclear-infrastructure (accessed May 4, 2021)
[36] Department of Energy, Philippines. *Philippine Energy Plan*.
[37] IAEA. *Report of the Phase 1 Integrated Nuclear Infrastructure Review Mission to the Philippines, 10–17 December 2018*. https://www.iaea.org/sites/default/files/documents/review-missions/inir-report-philippines-171218.pdf (accessed February 21, 2022).
[38] Ibid.

In July 2020, President Duterte issued an executive order mandating a study on the national position on a nuclear energy program and creating the Nuclear Energy Program Inter-agency Committee (NEPIAC) to conduct such a study and recommend further actions, including the possibility of the rehabilitation of the BNPP.[39] NEPIAC is composed of 17 government agencies. In December 2020, NEPIAC submitted its nuclear power plan and recommendations. On February 28, 2022, President Duterte signed Executive Order No. 164, adopting a national position for a nuclear energy program ─ in effect reviving the quest for nuclear power. The order expresses the Philippines' commitment to pursue the highest standards of nuclear safety, security, and safeguards as well as ensures the peaceful use of nuclear energy. The national position explains why nuclear power is being chosen, while taking into account the results of long-term energy planning and national priorities, such as energy security, climate change actions, including the mitigation of greenhouse gases, and economic development.[40] It took six years (essentially the full term) of the Duterte presidency to make a significant step on the adoption of a national position on nuclear power.

One key instruction of Executive Order No. 164 is for NEPIAC to study all audits made on the viability of BNPP to be rehabilitated and operationalized and make recommendations. Following the adoption of a national position on nuclear energy, the country's nuclear power program faces brighter prospects under President Marcos, who openly supports the inclusion of nuclear power in the energy mix. The adoption of nuclear power, as well as revisiting the 620 MW nuclear reactor, was a campaign promise of Marcos. In May 2022, South Korean Ambassador to the Philippines Kim Inchul met Marcos to express his country's support for the incoming administration – including an offer to help revive the BNPP.[41]

Current status of Bataan nuclear power plant

According to PNRI Director Arcilla, the government could simultaneously pursue efforts to rehabilitate and commission the shelved BNPP while developing plans to build new small modular reactor (SMR) nuclear power plants that are easier and faster to put into service. He pointed out that the BNPP is a 620 MW plant, while the Philippines is seeing a need to prepare for a power demand of more than 10,000 MW in a few years. The new administration can negotiate with South Korean power firm KEPCO and its subsidiary Korea Hydro and Nuclear Power, to get an updated feasibility study on the rehabilitation of the BNPP and determine the mode of contract for the project.[42] South Korea, which operates a nuclear plant that is an exact twin of the BNPP, has demonstrated its business interest in reviving the plant through the years. Other plants with the same design are in Slovenia and Brazil. The South Korean proposal is to invest just over $1 billion to reopen the BNPP – roughly the same amount needed to put up a coal-fired power plant with the same capacity. But a DOE official told me that the rehabilitation and operationalization of the Bataan NPP will require additional investments. Over the last two decades, firms from South Korea, China, and Russia have assessed the viability of the rehabilitation and operationalization. Estimates range from $1 billion to $5 billion. Unfortunately, they are not at liberty to divulge publicly the details of the proposal on rehabilitation as these are covered by non-disclosure agreements.[43]

On May 24, 2022, I conducted field research at the BNPP, located in the province of Bataan, 80 km away from Manila. I was able to interview nuclear engineers and maintenance staff of BNPP, who are employees of the state-owned National Power Corporation (NAPOCOR). The state-owned firm was supposed to be the operator of BNPP when it was completed in 1985. The late President Ferdinand Marcos Sr. ordered construction of the plant as a result of the 1973 global oil crisis that severely

[39] President of the Philippines. Executive Order No. 116, Directing a Study for the Adoption of a National Position on Nuclear Energy Program, Constituting a Nuclear Energy Program Inter-Agency Committee, and for Other Purposes, Manila, July 24, 2020.
[40] President of the Philippines. Executive Order No. 164, Adopting a National Position for Nuclear Energy Program, and for Other Purposes, Manila, February 28, 2022.
[41] Maricar Cinco. "Bataan nuke power talks revive hopes, fears," *ABSCBN News*, June 9, 2022. https://news.abs-cbn.com/spotlight/06/09/22/bataan-nuke-power-talks-revive-hopes-fears (accessed July 7, 2022).
[42] Rainier Ronda. "Nuclear science chief pushes BNPP rehab, small plants," *Philippine Star*, June 4, 2022. https://www.philstar.com/headlines/2022/06/04/2185915/nuclear-science-chief-pushes-bnpp-rehab-small-plants (accessed July 7, 2022).
[43] Interview with a Philippine regulatory official, Zoom, July 2020; Interview with Patrick Aquino, Undersecretary of the Department of Energy, Personal Communication, May 2022.

affected the Philippines. His administration considered nuclear energy to be key in addressing the country's energy demands and to decrease dependence on oil imports. But like Marcos, the BNPP was shrouded with controversies. The plant was set for commercial operations in June 1985, but was delayed. Then, the 1986 People Power Revolution toppled the two-decade Marcos regime. The BNPP was eventually mothballed by President Corazon Aquino in 1986 due to safety concerns in the wake of the Chernobyl accident as well as corruption allegations involving a Marcos crony. Westinghouse built the BNPP at a cost of $2.3 billion, although it never produced a single watt of electricity. [44] NAPOCOR currently has the legal mandate to maintain the power plant.

Located on a hill facing the West Philippines Sea/South China Sea, the BNPP reservation has a total land area of 389 hectares, housing the one power station already built. A vacant part of the reservation is allocated for a second unit. BNPP has already tested the site for safety from any potential hazards such as volcanic eruption, earthquakes, tsunamis, and typhoons. The plant is unlikely to be affected by a tsunami as it is located 18 meters above sea level, enough to withstand an eight-meter-high tsunami (the possible height of a tsunami that may hit the area). Engineers in the facility, citing the country's geological agency, the Philippine Institute of Volcanology and Seismology (PHIVOLCS), also debunked the claim that the BNPP is on a fault line. PHIVOLCS found the nearest fault line 60 km away. According to BNPP engineers, even if this fault or other major faults in or near the main island of Luzon would move, the plant could withstand the intensity of a strong tremor (Intensity VIII).[45]

While it has never been operated since 1986, the power plant is well maintained. The reactor unit, turbine generator, and the containment, which are all essential parts of a nuclear power plant, appear to be still new and in good condition. The engineers and staff clearly and confidently asserted that BNPP can still be operated and can be upgraded to a digital control system or can be rehabilitated. Even with its existing analog equipment, the manufacturers of such equipment still exist and can provide spare parts. The interior and various parts of BNPP, including the reactor unit, are well kept and there is no sign that they are deteriorating. I was told that one major reason is that all materials used to build BNPP were high quality and from reputable suppliers.[46]

South Korean companies are very interested in rehabilitating the BNPP. They have visited the site several times since 2008 to conduct assessment and feasibility studies.[47] Korea Hydro & Nuclear Power (KHNP) has offered to conduct a follow-up study to update its 2017 pre-feasibility study on the rehabilitation of BNPP as it expressed keen interest to participate in the Philippine government's push to add nuclear power generation into its energy mix. Its earlier studies were fully funded by the company. Younghwan Choi, KHNP senior manager for overseas nuclear business section, said they are ready to update their previous studies upon official request by the Philippine government. KHNP's proposal includes not just rehabilitation of the Bataan nuclear plant but also building SMRs and other large-sized nuclear plants.

Exploring small modular reactors

The Philippines is also considering small modular reactors (SMRs), including floating ones, given the archipelagic nature of the country. Deploying an SMR in the country might come sooner, given the development of SMR models that are suitable for island provinces and areas outside the main grid. [48]In 2019, the DOE and Korea Hydro and Nuclear Power (KHNP) jointly conducted a pre-feasibility study on the possibility of SMR deployment in Cagayan Economic Zone, a growing industrial enclave in northern Philippines. [49] In 2019, Russia and the Philippines also signed an agreement on nuclear energy cooperation to explore the possible construction of nuclear power plants, including floating nuclear reactors, by ROSATOM in the Philippines. Apart from Cagayan, other island provinces such as Sulu in the southern Philippines and Palawan expressed interest in hosting future SMRs.[50]

[44] Interview with Bataan Nuclear Power Plant engineers, Morong, Bataan, 24 May 2022; See also Benjamin Pulta. "Late Marcos crony owes country P1.1-B over BNPP project." Philippine News Agency, June 15, 2021. https://www.pna.gov.ph/articles/1143793 (accessed July 7, 2022).
[45] Interview with Bataan Nuclear Power Plant engineers, Morong, Bataan, 24 May 2022.
[46] Ibid.
[47] Ibid.
[48] Interview with a Philippine regulatory official, Zoom, July 2020.
[49] Department of Energy of the Philippines, Nuclear Power Program, Chapter 10 in *Philippine Energy Plan 2018-2040.* https://www.doe.gov.ph/sites/default/files/pdf/announcements/10_Nuclear%20Energy%20Program_19Aug2020.pdf (accessed February 21, 2022).
[50] Carlos Arcilla, Debunking Nuclear Myths. Presented at the NU-CLEAR: Webinar Series on Nuclear Power - Webinar 1. October 23, 2020.

Most recently, the Philippines and the United States signed a Memorandum of Understanding on Strategic Civil Nuclear Cooperation (NCMOU) on March 10, 2022, to further deepen the cooperation between the two countries in developing the Philippines' nuclear energy program. With the agreement, the Philippines' Department of Energy will intensify its collaboration with the United States to improve knowledge and understanding by furthering the capacities on nuclear infrastructure through technical assistance programs. Philippine energy officials stated that part of the cooperation is US technical assistance for the Philippines' small modular reactors study. After the signing of the MOU, the Philippines' DOE began a feasibility study to determine the viability of using SMRs in certain areas in the country.[51]

SMRs are perceived to be ideal for isolated Philippine regions that are not connected to the main grid, according to nuclear promoters in the country. DOE predicts that SMR deployment could come as early as 2027-2028.[52] One scenario being considered is that if the Philippines decides to pursue nuclear energy and even deploy SMRs in the future, other Southeast Asian countries may do so as well. In this regard, an important issue is the need to update existing regulatory and legislative frameworks on the peaceful use of nuclear energy in the region. This issue pertains to the safety and security of emerging SMRs using generation IV designs, i.e., thermal-neutron, molten-salt or gas (rather than water) cooled reactors, which are promoted to be safer, more secure, proliferation-resistant, and cheaper than conventional NPPs. However, without any concrete case of commercial SMRs ready to be deployed, licensing and regulatory best practices for this technology would remain abstract. This presents both a challenge and an opportunity for the Philippine regulatory framework as it needs to be updated so it can be adapted to this new reactor technology.

Key challenges to the Philippines' nuclear power program

Legal and regulatory framework must be revised

Executive Order No. 164 recognises a comprehensive legal and regulatory framework would be needed for its nuclear program. The Philippine Congress needs to legislate a comprehensive nuclear law that will replace decades-old, outdated laws. Such a proposed bill remains pending and it remains to be seen how and when the next Congress will act on it. Nonetheless, given that the Congress is controlled by allies of the Marcos administration, which has already expressed its commitment to nuclear power, there is a higher chance that such a bill will be enacted soon. There is also a need to establish an independent nuclear regulatory body and the Senate needs to ratify key global nuclear safety and security conventions and treaties.

There is a clear recognition from regulatory officials at PNRI that having a regulatory body that also promotes nuclear energy is a fundamental challenge to nuclear energy preparations in the country. Currently, PNRI has a dual but conflicting mandate of regulating the use of nuclear power for peaceful applications and promoting its uses and other applications. A regulatory official noted that this arrangement must be amended before the country embarks on nuclear power. The INIR Mission's report recommends that the Philippines must institutionalize a legal and regulatory framework that guarantees and governs national commitment to safety, security, and non-proliferation, including the creation of an independent regulatory agency. It must be emphasized that current nuclear laws are outdated, two of which were passed in 1957 and 1968, and require major amendments as they are not aligned with current global nuclear safety and security conventions. As the PNRI wants to be freed from its conflicting mandate of regulating and promoting nuclear technology, its officials are actively endorsing the proposed Comprehensive Atomic Regulation Act, particularly the creation of an independent Philippine Atomic Regulatory Commission. [53] It also contains provisions on radiation protection, emergency preparedness and

[51] Jane Bautista. "Gov't expert urges adoption of small nuclear reactors." *Philippine Daily Inquirer,* June 6, 2022. https://newsinfo.inquirer.net/1606794/govt-expert-urges-adoption-of-small-nuclear-reactors; Department of Foreign Affairs, Philippines. "PH, US Sign a Memorandum of Understanding to Boost Cooperation on Nuclear Energy." March 14, 2022. https://dfa.gov.ph/dfa-news/news-from-our-foreign-service-postsupdate/30223-ph-us-sign-a-memorandum-of-understanding-to-boost-cooperation-on-nuclear-energy

[52] Interview with a Philippine regulatory official, Zoom, July 2020.

[53] Interview with a Philippine regulatory official, Quezon City, the Philippines, May 26, 2022.

response, transport of radioactive material, import and export of nuclear and other radioactive material, management of spent fuel and radioactive waste, safeguards, physical protection and security, and civil liability for nuclear damage. The passage of such an important bill is needed even before the country embarks on its nuclear energy program.

Basically, the IAEA's INIR Mission Report strongly prescribes the following revisions to the current legal framework:

1. Push for the passage of a comprehensive nuclear law with a provision for the establishment of a separate and independent nuclear regulatory authority that will ensure nuclear safety; and
2. Amend and review of the EPIRA law to provide for the inclusion of nuclear power (ownership, funding and financing aspects).[54]

Increasing the number of nuclear regulators

A regulatory official from the current Marcos administration reiterated that it is very highly likely that the Philippines will adopt and introduce nuclear energy. However, there is a need to increase the manpower resources of the PNRI, given that even without nuclear power plants in the country, there is already a growing utilization of medical-related nuclear techniques that need to be regulated. Currently, there are only 30 staff deployed in the Nuclear Regulatory Division of PRNI, and only four are working on regulating nuclear security. With the likelihood of the Philippines building/opening nuclear power plants, the PNRI will definitely have additional regulatory responsibilities until a new regulatory commission is established. PNRI official asserted that the agency is ready to enhance its regulatory capacity, in particular the promulgation of updated nuclear-related regulations.[55]

Ratifying nuclear conventions and treaties

The country's record of ratification of nuclear treaties remains patchy, incomplete, thereby creating loopholes in the country's nuclear safety and security framework (see Table 1).

Treaty/Convention	Status of Ratification
Treaty on the Non-Proliferation of Nuclear Weapons	Ratified
Treaty on the Prohibition of Nuclear Weapons	Ratified
Safeguards Additional Protocol	Ratified
Convention on Physical Protection of Nuclear Materials (CPPNM)	Ratified
2016 CPPNM Amendment	Ratified
Nuclear Terrorism Convention (ICSANT)	Signed only
Comprehensive Nuclear Test-Ban Treaty (CTBT)	Ratified
Convention on Nuclear Safety (CNS)	Signed only
Joint Convention on Spent Fuel and Radiological Waste	Signed only
Convention Early Notification of a Nuclear Accident	Ratified
Code of Conduct on the Safety and Security of Radioactive Sources (Political Commitments/non-legally binding)	Political commitment registered

Table 1 Status of Ratification of Key Nuclear Conventions by the Philippine[56]

The INIR Mission recommended the completion of the legislative process for the ratification of Convention on Nuclear Safety, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management as well as the Amendment to the Convention on the Physical Protection of Nuclear Material.[56] These are important treaties that need to be included in domestic legislation especially if NPPs are planned to be built.

Enhancing nuclear security

Nuclear security is extremely relevant in the Philippines given the robust use of radioactive materials for various peaceful applications, even in the absence of an operating nuclear power reactor. As mentioned earlier, PNRI collaborates with external organizations—primarily the IAEA, European Union,

[54]IAEA. *Report of the Phase 1.*

[55] Interview with a Philippine regulatory official, Quezon City, the Philippines, May 26, 2022.

[56] IAEA. *Report of the Phase 1.*

and the ASEAN Network of Regulatory Bodies on Atomic Energy (ASEANTOM)—to enhance its capacity to enforce nuclear security regulations and train stakeholders involved in nuclear security. Nonetheless, with the possibility of operating NPPs in the future, the Philippines would need to expand its nuclear security regulatory framework and enforcement capacity to include nuclear power facilities and nuclear materials, not just radioactive materials being used for non-power applications.

The INIR Mission's report encourages the Philippines to assess and improve the national coordination mechanisms and existing frameworks for nuclear security to meet the needs of a nuclear power program.[57] The country's Integrated Nuclear Security Support Plan (INSSP) was reviewed in 2021, including the impact of the future use of nuclear power. [58] NEPIO also created its own Technical Working Group for Nuclear Security whose personnel have attended various nuclear security training courses and workshops from the Korea Institute of Nuclear Non-proliferation and Control (KINAC) and PNRI's Nuclear Security Support Center. There is also a plan to expand this technical working group and NEPIO to include key officials from other government agencies that have relevant nuclear security responsibilities, such as the Bureau of Customs, police, CBRN unit of the military, and the Philippine Coast Guard.[59]

Since its establishment in 2013, ASEANTOM has conducted a series of capacity building programs aimed at boosting cooperation among ASEAN member states and strengthening their collective and individual nuclear security capacities. These include joint cross-border nuclear security exercises on maritime and land borders by regulatory and law enforcement officers to prevent and investigate illicit use of and trafficking in nuclear and radioactive materials. [60] This is especially relevant for the Philippines given that provinces that may want to host future SMRs are near the country's porous maritime borders. Palawan remains vulnerable to potential terror attacks by extremist groups based in the southern Philippines. Sulu province still is a hotbed of the notorious Abu Sayyaf Group and the home base of several pirate groups. The country's maritime security concerns, such as piracy, the presence of terrorist groups, unsecured maritime borders, smuggling, hijacking, and territorial disputes, could pose serious security threats to floating reactors.

This issue was partially addressed by the Philippines' tabletop trilateral exercise with Malaysia and Indonesia on detection and response to nuclear security incidents in their maritime borders in 2018 and its participation in nuclear security simulation exercises among ASEAN security officers, with the assistance from the European Commission in 2016. These exercises promoted the harmonization and exchange of good practices among key nuclear security actors from the region. It tested the internal (i.e., interagency) and external (i.e., regional/international) communication and coordination mechanisms, which have been identified as key challenging issues in nuclear security detection.[61] [62]These issues were also noted by the INIR Mission sent to the Philippines. The Philippine police, military, PNRI, and other law enforcement officers considered these exercises as effective training modalities.[63]

"It is crucial for the Philippines to strengthen its nuclear emergency preparedness and response capability"

Currently, the PNRI is an active participant of the training project between ASEANTOM and the US National Nuclear Security Administration (NNSA), known as Exercise Development Training Series.

[57] Ibid.
[58] FNCA. Summary of Country Reports, 10th Workshop on Nuclear Security and Safeguards Project of Forum for Nuclear Cooperation in Asia (FNCA), February 19, 2021.
[59] IAEA. *Report of the Phase 1*
[60] ASEANTOM representative. Current Status and Future Plan of ASEANTOM. Presented at the Council for Security Cooperation in the Asia-Pacific-Nuclear Energy Experts Group Meeting, Singapore, February 6, 2020.

[61] Catherine Friedly. IAEA Holds Table Top Exercise to Strengthen Detection and Response Capabilities in Maritime Nuclear Security Events. IAEA, October 3, 2018, https://www.iaea.org/newscenter/news/iaea-holds-table-top-exercise-to-strengthen-detection-and-response-capabilities-in-maritime-nuclear-security-events (accessed February 21, 2022).
[62] European Commission. Improving nuclear security practices - simulation exercise with southeast Asian countries. 2016, https://ec.europa.eu/jrc/en/news/improving-nuclear-security-practices-simulation-exercise-southeast-asian-countries (accessed February 21, 2022).
[63] Catherine Friedly. IAEA Holds Table Top Exercise to Strengthen Detection and Response Capabilities in Maritime Nuclear Security Events. IAEA, October 3, 2018, https://www.iaea.org/newscenter/news/iaea-holds-table-top-exercise-to-strengthen-detection-and-response-capabilities-in-maritime-nuclear-security-events (accessed February 21, 2022).

Launched in 2019, the project is a regulator-led event that seeks to enhance members states' capabilities to prevent, counter, and respond to acts of radiological and nuclear terrorism. The series includes a training workshop and at least four exercises covering topics such as material theft, smuggling, and incident response. It also involves a train-the-trainer exercise equipping the regulators with fundamental skills required to plan, conduct, and evaluate their own exercises and to provide detailed instructions on how to lead nuclear security tabletop exercises. A kick-off workshop and two training events were conducted before the COVID-19 pandemic stalled the implementation.[64]

Preparing for nuclear emergencies

Another significant area of concern identified by the INIR Report is the assessment of existing emergency preparedness and response arrangements for the nuclear power program. It accentuates that NEPIO has not yet assessed existing arrangements against the requirements of its future nuclear power project and therefore encouraged it to do so.[65] The report notes that a nuclear or radiological emergency can be triggered by conventional emergencies, natural events/disasters, security incidents, and/or big national or global health crises. [66] In the context of the Philippines, natural hazards/events that regularly hit the country such as earthquakes, volcanic eruptions, typhoons and tsunamis, can pose safety challenges to its future NPPs if there is weak regulatory governance, leading to a large-scale nuclear emergency. Nuclear security challenges owing to the presence of non-state armed groups could also lead to emergencies if they manage to sabotage nuclear facilities and materials.

The PNRI has established the foundation of the national nuclear emergency preparedness and response framework. In 2000, it developed the National Radiological Emergency Preparedness and Response Plan (RADPLAN), establishing a national and coordinated emergency response capability for nuclear and radiological emergencies. The RADPLAN specifies roles and responsibilities of participating agencies and mandates them to develop and maintain their own plans, in coordination with the Office of Civil Defense and PNRI. The RADPLAN designates PNRI to coordinate the nuclear emergency response. It is currently being revised by the PNRI together with the country's disaster management coordinating council to meet the standards set by the IAEA Safety Standards Series on Preparedness and Response for a Nuclear or Radiological Emergency.[67]

It is crucial for the Philippines to strengthen its nuclear emergency preparedness and response capability. PNRI researchers determined that despite having no NPP facilities currently in operation, the Philippines is at risk of possible contamination from radioactive releases from nuclear emergencies that may happen in the Asia-Pacific region. It is proximate to countries operating NPPs, particularly in mainland China and Taiwan. They also noted that due to the country's geographical location, the Philippines is regularly hit by strong typhoons, storms and seasonal monsoons, which may spread nuclear fallout onto the Philippine environment in the event of a nuclear emergency. The possible rehabilitation and operation of the BNPP is another crucial reason. It is located 100 km from Metro Manila, which is within one of the BNPP's off-site emergency zones. Manila has a population of more than 12 million and necessitates "baseline radioactivity data to ensure a well-established radiation protection program in preparation for possible nuclear and radiological emergencies."[68]

Currently, the PNRI spearheads the enhancement of the country's nuclear emergency preparedness and response through several recurring training courses on nuclear or radiological emergency preparedness, and response for PNRI experts; medical doctors and hospital paramedics; and first responders from the police, military and other agencies representing the local disaster risk reduction and management offices. To monitor the radiation level in various parts of the country, PNRI implements the project titled "System for On-line Monitoring of Environmental Radiation" or SOMER, which includes installation of radiation monitoring stations and helps the agency determine whether there is a need to activate emergency preparedness and response. [69] The INIR Mission noted that there are 14 monitoring stations that were

[64] National Nuclear Security Administration. NNSA holds nuclear security training workshop with ASEAN members. August 29, 2019. https://www.energy.gov/nnsa/articles/nnsa-holds-nuclear-security-training-workshop-asean-members (accessed February 21, 2022).
[65] IAEA. *Report of the Phase 1.*
[66] IAEA. *Preparedness and Response for a Nuclear or Radiological Emergency Combined with Other Incidents or Emergencies*. Vienna: IAEA, 2020.
[67] Philippine Nuclear Research Institute. *2019 Performance Report*. Quezon City: DOST-PNRI, 2019.
[68] R. R. Encabo, et al. "Measurement of ambient gamma dose rate in Metro Manila, Philippines, using a portable NaI(TI) scintillation survey meter." *Environmental Monitoring and Assessment.* Volume 192, (2020).p 400.
[69] Philippine Nuclear Research Institute. *2019 Performance Report*. Quezon City: DOST-PNRI, 2019.

being built throughout the country, in cooperation with the IAEA.[70]

While these PNRI initiatives clearly indicate that it recognizes the importance of setting up an emergency preparedness and response framework, such a framework has yet to be institutionalized through a nuclear law. Moreover, it has yet to be fully integrated with the country's national disaster preparedness and response framework and implemented by relevant agencies, including the NEPIO. It remains uncertain whether the country's frontline agencies with rescue and response responsibilities and its healthcare system can fully prepare for and respond to the consequences of a nuclear incident within the country's jurisdiction.

The government also needs to ensure that any proposed NPP locations will be safe from disasters given that the Philippines is part of the Pacific Ring of Fire and the typhoon belt along the Pacific Ocean. A national hazard assessment can also verify the country's selection of potential NPP sites and potential hazards (if any) that need to be considered. The Philippines already has a geohazard assessment map, encompassing hydro-meteorological, seismic, and volcanic hazards that are present in every province, town and city. There are reportedly potential sites that can host NPPs with low vulnerability to such hazards. In 2021, the NEP-IAC shortlisted 15 sites: Racat Rapuli, Sinuangan and Matara Point in Sta. Ana, Cagayan; Concepcion and Tagbarungis in Puerto Princesa, Palawan; Sipalay and San Carlos, Negros Occidental; Bayawan, Negros Oriental; Piacon Point and Cauit in Siocon, Zamboanga, Bagac, Bataan; San Juan, Batangas; Padre Burgos, Quezon; Ternate, Cavite; and General Santos City. The deployment of SMRs is being considered for off-grid or isolated islands. Possible sites include Sulu, Palawan, and the Cagayan Economic Zone Authority (CEZA).[71]

Intensifying public education

Another key recommendation of the INIR Mission is to mitigate the negative perception about nuclear energy through a broad-based and updated communication plan. This negative perception is mainly reflected in op-ed commentaries, media statements, and small demonstrations by anti-nuclear groups. An energy official noted that "social acceptance is the biggest challenge to the introduction of nuclear power in the Philippines."[72] However, public acceptance of the use of nuclear power appears to be strong in the Philippines. President Duterte's Executive Order No. 164 cites a nationwide survey conducted in 2019 indicating that 79% of Filipinos support the rehabilitation of the shelved BNPP. Also, 65% are in favor of building new nuclear power plants.[73] When I visited the BNPP and the town of Morong that hosts the plant, I distinctly observed that it only has a small population while the center of the town population is 10 km away from the plant. While the local community may have had some reservations in the past regarding the rehabilitation of BNPP, it now appears that convincing a sparsely populated host community to support BNPP may not be difficult. In the past few years, relevant government agencies have actively promoted nuclear power as the best option for the country to bring down the cost of electricity. Promotional activities include regular media interviews by DOE and PNRI officials, quarterly seminars and, during the height of the COVID-19 pandemic, webinars broadcasted through social media accounts of key agencies involved in nuclear power preparations.[74]

Conclusion

With the new Marcos administration aiming to establish at least one NPP to be operational within his term (2022-28), the country will need at least five years to fulfil all preparatory requirements recommended by the INIR Mission of the IAEA. This presupposes that the legal and regulatory framework are also in place. Currently, the most urgent step is for Congress to pass legislation that meets the IAEA INIR requirements.

The Philippines' national position on adopting nuclear power as a future energy source took into account the results of long-term energy planning and national priorities, such as energy security, climate change actions, including the mitigation of greenhouse gases, and economic development. In the past six years, the Philippines has indeed considered these key factors to determine why it might need nuclear power in its future energy mix. However, its

[70] IAEA. *Report of the Phase 1.*
[71] Interview with Patrick Aquino, Undersecretary of the Department of Energy, Taguig City, Philippines, May 2022.
[72] Interview with Patrick Aquino, Undersecretary of the Department of Energy, Taguig City, Philippines, May 2022.
[73] President of the Philippines. Executive Order No. 164; See also *Philippine Energy Plan*
[74] See for example Carlo Arcilla. Debunking Nuclear Myths, Presented at the NU-CLEAR: Webinar Series on Nuclear Power - Webinar 1, October 23, 2020.

government must address critical preparatory issues and challenges to ensure the safe, secure, and peaceful use of nuclear power. With the projected growth of the Philippine economy and population, the increasing need for additional reliable power sources and worsening environmental problems associated with overreliance on imported fossil fuels in the country generate a strong demand for cleaner and more sustainable alternative sources.

The Philippines has decades-long experience in utilizing nuclear science and technology in various peaceful applications. Nuclear power development takes long lead times, but the country has the capacity to comprehensively address critical preparatory issues and the need to ramp up the country's pool of nuclear professionals.

5

Singapore's Energy Journey: Net-zero, New Perspectives & Nuclear?

Denise Cheong & Victor Nian

Introduction

As a small island state with an urban economy but land and resource constraints, Singapore relies heavily on imports for many of its basic needs, including the energy it needs for power generation. While energy security and affordability clearly lie at the heart of Singapore's economic competitiveness, the need for Singapore to play its part in addressing global challenges such as climate change and sustainable development has also increasingly brought environmental sustainability to the forefront. Earlier this year, Singapore had stated that it aims to achieve net zero emissions by or around mid-century, in line with the Glasgow Climate Pact adopted at the 26th UN Climate Change Conference (COP-26).

As a country with limited potential to deploy renewable energy, Singapore is actively exploring various low-carbon alternatives such as hydrogen, carbon capture, utilization, and storage (CCUS) as well as nuclear energy to diminish its reliance on natural gas as part of its clean energy transition. A 2022 report setting out expert recommendations on how Singapore can navigate the clean energy transition, has shone a light on the role that nuclear energy can play in this journey, a topic where safety and waste management remain key concerns.

It is within this context that this paper starts by looking at the outlook for the Singapore power market, followed by an overview of the power sector. It then proceeds to discuss Singapore's approach to clean energy transition, taking into consideration the abovementioned 2022 report's recommendations. As part of this broader discussion, the paper focuses, in particular, on the nuclear energy policy option. The paper concludes by reflecting on the challenges and opportunities facing Singapore in its journey towards net-zero emissions by or around mid-century.

Power market outlook

As of March 2021, imported natural gas provided 95% of Singapore's electricity needs.[1] Electricity is mainly generated through Combined Cycle Gas Turbine (CCGT), Co-Generation and Tri-Generation plants, which as of March 2021, collectively accounted for 87.2% of Singapore's total generation capacity at about 10.5 GWe (Figure 1[2]). As of June 2021, Tuas Power holds the largest market share of generation capacity at about 20.2%. This is followed by Senoko Energy at 17.6% and Keppel Merlimau Cogen at 13.9% (Figure 2[3]). Due to geographical and other constraints, solar energy is the main renewable energy option being actively pursued by the country, notwithstanding the limitations associated with its deployment.[4]

Energy consumption and demand outlook

Singapore's total electricity consumption declined by 1.7%, from 51.7 TWh in 2019 to 50.8 TWh in 2020, largely due to lower economic output during the Covid-19 pandemic.[5] The peak demand in 2020 was 7,376 MW which was just slightly over 50% of the total installed capacity.[6] The industrial-related sector represented the largest consumer of electricity in 2020

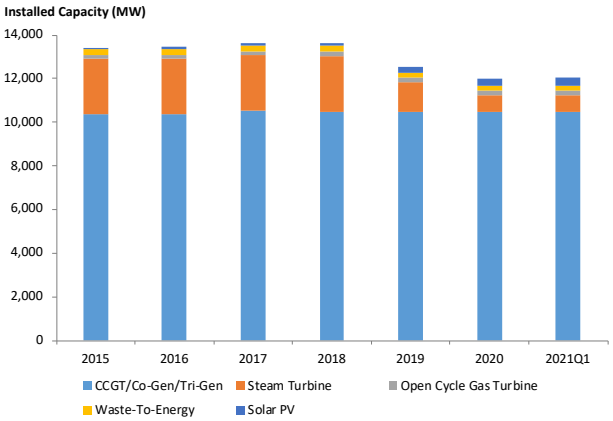


Figure 2 Installed Generation Capacity by Technology

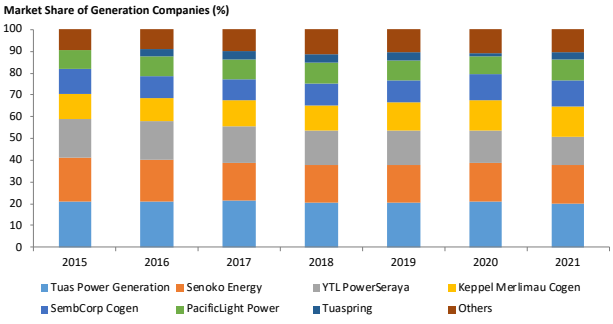


Figure 1 Share of Generation Capacity by Company

[1] "About Singapore's Energy Story," Energy Market Authority (Singapore), accessed May, 2022, https://www.ema.gov.sg/ourenergystory.
[2] Singapore Energy Statistics 2021, Energy Market Authority (Singapore), Last updated February 9, 2022.
[3] Singapore Energy Statistics 2021, Energy Market Authority (Singapore), Last updated February 9, 2022.
[4] *See* "Current energy transition blueprint" on p. [9] for more details.
[5] Singapore Energy Statistics 2021, Energy Market Authority (Singapore), Last updated February 9, 2022.
[6] Energy Market Authority (Singapore), *Singapore Electricity Market Outlook 2021 (SEMO 2021)*, November 10, 2021, https://www.ema.gov.sg/cmsmedia/PPD/Singapore-Electricity-Market-Outlook-2021.pdf, para. 2.1.

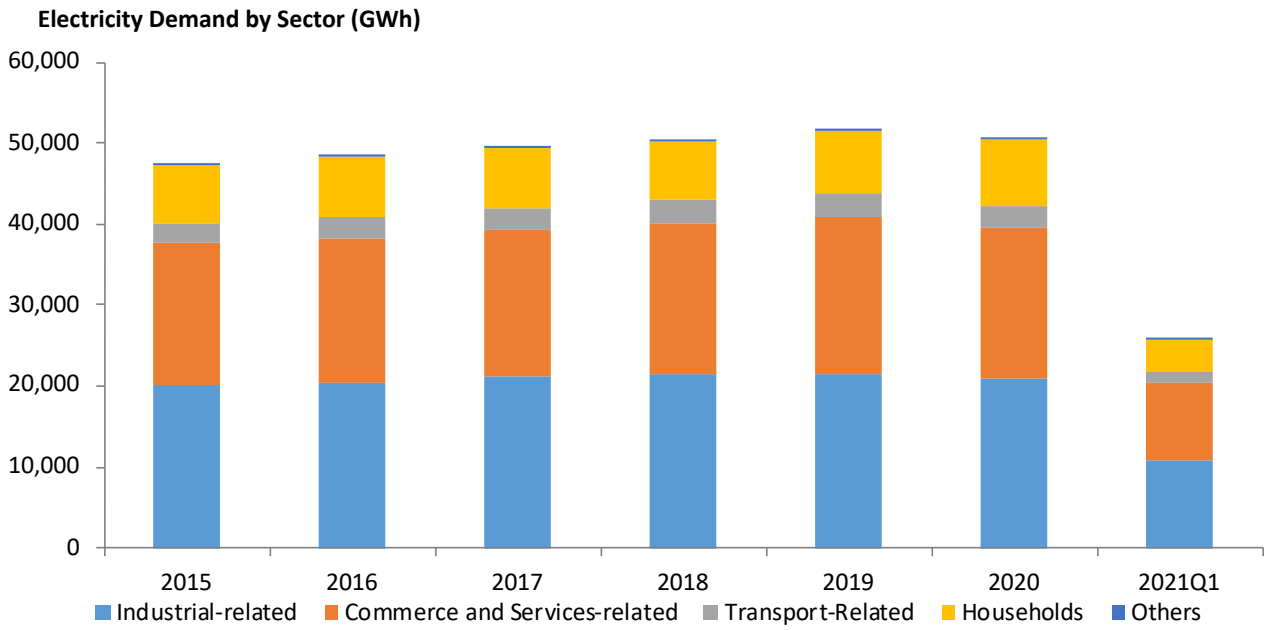


Figure 3 Electricity Demand by Sector

(41.3% share), followed by commerce & services-related (36.4%) and households (16.1%) sectors (Figure 3[7]). Due to the tropical climate of Singapore, the use of air-conditioning accounts for a major proportion of electricity demand within the households and commerce and services-related sectors. In the first half of 2021, Singapore consumed a total of 25.9 TWh of electricity.[8] Assuming the same growth trend, it is anticipated that the total electricity consumption in 2021 would have increased by 2% from 2020.[9]

Singapore's system demand saw a compound annual growth rate (CAGR) of 2.6% between 2009 and 2019. The system peak demand also grew over the same period, from 6,041 MW to 7,404 MW at a CAGR of 2.1%.[10] From 2021 to 2031, the annual system demand and system peak demand are projected to grow at a CAGR of between 2.5-3.1% (Figure 4 [11]). These projections take into account various factors, including changes to population, temperature rise due to global warming, projected GDP growth rate post-pandemic, and projected demand from new high-growth sectors such as data centres.

Supply outlook

Based on the indicative generation plans submitted by generation licensees and the projected growth of solar installed capacity in Singapore, the projected total electricity supply from 2021 to 2024 does not

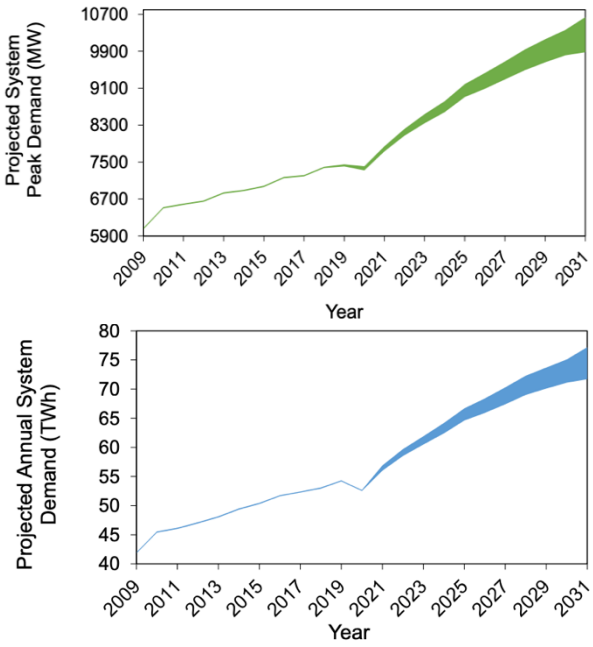


Figure 4 Projected Electricity Demand till 2031

[7] Singapore Energy Statistics 2021, Energy Market Authority (Singapore), Last updated February 9, 2022.
[8] Singapore Energy Statistics 2021, Energy Market Authority (Singapore), Last updated February 9, 2022.
[9] Singapore Energy Statistics 2021, Energy Market Authority (Singapore), Last updated February 9, 2022. As of 15 July 2022, figures in respect of the second half of 2021 are not publicly available.

[10] Energy Market Authority (Singapore), *Singapore Electricity Market Outlook 2020 (SEMO 2020)*, December 30 , 2020, https://www.ema.gov.sg/cmsmedia/PPD/Singapore-Electricity-Market-Outlook-2020.pdf, para. 2.1.
[11] Energy Market Authority (Singapore), *Singapore Electricity Market Outlook 2020 (SEMO 2020)*, December 30 , 2020, https://www.ema.gov.sg/cmsmedia/PPD/Singapore-Electricity-Market-Outlook-2020.pdf, 5-6.

show significant growth trends (**Error! Reference source not found.**[12]).[13] The sudden drop in 2021 can be attributed to the retirement of 600MW of generation capacity in 2020 and refurbishment, mothball and retirement plans for seven plants with a total of 1.7 GW of generation capacity in 2021 as indicated by generation licensees. It is projected that generation capacity will increase in 2022 based on the assumption that Singapore imports up to 100 MW through the Lao PDR, Thailand, Malaysia, Singapore – Power Integration Project (LTMS-PIP) and another 100 MW from the electricity imports trial with Malaysia.[14] In 2023 and 2024, increases in capacity will be mainly due to expectations that existing plants will complete refurbishment work and be reactivated from mothballed state.[15]

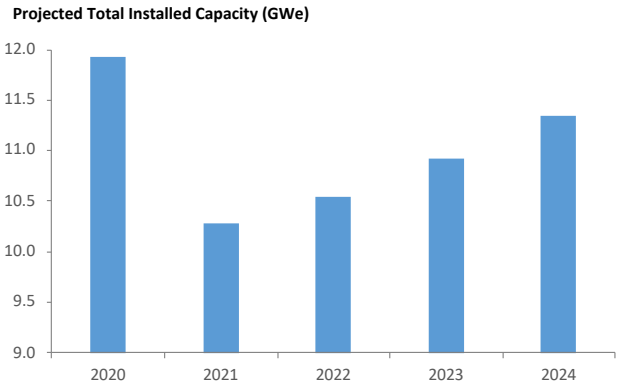


Figure 5 Projected Total Installed Capacity till 2024

With these projected developments, the reserve margin, which represents the ratio of the upper bound of the projected system peak demand over total installed generation capacity, remains above 27% between 2021 and 2024. However, any further increase in the total system demand, due to high growth sectors, such as those related to data centres and the electrification of transport will start to have a negative impact on the power sector. As it stands, there is very little incentive for generation companies in Singapore to invest in additional generation assets largely due to existing excess capacity and prevailing high fossil fuel prices. Rather, as part of its efforts to secure sufficient low-carbon electricity, Singapore is taking steps to import electricity, including electricity generated from solar energy.[16]

Overview of the power sector

The development of Singapore's energy market dates back to its early independence years when the then Public Utilities Board (PUB) was formed in 1963 as the agency responsible for the supply of electricity, water and gas in Singapore. Thirty years later, the electricity and piped gas undertakings under the agency were corporatized as Singapore Power (which now forms part of SP Group) to introduce competition in the energy sector while the PUB, Singapore's National Water Agency, remains responsible for the water supply in Singapore.[17]

Subsequently, as the energy market further liberalised, the Energy Market Authority (EMA) was set up in 2001 as part of the Singapore Government's efforts to oversee this process. Other key developments in this area included the opening up of generation and retail electricity markets to commercial players, establishment of a regulatory framework as well as introduction of a wholesale electricity market with spot bidding every 30 minutes.

Key stakeholders in the electricity market

The key stakeholders in the electricity market (Figure 6[18]) include the following:

Energy Market Authority (EMA)

The EMA is a statutory board under the Ministry of Trade and Industry and is the government agency that oversees Singapore's electricity and gas sectors. The EMA's main goals are to ensure a reliable and secure energy supply, promote effective competition in the energy market and develop a dynamic energy

[12] Energy Market Authority (Singapore), *Singapore Electricity Market Outlook 2020 (SEMO 2020)*, December 30 , 2020, https://www.ema.gov.sg/cmsmedia/PPD/Singapore-Electricity-Market-Outlook-2020.pdf, 7.

[13] In SEMO 2020, solar is assumed to have an average growth rate of about 140 MWac per year to reach 1.5 GWp by 2025. With a solar PV effective capacity of 28%, this means that 140 MWac of solar provides about 39 MWac of effective supply during peak periods.

[14] *See* "Current energy transition blueprint" on p. [9] for more details.

[15] Energy Market Authority (Singapore), *Singapore Electricity Market Outlook 2020 (SEMO 2020)*, December 30 , 2020, https://www.ema.gov.sg/cmsmedia/PPD/Singapore-Electricity-Market-Outlook-2020.pdf, para. 3.2.

[16] *See* "Current energy transition blueprint" on p. [9] for more details. *See also* Michelle Quah, "Solar cable project to help cut Singapore's emissions, boost electricity supply", *The Business Times*, November 1, 2021, https://www.businesstimes.com.sg/companies-markets/solar-cable-project-to-help-cut-singapores-emissions-boost-electricity-supply.

[17] SP Group, "Transforming to Serve Customers Better", media release, February 28, 2017, https://www.spgroup.com.sg/wcm/connect/spgrp/1d6ad20c-a510-456b-b784-77b7f30c85ed/%5B20170228%5D+Media+Release+-+Transforming+To+Serve+Customers+Better.pdf?MOD=AJPERES&CVID=.

[18] "Market Overview," Open Electricity Market, https://www.openelectricitymarket.sg/about/market-overview.

sector in Singapore.[19] The functions, duties and powers of the agency is set out in the Energy Market Authority of Singapore Act 2001 and the Electricity Act 2001.[20]

Since 2001, the EMA has been responsible for opening up the retail electricity market in Singapore. This is known as the 'Open Electricity Market Initiative' and it provides consumers with more options to manage their energy costs. When it was first introduced in 2001, it was only available to business consumers, but it has since been extended across Singapore to all consumers, including residential consumers in 2018.

Power generation companies

Power generation companies compete generate and sell electricity in the wholesale electricity market every half-hour. There are a total of eight power generation companies with the three largest players in terms of market share being Tuas Power Generation, Senoko Energy and Keppel Merlimau Cogen.[21]

Energy Market Company

The Energy Market Company Ltd (EMC) operates and administers the wholesale electricity market. Wholesale electricity trading started in 2003 and electricity is now bought and sold at half-hourly intervals through the Singapore Wholesale Electricity Market (SWEM), known as the National Electricity Market of Singapore (NEMS). The EMC administers the rules which govern the operations of the NEMS (encompassing its activities and that of market participants) to ensure a transparent and competitive trading environment.[22]

Electricity retailers

Electricity retailers buy electricity in bulk from the wholesale electricity market and compete to sell electricity to consumers.

SP Group

The SP Group owns and operates Singapore's electricity and gas transmission and distribution network. SP Group was first incorporated in 1995 as Singapore Power following the government's decision to corporatize the former electricity and gas undertakings of the Public Utilities Board.[23]

SP Services

SP Services, a member of the SP Group, is the Market Support Services Licensee (MSSL). It provides services such as the reading of electricity meters, management of meter data and facilitation of access to the wholesale electricity market.

SP PowerAssets and SP PowerGrid

SP PowerAssets is the Transmission Licensee. It owns the power grid which delivers electricity island-wide.

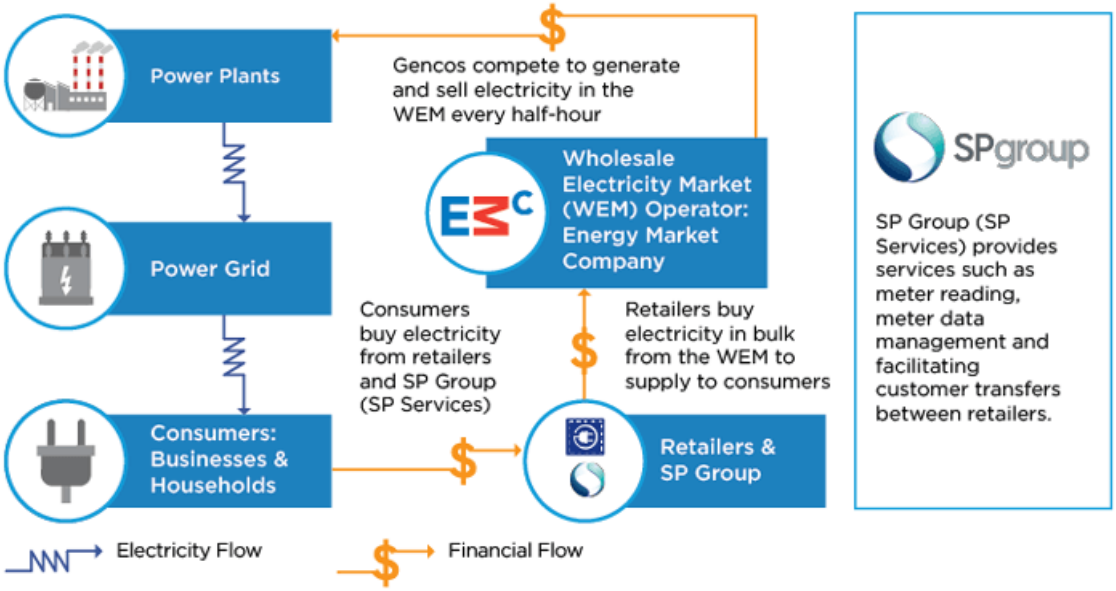


Figure 6 Singapore's Electricity Industry Structure

[19] "Vision, Mission & Values", Energy Market Authority (Singapore), updated March 14, 2022, https://www.ema.gov.sg/Vision_Mission_Values.aspx

[20] Energy Market Authority of Singapore Act 2001 (2020 Rev. Ed.) (Singapore), s.7; *See also*, Electricity Act 2001 (2020 Rev. Ed.) (Singapore).

[21] *See* "Figure 2" on p. [3] for more details.

[22] "Market Rules", Energy Market Authority (Singapore), updated March 16, 2022, https://www.ema.gov.sg/Licensees_Electricity_Market_Rules.aspx.

[23] Energy Market Authority (Singapore), *Introduction to the National Electricity Market of Singapore*, October 2010, https://www.ema.gov.sg/cmsmedia/handbook/nems_111010.pdf, 11.

SP PowerGrid is the agent appointed by SP PowerAssets to build and maintain the power grid. Both entities are members of SP Group.

Consumers

The end-consumers of electricity are broadly classified as residential consumers and non-residential consumers. Non-residential consumers are then further classified into non-contestable and contestable consumers based on their average monthly electricity consumption. Currently, the threshold for contestability is 2,000 kWh consumption per month.[24] Consumers have different options in terms of who they can purchase their electricity from, depending on the type of consumer they are and their monthly usage. Residential consumers can either purchase at the regulated tariff or from an electricity retailer. Non-residential consumers may purchase at the regulated tariff and from the wholesale electricity market. However, non-contestable consumers can only purchase from retailers participating in the Open Electricity Market, while contestable consumers can purchase from any licensed retailers.[25]

Clean energy transition

In February 2022, Singapore announced its aim to achieve net-zero emissions by or around mid-century.[26] Recent international developments have given Singapore greater confidence to raise its ambition. These include the conclusion of Article 6 of the Paris Agreement on carbon market rules at COP-26 and increased global investments in low-carbon technologies which present new decarbonisation opportunities.[27] Decarbonising the power sector is a key part of this challenge as it accounts for a 40% share of Singapore's overall emissions.[28] Furthermore, decarbonising this sector will also contribute to the decarbonisation of other major sectors such as transport and heavy industries through electrification.

However, given that Singapore is as an 'alternative energy-disadvantaged' country due to its lack of natural resources and small land area, decarbonising the power sector will be a more complex and challenging process compared to other countries and will require the government, industry and the public working together, as well as international cooperation.[29]

Since 2019, the Singapore Government has shifted towards harnessing "the 4 Switches" to guide and transform the country's energy supply.[30] In 2021, it put in place the Singapore Green Plan 2030 to advance the country's agenda on sustainable development, which includes plans on the clean energy transition.[31] More recently, in March 2022, the Energy 2050 Committee released its Report which provided recommendations for decarbonising Singapore's power sector and achieving net-zero emissions by or around mid-century. This section provides an overview of Singapore's current national strategy for the clean energy transition, highlights some of the regulatory and market-based measures and contemplates how recommendations in the Energy 2050 Committee Report may pave the way for future changes in Singapore's national energy strategy.[32]

[24] "Choosing Your Electricity Provider," Open Electricity Market, accessed 5 July 2022, https://www.openelectricitymarket.sg/business/purchase-options.

[25] "Choosing Your Electricity Provider," Open Electricity Market, accessed 5 July 2022, https://www.openelectricitymarket.sg/home.

[26] National Climate Change Secretariat et al., "Good Progress made on the Singapore Green Plan 2030 as Government Accelerates Decarbonisation and Sustainability Efforts", media release, March 8, 2022, https://file.go.gov.sg/joint-media-release-on-joint-segment-on-the-singapore-green-plan-2030-cos2022-9-march-2022.pdf, 5.

[27] National Climate Change Secretariat et al., "Good Progress made on the Singapore Green Plan 2030 as Government Accelerates Decarbonisation and Sustainability Efforts", media release, March 8, 2022, https://file.go.gov.sg/joint-media-release-on-joint-segment-on-the-singapore-green-plan-2030-cos2022-9-march-2022.pdf, para. 2; COP26 Outcomes: Market mechanisms and non-market approaches (Article 6)", United Nations Climate Change, accessed 18 August 2022, https://unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact/cop26-outcomes-market-mechanisms-and-non-market-approaches-article-6#eq-1

[28] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 12.

[29] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 4. *See also* "Speech by 2M Tan See Leng at the Asia Clean Energy Summit", Ministry of Trade and Industry (Singapore), October 26, 2021, https://www.mti.gov.sg/Newsroom/Speeches/2021/10/Speech-by-2M-Tan-See-Leng-at-the-Asia-Clean-Energy-Summit, para. 9.

[30] Energy Market Authority (Singapore), "The Future of Singapore's Energy Story", media release, October 29, 2019, https://www.ema.gov.sg/media_release.aspx?news_sid=20191029Yk3uENU5Z4bL.

[31] National Climate Change Secretariat et al., "Good Progress made on the Singapore Green Plan 2030 as Government Accelerates Decarbonisation and Sustainability Efforts", media release, March 8, 2022, https://file.go.gov.sg/joint-media-release-on-joint-segment-on-the-singapore-green-plan-2030-cos2022-9-march-2022.pdf.

[32] *See* "Nuclear Energy Option" on p. [15] for more details.

Current energy transition blueprint

The EMA's current energy transition blueprint to decarbonise Singapore's energy supply is based on "four switches": natural gas, solar power, electricity imports and regional power grids, and emerging low-carbon alternatives.[33] This blueprint seeks to transform Singapore's energy supply, while promoting energy efficiency to reduce demand and to this end has set certain goals for itself to achieve by 2030.

> **"Singapore is exploring low-carbon alternatives to help Singapore reduce its carbon emissions in the power sector over the longer term"**

Natural gas (first switch): Natural gas is the cleanest fossil fuel available today, currently generates around 95% of Singapore's electricity.[34] Apart from natural gas imported from Indonesia and Malaysia through pipelines, Singapore also imports liquefied natural gas.[35] As Singapore transitions towards cleaner energy sources, reliable and sufficient energy sources are needed to ensure supply reliability. Natural gas will continue to be a dominant fuel for Singapore as it finds ways to scale up the deployment of renewable energy. However, the blueprint recognises the need for the government to work with the power generation sector to improve the energy and carbon efficiency of natural gas generation units.[36]

Solar (second switch): Solar power is the most promising renewable energy in the near term for Singapore.[37] Under the Singapore Green Plan 2030, solar energy deployment is targeted to increase by five-fold to at least 2 gigawatt peak (GWp) by 2030.[38] Even as Singapore works towards achieving this target, solar power will constitute only around 3% of the country's total electricity demand in 2030.[39] Apart from the lack of available space to deploy solar panels, Singapore will also need to manage the issue of intermittency and enhance grid resilience as part of this switch.

Regional power grids (third switch): Singapore is taking steps to access cleaner energy sources beyond its borders by tapping on regional power grids.[40] Singapore plans to import up to 4 GW of low-carbon electricity accounting for 30% of its electricity supply by 2035.[41] To pave the way for these electricity imports, the EMA has been working with various partners on electricity import trials to assess and refine the technical and regulatory frameworks for importing electricity. These trials involve the import of electricity from Malaysia and Indonesia and as part of the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project.[42]

Emerging low-carbon alternatives (fourth switch): Singapore is exploring low-carbon alternatives to help Singapore reduce its carbon emissions in the power sector over the longer term. Alternatives being explored include hydrogen and CCUS. Advances in geothermal technology have also given Singapore the

[33] Energy Market Authority (Singapore), "The Future of Singapore's Energy Story", media release, October 29, 2019, https://www.ema.gov.sg/media_release.aspx?news_sid=20191029Yk3uENU5Z4bL, para. 3.

[34] Energy Market Authority (Singapore), "The Future of Singapore's Energy Story", media release, October 29, 2019, https://www.ema.gov.sg/media_release.aspx?news_sid=20191029Yk3uENU5Z4bL, para. 3.

[35] "Piped Natural Gas and Liquefied Natural Gas," Energy Market Authority (Singapore), accessed 6 July 2022, https://www.ema.gov.sg/Piped_Natural_Gas_and_Liquefied_Natural_Gas.aspx.

[36] Energy Market Authority (Singapore), "The Future of Singapore's Energy Story", media release, October 29, 2019, https://www.ema.gov.sg/media_release.aspx?news_sid=20191029Yk3uENU5Z4bL, para. 3. *See also* "Energy and carbon efficiency" on p. [11] for more details

[37] Energy Market Authority (Singapore), "Advancing Singapore's Energy Transition Towards a More Sustainable Future", media release, October 25, 2021, https://www.ema.gov.sg/media_release.aspx?news_sid=20211025JxngSPJ9UClo, para. 4.

[38] "Singapore Green Plan 2030 Key Targets", SG Green Plan, updated June 22, 2022, https://www.greenplan.gov.sg/key-focus-areas/key-targets.

[39] Ibid. *See also* Energy Market Authority (Singapore), "Advancing Singapore's Energy Transition Towards a More Sustainable Future", media release, October 25, 2021, https://www.ema.gov.sg/media_release.aspx?news_sid=20211025JxngSPJ9UClo, para. 5.

[40] "Regional Power Grids,", Beyond the Current, accessed 5 July 2022, https://www.beyondthecurrent.gov.sg/4-switches-city#regional-power-grids.

[41] Energy Market Authority (Singapore), "EMA Issues First Request for Proposal for Electricity Imports", media release, November 12, 2021, https://www.ema.gov.sg/media_release.aspx?news_sid=20211105MaR6EIwItObS#:~:text=On%2025%20October%202021%2C%20Minister,Singapore's%20electricity%20supply%20in%202035, para. 1.

[42] "Speech by 2M Tan See Leng at the Asia Clean Energy Summit", Ministry of Trade and Industry (Singapore), October 26, 2021, https://www.mti.gov.sg/Newsroom/Speeches/2021/10/Speech-by-2M-Tan-See-Leng-at-the-Asia-Clean-Energy-Summit, para. 11(a).

opportunity to consider the prospect of tapping on this energy source for power generation.[43] While some existing technologies such as nuclear may not be viable today, Singapore continues to monitor the progress of nuclear energy technologies and is building capabilities to better understand nuclear science and technology.[44]

Apart from the four switches, a key pillar in Singapore's energy transition is managing energy demand. Demand management considerations include those associated with post-pandemic economic recovery and increasing electrification where the core focus continues to be demand reduction through energy efficiency within industry.

"A transition framework will also be introduced to give existing emissions-intensive trade-exposed (EITE) companies more time to adjust to a low-carbon economy"

Regulatory and market-based measures

Singapore has put in place regulatory and market-based measures to support the clean energy transition, and these include measures to promote energy efficiency (in line with the blueprint as discussed above), to manage carbon emissions through taxation as well as to develop carbon markets.

Energy and carbon efficiency

To promote energy conservation, improve energy efficiency and reduce environmental impact of energy use, the Energy Conservation Act (ECA) was introduced in 2012 to mandate energy efficiency requirements and energy management practices. Large energy producers or energy consumers in prescribed industry and transport sectors that use 54 or more terajoules (TJ) of energy per year in at least two out of three preceding years had to monitor and report energy consumption, production and greenhouse gas emissions; submit energy efficiency improvement plans; and appoint an energy manager to assist with these and other requirements imposed by the ECA.[45]

Requirements were further tightened through amendments to the ECA in 2017. These amendments included those to strengthen the measurement and reporting requirements for greenhouse gas emissions, require companies to implement energy management systems, undertake regular energy efficiency opportunity assessments and meet minimum energy performance standards for common industrial equipment and systems.[46] The monitoring and reporting obligations for greenhouse gas emissions under the ECA were subsequently brought under the Carbon Pricing Act 2018 (CPA)[47] when it was enacted in 2018.[48]

As for the power sector, the EMA has been empowered to require power generation companies and other licensed parties to be more energy and carbon efficient through changes to the Electricity Act. EMA's regulatory powers now include implementing policies and strategies connected with the reduction of greenhouse gas emissions in the import, export, generation, transmission, or supply of electricity. While recognising the role that carbon tax plays in transitioning the sector to low-carbon generation sources, EMA now has the power to establish greenhouse gas emissions standards and policies that require power generation firms to use more energy-efficient technologies.[49] These powers

[43] Energy Market Authority (Singapore), "EMA to Explore the Potential of Geothermal Energy for Power Generation", media release, https://www.ema.gov.sg/media_release.aspx?news_sid=20211023kEitG26TOhWn. *See also* "Low-Carbon Alternatives," Beyond the Current, accessed 5 July 2022, https://www.beyondthecurrent.gov.sg/4-switches-city#lower-carbon-alternatives.

[44] *See* "Strengthening capabilities" on p. [18] for more details.

[45] Energy Conservation Act 2012, Cap 92C (2014 Rev. Ed.) (Singapore). *See also* Energy Conservation (Registrable Corporations) Order 2013, No. S 248 (Singapore) and Energy Conservation (Energy Management Practices) Regulations 2013, No. S 246 (Singapore).

[46] See Energy Conservation (Amendment) Act 2017, No. 24 (Singapore), Part III. *See also* National Environment Agency, "Enhancements to the Energy Conservation Act", March 8, 2017, https://www.nea.gov.sg/media/news/news/index/enhancements-to-the-energy-conservation-act.

[47] Carbon Pricing Act 2018, No. 28 of 2018 (Singapore).

[48] The amendment and repeal of relevant provisions under the ECA was effected by Section 79 of the Carbon Pricing Act 2018, No. 28 of 2018 (Singapore).The monitoring and reporting obligations for greenhouse gases under the CPA will be further discussed under "Carbon tax and other obligations" on p. [*].

[49] This change was introduced pursuant to the Energy (Resilience Measures and Miscellaneous Amendments) Act 2021, No. 37 (Singapore), clause 3(k). This provision of the Act came into effect on 29 January 2022. The EMA is now empowered through Section 16(2A) Electricity Act 2001 (2020 Rev. Ed.) (Singapore). *See also* "Speech by 2M Tan See Leng at the Second Reading of the Energy (Resilience Measures and Miscellaneous Amendments) Bill", Ministry of Trade and Industry (Singapore), November 2, 2021, https://www.mti.gov.sg/Newsroom/Speeches/2021/11/Speech-by-2M-Tan-See-Leng-at-the-Second-Reading-of-the-Energy-Bill-in-Parliament, para. 19 and Audrey Tan, "Laws proposed to set emissions standards for power

complement EMA's existing incentive schemes to encourage power generation companies to improve the energy efficiency of their existing units and shift towards cleaner and more efficient modes of power generation.[50]

Carbon tax and other obligations

To incentivise emissions reduction across all sectors and support the transition to a low-carbon economy, Singapore implemented a carbon tax on 1 January 2019 under the Carbon Pricing Act 2018, making it the first carbon pricing scheme in Southeast Asia.[51] Under this Act, all business facilities emitting 25,000 tonnes or more of greenhouse gas emissions (tCO2e) in a year would have to pay a carbon tax.[52] The carbon tax is presently set at S$5 per tonne but is set to increase substantially after 2023 to help Singapore achieve its climate ambition. The carbon tax will be raised to $25/tCO2e in 2024 and 2025, then $45/tCO2e in 2026 and 2027, with a view to reaching $50-80/tCO2e by 2030.[53]

Companies may also use high quality international carbon credits to offset up to 5% of their taxable emissions from 2024. This will cushion the impact of the carbon tax for companies that are able to source for credible carbon credits in a cost-effective manner.[54] A transition framework will also be introduced to give existing emissions-intensive trade-exposed (EITE) companies more time to adjust to a low-carbon economy.[55]

In addition to imposing a carbon tax, the CPA also imposes monitoring and reporting obligations on a business facility, depending on whether it is a "reportable facility" or "taxable facility".[56] Both types of business facility are required to submit a greenhouse gas emissions report annually but where the business facility is a "taxable facility", the emissions report must be based on an approved monitoring plan and also verified by an accredited external auditor, unless otherwise provided by the Act.[57]

Carbon services and green finance

Carbon credits provide a pathway to offset emissions, particularly for residual emissions which are difficult to abate. Corporations are increasingly looking to manage their climate impact through carbon credits and Singapore has expressed plans to position itself as a carbon service and trading hub and is taking steps to realise these plans.[58] For example, in 2021, DBS Bank, Singapore Exchange, Standard Chartered and Temasek jointly established a Singapore-based global carbon exchange market, Climate Impact X (CIX), which allows buyers and sellers to trade high quality carbon credits as well as purchase carbon credits directly from specific projects.[59]

Additionally, in respect of Renewable Energy Certificates (RECs), Singapore has launched a national standard for the production, tracking, management and usage of RECs, in support of efforts to strengthen the voluntary market for such market-based instruments, where buyers of such instruments can substantiate their claim of renewable energy use without physically consuming it.[60] The standard aims to enhance the credibility and accountability of such instruments and takes into account international practices and domestic considerations and is the first of its kind in Southeast Asia.[61]

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generation companies in Singapore", *The Straits Times,* August 27, 2021, https://www.straitstimes.com/singapore/environment/new-laws-proposed-to-set-emissions-standards-for-power-generation-companies-in.

[50] Ministry of Trade and Industry, "Speech by 2M Tan See Leng at the Second Reading of the Energy (Resilience Measures and Miscellaneous Amendments) Bill" (Singapore), published November 2, 2021, https://www.mti.gov.sg/Newsroom/Speeches/2021/11/Speech-by-2M-Tan-See-Leng-at-the-Second-Reading-of-the-Energy-Bill-in-Parliament, para. 20.

[51] "Carbon Pricing Act", Ministry of Sustainability and the Environment, updated June 15, 2022, https://www.mse.gov.sg/policies/climate-change/cpa#:~:text=Singapore%20is%20the%20first%20country,Carbon%20Pricing%20Act%20(CPA).

[52] Carbon Pricing Act 2018 (2020 Rev. Ed.) (Singapore). For more information on what constitutes a "taxable facility" and "reportable facility", see "Carbon Tax", National Environment Agency, updated March 31, 2022, https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/climate-change/carbon-tax.

[53] *See* Carbon Pricing Act 2018 (2020 Rev. Ed.) (Singapore), Part 1 of the Third Schedule. *See also* "Carbon Tax", National Environment Agency, updated March 31, 2022, https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/climate-change/carbon-tax.

[54] *See* "Carbon services and green finance" on p. [12] for more details.

[55] *See* "Carbon Tax", National Environment Agency, updated March 31, 2022, https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/climate-change/carbon-tax.

[56] Carbon Pricing Act 2018 (2020 Rev. Ed.) (Singapore). For more information on what constitutes a "taxable facility" and "reportable facility", see "Carbon Tax", National Environment Agency, updated March 31, 2022, https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/climate-change/carbon-tax.

[57] Carbon Pricing Act 2018 (2020 Rev. Ed.) (Singapore), sections 11, 12, 13.

[58] "Carbon Services and Climate Finance", National Climate Change Secretariat, accessed 4 July 2022, https://www.nccs.gov.sg/singapores-climate-action/carbon-services-and-climate-finance/.

[59] *See* "Introducing Climate Impact X (CIX)", Singapore Exchange, accessed 4 July 2022, https://www.sgx.com/climate-impact-x-cix.

[60] For more information, see "Renewable Energy Certificates," SP Group, https://www.spgroup.com.sg/sustainable-energy-solutions/our-low-carbon-solutions/renewable-energy-certificates.

[61] "Launch of Singapore Standards on Renewable Energy Certificates," Singapore International Energy Week 2022, https://www.siew.gov.sg/resources/articles/detail/2021/10/26/launch-of-singapore-standards-on-renewable-energy-certificates. *See also* "Speech by 2M Tan See Leng at the Asia Clean Energy Summit", Ministry of Trade and Industry (Singapore), October 26, 2021,

Singapore is also developing its own green finance taxonomy, to facilitate the flow of funds towards sustainable investments, including within the energy sector.[62] The development of the taxonomy is a key initiative by the Green Finance Industry Taskforce, an industry-led taskforce to accelerate the development of green finance.[63] Within the context of the environmental objective of climate change mitigation, technical thresholds and criteria have been proposed forthree priority sectors including the energy sector, which collectively account for close to 90% of ASEAN greenhouse emissions.[64] This will be followed by similar work in respect of the remaining five sectors and other environmental objectives proposed in the taxonomy. Other initiatives relating to green finance include the launch of the Sustainable Bond Grant Scheme (SBGS) and Green and Sustainability-Linked Loan Grant Scheme (GSLS) by the Monetary Authority of Singapore as part of its Green Finance Action Plan.[65] Both SBGS and GSLS seek to promote green and sustainable financing by defraying the expenses associated with engaging independent service providers to review the green and sustainability credentials of the bonds, loans or loan frameworks, as the case may be. Generally, to qualify for the schemes, the review has to be based on internationally-recognised principles and/or standards.[66] For example, the review of a sustainability-linked loan must demonstrate that the loan aligns with internationally-recognised sustainability-linked loan principles and that two of the total sustainability performance targets contribute to environmental objectives including those relating to affordable and clean energy (SDG 7) and energy efficiency.[67] Singapore Exchange Regulation, the regulatory arm of Singapore Exchange or SGX, is also phasing in mandatory climate reporting, being the first exchange in Asia to do so. This will initially apply to listed companies in priority sectors including the energy sector (these being sectors deemed to be most affected by climate change and the low-carbon transition), beginning from financial year 2023.[68]

Recommendations for energy transition to 2050

In 2022, the EMA commissioned the Energy 2050 Committee, comprising experts from the industry, academia and the Singapore Government, to "deliberate on the long-term future of Singapore's energy sector".[69] The Committee produced a report to help policymakers chart the course for Singapore's energy sector. The Report examined the long-term trends that would affect the energy sector and provided recommendations on how the EMA should plan for Singapore's future energy system and enable Singapore to capture the economic opportunities arising from the know-how and capabilities developed in the process. The Committee took a scenario-based approach to present three possible paths by which Singapore could achieve net-zero emissions by 2050.

The first scenario is "Clean Energy Renaissance" which envisages a world that rallies together against climate change and encompasses progress in technology and concerted collective action. Both energy and digital technologies develop rapidly, while strong global cooperation continues through the next three decades. Under these circumstances, Singapore decarbonises smoothly and achieves a diversified supply mix in 2050.[70]

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https://www.mti.gov.sg/Newsroom/Speeches/2021/10/Speech-by-2M-Tan-See-Leng-at-the-Asia-Clean-Energy-Summit, para 19-25.

[62] *See* Green Finance Industry Taskforce, *First GFIT Taxonomy Consultation Paper – Identifying a Green Taxonomy and Relevant Standards for Singapore and ASEAN*, January 28, 2021, https://abs.org.sg/docs/library/first_gfit_taxonomy_consultation_paper. *See also* Green Finance Industry Taskforce, *Second GFIT Taxonomy Consultation Paper - Identifying a Green Taxonomy and Relevant Standards for Singapore and ASEAN*, May 12, 2021, https://abs.org.sg/docs/library/second-gfit-taxonomy-consultation-paper.

[63] *See* Monetary Authority of Singapore, "Industry taskforce proposes taxonomy and launches environmental risk management handbook to support green finance", media release, January 28, 2021, https://www.mas.gov.sg/news/media-releases/Appointments-to-MAS-Board-of-Directors/industry-taskforce-proposes-taxonomy-and-launches-environmental-risk-management-handbook.

[64] Monetary Authority of Singapore, "Industry Taskforce Consults on Second Version of Green and Transition Taxonomy", media release, May 12, 2022, https://www.mas.gov.sg/news/media-releases/2022/industry-taskforce-consults-on-second-version-of-green-and-transition-taxonomy.

[65] Monetary Authority of Singapore, "Green Finance Action Plan", media release, October, 2022, https://www.mas.gov.sg/-/media/MAS/News/Media-Releases/2020/MAS-Green-Finance-Action-Plan.pdf.

[66] Monetary Authority of Singapore, "Sustainable Bond Grant Scheme", https://www.mas.gov.sg/schemes-and-initiatives/sustainable-bond-grant-scheme. *See also* Monetary Authority of Singapore, "Green and Sustainability-Linked Loans Grant Scheme", https://www.mas.gov.sg/schemes-and-initiatives/sustainable-bond-grant-scheme.

[67] Monetary Authority of Singapore, "Green & Sustainability- Linked Loan Grant Scheme (GSLS)", media release, https://www.mas.gov.sg/-/media/MAS/News/Media-Releases/2020/GSLS-Brochure.pdf.

[68] "Singapore Exchange proposes mandatory climate reporting in key sectors from 2023", S&P Global Commodity Insights, updated August 26, 2021, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/082621-singapore-exchange-proposes-mandatory-climate-reporting-in-key-sectors-from-2023.

[69] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050* – Energy 2050 Committee Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 4.

[70] *See* Energy Market Authority (Singapore), Charting the Energy Transition to 2050 – Energy 2050 Committee Report, March 2022,

The second scenario is "Climate Action Bloc" which envisages countries banding together for climate action in a supportive geopolitical environment that favours global solutions. However, technology advancement is slow, especially in energy technologies. Singapore arrives at 2050 with electricity imports as a mainstay source of supply while waiting for low-carbon technologies to mature.[71]

The final scenario is "Emergent Technology Trailblazer" which envisages a world that is fragmented geopolitically, while technology development accelerates closer to 2050. Under these circumstances, Singapore makes proactive investments in new technologies to decarbonise and banks on hydrogen as its main source of supply. Building on its earlier investments, Singapore is also able to start deploying other low-carbon alternatives such as nuclear energy, to diversify its supply mix and possibly scale up further when they become more commercially competitive. [72] See discussion below on the "Nuclear Energy Option". [73]

The main energy sources contemplated in the three scenarios correspond to those in the EMA's "four switches" to varying degrees, [74] which as discussed above, is its current energy-transition blueprint to decarbonize Singapore's energy supply. In all three scenarios, electricity imports and/or low-carbon hydrogen are major contributors to Singapore's energy supply, accounting for 70-80% when both sources are calculated collectively.[75]

All three scenarios also feature solar energy and geothermal energy, with renewable energy contributing up to 20% of the supply mix in the Clean Energy Renaissance Scenario and only a small percentage in the Emergent Technology Trailblazer Scenario. Natural gas continues to play a significant role in the Climate Action Bloc Scenario and the possibility of nuclear energy features only in the Emergent Technology Trailblazer Scenario.[76] At this juncture, it is difficult to predict which one of the three scenarios is likelier, given the many variables that could affect Singapore's energy transition over the course of the next 30 years. As such, the Committee has stressed the importance for Singapore to introduce flexibility into the power sector to provide optionality to pivot across different pathways.[77]

Nuclear energy option

Nuclear power as a policy option

As of May 2022, the World Nuclear Association has identified Singapore as a country that has discussed nuclear power as a policy option.[78] While Singapore has not made the decision to embark on a nuclear power programme, it has been discussing nuclear power as a policy option from as early as 2008.[79]

This section highlights, in brief, policy discussions on nuclear power surrounding recommendations by two expert committees, namely the Economic Strategies Committee and the Energy 2050 Committee. While both these committees addressed broader energy issues, the focus here is on policy discussions relevant to nuclear energy. In terms of a timescale, the ESC's recommendations were based on a - horizon of up to 10 years which would have ended in 2020, [80] while the Energy 2050 Committee's recommendations, released only earlier in 2022, were based on a longer horizon to 2050.

https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 24.

[71] *See* Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 27.

[72] *See* Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 31.

[73] *See* "Nuclear Energy Option" on p. [15] for more details.

[74] Energy Market Authority (Singapore), "The Future of Singapore's Energy Story", media release, October 29, 2019, https://www.ema.gov.sg/media_release.aspx?news_sid=20191029Yk3uENU5Z4bL.

[75] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 24, 27 and 31.

[76] Ibid.

[77] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 53.

[78] "Emerging Nuclear Energy Countries", World Nuclear Association, updated May, 2022, https://world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx.

[79] "Transcript of Minister Mentor Lee Kuan Yew's Points at the Singapore Energy Conference Dialogue," National Climate Change Secretariat, published November 4, 2008, https://www.nccs.gov.sg/media/speeches/transcript-of-minister-mentor-lee-kuan-yew's-dialogue-at-the-singapore-energy-conference-at-raffles-city-convention-centre-in-singapore-4-november-2008.

[80] Economic Strategies Committee, *Report of the Economic Strategies Committee*, Published February 1, 2010, https://www.mti.gov.sg/-/media/MTI/Resources/Publications/Report-of-the-Economic-Strategies-Committee/Full-ESC-Report---Ministry-of-Finance.pdf, vi.

Following from this, the section goes on to discuss efforts undertaken by Singapore to strengthen its capabilities in relation to nuclear science and technology. It also makes observations about Singapore's legal and regulatory infrastructure and public perception, in light of Singapore's prevailing policy position towards nuclear power.

Report of the Economics Strategies Committee

The Economic Strategies Committee (ESC) was established in May 2009 by the government to develop strategies for Singapore to build capabilities and maximise opportunities in a new world environment, with the aim of achieving sustained and inclusive growth. In less than a year, the ESC, comprising members drawn from the government, the labour movement, the private sector and academia, published its Report.

Amongst other recommendations, the Report of the ESC recommended that Singapore should aim to become a smart energy economy. To this end, one of its main recommendations was that Singapore should diversify its energy sources. In the long term, it identified nuclear energy as a possible option to meet baseload electricity demand as well as energy security and sustainability imperatives and recommended that Singapore study the feasibility of nuclear energy.[81]

The Report of the ESC noted that there were challenges with harnessing nuclear energy in Singapore given its small size and high urban density. Apart from safety being a key concern, these included challenges relating to nuclear fuel and waste disposal. Another challenge highlighted was the reliability of the power supply, given that issues such as the tripping of a large-sized nuclear plant could cause problems to Singapore's comparatively smaller energy supply. However, it recognised that advancements in nuclear technology, including small modular reactors, could address the challenges posed by earlier designs.[82] As such, it recommended that Singapore start studying the feasibility of the nuclear energy option and develop expertise in nuclear energy technologies.[83]

Pre-feasibility Study on Nuclear Energy

Agreeing with the ESC's recommendation in parliament in March 2010, the government announced that it would undertake a multi-agency pre-feasibility study on nuclear energy (hereinafter "Pre-feasibility Study") later that year. Reasons in support for this decision included nuclear energy's potential to enhance energy security, reduce carbon emissions and mitigate the impact of volatile fuel prices; its deployment by developed countries and steps taken by other countries to revive or explore the nuclear energy option; and development of nuclear technologies to address concerns associated with nuclear energy.[84] The study would entail an examination of the technical, economic and safety aspects of nuclear energy, with the aim of understanding and objectively evaluating the opportunities, challenges and risks involved with nuclear energy.[85]

The 2011 Fukushima Daiichi nuclear accident gave rise to concerns about nuclear energy and led to questions as to whether it had derailed the Pre-feasibility Study. The government clarified on the contrary, the accident made it all the more important that the study continue. This is so that Singapore to build its knowledge and understanding of nuclear energy and be able to assess its implications for the region and Singapore, even if Singapore does not proceed with the nuclear energy option.[86]

The Pre-feasibility Study was completed in 2012 and concluded that the nuclear energy technologies that were available at the time were not yet suitable for deployment in Singapore. Although the then latest designs of nuclear power plants were much safer than older designs that were being used in other countries, the risks to Singapore still outweighed the benefits. As Singapore was planning for very long-term energy needs, it was determined that the best approach was to wait for technology and safety to improve before reconsidering its options. Meanwhile, Singapore should monitor developments and work

[81] Economic Strategies Committee, *Report of the Economic Strategies Committee*, Published February 1, 2010, https://www.mti.gov.sg/-/media/MTI/Resources/Publications/Report-of-the-Economic-Strategies-Committee/Full-ESC-Report---Ministry-of-Finance.pdf, 26, 87.

[82] Ibid, 87.

[83] Ibid, 87.

[84] Republic of Singapore, *Parliamentary Debates,* Vol 86, Sitting No. 21 (March 8, 2010), Head V – Ministry of Trade and Industry, https://sprs.parl.gov.sg/search/topic?reportid=005_20100308_S0003_T0006.

[85] Republic of Singapore, *Parliamentary Debates,* Vol 86, Sitting No. 21 (March 8, 2010), Head V – Ministry of Trade and Industry, https://sprs.parl.gov.sg/search/topic?reportid=005_20100308_S0003_T0006.

[86] Republic of Singapore *Parliamentary Debates,* Vol 87, Sitting No. 27 (April 11, 2011), Feasibility of Nuclear Power for Singapore (Update on Assessment after Fukushima Incident), https://sprs.parl.gov.sg/search/topic?reportid=005_20110411_S0006_T0005.

to strengthen its capabilities to understand nuclear science and technology.[87] This would enable Singapore to assess the implications of evolving nuclear energy technologies and regional nuclear energy developments for Singapore and enhance its emergency preparedness.[88]

Energy 2050 Committee Report

Since the policy position adopted pursuant to the Pre-feasibility Study, there has not been any significant policy change. However, nuclear energy has once again been in the public-eye, following the release of the Energy 2050 Committee Report in March 2022. This development has led to questions being posed once again about the feasibility of deploying nuclear energy in Singapore.[89]

As discussed above, Singapore plans to rely on four switches of supply to transition to cleaner energy, including the use of low-carbon alternatives.[90] Nuclear energy is one such low-carbon alternative envisioned by the Energy 2050 Committee in its Report.[91] According to the Committee, in the "Emergent Technology Trailblazer" scenario, which is one of three possible futures in which Singapore could achieve net-zero emissions by 2050, nuclear energy will have the potential to supply around 10%[92] of Singapore's energy needs.[93]

The Committee's recommended strategy is for Singapore to actively monitor developments in new low-carbon supply technologies including nuclear technologies (such as nuclear fission small modular reactors (SMRs) and nuclear fusion technologies) and build capabilities in advance to allow Singapore to adopt promising technologies quickly when they become viable. In particular, given that nuclear technology will require highly specialized expertise to be deployed, regulated and operated, the Committee recommended that Singapore map out the required capabilities, regulations, resources, timeline for the respective technologies, and identify areas that should be developed in advance.[94]

However, the Committee highlighted that the patterns of technology advancement of low-carbon energy technologies such as nuclear technologies are critical uncertainties because they are contingent on successful research and development efforts, the scale of deployment by major countries and the global price of carbon.[95] At this stage, more research and development are needed in order to ascertain whether newer nuclear technologies would be suitable in Singapore.[96]

In light of these recommendations, questions were also posed in parliament about the feasibility of deploying nuclear energy in Singapore. In essence, it was stated that the government would carefully study the Committee's report and calibrate their plans accordingly as technologies evolve. As the current new designs and technologies that are being developed are still in the research and development phase and have not begun commercial operations, Singapore will continue to monitor them closely and any decision to deploy new energy technologies would need to be considered against its safety and reliability, affordability and environmental sustainability.[97] In the meantime, Singapore would continue building its ability to understand and assess

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[87] Republic of Singapore, *Parliamentary Debates,* Vol 89, Sitting No. 8 (October 15, 2012), Update on Singapore Nuclear Energy Pre-Feasibility Study, https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-123, 823.

See also "Strengthening capabilities" on p. [18] for more details.

[88] Republic of Singapore, *Parliamentary Debates,* Vol 89, Sitting No. 8 (October 15, 2012), Update on Singapore Nuclear Energy Pre-Feasibility Study, https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-123, 823; Republic of Singapore. *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety*. 2017. https://www.iaea.org/sites/default/files/singapore_nr-7th-rm.pdf, 3.

[89] Republic of Singapore, *Parliamentary Debates,* Vol 95, Sitting No. 60 (April 4, 2022), Singapore's Study into Feasibility of Nuclear Energy to Meet our Energy Needs, https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-2804. See also Republic of Singapore, *Parliamentary Debates,* Vol 95, Sitting No. 32 (July 6, 2021), Review of Generation IV Nuclear Reactors as Potential Source of Energy for Singapore, https://sprs.parl.gov.sg/search/sprs3topic?reportid=written-answer-na-8236.

[90] *See also* "Current energy transition blueprint" on p. [9] for more details.

[91] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 7.

[92] The Singapore Government has clarified that this does not represent a target for the energy mix in Singapore. *See* Republic of Singapore, *Parliamentary Debates,* Vol 95, Sitting No. 60 (April 4, 2022), Singapore's Study into Feasibility of Nuclear Energy to Meet our Energy Needs, https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-2804.

[93] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 31, 35.

[94] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 41.

[95] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 6.

[96] Energy Market Authority (Singapore), *Charting the Energy Transition to 2050 – Energy 2050 Committee* Report, March 2022, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/Energy-2050-Committee-Report.pdf, 19.

[97] Republic of Singapore, *Parliamentary Debates,* Vol 95, Sitting No. 60 (April 4, 2022), Singapore's Study into Feasibility of Nuclear Energy to Meet our

their safety, security and environmental implications before considering them for deployment. It was further stated that apart from the state of development of technologies, deployment would require significant infrastructure and specialised expertise, which would in turn require regulations and human resources support, resulting in longer lead time.[98]

Strengthening capabilities

As seen from the discussion above, the government has consistently maintained the importance of building capabilities to understand nuclear science and technology, since the time of the Pre-feasibility Study through to the present. To this end, Singapore has undertaken steps to strengthen its capability in a multi-level approach and continues to do so today. Nationally, Singapore has been strengthening its own research, regulatory and other capabilities, while trying to build up a local talent pool of nuclear experts in nuclear policy, science and safety. In doing so, Singapore has been cooperating and collaborating with a range of actors at the international, regional as well as bilateral levels.

In order to implement the recommendation of the Pre-feasibility Study, Singapore established the Nuclear Safety Research and Education Programme (NSREP) in April 2014, with funding of around S$63 million from the National Research Foundation (NRF). NSREP was conceived as a multi-year programme for research and education in nuclear safety, science and engineering. [99] NSREP encompasses research activities that directly meet the national needs in these areas as well as cutting-edge research undertaken with longer-term objectives.[100] The programme would also cover nuclear policy research and public education on nuclear technology.[101] The NRF sets the national direction for research and development and does so in a variety of ways, including through funding initiatives that strengthen research and scientific capabilities. It is a department within the Prime Minister's Office.[102]

Pursuant to the NSREP, the Singapore Nuclear Research and Safety Initiative (SNRSI) was set up in 2014 as a national centre of excellence for nuclear safety capability building that would tap into the existing expertise in local research institutions and build up new capabilities.[103] With SNSRI being the research arm of NSREP, the aim was to concentrate expertise and knowledge in nuclear technology and safety in a single institute i.e. SNSRI, and to sustain a critical mass of manpower engaged in a range of nuclear-related activities relevant to Singapore. [104]

"Nationally, Singapore has been strengthening its own research, regulatory and other capabilities, while trying to build up a local talent pool of nuclear experts in nuclear policy, science and safety"

Steps are being taken to further this aim.

Following the Pre-feasibility Study, in addition to efforts to build research capabilities, the government has also been taking the initiative to strengthen its own capabilities. For example, the National Environment Agency, since 2013, has sent its officers to attend post graduate programmes in nuclear engineering and relevant training courses and workshops on nuclear safety to acquire a deeper understanding and knowledge of the subject.[105] Such efforts will undoubtedly help the agency, being the

Energy Needs, https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-2804.

[98] Ibid.

[99] Lui Pao Chuen, "Singapore nuclear safety research and education programme." Report presented at 11th National Conference on Nuclear Science and Technology (VINANST-11), Da Nang City, Vietnam, August 2015. https://inis.iaea.org/collection/NCLCollectionStore/_Public/47/065/47065306.pdf?r=1.

[100] "About Us", Singapore Nuclear Research and Safety Initiative, accessed 5 July 2022, https://snrsi.nus.edu.sg/about-us/about.

[101] Grace Chua, "Singapore starts nuclear safety and science research programme," *The Straits Times*, April 23, 2014, https://www.straitstimes.com/singapore/singapore-starts-nuclear-safety-and-science-research-programme.

[102] *See* "Corporate Profile," National Research Foundation, updated August 27, 2021, https://www.nrf.gov.sg/about-nrf/national-research-foundation-singapore/corporate-profile.

[103] "About Us", Singapore Nuclear Research and Safety Initiative, accessed 5 July 2022, https://snrsi.nus.edu.sg/about-us/about.

[104] "About Us", Singapore Nuclear Research and Safety Initiative, accessed 5 July 2022, https://snrsi.nus.edu.sg/about-us/about; Republic of Singapore, *Parliamentary Debates*, Vol 95, Sitting No. 44 (January 10, 2022), Assessment on Use of Nuclear Energy in Singapore and Update on Achievements of Nuclear Safety Research and Education Programme, https://sprs.parl.gov.sg/search/sprs3topic?reportid=written-answer-na-9608.

[105] Republic of Singapore. *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety*, 2017, https://www.iaea.org/sites/default/files/singapore_nr-7th-rm.pdf, para. 4.

regulatory body, to strengthen its own regulatory capabilities.[106]

Singapore has also been taking steps to strengthen its capabilities through cooperation at the international, regional and bilateral levels. These steps, while strengthening its capabilities, also enable Singapore to play an active role in global and regional cooperation to improve nuclear safety, implementing yet another recommendation of the Pre-feasibility Study. [107] At the international level, Singapore collaborates closely with the International Atomic Energy Agency (IAEA) through various channels including its Technical Cooperation and Third Country Training Programmes. It also participates in activities organised by Asia-Europe Meeting, an international platform it initiated and founded.[108]

Singapore also engages in regional capacity-building activities through its participation in sectoral bodies such as the ASEAN Network of Regulatory Bodies on Atomic Energy (ASEANTOM).[109] In doing so, these efforts contribute to building up Singapore's knowledge of nuclear issues but also contribute towards strengthening regional preparedness to respond to a potential nuclear emergency.[110] At the bilateral level, Singapore has established several collaborations with regulators and organisations in other countries such as the US and France.[111]

Legal and regulatory infrastructure

In light of Singapore's current policy position on nuclear energy, it is not surprising that Singapore's current legal and regulatory framework does not cater for nuclear installations.[112] However, Singapore has the necessary legal and regulatory infrastructure to address radiation protection, including a regulatory body dedicated to radiation protection. The Radiation Protection Act 2007 control and regulate the import, export, manufacture, sale, disposal, transport, storage, possession and use of radioactive materials and irradiating apparatus in Singapore. [113] The National Environment Agency's Radiation Protection and Nuclear Science Group (RPNSG) is the national regulatory authority for radiation protection in Singapore.

As a member of the international community, Singapore supports international efforts to strengthen the global nuclear safety, security and safeguards architecture. The RPNSG and to the extent applicable, the Radiation Protection Act 2007, implement international conventions on nuclear safety, security and safeguards to which Singapore is a party to. [114] To strengthen and enhance the effectiveness of its regulatory infrastructure, Singapore has requested the IAEA for an Integrated Regulatory Review Service (IRRS) mission to review its national regulatory framework for nuclear and radiation safety.[115] This will be Singapore's first IRRS mission and is scheduled to take place from 10th to 19th October 2022.[116]

At the regional level, Singapore also works closely with ASEAN Member States through the ASEAN Network of Regulatory Bodies on Atomic Energy (ASEANTOM), a sectoral body under the ASEAN Political-Security Community Pillar. This is a

[106] *See also* "Legal and regulatory infrastructure" on p. [20] for more details.

[107] Republic of Singapore. *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety*, 2017, https://www.iaea.org/sites/default/files/singapore_nr-7th-rm.pdf, para. 3; Republic of Singapore, *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety: Eighth National Report*, August 2019, https://www.iaea.org/sites/default/files/national_report_of_singapore_for_the_8th_review_meeting.pdf, para. 5.

[108] Republic of Singapore, *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety: Eighth National Report*, August 2019, https://www.iaea.org/sites/default/files/national_report_of_singapore_for_the_8th_review_meeting.pdf, para. 12.

[109] Republic of Singapore. *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety*, 2017, https://www.iaea.org/sites/default/files/singapore_nr-7th-rm.pdf, para. 9. *See also* Republic of Singapore, *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety: Eighth National Report*, August 2019, https://www.iaea.org/sites/default/files/national_report_of_singapore_for_the_8th_review_meeting.pdf, para. 13, 14. *See also* "Legal and regulatory infrastructure" on p. [20] for more details.

[110] Republic of Singapore, *Parliamentary Debates*, Vol 95, Sitting No. 44 (January 10, 2022), Assessment on Use of Nuclear Energy in Singapore and Update on Achievements of Nuclear Safety Research and Education Programme, https://sprs.parl.gov.sg/search/sprs3topic?reportid=written-answer-na-9608.

[111] *See* Republic of Singapore, *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety: Eighth National Report*, August 2019, https://www.iaea.org/sites/default/files/national_report_of_singapore_for_the_8th_review_meeting.pdf, para. 8.

[112] Republic of Singapore, *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety: Eighth National Report*, August 2019, https://www.iaea.org/sites/default/files/21/07/national_report_of_singapore_for_the_8th_review_meeting.pdf, para. 38.

[113] Radiation Protection Act 2007 (2020 Rev. Ed.) (Singapore).

[114] Republic of Singapore, *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety: Eighth National Report*, August 2019, https://www.iaea.org/sites/default/files/21/07/national_report_of_singapore_for_the_8th_review_meeting.pdf, para. 39. *See also* "CIL Table of Treaty Adherence with information current as of 30 June 2021", Available on request.

[115] Republic of Singapore, *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety: Eighth National Report*, August 2019, https://www.iaea.org/sites/default/files/21/07/national_report_of_singapore_for_the_8th_review_meeting.pdf, para. 16(d).

[116] "Peer Review and Advisory Services Calendar," International Atomic Energy Agency, accessed 5 July 2022, https://www.iaea.org/services/review-missions/calendar?type=All&year%5Bvalue%5D%5Byear%5D=&location=3490&status=All.

platform for cooperation amongst nuclear regulatory bodies within ASEAN to enhance regional nuclear safety, security and safeguards, based on the implementation of relevant commitments to the IAEA's standards and guidelines and other multilateral agreements which ASEAN Member States are party to.[117]

Public perception

There have been several academic studies relevant to the issue of public perception of nuclear energy in Singapore, albeit based on specific conceptual frameworks and with certain limitations, where findings based on the relevant sample sizes cannot be generalised to the population of Singapore as a whole. [118] Nevertheless, they provide interesting insights which this section will briefly highlight, together with a recent industry-led survey of youth perception of nuclear energy in Singapore.

The first study examined (i) the public's credibility perceptions of nuclear-related information sources and their trust in potential stakeholders; and (ii) the public perceptions of the risks, benefits and support of nuclear energy in Singapore. The study showed that public perception varied across different age groups, depending on the issue. For example, although participants across the different age groups noted similar benefits (such as the high reliability and efficiency of nuclear energy as well as environmental and economic benefits), nuclear accidents was unanimously mentioned as a perceived risk. Overall, the study noted that participants were generally unsupportive of nuclear energy.[119]

Subsequently, a second study found that more than half of the people surveyed in Singapore were against the idea of nuclear energy development.[120] It found that 22% of those surveyed in Singapore favoured nuclear energy development. The findings showed that trust in institutions and risk perceptions were cues that the public would use to interpret scientific information and make judgments about nuclear energy development. These findings formed part of a broader study of public support for nuclear energy development in Southeast Asia.[121]

Interestingly, a more recent study examined how the public and energy experts in three countries, including Singapore, perceived the risks and benefits of energy technologies.[122] This study revealed that the public had extensive and diverse risk and benefit perceptions shaped by contextual factors, in contrast to energy experts who were more focused in this respect, largely relying on an evidence-based approach. Particularly for nuclear energy, the study showed that the public emphasised the risk of harm to humans, whereas such emphasis was not observed with the energy experts.[123] However, this study did

[117] Republic of Singapore, *National Report on the Implementation of Obligations Under the Convention on Nuclear Safety: Eighth National Report*, August 2019, https://www.iaea.org/sites/default/files/21/07/national_report_of_singapore_for_the_8th_review_meeting.pdf, para. 13. *See also* "Strengthening capabilities" on p. [18] for more details.

[118] Shirley S. Ho et al., "'I can live with nuclear energy if...': Exploring public perceptions of nuclear energy in Singapore", *Energy Policy* 120 (September 2018), https://www.sciencedirect.com/science/article/abs/pii/S030142151830377X; Shirley S. Ho and Agnes S.F. Chuah, "Why support nuclear energy? The roles of citizen knowledge, trust, media use, and perceptions across five Southeast Asian countries", *Energy Research & Social Science* 79 (September 2021) 102155, https://www.sciencedirect.com/science/article/abs/pii/S2214629621002486; Shirley S. Ho et al., "Mapping risk and benefit perceptions of energy sources: Comparing public and expert mental models in Indonesia, Malaysia, and Singapore", *Energy Research & Social Science* 88 (June 2022) 102500, https://www.sciencedirect.com/science/article/pii/S2214629622000081?via%3Dihub.

[119] Shirley S. Ho et al., "'I can live with nuclear energy if...': Exploring public perceptions of nuclear energy in Singapore", *Energy Policy* 120 (September 2018): 444, https://www.sciencedirect.com/science/article/abs/pii/S030142151830377X.

[120] Shirley S. Ho and Agnes S.F. Chuah, "Why support nuclear energy? The roles of citizen knowledge, trust, media use, and perceptions across five Southeast Asian countries", *Energy Research & Social Science* 79 (September 2021) 102155: 5, https://www.sciencedirect.com/science/article/abs/pii/S2214629621002486; *See also* Nanyang Technology University, "NTU Singapore study finds generally low public support for nuclear energy development in Southeast Asia", news release, November 2, 2021, https://www.ntu.edu.sg/docs/default-source/corporate-ntu/hub-news/ntu-singapore-study-finds-generally-low-public-support-for-nuclear-energy-development-in-southeast-asia-.pdf?sfvrsn=6d2991a3_1#:~:text=Based%20on%20its%20surveys%2C%20the,cent%20to%2039%20per%20cent.

[121] Shirley S. Ho and Agnes S.F. Chuah, "Why support nuclear energy? The roles of citizen knowledge, trust, media use, and perceptions across five Southeast Asian countries", *Energy Research & Social Science* 79 (September 2021) 102155: 8-9, https://www.sciencedirect.com/science/article/abs/pii/S2214629621002486; *See also* Nanyang Technology University, "NTU Singapore study finds generally low public support for nuclear energy development in Southeast Asia", news release, November 2, 2021, https://www.ntu.edu.sg/docs/default-source/corporate-ntu/hub-news/ntu-singapore-study-finds-generally-low-public-support-for-nuclear-energy-development-in-southeast-asia-.pdf?sfvrsn=6d2991a3_1#:~:text=Based%20on%20its%20surveys%2C%20the,cent%20to%2039%20per%20cent.

[122] Shirley S. Ho et al., "Mapping risk and benefit perceptions of energy sources: Comparing public and expert mental models in Indonesia, Malaysia, and Singapore", *Energy Research & Social Science* 88 (June 2022) 102500: 2, https://www.sciencedirect.com/science/article/pii/S2214629622000081?via%3Dihub.

[123] Shirley S. Ho et al., "Mapping risk and benefit perceptions of energy sources: Comparing public and expert mental models in Indonesia, Malaysia, and Singapore", *Energy Research & Social Science* 88 (June 2022) 102500: 5, https://www.sciencedirect.com/science/article/pii/S2214629622000081?via%3Dihub.

not provide an overall finding on public perception in Singapore.

Outside the academic domain, a survey targeting youths in Singapore has also been conducted, where youths, aged 19 to 28, were surveyed regardless of their citizenship status or educational backgrounds. 59.4% of the youths surveyed favoured Singapore adopting nuclear energy as part of its energy mix.[124] Those who were against it provided reasons ranging from health hazards, Singapore's limited land space, the high costs of deploying nuclear power and other reasons including waste disposal concerns and geopolitical tensions. [125] However, the survey revealed that a large majority of respondents gave themselves a low self-assessment score on their knowledge of nuclear energy. A vast majority of respondents felt that there had been insufficient coverage of nuclear energy in the media and educational institutions and there was a need to learn more.

"Singapore's import dependency, whether for natural gas or electricity, means that energy security will remain a key challenge for some time to come"

As for media coverage of nuclear energy, another recent academic study has shown that the media does play a role in enhancing public knowledge of nuclear energy in Singapore. The study found that attention to certain types of media simulates news elaboration (the process of making cognitive connections between new information gained from media and existing knowledge to form new knowledge and draw inferences to be stored in one's memory), subsequently enhancing factual knowledge, including knowledge of nuclear knowledge.[126]

The youth of today would appear to be a key stakeholder class whose perception will influence the support available for nuclear power deployment when the time comes. Meanwhile, since the time of the abovementioned studies and survey, the Energy 2050 Committee Report has sharpened the focus on the role that nuclear energy can play in Singapore's clean energy transition. This, in turn, raises the question of how, if at all, the recommendations in this report on nuclear energy have affected or could, in time to come, affect public perception.

Conclusion

Singapore's import dependency, whether for natural gas or electricity, means that energy security will remain a key challenge for some time to come. Singapore's ability to reduce its heavy reliance on imported natural gas is dependent on its ability to scale up not only electricity imports but also solar energy and other low-carbon alternatives. Meanwhile, security of supply of natural gas is an ongoing concern, given that existing supply contracts with Malaysia and Indonesia are set to end soon. In terms of electricity imports, uncertainties exist as to how successful existing electricity trials will be in laying the foundation for large-scale multilateral electricity imports over the longer term. Experience has shown that export states can easily impose bans to manage domestic resource shortages with implications on energy affordability for import states.

Furthermore, challenges surround all low-carbon alternatives featured in Singapore's energy transition blueprint. In the case of solar energy, the main challenge is the limited space available to deploy solar panels. As for the other low-carbon alternatives such as geothermal energy, CCUS, hydrogen and nuclear energy, the key issue is the feasibility of these emerging technologies. This will in turn depend on the success of research and development efforts, scale of deployment by major countries and the global price of carbon, factors which are presently hard to predict. Specifically, in the case of nuclear energy, other challenges include safety of technology, public acceptance and possibly also geopolitical sensitivities arising from transboundary risk concerns.

[124] Nuclear Business Platform, *Youth Perception on Nuclear Energy in Singapore*, July 2021, http://www.nuclearbusiness-platform.com/young-report/, 15.

[125] Nuclear Business Platform, *Youth Perception on Nuclear Energy in Singapore*, July 2021, http://www.nuclearbusiness-platform.com/young-report/, 15.

[126] Shirley S. Ho et al., "Thinking, not talking, predicts knowledge level: Effects of media attention and reflective integration on public knowledge of nuclear energy", *Public Understanding of Science* 31(5) (January 2022), 582-583 https://journals.sagepub.com/doi/abs/10.1177/09636625211070786.

Yet the Energy 2050 Committee has concluded in its report that it is realistic for Singapore's power sector to aspire to achieve net-zero emissions by or around mid-century, while still maintaining energy security and affordability. As part of this process, there will also be economic growth opportunities along the way that Singapore can position itself to capture. According to the report, however, Singapore must be prepared to make bold changes along the way based on technology trends. This would require Singapore to actively monitor developments, strengthen its capabilities in order to be able to evaluate such developments and be ready to adopt promising technologies quickly when they become feasible to do so. As part of this journey, Singapore should also be ready to seize "green growth" opportunities including in the area of sustainable energy solutions, by establishing itself as a technology frontrunner and a test bed and living lab for such solutions.

While Singapore faces significant challenges in its journey towards net-zero emissions by or around mid-century, it can draw on its existing strengths and/or unique characteristics to help it tackle these challenges as well as position itself for potential "green growth" opportunities. For example, Singapore has a strong research and development ecosystem which it is leveraging on to build capabilities in low-carbon solutions. It is also taking steps to establish itself as a carbon services and trading hub and promote green financing, building on its position as an international financial centre. Being a small but developed city state, it is also well placed, as mentioned above, to serve as a test bed and living lab for sustainable energy solutions, to support growth in this sector.

6

Thailand's Energy Landscape and the Potential Role and Place of Nuclear Technology

Doonyapong Wongsawaeng

Introduction

This article discusses Thailand's current strategic plan for long-term energy security, Power Development Plan (PDP) 2018 rev. 1, covering 2018 – 2037. The main electricity-generating entities in the nation are detailed and the COVID-19 economic impact on the national electricity consumption is analyzed. In general, the power is mainly provided by the state-owned power utility, the Electricity Generating Authority of Thailand (EGAT), which is also the Transmission System Operator (TSO). A summary of the proven reserves of natural gas in the Gulf of Thailand and the annual supply of natural gas including LNG is provided together with information on domestic production, imports, and utilization of crude oil and coal/lignite. The discussion details the support for clean energy to reach the goal of zero carbon emissions by 2065-2070. The technologies and the innovations promoting clean energy use, as well as the financial aspect, are also discussed. The long history of nuclear power development in Thailand is given, detailing the effort by EGAT in 1996 for the PDP 2007, the first PDP to include nuclear power in the nation's energy basket. The nuclear contribution has been adjusted up and down with subsequent PDPs—it was completely removed from the latest PDP. In addition, the domestic infrastructure requirements to support a potential project in the future are briefly described. The regulatory framework for nuclear energy/nuclear technology in Thailand is also provided in detail. Although Thailand has no nuclear power plants, the nation has a 45-year-old multipurpose 2 MW TRIGA Mark III nuclear research reactor and a number of high-energy electron beam accelerators and Co-60 gamma irradiators. A discussion on the possibility of employing small modular reactors (SMRs) in Thailand is provided. The detail and the analysis regarding the lack of public acceptance and its fear of nuclear accidents and radiation, as well as the recommendations on gaining public acceptance, are provided with a conclusion on how likely Thailand may construct and operate a nuclear power plant in the future.

Electrical energy analysis framework

Since the generation of electricity is a long-term investment that must correspond to the current and future demand requirements, Thailand has a strategic plan for long-term (15-20 years) energy security called the Power Development Plan (PDP). The main objective is to ensure that the long-term need for electricity is sufficiently met and securely supplied. To correctly respond to economic changes and other local and global events, the plan is reviewed every three years. The most recent version of Thailand's Power Development Plan is PDP 2018 rev. 1, which covers 2018 – 2037. Under this PDP, the total generating capacity by the end of 2037 is forecast to be 77,211 megawatts (MW), far surpassing 46,090 MW—the power generation capacity at the end of 2017. This additional capacity of 56,431 MW is to be provided by the following options: 20,766 MW by renewable energy power plants, 500 MW by pump-storage hydropower plants, 2,112 MW by co-generation power plants, 1,200 MW by coal/lignite power plants, 15,096 MW by combined cycle power plants, 5,857 MW by power purchased from neighboring countries, 6,900 MW by other new alternative power plants, and 4,000 MW through energy conservation. No nuclear power option is envisioned in this version of the PDP.[1] The projected total energy mix in 2037 is shown in Figure 1. For comparison, the 2036 targets under PDP 2015 and the 2037 targets under PDP 2018 are shown in Table 1. Since PDP 2018 rev. 1 relies heavily on imported energy, the country's energy security, as well as its overall energy cost, are all affected. As a result, the government has decided to raise its renewable energy and imported hydropower target to 30% by 2037 through the Alternative Energy Development Plan (AEDP) 2015.

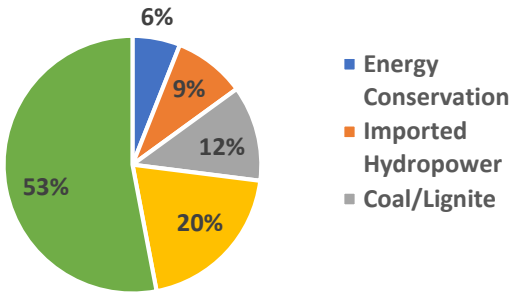

Figure 1 Projected total energy mix in 2037 according to PDP 2018 rev. 1

[1] Tunpaiboon, N., *Industry Outlook 2021-2023: Power Generation*, in *Krungsri Research* 2021, Bank of Ayudhya Public Company Limited: Thailand. p. 1-13.

Type of energy source	2036 Targets (%) under PDP 2015	2037 Target (%) under PDP 2018 rev. 1
Natural Gas	37	53
Coal	23	12
Hydropower from neighboring country	15	9
Alternative Energy	20	20
Nuclear	5	0
Others	0.1	0.06
Energy efficiency	0	6

Table 1 Comparison of 2036 targets under PDP 2015 to 2037 targets under PDP 2018 rev. 1

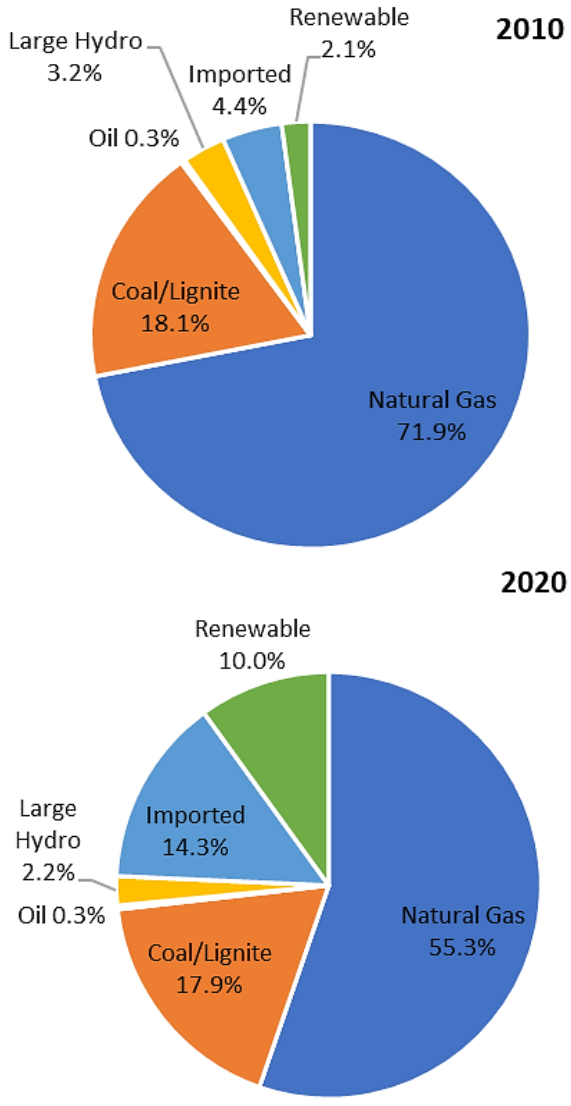

Figure 2 Power generation by fuel type of year 2020 compared to 2010

In 2020, Thailand generated electricity from fossil fuels, renewables, and other alternative sources. Fossil fuels included natural gas, coal/lignite, and oil, as well as large-scale hydropower plants (hydroelectric dams are indeed considered part of the fossil fuel fleet). Renewables and alternative sources included biomass, biogas, wastewater, bioenergy crops, consumer and the industrial wastes, solar, wind, and micro-hydro plants. Figure 2 demonstrates the power generation by fuel type for 2020 compared to 2010. The current energy mix increases renewable and imported energy substantially to reduce the heavy dependence on the natural gas.[2] [3]

Demand outlook

For the period of 2021-2023, electricity demand was predicted to increase by 2.8 - 3.8% annually, driven by an anticipated economic recovery from the

[2] N. Tunpaiboon, "Industry Outlook 2021-2023: Power Generation," in Krungsri Research 2021, Bank of Ayudhya Public Company Limited: Thailand, 2021, pp. 1-13.

[3] E.P.a.P.o. (EPPO), Electricity, 2022, [cited 2022 April 9, 2022], available from: http://www.eppo.go.th/index.php/en/en-energystatistics/electricity-statistic

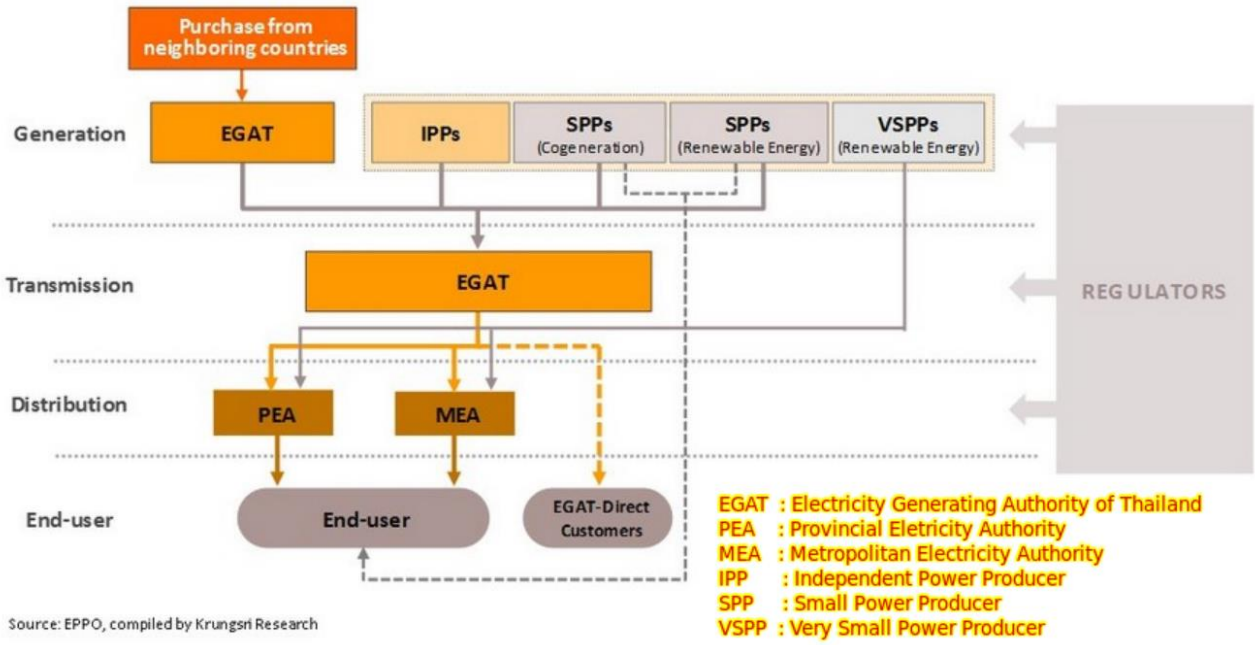

Figure 3 Thailand's electricity supply chain

COVID-19 pandemic. [4] The effect of the recent Russian invasion of Ukraine was not envisioned in this scenario, however. In general, Thailand's electricity demand growth depends primarily on domestic demand and government policy. For example, the Thai government articulated its support under PDP 2018 rev.1 and AEDP 2015/2018 to encourage and facilitate investments in rooftop solar PE, biomass, biogas, and waste-to-energy segments. In 2020, the major sources of demand were industry (43.9%), household (28.3%) and business sectors (23.5%). The food industry was the major energy consumer in the industrial sector, followed by steel & basic metals, electronics, auto assembly, and plastics production.[5]

In 2020, the COVID-19 pandemic and the accompanying economic slowdown reduced national electricity consumption by 3.1%. The demand drop in the business sector was the highest at 10.5%, followed by the industrial sector at 4.6%. As the nation's economic activity relied heavily on tourism, the severe drop in electricity consumption was in those directly connected to tourism (hotels (-36.4%), restaurants (-18.4%), department stores (-15.5%), and apartments and guesthouses (-9.6%)). For the industrial sector, declines were highest in textile production (-8.9%), auto assembly (-18.7%), steel and basic metals (-8.9%), and chemicals (-4.1%). On the other hand, with the work-from-home policies mandated nationwide on several occasions, the electricity demand from the household sector actually increased by 7.4% for the year of 2020.[6]

Supply sources

In Thailand, the main electricity generating entity is the Electricity Generating Authority of Thailand (EGAT), which is a state-owned utility under the Ministry of Energy. In 2020, EGAT contributed 32.3% of Thailand's total electricity generating capacity. EGAT is also the Transmission System Operator (TSO). It manages the balance of supply and demand in the transmission system and controls and administers the transactions of all the electricity generated, purchased, and sold into and out of the country. Apart from EGAT, electricity is also provided by a number of large private independent power producers (IPP) such as Electricity Generating Public Company Limited (EGCO), Ratchaburi Electricity Generating Holding Public Company Limited, and some other small and very small power producers (SPP and VSPP). In 2020, the private sector provided 56.1% of power generating capacity (28.7% from Independent Power Producers, 19.1% from Small Power Producers and 8.3% from Very Small Power Producers). The remaining 43.9% was supplied by EGAT (32.3% production and 11.5% imported). The supply chain is shown in Figure 3. Also, for the past decade, the share of electricity

[4] N. Tunpaiboon, "Industry Outlook 2021-2023: Power Generation," in Krungsri Research 2021, Bank of Ayudhya Public Company Limited: Thailand, 2021, pp. 1-13.

[5] Ibid.

[6] Ibid.

production from SPPs and VSPPs has increased substantially due to support from AEDP. In 2020, their contribution was 5.4% compared with 0.7% in 2010. At the same time, EGAT also increased energy imports to keep up with the increasing electricity demand.[7]

To broaden the perspective on Thailand's energy supply beyond electricity generation, Figure 4 shows the energy supply trend by source since 1990. Although Thailand could produce some oil and natural gas, the country has to rely heavily on imports to sustain the rising demand over the past few decades.

For natural gas, the current proven reserves (P1) in the Gulf of Thailand are 4.9 trillion cubic feet. With an annual consumption of 1.3 trillion cubic feet [3], this reserve can sustain Thailand for only 4 years. In 2021, as a result, only 73% of the natural gas consumed was domestically produced (from 13 major natural gas fields [4]); 14% was imported from Myanmar and 13% was from imported LNG [5]. Consequently, for energy security, the PDP emphasizes increasing the use of renewable energy.[8]

Thailand has been importing LNG since 2011. PTT Public Company Limited, a Thai state-owned oil and gas company, is the only importer. The company has signed a long-term purchase contract with Qatar for 2 million tons per year, Shell for 1 million tons per year, BP for 1 million tons per year, and Petronas for 1.2 million tons per year.[9] This turns out to be quite a foresight for the country, considering the rise in LNG price after the recent sanctions placed on Russia. Since 2019, the country has become a regional LNG hub. An LNG receiving terminal (11.5 million tons per year capacity) at Map Ta Phut, Rayong Province, has long been in use and a second terminal (7.5 million tons per year capacity) at Ban Nong Fab, Rayong Province, is expected to be completed in 2022.[10] With the concession of the two main natural gas operations at Erawan and Bongkot gas fields in the Gulf of Thailand (1,851 MMSCFD) expiring in 2022 and 2023, the ending of the contract for the natural gas from Myanmar in 2023 and 2024, and the conclusion of a Joint development area (JDA) agreement between Thailand and Malaysia for the exploration and exploitation of non-living natural resources in 2027, it is predicted that the nation will have to rely entirely on LNG within the next 15 years.[11]

For crude oil, in 2019, 57% was imported from the Middle East (28,480 million liters), 15% from Southeast Asian countries such as Malaysia, Indonesia and Brunei (7,337 million liters), and 28% from the other regions such as Russia and Australia

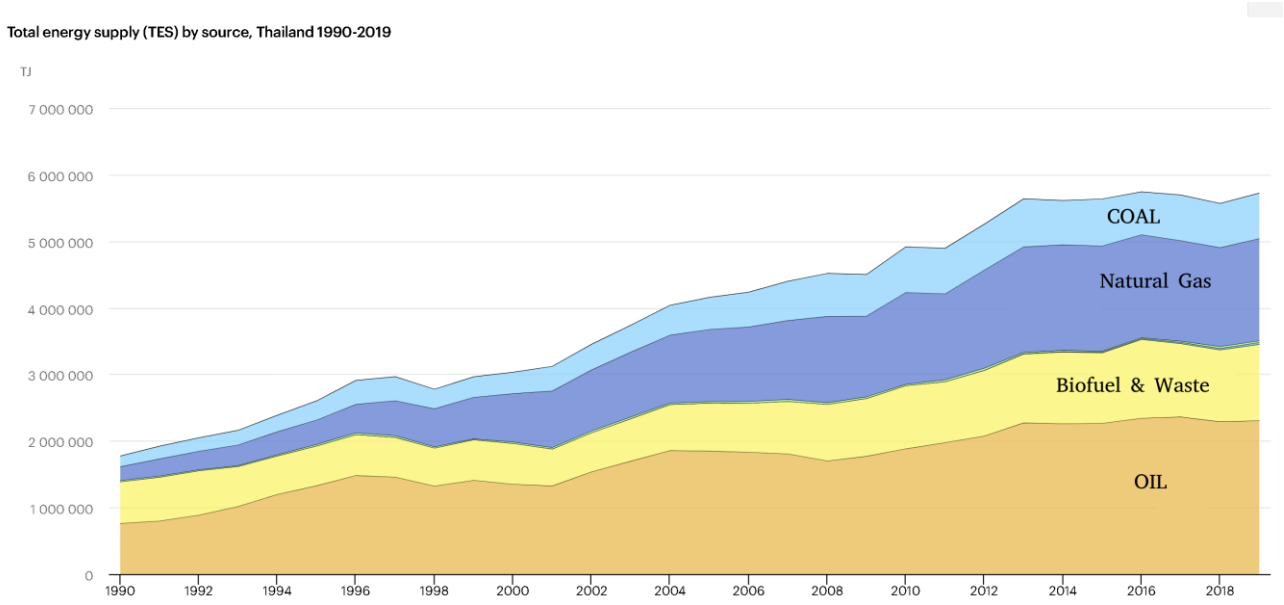

Figure 4 Trend of energy supply by source

[7] N. Tunpaiboon, "Industry Outlook 2021-2023: Power Generation," in Krungsri Research 2021, Bank of Ayudhya Public Company Limited: Thailand, 2021, pp. 1-13.
[8] Ibid.
[9] International Trade Administration, "Thailand - Oil & Gas," 2021, [cited 2022 June 20, 2022], available from: https://www.trade.gov/energy-resource-guide-thailand-oil-and-gas
[10] Ibid.
[11] Ibid.

(13,870 million liters).[12] As of the current time, since only 3% (5.22 million liters of refined oil per day) is purchased from Russia, the impact of the sanctions on its availability is expected to be minimal.[13] It should be noted that, in 2019, the country's crude oil production capacity was 125,889 barrels per day while the total production of petroleum products was 1,135,291 barrels/day (368,845 barrels/day gasoline, 466,719 barrels/day diesel, 94,434 barrels/day fuel oil and 190,831 barrels/day LPG).

For coal/lignite, EGAT's mine in Mae Moh, Lampang Province in northern Thailand, has essentially been the only source of lignite for the country and has been mostly utilized for electricity generation. In 2019, Thailand produced 14 million tons of coal (98% was from EGAT's Mae Moh resource). Almost 100% of it was used for electricity generation, together with the 21 million tons of high-grade coal imported from oversea sources such as Australia. Of the total coal available (domestic production and imports), 60% is utilized for electricity production while the remaining is used by the industrial sector.[14]

Connectivity

As discussed earlier, EGAT is responsible for electricity transmission to customers, i.e., MEA, PEA, a number of direct clients prescribed by law, and the neighboring countries. EGAT owns, constructs and operates the national transmission network including transmission lines and substations of various high voltage levels covering the entire country. Even though in principle, the Energy Industry Act allows any applicants to apply for an electricity transmission license, EGAT remains the only entity that has been awarded this license thus far.[15] In addition, Thailand is connected to the Lao People's Democratic Republic (Laos) and Malaysia for a total capacity of 3,877.60 MW.

Power plant	Contracted capacity (MW)					
	2020	2021	2022	2023	204	2037
(1) Government support						520
Waste energy			400	400	400	400
Biomass			60	120	120	120
(2) Under AEPD						18,176
Biomass (community)	200	300	400	500	600	600
Biogas-crops (community)	200	300	400	500	600	600
Biogas-waste (community)	100	150	183	183	183	183
Solar hybrid (community)	200	300	390	470	550	550
New wind			90	180	290	1,485
Small hydro (EGAT)	-	-	-	-	-	69
Floating solar and hydro (EGAT)	45	45	45	69	69	2,775
Solar	50	100	150	200	250	8,740
Biomass	-	-	-	-	-	2,780
Biogas	-	-	-	-	-	400
Industrial waste	-	-	-	-	-	44
Total	**795**	**1,195**	**2,118**	**2,622**	**3,042**	**18,696**

Table 2 Renewable energy capacity under PDP 2018 rev. 1

[12] International Trade Administration, "Thailand - Oil & Gas," 2021, [cited 2022 June 20, 2022], available from: https://www.trade.gov/energy-resource-guide-thailand-oil-and-gas

[13] L. Apisitniran, P. Arunmas, and W. Chantanusornsiri, "Oil prices have authorities on edge," 2022, [cited 2022 June 20, 2020], available from: https://www.bangkokpost.com/business/2269763/oil-prices-have-authorities-on-edge

[14] International Trade Administration, "Thailand - Oil & Gas," 2021, [cited 2022 June 20, 2022], available from: https://www.trade.gov/energy-resource-guide-thailand-oil-and-gas

[15] S. Boonsanong and C. Charoonchitsathian, "Electricity regulation in Thailand: overview," [cited 2022 April 4, 2022], available from: https://uk.practicallaw.thomsonreuters.com/1-628-5906?transitionType=Default&contextData=(sc.Default)&firstPage=true

Investment outlook

With PDP 2018 rev. 1 and AEDP 2018, the overall 2037 target for the renewable sources is set at 18,696 MW as demonstrated in Table 2. [16]

To promote alternative energy, the Thailand Board of Investment (BOI) offers a wide range of incentives. For example, tax-incentives include exemption from import duties on machinery and raw materials, as well as corporate income tax for up to eight years. As for non-tax incentives, a company will be allowed to bring in expatriates, own the land, and take or remit foreign currency abroad. Any approved projects involving alternative energy will directly benefit from these incentives.[17]

Electrical energy policy framework

The Energy Ministry is responsible for electrical energy management, focusing on sustainable development at a fair price that everyone can access and encouraging economic development by creating a mechanism so that the communities can participate (Energy for All Policy). The policy emphasizes that each community gets involved in the electricity generation process based on the clean resources available in each area as reflected in the current version of the PDP.

With the Energy for All Policy, each part of the country is to get involved to help ensure the country as a whole is improved. This will help sustain the economy and move it forward even when uncontrollable external parameters are encountered. To accomplish this policy, six objectives are set:[18] 1) reduce the cost of energy, 2) provide access to electricity to all parts of the country, 3) establish no less than 700 MW of community power plants, 4) each is constructed at potential sites across the country, 5) employ B10 as the standard diesel fuel grade and B20 for large trucks, and 6) encourage and support the use of electric vehicles (EVs).

Energy improvement plans

The objective of the nation's energy policy is to achieve the goal of a low-carbon economy and society.[19] [20] This will be accomplished by committing to the green energy as described in AEDP 2018. The details of this energy improvement plan are provided in the subtopic of Policies and Process under the topic of Challenges and Opportunities.

Measurement and monitoring

The indicators of success are based on three areas of development: energy security, the economy, and the environment.[21] [22] [23] For energy security, the stability of power generation, power transmission, and power distribution systems must be sufficient to support the country's economic growth. For the economy, the overall electricity price must be at an appropriate level, not becoming a burden on users and not hindering long-term economic and social development. For the environment, implementation of the PDP must not affect the environment any more than the original expectation, i.e., CO_2 emissions per unit of generated electricity generated.[24]

In operating the power grid system, EGAT is responsible for assessing, inspecting, monitoring, and maintaining the power grid system so that the quality of the electrical system is within the standard, and effectively supplying electricity to the country and its neighbors.[25]

Challenges and opportunities

The Ministry of Energy has established the policy of "Collaboration for Change (C4C)," which is focused

[16] N. Tunpaiboon, "Industry Outlook 2021-2023: Power Generation," in Krungsri Research 2021, Bank of Ayudhya Public Company Limited: Thailand, 2021, pp. 1-13.
[17] C. Thunyaratchatanon, et al., "Influence of Mg modifier on cis-trans selectivity in partial hydrogenation of biodiesel using different metal types," Applied Catalysis A: General, vol. 520, 2016, pp. 170-177.
[18] *Thailand Alternative Energy*, T.B.o. Investment, Editor., Thailand Boad of Investment. p. 1-11.
[19] Energy News Center, "รื้อแผน PDP 10 ปีแรกเพิ่มสัดส่วนไฟฟ้าพลังงานหมุนเวียนแทนฟอสซิล กพช.ไฟเขียวโครงสร้างราคาก๊าซใหม่," 2021, [cited 2022 April 17, 2022], available from: https://www.energynewscenter.com/%e0%b8%95%e0%b8%b1%e0%b9%89%e0%b8%87%e0%b9%80%e0%b8%9b%e0%b9%89%e0%b8%b210
[20] P.B. Office, Download รายงานการวิเคราะห์งบประมาณรายกระทรวง ประจำปีงบประมาณ พ.ศ. 2565, 2022, accessed April 9, 2022, https://www.parliament.go.th/ewtadmin/ewt/parbudget/ewt_news.php?nid=1063
[21] สำนักงานคณะกรรมการการพัฒนาระบบราชการ, ตัวชี้วัดสำนักงานนโยบายและแผนพลังงาน (กระทรวงพลังงาน, 2020), 1-10.
[22] Energy Policy and Planning Office Ministry of Energy (E.P.a.P.O.M.o.), Thailand Energy Trilemma Index (Energy Policy and Planning Office Ministry of Energy, 2021), 1-16.
[23] สำนักงานนโยบายและแผนพลังงาน, นโยบายและแผน: การติดตามและประเมินผล, 2019, accessed April 17, 2022, http://www.eppo.go.th/index.php/th/plan-policy/evaluation/eva-operrate?orders[publishUp]=publishUp&issearch=1
[24] สำนักงานนโยบายและแผนพลังงาน, นโยบายและแผน: การติดตามและประเมินผล, 2019, accessed April 17, 2022, http://www.eppo.go.th/index.php/th/plan-policy/evaluation/eva-operrate?orders[publishUp]=publishUp&issearch=1
[25] Thailand Electricity Generating Authority of Thailand (T.E.G.A.o.), Power for Happiness, in Annual Report 2019: Electricity Generating Authority of Thailand (Thailand, 2019), 1-251.

on the clean energy transition.[26] However, given the context of the country and the constraints of renewable energy, the transition will take time and fossil fuel-based power plants will still be needed for stability of the power system.

Utilizing clean energy depends on several factors. An important part is government policy.[27] On August 4, 2021, the National Energy Policy Council (NEPC) adopted the National Energy Plan Framework (AEDP 2018) to promote green energy investment. The essence of this plan is to support the goal of Thailand achieving zero carbon dioxide emissions (carbon neutrality) by 2065-2070 via the following means:[28]

1. Increase the proportion of electricity generated from the renewable energy by no less than 50%. This is considered together with the cost of long-term energy storage to minimize the cost of the electricity generation.
2. Change energy consumption in the transport sector to green electricity through the use of electric vehicles according to the 30@30 policy. This is expected to reduce the greenhouse gas emissions, improve the efficiency of energy usage in the transport sector, and help solve the problem of PM 2.5 emission. At present, the National Electric Vehicle Policy Committee has set the 30@30 policy, which intends to increase the use of electric vehicles to 30% by 2030.
3. Increase energy management efficiency by more than 30%. The intent is to reduce greenhouse gas emissions by adopting modern technologies and innovations to enhance energy management efficiency.
4. Restructure the energy industry to support the clean energy transition according to the 4D1E guidelines. This consists of reducing carbon dioxide emissions in the energy sector (decarbonization), the use of digital technology to manage the energy systems (digitalization), the reorganization of power generation management and its infrastructure (decentralization), the improvement of regulation to support the modern energy policy (deregulation), and the change in technologies used in electricity production (electrification). Table 3 shows a summary of AEDP 2018 vs. AEDP 2015.[29]

According to AEDP 2018, the share of renewable and alternative energy increased to 34.23%, from 10.04%

Type of alternative energy	AEDP 2015 achieved (MW)	AEDP 2018 target (MW)
Solar	2,849	12,139
Hydro-floating Solar Hybrid	-	2,725
Biomass	2,290	5,790
Wind	1,504	2,989
Biogas	382	1,565
Community waste	500	900
Industrial waste	31	75
Small hydro	239	308
Large hydro	2,920	2,920
Total	**10,715**	**29,411**
Generate electricity from alternative energy	**10.04%**	**34.23%**

Table 3 Summary of AEDP 2018 vs. AEDP 2015

[26] จรีพร จารุกรสกุล, ENERGY TRANSITION. 2022 [cited 2022 April 7]; Available from: https://www.wha-industrialestate.com/en/media-activities/articles/4269/energy-transition

[27] ERC, ก., "พลังงานสะอาด" (Green energy), in ERC Mag. 2013, กกพ ERC

[28] กระทรวงพลังงาน, ส.ส. มติการประชุมคณะกรรมการนโยบายพลังงานแห่งชาติ ครั้งที่ 2/2564 (ครั้งที่ 154). 2021 [cited 2011 April 8]; Available from: http://www.eppo.go.th/epposite/index.php/th/component/k2/item/17213-nepc-prayut04-08-64

[29] The Bangkok insight editorial team, รู้จักแผนพลังงานทดแทนและพลังงานทางเลือกของประเทศไทย (AEDP). 2021 [cited 2022 April 9]; Available from: https://www.thebangkokinsight.com/news/environmental-sustainability/532175/

in AEDP 2015. Six technologies for electricity generation were added: solar energy (15,574 MW), biomass (5,790 MW), wind energy (2,989 MW), biogas (agricultural wastewater/waste materials) (1,565 MW), municipal waste (900 MW), industrial waste (75 MW), and small hydropower (308 MW). The large hydropower was not changed from the original plan (2,920 MW).

Technology

As EGAT is the main organization supporting and promoting clean energy, information provided by EGAT is used to illustrate the usage of various technologies to produce electricity.

1. EGAT has installed solar PV panels at various government facilities and other public/private buildings, for a total of 1,000 MW in over 10 years. In addition, EGAT also has initiated the production of electricity using solar PV for self-use by public sectors and communities in various regions of the country. These "community power plants" can also be made hybrid so that they can be more effective in serving local users. If excess electricity is produced, it can be sold back to EGAT.
2. EGAT supports community waste and biomass power plant projects. The projects are also aimed at energy conservation in the agricultural industry. It is expected to annually save 54,371 tons of crude oil, which is equivalent to 4,000 MW of power plants and resulting in a reduction of approximately 170 million tons of CO_2 emissions.[30]
3. EGAT owns and operates two wind power generation and distribution systems, one at Laem Phromthep, Phuket Province, and the other one at the "Lam Ta Khong Cholapa Watthana Power Plant", Sikhio District, Nakhon Ratchasima Province.
4. EGAT's multipurpose dam, which is a combination of the hydropower and the floating solar cells. A total of 16 such projects with 9 dams for a total capacity of 2,725 MW are now being planned. Such a system generates electricity at daytime from the solar panels on buoys and at nighttime from the hydropower.[31]
5. EGAT has promoted and supported the government's policy on electric vehicles. There are research projects to convert public buses to electrical ones and to begin employing fast charger stations.
6. EGAT and other three leading agencies, namely Bloom Energy, ATE, and EGCO Group, have joined to develop and implement hydrogen energy technology in the country based on Solid Oxide Fuel Cell (SOFC) and Solid Oxide Electrolyzer Cell (SOEC) technologies.
7. EGAT has a pilot project for smart grid development in Mae Hong Son Province. This is a short-term plan to demonstrate its potential. The plan is scheduled for completion in 2022.
8. EGAT and Thailand Institute of Nuclear Technology (TINT) have cooperated in a project to employ the first Tokamac in Thailand. This is aimed to study fusion technology and its application.

Financial

The Thai government has allocated a substantial amount of funding to support the clean energy policy. From 2017 to 2022, the Department of Alternative Energy Development and Efficiency has received a total budget allocation of around 6,700 million baht[32] (approximately US$ 200 million). For 2022 alone, its budget is 1,542 million baht (approximately US$ 46 million), a 37.73% increase from the 2021 budget. From this budget, about 829 million baht is set for the development of the renewable energy and to improve its efficiency. This is divided into 2 parts: one is for hydroelectric power projects (328.2955 million baht) and one is to subsidize crude palm oil purchased by EGAT (500.5275 million baht). About 46 million baht is set aside for energy efficiency improvement and energy conservation projects. 2.14 million baht is set aside for testing electric vehicles. The last 46 million baht is to be used for maintenance and renovation of hydropower stations.

[30] สุทธมน เฮงรัศมี, พลังงานสะอาดมาแรง ไปดูแผนผลิตไฟฟ้าไทยใน 20 ปีกัน. 2021 [cited 2022 April 9]; Available from: https://www.greenery.org/articles/cleanpower-electric-energy/

[31] Thunyaratchatanon, C., et al., Influence of Mg modifier on cis-trans selectivity in partial hydrogenation of biodiesel using different metal types. Applied Catalysis A: General, 2016. 520: p. 170-177.

[32] Office, P.B. Download รายงานการวิเคราะห์งบประมาณรายกระทรวง ประจำปีงบประมาณ พ.ศ. 2565. 2022 [cited 2022 April 9]; Available from: https://www.parliament.go.th/ewtadmin/ewt/parbudget/ewt_news.php?nid=1063

In addition, Thailand signed a letter of intent on the Clean Energy Demand Initiative (CEDI) with the United States during the Second US - Thailand Energy Policy Dialogue (2nd UTEPD), hosted by the Thai Ministry of Energy on February 17, 2022. This letter of intent shows the mutual commitment of Thailand and the United States to promote investment in clean energy. The United States will persuade investors to conduct their businesses in Thailand, whereas Thailand will facilitate and support the procurement of clean energy for investors under the relevant terms and conditions. Initially, up to US$2,384 million worth of investment are expected from 19 companies, namely 1) HP Inc., 2) Apple, 3) Akamai, 4)Meta Platforms Inc., 5) Johnson & Johnson, 6) Nike, 7)Dow Inc., 8) Iron Mountain, 9) Inter IKEA Group, 10) Lululemon, 11) Spiber Inc., 12) Ralph Lauren Corp., 13) Unilever, 14) TAL Apparel, 15) Amer Sports, 16) RIFE International, 17) Amazon, 18) WeWork and 19) TCI Co., Ltd.[33]

Currently, 10 leading Thai companies have gotten involved in clean energy. These are as follows: (1) B.Grimm Power Public Co., Ltd., (2) Gulf Energy Development Public Co., Ltd., (3) Global Power Synergy Public Co., Ltd., (4) ELECTRICITY GENERATING Public Co., Ltd., (5) Ratch Group Public Co., Ltd., (6) Banpu Power Public Co., Ltd., (7) Energy Absolute Public Co., Ltd., (8) Gunkul Engineering Public Co., Ltd., (9) Absolute Clean Energy Public Co., Ltd. and (10) TPI Polene Power Public Co., Ltd.

Nuclear energy options

Thailand's nuclear power development program started in 1966 when EGAT's project was first submitted to the government. A site situated next to the Gulf of Thailand in Ao-Phai, Chonburi, an eastern province of Thailand was approved for the project in 1970. Two years later, the government approved a 600 MW boiling water reactor (BWR) and uranium fuel from the US Energy Research and Development Administration was reserved. In 1978, the program was postponed indefinitely due to the discovery of a large natural gas reserve in the Gulf of Thailand, which was considered safer and more economical.[34] Nonetheless, between 1982 and 1991, EGAT continued with site selection and evaluation—a total of five suitable sites were identified.

PDP 2007 included plans for 2,000 MW of installed nuclear capacity in 2020 and another 2,000 MW in 2021. This was the first PDP to include nuclear power in the nation's energy mix. At that time, the reasons for including nuclear power were to increase energy security, reduce the effect of the global warming and the climate change, keep the energy price stable and competitive, and reserve natural gas for other more valuable purposes.

In the following PDPs, the nuclear contribution was regularly redefined due to reasons such as the economic crisis in 2009 and the Fukushima accident in 2011. In any case, the nuclear portion was totally removed in PDP 2018 rev.1. Nonetheless, many activities involving the preparation for nuclear power and, specifically, the public acceptance and human resources development are still being conducted by various agencies.[35]

"Other existing laws regarding radiation and nuclear safety, security and safeguards, and nuclear non-proliferation would be applied in conjunction with the Nuclear Energy for Peace Act"

ASEAN Centre for Energy [36] conducted a pre-feasibility study and identified Thailand, Indonesia, Malaysia, the Philippines, and Vietnam as the prime candidates to establish nuclear power programs by 2030 to 2035. The study argued that ASEAN countries need to create an international agency "ASEANTOM" to oversee the capacity-building in nuclear safety, security and safeguards, as well as a Nuclear Energy

[33] Online, M. ครม.เคาะหนังสือเจตจำนงใช้พลังงานสะอาด ไทย-เอกชนสหรัฐฯ ลงทุนสะพัด 2.38 พันล้านเหรียญ. 2022 [cited 2022 April 10]; Available from: https://mgronline.com/politics/detail/9650000015564

[34] Engineering, D.o.N. Home. 2022 [cited 2022 April 19]; Available from: http://www.ne.eng.chula.ac.th/wp/

[35] Analysis: Impacts of a Disruption of Myanmar Gas Imports on Thailand's Energy Security. 2021 [cited 2022 22 April]; Available from: https://earthrights.org/publication/analysis-impacts-of-a-disruption-of-myanmar-gas-imports-on-thailands-energy-security/

[36] Energy, A.C.f., Pre-Feasibility Study on the Establishment of Nuclear Power Plant in ASEAN. 2018, ASEAN Centre for Energy: Jakarta, Indonesia.

Programme, to build public acceptance, and to ensure nuclear regulator independence with strong nuclear legality. This is an ongoing process and will take some time to finalize.

Infrastructure

Without prior knowledge and direct experience, if Thailand is going to have a nuclear power plant, the first one is most likely to be a turnkey project. In October 2010, Thailand submitted the self-evaluation report to IAEA and was visited by the INIR mission December 13-18, 2010. The mission concluded: "*The INIR Mission Team reviewed all of the 19 issues based on the IAEA reference documents. The Team concluded that based on the progress in addressing 19 issues, which will be included in Readiness Report, Thailand can make a knowledgeable decision on the introduction of nuclear power.*" [37] The mission, however, stated that public acceptance, laws and regulations regarding nuclear power, as well as a strong regulatory body were needed for Thailand to proceed with a nuclear project.

Regulatory framework

Regarding laws related to nuclear and radioactive materials in Thailand, the most relevant one is the Nuclear Energy for Peace Act (No. 2) (2019), which is the updated version of the Atomic Energy for Peace Act (1961) and is the direct result from the INIR mission in 2010. Based on this law, a number of regulations on handling radioactive and nuclear materials and procedures governing industries involving such materials and their processes have been issued. In addition, other existing laws regarding radiation and nuclear safety, security and safeguards, and nuclear non-proliferation would be applied in conjunction with the Nuclear Energy for Peace Act.

The regulatory body is composed of two authorities. The Nuclear Energy for Peace Commission (formerly the Atomic Energy for Peace Commission, AEC) oversees compliance with the related laws and regulations. It is composed of representatives from the related government agencies and is chaired by the prime minister. Second, the Office of Atoms for Peace (OAP), formerly the Office of Atomic Energy for Peace, is an agency under the Ministry of Higher Education, Science, Research and Innovation. OAP acts as the operating arm of the commission. The secretary-general of OAP also serves as the secretary of the commission.[38] By the Ministerial Regulation, the duties and powers of OAP are as follows:

1. Implement the nuclear energy for peace and other relevant laws.
2. Be responsible for the secretary work of the Nuclear Energy Committee for Peace.
3. Supervise nuclear and radiation safety, security, and safeguards.
4. Suggest policies, guidelines, and strategic plans for peaceful use of nuclear energy.
5. Study, analyze, research, and develop a body of knowledge, technology, and standards on the regulation of nuclear and radiation safety, security, and safeguards.
6. Coordinate and cooperate with agencies both within the country and abroad and operate in accordance with the international obligations and agreements.
7. Perform any other acts prescribed by law to be the duties and authorities of the OAP, or as assigned by the Minister or the Cabinet.

Financial

At present, as nuclear energy is not in consideration, financial information on investment, construction, and other aspects related to establishing a nuclear power station is not available. However, based on the Policies and Strategic Plan for the Development of Nuclear Energy of the Country (2017 – 2026),[39] some information regarding the preparation for the nuclear program is described. The preparation consists of four main strategies, (1) international cooperation, (2) nuclear safety, security, and safeguards supervision, (3) human resource development and (4) infrastructure development. In total, 170 projects for the period from 2017 to 2021 were implemented with a total budget of 4,538.1828 million baht (about US$135.5 million).

Technology

As Thailand has no nuclear power plant, the only technology related to nuclear energy is the 2 MW TRIGA Mk-III research reactor operated by TINT.

[37] Pricha Karasuddhi. Nuclear Power Development in Thailand. 2022 [cited 2022 June 20]; Available from: https://www.nst.or.th/jnal/seta2016/04%20Mr.Pricha%20-%20Nuclear%20Power%20Development%20in%20Thailand%20new.pdf.

[38] OAP. ประวัติสำนักงาน. 2016 [cited 2022 April 15]; Available from: http://www.oap.go.th/about-us/history

[39] คณะกรรมการพลังงานนิวเคลียร์เพื่อสันติ, นโยบายและแผนยุทธศาสตร์การพัฒนาด้านพลังงานนิวเคลียร์ของประเทศ พ.ศ. ๒๕๖๐ - ๒๕๖๙. 2017, สำนักงานปรมาณูเพื่อสันติ กระทรวงวิทยาศาสตร์และเทคโนโลยี

The very first Thai Research Reactor (TRR-1) went critical on October 27, 1962. The reactor was later modified to be operated with 20% U-235 enriched U-ZrH fuel. It is situated at TINT headquarters in Bangkok, next to Kasetsart University. This research reactor has been the country's largest neutron source for a wide range of neutron applications. As of 2021, a plan for a new research reactor has been proposed by TINT and is expected to be operable in 2032. In addition, TINT also has two high-energy electron beam accelerators (21.5 MeV and 8 MeV maximum energy) and several Co-60 gamma irradiators to be used in conjunction with the research reactor. As for EGAT, if and when a nuclear power program is approved, EGAT is likely to be the responsible agency for the construction and operation. At present time, however, EGAT appears to have an interest in the small modular reactors but had not given any official comment on this development.

Small modular reactors

This section discusses the small modular reactors (SMRs) in the context of the possibility of being deployed in Thailand. SMRs are the advanced nuclear power reactors that can generate the electricity from as low as 10 MW to as high as 300 MW. Being modular, the reactors can be produced more economically within a much shorter period.[40] As SMR footprints are much smaller than large nuclear power plants, this could reduce public fear of a nuclear incident and enhance the possibility of acceptance. Thailand is considered a potentially emerging nuclear energy country according to the World Nuclear Association [41] with a potential for microreactors, which are a subset of SMRs with the capacity range of 1 - 20 MW. In a hybrid energy system, SMRs with the shorter construction times could be paired with the renewable sources such as wind and solar to increase the efficiency and overall availability. Thus, SMRs could in principle assist Thailand in its transition to the clean energy.

“The COVID-19 pandemic and the accompanying economic slowdown understandably reduced national electricity consumption by 3.1% in 2020”

Public acceptance

Previous attempts at nuclear power programs in Thailand have faced public communication difficulties. The lack of public involvement in government decisions for many large projects that failed or had negative effects on local communities in the past may have been the major reason for this problem.[42] The situation becomes more complicated due to many political and cultural conflicts and interests. For nuclear power, its bad image as a potential source for nuclear weapons, the devastating results from the nuclear accidents such as Chernobyl and Fukushima, and local radioactive incidents such as that of the missing Co-60 in Samutprakarn Province also create public fear and distrust. All of these lead to the problem of the public acceptance of the nuclear power.

The issue of public acceptance even affected the Ongkarak research reactor project. The following examples summarize interesting points of concern by some local individuals.[43]

- Radiation leakage to the environment
- Effect of an earthquake on the installation
- Radioactive waste storage
- Mismanagement of corruption in the project
- Emergency preparation
- Benefit and remuneration
- Unable to make an informed decision due to lack of knowledge

These concerns regarding the research reactor seem to center around the fear of radiation and accidents. Even with the numerous attempts by the relevant agencies to provide information and to get more public involvement to gain more acceptance and to ensure the public safety, they most likely would be amplified had it been the actual plan for the nuclear power plant.

[40] Liou, J. What are Small Modular Reactors (SMRs)? 2021 November 4 2021 [cited 2022 May 13]; Available from: https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs

[41] World Nuclear Association, US study sees future markets for microreactors. 2021 [cited 2022 May 18]; Available from: https://www.world-nuclear-news.org/Articles/US-study-sees-future-markets-for-microreactors

[42] ประชาไท (Prachathai), "เสียงคนอีสาน: คนอุบลค้านโรงไฟฟ้านิวเคลียร์," 2011, accessed April 13, 2022, https://prachatai.com/journal/2011/01/32763

[43] บ.ค.อ.เ.จ. (COT), รายงานสรุปผลการฟังความคิดเห็นของประชาชนครั้งที่สองฯ, 2019, บริษัท คอนซัลแทนท์ ออฟ เทคโนโลยี จำกัด (COT).

One possible way to alleviate public fear of nuclear power and also to provide the needed information is through education. At the school level, by introducing basic courses in nuclear and radiation technology and safety into the curricula, students would learn and familiarize themselves with the technology at the early age. For the local community, a public nuclear education center could be established so that people could study the technology. At the university level, a scholarship could be set up to study nuclear and radiation technology. This would produce a competent workforce. At the same time, the students who graduated from the program could return to their communities and communicate with people in the area to help ensure a better understanding.

Conclusion

Electricity generation in Thailand has relied heavily on natural gas and coal/lignite with a small part being from the renewable sources. To reduce such dependence, the government encourages the use of renewable energy from agricultural waste and sets a new renewable energy target of 30% by 2037 in PDP 2018 rev.1. As more than half of the nation's energy sources are imported and are likely to keep increasing, the government is seeking to diversify energy sources and strongly promotes alternative energies. Consequently, Thailand Board of Investment (BOI) has offered a wide range of tax-based and non-tax incentives. The direction of the nation's energy policy is clearly to drive the energy sector to achieve the goal of a low-carbon economy and society, and to reach zero carbon dioxide emissions by 2065-2070. This is in line with the goals set by other ASEAN countries, and the global goals of reducing carbon emissions and promoting clean energy. The goals and the priorities outlined in the PDP, especially the 30% renewable energy contribution, appear to be feasible as Thailand is an agricultural country with ubiquitous agricultural waste. Also, with the technologies and innovations that promote clean energy use being actively pursued by EGAT, these will strongly contribute to the transition from fossil fuels to clean energy sources. Moreover, since Thailand is situated near the equator, the high availability of the sunlight and the existing large empty areas help facilitate solar PV installations as a clean energy source. The country, however, needs significant investment over the next 20 years to develop the infrastructure.

In Thailand, EGAT is the major electricity generating entity. It generates, transmits, and wholesales electricity for the country. EGAT is also the Transmission System Operator (TSO) that manages the balance of supply and demand in the transmission system. For connectivity, Thailand is connected to Laos and Malaysia for a total of 3,877.60 MW.

The COVID-19 pandemic and the accompanying economic slowdown understandably reduced national electricity consumption by 3.1% in 2020. For 2021-2023, the electricity demand was predicted to rise by 2.8 - 3.8% annually due to the anticipated economic recovery. However, the recent Russian invasion of Ukraine that began in February 2022 can still have an impact on Thailand's economy. The effect is believed to be minimal as Thailand does not rely on any energy source from Russia and the affected regions (except for the minor 3% import of oil from Russia). However, the rising crude oil price will definitely have an impact on the global economy and energy prices. The magnitude of the impact remains uncertain.

The latest PDP 2018 rev.1 completely removed the nuclear power option from Thailand's energy planning. Nevertheless, nuclear power may be considered again in the future. In any case, all related government agencies are still working on the preparation for nuclear power, specifically on promoting public acceptance and human resource development. As Thailand has never had a nuclear power plant, the required industrial and human resources may not be readily available if a decision was made to pursue nuclear energy. The regulatory framework for nuclear energy/nuclear technology in Thailand consists of laws/regulations and a regulatory body. The main Thai laws related to nuclear power are the Nuclear Energy for Peace Act (2016) and the Nuclear Energy for Peace Act (No. 2) (2019). The Nuclear Energy for Peace Commission, chaired by the prime minister, and OAP, the agency under the Ministry of Higher Education, Science, Research and Innovation, together work as the regulatory body. The emerging SMR technologies, which exhibit several positive attributes compared to the conventional large-sized nuclear power plants, have become the topic of interest and may be considered in the future.

Public acceptance has been the most difficult part of all previous Thai nuclear power development

projects. The primary reasons have been the lack of trust from the people and the lack of public participation in energy security decision-making. The political situation and conflicts of interest also contribute to this difficulty. The problem is compounded by the public fear and mistrust of nuclear technology due to its bad image and the lack of knowledge. The suggested policy recommendations (nuclear curricula, learning centers and scholarships) to remedy the situation will take some time to show a fruitful effect. Consequently, the nuclear option whether in the conventional form or in the form of SMRs will likely not be considered for the time being.

7

Energy Landscape and Requirements of Vietnam

Nguyen Nhi Dien

I. Introduction

Vietnam's electricity system has the function of producing, transmitting, and distributing electricity to all 64 provinces and large cities across the country, and consists of three main power components: source, grid, and load. Due to geographical features, the territory of Vietnam is narrow but extends over 3,200 km from north to south. The electricity system is divided into three regions: Northern, Central, and Southern, which are linked together by the "extra high voltage network" of 500kV transmission lines.

By the end of 2021, the system's total installed capacity of power sources reached 76,620 MW, of which the capacity of renewable energy sources (solar and wind energies) was 20,670 MW and accounted for about 27% of the total capacity; the remaining energy sources (hydropower, coal-fired thermal power, gas turbines, oil thermal power, biomass, diesel generators) were about 73%. Renewable energy sources, especially wind power and solar power, were developed very rapidly during the last five years. The electricity produced and imported for the whole system is about 256.7 billion kWh and the maximum load capacity of the whole system is about 43,518 MW.

After the policy decision to build two nuclear power plants was adopted by the National Assembly on November 25, 2009, two National Power Development Plans (PDP) have been approved by the Prime Minister: PDP-VII in July 2011 for the period 2011–2020 with a vision to 2030[1] and the revised PDP-VII in March 2016 for the same period.[2] A final draft of PDP-VIII for the period 2021–2030 with a vision to 2045[3] has been submitted to the Prime Minister for approval. The revised PDP-VII was developed taking into account Vietnam's agreement at the December 2015 UN Climate Change Conference of the Parties (COP21) in Paris to limit global warming to well below 2 degrees and aim for 1.5 degrees **Celsius**. PDP-VIII was developed taking into account the Vietnam's commitment at the November 2021 UN Climate Change Conference of the Parties (COP26) in Glasgow to reduce net emissions to zero by 2050. This report gives a brief overview of the electrical energy development of the country for the period 2010–2030 with a vision to 2045 in the context that Vietnam is initiatively implementing the above international agreement and commitment, and that the National Assembly adopted the decision on postponement of the Ninh Thuan nuclear power project in November 2016.

II. Electrical energy analysis framework

2.1. Status of the national power sources development

2.1.1. Installed capacity of the national power system

According to the revised PDP-VII and other additional decisions, the planned power source capacity development for the period 2016–2030 was 109,090 MW, of which the period 2016–2020 was 35,470 MW, 2021–2025 was 45,030 MW and 2026–2030 was 28,590 MW. In fact, the total capacity put

Electricity sources	Hydro-power	Coal-fired thermal	Gas turbine	Wind power	Solar power	Other sources	Imported electricity	Total
Power capacity (MW)	20,993	21,383	9,025	538	16,506	325	572	69,342
Ratio of capacity (%)	30.3	30.8	13.1	0.8	23.8	0.4	0.8	100
Ratio of production (%)	29.6	50.0	14.6	0.4	3.7	0.5	1.2	100

Table 1 Installed capacity of power sources by the end of 2020

[1] Decision No. 1208/QD-TTg dated July 21, 2011 of the Prime Minister on the National Power Development Plan for the period 2011–2020 with a vision to 2030.

[2] Decision No. 428/QD-TTg dated March 8, 2016 of the Prime Minister on the revisions to the National Power Development Plan for the period 2011–2020 with a vision to 2030.

[3] Draft version of the National Power Development Plan for the period 2021–2030 period, with vision to 2045, April 2022.

into operation in the period 2016–2020 was only 28,377 MW (only 80% of the planned of 35,470 MW). By the end of 2020, the total installed capacity of the national power system was 69,342 MW, in which, hydropower was 20,993 MW; coal-fired thermal power was 21,383 MW; gas turbine power was 9,025 MW; wind power was 538 MW; solar power was 16,506 MW; other sources (biomass, oil thermal, diesel) were 325 MW; and imported electricity was 572 MW, as shown in Table 1. The maximum power load of the national power system was 38,617 MW.[4][5]

The national power system ensures the capacity to meet the load demand. Although the installed capacity of 69,342 is high relative to the maximum load of 38,617 MW, the system's available capacity redundancy is quite low due to the seasonal nature of hydropower, the need for repair and maintenance of thermal power and the uncertainty of wind and solar power sources. If wind and solar power sources are excluded, the reserve capacity of available capacity is only 9.06% in the rainy season and about 8.16% in the dry season.

From the point of view of green energy transition, Table 1 shows that solar power developed too fast with an installed capacity ratio of 23.8% and a power production ratio of 3.7% in the national power system. According to the revised PDP-VII, installed solar power should increase from about 20 MW in 2016 to about 850 MW by 2030 and electricity produced from solar energy should be about 0.5% by 2020, about 1.6% by 2025 and about 3.3% by 2030.

The electricity production ratio of the coal-fired thermal power is still high, with 50% in the national power system up to 2020. This ratio will decrease gradually until 2030 and then decrease rapidly until 2045 as many operational power plants will close, while the number of new coal-fired thermal plants will be limited due to strict technological and environmental requirements.

2.1.2. Installed capacity by regions

The country's power source development is managed in 3 regions: the Northern, the Central and the Southern. By the end of 2020, the installed capacity of the Northern, Central and Southern regions reached of 25,121 MW (36.2% of the total capacity), 12,323 MW (17.8% of the total capacity) and 31,898 MW (46% of the total capacity), respectively.[6]

The North's power source structure was mainly hydropower (46%) and thermal power (51%) in 2020. The North had the highest load growth rate in the country at 9.3% per year in the 2016–2020 period, with an increase of nearly 6,000 MW, while the power source only increased by 4,600 MW, with a growth rate of 4.7% per year. This leads to a decreasing ratio of installed capacity/ maximum capacity (Pmax) in the North from 55% in 2016 to 31% in 2019–2020. As a result, the transmission electricity output from the Central to the North in 2020 increased to over 2 billion kWh and this trend is forecasted to increase.

The Central region's power source structure was mainly hydropower as well, with over 5,400 MW (57%) and solar power with 3,150 MWac (33%) in 2020. This was the lowest proportion in the national load structure (about 10%). The growth rate was also the lowest, averaging 6.3% of electricity consumption and 5.3% of Pmax in the period 2016–2020. The total electricity capacity of the Central region increased from 5,500 MW in 2016 to 9,560 MW in 2020, the average power source growth rate was 16.5% per year, much higher than the load growth rate; the growth was mainly from solar power. The ratio of installed capacity/Pmax increased from 109–125% in 2016–2019 to 237% in 2020.

The Southern region had a diversified source structure, with 34,580 MW of total installed capacity in 2020, of which solar power was 37%, coal-fired thermal power was 25%, gas turbines was 22%, hydropower was 11% and other sources (oil, biomass, ...) was 4%.

The growth rate of electricity in the South in the period 2016–2020 was over 21%, 12,600 MW of solar power and 5,000 MW of coal-fired thermal power plants with six large plants put into operation. The average growth rate of Pmax in this period was only 7%. The ratio of installed capacity/Pmax increased from 13% in 2016 to 87% in 2020.

[4] National Load Dispatch Centre, Introduction to Vietnam's electrical system, https://www.nldc.evn.vn/newsg/6/1855/Gioi-thieu-he-thong-dien-Viet-Nam/default.aspx, May 29, 2021.

[5] Do Thi Bich Thuy, Evaluation of the implementation of electricity source and grid projects, Vietnam Institute of Strategy and Policy for Industry and Trade, Ministry of Industry and Trade (in Vietnamese).

[6] Do Thi Bich Thuy, Evaluation of the implementation of electricity source and grid projects, Vietnam Institute of Strategy and Policy for Industry and Trade, Ministry of Industry and Trade (in Vietnamese).

The South's electricity consumption was the highest in the country, reaching 111.4 billion kWh in 2020, growing by 6.8% per year in the period 2016–2020. The largest output was coal-fired thermal power with 45%, gas turbines power was 36%, hydropower was 8%, and solar power was about 20% (about only 7% of power output). In the past years, the South has always received a huge amount of electricity from the inter-regional transmission system; in 2017–2018, the South's power output received nearly 20 billion kWh.

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2.1.3. Commercial power for the period 2010–2020

The load was concentrated mainly in the Northern and Southern regions while the load in the Central region was quite low. Statistics of commercial power data between regions for the period 2010–2020 are shown in Table 2.

Table 2 shows that the growth rate of commercial power of the whole country reached 9.6%/year in the period 2011–2020 and 10.7% in the period 2011–2015. In the period 2016–2020 the growth rate was only 7.7% which was lower than that of previous period due to the impact of the Covid-19 pandemic in 2020, the growth rate of this year reached only 3.36%, corresponding to commercial electricity reaching 215.271 billion kWh. It can be seen that power consumption was mainly concentrated in the North and South, accounting for 90% of the total power consumption of the country, the Central region accounted for about 10% of the total national consumption.

Regions	2010	2015	2019	2020	Average growth (%)		
					2011–2015	2016–2020	2011–2020
Northern	32,766 (38.8%)	58,917 (41.5%)	89,647 (43.2%)	94,915 (44.1%)	12.5%	10.0%	11.2%
Central	8,323 (9.9%)	13,529 (9.5%)	19,303 (93%)	19,119 (89%)	10.2%	7.2%	8.7%
Southern	43,393 (51.4%)	69,535 (49.0%)	98,726 (47.5%)	101,237 (47.0%)	9.9%	7.8%	8.0 %
Whole country	**84,482**	**141,981**	**207,676**	**215,271**	**10.7%**	**7.7%**	**9.6%**

Table 2. Commercial power (GWh) and average growth (%) in the period 2010-2020

2.1.4. Maximum power consumption of the regions

Table 3 shows the statistics of the maximum power capacity (Pmax) of the national power system by regions in the period 2010–2020. It reveals that maximum power consumption in the Northern region increased the fastest with a growth rate of 11.6% and the lowest is of the Central region with a growth rate of 6.9% in the period 2011–2020. The national power system is meeting the load demand, but the system's available capacity reserve is quite low due to the seasonal nature of hydropower, the maintenance needs of thermal power, and the uncertainty of wind and solar power.

Regions	2010	2015	2016	2019	2020	Average growth (%)		
						2011–2015	2016–2020	2011–2020
Northern	6,547	11,874	13,517	18,313	19,271	13.4%	9.3%	11.6%
Central	1,648	2,546	2,740	3,535	3,365	8.5%	5.3%	6.9%
Southern	7,566	11,798	13,262	17,139	17,362	10.0%	7.0%	8.9%
Whole country	15,416	25,809	28,109	38,249	38,617	11.9%	8.3%	9.9%

Table 3. Maximum power capacity (MW) and average growth (%) by regions in the period 2010-

The power load structure of the national power system was distributed to the following sectors: Industry and construction, 54%; Management and residential, 34%; Commercial, hotel and restaurant, 5%; Agriculture, forestry and fishery, 3%; and other activities, 4%.[7]

2.2. Current status of electrical grid

2.2.1. Size of the grid

The national power system is linked by a 500 kV transmission line system between the three regions. At the end of 2020, the total length of transmission lines of 110 kV, 220 kV and 500 kV of the national power system was 51,322 km, of which the length of 500 kV lines was 8,527 km, the length of 220 kV lines was 18,477 km and the length of 110 kV lines was 24,318 km. The total capacity of all transformer substations of the power system was 195,621 MVA, of which the capacity of 500 kV transformer substations was 42,900 MVA, the capacity of 220 kV transformer substations was 67,824 MVA and the capacity of 110 kV transformer substations was 84,897 MVA.[8][9]

[7] National Load Dispatch Centre, Introduction to Vietnam's electrical system, https://www.nldc.evn.vn/newsg/6/1855/Gioi-thieu-he-thong-dien-Viet-Nam/default.aspx, May 29, 2021.

[8] National Load Dispatch Centre, Introduction to Vietnam's electrical system, https://www.nldc.evn.vn/newsg/6/1855/Gioi-thieu-he-thong-dien-Viet-Nam/default.aspx, May 29, 2021.

[9] Do Thi Bich Thuy, Evaluation of the implementation of electricity source and grid projects, Vietnam Institute of Strategy and Policy for Industry and Trade, Ministry of Industry and Trade (in Vietnamese).

2.2.2. *Operational situation*

Most of the 500 kV substations are currently operating within the allowable technical limits. However, there are still some 500 kV substations supplying electricity to the Northern and Southern load centers that are full or overloaded related to the fact that many renewable energy sources have been put into operation over a short time, the rapidly growing load rate, and the slow progress of many transmission grid projects.

The 110 kV power grids receive electricity from 500 kV substations and power plants. Currently, the 220 kV electricity grids have not yet ensured the N-1 grid reserve/backup level, especially in the Northern and Southern load centers. Therefore, in cases of power source failure, grid failure or high load, there is overloading of connected 220 kV lines. Some 220 kV transmission lines and substations in the Central Highlands, South Central and Southern areas were overloaded when many renewable energy sources were put into operation, especially land-mounted and rooftop solar power units, between 2019–2020.

2.2.3. *Current capacity of transmission grid*

The basic transmission grid ensures the backbone role of the national power system. However, due to the high load growth rate, the time required to put the grid into operation was increasingly prolonged due to the complicated ground clearance process. So, the development of the electricity transmission system still faces many difficulties, affecting the operation and ensuring the security of power supply. The local power grid in some areas has not yet met the technical criteria for transmission grid operations. In many locations, the grid has not yet met the N-1 operating criteria, and still has to operate in full and overload conditions.[10][11]

The rapid development of solar power projects with short construction time in the Central region, the South Central and Southwest areas in recent years has outpaced the development of the transmission grid, leading to the occasional need to cut power generation. In addition, operating the transmission grid in that situation contains many potential risks to the safe and stable operation of the transmission network.

The increase in investment and modernization of the electrical grid has helped as the power loss target of the entire power system in 2020 reached about 6.42%. The average outage time index of customers in the year (SAIDI) has sharply decreased from 2,281 minutes in 2015 to 356 minutes in 2020, exceeding the assigned target (400 minutes) in the five-year plan 2016–2020 of the Vietnam Electricity Corporation (EVN).

2.3. Investment outlook

According to the PDP-VII, the total investment capital for the whole power sector for 2011–2030 period is approximately USD $124 billion (each year needs over $4.8 billion), of which the investment for power sources development is about $82 billion (66% of the total) and the investment for power grids is about $42 billion (34% of the total). According to the revised PDP-VII, the total investment in the development of power sources and grids (excluding BOT investments) from 2016 to 2030 is about $148 billion, in the following phases: For 2016–2020, nearly $40 billion, averagely $7.9 billion per year, of which 75% is allocated to power sources and 25% to power grids. For 2021–2030, the allocation is nearly $108 billion, averaging over $10.8 billion per year, of which 74% is for power sources and 26% for power grids.[12][13]

Solutions for creating investment capital for development of the national power system are:

- Expediting the equitization of corporations and power generation companies under EVN, Vietnam Oil and Gas Corporation (PVN) and Vietnam Coal – Mineral Industries Corporation (Vinacomin);
- Gradually increasing the ability to mobilize internal finances in power companies by enhancing their efficiency and performance and maintaining accumulations and self-financed capital for development investment;

[10] National Load Dispatch Centre, Introduction to Vietnam's electrical system, https://www.nldc.evn.vn/newsg/6/1855/Gioi-thieu-he-thong-dien-Viet-Nam/default.aspx, May 29, 2021.

[11] Do Thi Bich Thuy, Evaluation of the implementation of electricity source and grid projects, Vietnam Institute of Strategy and Policy for Industry and Trade, Ministry of Industry and Trade (in Vietnamese).

[12] Decision No. 428/QD-TTg dated March 8, 2016, of the Prime Minister on the revisions to the National Power Development Plan for the period 2011–2020 with a vision to 2030.

[13] Decision No. 1208/QD-TTg dated July 21, 2011, of the Prime Minister on the National Power Development Plan for the period 2011–2020 with a vision to 2030.

- Developing corporations operating in the power industry with high financial credibility to reduce the cost of capital mobilization for power projects;
- Mobilizing more capital by issuing bonds domestically and abroad to gain investments in power projects and facilitating the conversion of domestic savings to investments in infrastructure;
- Establishing local and overseas joint ventures to attract foreign investors to engage in power projects;
- Equitizing power companies, in which the government's full holding is not essential;
- Encouraging foreign direct investment (FDI) into power projects; and
- Appealing to foreign investments in power-related facilities from preferential and non-preferential official development assistance, foreign commercial loans, etc.

In addition, solutions on power prices will be applied:

- Implement market-based pricing policy under the government's regulation in which electricity pricing must energize electricity development, create an investment magnet, and encourage competition in production, transmission, distribution, retail and consumption of electric power;
- Continue renovating and completing the current electricity tariff to ensure electricity price is gradually revised to establish the long run marginal cost of power systems;
- Electricity pricing must recover expenses and generate reasonable profit to assure power companies' financial autonomy;
- Electricity pricing must aim at conserving energy, avoiding the dilapidation of non-renewable energy, encourage the rational consumption of energies and use of domestic energy resources, and lessen reliance on energy import.

III. Electrical energy policy framework

3.1. Roles and responsibilities

The Power Law prescribes the power development planning and investment; power saving; power markets; rights and obligations of organizations and individuals conducting power activities and using power; protection of power equipment and facilities, power works and power safety. The Power Law applies to organizations and individuals conducting power activities, using power or engaged in other power-related activities in Vietnam.[14]

Every 10 years, the Prime Minister issues the National Power Development Plans (PDP) for the period of 10 years, with a vision up to 20 years.[15] In addition, during implementation of PDPs, mechanisms for encouraging and supporting the power energy projects have been approved by the Prime Minister.

3.2. Energy policy

According to the Power Law, [16] power development policies have addressed:[17]

- Developing power in a sustainable manner on the basis of optimally tapping all resources, satisfying demands for power energy with stable quality, safety and economy, civilized services, thus contributing to the maintenance of national defense, national security and energy security.
- Building the power market on the principle of availability, equality, and fair competition with State regulation to raise efficiency; ensuring the legitimate rights and interests of power units and power-using customers; attracting all economic sectors to participate in activities of power generation, electricity distribution, power wholesaling, power retailing and/or specialized power consultancy. The State holds a monopoly in the transmission, power system regulation, construction, and operation of power plants with particularly important socio-economic, national defense or security significance.

[14] Power Law No. 28/2014/QH11 of the National Assembly dated December 3, 2004.

[15] National Load Dispatch Centre, Introduction to Vietnam's electrical system, https://www.nldc.evn.vn/newsg/6/1855/Gioi-thieu-he-thong-dien-Viet-Nam/default.aspx, May 29, 2021.

[16] Power Law No. 28/2014/QH11 of the National Assembly dated December 3, 2004.

[17] Law No. 24/2012/QH13 of National Assembly dated November 20, 2012 on amending and supplementing a number of articles of the Power Law No. 28/2014/QH11.

- Applying scientific and technological advances to power activities with a view to raising the efficiency of various energy sources and ensuring environmental protection.
- Encouraging research, development, production and use of modern equipment to service for the requirement of power development.
- Increasing the exploitation of new energy sources and renewable energy for power generation through incentive policies for investment in development of power plants.

3.3. Energy improvement plans

On July 21, 2011, the Prime Minister signed Decision No. 1208/QD-TTg approving the PDP-VII for 2011–2020 with a vision to 2030.[18] The objective of the PDP-VII was to provide total power produced and imported of about 194–210 billion kWh by 2015, about 330–362 billion kWh by 2020 and about 659–834 billion kWh by 2030, while reducing the power elastic coefficient/GDP from an average of 2.0 by 2010 to 1.5 by 2015 and to 1.0 by 2020.

PDP-VII identified the development of renewable energy sources (wind power, solar power, biomass power, etc.) for power production as the top priority by rapidly developing and gradually increasing the proportion of power produced from these energy sources from 3.5% of total power produced by 2010, to 4.5% by 2020 and to 6% by 2030. The total capacity of wind power sources would be from a negligible level in 2010 to about 1,000 MW by 2020 and about 6,200 MW by 2030. Electricity produced from wind power would account for 0.7% by 2020 to 2.4% by 2030. Nuclear power was planned for the first time in the PDP-VII, with the expectation that the first nuclear power unit would be put into operation in 2020. Nuclear power capacity was expected to reach about 10,700 MW by 2030, producing about 70.5 billion kWh and accounting for 10.1% of the country's electricity production.

The PDP-VII also identified development of hydropower sources as a priority, with total capacity of hydropower moving from 9,200 MW in 2010 to 17,400 MW by 2020. Thermal power plants were to be developed at an appropriate rate, in accordance with the supply and distribution capacity of fuel sources.
At COP21, which took place in Paris in December 2015, every country including Vietnam agreed to work to limit global warming to well below 2 degrees and aim for 1.5 degrees Celsius. In this context and with Vietnam's new green power policies, PDP-VII needed to be revised. As result, on March 18, 2016, Decision No. 428/QD-TTg, the revision to PDP-VII, was approved.[19]

General objectives of the revised PDP-VII were to:

- Mobilize all domestic resources for power development to maintain the supply of power energy of higher quality at reasonable price for the nation's growth in economy and society;
- Utilize varied resources of primary energy for effective production of electricity;
- Develop and use of renewable energy sources for electricity generation to gradually increase the volume of electricity generated by renewable sources to reduce dependence on coal imports, contribute to power security, mitigate climate change, and protect the environment in a sustainable manner;
- Establish and develop smart power systems compatible with the high use of renewable energy sources.

The revised PDP-VII identified five specific objectives:

- Supply adequate electricity on a national basis with commercial power of about 235–245 billion kWh by 2020, about 352–379 billion kWh by 2025 and about 506–559 billion kWh by 2030;
- Output of generated and imported electricity of about 265–278 billion kWh by 2020, about 400–431 billion kWh by 2025 and about 572–632 billion kWh by 2030;
- Prioritize the development of renewable energy resources for power production, by increasing the proportion of renewable power (excluding hydropower) to about 7% by 2020 and over 10% by 2030;
- Construct flexible, highly automated power grids from transmission to distribution, develop electrical substations minimally

[18] Decision No. 1208/QD-TTg dated July 21, 2011 of the Prime Minister on the National Power Development Plan for the period 2011–2020 with a vision to 2030.

[19] Decision No. 428/QD-TTg dated March 8, 2016 of the Prime Minister on the revisions to the National Power Development Plan for the period 2011–2020 with a vision to 2030.

Power sources	PDP-VII (before COP21)		Revised PDP-VII (with COP21 consideration)		
	2020	2030	2020	2025	2030
Total installed power capacity, MW	75,000	146,800	60,000	96,500	129,500
Hydropower, %	25.5	15.7	30.1	21.1	16.9
Coal-fired thermal power, %	48.0	51.6	42.7	49.3	42.6
Gas-fired + LNG thermal power, %	16.5	11.8	14.9	15.6	14.7
Renewable power, %	5.6	9.4	9.9	12.5	21.0
Nuclear power, %	1.3	6.6	-	-	3.6
Imported power,	3.1	4.9	2.4	1.5	1.2
Total output of electricity, billion, kWh	330–362	695–834	265–278	400–431	572–632
Hydropower, %	19.6	9.3	25.2	17.4	12.4
Coal-fired thermal power, %	46.8	56.4	49.3	55.0	53.2
Gas-fired + LNG thermal power , %	20+4	10.4+3.9	16.6	19.1	16.8
Renewable power, %	4.5	6.0	6.5	6.9	10.7
Nuclear power, %	2.1	10.1	-	-	5.7
Imported power, %	3	3.8	2.4	1.6	1.2

Table 4. Power source development plan of the PDP-VII and the revised PDV-VII
Source: National Power Development Plan for the period 2011-2020

manned to improve the labor productivity of the power sector; and

- Develop nuclear power to stabilize the power supply in the future, in which the first nuclear power unit would be put into operation in 2028, with nuclear-based electric power reaching about 4,600 MW by 2030, producing about 32.5 billion kWh of electricity, making up 5.7% of the total power produced.

Table 4[20] summarizes the main power sources of the PDP-VII approved in 2011, before COP21 agreement, and the revised PDP-VII approved in 2016 with COP21 consideration. Table 4 shows [21] that the installed power capacities of renewable power by 2020 and 2030 of PDP-VII and the revised PDP-VII, with the share of renewable energy doubled in both power capacity and electricity production in the revision.

As planned, on March 26, 2021, the first version of the National Power Development Plan for the period 2021–2030, with a vision to 2045 (referred as PDP-VIII) was submitted to the Prime Minister. PDP-VIII was built based on the orientation in Resolution No. 55/NQ-TW dated February 11, 2020, of the Politburo, with three core points of view. First, power development is one step in providing enough power to meet the requirements of socio-economic development and power demand for people's daily life. Second, synchronous development of power sources and the electrical grid is necessary; investment in power development must be balanced among regions on the basis of rational and efficient use of primary energy resources of each region; avoid building more inter-regional power transmission lines in the 2021–2030 period; and minimize construction of new inter–regional power transmission lines in the period 2031–2045. Third, continue to develop hydroelectricity, renewable energy, and new energy (wind power, solar power, biomass power, garbage power) with an appropriate scale; consider the roadmap to reduce coal power sources and develop LNG gas power sources reasonably.[22]

PDP-VIII was prepared in the context of many big changes in national power development: mechanisms to encourage and support the development of solar and wind energies that created an investment boom for solar and wind power projects (mainly implemented by private investors – a new point compared to the past when most of the power projects and works are invested by state corporations); delays and difficulties in investment and construction of thermal power plants (especially traditional thermal power plants); development of technology in power production and transmission (especially solar and wind power technologies), leading to deep reductions in the production costs of this type of power source; and the emergence of the Industrial Revolution 4.0. These changes had a great influence on the production, transmission, and distribution of electricity. So, the formulation of the PDP-VIII was necessary and urgent task. The PDP-VIII also takes into account Vietnam's agreement at COP21 to limit global warming, its adaptation to the impacts of a changing climate, and its commitment at COP26 to reduce net emissions to zero by 2050.

A new point of emphasis in PDP-VIII was the importance of understanding how the power source

[20] Decision No. 1208/QD-TTg dated July 21, 2011, of the Prime Minister on the National Power Development Plan for the period 2011–2020 with a vision to 2030.

[21] Decision No. 428/QD-TTg dated March 8, 2016, of the Prime Minister on the revisions to the National Power Development Plan for the period 2011–2020 with a vision to 2030.

[22] Resolution No. 55/NQ-TW dated February 11, 2020, of the Vietnamese Politburo on National Energy Development Strategy orientation to 2030, with a vision to 2045.

structure will be planned to ensure enough power is reliably supplied to meet the requirements of socio-economic development, which is reflected in the plan. First, the power source development program ensures optimality, enhances the autonomy of each region, and creates a balance between supply and demand within the region. PDP-VIII has reviewed, evaluated and appropriately adjusted the power sources that have been supplemented to the previous revised PDP-VII.

Second, PDP-VIII ensures the highest self-balancing ability within each area of the country, avoiding long-distance transmission. The system uses the current 500 kV transmission grid to link areas and there will be no development of a new 500 kV power grid until 2030 to reduce power loss in transmission and improve reliability of the power supply.

Third, renewable energy sources will continue to be prioritized for development, in line with the overall power system development program for the period up to 2030, which was approved in the revised PDP-VII. Renewable energy can continue to develop with a reasonable penetration rate into the power system, in line with the power source structure in the period up to 2030 of the national power system. In addition, PDP-VIII has minimized the development of new coal-fired power plants. The coal-fired power projects that continue to be implemented are those that have been approved in the revised PDP-VII. Many planned coal-fired plants have been modified to use LNG as a power source, which is more environmentally friendly.

Power sources	Installed capacity, MW		
	By 2025	By 2030	By 2045
Total installed capacity	106,521	156,385	416,254
Coal-fired thermal power	29,679	37,467	37,467
Ratio of coal thermal power	*28%*	*24%*	*9%*
Gas thermal power using domestic gas	10,907	14,930	14,930
Gas thermal power using imported LNG	3,500	23,900	31,400
Flexible source using gas, hydrogen	0	150	28,200
Thermal power and Oil gas turbine	898	0	0
Hydropower (including small hydropower)	25,529	28,946	35,139
Ratio of hydropower	*24%*	*18.5%*	*8.4%*
Wind power (land-mounted)	12,070	16,121	55,950
Wind power offshore	0	7,000	66,500
Ratio of all wind power types	*11.3%*	*14.8%*	*29.4%*
Land-mounted and floating solar power	18,040	8,736	75,987
Rooftop solar power		7,755	20,679
Ratio of all solar power types	*16.9%*	*10.5%*	*23.2%*
Biomass power and other renewable fuels	1,170	1,230	5,210
Stored hydropower and storage batteries	0	2,450	29,250
Imported electricity	4,728	5,000	11,042
Thermal power supplied to separate loads (cogeneration)	0	2,700	4,500

Table 5. Installed capacity of the last version of PDP-VIII

Fourth, PDP-VIII has set out a number of principles and criteria for closely monitoring the implementation process: organizing the planning, coordinating between sectorial management agencies and local provinces/big cities; proposing management mechanisms to limit shortcomings in the planning process; and strengthening inspections to promote timely project implementation and promptly resolving difficulties and problems.

Table 5[23] summaries of the installed power sources of the last version of PDP-VIII, as of April 2022.[24]

An examination of Table 4 and Table 5 shows that PDP-VIII is much 'greener' than the revised PDP-VII. For example, coal-fired power installed capacities by 2030 are 24% and 42.6%, respectively, and remains unchanged until 2045, with the note that coal-fired power will switch to combustion of biomass and/or ammonia. If the burning of biomass and ammonia can replace coal, coal-fired power can be practically eliminated by 2045. In addition, Table 5 shows that the ratio of wind power increases from 11.3% by 2025 to 14.8% by 2030 and to 29.4% by 2045; the ratio of solar power increases from 10.5% by 2030 to 23.2% by 2045.

3.4. Measurement and monitoring

Vietnam's regulatory system for electric energy development generally consists of 3 levels: Level 1 includes the Electricity Law approved by the National Assembly; Level 2 includes the Prime Minister's Decisions on national electricity development master plans with a 10-year period to implement the master plans; and Level 3 includes Circulars or Decisions issued by the Ministry of

[23] Dao Nhat Dinh, Power Development Planning VIII approved, difficulties still ahead, May 11, 2022, https://nangluongvietnam.vn/quy-hoach-dien-viii-duoc-thong-qua-kho-khan-van-o-phia-truoc-28708.html.

[24] Nguyen Huy Hoach, "Power planning VIII: Breakthrough in energy transition", https://nangluongvietnam.vn/quy-hoach-dien-viii-buoc-dot-pha-chuyen-dich-nang-luong-28115.html

Industry and Trade (MOIT) to guide electricity units to implement the plans.

The MOIT performs the function of state management of industry and commerce. In the field of power energy management, it includes the following sectors: Electricity, coal, oil and gas, new energy, renewable energy. Vietnam Electricity (EVN), a state-owned one-member limited liability company, has the task of providing electricity for the country's socio-economic development needs, with the following main functions:

- Organize, manage and administer electricity generation, transmission, distribution, electricity wholesale and retail activities to ensure safe, stable, continuous, and high-quality electricity supply;
- Conduct investment activities, sign contracts with domestic and foreign organizations and individuals to ensure electricity supply;
- Conduct business for profit in accordance with the law, preserving and developing EVN's capital;
- Invest in subsidiaries and associated companies and govern the subsidiaries on the basis of the holding ratio of charter capital of such companies in accordance with the law; and
- Exercise the rights and perform the obligations of the owner's representative for the capital portion of EVN in subsidiaries and associated companies.

EVN currently has three power generation corporations (GENCO 1, 2, 3) and nine hydro/thermal power companies in the field of power production. Five power corporations trade electricity to customers: Northern Electricity Corporation (EVNNPC), Central Power Corporation (EVNCPC), Southern Electricity Corporation (EVNSPC), Electricity Corporation of Ha Noi City (EVNHANOI), and Electricity Corporation of Ho Chi Minh City (EVNHCMC). Currently in charge of the electricity transmission field of EVN is the National Power Transmission Corporation (EVNNPT).

IV. Challenges and opportunities

The future development of Vietnam's power industry will face more challenges in satisfying the needs of economic growth and improving people's living standards. Power demand is growing and will continue to grow at a high rate, Primary energy sources are gradually being exhausted and the ability to supply primary energy sources is limited, leading to the need to import fuel. Many power sources have been constructed that do not follow the approved plan. Distribution is currently unbalanced, leading to an increase in wasted electricity and high transmission loss. The development of power sources using renewable energy such as wind and solar leads to certain difficulties in power system operation such as increasingly strict requirements on environmental protection in power activities.

PDP-VIII is needed to overcome these difficulties and challenges to ensuring a stable and reliable power supply. This planning will orient the future development of the power industry; quantify power supply target values; determine the scale, progress, and spatial allocation of power source projects, and power grids; and propose solutions to implement the planning.

4.1. Clean energy transition

4.1.1. Policies and process

The government recognizes that in the transition to renewable energy, wind and solar power play an important role in realizing its proposed goal of green and sustainable development. During the past 10 years, the Prime Minister has issued many policies to encourage the development of renewable energy sources. The policy of clean energy transition was confirmed since 2011 in PDP-VII, with a priority on renewable energy source development to increase the proportion of electricity produced from wind, solar and biomass to 4.5% of the country's electricity production by 2020 and to 6% by 2030. Meanwhile, the June 29, 2011 Decision No. 37/2011/QD-TTg on mechanisms for supporting wind power projects [25] and the March 24, 2014 Decision No. 24/2014/QD-TTg on mechanisms for supporting the development of biomass power projects [26] included capital, tax, charge, and land infrastructure preferences as well as support of electric price for grid-linked wind and biomass power projects. Further, the November 25, 2015, Decision No. 2068/QD-TTg approving Vietnam's renewable energy development strategy to

[25] Decision No. 37/2011/QD-TTg dated June 29, 2011, of the Prime Minister on mechanisms for supporting the development of wind power project in Vietnam.

[26] Decision No. 24/2014/QD-TTg dated March 24, 2014, of the Prime Minister on mechanisms for supporting the development of biomass power project in Vietnam.

2030, with a vision to 2050, included an objective to reduce greenhouse gas emissions in various energy activities by about 5% in 2020, about 25% in 2030, and around 45% in 2050.[27]

The revised PDP-VII, which was approved in 2016, re-confirmed the increased proportion of electricity to be generated by renewable sources (excluding hydropower) at about 7% by 2020 and over 10% by 2030. In fact, at the end of 2021, the proportion of renewable sources was about 27%, nearly four times higher than the planned level. The main reason for the higher proportion was the direction provided in the April 11, 2017 Decision No. 11/2017/QD-TTg[28] and the April 20, 2020 Decision No. 13/2020/QD-TTg[29] on mechanisms to encourage the development of solar power projects; the September 10, 2018 Decision No. 39/2018/QD-TTg[30] on amending and supplementing a number of articles of the June 29, 2011 Decision No. 37/2011/QD-TTg on mechanisms for supporting wind power projects. Further, the February 11, 2020, Politburo Resolution 55-NQ/TW on the national energy development strategy to 2030 with a vision to 2045 directed that the share of renewable energy sources in the total primary energy supply must reach about 15-20% by 2030 and 25–30% by 2045. Finally, the Prime Minister signed the October 1, 2021, Decision 1658/QD-TTg,[31] the national strategy to green growth for the period 2021–2030, with a vision to 2050.

The approved incentive mechanisms for buying electricity to encourage and support the development of renewable sources for the clean energy transition, are summarized in Table 6.[32][33][34] In addition, renewable energy projects can also enjoy other support mechanisms such as incentives for corporate income tax, equipment import tax, land use, and concessional loans from banks.

With the incentive mechanisms, solar power had an explosive development in 2019 and 2020, both in large-scale farms and small-scale rooftop installations. The first solar power project in Vietnam (named Mo Duc wind power plant) started construction in May 2018 and was inaugurated in April 2019 with installed capacity of 19.2 MW. By the end of 2019, 82 solar power plants, with a total installed capacity of about 4,500 MW, were successfully tested and put into operation; during 2020, more than 60 solar power projects were put into operation. By the end of 2020, total installed capacity of solar power reached about 16,500 MW.

Type of renewable energy	Type of technology	Incentive mechanism and validity period	Selling price without VAT
Wind power (for projects put into operation before November 2021)	Land-mounted wind power project	FIT for 20 years	8.5 US cents/kWh
	Offshore wind power project	FIT for 20 years	9.8 US cents/kWh
Solar power	Floating solar power project	FIT for 20 years	7.69 US cents/kWh
	Land-mounted solar power project	FIT for 20 years	7.09 US cents/kWh
	Rooftop solar power project	FIT for 20 years	8.38 US cents/kWh
Biomass power	Co-generation of heat-electricity	FIT for 20 years	7.03 US cents/kWh
	Not Co-generation of heat-electricity	FIT for 20 years	8.47 US cents/kWh
Small hydropower (less than 30 MW)	Power production	Avoidable cost tariff	Avoidable cost tariff is published annually by the MOIT
Electricity from waste	Burn	FIT for 20 years	10.05 US cents/kWh
	Bury	FIT for 20 years	7.28 US cents/kWh

Table 6. Mechanisms to encourage the development of renewable energy

For wind power, the feed-in tariff (FIT) price is also a "push" for this type of projects. As of October 31, 2021, 84 wind power projects (out of 106 registered projects) with a total capacity of about 3,980 MW had been recognized for commercial operation date (COD), which should make total wind capacity increase rapidly in the period 2021–2030 and beyond, especially offshore wind power technology.

[27] Decision No. 2068/QD-TTg dated November 25, 2015, of the Prime Minister on approving Vietnam's renewable energy development strategy to 2030, with a vision to 2050.
[28] Decision No. 11/2017/QD-TTg dated April 11, 2017, of the Prime Minister on mechanisms to encourage the development of solar power projects in Vietnam.
[29] Decision No. 13/2020/QD-TTg dated April 6, 2020, of the Prime Minister on mechanisms to promote the development of solar power projects in Viet Nam.
[30] Decision No. 39/2018/QD-TTg dated September 10, 2018, of the Prime Minister on amending and supplementing a number of articles of the Decision No.37/2011/QD-TTg dated June 29, 2011 on mechanisms for supporting the development of wind power project in Vietnam.
[31] Decision No. 1658/QD-TTg dated October 1, 2021, of the Prime Minister on the national strategy to green growth for the period 2021–2030, with a vision to 2050.
[32] Decision No. 11/2017/QD-TTg dated April 11, 2017, of the Prime Minister on mechanisms to encourage the development of solar power projects in Vietnam.
[33] Decision No. 13/2020/QD-TTg dated April 6, 2020, of the Prime Minister on mechanisms to promote the development of solar power projects in Viet Nam.
[34] Decision No. 39/2018/QD-TTg dated September 10, 2018, of the Prime Minister on amending and supplementing a number of articles of the Decision No.37/2011/QD-TTg dated June 29, 2011, on mechanisms for supporting the development of wind power project in Vietnam.

4.1.2. Technology

Currently, solar technology for electricity production is divided into two categories: Photovoltaic technology (Solar Photovoltaic, PV) and Concentrating Solar Thermal Power (CSP) or solar thermal power technology. PV technology has mainly been used in Vietnam. Crystalline-silicon (c-Si) and thin-film (TF) technologies dominate the PV market; c-Si technology uses high-fidelity silicon material used as PV cells and TF technology consists of thin films of semiconductor materials overlaid with inexpensive, large-scale substrates such as glass, polymer or metal. C-Si technology is older and currently accounts for 85–90% of the market share.

Until now, three types of solar power projects have been applied in Vietnam, including land-mounted, roof-mounted, and floating. In the case of wind energy, land-mounted wind power projects have been mainly applied and offshore wind power technology is planned to be used in the near future.

4.1.3. Financial

According to the National power development plans, financial issues related to investment in electrical projects focus on sources and adequacy of capital investment and ensuring efficient delivery to consumers.

The plans promote the availability of investment capital by encouraging domestic economic sectors and foreign investors to participate in the construction of power source and distribution grid projects according to investment mechanisms prescribed by national law. Capable domestic investors may mobilize all capital sources to invest in power source and grid projects under the self-borrowing and self-pay mechanism. Price calculation for buying and selling electricity is determined by market direction, which should encourage domestic and foreign investors to invest in power source projects.

The State holds 100% of the charter capital for enterprises that operate the transmission lines of the national power system and large-scale power generation of special importance to national socio-economic, defense and security. The State holds more than 50% of the total shares of enterprises that play a large role in balancing and stabilizing the electricity production market. Equitization of units under the EVN is closely by the State.

4.1.4. Opportunities and challenges in solar power development

Vietnam has a relatively high amount of sunlight according to the world solar radiation map. The average annual amount of solar radiation ranges from 4.3–5.7 million kWh/m, with the average number of sunshine hours per year in the Central and Southern regions reaching about 2,000–2600 hours per year. It is theoretically estimated that the potential of solar power is about 43.9 billion ton of oil equivalent (TOE).

"Although Vietnam has policies and mechanisms for wind as a power source, the number of projects implemented is still small due to the lack of strong and synchronous policies"

The issue of safe and efficient operation of a large-capacity solar power system is not only a challenge for Vietnam, but even leading countries in this field. It is the specific nature of solar power that makes it difficult to operate the system since it fluctuates almost instantaneously and is hard to control. Meanwhile, the electricity produced needs to be consumed immediately. Therefore, EVN has to ensure a very large amount of reserve capacity, which means thermal power plants are not mobilized at their full capacity to allow immediate mobilization to compensate for the potential shortfall, especially during the dry season. As a result, EVN's operating costs increase.

Solar power is a DC power source, while the national electrical grid is AC system. As such, an inverter is required. If the quality of this equipment is not guaranteed, it will directly affect the electricity usage of customers. However, this issue can be overcome with the development of more advanced inverter devices, with efficiency up to 96% and negligible loss. Moreover, the indicators of phase stability, frequency stability, etc. have been improved, so this problem is not worrisome.

4.1.5. Opportunities and challenges in wind power development[35]

As one of the countries severely affected by climate change, Vietnam has been interested in investing in wind power production to meet its domestic energy demand and reduce greenhouse gas emissions. Vietnam has a long coastline of more than 3,200 km and according to a World Bank assessment, Vietnam has a large wind energy potential with more than 39% of country's total area estimated to have an average annual wind speed greater than 6 m/s at an altitude of 65 m, equivalent to a capacity of 512 GW. In particular, nearly 8% of Vietnam's area is ranked as having very good wind potential, with wind speed at an altitude of 65 m of 7–8 m/s.

Besides land-mounted wind power projects, offshore wind power projects have also been developed with the capacity of installed projects reaching about 100 MW. In July 2020, the government granted a survey permit to build a large offshore wind power plant, with a capacity of 3,400 MW in Binh Thuan province. Once completed, its capacity will exceed that of coal- and gas-fired thermal power plants and even the nation's largest hydropower plant.

Despite the great potential, along with some supportive governmental policies in recent years, in reality, the wind energy market in Vietnam is still in the early stages and wind power projects have not been effective, due to too many challenges and difficulties. First, although Vietnam has policies and mechanisms for wind as a power source, the number of projects implemented is still small due to the lack of strong and synchronous policies, including investigation and assessment of potential, project exploitation, and utilization.

Second, regarding technology, there is a lack of necessary and reliable data on wind speed for research and development of wind power sources in different areas. There is a lack of assessment information on offshore wind power potential, as well as grid connection of wind power plants after project completion. Wind power projects in coastal alluvial land have relatively complex topography and geology and are affected by severe weather such as rain, storms, big waves, high winds, combined with an unstable tidal regime, leading to many challenges during construction and installation of equipment. There is also a lack of capacity to manage, operate, maintain and repair wind power projects. Domestic contractors do not have much experience in the construction and installation of wind turbines at sea. New technology and complicated operating techniques also require extensive training and workforce development. Facing the possibility of a shortage of high-quality labor, as well as the underdevelopment of supporting industries is also a challenge.

Third, the biggest economic and financial challenges for wind power development lie in the availability of investment capital.

Fourth, wind power is electricity that is only generated when there is wind, and the output power changes with the wind level. Favorable areas for installing turbines are often far from consumption areas, causing great difficulties in the operation and stability of the system. There have also been difficulties in importing equipment and finding foreign experts for technical coordination.

Fifth, there are practical difficulties in site clearance, construction of foundation for turbine piers, transmission line poles, and line corridors since onshore wind power projects need about 20,000 ha. This represents a loss of arable land and people's livelihood.

4.2. <u>Nuclear energy options</u>

On January 3, 2006, Vietnam approved the strategy for the application of atomic energy for peaceful uses, in which the country's first nuclear power plant (NPP) was expected to be introduced by 2020.[36] Vietnam began to implement this "Long-term Strategy" by establishing the Master Plan for implementation of the Strategy in 2007,[37] enacting the Atomic Energy Law in 2008 [22], and approving Resolution No. 41/2009/QH12 on November 25, 2009 for the investment policy of Ninh Thuan nuclear power project.[38]

[35] Hoang Thi Kim Xuan, "Wind Power in Vietnam: Identifying challenges and proposing development solutions", https://tapchicongthuong.vn/bai-viet/dien-gio-tai-viet-nam-nhan-dien-thach-thuc-va-de-xuat-giai-phap-phat-trien-86192.htm

[36] Decision No. 01/2006/QD-TTg dated January 3, 2006, of the Prime Minister on approving Strategy for application of atomic energy for peaceful purposes to 2020.

[37] Decision No. 114/2007/QD-TTg dated July 13, 2007, of the Prime Minister on approval of the Master Plan for implementation of the Strategy for application of atomic energy for peaceful purposes by 2020.

[38] Resolution No. 41/2009/QH12 dated November 25, 2009, of the National Assembly on the investment policy of Ninh Thuan nuclear power project.

According to the above Resolution, the Ninh Thuan nuclear power project included two NPPs, with each plant having two units and each unit having a capacity of about 1000 MWe. The total estimated cost was about 200,000 billion VND (about $12 billion). Following that, in October 2010, Vietnam signed the intergovernmental cooperation agreement with Russia on the construction of the Ninh Thuan 1 nuclear power project. In January 2011, the agreement on the construction of the Ninh Thuan 2 nuclear power project with Japan was signed.

However, Vietnam's macroeconomic development changed a lot compared to the time when the project investment was approved. Further, Vietnam needs large capital investment in modern and synchronous infrastructure to sustain socio-economic development, It also needs to address problems caused by climate change. Therefore, the National Assembly adopted Resolution No. 31/2016/QH14 on November 22, 2016, to "postpone implementing the investment policy of Ninh Thuan nuclear power projects". It can be concluded that the postponement of the Ninh Thuan nuclear power projects is mainly due to the country's economic situation and the transition to new renewable energy, rather than due to problems with technology, nuclear infrastructure, or nuclear safety.

At COP26 in November 2021, most countries committed to balance CO_2 emissions by 2050/2060. This would be accomplished by gradually phasing out coal-fired power, reducing thermal power, using natural gas and liquefied natural gas (LNG), and promoting the development of renewable energy. In this context, some see nuclear power as a clean power source without CO_2 emissions that can play an important role in the power source structure of a country. Vietnam also made a commitment to balance carbon by 2050, which is a big challenge for a developing country, with high annual electricity growth, especially as hydropower resources are exhausted. On the other hand, power produced from renewable energy is a clean electric source that can be developed well, but it depends on weather and climate conditions. Therefore, the combination of nuclear power and renewable energy is a trend that will likely be revisited in the near future.

Vietnam began considering nuclear power in the 1980s, and its nuclear power development program was strongly implemented, especially from 2010–2016 when Ninh Thuan nuclear power projects were being developed. In the context of the general agreement to limit global temperature rises to 1.5 degrees Celsius at COP21 and the commitment to reduce net emissions to zero at COP26, the return to nuclear development is a matter that needs to be considered comprehensively and carefully.

"Vietnam also made a commitment to balance carbon by 2050, which is a big challenge for a developing country, with high annual electricity growth, especially as hydropower resources are exhausted"

4.2.1. National infrastructure for nuclear power

Recognizing its importance for nuclear power projects, the improvement of national infrastructure was considered and implemented by the government. To implement the Ninh Thuan nuclear power projects, the State Steering Committee was established by the April 7, 2010, Prime Minister's Decision No. 446/QD-TTg and by the May 4, 2010 Decision No. 580/QD-TTg. Its 5 sub-committees were established between 2013 and 2014. The National Nuclear Safety Council and the National Atomic Energy Council were also established to serve as advisory bodies to the Prime Minister, and the State Steering Committee was made responsible for assisting the Prime Minister in implementing Ninh Thuan nuclear power projects, acting as a NEPIO (Nuclear Energy Programme Implementing Organization), as defined in the International Atomic Energy Agency (IAEA) document of NG-G-3.1

Milestones in development of a national infrastructure for nuclear power."[39]

With the assistance of the IAEA, some technical cooperation projects were approved by the IAEA and implemented by the local authorities, including: VIE/4/015 "Developing Nuclear Power Infrastructure (Stage I)" in 2009, VIE/2/010 "Developing Nuclear Power Infrastructure (Stage II)" in 2012, VIE/2/012 "Developing Nuclear Power Infrastructure (Stage III)" in 2014, VIE/9/014 "Developing a Nuclear Safety Infrastructure for the First Nuclear Power Plant" in 2012, and VIE/9/015 "Strengthening the National Infrastructure and Capacity for Regulating the First Nuclear Power Programme" in 2014.

Upon request from Vietnam's authority, in November 2009 the IAEA carried out the first Integrated Nuclear Infrastructure Review (2009 INIR) to make recommendations and suggestions to assist national authorities of Vietnam in developing the national infrastructure necessary to implement its nuclear power program. As a result, the 2009 INIR mission made 12 recommendations and 22 suggestions following the 19 infrastructure issues in the three milestones of nuclear power projects according to the IAEA guideline.[40] Results of 2009 INIR mission showed that Vietnam achieved Milestone 1 "Ready to make a knowledgeable commitment to a nuclear power programme" of the Phase 1 "Considerations before a decision to launch a nuclear power programme is taken", and the number of activities for Phase 2 "Preparatory work for the contracting and construction of a nuclear power plant after a policy decision has been taken" was under implementation.

In December 2012, the second INIR mission (2012 INIR) was carried out for the Ninh Thuan nuclear power projects. As a result, the 2012 INIR mission made 42 recommendations, 14 suggestions, and identified two good practices. A lot of work needed to be done to complete Phase 2 as this Phase usually takes at least 10–15 years.

An INIR follow-up mission was conducted in November 2014. The INIR team noted that major actions had been taken since the 2012 INIR mission: the National Atomic Energy Council was established in May 2013; Viet Nam acceded to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management; some legal documents including regulations/ circulars were issued, for example in emergency preparedness and response, siting, and waste management; the final version of the Master Plan for nuclear power infrastructure was submitted for approval; several measures were implemented to provide incentives for recruitment and retention of personnel; five Technical Subcommittees were established under the State Steering Committee; the project on public information and communication for nuclear power and an associated plan for its implementation were approved in February 2013.

The 2014 INIR team also found that Vietnam continued to make progress on the national infrastructure for nuclear power. Vietnam completed implementation of six recommendations from the 2012 INIR mission, in the areas of electrical grid, stakeholder involvement, site and supporting facilities, environmental protection, and industrial involvement. The other 36 recommendations required further work, of which many recommendations were ongoing activities. On December 11, 2014, Decision No. 2241/QD-TTg on approving the Master Plan for the development of nuclear power infrastructure up to 2020 was approved by the Prime Minister.[41] The overall goal of the Master Plan was to develop synchronously and comprehensively the national nuclear power infrastructure in accordance with the IAEA guidelines and Vietnam's practice, meeting the requirements for deploying Ninh Thuan nuclear power projects to ensure safety, security and efficiency of the projects. The specific objectives of the Master Plan were to complete the system of legal documents, mechanisms and policies in service of nuclear power development and to conduct training and developing human resources to meet requirements on structure, quantity and quality for state management, technical support, research and training, and construction and operation of nuclear power plants (NPP).

4.2.2. Regulatory framework

Vietnam has made every effort in developing its legal system, taking into consideration the IAEA guidelines and experiences of nuclear safety

[39] International Atomic Energy Agency, Nuclear Energy Series No. NG-G-3.1 (Rev. 1), 2015, Vienna.
[40] Ibid.
[41] Decision No. 2241/QD-TTg dated December 11, 2014 of the Prime Minister on approving the Master Plan for the development of nuclear power infrastructure up to 2020.

authorities from foreign countries, especially Russia, United States, Japan, South Korea, and the European Union.

In 2008, the National Assembly passed the Atomic Energy Law, which came into effect on 01 January 2009.[42] This is the highest legal document governing nuclear energy. The law governs all activities in the field of atomic energy including promoting activities and the assurance of safety and security for those activities. Due to inadequacies of the law, especially in connection with licensing issues for the NPP, emergency response, etc., the government decided to amend the Atomic Energy Law. However, following the decision to postpone the Ninh Thuan nuclear power projects, the plan for amending the law was also suspended.

The regulatory framework for the nuclear power development program has been identified in the Atomic Energy Law. Article 7 designates the responsibilities for State management in the field of nuclear energy as follows:

- The government will unify State management on activities in atomic energy.
- The Ministry of Science and Technology (MOST) will be responsible for conducting State management on activities related atomic energy.
- Ministries, ministerial-level agencies, within their functions and authorities, will manage State activities in the field of atomic energy in accordance with their responsibilities designated by the government.
- Provincial/city People's Committees (Provincial level), within their functions and authorities, will manage State activities in the field of atomic energy in accordance with their responsibilities designated by the government.

"When developing a set of criteria for selecting nuclear power technology for the Ninh Thuan nuclear power projects, lessons learned and safety design requirements must be clearly shown in the technology selection criteria"

In connection with nuclear power plants (NPP), as specified in the prevailing Atomic Energy Law, the current licensing system in Vietnam is complicated. The Prime Minister is responsible for site and feasibility study approval, MOST is responsible for construction permitting, MOIT is responsible for operation license, MOST/VARANS (Vietnam Agency for Radiation and Nuclear Safety) is responsible for assessment of the safety analysis report at all stages of nuclear power project, the Ministry of Natural Resource and Environment is responsible for assessment of the environment impact assessment report, and the Ministry of Construction is responsible for disposal and storage of radioactive waste siting. The National Nuclear Safety Council advises the Prime Minister on policies and measures to assure nuclear safety in the use of atomic energy, in the course of operating NPPs as well as measures to remedy particularly serious nuclear incidents, to examine and evaluate safety reports of NPPs, and the results of assessments by VARANS.

Recognizing the importance of international cooperation, especially the contribution of international regimes, in achieving and maintaining a high level of nuclear safety, Vietnam has been a party to a number of international and regional instruments as IAEA member state, Asian member state, and regional cooperation as well.

4.2.3. Technology

In order to advise the State Steering Committee on nuclear power and the project investor (EVN), the Vietnam Atomic Energy Institute (VINATOM) implemented two national research projects for the evaluation and selection of technology for Ninh Thuan nuclear power projects. For this purpose, a set of criteria for technology selection was developed based on IAEA guidelines and the guiding documents and design requirements of Europe, as Europe is an area with a dense population and limited area similar to Vietnam. In addition, the nuclear accident at Japan's Fukushima NPPs in

[42] Atomic Energy Law No. 18/2008/QH12 of the National Assembly dated June 3, 2008.

March 2011 was a profound lesson for countries preparing to develop a nuclear program as well as countries developing nuclear technologies.
A set of criteria for technology selection was developed based on a set of requirements and used as a basis for consideration, assessment, and selection of the technology for the Ninh Thuan nuclear power projects. It includes four main content areas: reactor technology and plant design, safety assurance, economy of NPPs, and Vietnam's specific requirements.

This set of requirements was the basis to ensure that the nuclear technology imported into Vietnam would be the most advanced technology, ensuring the highest possible safety, and thus ensuring the sustainability of the nuclear development program. The requirements were also the basis for establishing criteria for evaluation, ranking, and selection of the most appropriate technology for Vietnam.

For the Ninh Thuan 1 nuclear power project, four types of pressurized water reactor (PWR) technology were proposed, namely AES-91 (VVER-1000 model V428), AES-92 (VVER-1000 model V412), AES-2006 (VVER-1200 model V491) and AES-2006 (VVER-1200 model 392M). VVER-1000/V428 and VVER-1000/V412 have a capacity of 1000 MWe each, belonging to the generation III, designed by Saint Petersburg and the Moscow Research Institutes, respectively; VVER-1200/V491 and VVER-1200/V392M have a capacity of 1200 MWe each, belonging to the generation III+, designed also by Saint Petersburg and the Moscow Research Institutes, respectively.

On the basis of analysis, comparison and evaluation of technological systems for normal operation and safety systems as well as rating according to the criteria for the four above types of PWR technology, the results showed that the AES-2006 type using VVER-1200/V-491 was the most suitable choice for the Ninh Thuan 1 nuclear power project.

For the Ninh Thuan 2 project, three types of PWR technology and one type of advanced boiling water reactor (ABWR) technology were proposed, namely MPWR (1100 MW) of Mitsubishi, ATMEA1 (1350 MWe) of Areva-Mitsubishi Consortium, AP-1000 (1150 MWe) of Toshiba-Westinghouse, and ABWR (1380 MWe) of Toshiba. The same procedures of analysis, comparison, and evaluation of technologies were used. The results showed that the AP-1000 was the most suitable choice for the Ninh Thuan 2 nuclear power project.

In terms of technology, the design of new NPP of generation III+ LWRs was formed from all previous experience with enhancing the ability to ensure safety and preventing the progression of events if abnormal problems occur. The approach to safety issues was formed from statistics, experiences, and the ability to analyze and evaluate incident events using modern computer simulation and prediction tools. The safety systems were enhanced to combine active safety with passive safety to ensure safety even if the power supply was lost. Many redundant systems were additional installations in the designs. In addition, the new generation III+ NPPs meet all safety requirements including those introduced after Fukushima. Because equipment is built in strict compliance with regulations and high standards, high quality and has a long service life, the operating time of the new NPPs can reach 60 years, with the possibility of extending it to 80 years. Therefore, the electricity price would still competitive despite the high investment rate of NPP.[43]

In addition to generation III+ LWRs, Small Modular Reactor (SMR) and small-scale reactor technologies with a power under 300 MWe are receiving some attention. SMRs can deploy either single- or multi-module; modules are manufactured and quality-tested at the factory, then transported to the site for installation, avoiding on-site assembly with potential safety risks. SMRs ensure safety and economy higher than current LWR. There are many different types of SMRs in design today, of which light water-cooled, land-based reactors are the most popular, including: NuScale and SMR-160 of USA, RITM-200N of Russian Federation, ACP-100 and CAP-200 of China, SMART of Republic of Korea, etc. In addition, light water-cooled, marine-based reactors (FNPP) also show some potential, such as: KLT-40S and RITM-200M of Russian Federation, ACPR-50S of China, etc. However, SMR is a new technology and has not been commercially deployed at present. It takes about 20 years for commercial deployment and verification. The cost of SMRs is still high because they cannot be mass-produced, but SMRs coupled with phased

[43] Tran Chi Thanh, "The role of nuclear power in energy structure transition", dated April 7, 2022, https://vinatom.gov.vn/vai-tro-cua-dien-hat-nhan-trong-chuyen-doi-co-cau-dien-nang/.

project rollouts are making nuclear power a more cost-effective option.

Vietnam's nuclear power development program could be restared within the next 10 years. If it does, PWRs generation III+ and SMRs would likely be the preferred technologies. In addition, FNPPs are interesting for Vietnam in the future. The main criteria for technology evaluation and selection of NPPs include: the combination of active and passive safety measures, proven technology, predictability, and economically beneficial.

4.2.4. Public acceptance

Recognizing the importance of public acceptance for nuclear power, on February 28, 2013, the Prime Minister issued Decision No. 370/2013/QD-TTg on approving the project of public information and communication for the nuclear power development program in Vietnam up to 2020. [44] Up to 2016, numerous activities were implemented, including: Nuclear power exhibitions organized in Ninh Thuan province, Phu Yen province, and Ho Chi Minh City; an international nuclear expo organized in Hanoi in 2001, 2004, 2006, 2008, 2010 and 2012; activities in local communities organized by EVN and local authorities at Ninh Thuan; IAEA-Vietnam Workshop on public information for nuclear power in 2011, 2013 and 2014; establishment of the Centre on Atomic Energy Information in cooperation with ROSATOM in December 2012; and so on.

4.2.5. Financial

Article 5 of the Atomic Energy Law defines the State policy in the field of nuclear energy, in which the State focuses its investment on nuclear power development and on technological infrastructure, human resources, scientific research and technological development to facilitate the development of nuclear power. Government Decree No. 70/2010/ND-CP dated June 22, 2010 stipulates that the investor/operator of NPPs, when applying for licenses for different stages of NPP development, shall provide financial arrangement for the construction, operation, and decommissioning, as well as for nuclear liability in the case of a nuclear accident. [45] The January 23, 2014 Prime Minister Decision No. 09/2014/QĐ-TTg indicates that the NPP operating organization annually has to extract a part of turnover of electricity sale during operating period of NPP to create a fund for dismantling and decommissioning of NPP. [46]

Nuclear power projects require large investments in a short period of time. Also, due to the increasing requirements for nuclear safety, especially after the Fukushima accident, many safety criteria including active safety and passive measures need to be incorporated into the design. So, the NPPs with the generation III+ reactors cost much more than the previous NPPs using generation II or III reactors.

In the case of Ninh Thuan nuclear power projects, the initial estimate in the 2005 pre-feasibility study was about $3 billion for each unit using the generation III PWR. About 10 years later, according to the results of the 2015 feasibility study, it was estimated that the price for a generation III+ PWR unit had doubled, which was one of the reasons for the National Assembly of Vietnam's decision to postpone investing in the project.

Regarding financial arrangements, the Vietnamese government should ask for a credit loan with a preferential interest rate given by the supplier through a financial agreement between the two countries. In the case of Ninh Thuan 1 project with the Russian Federation, an inter-governmental agreement between Vietnam and Russia on the credit loan for the construction of NPP in Vietnam was signed in November 2011. Meanwhile, there was not an inter-governmental agreement signed yet between Vietnam and Japan for the construction of Ninh Thuan 2 nuclear power project prior to its cancellation.

V. Conclusion

The National Power Development Plans (PDPs) of Vietnam have been developed every 10 years with 5-year revisions. The PDP has set up plans, made appropriate policies, and arranged investment capital to develop national power sources, improve

[44] Decision No. 370/2013/QD-TTg dated February 28, 2013 of the Prime Minister on approving the project of public information and communication for nuclear power development programme in Vietnam up to 2020.

[45] Decree No. 70/2010/ND-CP dated June 22, 2010 of the Government on detailed provisions and instructions for implementation of some articles of the Atomic Energy Law.

[46] Decision No. 09/2014/QĐ-TTg dated January 23, 2014 of the Prime Minister on financial responsibilities of organizations having a nuclear power plant, managing mechanism of financial fund for decommissioning of nuclear power plants.

the power transmission grids, determine the structure of energy sources toward clean energy transition, etc. Therefore, the national power system is improving, meeting the requirements of power supply for people's life, socio-economic development and climate change mitigation.

To implement the Agreement and Commitment of Vietnamese Government on keeping the global temperature increase at 1.5 degrees Celsius at COP21 and achieving the CO_2 emission balance by 2050 at COP26, respectively, the recent PDP, calls for gradually reducing fossil power sources and rapidly increasing clean power sources. Besides, clean energy sources such as biomass, ammonia, the plan also encourages investment in small hydropower, stored hydropower, and green hydrogen.

The world nuclear power industry is changing, entering a period of strong development in the context of mitigating climate change and the changing geopolitics in the world. Nuclear power is a source of electricity with high capacity, stable and reliable operation, a clean power source without greenhouse gas emissions, and will make an important contribution in the period of structural transition of power sources of countries around the world. Electricity from renewable energy is a well-developed clean power source; however, this source, especially from solar and wind energies, depends on weather and climate conditions. Therefore, the combination of nuclear power and renewable energy for clean power transition is a trend that will be prioritized in the coming years.

For the case of Vietnam, the current base-running electricity only has coal-fired power and or hydropower. But coal power no longer has the conditions to develop, and hydropower has also run out of space. Therefore, the development of nuclear power is an inevitable trend. In this context, Vietnam needs to consider restarting the nuclear power development program for putting nuclear power in the new PDP of the next period 2031–2040 with a vision to 2050.

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