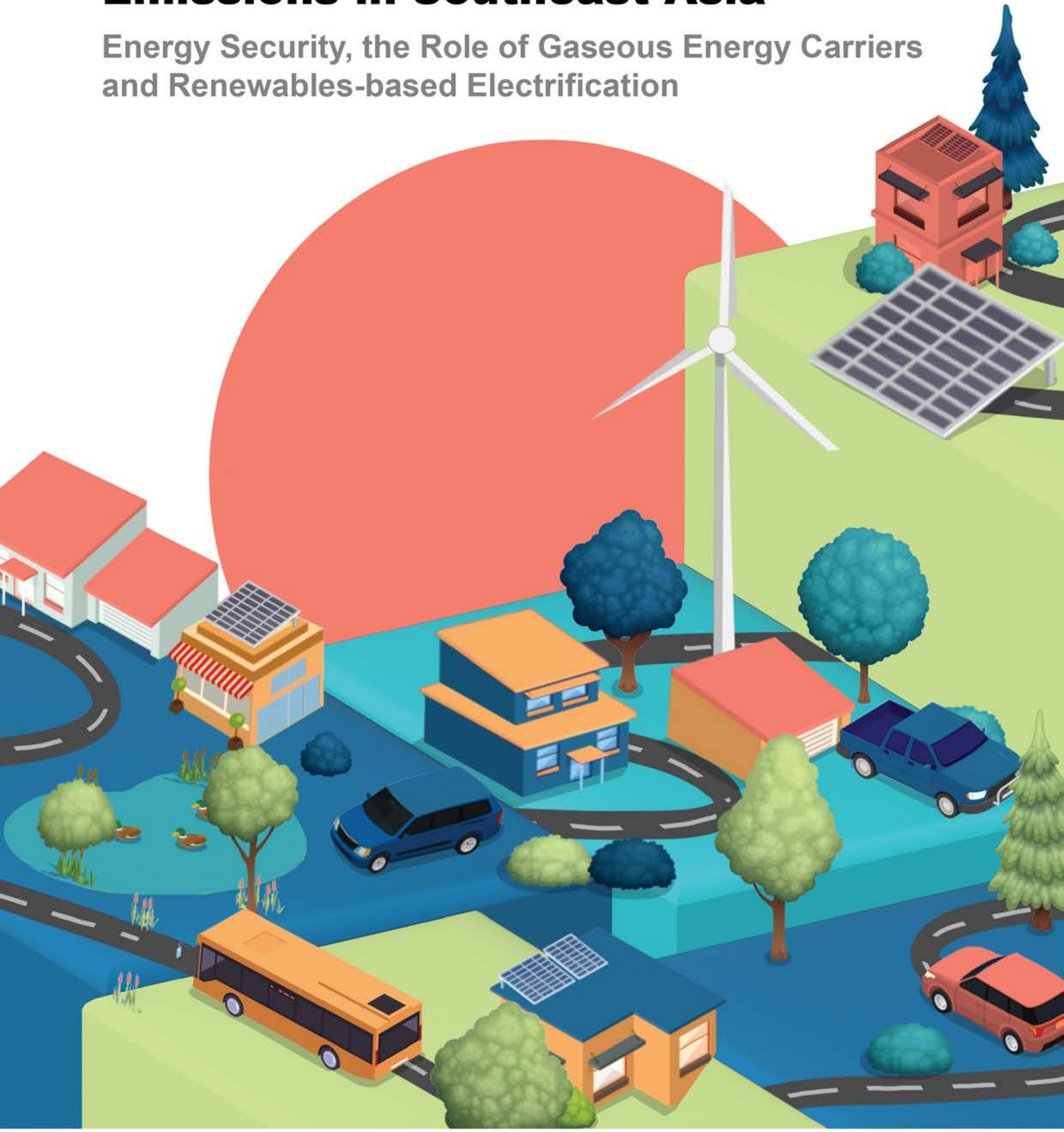
Navigating the Transition to Net-zero Emissions in Southeast Asia

Energy Security, the Role of Gaseous Energy Carriers and Renewables-based Electrification



CASE for Southeast Asia

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IKI INTERNATIONAL CLIMATE INITIATIVE

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In the context of CASE
Southeast Asia (SEA) is the fastest developing region in the world, with Indonesia, the Philippines, Thailand, and Viet Nam representing around 80% of the region's total energy share and population. The four countries also have the highest projected green house gas emissions and energy demand in the region. SEA is a key region to drive global climate action and to achieve the Paris Agreement objective.

The "Clean, Affordable and Secure Energy for Southeast Asia" (CASE) project aims to support a narrative change in the power sector towards an evidence-based energy transition that robustly supports the region's development strategies as it pursues the Paris Agreement goals. The project harnesses available research initiatives to generate new evidence grounded in local realities that can persuade economic advisors, power sector decision-makers, industry leaders and consumers to support rapid and responsive strategic reforms in the power sector.

To reach this objective, the project applies a joint fact-finding approach involving expert analysis and dialogue to work towards consensus by converging areas of disagreement. The creation of this evidence is expected to equip stakeholders with the knowledge and capacities to manage the power sector transition in a socially just way. CASE also supports exchange and coordination in the SEA power sector, provides technical and policy support and facilitates discourse around a new energy vision. By implementing these activities, CASE will directly contribute to the transition of the power sector towards clean, affordable and secure energy for Southeast Asia.

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Summary

Over the past decades, Southeast Asia has experienced significant growth in population, economic activities, and industrialisation, largely driven by fossil energy resources. To meet the surging energy demand and create economic opportunities, the region still heavily relies on fossil fuels and further investments in fossil fuel infrastructure are in the pipeline. However, their commitment to limiting temperature rise to 1.5°C and net-zero emission targets, which were set by most of the countries in the region, would require a rapid reduction of fossil fuel use and a shift to renewable energy sources to decarbonise their energy sectors. And fossil fuel resources are depleting in Southeast Asia, indicating that the region will turn from a net exporter of energy to a net importer in the next years. This shift will have implications for trade balances and increase the region's vulnerability to global market prices.

The evolving global energy landscape has made renewable electricity, such as wind and solar power, more cost-competitive, and alternative energy supplies, such as direct electrification or green hydrogen, more widely available for targeted applications, particularly in the industry sector. Such changes provide Southeast Asian countries with a crucial opportunity to improve the well-being of their populations while transitioning from predominantly fossil-based economies to renewable energy sources.

In this research briefing, we present key findings and recommendations from the report titled "Decarbonization Pathways for Southeast Asia", focusing on the four countries that are part of the project: Clean Affordable and Secure Energy for Southeast Asia (CASE) – Indonesia, Philippines, Thailand, and Viet Nam. The findings are based on a modelling exercise that examines the role of gaseous energy carriers, including fossil gas or hydrogen, in the countries' net-zero pathways under two different scenarios: one centred on electrification ("highly electrified" scenario) and the other on renewable gases ("gas-based" scenario).

The results show that drastic shifts need to happen to get on a pathway to net zero. To drive these shifts in an orderly and affordable manner, redefining energy security is essential. We suggest shifting the focus from "securing sufficient energy resources" towards a long-term, integrated vision that increases the share of renewable electricity, enhances energy efficiency, promotes electrification and fosters flexibility among energy producers and users. The following key insights inform this vision:

- **The use of fossil gas must decrease quickly in the power sector, remain low overall and phase out in the long run to meet growing energy demand at lower costs, while aligning with climate commitments.** Adequate transition pathways for fossil gas are not yet adequately integrated into the energy sector roadmaps of Indonesia, Viet Nam, Thailand, and the Philippines. In fact, all four countries plan to add gas-fired power generation over the next decade, even in countries where fossil gas currently plays a limited role. Furthermore, strategies often rely on technologies to abate mid-term power sector emissions, such as blending hydrogen or ammonia, or capturing downstream emissions at the power plant level through CCS. Such wagers involve significant technological, economic and environmental risks, and expose countries to higher energy imports, which heightens the challenge of achieving net-zero targets.

- **Electrification is the most efficient solution for replacing fossil fuels in end-use sectors, and the use of hydrogen should be limited to specific cases.** The electrification of energy end-use is critical for realising any net-zero pathway. Pathways that first convert electricity to hydrogen or its derivatives are highly electricity-intensive. Such alternative gaseous fuels will likely remain scarce and expensive, and thus their use should be reserved for specific cases where electrification solutions are less readily available, such as in industry process like streel production. Directly using renewable electricity enhances overall energy system efficiency and reduces the need for gaseous energy carriers. Across all sectors, technologies and processes that use electricity (e.g. electric vehicles, heat pumps and electric boilers) are already widely available and commercialised.

- **The speed of renewable energy deployment, particularly solar power, needs to accelerate significantly and go beyond current government plans to align with net-zero targets.** Solar is the renewable energy resource with the most potential in Southeast Asia. Wind power plays a less prominent role, except in Viet Nam, which has considerable offshore wind potential, and in the Philippines. Given the region's geographical constraints and limited land availability, there is a need to explore technologies that are not yet widely adopted, including offshore wind (especially floating solutions), agrivoltaics, and floating PV. As such, the potential for the domestic production of renewable hydrogen for export purposes using current technologies is relatively limited. In fact, the region could likely become a net importer of green hydrogen from more competitive regions like Australia.

- **As renewables displace fossil fuels, system flexibility becomes the cornerstone of energy security.** In a decarbonised future, the energy systems will need to be more flexible to accommodate the shift in energy carriers and to meet new electricity demand patterns. A reliable and affordable system that integrates more renewables will require more electricity storage, enhanced demand-side management, and improved grid infrastructure.

Navigating the Transition to Net-zero Emissions in Southest Asia

Energy Security, the Role of Gaseous Energy Carriers and Renewables-based **Electrification**

Introduction

Over the past decades, Southeast Asia has witnessed significant growth in population and economic activity, as well as rapid industrialisation. This growth has been largely fuelled by the consumption and production of fossil energy resources (coal, oil and gas), implying economic dependencies and employment opportunities tied to those fuels.

We find ourselves at a pivotal moment: the energy sector is rapidly evolving globally, with renewable electricity sources, such as wind and solar power, becoming competitive with fossil fuel power plants. In addition, the development of alternative clean energy carriers, such as green hydrogen, has generated an enormous amount of attention over the past few years, with more than 50 countries publishing hydrogen strategies. At the same time, the International Energy Agency (IEA) asserts that “the golden age of gas is over” (IEA, 2023c). With the ratification of the Paris Agreement in 2015, the global community, including all Southeast Asian countries, committed to joint efforts to limit temperature increase to 1.5°C within the context of sustainable development and poverty eradication. The Conference of Parties of the United Nations Framework Convention on Climate Change in December 2023 called on Parties to contribute to the “transitioning away from fossil fuels in energy systems […]” (UNFCCC, 2023).

These developments hold profound implications for Southeast Asia. Most Southeast Asian nations have adopted net-zero emission targets that implicitly require a rapid and sustained reduction of fossil fuel use. The countries face the challenge of continuing to improve the well-being of their populations while transitioning from predominantly fossil-based economies towards renewable energy sources.

To provide policymakers with a broad corridor to navigate feasible pathways in alignment with the Paris Agreement and national net-zero pledges, the project Clean, Affordable and Secure Energy for Southeast Asia (CASE), with the support of the research institutes Fraunhofer Institute for Systems and Innovation Research ISI and Artelys, explored scenarios for the decarbonisation of the energy systems among Southeast Asia, with a focus on the four countries that are part of CASE - Indonesia, Philippines, Thailand, and Viet Nam.

Titled “Decarbonization Pathways for Southeast Asia” (Müller et al., 2024), the report analyses the role of gaseous energy carriers, such as fossil gas or hydrogen, in the countries, transitions from fossil-fuel-based production to zero-carbon alternatives. Two extreme scenarios were investigated, both of which decarbonise the energy systems in line with the countries’ climate change mitigation targets. The scenarios differ in their reliance on electrification versus hydrogen. The “highly electrified” scenario reflects a high degree of electrification, whereas the “gas-based” scenario places a stronger focus on the use of hydrogen (see Box below).

Box: Scenario definitions and key assumptions (extracted and adapted from (Müller *et al.*, 2024))

The "highly electrified" scenario prioritises electrification as the preferred option wherever possible and uses renewable hydrogen only when no other alternatives are currently available. Energy efficiency improvements are more pronounced in this scenario, as direct electrification often simultaneously reduces the final energy demand of different end-uses compared to other technology options (e.g. battery electric vehicles in road transport or heat pumps or electric boilers in process heat generation).

The "gas-based" scenario is less optimistic about the rate and depth of direct electrification. Given the constraint of full decarbonisation, green gases, especially renewable hydrogen, are increasingly used in applications where this is a viable option (e.g. a higher share of fuel cell trucks and industrial hydrogen boilers instead of battery electric vehicles and heat pumps or electric boilers). As electrification is less pronounced in this scenario, it is accompanied by lower energy efficiency gains.

The exact definition of the scenarios and additional assumptions can be found in the technical background report (Venegas *et al.*, 2024). Detailed modelling results by country and for the ASEAN region overall are available in the main report, "Decarbonisation Pathways for Southeast Asia" (Müller *et al.*, 2024).

The following technologies are excluded as decarbonisation options in both scenarios:

Carbon Capture and Storage (CCS) in the energy sector, including CCS in power plants and for hydrogen production based on fossil gas ("blue" hydrogen). CCS for power generation is not commercially available and will not become competitive against renewable energy (IRENA, 2023). While CCS for hydrogen production may eventually become economically viable, hydrogen produce through this route cannot be classified as it is not a clean fuel (methane leakage and capture rates well below 100%). Finally, green hydrogen is expected to become cheaper than hydrogen produced with fossil-fuels and CCS by as early as 2030.

Nuclear power is currently an expensive low-carbon technology. While the nuclear option remains open in some policy statements in Southeast Asia, no nuclear power plant is currently in operation in the region. Furthermore, no country in the region has developed the institutional and regulatory frameworks needed to ensure the safe development of a nuclear program (the Philippines is the only country in the region that has successfully initiated a nuclear program in the 1970s and built a power plant in the early 1980s, but the project was abandoned after the Chernobyl nuclear accident).

Co-firing ammonia in coal-fired power plants causes efficiency losses in the system and has low economic and environmental viability.

We excluded these technologies from the analysis due to their limitations and low cost-effectiveness.

In this commentary, we present key findings and recommendations based on our analysis of the modelling exercises conducted across the four countries. We begin by examining the role of fossil gas in scenarios aimed at meeting net-zero targets. Specifically, we highlight areas where renewable energy sources must replace fossil gas. We then explore the implications of a highly electrified scenario compared to a scenario based on a high share of (renewable) gas in replacing fossil gas. In both scenarios, we observe a strong demand for renewable electricity, which is the focus of the third section. Given the importance of integrating these renewables into the energy system and the need for upfront planning, the final section explores strategies for achieving integration across energy systems.

Fossil gas: The use of fossil gas must decrease quickly in the power sector, remain low overall and phase out in the long run, to meet growing energy demand at lower costs, while aligning with climate commitments

Transition pathways for fossil gas are not yet adequately integrated into the current energy sector roadmaps of Indonesia, Viet Nam, Thailand, and the Philippines. In fact, all four countries plan to add gas-fired power generation over the next decade, even in countries where fossil gas currently plays a limited role. In addition, strategies are relying on technologies to abate mid-term power sector emissions such as blending hydrogen or ammonia or capturing downstream emissions at the power plant level through CCS. Such wagers involve significant technological, economic and environmental risks, and expose countries to higher energy imports, which heightens the challenge of achieving net-zero targets.

Current developments: Power sectors in the CASE countries heavily rely on fossil gas, and it remains part of their energy system planning.

Fossil gas has not experienced the same rapid growth as coal in Southeast Asia, but it plays a relevant role in the power sector today in some CASE countries, most importantly Thailand. All four CASE countries are increasingly exploring gas as an alternative to coal to meet their growing power demand.

Viet Nam plans to increase gas capacity in the power sector to 37 GW by 2030 (Prime Minister of Vietnam, 2023), from about 10 GW installed today (SIPET, 2022). This would invert the downward trend of gas consumption over the past decade and increase the share of gas in the power sector again despite depleting fossil gas reserves and difficulties in developing new extraction sites (GEM, 2023). In Thailand, fossil gas supplies most of the electricity today with about 30 GW of installed capacity or about 60% of total power generation. The share of gas was even higher in the past decades but has decreased since then. According to the current draft Power Development Plan (2020, currently under revision) the share of gas should remain at about 60% in 2030, which means a slight increase in capacities (Ministry of Energy of Thailand, 2020). In the Philippines, 3.5 GW of gas-fired power plants are currently operational, with plans to double the amount by 2030 (Department of Energy, 2020a). Indonesia is the only country planning to decrease the share of fossil gas in the power sector from 32% in 2020 to 25% by 2030, according to the current electricity plan (RUPTL). However, government plans include an absolute growth in fossil gas capacity from 20 GW to 26 GW by 2030, because of high projected growth in total power demand (Government of the Republic of Indonesia, 2021).

To meet those plans, the Liquified Natural Gas (LNG) infrastructures (and to a lesser extent, pipelines) in Thailand, Indonesia and the Philippines are already expanding. Viet Nam is also planning significant new infrastructure investments to accomodate its pipeline of new gas power plants.

Relying heavily on fossil gas in power sector strategies, however, heightens the risk of increased dependence on energy imports, given the rapidly declining gas reserves in the ASEAN region. Estimates from the ASEAN Centre for Energy (ACE) and International Energy Agency IEA suggest that the region as a whole may become a net importer by 2025 (Venegas *et al.*, 2024). Reserves are dwindling, particularly in Thailand and the Philippines, and those countries will become increasingly reliant on LNG imports if they stick to their current plans (Cruz and Chow, 2023). In particular, the Philippines, a relatively small player in the global market, will be particularly vulnerable to international price fluctuations in fossil gas imports, due to its limited ability to influence these prices.

Box: Investments in gas infrastructure in Germany risk stranded assets

Increased investments in fossil gas power plants and LNG terminal infrastructure are not unique to Southeast Asia. Germany, for example, has upscaled its LNG import capacity to diversify its supply as a reaction to the energy crisis caused by the Russian invasion of Ukraine (Marquardt *et al.*, 2023). It is also planning to invest in new gas-fired power plants, with the intention of switching them to green hydrogen as soon as possible as a means to balance variable renewable energy sources (Federal government of Germany, 2024).

Priorities for transition: Achieving net zero requires a steep reduction in fossil gas usage in electricity generation, shifting power plants towards peaking operation.

Regardless of the modelled scenarios, whether highly electrified or gas-based, the share of fossil gas would quickly decrease in the power sector on the pathway to net zero. This trend is particularly evident in the cases of the Philippines and Thailand, where fossil gas currently plays a significant role in power generation (see Figure 1). For the Philippines, both scenarios suggest keeping electricity generation from gas-fired power plants in 2030 roughly at today's level, which is about 25% less than what's outlined in the Philippines' Energy Plan for the same year. For Thailand, with a very high share of gas in the power sector today, both scenarios suggest a significant decline by 2030 compared to today, in contrast to a clear increase in generation under the current country's Power Development Plan. A revision of the power plan is under development and is expected to reflect the carbon neutrality target of the Thai government.

Both scenarios show a shift in the role of gas turbines from running almost all year to covering mid-merit and peaking operations: (average full-load hours of gas power plants drop to between 2000 and 3000 hours per year on average).

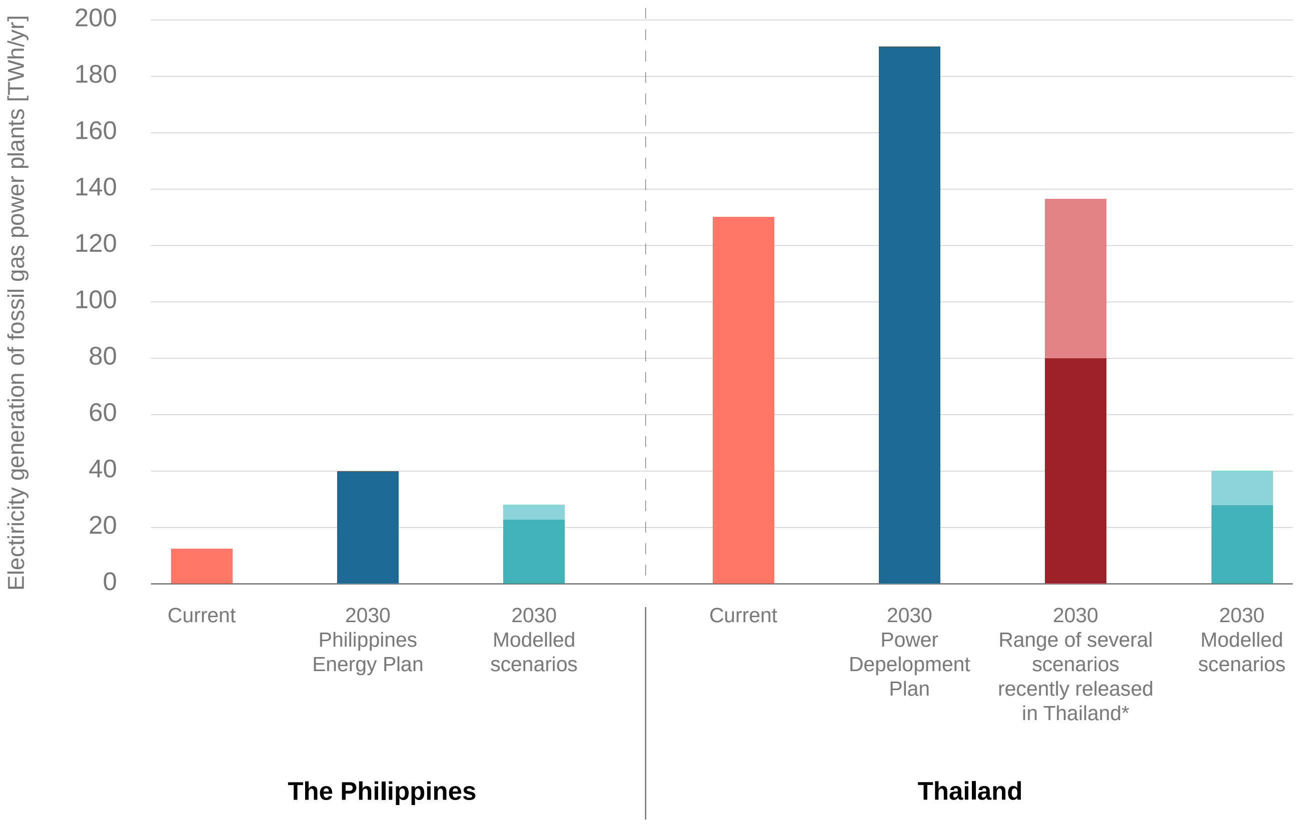

Figure 1: Gas power generation in the Philippines and Thailand today and by 2030 under governments' plans and under the modelled scenarios (high/low)
*Sources: (Ministry of Energy of Thailand, 2020), (Department of Energy, 2020b), *(CASE, forthcoming; Office of Natural Resouces and Environmental Policy and Planning, 2022), *(Office of Natural Resources and Environmental Policy and Planning, 2022).*

According to the modelled scenarios, hydrogen plays a secondary role to renewable energy in replacing fossil gas in the power sector, in providing power system flexibility services to alongside battery storage.

This suggests that any investment in new gas-fired power plants should consider the changing roles of gaseous energy carriers in the power sector during the transition. This includes ensuring the readiness of power plants to switch from fossil gas to hydrogen once it becomes economically viable, as hydrogen-fuelled power plants require different technical designs compared to fossil gas.

Priorities for transition: Aim for a high degree of electrification of transport and industry to limit the overall need for gaseous energy carriers.

The degree of electrification in industry and transport will determine the overall demand for gaseous energy resources, energy import needs and requirements for infrastructure. In the "highly electrified" scenario, all CASE countries need significantly less fossil gas, shifting towards electricity and, to a lesser extent, to hydrogen.[1] The electrification of the industrial sector, which constitutes a dominant share of final energy demand, significantly reduces the required amount of gaseous energy carriers.

The peak year for fossil gas demand also varies significantly between the two scenarios, ranging from 2030 and 2050 (Figure 2). In the "highly electrified" scenario, gas consumption would peak in all countries no later than 2030, with Viet Nam and Indonesia already experiencing a decline as of today. This means that the long-term infrastructure needs for gas under pathways to net zero would drastically differ from today's infrastructure and policy plans designed for fossil gas.

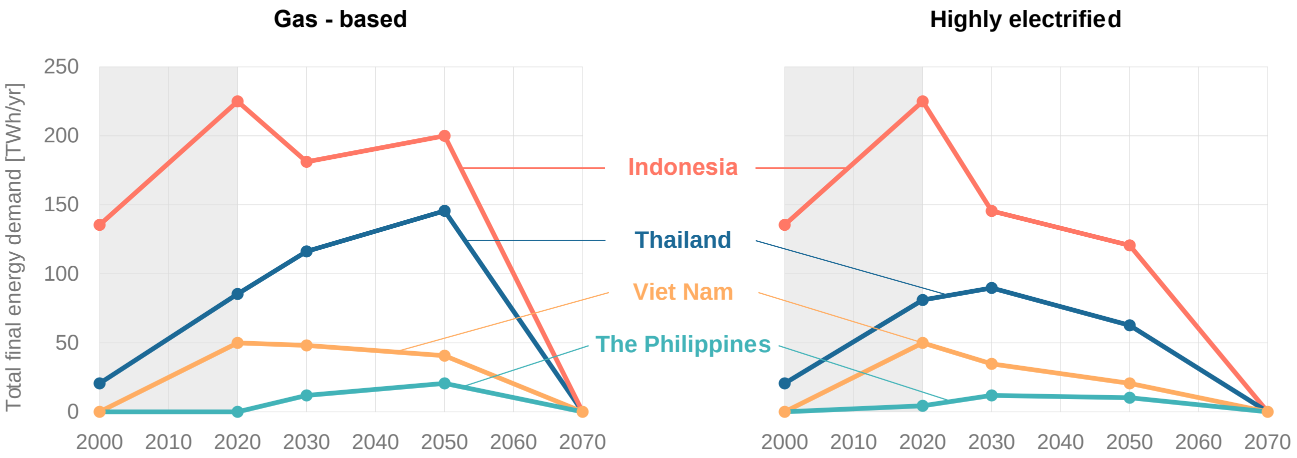

Figure 2: Fossil gas in total final energy demand under the "gas-based" and the "highly electrified" scenario.

[1] The modelling exercises only included only hydrogen derived from renewable electricity or imported hydrogen. Hydrogen derived from fossil gas with CCS was excluded (see Introduction Box).

Priorities for transition: Coal capacities need to be replaced through renewable energy: detours via fossil gas or ammonia **co-firing are not economical.**

Decarbonising the power sector while maintaining a high share of gas would be excessively expensive: fossil gas with CCS and hydrogen both entail extra costs compared to fossil gas alone, unlike renewable energy which is already cost-competitive with fossil gas.

None of modelled scenarios towards net zero suggest a shift from coal to gas for any of the four countries and analysed. Figure 3 illustrates the development of gas capacities in the power sector in Indonesia and Viet Nam, two CASE countries that are heavily reliant on coal today. In both scenarios, the gas capacities would slightly increase by 2030 in Indonesia and remain below the current government plans. In Viet Nam, gas capacities would even decrease below today's level, whereas the government plans are about four times this amount for 2030.

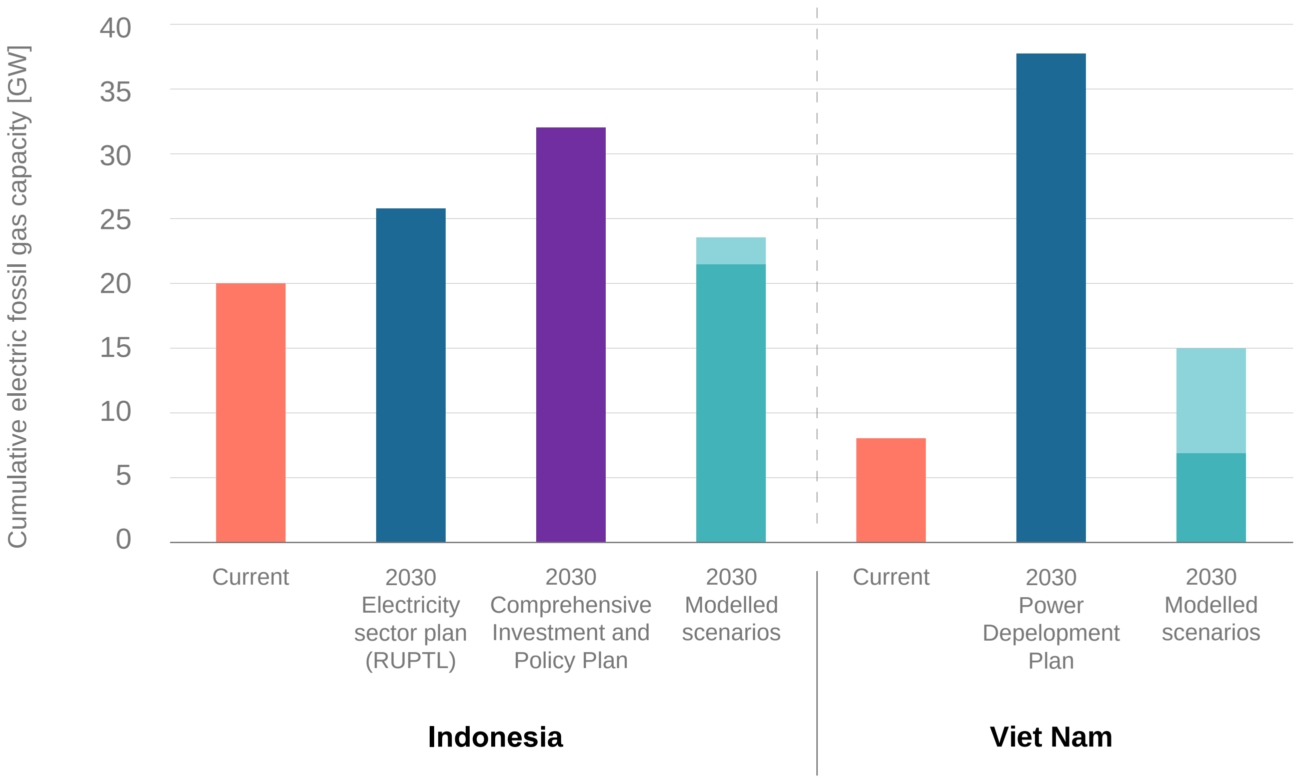

Figure 3: Cumulative gas-fired power plants capacity in Indonesia and Viet Nam today and by 2030 under governments' plans and under the modelled scenarios (high/low)
Sources: (Government of the Republic of Indonesia, 2021),; (Prime Minister of Vietnam, 2023),; (Müller *et al.*, 2024);(Agora Energiewende, 2023)

Box: Diversions on the path from coal to renewables via fossil gas in the UK and US
In the first two decades of this century, other countries like the US and the UK have relied on fossil gas to transition away from coal. However, renewable technologies have since become more cost-effective, and are often cheaper than fossil gas power plants. In 2022, the levelized costs of electricity generation for onshore wind were 0.033 USD/kWh (global weighted average) while solar PVs ranged from 0.03 to 0.12 USD/kWh (IRENA, 2023). Both the US and the UK have committed to achieving a carbon-neutral power sectors by 2035, which will require a near-complete phase-out of fossil gas. Unlike most Southeast Asian countries, the US and the UK had well-connected gas grids and supporting infrastructures, which allowed for a relatively straightforward them to transition from coal to gas without requiring significant changes in their gas infrastructure.

Retrofitting coal-fired power plants to co-firing ammonia should also be avoided due to the inefficiency it causes and lack of cost-competitiveness. Despite many countries across Asia and Southeast Asia discussing ammonia co-firing as a solution to decarbonise existing coal assets, it is more efficient in terms of energy use and costs to use renewable electricity directly. During the conversion process, about 75% of energy is lost (producing clean ammonia first and then burning it in power plants), compared to using electricity directly (NewClimate Institute, 2023). Our modelling excludes ammonia co-firing for this reason and both scenarios show that it will be already challenging enough to domestically meet the demand for renewable hydrogen in essential applications (e.g. steel production). Such inefficient use of ammonia would likely further increase energy import dependencies. For example, calculations have shown that introducing 20% ammonia co-firing in all the existing coal power plants in Japan and Southeast Asia by 2030 would increase global ammonia demand by up to 100 Mt, which represents half of global ammonia demand in 2020 (Agora Industry and Agora Energiewende, 2024). Furthermore, ammonia co-firing has been demonstrated to not be cost-competitive with new renewable energy installations. (BNEF, 2023b, 2023a).

Electrification and renewable gases: **Electrification of processes is the most efficient solution for replacing fossil fuels** in end-use sectors, and the use of hydrogen **should be limited to specific cases**

The electrification of energy end-use is critical for realising any net-zero pathway. Pathways that first convert electricity to hydrogen and its derivatives are highly electricity-intensive. Such gaseous fuels will likely remain scarce and expensive, and thus their use should be reserved for specific cases, particularly in industry. Directly using renewable electricity enhances the overall energy system efficiency and reduces the need for gaseous energy carriers. Across all sectors, technologies and processes that use electricity (e.g. electric vehicles, heat pumps and electric boilers in industries) are already widely available and commercialised.

Current developments: Industrial and transportation sectors in the CASE countries heavily rely on fossil fuels, but they have **great potential for electrification.**

Fossil fuels are the predominant energy carriers in the end-use sectors (residential, commercial, transportation and industrial sectors) throughout all CASE countries. In transportation and industry, they account for between 88% and 100% and between 50 and 70% of final energy consumption, respectively (see Figure 4). The share of electricity use in transport is close to zero, and between 15% and 35% in industry. Currently, the role of gases based on renewable energy in both transport and industry is negligible, as is the case globally (Boehm et al., 2023).

Like in the power sector, industries in the region faces the dual challenge of decarbonising the existing manufacturing base while ensuring that new industrial capacities are compatible with net-zero pathways. The industrial sectors in the region are growing faster than the global average, partially driven by the region's growing infrastructure needs for basic materials such as iron, steel and cement. In Viet Nam and Indonesia, three rapidly growing industries – steel, cement, and chemicals – already account for over half of industrial energy demand and rely heavily on fossil fuels.

The transport sectors in the region continue to be dominated by oil, although all ASEAN nations recently adopted policies to accelerate the electrification of transport. Indonesia, Thailand and Viet Nam have also initiated biofuel blending mandates, while Thailand has also incorporated about 7% fossil gas in its mix. Electric vehicle (EV) markets are beginning to grow rapidly across the region. In 2023, it was announced that battery EV sales increased 10-fold in just one year. Thailand leads in EV sales in the region, accounting for over 75% of EV regional sales, followed by Indonesia and Viet Nam. However, it will take time for these shifts to manifest into significant increases in electricity's share of final energy use.

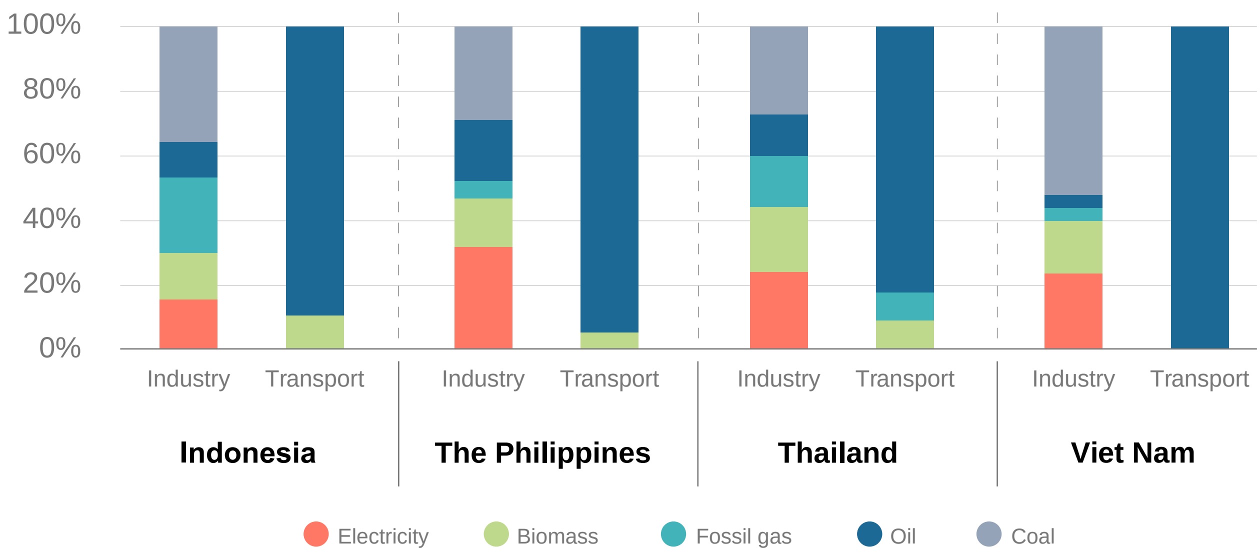

Figure 4: Share of final energy use in 2021 in the four CASE countries in the industrial and transport sectors, by energy carrier.
Data source: (IEA, 2023b)

The CASE countries already have policies and technologies for electrification and production of renewable electricity available and, in many cases, deployed, while renewable hydrogen is at a much earlier stage. The adoption of net-zero pledges has placed increased scrutiny on how these commitments can be implemented while providing opportunities for industrial modernisation. Technologies such as solar PV and electric vehicles have progressed rapidly and have established themselves as no-regret solutions worthy of policy support and investment. Hydrogen and its role in enabling the transition to net-zero has garnered enormous attention over the past five years, yet there remain open questions about how it can be supplied sustainably and where its use makes the most sense.

In Southeast Asia countries, a handful of hydrogen strategies have been adopted, particularly in Malaysia, Singapore, Indonesia and Viet Nam (Singapore - Ministry of Trade and Industry, 2022; Kementerian Energi Dan Sumber Daya Mineral, 2023; Ministry of Science Technology and Innovation Malaysia, 2023; Prime Minister of Vietnam, 2024). a handful of hydrogen strategies have been adopted, particularly in Malaysia, Singapore, Indonesia and Viet Nam (Singapore - Ministry of Trade and Industry, 2022; Kementerian Energi Dan Sumber Daya Mineral, 2023; Ministry of Science Technology and Innovation Malaysia, 2023; Prime Minister of Vietnam, 2024). Others in the region are working on them. In addition, pilot projects for green hydrogen are underway. In Indonesia, the number of pilot projects and Memorandums of Understanding have grown significantly between 2022 and 2023 (IEA, 2022b, 2023a).

Priorities for transition: A highly electrified scenario reduces the required level of renewable hydrogen to one-fifth, compared to the gas-based scenario.

The extent to which gaseous energy carriers, particularly hydrogen, will be used in the future in the region depends on choices made regarding electrification. The gas-based scenario would see a significantly higher demand for hydrogen compared to the highly electrified scenario in all four countries. In total, across the four countries, the highly electrified scenario leads to about 100 TWh of demand for renewable hydrogen in 2050, while it reaches about 450 TWh under the gas-based scenario (see Figure 5).

Directly replacing fossil fuels with electricity in transport or heavy industry, as in the highly electrified scenario, increases the overall efficiency of the system by avoiding conversion losses in the production of renewable hydrogen. This would result in smaller renewable capacity needs and reduce reliance on energy imports.

Higher demand for renewable hydrogen, as in the gas-based scenario, would pose challenges for the CASE countries in achieving net zero because it would either require high imports or an even faster build-up of renewable electricity technologies in the case of domestic production (see the next section on renewable energy additions). Relying on hydrogen produced from fossil gas and CCS would mean continued or increased reliance on imports of fossil gas and their associated risks for most countries. Additionally, it is important to note that this form of hydrogen is not truly zero-carbon, due to less than 100% carbon capture rates and the inherent upstream GHG emissions from fossil gas production.

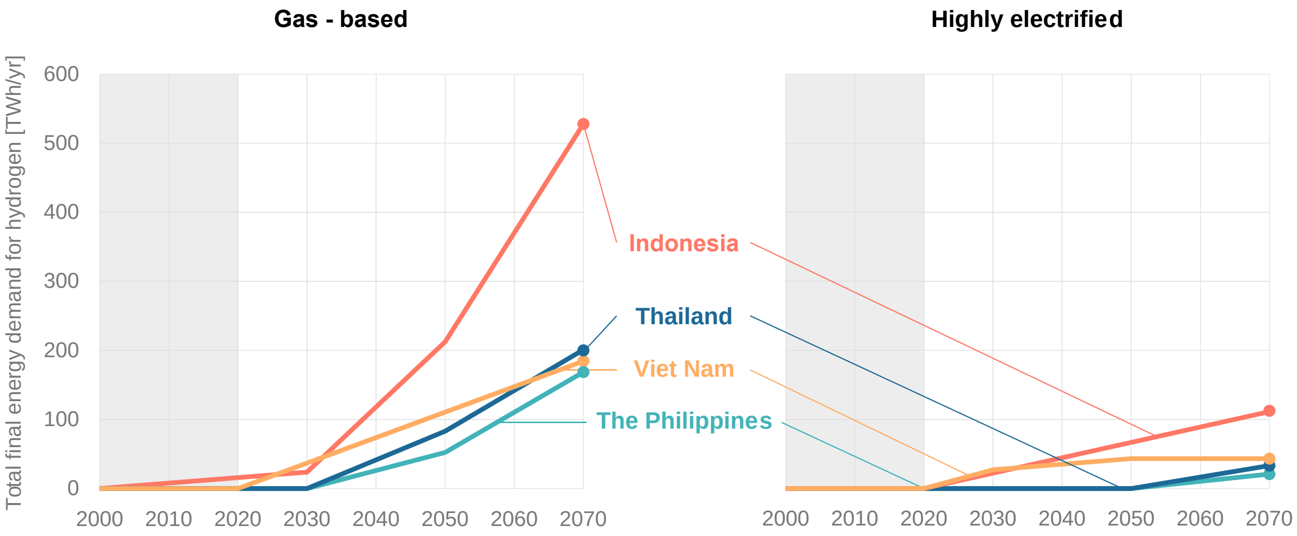

Figure 5: Current and projected green hydrogen in final energy demand in the two scenarios.
Data source: (Müller *et* al., 2024)

Within the CASE countries, electrifying ground transport and industrial processes are key levers for keeping demand for gaseous energy carriers in check. The modelling identifies international aviation and shipping as another key driver for renewable fuels under net-zero pathways in the region, with major global transportation hubs in Thailand, Singapore and Malaysia. Those use cases will be very difficult to electrify and will lead to an increased demand for fuels based on renewable hydrogen under a net-zero pathway.

Renewable electricity: The speed of renewable electricity development, particularly solar **power, needs to accelerate significantly and** go beyond current government plans to align with net-zero targets

Solar is the renewable energy resource with the most potential in Southeast Asia. Wind power plays a less significant role, except in Viet Nam, which has considerable offshore wind potential, and in the Philippines. Given the region's geographical constraints and limited land availability, there is a need to explore technologies that are not yet widely adopted, including offshore wind (especially floating solutions), agrivoltaics, and floating PV. As such, the potential for domestic production of renewable hydrogen for export is relatively limited. In fact, the region could likely become a net importer of green hydrogen from more competitive regions like Australia.

Current developments: Targets to increase the share of renewable energy in the CASE countries fall short of their net-zero ambitions, especially with wind and solar power still in their infancy.

Currently, renewables in Southeast Asia account for 28% of total electricity generation, largely dominated by hydropower, geothermal, and, to a lesser extent, biomass. The deployment of wind and solar power has been slower than global averages, with these technologies making up less than 1% of electricity generation in Indonesia and about 5% in Thailand (Ember Climate, 2024). In Thailand, solar has yhe highest renewable electricity potential, because wind speeds are generally low, attractive locations for wind energy are subject to land restrictions (forests) and lack grid connection (Global Wind Energy Council, 2019). An exception amongst the CASE countries is Viet Nam, where 18 GW of solar PV and 5 GW of wind was installed over the last five years, with variable renewables constituting about 15% of electricity generation today.

All CASE countries have established targets to increase the contribution of renewable energy in their power sectors (See Figure 6). However, these targets generally fall short of their net-zero ambitions (Agora, 2023). Indonesia and Viet Nam have additionally agreed on Just Energy Transition Partnerships with donor countries, demonstrating their increased ambitions to scale up renewable energy and reduce coal dependence. However, given the expected growth in electricity demand across the region, even maintaining current shares of renewables will require significant capacity expansion.

Priorities for transition: In the CASE countries, renewable energy capacities need to increase by more than four times by 2030.

According to the modelled scenarios, the combined capacity of all renewable energy technologies in the power sectors of Viet Nam, Indonesia, Thailand and the Philippines needs to reach about 330-350 GW in 2030 (against 80 GW today). This is much faster than current government plans anticipate, except for Viet Nam, where the current Power Development Plan aligns with our scenarios for the year 2030 (see Figure 6). Viet Nam started at a higher level of renewable energy after a sharp increase in wind and solar, particularly in the year 2020, when about 12 GW of solar were added to the grid. This sharp increase indicates that ramping up renewable capacities in the short term is possible, but the high rates of curtailment and grid instability also foreshadow how other supporting infrastructure will need to keep pace.

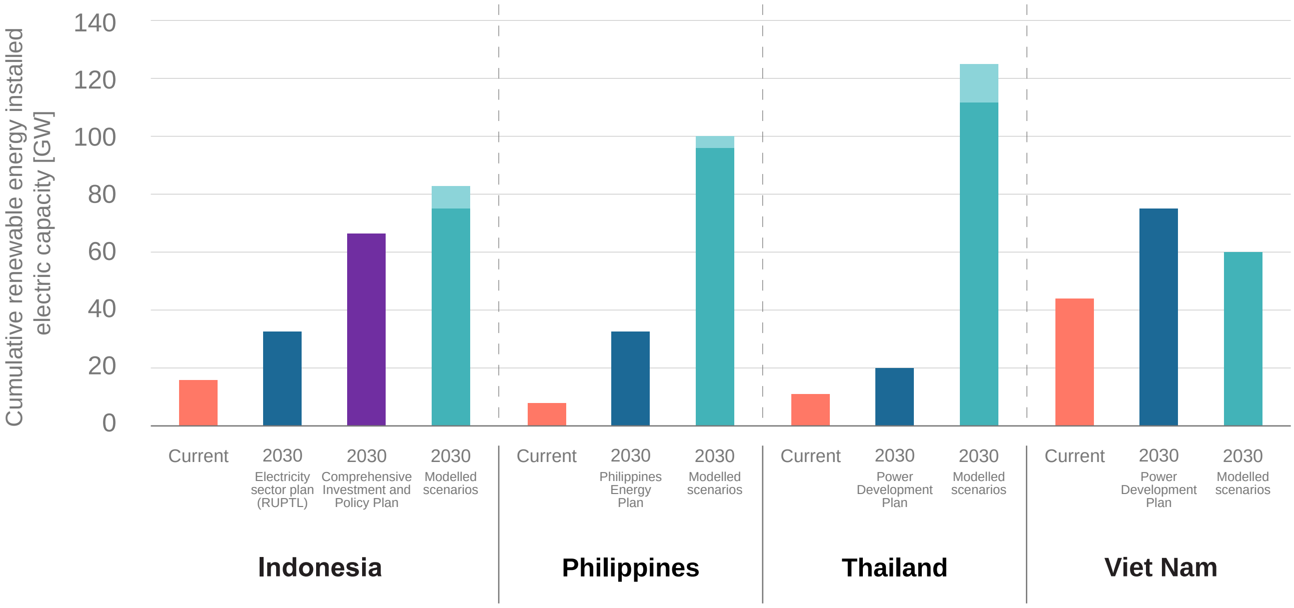

Figure 6: Current and projected renewable energy capacity in the power sector in the two scenarios and in government plans for the year 2030.
Sources: Ministry of Energy of Thailand, 2020; Government of the Republic of Indonesia, 2021;Prime Minister of Vietnam, 2023; Department of Energy, 2020b; IRENA 2024).

Note that for Viet Nam, the Fraunhofer modelling suggests a lower build-up of renewable energy than indicated in the graphic above. The reason for this is that the modelling uses 2019 as the base year, meaning it does not reflect the significant growth of solar PV and wind in recent years. Additionally, the electricity generation is assumed to be much lower in our pathways compared to Viet Nam's Power Development Plan (280 – 295 TWh/yr compared to 567 TWh/yr in the year 2030. To create the graphic above, we added the difference in renewable capacities from 2023 and 2019 to the 2030 value. This increased the original modelling values by about 18 GW. We assume that over time, this effect evens out, meaning there is no correction needed for modelling years beyond 2030.

The scenarios show that most of the renewable capacity additions will come from wind and solar power, which have become the most cost-effective sources of electricity generation. Due to limited onshore wind potential and geographical constraints like limited land availability and sharply sloping coastlines, wind power will play a relatively smaller role in Southeast Asia compared to other regions. Among CASE countries, Viet Nam and some locations in the Philippines have good onshore wind resources (see Figure 13 in Müller et al., 2024). In these two countries, offshore wind resources, especially those farther from the coast, can significantly contribute to renewable energy generation, potentially using floating offshore technologies (International Bank for Reconstruction and Development/World Bank, 2021, 2022). The use of solar PV resources through new methods like agrivoltaics and floating PV systems can ease the pressure on land while contributing to meeting increasing electricity demand.

Other renewable sources, such as hydropower, geothermal and bioenergy, could be also considered, given they can also be cost-competitive dispatchable options. While the scenarios demonstrate their supporting roles in integrating wind and solar into the grid, their expansion potential is constrained by resource availability as well as sustainability concerns regarding their environmental and social impacts. For example, hydropower could be expanded to some extent if sustainably managed. However, its primary value lies more in freshwater storage for purposes like irrigation and municipal consumption. In addition, relying heavily on hydropower for power generation is risky, as its operations could be increasingly constrained by climate change, which is expected to increase the frequency and severity of extreme weather events like heatwaves, droughts and floods.

Given these constraints and surging demand for electricity, the potential for domestic hydrogen production using renewables is relatively limited, especially in the short and medium term. A heavy reliance on renewable fuels supplied by domestic hydrogen production would require a significant[2] increase in renewable energy capacity and storage, meaning that higher-cost resources would need to be tapped. Without careful use of hydrogen and its derivatives in end-use sectors, the region will therefore likely become a net importer of renewable hydrogen from more competitive regions, such as Australia.

[2] For more detail, see section 3.4.1 of the main modeling report (Müller et al., 2024).

Flexible energy systems: as renewables displace fossil fuels, system flexibility becomes the cornerstone of energy security

The energy systems in a decarbonised future will need to be more flexible to accommodate shifts in energy carriers and new electricity demand patterns. A reliable and affordable system that integrates more renewables will require the development of electricity storage, enhanced demand-side management, and improved grid infrastructure.

Current developments: Given the important potential of solar **PV, specific seasonal variability and consumption behaviours, targeted storage and flexibility solutions will quickly grow in** relevance in the region.

The geographical features of Southeast Asia, characterised by tropical climate and vegetation with high solar irradiation and limited potential for wind energy on land, present specific challenges for energy storage infrastructure and demand-side management. There is some complementarity between wind and solar power, but it is lower than in other regions. Additionally, the region observes seasonal variability of solar potential because of monsoons and increased peaking demand behaviour in the evening during hot months (given the intense use of air conditioners).

Electric battery storage systems are starting to gain traction in Southeast Asia, but their adoption is still in its early stages. For example, Indonesia's state utility Perusahaan Listrik Negara (PLN) aims to replace diesel generators through solar PV and batteries, and Singapore has initiated various solar plus battery projects in Indonesia to supply Singapore through a direct interconnection. Thailand has included solar PV plus battery storage in their renewable energy procurement (Beckstead, 2024), but its Power Development Plan lacks a clear storage target. Viet Nam's JETP and Power Development Plan set a target of 2.7 GW of storage by 2030, with plans to grow this to between 30 and 45 GW by 2050 (Viet Nam Government, 2023). The Philippines has decided to install a total of 1 GW of battery storage across the country (SMGP, 2023), but its Power Development Plan does not specify a target for energy storage. A rapid scale-up of storage will require targeted policy support.

There is also potential to support the integration of renewable energy through managing the demand side, given the emergence of additional and new demand patterns driven by electrification (e.g. EV) and economic growth. If left unmanaged, the changes in demand could significantly increase the systems' peak demand, which consequently requires the expansion of generation capacity and other flexibility resources. Demand-side response has the potential to make the electrification 'smart' and can help avoid excessive investments into the power system. The CASE countries are starting to address this issue. For example, in 2022, Thailand introduced a feed-in tariff scheme specifically for solar PV projects coupled with battery storage (Santos, 2022). The Philippines has a sophisticated spot market design with high temporal and spatial resolution, which offers, in principle, greater flexibility in responding to supply fluctuations and meet electricity demand (IEMOP, 2024). The smart coupling of electrified demand sectors, like transport, can provide new sources of flexibility. For example, a large fleet of EVs equipped with the ability to charge dynamically and potentially feed back into the system (Vehicle-to-Grids) can reduce peak demand and further help accommodate higher shares of variable wind and solar.

Transmission and distribution grids also need to be built up rapidly, as they represent bottlenecks for the integration of renewables. This situation is particularly prevalent in Viet Nam, where renewable energy has grown at an unprecedented pace compared to the grid infrastructure. As a result, the most recent power development plan only allows for distributed rooftop solar installations where grid overload is not expected (Viet, 2023). Indonesia and the Philippines face the additional challenge of managing energy systems across a number of islands. Still, expanding electricity grids will likely be more cost-efficient than building pipelines for transporting green gases, especially for Indonesia (IEA, 2022a).

Increasing the interconnectivity of electricity grids on a regional level is also an important step towards a more flexible energy system in Southeast Asia (ACE, 2024). Regional grid interconnections provide benefits like pooling flexibility resources and increasing the area over which supply and demand can be balanced. Establishing a regional grid connecting Southeast Asian nations could reduce the costs of decarbonising the sector by 11% by lowering the total renewable energy and storage requirements (DNV, 2024). Still, regional interconnections are only as strong as the grids they connect, so they should be developed in alignment with national grid expansion plans to ensure a coordinated approach.

Priorities for transition: Activating system flexibility through storage and demand-side response reduces the requirements for growth in renewable capacity.

Under both scenarios and in all four countries, storage capacity experiences rapid growth, starting from close to zero today. In Indonesia and Viet Nam, storage capacity would increase to around 10 GW. In the Philippines and Thailand, it would reach 20-30 GW by 2030, and then exceed 100 GW in all countries thereafter (see Figure 7).

The storage requirements vary between scenarios and across countries. The highly electrified scenario requires more storage than the gas-based scenario. This is because the highly electrified scenario relies more on domestically produced electricity, whereas the gas-based scenario ends up relying on imported fuels.

In the short term, the difference between countries stems from the availability of hydropower. In Viet Nam and Indonesia, hydropower power plants store energy in their reservoirs, reducing the need for additional storage. In contrast, in Thailand and the Philippines, which have less hydropower available, the need for additional battery storage increases much sooner.

In the long run, absolute storage needs depend mostly on the size of each country's electricity system. It should be noted that, relative to the total capacity installed, storage needs are lower in Viet Nam and Indonesia compared to the Philippines and Thailand. In both scenarios, batteries would make up the largest share of the storage capacity, followed by hydrogen storage and hydropower. The modelling result shows that the required battery storage capacity can be reduced by 10% to 22% in 2050, by using smart charging in battery electric vehicles as a form of flexible demand. Other approaches were not modelled, so the overall potential of demand-side management will likely be higher.

Renewable hydrogen can also provide additional flexibility to the system: electrolysers can absorb high amounts of renewable electricity, producing hydrogen that is fed back into the system (through hydrogen-fired turbines) for adequacy purposes. Hydrogen storage for power generation only comes into play around 2050, once significant solar PV capacities have been deployed. Given the relative inefficiency of converting electricity to hydrogen and then back to electricity again, hydrogen for electricity generation is used only to cover peak loads for short periods when solar PV and batteries cannot meet demand.

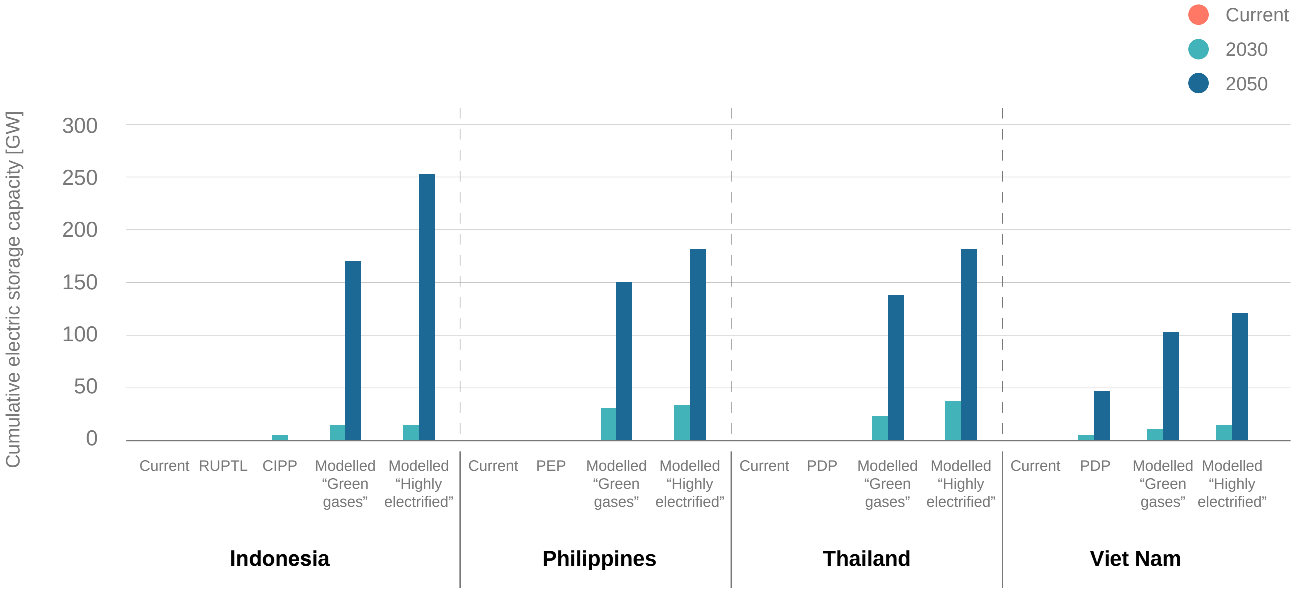

Figure 7: Cumulative electric storage capacity in power development plans (where available) and according to the modelled pathways

Conclusions and outlook: Redefining energy security in the context of decarbonisation trajectories

The global energy landscape is evolving rapidly, presenting a pivotal moment for Indonesia, Viet Nam, the Philippines, and Thailand. The net-zero targets, the Paris Agreement and the COP28 decision to transition away from fossil fuels require significant shifts in the countries' energy systems. While renewable energy is gaining traction in the region and green hydrogen appears increasingly accessible, current energy systems in the CASE countries are still heavily reliant on fossil fuels and government plans still include increasing fossil fuel use to meet growing energy demands. Energy development plans in all four countries do not fully align with national climate commitments. Such policy misalignment exposes countries to additional risks regarding their development goals. Committing to long-term investments into fossil infrastructure risks locking systems into high-carbon pathways of development, thereby endangering their economic futures. Investing in gas infrastructure could also divert funds from renewable energy projects, especially if long-term contracts are adopted. Such long-term contracts could result in overpaying for energy supply in the long run, while renewables would reduce import bills.

Once infrastructure is in place, gas supply chains are at risk of price volatility and import dependency and are particularly sensitive to geopolitics and global interdependencies. This infrastructure also risks becoming a stranded asset. Our analysis indicates that a transition away from fossil fuel in the region will require adjustments to infrastructure, processes, and economic activities, alongside the rapid scaling up of renewable energy.

Given the surging energy demand across the four CASE countries, some form of energy imports seems likely under any development scenario. In both a highly electrified and a gas-based scenario, we do not expect the region overall to remain a key exporter of energy because fossil gas reserves in many countries are dwindling. This would remain true if the countries continue on their current trajectory.

Based on our analysis, we suggest the following priorities:

- **Redefine energy security as "creating a flexible and resilient system that minimises demand and maximises the share of domestic renewable sources":** An efficient energy system that minimises primary energy needs and supplies them efficiently is the most important step to enhance energy security. Energy security has traditionally been defined as "securing sufficient energy sources". However, countries or regions can expand or redefine their understanding of energy security by implementing an integrated plan to transition to a decarbonised energy system, primarily fuelled by domestic or regional renewable energy. This means prioritising energy efficiency in demand, electrification, and the integration between energy producers and users.

- **Plan the systems in a more integrated way and with a long-term vision in mind:** Future energy systems under net-zero pathways will be much more dynamic and decentralised. All the different components will need to align to ensure a reliable and affordable energy supply. Governments should thus begin investigating long-term infrastructure needs now, particularly when considering new large-scale infrastructure projects. Profound shifts will be needed under any net-zero scenario. It is essential to recognise and address elements of current systems that conflict with long-term visions and facilitate an orderly transformation of the fossil-fuelled infrastructure. Providing ample time and certainty for people and companies to anticipate changes can facilitate a smoother transition. Mechanisms to ensure fairness in the process and outcomes are required, especially where certain populations are disproportionately affected by the transition.

- **Go all-in on renewable electricity, focusing on the expansion of wind and solar:** With falling technology costs globally and a huge need for energy in the region, Southeast Asia cannot afford to delay the ramp-up of renewable energy. Countries need to accelerate the adoption of renewables while expanding storage options and integrating them into the power system. Market barriers need to be tackled urgently. Any fossil energy infrastructure should undergo stress testing to ensure its alignment with a pathway towards high renewables. Power plants, both coal-fired and gas-fired, need to move away from baseload operation. Theenergy transition required to reach net-zero targets requires unprecedented efforts and international support. The international community needs to prioritise meaningful support to enable this transition without overburdening the countries in the region.

- **Focus on electrifying processes and appliances, use hydrogen only where essential:** The fact that renewable hydrogen and its derivatives might become available should not divert attention from electrifying and decarbonising energy use where already possible. Electrifying vehicles and industrial processes are key levers for an efficient overall system. Renewable hydrogen will remain relatively expensive compared to the direct use of electricity. Relying on hydrogen imports could make the energy transition more expensive than necessary. A pathway that builds on a high degree of electrification would lead to a lower primary energy demand and reduced imports, compared to relying on gaseous energy carriers produced via renewable energy to decarbonise the economy. Fossil hydrogen with CCS can only play a limited role during the transition to net zero, as it is not a zero-carbon option.

- **Increase the interconnectivity of electricity systems in the region:** Interconnected electricity grids can balance out variable renewable resources in different parts of the region. A significant expansion of electricity grids and hydrogen transport networks between the ASEAN member countries would reduce the costs of decarbonising the complete system. Initiating bilateral interconnections is a first step in line with ASEAN priorities.

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