Achieving a Net Zero Electricity Sector in Viet Nam

Exploring Decaborbonisation Pathways

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Building on Viet Nam's Power Development Plan 8 (PDP8), this *Achieving a Net Zero Electricity Sector in Viet Nam* report aims to provide stakeholders in Viet Nam and internationally with an assessment of different pathways for achieving its emissions reduction targets and reaching net zero emissions in the power sector by 2050. The pathways were developed in the IEA Global Energy and Climate Model framework, benchmarked against the PDP8 and considering the emissions reduction targets set out in the 2022 Just Energy Transition Partnership.

Successfully scaling up the power sector in Viet Nam in recent years has underpinned rapid economic development and approaching universal access to electricity. Electricity demand in Viet Nam surged eightfold from 2002 to over 240 TWh in 2022. Industry is the largest consumer of electricity, with recent growth particularly in manufacturing. Electricity use in the residential and commercial sectors has also been growing rapidly. To meet growing electricity demand, natural gas increased the most from 2000 to 2010, then coal and hydro expanded rapidly from 2010 to 2020 with new capacity coming online, followed by strong growth for solar PV in the last few years. In 2022, coal was the largest source of electricity supply at 41% of the total, followed by hydro (35%), natural gas (11%) and solar PV (10%).

PDP8 provides a blueprint for the comprehensive transformation of Viet Nam's electricity sector, with a clearly defined pathway to 2030 and vision to 2050. Alongside strong economic growth, PDP8 foresees electricity demand doubling by 2030 and rising about fivefold to nearly 1 200 TWh in 2050. In our PDP8 Scenario, unabated coal-fired power peaks in the mid-2020s, made possible by strong growth for natural gas and wind power, and modest growth for hydro and solar PV. In the vision to 2050, wind and solar PV become the dominant sources of electricity, complemented by hydro, bioenergy, natural gas, and significant amounts of low-emissions hydrogen and ammonia. As a result, investment needs increase rapidly to nearly USD 30 billion in 2030 and peak at USD 60 billion in the 2040s, though falling fuel expenditures as the share of renewables increases mean that average costs per unit of electricity for consumers remains below USD 100/MWh throughout. CO_2 emissions in the electricity sector peak in 2030 at 250 Mt and decline to around 30 Mt by 2050.

The pace of electricity demand growth is a critical building block in considering the pathways to net zero emissions in the power sector. While the PDP8 Scenario reflects the foreseen growth in the PDP8 directly, we identified efficiency opportunities to reduce electricity demand growth by nearly 20% to 2030 and 30% to 2050. The main efficiency opportunities are in industry, through faster uptake of high-efficiency motors, and in buildings, through more efficient air conditioning, lighting and electric cooking. These opportunities are incorporated into a lower demand trajectory in the Power Development Plan 8 + Energy Efficiency (PDP8+EE) Scenario, Power Development Plan 8 + Energy Efficiency and Low Hydrogen (PDP8+EE+LH) Scenario and Net Zero Emissions by 2050 (NZE) Scenario.

Expanding renewable energy is the primary means of decarbonising Viet Nam's power sector in all scenarios. Our analysis shows that building a secure, reliable and affordable electricity supply with very high shares of variable renewables is feasible. To 2030, PDP8 plans are represented directly in both the PDP8 and PDP8+EE Scenarios, while delayed delivery of some onshore and offshore wind projects, an emerging risk, is represented in the PDP8+EE+LH Scenario and the NZE Scenario. There is also potential for renewables to grow faster than this, in particular rooftop solar PV, which can be rapidly deployed. To 2050, PDP8 envisions record-breaking development of offshore wind to over 220 GW to produce low-emissions electricity and low-emissions hydrogen, some of which is then used in the power sector. Our analysis indicates that there are cost advantages in using less hydrogen or ammonia (derived from hydrogen), cutting the need for offshore wind by about half. Solar PV returns to strong growth after 2030 in all scenarios, reaching 170 GW to 200 GW in 2050, compared with 19 GW in 2022. Onshore wind expansion is similar across scenarios, rising from 4 GW today to a range of 60 GW to 80 GW in 2050.

The transition away from unabated fossil fuels is a necessary part of any decarbonisation pathway. Unabated coal-fired power generation peaks in the mid-2020s in all scenarios, and in our alternative pathways to PDP8, lower electricity growth leads to steeper declines for coal. It also can lead to lower use of unabated natural gas, as in the PDP+EE Scenario, unless additional coal-to-gas switching opportunities are taken up to further reduce coal-fired power, as incorporated in the PDP8+EE+LH and NZE Scenarios. By 2050, unabated fossil fuels are greatly reduced in the PDP8 and PDP8+EE Scenarios, and fully phased out in the PDP8+EE+LH and NZE Scenarios. Hydrogen and ammonia enter the mix after 2035, but our analysis finds that the primary role of these plants will be to ensure security of supply, through flexibility and operating at peak times, rather than to produce large amounts electricity, and volumes can thus be much smaller than envisioned in PDP8. Nuclear power could play a complementary role in decarbonising electricity in Viet Nam, particularly where innovation and cost reductions materialise for new reactors designs, including small modular reactors.

CO_2 emissions in the power sector peak at 250 Mt in 2030 in the PDP8 Scenario. In the PDP8+EE Scenario, higher energy efficiency leading to lower electricity demand growth alone brings emissions down to about 180 Mt, over 35% below PDP8. In the PDP8+EE+LH and NZE Scenarios, mainly through the combination of lower electricity demand and more coal-to-gas switching, emissions fall to below the JETP limit of 170 Mt by 2030, even though this limit is temporarily exceeded in the late 2020s. Additional renewables that can be deployed rapidly, such as rooftop solar PV, or additional energy efficiency measures, could help limit near-term emissions growth and keep peak emissions under 170 Mt.

Maintaining the security of electricity supply is crucial at all times and in all cases. In light of rebuilding the electricity supply based on solar PV and wind, envisioned in PDP8 and our alternative scenarios, we carried out detailed modelling of the hourly balance of electricity demand and supply in 2050 for the most ambitious case, the NZE Scenario. This analysis, including stress-testing the power system for different observed weather patterns, demonstrates that power system adequacy and flexibility can be ensured at all times. To achieve this, though, it will be critical to expand and modernise electricity grids, unlock demand response, and scale up storage technologies, including batteries, to meet short-term flexibility needs, and carefully manage hydropower to meet seasonal flexibility needs.

Power sector investment rises significantly in all scenarios. Compared with the starting point of less than USD 10 billion spent annually now, investment reaches at least USD 25 billion by 2030 in all scenarios and continues rising. The 2040s see the highest level of investment in each scenario, though the PDP8 Scenario has the highest peak at over USD 60 billion, around 25% above any other scenario due to the high investments into offshore wind dedicated to produce hydrogen and ammonia for use in the power sector. The NZE Scenario shows that with relatively little additional investment, it is possible to accelerate emissions reductions and reach net zero well before 2050.

In terms of affordability, total costs per unit of electricity remain between USD 90/MWh and USD 100/MWh until 2030 in all scenarios. In the long run, a higher reliance on renewables and lower reliance on costly hydrogen-based fuels means that electricity prices in our alternative scenarios are lower than in the PDP8 or PDP8+EE Scenarios. Energy efficiency can lower consumer bills but result in a higher cost per unit of electricity produced as total system costs are spread out over fewer units of electricity. Investments into energy efficiency that lower electricity demand more than pay for themselves, with the potential to yield significant savings for consumers.

Many of our key findings are in agreement with the set of recommendations published in the Viet Nam Energy Outlook Report (2024), including: renewables investment needs to scale up, enabling more affordable electricity for consumers; energy efficiency in all sectors is an important building block of the transition and is cost-effective; solar PV, onshore wind and offshore wind lead the transition but require efforts to integrate them effectively, particularly enhancing power system flexibility and expanding transmission; nuclear power can play a complementary role to renewables.

1 Introduction

Viet Nam is one of the world's energy success stories in recent times. Over the past 20 years it has met an eightfold increase in electricity demand, driven by rapid economic growth – averaging over 6% per year – and the attainment of near universal access to electricity.

Having established a reliable and affordable power supply and become the second-largest electricity producer in Southeast Asia, Viet Nam is now facing a new challenge: halting the increase in power sector carbon dioxide (CO_2) emissions and pushing towards net zero by 2050, in line with its policies, plans and international commitments, while continuing to meet strong expected electricity demand growth and ensuring the electricity supply remains reliable, secure, and affordable.

The Power Development Plan 8 (PDP8), approved in May 2023, is an important element of Viet Nam's strategy to achieve its energy and emissions reduction objectives. It sets out the country's increased ambition and provides a blueprint for power sector development to 2030 and a longer-term vision to 2050. In addition to Viet Nam's own clear energy transition strategy, international support, including the Just Energy Transition Partnership (JETP) – which was signed by Viet Nam's prime minister in 2022 and saw the release of a Resource Mobilisation Plan at the end of 2023 – can accelerate the shift towards clean energy, in turn leading to peak and decline for coal-fired electricity generation.

Building on PDP8, *Achieving a Net Zero Electricity Sector in Viet Nam* aims to provide stakeholders in Viet Nam and internationally with an assessment of different pathways for achieving its targets and reaching net zero emissions in the power sector, benchmarked against the PDP8 and considering the JETP. The pathways are designed to be cost-effective and technology-neutral, considering all low-emissions technologies (renewables, nuclear, carbon capture, hydrogen and ammonia) as potential options. Key outcomes of the analysis include the identification of important milestones on the road to net zero, including for the deployment of renewables, interim emissions targets and the coal phase-out schedule, while highlighting key challenges. This roadmap also quantifies power sector investment needs and assesses the affordability of electricity supplies to 2050 and lays out strategies to ensure the reliability and security of the electricity supply while integrating rising shares of variable renewables.

Sections 2 and **3** provide an overview of the current state of play in Viet Nam's electricity sector and key policy initiatives.

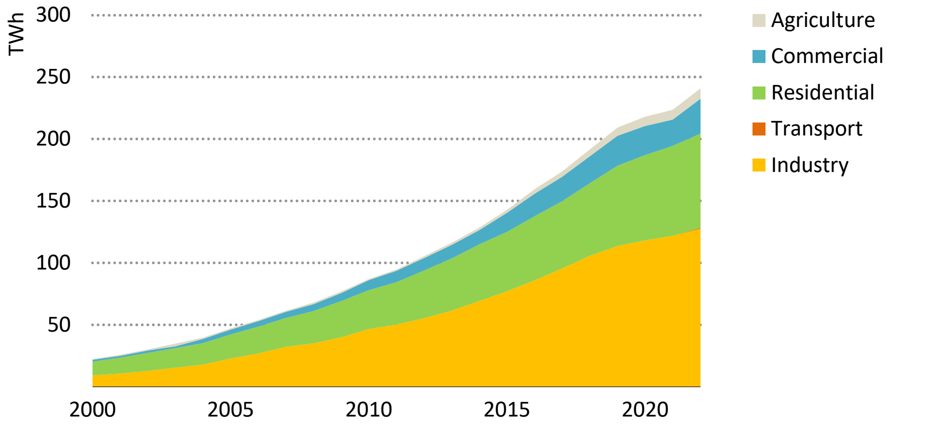
Section 4 describes the scenarios and the modelling approach underpinning this analysis.

Section 5 presents an in-depth analysis of PDP8, serving as a benchmark against which alternative pathways are compared in **Sections 6** to **10** of the report, focusing on the evolution of electricity demand (6), electricity supply (7), power system flexibility and security of supply (8), power sector CO_2 emissions (9), and investments and affordability (10).

2 Viet Nam's electricity system

Driven by strong economic growth and the achievement of near universal access to electricity, electricity demand[1] in Viet Nam surged eightfold between 2002 and 2022, from around 30 terawatt-hours (TWh) to over 240 TWh (Figure 2.1). This huge increase was mainly driven by industry, light industry in particular, with strong growth especially in manufacturing. Industry accounts for over 50% of electricity demand today. The residential and commercial sectors are responsible for most of the remaining consumption, with strong growth there resulting from an increase in the rate of access to electricity, to virtually complete coverage today, as well as rising ownership of electrical appliances and air conditioners. Over the past 20 years, electricity demand from the industry sector showed annual growth of 12%, residential 9% and commercial 14%. The agricultural sector has also seen growth over the past 20 years, from less than 1 TWh in 2002 to around 8 TWh in 2022, accounting for 3% of the total electricity demand. Currently there is almost no electricity demand from the transport sector due to low deployment of electric vehicles.

Figure 2.1 ▻ Historical electricity demand in Viet Nam by sector, 2000-2022



Electricity demand has increased eightfold in the last 20 years, led by growth in industry, particularly manufacturing, which accounts for over 50% of today's electricity demand

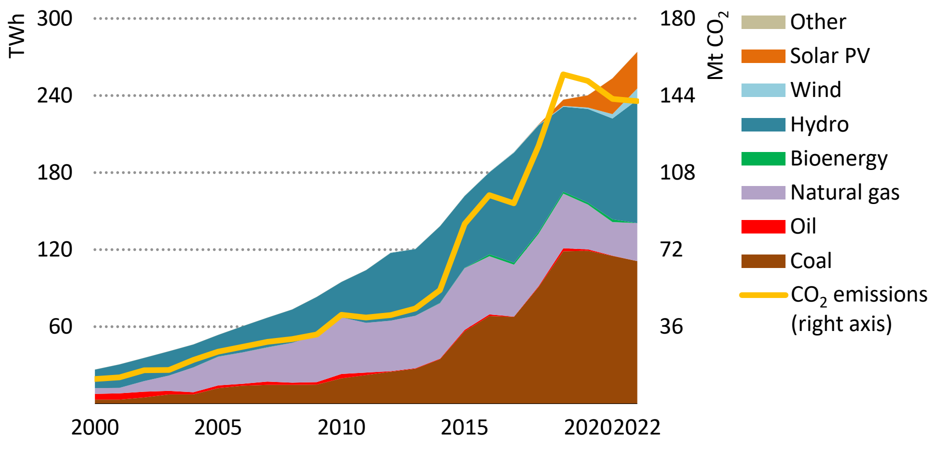
Total electricity generation rose almost eightfold, from around 35 TWh in 2002 to 270 TWh in 2022. Much of the increase was met by coal-fired power generation, which grew from only 5 TWh in 2002 (14% of the electricity supply) to 111 TWh in 2022 (41% of the electricity supply), with most of the growth occurring after 2010, when coal had overtaken hydro to become Viet Nam's largest source of electricity (Figure 2.2). As the second-largest source of

[1] Excluding transmission and distribution losses.

electricity, hydro accounted for 96 TWh in 2022 (35% of the electricity supply). Gas-fired power plants supplied around 11% of electricity in 2022. The output has almost halved since 2015, dropping from 48 TWh (30% of the electricity supply) to 29 TWh in 2022. The implementation of a generous feed-in tariff led to a surge in solar photovoltaic (PV) capacity additions between 2019 and 2021, significantly raising solar PV's share in the electricity mix and helping limit the need for additional coal-fired electricity generation to meet the increase in electricity demand between 2019 and 2022. Electricity generation from solar PV grew sixfold in this period, from around 5 TWh in 2019 to 28 TWh in 2022. The contribution from onshore and near-shore offshore wind also increased recently, their combined generation rising to about 9 TWh in 2022. The combined share of solar PV and wind surged to nearly 15% of electricity generation in 2022.

The strong growth of coal-fired electricity generation in particular has significantly increased power sector CO_2 emissions. From 16 million tonnes (Mt) in 2002 they grew almost tenfold to 2019, eclipsing 150 Mt. After 2019, however, the surge in the deployment of variable renewables, most importantly solar PV, helped turn this around. Coal-fired generation stayed roughly flat from 2019 to 2022 while gas-fired generation decreased, leading to CO_2 emissions falling from their 2019 peak, to around 140 Mt in 2022.

Figure 2.2 ▷ Historical electricity generation by source and CO_2 emissions from electricity generation in Viet Nam, 2000-2022



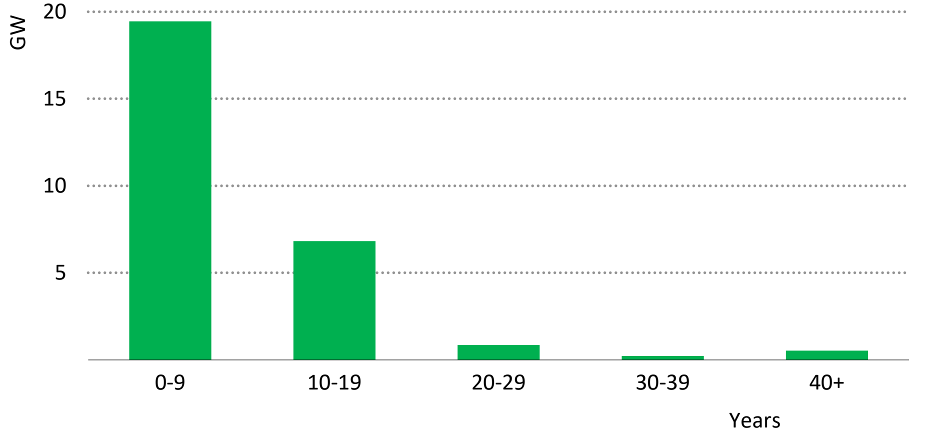
Since 2000, coal, hydro, natural gas and, most recently, solar PV have grown to meet rising demand; fossil fuels accounted for over half of electricity supply in Viet Nam in 2022

However, the high uptake of solar PV and wind has at the same time posed challenges for Viet Nam's electricity grid. Bottlenecks in the transmission and distribution systems have been hindering the expansion of renewables and resulted in significant curtailment.

Furthermore, the lack of an alternative pricing mechanism after the removal of the feed-in tariff that underpinned much of the earlier growth in capacity has led to some projects being unable to sell electricity to the grid. Corruption allegations and associated probes have also contributed to a marked slowdown in investments. As a result, utility-scale solar PV capacity additions have almost ceased since then. This highlights that boosting investment in grids and improving regulatory and governance frameworks plays a crucial role in supporting further deployment of renewables to decarbonise Viet Nam's electricity system.

With a share of over 40% of total electricity generation, coal remains the largest power source in Viet Nam. Moreover, the fleet of coal power plants is relatively young: of the total capacity of about 28 gigawatts (GW) of coal-fired power in the country in 2023, almost 70% was commissioned after 2015 (Figure 2.3). CO_2 emissions from coal doubled between 2014 and 2015, from around 35 Mt to 68 Mt, growing further to over 130 Mt in 2022. Currently coal alone is responsible for over 90% of CO_2 emissions from electricity generation in Viet Nam. Much of the existing coal fleet is expected to keep operating over the next few decades. Several coal plants are still under construction and expected to start operating by 2030. This illustrates the challenge associated with putting emissions from coal-fired electricity in Viet Nam into decline and highlights the need for comprehensive strategies to phase down coal use while meeting demand growth and ensuring a secure and affordable supply of electricity.

Figure 2.3 ▹ Coal capacity in Viet Nam by age of coal fleet, 2023



As of 2023, the majority of the coal-fired power plants in Viet Nam had been in operation for less than a decade

3 Recent policy developments

Since the 26th Conference of the Parties (COP26) in Glasgow in November 2021, Viet Nam has significantly increased its ambitions to peak and dramatically cut power sector CO_2 emissions, whilst ensuring a reliable, secure and affordable supply of electricity in the face of ongoing rapid electricity demand growth. PDP8, approved in May 2023, represents the keystone, setting out the country's increased ambition while presenting a detailed pathway for power sector development to 2030 and a longer-term vision to 2050.

Power Development Plan 8

The PDP8 aims to scale up the electricity supply in order to meet anticipated strong growth in electricity demand, underpinned by an average gross domestic product (GDP) growth of about 7% per year between 2021 and 2050. It also seeks to reduce the emissions intensity. The plan aims to keep the emissions from electricity generation about 204 Mt to 254 Mt in 2030, which could be reduced to 170 Mt if the JETP commitments are fully met.

In line with JETP commitments, coal-fired capacity in PDP8 is planned to peak at about 30 GW in 2030, down from 55 GW in the previous PDP. Beyond 2030, coal plants would have to close when they are 40 years old unless converted to run on ammonia or biomass. According to the plan, unabated coal is entirely phased out by 2050, with all remaining plants converted to either ammonia or biomass. Gas-fired power capacity (including liquefied natural gas [LNG]) is planned to reach almost around 37 GW by 2030, then slightly increase to about 40 GW in 2050. About 80% of gas-fired power capacity in the country is planned to be retrofitted for full hydrogen use by 2050. The biggest challenge associated with the large-scale conversion of power plants to hydrogen and ammonia will be obtaining the necessary fuels at an acceptable cost: in order to provide the required volumes to the power sector, the PDP8 foresees the construction of up to 240 GW of off-grid offshore wind capacity coupled directly to electrolysers for the production of low-emissions hydrogen and ammonia, along with new infrastructure for the transmission, distribution and storage of these fuels. Another potential issue is that the combustion of hydrogen and ammonia may result in higher nitrous oxide emissions, owing to higher flame temperatures for hydrogen and the fact that ammonia contains nitrogen. While potential solutions are currently at the demonstration stage, mitigating these emissions is an issue that has not yet been fully implemented at scale.

Significantly raising the share of variable renewables in the electricity mix is another key component of the plan. Wind, especially offshore wind, is planned to play a central role, reflecting the fact that Viet Nam is home to some of the best offshore wind resources in Southeast Asia. Viet Nam aims for an installed capacity of 6 GW of offshore wind and nearly 22 GW of onshore wind by 2030. This ramps up significantly towards 2050, to 60 GW to 77 GW of onshore wind and 70 GW to 90 GW of grid-connected offshore wind. The PDP8 also sees solar PV capacity additions pick up again, especially after 2030. By 2050, the installed capacity of solar PV is set to reach between 170 GW and 190 GW. This significant capacity growth is accompanied by a recognition that substantial investment in grids is needed to make this work.

One important regulation to facilitate the expansion of renewables is the decree (No. 80/2024/ND-CP) on the direct power purchase agreement mechanism published in July 2023. The decree allows direct transactions between renewables producers and large electricity consumers and is expected to play an important role in facilitating renewables expansion in Viet Nam.

National net zero commitment (2050)

As one of the world's most vulnerable countries to climate change, Viet Nam has demonstrated a strong commitment to climate action. At COP26 in Glasgow in 2021, Viet Nam announced its goal of reaching net zero emissions by 2050 and agreed internationally to transition away from unabated coal by 2040. The net zero target was enshrined in law when Viet Nam issued its National Climate Change Strategy (NCCS), adding a medium-term target (peaking emissions by 2032) and setting out detailed sectoral targets on the road to a net zero emissions economy.

International co-operation is a key element of the process. The Viet Nam government established a National Steering Committee two months after COP26 and kicked off several discussions on topics such as developing an action plan following COP26, reviewing and updating nationally determined contributions (NDCs), negotiating a JETP and completing the PDP8.

The NCCS defined national mid- to long-term emissions reduction targets for the different sectors of the economy. By 2030, it aims to reduce total greenhouse gas emissions by 43.5% compared with a business-as-usual scenario. Key measures to support the targets include attaining a renewables share of 33% in the electricity mix by 2030 and 55% by 2050. The document also recognises the importance of storage technologies, grid development and breakthrough technologies such as carbon capture and storage on the supply side. On the demand side, energy efficiency is key to achieve decarbonisation across all sectors.

Just Energy Transition Partnership

Marshalling the necessary finance to fulfil clean energy transition objectives can be challenging for emerging market and developing economies, as they tend to rely heavily on public investment by governments or state-owned enterprises. They face relatively high borrowing costs, and stepping up investment calls for multiple sources of finance: both domestic and international private finance have pivotal roles to play. Mobilising this capital requires international co-operation, involvement of international and development finance institutions, and reforms to domestic policy and regulatory frameworks that facilitate private investment.

JETPs, launched at COP26 in Glasgow in 2021, attempt to address this challenge. They are a financing co-operation mechanism between advanced economies and a coal-dependent emerging market and developing economy which commits to ambitious emissions reduction targets and defines a credible national transition pathway. The JETP framework includes multilateral development banks, national development banks and private lenders. The aim is to make available a mix of financing, some at concessional terms, with the goal of mobilising more resources by catalysing international private investment. JETPs also aim to reduce political and regulatory risks for clean energy investments by developing roadmaps for regulatory reforms.

The JETP between Viet Nam and the International Partners Group (IPG) was developed to support the country in pursuit of its target to reach net zero emissions by 2050. It was translated into national policy by Decision No. 1009/Qd-Ttg regarding Approval of the Project for the Implementation of the Political Declaration Establishing a Fair Energy Transition Partnership (31 August 2023). The JETP reflects Viet Nam's ambition to accelerate its transition to a carbon-neutral energy system, including its intention to bring about a peak in emissions by 2030, with power sector emissions not exceeding 170 Mt of carbon dioxide equivalent per year. In pursuit of this objective, Viet Nam aims to cease issuing permits for the construction of new coal-fired power plants, peaking installed coal capacity at no more than 30 GW; promote the development of renewables and boost their share in the electricity mix to 47% by 2030; and improve energy efficiency, while ensuring energy remains secure and affordable. The Viet Nam JETP aims to mobilise at least USD 15.5 billion over the next five years. Half of this, nearly USD 8 billion, consists of public sector finance backed by the IPG, with the remainder to be obtained through a combination of market-rate loans and private investment.

Another objective of the partnership is to help Viet Nam update its technical and regulatory frameworks in order to overcome barriers to investment, facilitate the deployment of support and mobilise further domestic and international capital to speed up the transition to net zero emissions. A major milestone for reaching these objectives was the release of the Viet Nam JETP Resource Mobilisation Plan (RMP) at the 28th Conference of the Parties (COP28) in November 2023. The RMP sets out investment needs, identifies priority investments, defines policy actions and regulatory reforms designed to enable and boost investments into renewables and other JETP-related projects, and establishes a framework for the monitoring and evaluation of progress towards the JETP objectives.

4 Methodology

This report presents four different transition pathways for Viet Nam's electricity sector derived using a set of interlinked models of Viet Nam's electricity system, building on the IEA's extensive modelling for the World Energy Outlook 2023.

Scenarios

The four scenarios describe different transition pathways for Viet Nam's electricity sector. They build on the foundation provided by PDP8 and aim to achieve or exceed the objectives laid out in PDP8 and Viet Nam's emissions reduction commitments under the JETP.

The **PDP8 Scenario** represents a full implementation of PDP8's capacity and generation targets for all electricity generating technologies to 2030 and the PDP8 vision to 2050, with electricity demand developing as projected for PDP8. It serves as a benchmark against which the other scenarios are compared.

The **Power Development Plan 8 + Energy Efficiency (PDP8+EE) Scenario** assumes that the evolution of the capacity mix will follow PDP8 to 2030, but that additional investments into energy efficiency temper demand growth relative to the PDP8 Scenario. Out to 2050, the shares of individual generating technologies in the electricity mix are assumed to correspond to those outlined in the PDP8's vision to 2050.

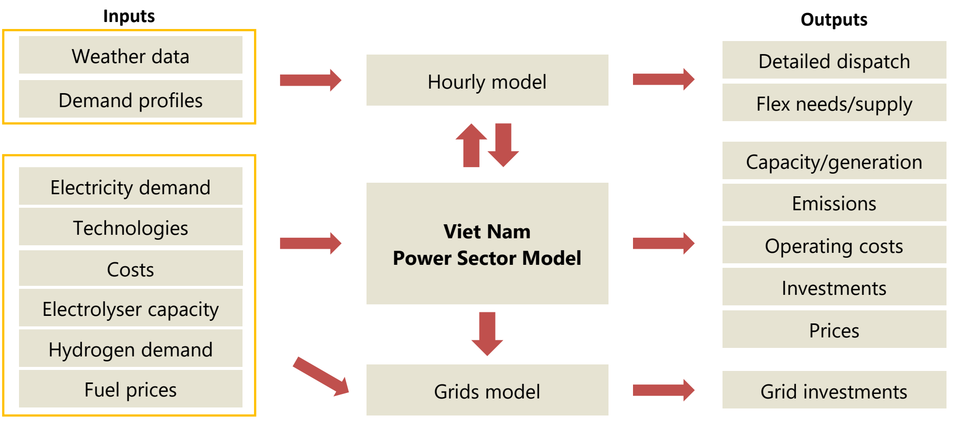
The **Power Development Plan 8 + Energy Efficiency and Low Hydrogen (PDP8+EE+LH) Scenario** presents a lower-cost pathway that achieves Viet Nam's emissions reduction targets, namely reaching net zero emissions by 2050 and meeting the JETP target of limiting power sector CO_2 emissions to 170 Mt by 2030. It assumes a slightly slower expansion of wind energy until 2030 and a much lower reliance on hydrogen and ammonia in the period from 2035 to 2050. The evolution of electricity demand is assumed to be identical to the PDP8+EE Scenario.

The **Net Zero Emissions by 2050 (NZE) Scenario** presents a plausible pathway for Viet Nam's power sector to reach net zero emissions five years earlier – in 2045 – in the context of a global, energy-system-wide transition to net zero emissions by 2050. Electricity demand grows faster than in the PDP8+EE Scenario and the PDP8+EE+LH Scenario, owing to an accelerated electrification of other sectors of the economy, such as transport and industry.

Modelling framework

The projections developed for the four scenarios were generated using three interlinked models. At the heart sits the purpose-built, technology-rich Viet Nam Power Sector Model, which is used to perform a year-by-year simulation of Viet Nam's power system, modelling the evolution of the capacity and generation mix, as well as emissions,[1] operating and investment costs. The Viet Nam Power Sector Model is linked to a grids model, which estimates grid expansion and replacement needs based on the development of electricity demand and the technology mix derived by the power sector model, and an hourly dispatch model, which is used to simulate the dispatch of the power plant fleet in detail, estimate system flexibility needs and "stress-test" the system for scenarios with very high shares of variable renewables (Figure 4.1).

Figure 4.1 ⊳ Schematic of Viet Nam modelling framework and data flows



The analysis is performed using three interlinked models

The models build on a comprehensive set of inputs, including a sector-by-sector, bottom-up assessment of Viet Nam's electricity consumption, and the analysis benefits from its close link to the IEA's Global Energy and Climate Model and the extensive work carried out for the World Energy Outlook 2023 (WEO 2023). Key inputs, such as technology costs, efficiencies and global fossil fuel prices (Table 4.1), are aligned with the WEO 2023. More information on the Global Energy and Climate Model, including on the bottom-up model of electricity demand, can be found in the documentation.

The hourly dispatch model is used to analyse the impact of weather-induced variability on power system operations and long-term flexibility needs in Viet Nam's power system, focusing on the year 2050 and the NZE Scenario, which represents the scenario with the highest share of variable renewables in the system. As this represents the scenario with the

[1] Only direct emissions of fuel combustion in power plants are accounted for in the projections. No offsets from land use, land-use change and forestry (LULUCF) are included. The only negative emissions technology included is bioenergy with carbon capture and storage (BECCS), which is deployed in the NZE Scenario.

greatest integration challenges, its insights can be applied to the other scenarios, which see lower shares of variable renewables by 2050, as well.

The hourly dispatch model is applied to quantify power system flexibility needs on timescales ranging from hours over days and weeks to seasons, and to identify how these needs can be met in a cost-optimal manner. It represents all hours in a year, setting the objective of meeting electricity demand in each hour of the year at the lowest possible cost, while respecting operational constraints. The model was built in Python using the Python for Power System Analysis (PyPSA) open-source Python environment for energy system modelling and is solved using linear optimisation, which ensures that power plants, energy storage technologies, demand response and electrolysers are operated in a way that minimises the total system cost (thus maximising their utility for the system).

Table 4.1 ▷ Fossil fuel import price assumptions for Viet Nam by scenario, 2022, 2030 and 2050

		PDP8, PDP8+EE and PDP8+EE+LH Scenarios		NZE Scenario	
Real terms (USD 2022)	**2022**	**2030**	**2050**	**2030**	**2050**
IEA crude oil (USD/barrel)	98	85	83	42	25
Natural gas (USD/MBtu)	14.4	7.0	4.9	4.0	3.7
Steam coal (USD/tonne)	65	58	48	49	39

Notes: MBtu = million British thermal units. The IEA crude oil price is a weighted average import price among IEA member countries. Natural gas prices reflect a weighted average of domestic production and LNG imports expressed on a gross calorific value basis. Coal prices are weighted averages adjusted to 6 000 kilocalories per kilogramme. In the NZE Scenario, a rapid decline in the global consumption of oil, natural gas and coal leads to a faster drop in the prices of these commodities. For more information, please consult the WEO 2023.

Production profiles for wind, solar PV and run-of-river hydro, as well as inflow profiles for reservoir hydro, were generated using the Atlite open-source Python library, which provides functions that convert weather data such as wind speeds, solar irradiance, temperature and run-off into hourly wind power, solar power, run-of-river hydro power and hydro reservoir inflow. Demand profiles are developed at the hourly resolution for each electricity end use, to properly reflect the impact of the full scope of demand-side integration measures. Load profiles are derived from historical load and temperature data along with survey data where available.

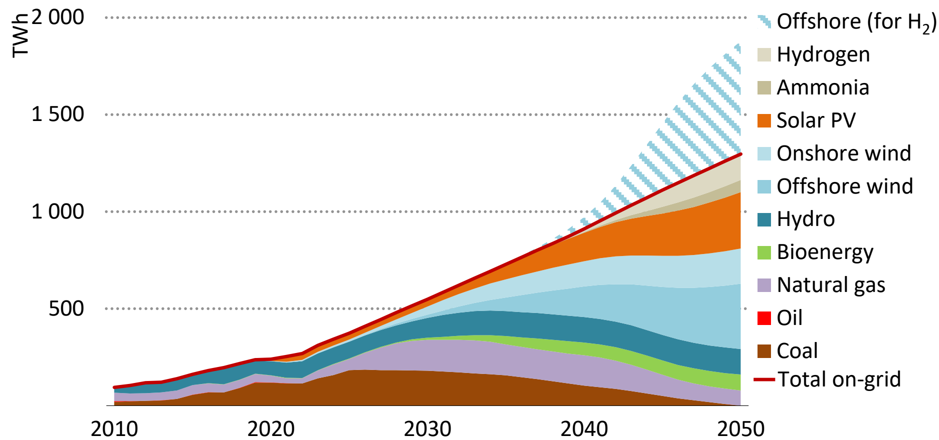
To assess the potential variability of weather-dependent renewables and temperature-dependent demand across years and capture extreme events, weather data for 30 historical weather years (1987-2016) were obtained from the ERA5 reanalysis dataset of the European Centre for Medium-Range Weather Forecasts (ECMWF). The model includes a detailed representation of reservoir and pumped storage hydro, as well as temperature-sensitive demand and demand response, hydrogen electrolysers, and hydrogen storage. Hydro reservoir and pumped storage dispatch is constrained by water levels in reservoirs, with natural inflows derived based on run-offs and hydrological basins for each hydropower plant.

To model the possible interactions between the electricity and hydrogen systems, the model optimises the operation of grid-connected electrolysers, hydrogen storage and thermal power plants using hydrogen, while considering hydrogen production from off-grid electrolysers connected to dedicated renewables as well as demand profiles for other uses of hydrogen. To assess the impact of transmission constraints, Viet Nam’s electricity system is divided into seven nodes, with the exchange of electricity between the nodes limited by the maximum transmission capacity.

5 Power Development Plan 8 Scenario

PDP8 provides a blueprint for the transformation of Viet Nam's electricity sector, away from a strong reliance on dispatchable coal, hydro and natural gas, towards a low-emissions electricity system characterised by high shares of variable wind and solar PV, most notably wind, while accommodating high electricity demand growth.

Figure 5.1 ▹ Electricity generation by source in Viet Nam in the PDP8 Scenario, 2010-2050



Coal is expected to peak in the mid-2020s; higher uptake of renewables, notably offshore wind, plays a significant role in meeting growing electricity demand towards 2050

Note: Offshore (for H_2) refers to offshore wind farms dedicated to the production of hydrogen and ammonia and not connected to the grid.

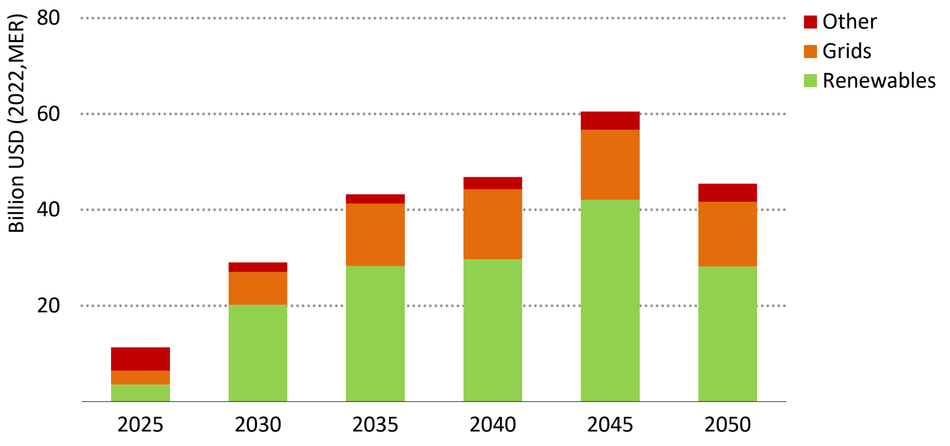
In the PDP8 Scenario, total electricity generation reaches around 1 300 TWh by 2050, rising from around 380 TWh by 2025 and 550 TWh by 2030. On top of that, almost 600 TWh are generated by offshore wind farms that are dedicated to hydrogen production and are not connected to the grid by 2050 (Figure 5.1). The huge rise in the share of wind and solar PV in total on-grid generation in this scenario, which increases from 18% in 2030 to 62% in 2050, fundamentally reshapes the power system. Generation from wind and solar PV more than doubles by 2030 and increases twenty-fold by 2050. Electricity generation from wind shows significant increase from 9 TWh in 2022 to around 520 TWh in 2050. Offshore wind surpasses onshore wind in late 2030s and becomes the leading generation source after 2040.

Hydropower remains the largest source of renewable electricity until 2030, when it is surpassed by wind and solar PV combined. Hydro generation gradually increases to 103 TWh by 2030 and remains at around 130 TWh per year after 2040. Hydropower increasingly supports the integration of variable renewables by providing flexibility across timescales ranging from days to seasons.

Unabated coal-fired power generation plateaus between the late 2020s and early 2030s and is gradually phased down afterwards as plants are either decommissioned or converted to ammonia or biomass. Plants with a lifespan of more than 40 years are shut down if a conversion to low-emissions fuels is not feasible. As demand continues to grow, the share of coal-fired power generation starts to decrease from about 41% in 2022 to 33% in the early 2030s, and a complete phase-out by 2050. Unabated natural gas-fired generation is set to grow rapidly in the near term, reaching a share of 30% in the late 2020s, as additional LNG-fired capacity is commissioned. Unabated gas-fired generation peaks in the early 2030s.

After 2040, an increasing number of gas plants are retrofitted to use hydrogen once the technology is ready, but gas remains an element of the generation mix until 2050. Beyond 2035, ammonia and hydrogen are envisioned to play an increasingly important role as dispatchable sources of low-emissions electricity. Their combined share in the electricity mix increases to about 15% in 2050. The ammonia and hydrogen used in the power sector is produced largely by off-grid electrolysers that are powered by dedicated offshore wind farms. By 2050, this will require the installation of over 130 GW of additional offshore wind capacity.

Figure 5.2 ▻ Investment spending in Viet Nam by type in the PDP8 Scenario, 2025-2050



In the PDP8 Scenario, power sector investment needs peak at over USD 60 billion per year by 2045

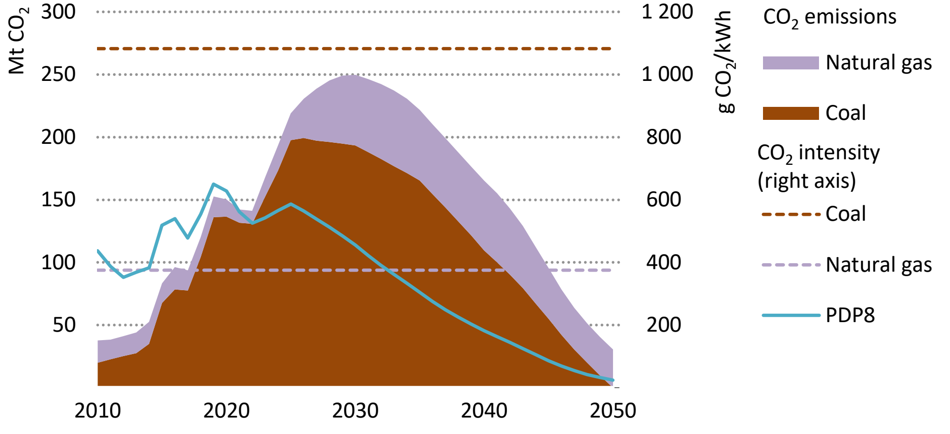
Notes: MER = market exchange rate. Other includes thermal power plants and batteries.

Fulfilment of the PDP 8 will require a substantial increase in investments into renewables, electricity grids, and other generating technologies such as thermal power plants and battery storage systems over the next decades. PDP8 underlines the necessity of enhancing

Viet Nam's policy and regulatory frameworks and developing a competitive electricity market to help mobilise the required investments.

Until the mid-2020s, most investment is directed to new thermal plants, most notably new LNG-fired power plants and additional coal capacity. However, the planned growth in wind capacity in particular means that by 2030, renewables will receive the lion's share of investments, followed by grids, which need to be strengthened and expanded to accommodate an increasing share of variable renewables and rise in peak electricity demand. Total power sector investment peaks at above USD 60 billion per year in 2045, which is about 15 times higher than average annual power sector investments over the 2018 to 2022 period, when solar PV and wind installations first surged (Figure 5.2). The great majority of the additional investments needed over the period to 2050 are associated with renewables, accounting for an average of about 65% of total power sector investments between 2030 and 2050, and grids, while investments into other generating technologies remain broadly stable across the outlook period.

Figure 5.3 ⊳ Annual power sector CO_2 emissions and emissions intensity of the electricity mix in Viet Nam in the PDP8 Scenario, 2010-2050



Power sector CO_2 emissions peak in 2030; switching from coal to natural gas as well as the high uptake of renewables accelerate decarbonisation

Note: g = grammes; kWh = kilowatt-hour.

Over the past 20 years, power sector CO_2 emissions have been increasing mainly because of the strong growth in coal-fired power to meet the fast-growing electricity demand. The PDP8 Scenario sees power sector CO_2 emissions in Viet Nam peaking at around 250 Mt in 2030, more than 1.5 times above their 2022 level of about 140 Mt (Figure 5.3). After 2030, power sector CO_2 emissions rapidly decrease by 10% per year on average to 30 Mt CO_2 in 2050.

CO_2 emissions from coal are projected to reach their peak in the late 2020s and enter a steep decline after 2030, until unabated coal is completely phased out by 2050, with plants retiring after 40 years of operations unless converted to co-fire ammonia and biomass.

While coal-to-gas switching plays an important role in limiting the increase in CO_2 emissions to 2030, emissions from natural gas-fired generation too peak at around 60 Mt CO_2 in the early 2030s and then decline as the expansion of renewables accelerates. As coal is completely phased out by 2050, natural gas becomes the largest source of CO_2 emissions from the power sector in the late 2040s, and gas-fired power plants are responsible for the residual emissions of 30 Mt CO_2 in 2050.

Technology costs in Viet Nam have evolved over time as a function of several factors relating to the cost of manufacturing, installation, availability of critical minerals and overall market maturity, and continue to do so through to 2050 in the PDP8. Technology costs are important in determining the most cost-effective technologies to be built to meet the electricity demand. Capital costs for solar PV and wind are based on data from the International Renewable Energy Agency (IRENA), whereas assumptions for coal and gas power plants are based on surveys. These cost assumptions are broadly aligned in the latest Viet Nam Technology Catalogue for Power Generation. Today, open-cycle gas turbines remain one of the least-cost options for new power plants in Viet Nam, followed by combined-cycle gas turbines (Table 5.1). Solar PV is the next least-cost option, having already surpassed coal-fired generation in terms of cost-competitiveness. Although offshore wind, at nearly three-and-a-half times the cost of solar PV, is still relatively expensive today, onshore wind is already lower-cost than hydro. It should be noted that these are estimates based on real-world projects in Southeast Asia, but in practice factors such as regulatory uncertainty, for instance relating to the frameworks governing the integration of solar PV or wind into the electricity system, can make certain technologies less competitive because investors require higher returns to compensate for the additional risk.

Through to 2050, capital costs of coal- and gas-fired plants remain constant in the PDP8 Scenario due to their technological maturity and low reliance on critical minerals that might otherwise increase the risk of cost volatility. In contrast to this, renewables such as solar PV and wind – costs of which have already come down by more than 4 times and 1.5 times respectively over the past decade – continue to decline in the PDP8 Scenario, with both solar PV and offshore wind capital costs both around 25% lower by 2030 and over 50% lower by 2050 compared with 2023 levels, driven by declining manufacturing and installation costs, as well as further technology improvements. However, there remains uncertainty about how these cost-related factors will evolve for certain technologies. As a result, plans to 2050 should remain flexible to account for this, with a broad range of technology choices available.

As technology costs and the electricity mix continue to change in Viet Nam in the PDP8 Scenario, the levelised cost of electricity (LCOE) of each technology also changes accordingly. To 2030, the LCOE of coal- and gas-fired power plants declines, as rising capacity factors and relatively stable fuel prices push down the cost per unit of electricity. After 2035, however, as these power plants are increasingly retrofitted for use with hydrogen-based fuels – with

80% of the remaining gas fleet converted to hydrogen and 100% of the remaining coal fleet converted to ammonia or biomass by 2050 – their LCOE increases substantially due to the switch to these fuels, which are several times more expensive. Until 2050 in the PDP8 Scenario, unabated coal-fired power plants are phased out completely, while the LCOE of unabated combined-cycle gas turbines is about 20% higher than in 2023 owing to reduced running hours in a power system characterised by high shares of renewables.

Table 5.1 ▷ Capital costs and LCOE for selected technologies in Viet Nam in the PDP8 Scenario, 2022, 2030 and 2050

Technology	Capital costs (USD/kW)			LCOE (USD/MWh)		
	2023	2030	2050	2023	2030	2050
Coal (unabated)	1 600	1 600	1 600	85	60	N/A
Natural gas CCGT (unabated)	700	700	700	80	70	75
Natural gas OCGT (unbated)	400	400	400	155	145	145
Solar PV	1 080	830	520	85	65	35
Wind onshore	1 870	1 750	1 630	80	75	70
Wind offshore	3 690	2 690	1 750	135	95	55
Hydro	2 100	2 100	2 090	80	80	75

Notes: kW = kilowatt; MWh = megawatt-hour; CCGT = combined-cycle gas turbine; OCGT = open-cycle gas turbine. All costs are in USD 2022. The LCOE is calculated using a weighted average cost of capital (pre-tax, in real terms) of around 6% for solar PV, onshore wind and offshore wind, 8% for hydro and 7% for all other technologies.

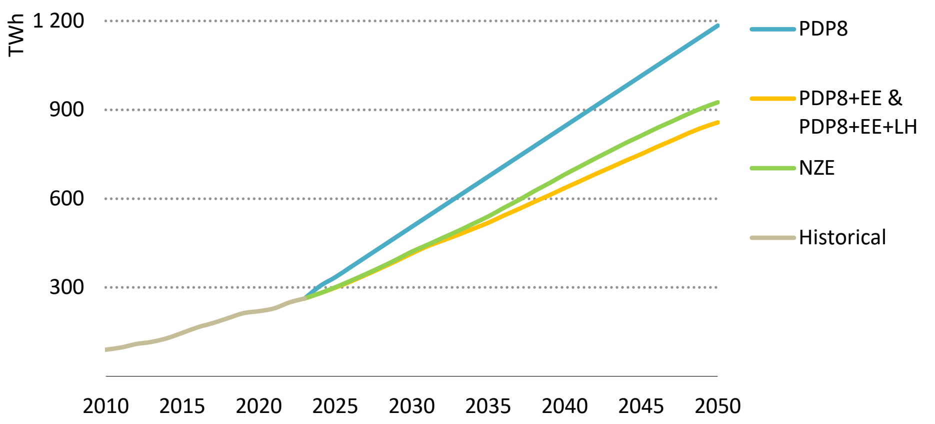
The outlook to 2050 in the PDP8 Scenario looks quite different for renewables, whose LCOEs continue to decline steadily from 2023 levels. The decrease in capital costs for solar PV and wind contributes significantly to the reduction of their LCOE due to their lack of fuel costs and comparatively small operating and maintenance expenses. By 2030, the LCOE of both new solar PV and offshore wind is at least 25% lower, with this gap widening to over 50% by 2050 when compared with 2023 levels. While the reduction of the LCOE of onshore wind is smaller, by 2050 it still declines by more than 10% relative to 2023 (Table 5.1). Although the LCOE remains limited in its ability to fully capture the value added to the power system for each technology, it does provide insight here as to the ways in which renewables compare with other technologies in the Viet Nam power mix.

6 Electricity demand outlook

Viet Nam has experienced strong electricity demand growth over the last two decades, growing by an average of 10% year-on-year, exceeding GDP growth, which amounted to 6% per year between 2002 and 2022. While industrial electricity demand has risen most of all, growing affluence has resulted in increasing residential and service sector electricity demand as well. The country has attained near universal access to electricity, a great success story.

All scenarios see strong demand growth continuing over the next 25 years (Figure 6.1), with electricity demand rising from around 250 TWh in 2022 to 415 TWh in 2030 and 860 TWh in 2050 in the PDP8+EE Scenario and the PDP8+EE+LH Scenario, driven mainly by continuing growth in industrial electricity demand, in particular from manufacturing, and rising air-conditioner uptake. In the NZE Scenario, which assumes a more rapid decarbonisation of the global energy system, resulting in an accelerated transition in Viet Nam as well, demand grows even more strongly as road transport is electrified more rapidly and hydrogen production in industry ramps up faster. As a result, electricity demand in 2050 is nearly 10% higher than in the PDP8+EE+LH Scenario and the PDP8+EE Scenario.

Figure 6.1 ▹ Electricity demand in Viet Nam by scenario, 2010-2050



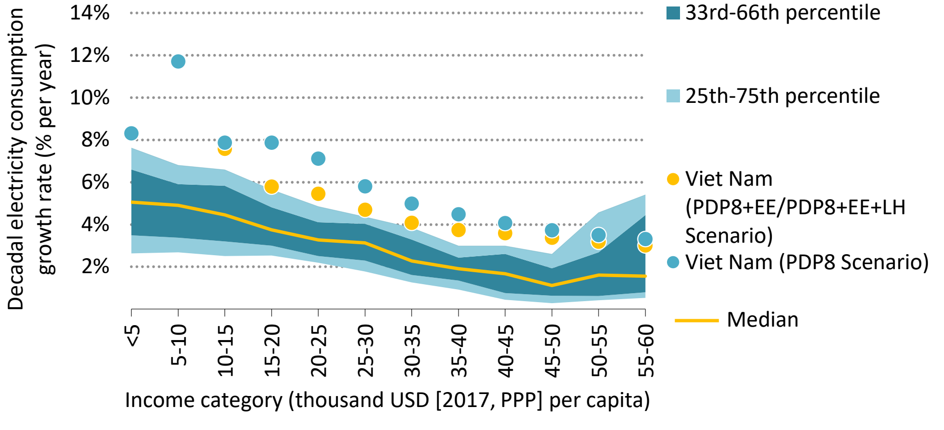
Electricity demand growth in the PD8+EE and PDP8+EE+LH Scenarios follows current trends, while additional electrification leads to slightly faster growth in the NZE Scenario

Viet Nam's own PDP8 assumes even stronger electricity demand growth moving forward, an acceleration compared with even the rapid increase witnessed over the last two decades. However, there are factors which suggest that future demand growth could be lower than assumed by PDP8, which are reflected in the IEA's own modelling of Viet Nam's future electricity demand. Most notably, the increasing efficiency of electricity end uses has the potential to temper demand growth, while supporting similar levels of economic growth and rising living standards, as shown in the following subsections.

Rising efficiency and its impact on electricity demand growth

The IEA's demand projections for Viet Nam see electricity demand grow less strongly than assumed in PDP8, while delivering similar levels of economic growth. Looking at countries across the world, historical experience suggests that the trajectory for economic growth set out in PDP8 might in fact result in lower electricity demand growth. When compared with other countries at similar levels of GDP per capita, Viet Nam has historically seen very significant increases in electricity demand in relation to GDP growth – more so than most other countries around the world. The electricity demand growth assumed in PDP8 would see Viet Nam remain a global outlier, outside the 25th-75th percentile of the historically observed relationship between decadal electricity demand growth and income level expressed through GDP per capita. In the PDP8 Scenario, electricity demand remains far above the global average of countries at similar levels of GDP per capita and moves towards the global average only once Viet Nam attains advanced economy status around 2050. In the PDP8+EE+LH Scenario and PDP8+EE Scenario, by contrast, electricity demand grows less aggressively, more in line with what has historically been observed in countries at similar levels of economic development, albeit still at the upper end of the distribution and significantly above the median (Figure 6.2).

Figure 6.2 ▻ Relationship between electricity demand growth and GDP per capita in Viet Nam compared with international experience



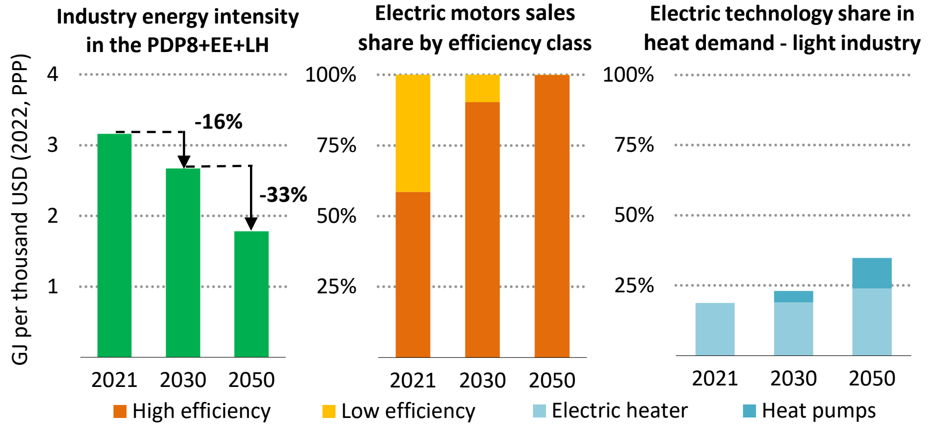
Viet Nam has historically seen exceptionally high electricity demand growth in relation to its GDP per capita

Notes: PPP = purchasing power parity. The median and distribution of decadal electricity demand growth by income category has been calculated using the GDP per capita and electricity demand of 127 countries globally for the period from 1971 to 2017. The results presented for Viet Nam include the projection period to 2050.

The mechanisms through which rising GDP per capita translates to a lower energy intensity per unit of GDP per capita are the proliferation of more efficient technologies and appliances in the industrial, residential and service sectors, and a shift of economic activity towards lower energy intensity but higher value-added activities such as high-tech manufacturing and professional services.

Thanks to the removal of old and inefficient boilers and motors in conjunction with the deployment of more advanced technologies, the energy intensity of industry (expressed as industrial energy use per unit of value added by industry) decreases notably in the PDP8+EE+LH Scenario and PDP8+EE Scenario, dropping by 16% until 2030 and another 33% between 2030 and 2050. Electric motors account for more than half of industrial electricity demand today. The demand projections undergirding the PDP8+EE Scenario, PDP8+EE+LH Scenario and NZE Scenario assume that older, lower-efficiency motors are rapidly replaced by more efficient ones, driving down the electricity requirements of machinery. In light industries today, electric boilers meet a fifth of the demand for process heat. Moving forward, most of the incremental low- and medium-temperature process heat demand is met by heat pumps, which are three to five times more efficient than electric heaters (Figure 6.3).

Figure 6.3 ▷ Efficiency gains in industry in Viet Nam in the PDP8+EE+LH Scenario, 2021, 2030 and 2050

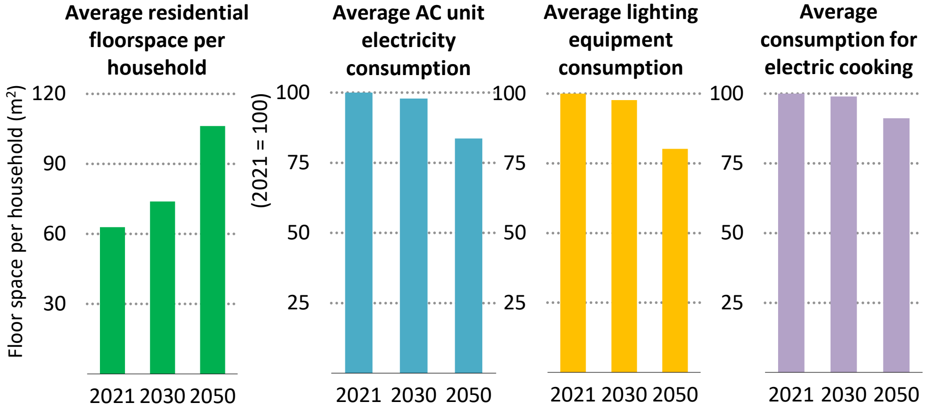


A shift towards more efficient motors and electric heat pumps helps slow down growth in industrial electricity consumption

Note: GJ = gigajoules.

Growth in electricity demand in the buildings sector is also curbed by energy efficiency improvements, enabled by the increasing installation of best-in-class air-conditioning units, the widespread adoption of light-emitting diodes (LEDs) for lighting and the rising proliferation of more efficient electrical cooking equipment (e.g. vitro-ceramic or induction hobs). In the PDP8+EE Scenario, PDP8+EE+LH Scenario and NZE Scenario, the average floor space per household rises to 75 square metres, 29 million air-conditioning units are installed in residential buildings, half of households are cooking with electricity, and LEDs are ubiquitous for lighting by 2030. The trend towards the adoption of more efficient electrical appliances continues afterwards (Figure 6.4).

Figure 6.4 ▷ Efficiency gains in the residential sector in Viet Nam in the PDP8+EE+LH Scenario, 2021, 2030 and 2050



As household wealth increases, the rising adoption of more efficient appliances helps temper electricity demand growth in the residential sector

Note: m^2 = square metre; AC = air conditioning.

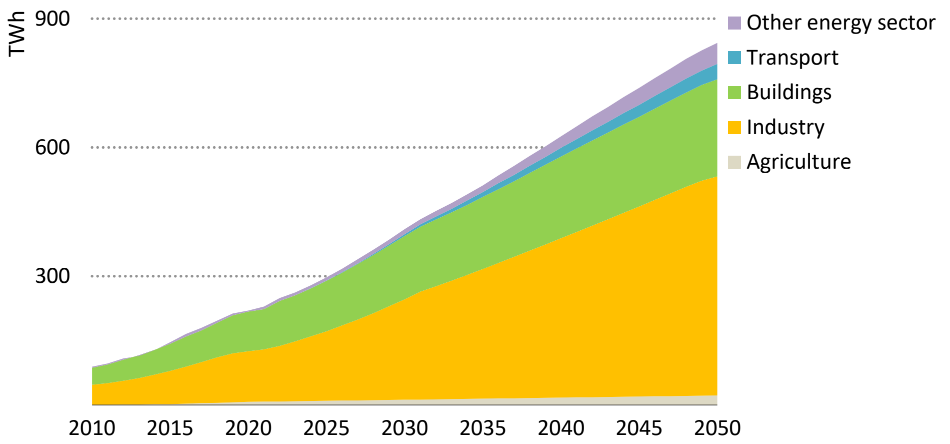
The more rapid uptake of more energy-efficient technologies in the PDP8+EE Scenario and PDP8+EE+LH Scenario relative to the PDP8 Scenario comes with additional investments of USD 13 billion over the 2023 to 2030 period and USD 100 billion over the 2031 to 2050 period. Driven by higher electrification, investments into technologies that reduce electricity demand or consume electricity more efficiently are even higher in the NZE Scenario, more than 50% above the level observed in the PDP8+EE Scenario and PDP8+EE+LH Scenario for the 2023 to 2050 period. However, while these are significant sums, on the order of 15% of total power sector investments in the PDP8+EE+LH Scenario, our projections show that the savings realised by these energy efficiency measures will be several times greater than their cost. This is presented in more detail in Section 10 below. The key role of energy efficiency in enabling cost-effective power sector transitions and lowering energy costs is also highlighted in the Vietnam Energy Outlook Report, published by the Electricity and Renewable Energy Authority (EREA) and the Danish Energy Agency (DEA) in June 2024.

Evolution of electricity demand by sector

Over the course of the last decade, industry, in particular light industry, accounted for more than half of electricity demand growth, which was driven by an expansion of food, machinery and textile manufacturing, alongside steel and aluminium production. In 2022, industry accounted for 52% of final electricity consumption, followed by the buildings sector with over 40%.

In the PDP8+EE+LH Scenario and PDP8+EE Scenario, electricity demand continues to grow strongly over the outlook period, rising to over 400 TWh by 2030 and over 850 TWh by 2050. The projection sees light industries, most importantly manufacturing, remain the primary contributor to electricity demand growth over the outlook period. The proliferation of more efficient equipment and appliances reduces the pace of demand growth in industry, as well as in the residential and service sectors. However, between 2030 and 2050, the reduction in the pace of demand growth due to rising efficiency in traditional applications is partially compensated for by growing demand from new applications, such as electric vehicles in the transport sector and hydrogen production in industry (Figure 6.5).

Figure 6.5 ▹ Electricity demand by sector in Viet Nam in the PDP8+EE+LH Scenario and PDP8+EE Scenario, 2010-2050



Industry remains the primary driver of electricity demand growth. Electric vehicles and hydrogen production (other energy sector) emerge as additional drivers after 2030

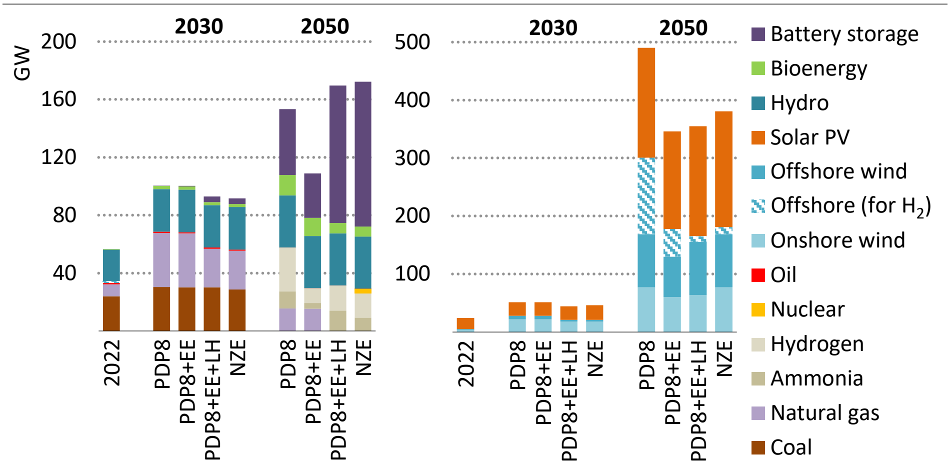
7 Electricity supply outlook

Across scenarios, the electricity supply in Viet Nam undergoes significant changes, moving from a majority fossil fuel-based power system today to one centred on renewables by 2050. While pathways differ in which technologies and fuels are relied on most heavily, all scenarios diverge strongly from the power system of today, with high ambitions towards full decarbonisation by mid-century. The resulting differences in these choices are reflected in installed capacities as well as electricity generation, with implications for investment, affordability and ultimately emissions.

Installed capacity

To 2030, installed capacities in Viet Nam increase for nearly all generation technologies across all scenarios (Figure 7.1). As set out in PDP8, coal capacity climbs to a peak of 30 GW in the PDP8 Scenario, PDP8+EE Scenario and PDP8+EE+LH Scenario as an additional six coal projects currently under construction or in an advanced stage of planning are completed, with no further additions beyond that.

Figure 7.1 ▹ Installed capacity of dispatchable (left) and variable renewable electricity sources (right) by scenario, 2022, 2030 and 2050



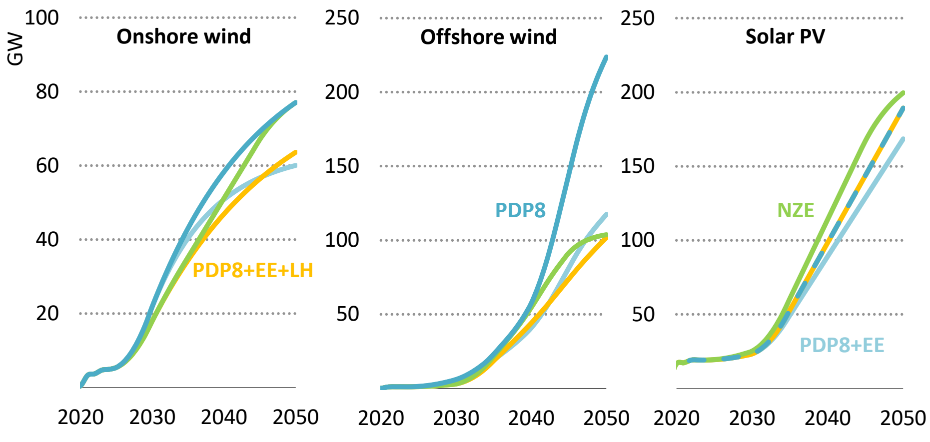
In Viet Nam, the installed dispatchable capacity triples to 2050, with nearly half of it provided by batteries in the PDP8+EE+LH Scenario and NZE Scenario

Note: Offshore (for H_2) refers to offshore wind farms dedicated to the production of hydrogen and ammonia and not connected to the grid.

Natural gas is the fastest-growing source of dispatchable capacity to 2030, rising from around 8 GW in 2022 to 37 GW in 2030 in the PDP8 Scenario and PDP8+EE Scenario, in line with the planning outlined in PDP8, with gas overtaking both coal and hydro to become the largest source of dispatchable capacity. Capacity grows less strongly in the PDP8+EE+LH Scenario and the NZE Scenario, to 27 GW in 2030, reflecting a lower need for peaking capacity as electricity demand grows less rapidly than in the PDP8 Scenario.

Renewables continue to rise as well. In all four scenarios, an additional 7.5 GW of hydro capacity are installed until 2030, retaining its position as the second-largest source of dispatchable capacity in the PDP8+EE+LH Scenario and becoming the largest in the NZE Scenario. Offshore wind ramps up quickest in the PDP8 Scenario and the PDP8+EE Scenario, where 6 GW are added until 2030 (Figure 7.2). In the PDP8+EE+LH Scenario and NZE Scenario, offshore capacity grows more slowly, anticipating that putting an appropriate regulatory framework in place and establishing local offshore wind supply chains will likely take more time. In the two scenarios, installed offshore wind capacity grows to 3 GW by 2030. In line with the objectives laid out in PDP8, onshore wind capacity increases significantly in the PDP8 Scenario and the PDP8+EE Scenario, exceeding 20 GW by 2030. Solar PV has experienced significant growth in recent years, but the PDP8 foresees only modest growth until 2030, mostly from rooftop solar. This is reflected in the PDP8 Scenario, the PDP8+EE Scenario and PDP8+EE+LH Scenario, while the NZE Scenario recognises that there is significant upward potential for rooftop solar PV, with an additional 2 GW installed to 2030 compared with the other scenarios. Since solar can be deployed quickly, with enabling regulation in place, growth to 2030 could be even faster, as outlined in the Viet Nam Energy Outlook Report (2024).

Figure 7.2 ▷ Installed onshore wind, offshore wind and solar PV capacity in Viet Nam by scenario, 2020-2050



The PDP8 Scenario has twice as much offshore capacity by 2050 as the PDP8+EE Scenario, PDP8+EE+LH Scenario and NZE Scenario, much of it dedicated to hydrogen production

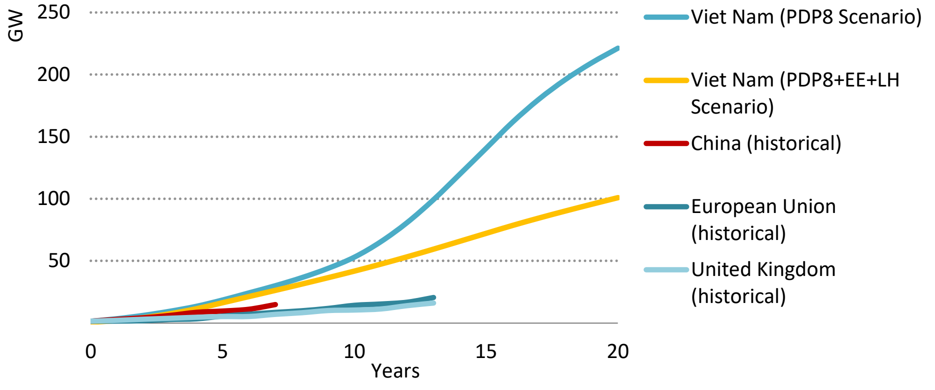
Note: Offshore wind includes both grid-connected offshore wind farms and non-grid connected dedicated to the production of hydrogen and ammonia.

Beyond 2030, coal-fired plants in the PDP8 Scenario face two distinct paths, with some retired after 40 years of operation, while others undergo conversion to co-fire and ultimately switch completely to ammonia or biomass by 2050. In the PDP8 Scenario, these retrofitted plants contribute 15 GW to the capacity mix by 2050. Similarly, a significant fraction of natural gas-fired plants in the PDP8 Scenario are retrofitted for co-firing with hydrogen, retrofitting 80% for full hydrogen use by 2050, with the remaining fleet continuing as traditional natural gas-fired capacity. In the PDP8+EE Scenario, the same approach of retrofitting coal- and gas-fired capacities is followed, while in the PDP8+EE+LH Scenario and NZE Scenario less of the coal- and gas-fired fleet remains online, with all remaining capacity retrofitted for 100% ammonia or hydrogen use. Whereas these plants generate much less electricity than in the PDP8 Scenario, they get called on when the system is tight, providing essential secure capacity to maintain the power supply adequacy. Nuclear power becomes a small part of the cost-effective mix in the NZE Scenario by 2050, as accelerated development to reach a global doubling of nuclear capacity drives innovation and cost reductions, including for small modular reactors.

For renewables, solar PV and wind capacities rise rapidly to 2050, with a combined installed capacity two times larger than all combined dispatchable capacity by 2050 in the PDP8+EE+LH Scenario and NZE Scenario. In the PDP8 Scenario, offshore wind goes furthest with around 225 GW in 2050, the majority of which is dedicated to hydrogen production by electrolysis, while in other scenarios offshore wind still reaches an impressive 100 GW. Onshore wind climbs steadily as well after 2030, where both the PDP8 Scenario and NZE Scenario near 80 GW by 2050. Solar PV sees robust expansion across scenarios to 2050, with the PDP8+EE+LH Scenario meeting PDP8 levels of 190 GW and highest in the NZE Scenario where additional rooftop solar PV capacities propel it to reach 200 GW. Battery storage grows alongside renewables across all scenarios. It is highest in the PDP8+EE+LH Scenario and NZE Scenario, reaching 95 GW and 100 GW respectively by 2050 to complement solar PV in providing flexibility and secure capacity. Hydro retains its position as an important dispatchable capacity, with around 36 GW across scenarios by 2050.

The growth of offshore wind in PDP8's vision to 2050 is highly ambitious. Compared with recent growth rates in key offshore wind markets globally, the increase envisaged in the PDP8 would far exceed what has so far been achieved in the People's Republic of China, the European Union and the United Kingdom (Figure 7.3). Over the past ten years, the European Union has installed around 15 GW of offshore wind and the United Kingdom around 12 GW, whereas the PDP8 would, starting from 2025, see more than 21 GW installed in the same ten-year development time frame. By 2050, the PDP8 level of offshore wind additions would make Viet Nam one of the largest markets worldwide, a commendable feat especially taken in context with the comparative size of its economy. In the PDP8+EE+LH Scenario, very strong growth is also realised, reaching 100 GW of installed capacity by 2050, beyond the installed capacity of any country today. While this annual capacity expansion is still more ambitious than other leading markets, it remains broadly stable throughout the period to 2050 compared with the PDP8 Scenario, where growth continues to accelerate.

Figure 7.3 ▷ Cumulative offshore wind capacity additions in Viet Nam by scenario compared with international experience



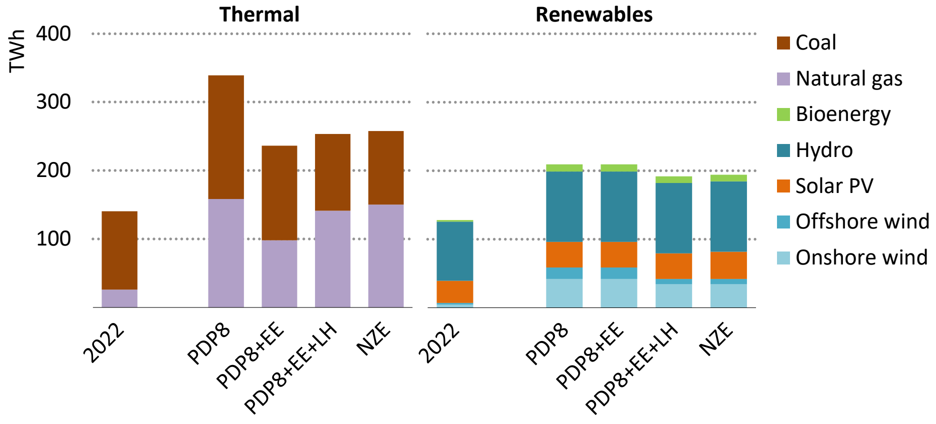
While the PDP8+EE+LH Scenario sees less than half as much offshore wind added as PDP8, even this pace of deployment is more ambitious than what has historically been achieved in major markets

Note: The cumulative additions are counted from when 1 GW installed capacity is exceeded.

Electricity generation

The electricity generation in Viet Nam undergoes major changes to 2050 across all scenarios, moving from a system with over 50% of generation today from fossil fuels to a renewables-based one. Nonetheless, fossil fuel-based generation increases strongly to its peak in 2030 across scenarios (Figure 7.4). Coal-fired generation dominated fossil fuel electricity generation in 2022, accounting for nearly 80% of thermal generation and 41% of total electricity generation. By 2030, coal-fired generation is over 60% higher than 2022 levels in the PDP8 Scenario, and nearly 25% higher in the PDP8+EE Scenario, while it remains at a current level in the PDP8+EE+LH Scenario, compared with a decrease of 3% in the NZE Scenario. Natural gas expands rapidly to 2030 across scenarios, increasing more than fivefold from 2022 levels in the PDP8 Scenario, NZE Scenario and PDP8+EE+LH Scenario, while slightly slower growth, but still a fourfold increase, in the PDP8+EE Scenario. Until 2030, renewables generation increases by nearly 60% in the PDP8 Scenario and PDP8+EE Scenario and by about 45% in the PDP8+EE+LH Scenario and the NZE Scenario, driven by an ambitious expansion of installed capacity led by solar PV and wind. In the PDP8+EE+LH Scenario and NZE Scenario, this rise of renewables along with some coal-to-gas switching allows for the JETP emissions target of 170 Mt CO_2 by 2030 to be met (see section on emissions below).

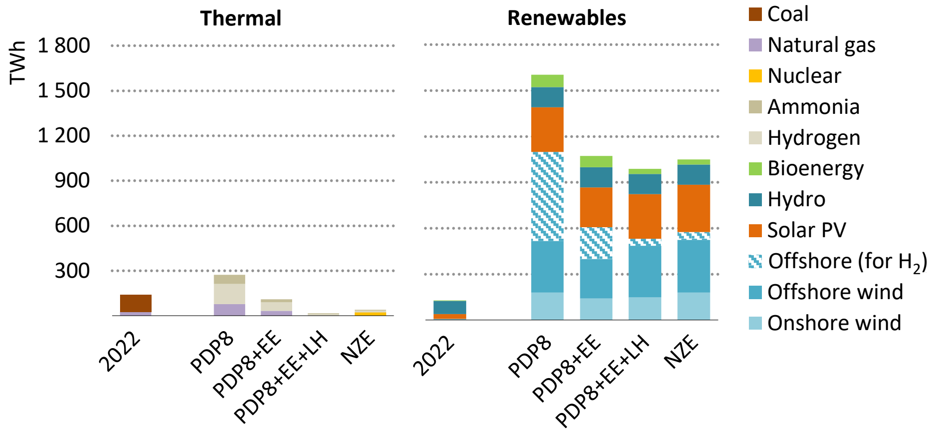
Figure 7.4 ▷ Electricity generation in Viet Nam by source and scenario, 2022 and 2030



Coal- and natural gas-fired generation peaks around 2030 in all scenarios, while generation from renewables rises considerably

After 2030, pathways for fossil fuel-based generation diverge between scenarios. Most coal-fired plants continue operations through the 2030s before being either largely retired, as seen in the PDP8+EE+LH Scenario and NZE Scenario, or retrofitted for use with ammonia and biomass, as in the PDP8 Scenario and the PDP8+EE Scenario. While both the NZE Scenario and PDP8+EE+LH Scenario make use of ammonia-fired generation, they show that its role can be smaller in a decarbonised power system. By 2050, across scenarios, unabated coal-fired generation is completely phased out, with the remaining plants running entirely on ammonia and biomass. Natural gas-fired plants are increasingly retrofitted to co-fire hydrogen in increasing shares in all scenarios. However, while in the PDP8+EE+LH Scenario and NZE Scenario, the entire fleet is converted to hydrogen by 2050, the PDP8 Scenario and the PDP8+EE Scenario leave room for some unabated natural gas-fired generation. This means that in both scenarios, natural gas-fired generation in 2050 is larger in absolute terms than in 2022 (about 2.5 times in the PDP8 Scenario and 1.1 times in the PDP8+EE Scenario Scenario), which means that the power sector itself is not fully decarbonised. In the NZE Scenario, nuclear power becomes another dispatchable low-emissions option for the power system, similar to the role that hydro continues to play across scenarios. However, the most significant change to system after 2030 across scenarios is the meteoric rise of solar PV and wind, which surpass the scale of all other generation by 2050 (Figure 7.5).

Figure 7.5 ⊳ **Electricity generation in Viet Nam by source and scenario, 2022 and 2050**



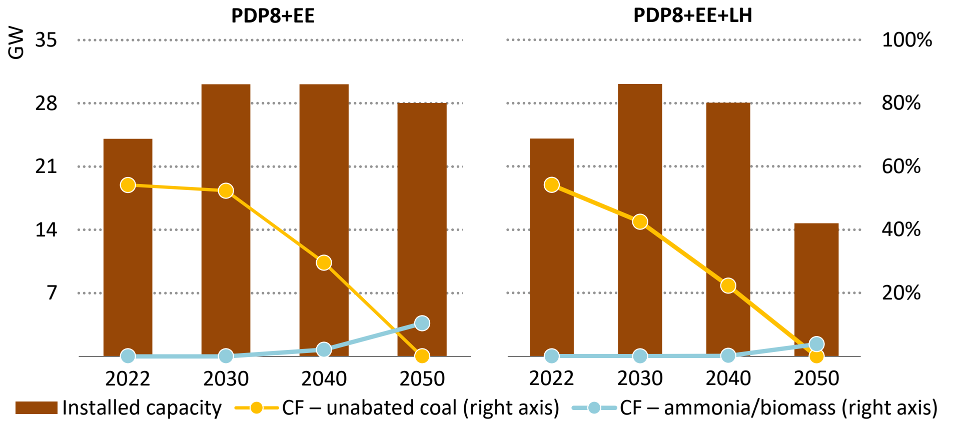
In the long run, wind and solar PV dominate the electricity supply. PDP8+EE+LH Scenario and NZE Scenario find a smaller role for hydrogen and ammonia than envisaged by PDP8

Note: Offshore (for H_2) refers to offshore wind farms dedicated to the production of hydrogen and ammonia and not connected to the grid.

After 2030, solar PV and wind generation expand significantly faster than before in all scenarios, reaching 80% of total on-grid electricity generation by 2050 in the PDP8+EE+LH Scenario and NZE Scenario, and at least 1.7 times higher than all other generation combined across scenarios. Renewables generation is highest in the PDP8 Scenario in absolute volumes, where a significant amount is offshore wind for hydrogen production. Onshore wind and solar PV grow strongly to 2050 too, rising to meet at least 14% and 22% of on-grid generation across scenarios, with the NZE Scenario reaching PDP8 levels for onshore wind and outpacing all others for solar PV.

Reflecting the pipeline of new projects contained in PDP8, installed coal-fired generating capacity continues to grow and then peak by 2030 in the PDP8 Scenario, PD8+EE and PDP8+EE+LH Scenario, in line with Viet Nam's JETP commitments. In the PDP8 Scenario and PDP8+EE Scenario, installed capacity declines only slowly thereafter, as plants are either retired after reaching 40 years of operations, or converted to burn ammonia or biomass. In the PDP8+EE+LH Scenario, the installed coal capacity declines faster as fewer plants are converted to ammonia, and more are shut down after a 40-year operating life. It declines fastest in the NZE Scenario, which sees an accelerated closure of less efficient subcritical coal plants until 2030.

Figure 7.6 ▷ Installed coal/ammonia capacity and capacity factor in Viet Nam in the PDP8+EE Scenario and PDP8+EE+LH Scenario, 2022-2050



The capacity factor of the coal fleet drops significantly in all scenarios as the share of renewables increases. By 2050, all plants are converted to ammonia or biomass

Notes: CF = capacity factor. The capacity factor is defined as the annual gross electricity generation divided by the net capacity times 365 (days/year) times 24 (hours/day).

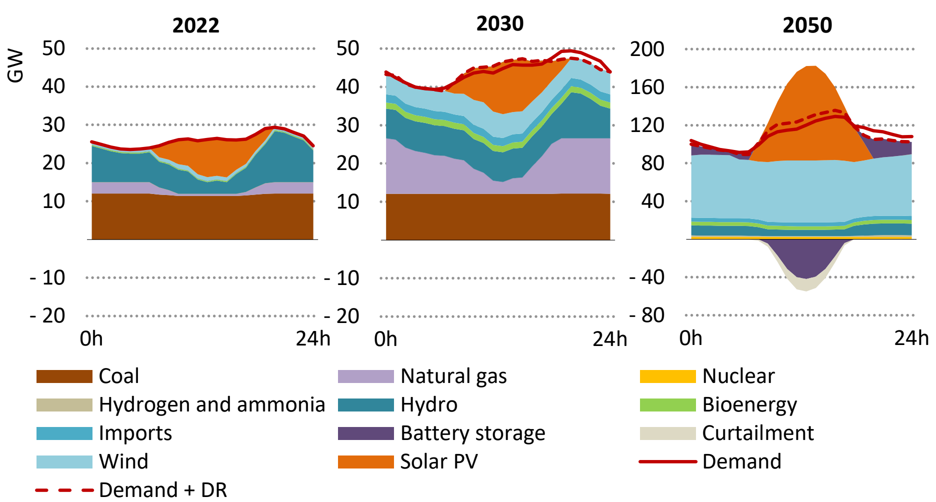
As the share of variable renewables in the electricity mix increases, the way the coal fleet operates changes, with plants increasingly switching from baseload operations to the provision of flexibility and backup capacity. While average capacity factors remain at about 55% to 2030 in the PDP8+EE Scenario, they drop to under 45% in the PDP8+EE+LH Scenario, where additional coal-to-gas switching to cut emissions more strongly reduces the share of coal in the electricity mix. Focusing operations on flexibility and system adequacy services means that coal plants operate at lower capacity factors, producing less electricity and emissions, but remain available at times when the system needs are highest, helping facilitate the integration of rising shares of variable renewables. While some coal plants may require minor equipment upgrades to operate more flexibly, the main hurdles are often existing operational practices and contract structures, which would need to be adapted. Between 2030 and 2050, the capacity factor of unabated coal-fired power plants drops further in both scenarios, and a portion of the fleet is successively retrofitted to co-fire ammonia or biomass, with the residual capacity fully converted by 2050. Both fuels are, however, relatively expensive and as a result, these plants operate primarily as backup capacity for when the system is short on alternative generation. Until 2050, fleet-average capacity factors therefore drop to around 10% in the PDP8+EE Scenario and less than 4% in the PDP8+EE+LH Scenario (Figure 7.6).

8 System flexibility and security of supply

Rising shares of wind and solar PV in Viet Nam's electricity mix cause the variability of the electricity supply to grow significantly over the outlook period, in particular after 2030. This leads to a substantial increase in flexibility needs across all timescales, from hours to days and across seasons. Combined with rising demand and the phase-out of dispatchable coal-fired power plants that today represent the backbone of Viet Nam's power system, this calls for the deployment of new technologies and solutions to provide flexibility and ensure security of supply at all times. Our analysis shows that with the right measures, the integration of high shares of variable renewables into the electricity system is feasible and cost-effective.

Out of the four scenarios presented in this analysis, the NZE Scenario represents the most profound transition of the electricity system, with the share of variable renewables in the electricity mix exceeding 80% by 2050. The assessment of system flexibility and security of supply presented in this section therefore focuses on this scenario, but any of its insights would also apply to scenarios describing less aggressive transition pathways.

Figure 8.1 ▷ Hourly electricity supply for a sample day in Viet Nam in the NZE Scenario, 2022, 2030 and 2050



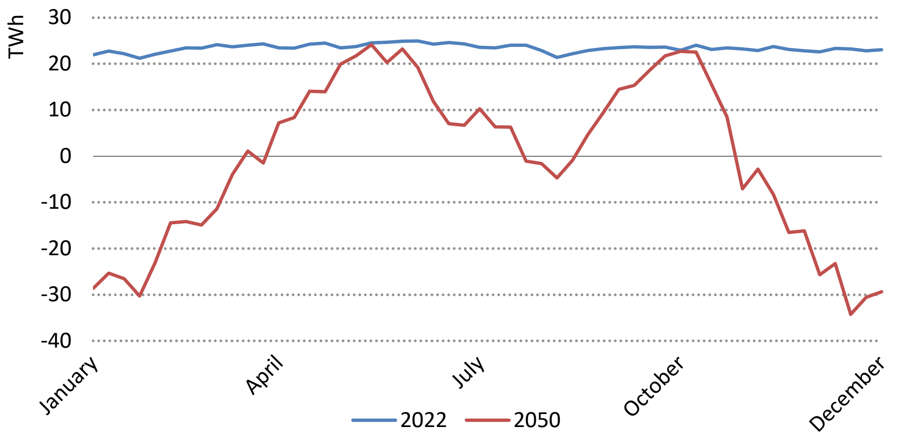
Driven by solar PV, the daily variability of the electricity supply grows significantly between 2030 and 2050, with batteries and demand response becoming essential for balancing

Note: DR = demand response (including on-grid electrolysis).

The electricity supply transforms significantly from today to 2050. The daily variability of the electricity supply increases as the share of solar PV in the electricity mix rises, especially between 2030 and 2050. In 2050, wind and solar PV dominate the mix, and its daily variability is shaped largely by the daily pattern of solar PV. There is usually a significant surplus of solar PV generation during the day, which is absorbed by shifting some electricity consumption through demand response and charging battery storage (Figure 8.1).

While solar PV is the main contributor to the increase in daily variability, the rising share of wind in Viet Nam's electricity mix has a significant impact on the seasonality of the net load (the load that remains when deducting the contribution of variable wind and solar PV as well as run-of-river hydro from electricity demand). Wind generation tends to peak in the dry season, with a secondary peak in September, leading to a structural surplus of electricity in these months (Figure 8.2). The variability of the net load is projected to increase dramatically between today and 2050 in all scenarios as the share of wind in the electricity mix rises to between 40% and 50%, with the highest levels observed in the NZE Scenario.

Figure 8.2 ▷ Seasonality of the net load in Viet Nam in the NZE Scenario, 2022 and 2050



Driven mostly by the rising share of wind generation, the electricity supply becomes highly seasonal by 2050, with a structural surplus between October and April

Note: Net load = demand minus output from wind, solar PV and run-of-river hydro.

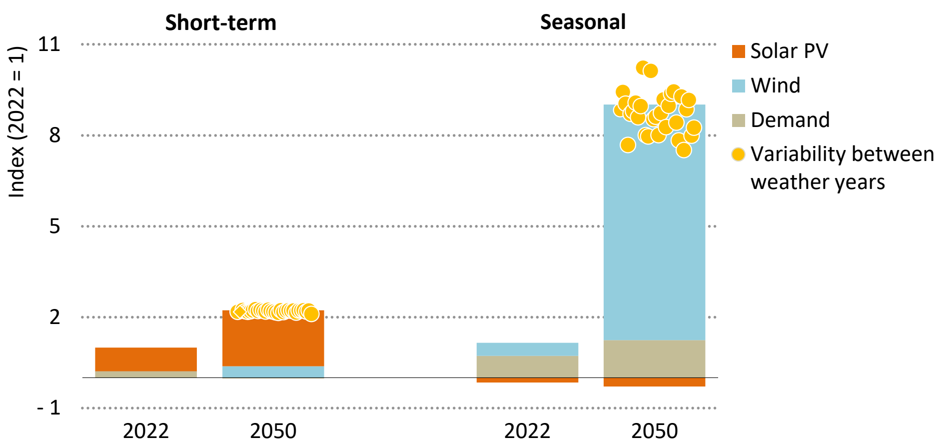
Flexibility

Power system flexibility needs increase significantly in Viet Nam to 2050, especially on seasonal timescales. Thermal power plants and hydro are the mainstay of the flexibility supply today, but alternative sources of flexibility, such as batteries and demand response, are set to become increasingly important as the system decarbonises.

Power system flexibility needs are driven primarily by the rising share of variable wind and solar PV in electricity generation and by changes in electricity demand profiles. Flexibility needs are defined over specific time frames, ranging from milliseconds (to ensure grid stability) to short-term flexibility (hourly balancing) and seasonal flexibility needs (seasonal balancing). Rising shares of wind and solar PV increase the variability of the net load while the electrification of additional end uses, e.g. electric heating, road transport or industrial processes, raises peaks and increases the variability of electricity demand. Together they drive up power system flexibility needs.

Short-term flexibility needs in Viet Nam's power system more than double until 2050 in the NZE Scenario, driven primarily by the rising share of solar PV, but it is seasonal flexibility needs that increase most of all. They rise ninefold until 2050, chiefly due to the substantial increase in wind generation. The rising share of weather-dependent variable renewables means that year-on-year variations increase as well. Wind output in particular varies significantly from one weather year to the next (in contrast to solar PV, which can vary significantly from day to day but delivers relatively predictable output year to year), which means that seasonal flexibility needs can vary from seven to up to ten times the current level in 2050 (Figure 8.3).

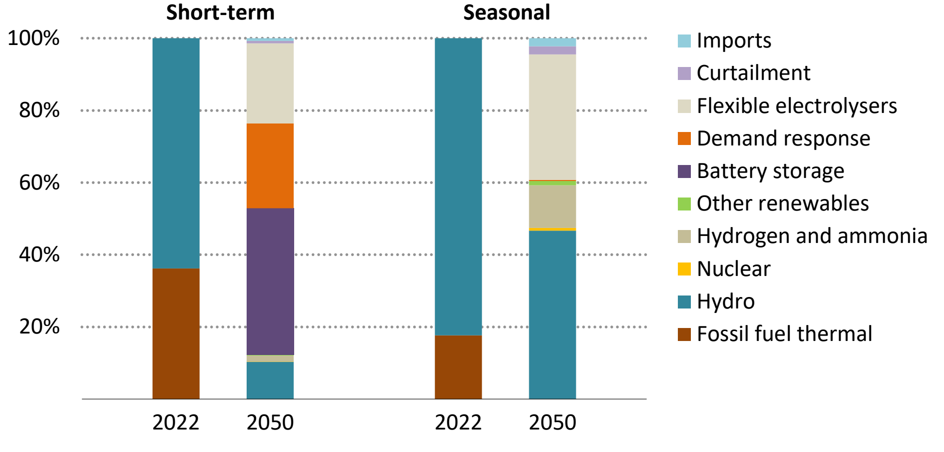
Figure 8.3 ▷ Short-term and seasonal flexibility needs in Viet Nam in the NZE Scenario and their most important drivers, 2022 and 2050



Seasonal flexibility needs grow ninefold to 2050, due mostly to the seasonal variability of wind generation, while short-term flexibility needs double

In Viet Nam today, both short-term and seasonal balancing are provided by hydro and fossil fuel thermal power plants, most notably coal and gas. As the share of variable renewables increases to 2030 and beyond, tapping the full flexibility potential of existing thermal power plants by refocusing operations on system adequacy or flexibility services will be essential, a point also highlighted in recent analysis from Agora Energiewende and in the Viet Nam Energy Outlook Report (2024). However, alternative sources of flexibility are set to become increasingly important over time as they scale up and the share of coal- and gas-fired thermal power plants in the electricity mix declines, in particular after 2030. By 2050 in the NZE Scenario, hydro and thermal power plants (in 2050 fuelled by ammonia or hydrogen) make relatively small contributions to the short-term flexibility supply. Instead, battery storage and demand response (mostly through the controlled, timed charging of electric vehicles) become the largest sources of short-term flexibility, with a combined share of nearly 60%. As electrolysers for hydrogen production become an important consumer of electricity, leveraging the flexibility they can provide when combined with hydrogen storage becomes an important tool for balancing the system across all timescales. By 2050, flexible electrolysers become the third-largest source of short-term flexibility. While most of the hydrogen and ammonia consumed in the NZE Scenario is produced using electricity from dedicated wind projects not connected to the grid, a minority is produced by grid-connected electrolysers that can provide important seasonal balancing to the electricity system by modulating hydrogen production to make use of seasonal surpluses in wind generation, taking advantage of the possibility of storing hydrogen for later use in underground storage sites or through line packing in hydrogen pipelines. These provide about a third of the seasonal flexibility required in 2050. The remainder is provided mostly by hydro and thermal power plants using ammonia or hydrogen, which remain essential for balancing across seasonal timescales (Figure 8.4).

Figure 8.4 ▹ Power system flexibility supply in Viet Nam by source in the NZE Scenario, 2022 and 2050

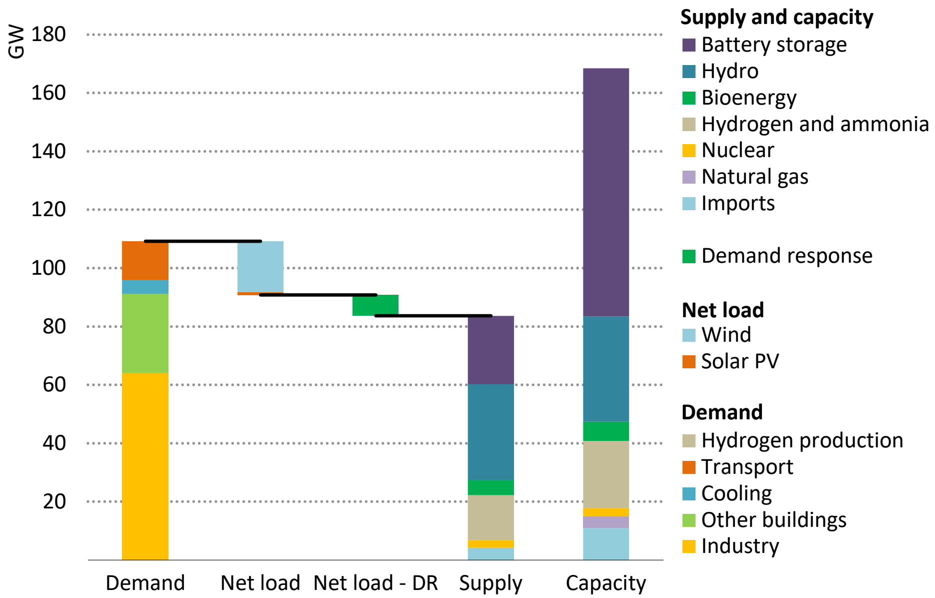


Power system flexibility shifts away from fossil fuels to batteries and demand response for short-term needs, while hydro remains critical for seasonal needs, plus flexible electrolysers

Security of supply

Enhancing power system flexibility is essential not only to integrate rising shares of solar PV and wind, but also to ensure electricity security of supply. IEA analysis suggests that it will be possible to maintain security of supply even with very high shares of variable renewables in the electricity mix and that, in addition to scaling up new sources of secure capacity, such as battery storage, maintaining sufficient thermal generating capacity will be essential to do so.

Figure 8.5 ▷ Contribution by technology in peak hours in Viet Nam in the NZE Scenario, 2050



Battery storage, hydro, and thermal power plants using ammonia and hydrogen ensure that demand can be met reliably in critical hours in 2050 in the NZE Scenario

Notes: DR = demand response. Net load = demand minus output from wind, solar PV and run-of-river hydro. Peak hours are defined as the 100 hours with the highest net load in the weather year with the highest observed peak net load for the NZE Scenario in 2050.

Historically, the key metric to assess the tightness of power systems was the peak demand. However, in systems characterised by high shares of variable renewables, the situations in which the system is short on supply are the peak hours of the net load, when electricity demand is high, and the availability of variable renewables is low. Figure 8.5 displays the electricity demand, split by end use and the electricity supply by technology during peak net load in Viet Nam (computed as the top 100 hours over the year), in the weather year with the highest observed peak net load for the NZE Scenario in 2050. In these critical hours, demand is driven primarily by industrial and residential consumption and electric vehicle charging, and peaks at around 110 GW.

Even at periods of peak net load, the system typically still sees significant wind generation, while solar PV makes almost no contribution at these times. Demand response, primarily from delaying electric vehicle charging, supports the system by shifting about 7 GW of demand.

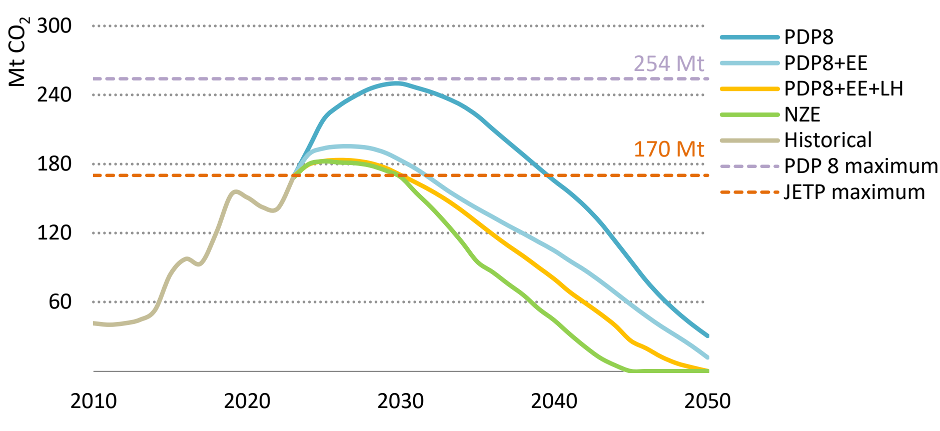
Hydropower plants, utility-scale batteries, and thermal plants using ammonia or hydrogen are the primary sources of supply, together accounting for over 85% of the net load peak. Hydropower is the biggest source of electricity at times of peak net load. Battery storage is the second-biggest source, providing roughly a quarter of the required electricity, even though the full installed capacity of batteries is not available, as the duration of peak net load periods may extend beyond typical battery discharge times. Thermal power plants using ammonia or hydrogen are the third-largest source of electricity during the net load peak, highlighting that dispatchable thermal capacity continues to be essential for ensuring security of supply at peak, even though its full available capacity is needed only in a few critical hours per year. The remaining supply is provided by bioenergy and nuclear (running at full available capacity). Imports of hydroelectric power from the Lao People's Democratic Republic provide some capacity during peak net load. However, the system still has significant margins that would allow it to ensure security of supply even without these imports.

These results highlight that in 2050 in the NZE Scenario, which represents the most aggressive decarbonisation pathway with the highest share of variable renewables out of the four scenarios presented in this report, it should be possible to match electricity supply and demand during periods of extreme system stress. However, it is important to emphasise that this analysis does not constitute a comprehensive security-of-supply assessment. As an aggregate assessment based on a model with a limited number of grid nodes, it potentially underestimates local peaks and grid congestion within nodes, which could require greater shares of the remaining margin to be used to ensure adequacy of supply.

9 Power sector CO_2 emissions

Annual power sector CO_2 emissions rise in all scenarios to a peak before 2030, complying with the NCCS's objective of peaking emissions before 2032. In the PDP8 Scenario, they peak at around 250 Mt CO_2. In the lower demand scenarios, a lower and earlier peak in emissions means that the JETP target of limiting peak power sector emissions to no more than 170 Mt CO_2 by 2030 is within reach. In the PDP8+EE Scenario, lower electricity demand growth alone brings emissions down to about 180 Mt, over 35% below PDP8. In the PDP8+EE+LH and NZE Scenarios, mainly through the combination of lower electricity demand and more coal-to-gas switching, emissions fall to below the JETP limit of 170 Mt by 2030, even though this limit is temporarily exceeded in the late 2020s. Additional renewables that can be deployed rapidly, such as rooftop solar PV, or additional energy efficiency measures, could help keep near-term emissions growth in check and keep the peak level under 170 Mt. After 2030, emissions decline rapidly in all scenarios. In the PDP8 Scenario, they fall by more than 85% to 2050 from their 2030 levels, to about 30 Mt CO_2. Emissions decline further in the PDP8+EE Scenario, falling to about 12 Mt CO_2 by 2050. However, it is only the PDP8+EE+LH Scenario and the NZE Scenario that reach net zero in the power sector, with the PDP8+EE+LH Scenario hitting net zero by 2050 and the NZE Scenario by 2045 (Figure 9.1).

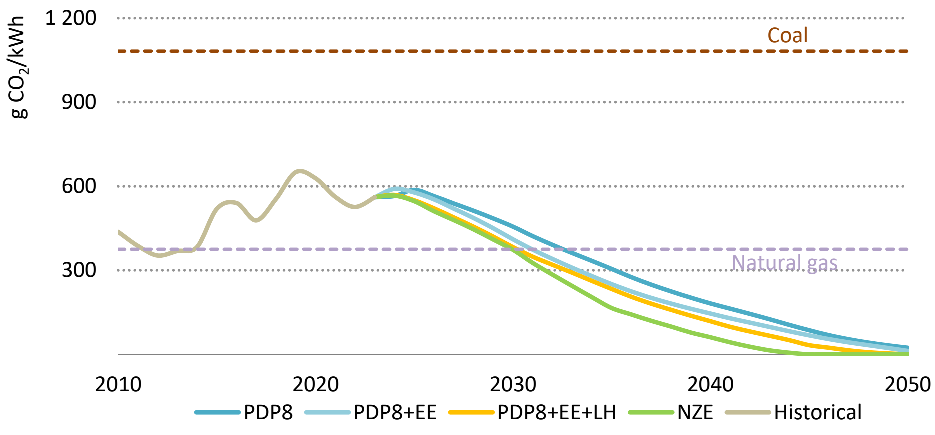
Figure 9.1 ▷ Annual power sector CO_2 emissions in Viet Nam by scenario, 2010-2050



Emissions peak in all scenarios near 2030 before falling significantly to 2050. The PDP8+EE+LH Scenario and NZE Scenario show that with minimal additional effort, full decarbonisation is possible

Similarly, emissions intensity also peaks in the near term in all scenarios, so that from the mid-2020s onwards, emissions intensity is already declining, with differences between scenarios reflecting differences in the relative contributions of coal and natural gas and shares of renewables. For the period to 2030, due to the high share of coal in the mix, the emissions intensity of the electricity mix remains significantly above that of natural gas-fired generation on its own, suggesting there is significant potential to bring down emissions by switching from coal to natural gas. Some of this potential is realised in the PDP8+EE+LH Scenario and the NZE Scenario, where additional coal-to-gas switching ensures power sector CO_2 emissions remain below the JETP ceiling of 170 Mt of CO_2 by 2030. By 2030, the PDP8 and PDP8+EE Scenario have higher installed capacities of wind that act to reduce emissions intensity; however, they continue to rely more on coal-fired generation than the PDP8+EE+LH Scenario and NZE Scenario, which shift to less coal-fired and more gas-fired generation. Beyond 2030, all scenarios move rapidly towards zero or near-zero emissions intensity by 2050 (Figure 9.2). These pathways are achieved in different ways, with the PDP8 and PDP8+EE Scenarios retrofitting coal- and gas-fired plants for significant fuel blending with hydrogen, ammonia and biomass and the PDP8+EE+LH Scenario and NZE Scenario relying more on direct decarbonisation through additional grid-connected renewables. While all scenarios rapidly scale up solar PV and wind, the PDP8+EE+LH Scenario and the NZE Scenario rely less on co-fired hydrogen, ammonia and biomass and instead concentrate even more on further additions of renewables paired with battery storage to bring down emissions intensity to zero by 2050 or earlier.

Figure 9.2 ▷ Emissions intensity of the electricity mix in Viet Nam by scenario, 2010-2050



Emissions intensity peaks in all scenarios by the mid-2020s and then rapidly declines to zero or near zero by 2050

10 Investments and affordability

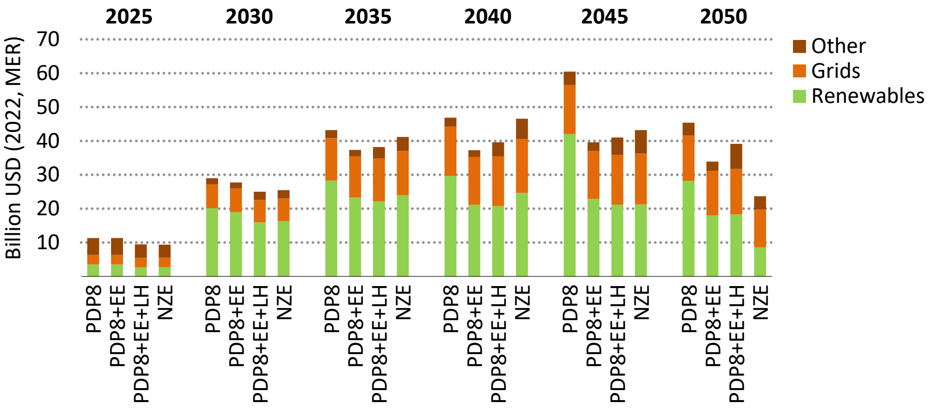
The transition from a majority fossil fuel-based power sector to one based on renewables will require significant investment in Viet Nam through to 2050, with investments rising from 2022 levels across all scenarios. Investments are needed not only to fund new solar PV, wind, and other power plants, but also for the other components of the system including grids, along with retrofits of existing coal- and gas-fired plants for use with hydrogen-based fuels and biomass. However, the transition to a decarbonised electricity sector does not need to make monthly bills higher for consumers, and long-term continued affordability is key to the overall success of this transition.

Investments

Power sector investment needs are projected to increase significantly in all scenarios, driven mainly by the strong expansion of renewables, most notably offshore wind, and the need to expand and reinforce power grids to accommodate rising demand and rising shares of variable renewables. Renewables account for the lion's share of additional investments in all scenarios across the outlook period, followed by grids, while investments into other generating capacity, such as new thermal power plants, increasingly also batteries and – beyond 2035 – retrofits to convert coal and gas plants to ammonia and hydrogen, remain at roughly current levels. In 2022, Viet Nam invested around USD 2.5 billion in the power sector, around 40% on new generating capacity and 60% on reinforcing and expanding transmission and distribution systems. PDP8 requires a significant increase in investment volumes in the near term: by 2025, total power sector investments expand to USD 11 billion in the PDP8 Scenario and PDP8+EE Scenario, before rising further to almost USD 30 billion by 2030 (Figure 10.1). While power sector investments grow strongly in the PDP8+EE+LH Scenario and NZE Scenario as well, they are more tempered, reaching around USD 27 billion by 2030.

Beyond 2030, power sector investment needs grow even more strongly in the PDP8 Scenario, largely on account of its vision for a massive expansion of offshore wind to produce hydrogen and ammonia for use in converted thermal power plants. Power sector investment peaks at around USD 60 billion per year by 2045, nearly 25 times higher than in 2022. Slower electricity demand growth and a lower reliance on hydrogen and ammonia In the PDP8+EE Scenario, requiring less investment into dedicated offshore wind to produce these fuels, means that investments do not rise to the same extent, reaching a maximum of around USD 40 billion. In the PDP8+EE+LH Scenario and NZE Scenario, the trade-off between a lower reliance on hydrogen and ammonia and a higher reliance on solar PV and onshore wind means that in the PDP8+EE+LH Scenario, investments are only marginally higher than those in the PDP8+EE Scenario in 2050. The NZE Scenario, which hits net zero emissions in the power sector by 2045, is the scenario with the lowest investment needs by 2050, largely because most of the investments to reach net zero emissions already occur prior to 2045.

Figure 10.1 ▷ Power sector investment in Viet Nam by type and scenario, 2025-2050



All scenarios see a need for rising investment. Our analysis shows that with energy efficiency, lower investments can deliver deeper emissions reductions

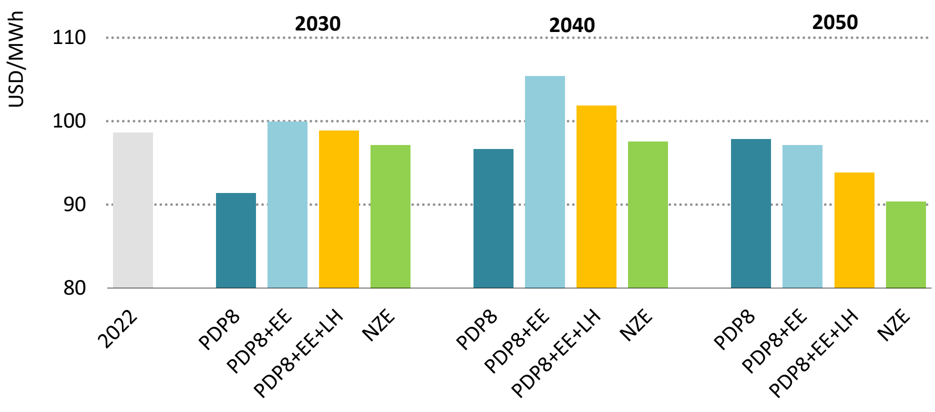
Mobilising capital on the scale seen in the four scenarios will require a significant increase in the role of the private sector, in particular in investing into renewable energy projects, while public finance will remain essential for investments into large-scale infrastructure such as power grids. This was also highlighted by the World Bank in its 2022 Country Climate and Development Report on Viet Nam. Enhanced international co-operation, including through international and development finance institutions, will be critical to catalyse this investment. International support and collaboration such as through the JETP and the Asian Zero Emission Community (AZEC) can lead further international engagement and attract more foreign capital.

Affordability

Electricity affordability remains crucial to Viet Nam's energy transition. In our scenarios, electricity prices reflect the cost of building and running power systems, including capital recovery (annuities paid over the economic lifetime of generation or grid assets to recover upfront investment), fuel costs, operation and maintenance expenses, and, if applicable, CO_2 prices (note that revenue from a carbon tax or emissions allowance auctions can be returned to consumers). While electricity prices can differ significantly between consumer groups depending on regulations and taxes, with industrial consumers, for example, facing lower grid costs for their higher voltage connections and paying lower tariffs than residential consumers, the average cost per unit of electricity represents a good indicator of electricity price levels and their projected development.

In 2022, the average cost per unit of electricity produced in Viet Nam stood at just under USD 100/MWh, compared with a global mean of approximately USD 105/MWh. Moving forward, the average cost per unit of electricity varies between scenarios, reflecting differences in total system costs, as well as total electricity generation (Figure 10.2). Assuming all else is held equal, the greater the volume of electricity generated, the more fixed costs are diluted, lowering the average cost per unit of electricity. However, it is crucial to emphasise that the scenario with the lowest cost per unit of electricity may not necessarily yield the lowest consumer bills. Scenarios in which investments in energy efficiency lead to lower electricity demand may feature higher average costs per unit of electricity, but lower overall spending on electricity, freeing up funds for other purposes. In this way, the average cost per unit of electricity is not necessarily the best metric to gauge electricity affordability.

Figure 10.2 ▻ Annual average cost per unit of electricity in Viet Nam by scenario, 2022-2050



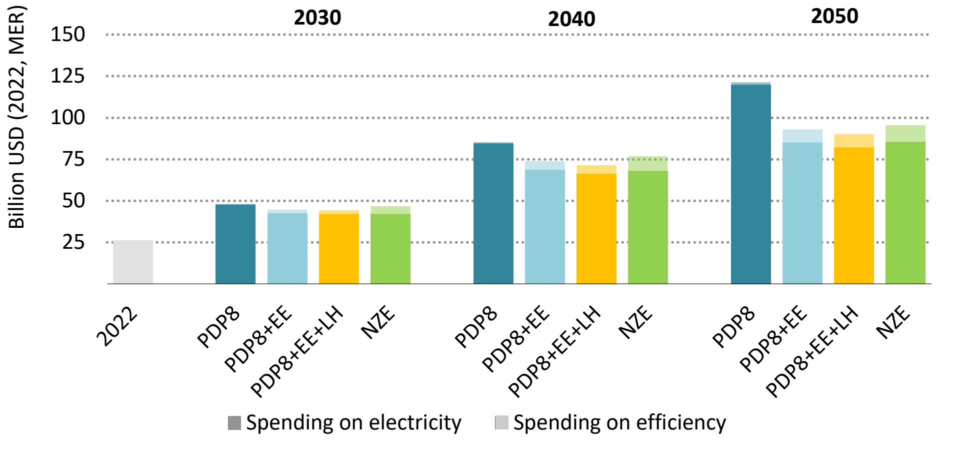
Electricity affordability remains crucial to Viet Nam's energy transition, with the PDP8+EE+LH and the NZE scenarios able to deliver the lowest cost per unit of electricity in the long term

In the PDP8 Scenario, the average cost per unit of electricity drops until 2030, with fast-rising electricity demand and declining coal and gas prices offsetting the increase in capital recovery spending as investment into renewables and grids ramps up. In the PDP8+EE Scenario, PDP8+EE+LH Scenario and NZE Scenario, by contrast, investments into energy efficiency reduce the pace of electricity demand growth, and while in all three scenarios total system costs are lower than in the PDP8 Scenario, they are distributed across smaller volumes of electricity, resulting in higher average costs per unit of electricity, which remain at roughly current levels. This is driven primarily by the significant increase in investments into renewables and grids, which raise the capital intensity of the electricity supply.

This shift continues after 2030, with total system costs increasingly dominated by capital spending rather than fuel costs as the share of zero-marginal-cost variable renewables increases further. In the PDP8 Scenario, average costs per unit of electricity rise through 2040 and to 2050 as rising investments and an increasing reliance on (relatively expensive) hydrogen and ammonia drive up total system costs. In the PDP8+EE Scenario, PDP8+EE+LH Scenario and NZE Scenario, by contrast, average costs per unit of electricity decline between 2040 and 2050, largely because a lower reliance on hydrogen and ammonia results in a much slower increase in total system costs. In 2050, this results in all three scenarios featuring a lower average cost per unit of electricity than the PDP8 Scenario.

All four scenarios deliver similar levels of economic growth and material prosperity. Although the PDP8 Scenario features the lowest cost per unit of electricity until well into the 2040s, this does not mean that it is the most affordable to consumers. Investments in energy efficiency – which range from more efficient electric motors in industry and more efficient air conditioners and electric appliances in the residential and service sectors to improvements in building envelopes that reduce cooling needs – ensure that electricity demand growth in the PDP8+EE+LH Scenario, PDP8+EE Scenario and NZE Scenario is slower than in the PDP8 Scenario. The lower demand means that consumers need to spend less money on electricity, freeing up funds for other purposes. The increased spending on energy efficiency in these scenarios is significantly smaller than the savings associated with the lower electricity consumption (Figure 10.3), highlighting that investments into energy efficiency pay off quickly. Compared with the PDP8 Scenario, consumers spend a cumulative USD 400 billion less from 2023 to 2050 in the PDP8+EE+LH Scenario. These savings are nearly four times larger than the additional USD 115 billion spent over the same time frame on more efficient electrical appliances and other measures that reduce electricity consumption.

Figure 10.3 ▷ Total annual spending on electricity and efficiency measures in Viet Nam by scenario, 2022-2050



The PDP8+EE+LH Scenario also delivers the lowest levels of consumer spending on electricity in the long run, freeing up funds for other purposes

Abbreviations and acronyms

AZEC	Asian Zero Emission Community
BECCS	Bioenergy with carbon capture and storage
CO_2	carbon dioxide
COP26	26th Conference of Parties (UNFCCC)
COP28	28th Conference of Parties (UNFCCC)
DEA	Danish Energy Agency
ECMWF	European Centre for Medium-Range Weather Forecasts
EREA	Electricity and Renewable Energy Authority
GDP	gross domestic product
H_2	hydrogen
IEA	International Energy Agency
IPG	International Partners Group
IRENA	International Renewable Energy Agency
JETP	Just Energy Transition Partnership
LCOE	levelised cost of electricity
LED	light-emitting diode
LNG	liquefied natural gas
LULUCF	Land use, land-use change and forestry
NCCS	National Climate Change Strategy
NDC	Nationally Determined Contribution
NZE	Net Zero Emissions by 2050 Scenario
PDP8	Power Development Plan 8
PDP8+EE	Power Development Plan 8 + Energy Efficiency
PDP8+EE+LH	Power Development Plan 8 + Energy Efficiency and Low Hydrogen
PPP	purchasing power parity
PV	photovoltaics

PyPSA	Python for Power System Analysis
RMP	Resource Mobilisation Plan
WEO	World Energy Outlook

Units of measurement

g	gramme
GJ	gigajoule (1 joule x 10^9)
GW	gigawatt (1 watt x 10^9)
kW	kilowatt (1 watt x 10^3)
kWh	kilowatt-hour
m^2	square metre
MBtu	million British thermal units
Mt	million tonne (1 tonne x 10^6)
MWh	megawatt-hour
TWh	terawatt-hour

Unless otherwise indicated, all material presented in figures and tables is derived from IEA data and analysis.

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Achieving a Net Zero Electricity Sector in Viet Nam

World Energy Outlook Special Report

Achieving a Net Zero Electricity Sector in Viet Nam aims to provide stakeholders in Viet Nam and internationally with an assessment of different pathways for achieving its targets and reaching net zero emissions in the power sector. The analysis is benchmarked with Viet Nam's Power Development Plan 8 (PDP8), a detailed plan for the transformation of the power sector approved in May 2023, and considers the Viet Nam Just Energy Transition Partnership (JETP), which was signed by Viet Nam's prime minister in 2022.

The decarbonisation pathways are designed to be cost-effective and technology-neutral, considering all low-emissions technologies – renewables, nuclear, carbon capture, hydrogen and ammonia – as potential options. Key outcomes of the analysis include the identification of important milestones on the road to net zero, including for the deployment of renewables, interim emissions targets and the coal phase-out schedule, while highlighting key challenges.

This roadmap also discusses the role of energy efficiency, quantifies power sector investment needs and assesses the affordability of electricity supplies to 2050 and lays out strategies to ensure the reliability and security of the electricity supply while integrating rising shares of variable renewables. The project benefitted from engagement and feedback from the government of Viet Nam and has been conducted in close collaboration with international stakeholders.