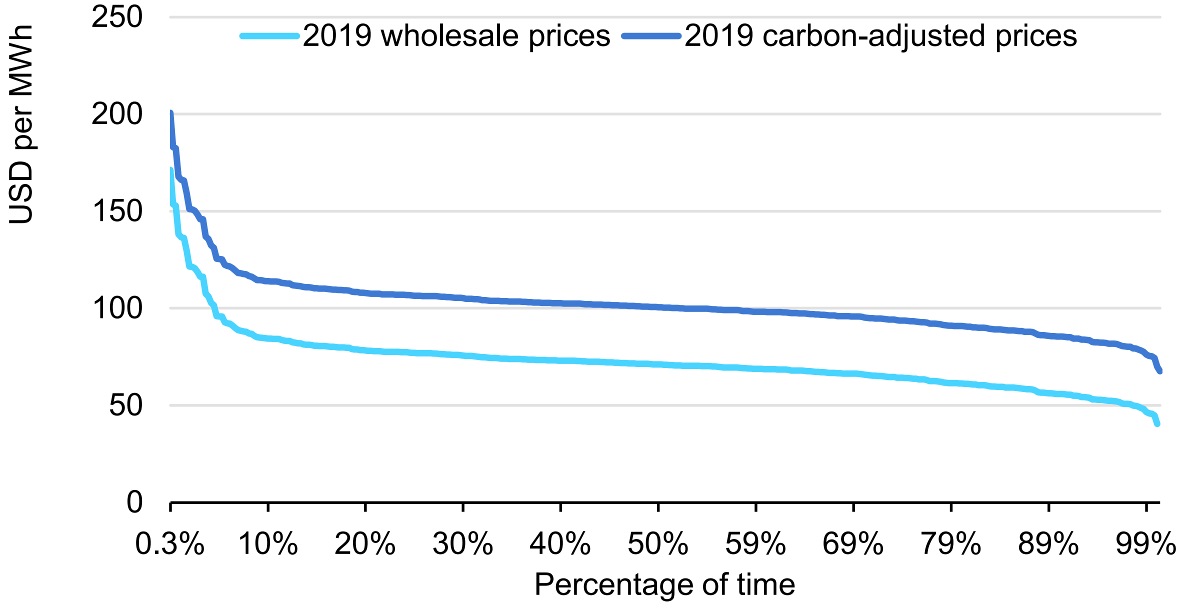
Wholesale energy price duration curve in Japan, 2019

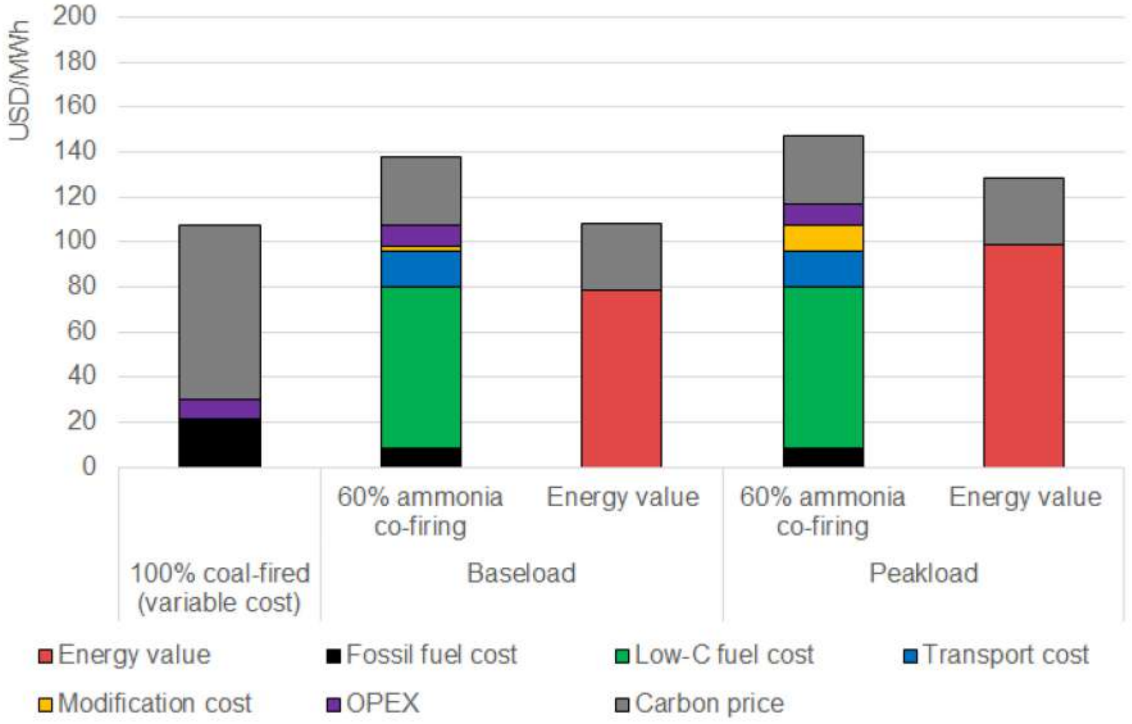


Source: Japan Electric Power Exchange (2021).

In the figure below, the 2019 wholesale energy prices for Japan are modified by adding a SDS 2030 carbon price of USD 82/tCO2 for advanced economies. The peak load energy value represents the average of the top 15% of hours, while the baseload energy value represents the average of the top 70% of hours. These energy market values are then compared against the generation cost of an existing coal power plant, co-firing 60% of imported low-carbon ammonia from Saudi Arabia operating respectively under baseload (CF 70%) and peak or mid-merit load (15%).

As discussed in Chapter 4, the generation costs are higher for a plant that operates under peak or mid-merit than under baseload. However, higher generation costs can be compensated by capturing higher wholesale prices for the generated electricity.

Energy value and LCOE of ammonia co-firing for Japan in the Sustainable Development Scenario 2030

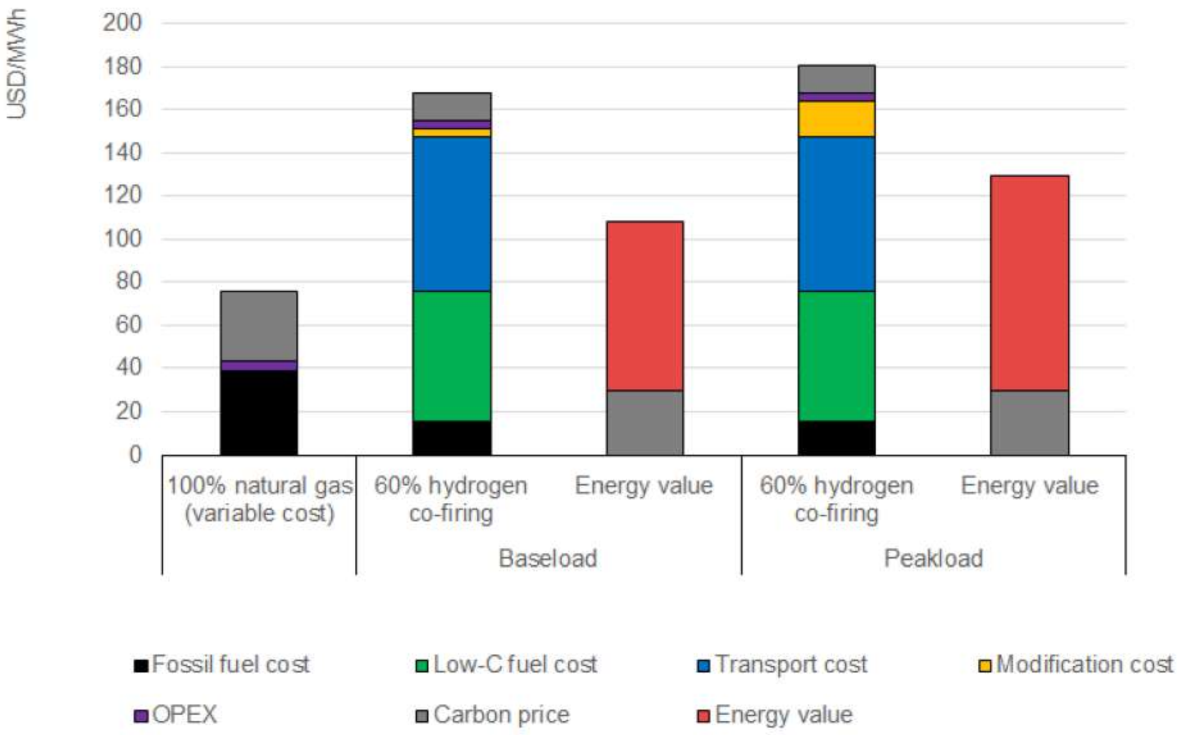


Note: Ammonia produced from natural gas with CCUS in Saudi Arabia and shipped to an existing coal-fired power plant in Japan. Energy value is based on 2019 wholesale energy price duration curve in Japan, adjusted with USD 82/tCO_2 carbon price for advanced economies in the SDS in 2030.

This is exemplified in the above figure that illustrates generation costs and carbon-adjusted energy values for baseload and peakload operation. Co-firing 60% ammonia in a coal power plant is expected to cost 30 USD/MWh (138 USD/MWh – 108 USD/MWh) more than the carbon-adjusted energy value for baseload operation, which is reduced to 18 USD/MWh (147 USD/MWh -129 USD/MWh) under peakload operation.

Similar comparison is illustrated in the figure below for a natural gas power plant. The gap between the cost of co-firing 60% low-carbon hydrogen and its average market energy value under peakload operation (181 USD/MWh - 129 USD/MWh = 52 USD/MWh) is smaller than the respective gap under baseload operation (168 USD/MWh - 108 USD/MWh = 60 USD/MWh). However, in absolute terms the gaps are wider than for ammonia co-firing, which is explained by the higher supply cost of hydrogen via sea, and the lower impact of carbon price on the cost of natural gas than coal.

Energy value and LCOE of hydrogen co-firing for Japan in the Sustainable Development Scenario 2030



Note: Hydrogen produced from coal with CCUS in Australia and shipped to an existing natural gas fired power plant in Japan. Energy value is based on 2019 wholesale energy price duration curve in Japan, adjusted with USD 82/tCO_2 carbon price for advanced economies in the SDS in 2030.

As Japan's power system evolves towards more renewable capacity, the average energy value of peak hours is expected to increase. This will further reduce the gap between low-carbon generation costs and value. The newly created capacity market will provide an additional source of revenue to plants using low-carbon fuels that will further enhance competitiveness.

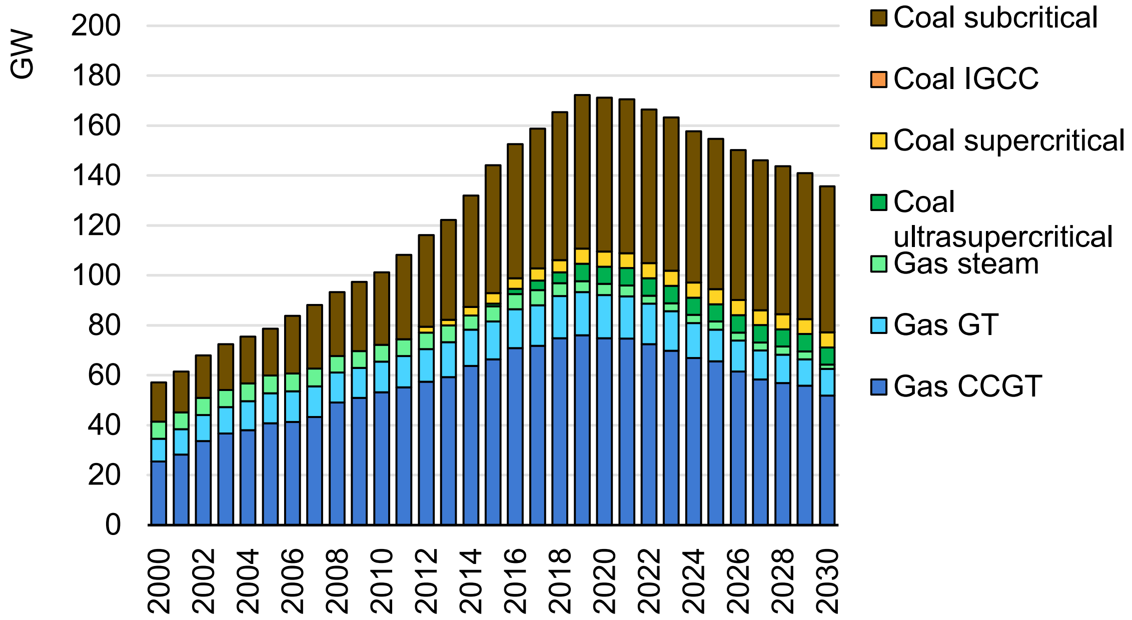
Drivers and conditions for low-carbon fuels use in Southeast Asia

In order to reach their NDC's the countries of Southeast Asia will need to decarbonise their power sector. While net zero targets are yet to be officially announced by any of the ASEAN Member States, the region does have an aspirational target of 23% renewable energy (excluding traditional use of biomass) in total primary energy demand by 2025. Looking further into the future, even higher targets of renewable energy need to be realised in Southeast Asia in order to keep the world on track for 1.5°C temperature increases. Several ASEAN countries are also developing long-term strategies towards carbon neutrality.

Southeast Asia has a large and young thermal power plant fleet

Southeast Asia has a large thermal fleet in which coal and gas are the major sources of electricity generation at present. The composition of the fleet varies from country to country. In Thailand, around 60% of electricity generation in 2020 was from gas-fired generation, while Indonesia generated around 70% of its electricity in 2020 from coal-fired power plants.

Cumulative capacity in ASEAN without new additions from 2020

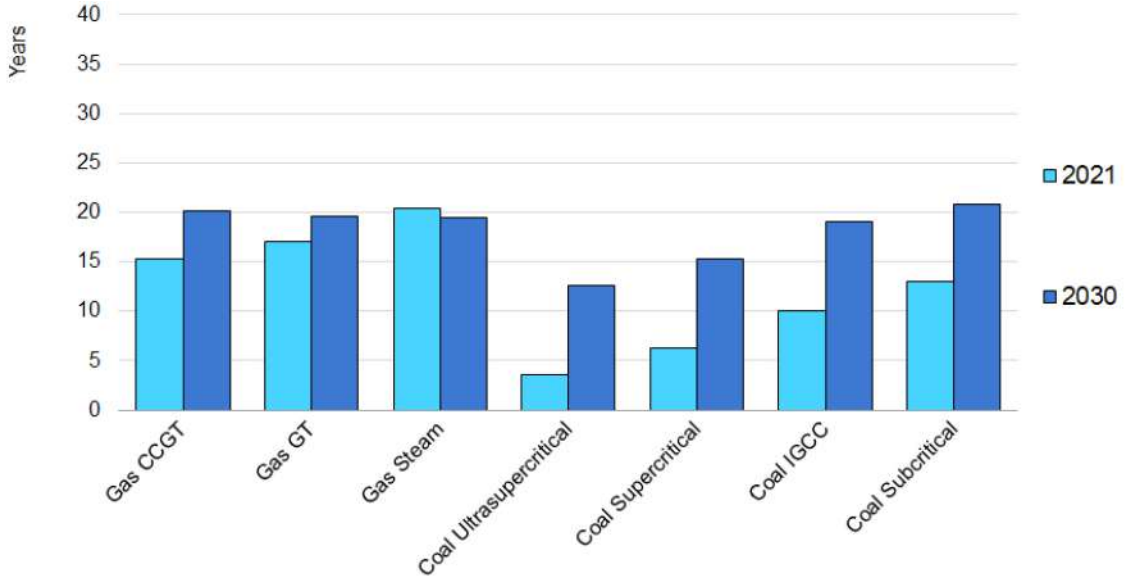


Source: IEA (2020).

The age of the thermal power plants in this region is relatively young. The current average age of the ultra-supercritical and supercritical coal plants in Thailand and Indonesia is today between 5 and 10 years. By 2030, a substantial portion of these coal assets will have used less than half of their technical life expectancy.

Given the large share of existing thermal fleet, many of the ASEAN countries are considering power plant retrofits as one of the options to improve technical flexibility. For example, there is a pilot project at a gas-fired power plant in Thailand to improve key operational characteristics. This opportunity could also provide a long-term pathway for decarbonising existing thermal power plants in this region to run on less carbon-intensive fuels.

Capacity-weighted average age today (2021) and in 2030 (without new additions) in ASEAN



Note: The technical lifespan assumptions of coal and gas plants are 40 years and 30 years, respectively.
Source: IEA (2020).

Currently some of the countries, including Indonesia and Thailand, are facing the issue of generation overcapacity and a high reserve margin. In Thailand, the reserve margin is in the range of 40%, which is expected to remain in the short- to medium-term due to the impact of Covid-19. By 2035, the reserve margin is expected to drop to around 25%.

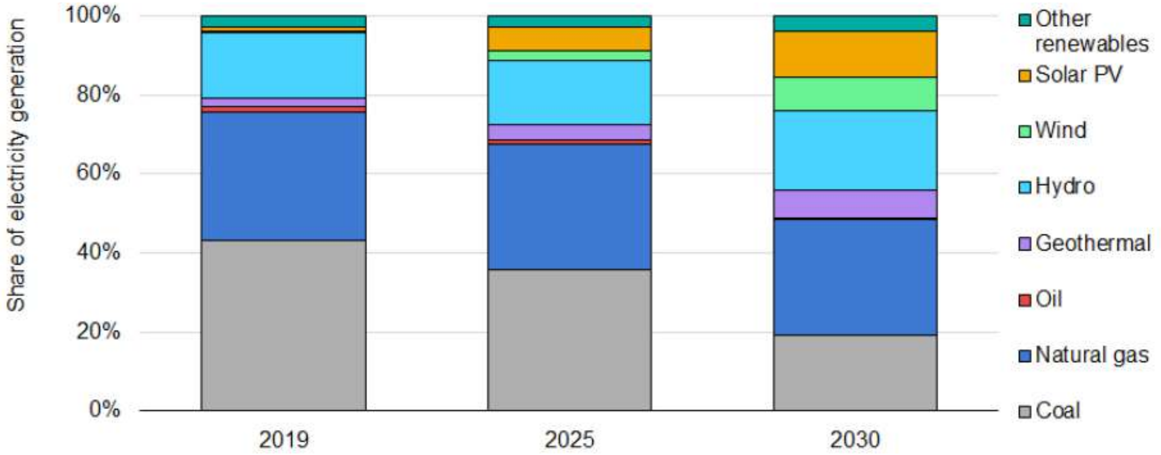
In the coming decades, electricity demand in Southeast Asia is expected to grow strongly. In fact, the demand growth is expected to be among the world's highest along with India and Africa. There are several factors influencing demand growth. Population growth, with economic growth as well as targeted policies for electrification of transport and clean cooking, for example, are among the long-term drivers of electricity demand growth in the AMS.

Thermal generation still provides bulk of system flexibility in ASEAN in 2030

In meeting the demand growth, the generation capacity in the ASEAN region will significantly increase in the coming decades. The bulk of generation capacity additions will come from renewables. This region has a very diverse range of renewable energy resources including biomass, hydro, wind, solar, geothermal and a potential for ocean energy. By 2040, renewable generation accounts for more than 70% in the SDS with solar PV, wind and hydropower being the largest sources, at a combined capacity of over 600 GW in 2040. The booming growth of solar PV will continue, as has been the case in recent years in countries such as Thailand and Vietnam.

The very high share of renewable energy requires sufficient flexibility resources to ensure the reliability and security of the power system while the ASEAN countries move towards decarbonisation. Currently many of the power systems in this region have considerable latent flexibility that can be activated by targeted policy measures. This includes conventional plants (both thermal and hydropower) and grid infrastructure (including cross-border interconnectors).

Shares of ASEAN electricity generation in the Sustainable Development Scenario, 2025-2030



Source: IEA (2020).

In the short term, increasing the efficiency of the key power system assets will unlock enough flexibility to integrate renewable energy to meet the 2025 targets. However, in order to increase efficiency to meet longer-term requirements, appropriate policies and regulatory support frameworks are needed.

In Indonesia, implementing updated system operation procedures, such as advanced day ahead forecasting, will be an important tool to manage the variability of renewable energy in the grid. Building out grid infrastructure and connecting islands like Sumatra and Java will also increase the reliability of the system and improve electricity security while allowing for higher shares of renewable energy to be integrated into the system.

In Thailand, a recent IEA study on Thailand power system flexibility shows that one of the major barriers to flexibility in the country is contractual structures, which limit the utilisation of the system's latent technical flexibility from current assets. High minimum-take obligations in power purchase agreements as well as daily-take or pay clauses in gas supply contracts hinder the optimal operation of the generation fleet. These constraints prevent the thermal fleet, which has technical capability, to operate flexibly to accommodate the integration of renewable energy. This pattern is also identified as an issue for other countries such as Indonesia and Vietnam. The contractual constraint is likely to present a major obstacle for the region's young gas fleet. Thus, the governments could consider the co-firing option with low-carbon fuels, particularly hydrogen and ammonia.

One of the main sources of flexibility in this region is cross-border interconnectors with the option for multilateral power trade, which will allow resource sharing among ASEAN countries, particularly renewable resources. In Thailand, for example, a more dynamic setup for multilateral power trade will enable hydropower from Laos PDR to contribute to increased flexibility in the country thereby facilitating integration of variable renewable energy and reducing the overall costs of the system. By making use of the existing assets, the low-carbon option in the form of hybrid power plants is also becoming a viable means from both the technical and economic perspectives. Hydro-floating solar PV hybrid power plants have been planned or carried out in Indonesia, Singapore, Thailand and Vietnam. For example, in Thailand, the first hydro-floating solar hybrid project of 45 MW capacity was completed in 2021.Indonesia is planning to install a -MW floating solar PV project on a reservoir in West Java. It will be the largest in the ASEAN region.

In general, there are many short- to medium-term actions that ASEAN countries can take to increase flexibility and enable significantly higher shares of renewable energy which are cost-effective, reliable and secure.

Long-term pathways for implementing low-carbon fuels in the ASEAN Region – opportunities and challenges

When looking beyond the 2025 targets in ASEAN, the flexibility options described above may not be enough. Emerging technologies are also gaining much interest from policymakers and key stakeholders in this region, including battery storage and longer-term storage options in order to cope with the challenges from the high share of VRE.

In the longer-term, there are opportunities for hydrogen-derived fuels, which could play a role in ASEAN countries in achieving carbon neutrality. Indonesia, Malaysia, the Philippines and Thailand are also gaining experience in piloting green hydrogen and fuel cell systems for remote power provision in many sectors. Wind and solar PV are expected to become the main sources of electricity generation in this region. As this can pose challenges for the grid, some of the ASEAN countries are expressing an interest in exploring the role of hydrogen to cope with such challenges given their long-term storage attribute. Thailand EGAT, which is the leading state-owned power utility, built a wind-hydrogen hybrid system prototype project in 2019 for utility-scale application. This project combines a 24-MW wind power plant with a 1-MW electrolyser and a 300-kW fuel cell to provide clean electricity to a building during high demand periods. For Indonesia, a country comprised of about 6 000 inhabited islands, solar PV will be the main source of electricity. In addition, given that the off-grid generator set (genset) has been the source of electricity generation, there is an opportunity to convert such a genset from using diesel oil to use ammonia, which can be relatively easy to store and transport by trained personnel.

Despite the potential and interest, it is important to note that because capital is very constrained in this region, the ASEAN countries are highly price sensitive.

In order for low-carbon fuels to be economically feasible in ASEAN, it is important that the costs associated with these options come down. Developed economies can play a key role by investing in maturing the technologies for low-carbon fuels along with creating global supply chains and infrastructure that the countries of ASEAN can tap into.

Low-carbon fuels may be needed in the ASEAN region to achieve carbon neutrality in the long-term, but currently the ASEAN countries are still in the early phases of transitioning towards clean energy. In the short- to medium-term, the priority is to switch fuel from coal to gas when available, and to utilise the existing latent flexibility in the system to integrate more renewables. Deployment of low-carbon fuels could be an option in the longer-term if targeted policy reforms are successfully implemented and significant cost reductions are achieved by the world’s more advanced economies first. The markets and technologies will require significant maturing to become viable in the ASEAN region.

Electricity security in India and the value of thermal power plants in a low-carbon future

Coal-fired power has historically been the primary source of electricity generation in India. However, further capacity additions over the next decades will come mostly from solar PV and wind due to their falling costs. With the rising share of variable resources and changes in demand and supply, coal-fired thermal plants in India’s power system have needed to become more flexible. Despite the decline in the utilisation, dispatchable thermal power plants are likely to remain a valuable resource in meeting the increasing need for flexibility in the system and in ensuring the security of electricity supply.

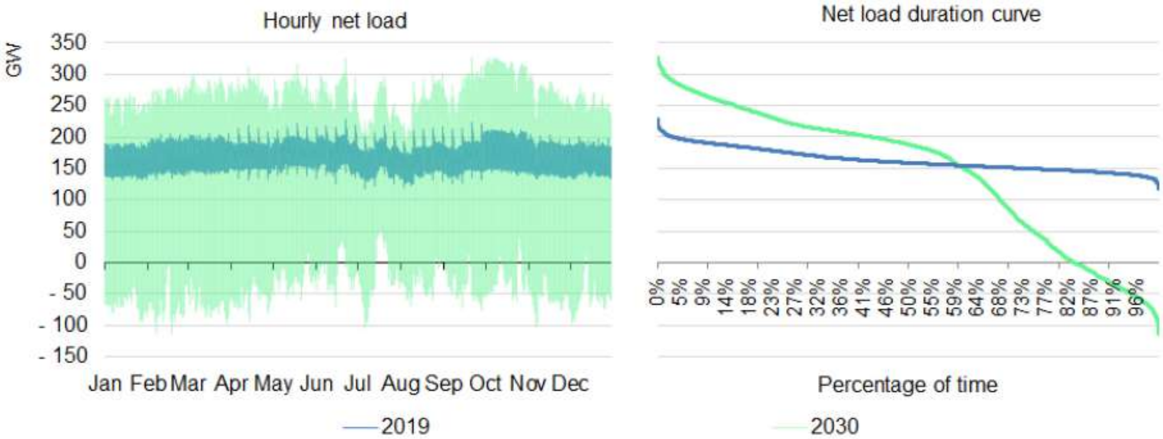
To provide context for the obtained results, we conducted a power system modelling exercise to analyse the potential role of dispatchable fossil fuel based thermal power plants in clean energy transitions, and their contribution in maintaining the security of supply of India's power system.

High shares of wind and solar PV increase variability in net load profiles

Under the SDS, renewable energy will become the main source of electricity generation in India in 2030 with an annual share of around 60%, with wind and solar PV together accounting for almost 40%. High penetration of VRE and increased use of air-conditioning present the main challenges for India's power system.

The variability of India's net demand (demand minus VRE generation) will continue to increase over all timescales- –from minutes to hours, days and weeks and seasons, and will lead to significant changes in the net load profiles in 2030 (see Figure below). By 2030, the hourly net demand ranges from a low of -110 GW (more VRE generation than demand resulting in potential VRE curtailment) to a high of over 300 GW, a difference of 410 GW. This difference is about four times higher (low of 120 GW to a high of 225 GW) than in 2019. The system will experience higher hourly and sub-hourly ramps, and larger differences between minimum and maximum daily demand, which will require additional resources to meet flexibility needs to avoid large curtailment of wind and solar generation (see the Figure below). Key flexibility resources include grid infrastructure and distributed energy resources such as cold storage in cooling devices based on distributed PV, which can also reduce strain on the grid.

Net load profiles in India in the Sustainable Development Scenario, 2019 and 2030

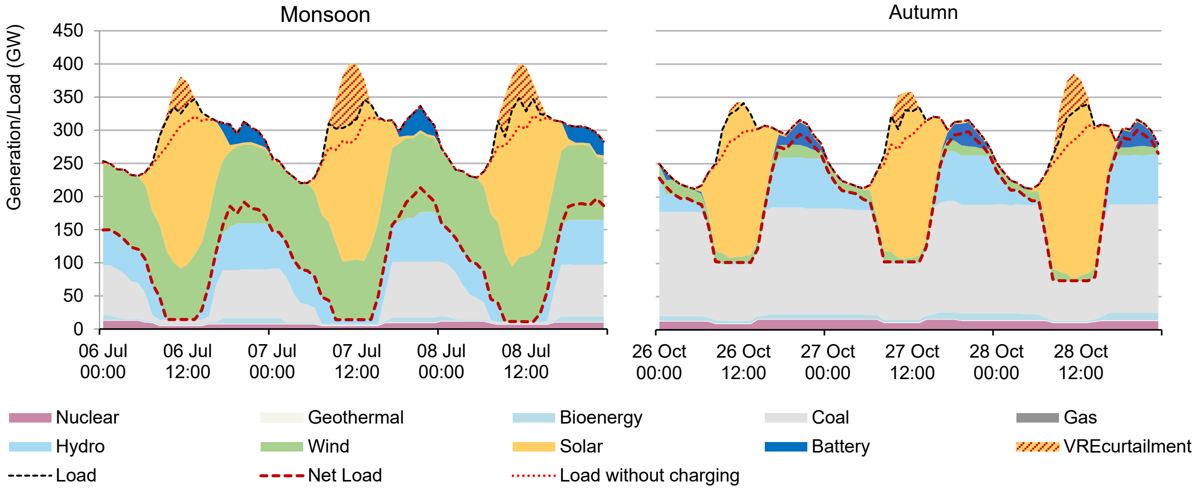


Note: The net load profiles did not take into account demand response and batteries in order to illustrate the underlying challenge.
Source: IEA analysis.

The role of dispatchable resources in providing system flexibility in India

Today, thermal power plants are the primary source of electricity in India, accounting for over 70% of the total generation mix. In the SDS, the share of thermal power generation (mainly coal- and gas-fired) in India's power system is reduced by 25% to 45% in 2030. With the high share of wind and solar PV, dispatchable thermal plants will contribute to meeting the daily, weekly and seasonal flexibility requirements. For example, each day begins with a high ramp (variation in net demand) period and during the evening peak period when solar PV output decreases, demand is ramping up (see Figure below). During the transition to a low-carbon future, thermal power plants will no longer provide the traditional baseload. They will combine the features of both intermediate and peaking generation and need to ramp up, start up and shut down more frequently to suit the needs of the system.

Generation pattern in the Sustainable Development Scenario for a low net load day occurring in the monsoon season and a high net load day in autumn, 2030



Source: IEA analysis.

India’s electricity demand and renewable generation output also vary throughout the year according to seasonal patterns (winter, summer, monsoon and autumn). Dispatchable thermal plants can provide the needed flexibility to meet the seasonal variability of demand, and more notably the fluctuating supply of power from renewables. They presently contribute most to the system between October and November when the output from renewables (mainly wind and hydropower plants) is low. During India’s monsoon season (June to September), which is characterised by high wind and reasonable hydropower generation output, the contribution of thermal generation can be as low as 13% of total generation, particularly during the day due to high solar PV output that often results in curtailment. However, thermal generation still contributes to the system during the off-peak period at night. The generation pattern of dispatchable thermal plants across the year reflects their flexibility attributes in being able to start/stop, and ramp up and down to accommodate the net demand variability.

India’s transition to a low-carbon future with a high share of renewables requires a range of services from different technologies to meet flexibility need and ensure electricity security in the power system. In 2019, India’s thermal power plants provided a major contribution to energy; peaking capacity and inertia since they operated as the traditional baseload generation while hydropower was the main source for ramping given its flexible technical capabilities (see Figure below). By 2030, when renewables become the main source of electricity generation and with the rise of other emerging technologies, thermal power plants will still provide multiple key system services. Despite the lower contribution to energy by thermal generation, these plants will still provide peak capacity and ramping flexibility