Southeast Asia Energy Outlook 2024

INTERNATIONAL ENERGY AGENCY

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Foreword

Today, anyone considering the world's energy future has to pay close attention to Southeast Asia, an economically dynamic region that has become an increasingly influential force in the global energy system.

Following two decades of remarkable growth, the countries of the Association of Southeast Asian Nations (ASEAN) are collectively poised to become one of the world's top five largest economies by 2030. At that point, Southeast Asia is also set to be home to nearly one in every 12 people globally, with a population of over 720 million.

This sixth edition of the *Southeast Asia Energy Outlook* from the International Energy Agency (IEA) confirms that this region is poised to strengthen its position as an energy heavyweight. Southeast Asia alone accounts for 25% of the increase in global energy demand to 2035, and it is on track to surpass overall consumption in the European Union by 2050.

The upshot is clear: for conversations on the biggest energy issues of the day, from ensuring energy security to accelerating clean energy transitions, Southeast Asian countries must have a central role. Each of the ASEAN countries are diverse in their development, industry, politics, geography, and energy needs. Advancing clean energy transitions requires tailored strategies that consider both regional and national contexts.

That is why the IEA is taking the major step of opening a new office – the Agency's first office outside of its Paris headquarters in its 50-year history. It enables the IEA to deepen and expand its longstanding collaboration with countries in Southeast Asia and beyond as they navigate the significant energy opportunities and challenges ahead. Singapore, as Southeast Asia's sustainable finance hub, is the natural home for the new office.

This *Outlook* vividly underscores the increasingly deep partnership between the IEA and ASEAN. It provides a thorough examination of Southeast Asia's energy markets, energy security and climate ambitions, exploring the challenges and opportunities for the region in clean energy transitions. It incorporates a wide range of insights and observations gained from dialogue with regional stakeholders.

This report also represents a strong collective effort from across the IEA, with an excellent team working skilfully and tirelessly under the leadership of my colleague Tim Gould, our Chief Energy Economist. I would like to extend my gratitude to all those, both within and beyond the IEA, whose expertise and support contributed to its realisation.

Dr. Fatih Birol

Executive Director

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Executive summary

Southeast Asia is a very dynamic region and a driving force behind global energy trends, with a projected rise in energy demand over the coming decades second only to India. It has accounted for 11% of global energy demand growth since 2010 but is projected to contribute more than 25% of the growth over the period to 2035 in the Stated Policies Scenario (STEPS), which indicates the direction of travel for the energy sector based on today's policies. This increase in demand is underpinned by strong economic expansion, population growth, and Southeast Asia's position as a global manufacturing and industrial hub. However, this scenario brings serious concerns for energy security and sustainability: rising dependence on fossil fuel imports, escalating import costs, and a projected one-third increase in energy-related CO_2 emissions by 2050.

Eight of the ten countries in Southeast Asia have net zero emissions goals: Brunei Darussalam, Cambodia, Lao PDR, Malaysia, Singapore and Viet Nam have set a target date of 2050; Indonesia of 2060; and Thailand of 2065. While momentum is building for clean energy transitions across the region, far greater efforts are needed to get on track for these national goals, which would mean cutting today's emissions by almost two-thirds by 2050. Aligning with the targets agreed at COP28 and achieving global net zero emissions by mid-century would demand an even faster transformation in Southeast Asia.

At a time of heightened geopolitical tensions, energy security and affordability remain top priorities for Southeast Asia. The recent global energy crisis highlighted the region's vulnerability to fuel price shocks, with fossil fuel consumption subsidies soaring to a record USD 105 billion in 2022 – nearly 60% above the previous peak. Energy security risks continue to loom large as Russia's war in Ukraine continues and conflicts in the Middle East escalate, with Southeast Asia reliant on the Middle East for 60% of its current oil imports.

Energy-related environmental issues, including poor air quality and the impacts of climate change, are becoming more urgent. In 2023, 85% of Southeast Asia's population was exposed to polluted air, far exceeding the World Health Organization's recommended safe limits, leading to 300 000 premature deaths from outdoor air pollution and 240 000 from indoor air pollution linked to the use of polluting fuels for cooking. The region also faces risks from extreme weather, including a crippling heat wave in 2024 and heightened flood risks around rivers and coastal areas.

Fossil fuels – led by coal – have met nearly 80% of Southeast Asia's rising energy demand since 2010. Today, oil and coal each make up over a quarter of the region's energy demand, with natural gas contributing around one-fifth. In 2023, coal generated half of the region's electricity, accounting for 80% of power sector emissions, while also meeting 30% of industrial energy demand, including a rise in nickel production in Indonesia. Southeast Asia stands out as one of the few regions, alongside the Middle East, where GDP and emissions continue to rise in tandem, a sign that Southeast Asia's economic development remains very carbon intensive.

The region's energy future looks different from its past, but demand for all the major energy sources continues to rise in the STEPS. Clean energy is set to meet more than 35% of energy demand growth to 2035 in the STEPS, driven by a rapid expansion of wind and solar PV, along with sustained momentum for modern bioenergy, geothermal and other low-emissions technologies. As a result, the share of clean energy in the energy mix rises to one-quarter. However, fossil fuel use is also set to rise in this scenario, with oil demand increasing by 20% over the period to 2035 and coal and gas demand growing by over 30%.

Significant progress has been made towards achieving universal access to energy, yet challenges remain in closing the access gap, especially for clean cooking. Over 95% of households in the region now have electricity, but around 20% of the population still lacks access to clean cooking technologies, notably in Lao PDR, Myanmar and Cambodia. Southeast Asia is on track to reach universal electricity access by 2030 in the STEPS; however, more than 100 million people (15% of the region's population) continue to rely on traditional biomass, coal or kerosene for cooking. Stronger policies and pledges are needed to achieve universal clean cooking access by 2030.

Southeast Asia's electricity demand is set to rise 4% annually to 2035 in the STEPS, outpacing the 3% growth in overall energy demand. From over 1 300 TWh today, electricity demand rises above 2 000 TWh by 2035 in the STEPS, more than double Japan's current electricity demand and 15% higher than in the last edition of this *Outlook*. This is driven by the buildings sector, where air conditioning (AC) usage is surging, followed by transport and industry. Today, 16% of electricity used in buildings is for cooling; this grows to around 30% by 2035 in the STEPS. In Indonesia, the share of households with ACs rises from less than 15% today to 50% by 2035. Cooling alone accounts for almost one-third of the region's growth in electricity use, underscoring the need for stronger efficiency regulations and standards for new buildings to mitigate peak demand and alleviate pressure on the power system.

Renewables meet more than half of the increase in electricity demand in the STEPS to 2035, but their growth in Southeast Asia lags global trends. The generation mix is changing as renewables, led by solar, enter a period of rapid expansion, supplying more than one-third of the region's electricity by 2035 in the STEPS. Viet Nam continues to lead the region as the largest renewable power market, followed by Indonesia and the Philippines. However, the projected doubling in renewable capacity to 2030 is modest compared with global trends and falls well short of what is needed to match the growth in electricity demand. As a result, generation from unabated coal-fired power continues to rise by an average of 2% per year to 2035, although its share in the mix drops to around 35%. Increasing supplies of liquefied natural gas (LNG) support a slight uptick in the share of gas-fired power, which reaches a high point of 28% in the late 2020s.

Southeast Asia's relatively young fleet of coal-fired plants – averaging under 15 years old – requires innovative strategies to reduce their emissions. Reducing reliance on coal without compromising electricity security means scaling up clean, affordable alternatives that can replace the energy services provided by coal, including generation and balancing services. Early retirement of coal plants requires funds and effective strategies for a managed phase-out. Several countries are working to operate coal plants more flexibly, allowing for better integration of low-cost wind and solar, which involves addressing inflexible contractual arrangements. Others are exploring co-firing coal plants with low-emissions fuels like biomass and ammonia. By incorporating more cost-competitive sources into the mix, the average cost of electricity decreases from around USD 120 per MWh today – above the global average – to just under USD 100 per MWh by 2035 and to USD 80 per MWh by 2050.

Expanding and modernising electricity grids, including enhancing regional interconnections, is essential for ensuring electricity security and flexibility. By 2035, annual investment needs for electricity networks more than double to around USD 22 billion in the STEPS. This includes infrastructure investments tied to regional initiatives such as the ASEAN Power Grid, which aims to connect all 10 ASEAN countries, and the power trade agreement among the six countries of the Greater Mekong Subregion, as well as renewables-based microgrids for remote areas and islands.

Today's electricity systems can accommodate higher shares of variable renewables across much of Southeast Asia but additional sources of flexibility – both for short-term and seasonal needs – will be needed as wind and solar deployment gains momentum. Currently, thermal power plants are the main sources of flexibility and, together with hydropower, they remain important to meeting variations in demand. However, as the share of wind and solar increases, other flexibility sources come into play. These include batteries and demand response for short-term flexibility, as well as low-emissions dispatchable generation for seasonal needs, including geothermal and thermal power plants fired with low-emissions fuels. In the longer term, flexible grid-connected electrolysers emerge as an option for both short-term and seasonal balancing.

Southeast Asia is a major manufacturing centre, with potential to expand its role in clean energy value chains that have already created over 85 000 jobs in the region since 2019. Viet Nam, Thailand and Malaysia are the largest solar PV manufacturers after China. The region has 16 GWh of electric vehicle (EV) battery cell manufacturing capacity, with plans to add almost 40 GWh more by 2030, particularly in Indonesia, which is set to become one of the region's leading hubs for lithium-ion batteries and components due to its natural resources. Indonesia and the Philippines are the world's top producers of nickel, together accounting for about 65% of global mined production. However, increasing economic fragmentation and trade barriers present significant risks for Southeast Asia, given its integration into global value chains across various industries. While employment in clean energy is approaching parity with fossil fuel-related jobs, it holds much greater potential for growth. For large coal-producing countries like Indonesia and Viet Nam, ensuring just and orderly transitions for workers and local economies is crucial.

Enhancing Southeast Asia's advantages as a manufacturing and production hub will require a reduction in its emissions intensity. The emissions associated with production processes around the world are coming under increasing scrutiny. In the STEPS, Southeast Asia's industry remains dependent on fossil fuels; however, there are opportunities for clean electrification and greater use of low-emissions fuels, including modern bioenergy, hydrogen and fossil fuels with CCUS. In the nickel sector, replacing coal with natural gas, bioenergy and other low-emissions fuels for heat and refining is key. Singapore, as the world's largest bunkering port, has a pivotal role in decarbonising shipping, with efforts focusing on ammonia and methanol bunkering.

Biofuels, electrification, fuel economy standards and the development of public transport are key strategies to reduce Southeast Asia's dependence on imported oil for transportation and to bring down emissions. While the region's oil production is declining, demand is set to rise from 5 mb/d today to 6.4 mb/d by 2035 in the STEPS. Biofuels are already well-established in Southeast Asia, meeting nearly 10% of road transport energy demand – twice the global average. When developed sustainably, biofuels can reduce transport emissions and reliance on oil imports. Electric vehicles are also gaining traction, accounting for 15% of car sales in Viet Nam and 10% in Thailand in 2023, with potential to exceed the projected 25% EV share of total car sales by 2035 in the STEPS. The electrification of two/three-wheelers presents another major opportunity, as ownership levels in Southeast Asia are nearly four times the world average. Additionally, implementing efficiency measures like fuel economy standards can further diminish oil dependence and accelerate the transition to EVs, while mass transit solutions can help alleviate traffic issues in rapidly developing cities.

Today's policy settings leave Southeast Asia facing significant energy security risks. In the STEPS, Southeast Asia's annual oil import bill surpasses USD 200 billion by mid-century, up from USD 130 billion today, and the region is set to become a net importer of gas by the late 2020s. Accelerating progress toward Southeast Asia's structural transformation – in line with countries' announced climate goals – would mitigate these vulnerabilities. In such a scenario, annual fossil fuel import bills peak at some USD 140 billion around 2030 before dropping to under USD 90 billion by 2050 – one-third of the amount projected in the STEPS.

The pace of Southeast Asia's energy transitions is enough to weaken the link between GDP growth and emissions, but not sever it entirely. The region's net zero plans and the global energy targets agreed at COP28 outline the actions that can slow and then ultimately reverse projected emissions growth. Achieving this will require much more than the almost doubling of renewable capacity anticipated in the STEPS by 2030. It will also necessitate speeding up energy efficiency improvements, addressing methane leaks, expanding grid and storage infrastructure, advancing low-emissions fuels, and phasing out inefficient fossil fuel subsidies. Cost-competitive clean technologies open a huge opportunity for Southeast Asia to chart a new course for its energy sector.

Scaling up clean energy investment demands ambitious, credible and investable national transition pathways, along with active engagement from the private sector and enhanced international financial and technical support. In 2023, Southeast Asia accounted for only 2% of global clean energy spending, well below its share in global GDP (6%), global energy demand (5%) and population (9%). Today, for every dollar invested in fossil fuels in the region, about 80 cents go to clean energy – far from the global ratio of nearly 2-to-1 in favour of clean energy. Achieving a pathway aligned with the region's climate goals requires over USD 190 billion in clean energy investments in 2035 – more than double the amount projected in the STEPS and five times the current level. Most of this additional financing needs to come from private and commercial sources, necessitating policy reforms and increased volumes of development and concessional funding to bring down risks that raise the cost of capital. At present, the cost of capital for clean energy projects in Southeast Asia is at least twice that of advanced economies or in China.

Robust regional and international cooperation frameworks provide an important anchor for secure, people-centred clean energy transitions in the face of geopolitical tensions and climate risks. Each of the ten countries in Southeast Asia is distinctive in terms of development, industrial output, politics, geography and energy needs. Advancing energy transitions in this region requires tailored approaches that reflect both regional and individual country circumstances. Cooperation within the ASEAN framework and with international partners brings important benefits. Initiatives like the Just Energy Transition Partnerships and the Asia Zero Emission Community bring stakeholders together to accelerate policy action and financing support. The establishment of the IEA's Regional Cooperation Centre in Singapore – the first ever IEA office outside its Paris headquarters – is testament to Southeast Asia's importance in global energy affairs and the shared commitment to supporting its countries in achieving a safer and more sustainable energy future.

Introduction

Introduction

The *Southeast Asia Energy Outlook 2024* is the sixth edition of this special report, making Southeast Asia by far the most regularly updated regional outlook compiled by the International Energy Agency (IEA). This reflects the dynamism of the region, as well as the importance of the IEA's partnership with the ten countries that make up the Association of Southeast Asian Nations (ASEAN) – Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam.

The relationship between the Agency and this region is being further strengthened in October 2024 with the opening in Singapore of an IEA Regional Cooperation Centre during the Singapore International Energy Week (alongside the release of this report). This is the first IEA office outside its Paris headquarters.

Energy markets have continued to be quite turbulent since the publication of the last edition of this report in 2022. At that time, the region had started to emerge from the major shock of the Covid-19 pandemic when it was hit by high energy prices after the Russian Federation's (hereafter "Russia") full-scale invasion of Ukraine. This period of disruption and volatility left its mark on Southeast Asia, which now needs to chart its energy future in a more uncertain and fragmented international environment, as escalating conflicts in the Middle East underscore continued energy security risks.

An open question, examined in this report, is whether the upheaval of the last few years will result in a renewed push for a more sustainable and secure energy system, in line with the commitments to rapid energy transitions now made by almost all the countries in the region. Eight of these ten countries have announced the intention to achieve net zero emissions, typically conditional on receiving adequate international support for the necessary transformation. Brunei Darussalam, Cambodia, Lao PDR, Malaysia, Singapore and Viet Nam have announced a target date of 2050; Indonesia of 2060; and Thailand of 2065.

A key uncertainty for the future trajectory of the region's energy sector is how the ten governments' policies will evolve. This is the main differentiating factor between the three scenarios examined in this *Outlook* – none of which is a forecast – detailed as follows:

The **Stated Policies Scenario (STEPS)** provides a sense of the prevailing direction that Southeast Asia's energy sector could take, by considering how it might develop based on a detailed reading of the latest policy settings in the region, including energy, climate and related industrial policies that are in place or that have been announced. The targeted aims of these policies are not automatically assumed to be met; they are incorporated in the scenario to the extent that they are underpinned by adequate provisions for their implementation.

The **Announced Pledges Scenario (APS)** starts from the same detailed reading of government policies but takes a different view on their implementation. Notably, this scenario assumes that all the national energy and climate targets made by governments are met in full and on time, including long-term net zero goals. This is naturally a strong assumption, given that most governments are still far from having policies in place to deliver on these long-term pledges. This scenario outlines a way to achieve all of Southeast Asia's current announced climate aspirations.

The analysis also explores the regional implications of the **Net Zero Emissions by 2050 (NZE) Scenario**, which shows a pathway for the global energy sector to achieve net zero CO_2 emissions by 2050 and to limit long-term global warming to 1.5 °C. The NZE Scenario provides a global benchmark against which changes at the regional level can be assessed.

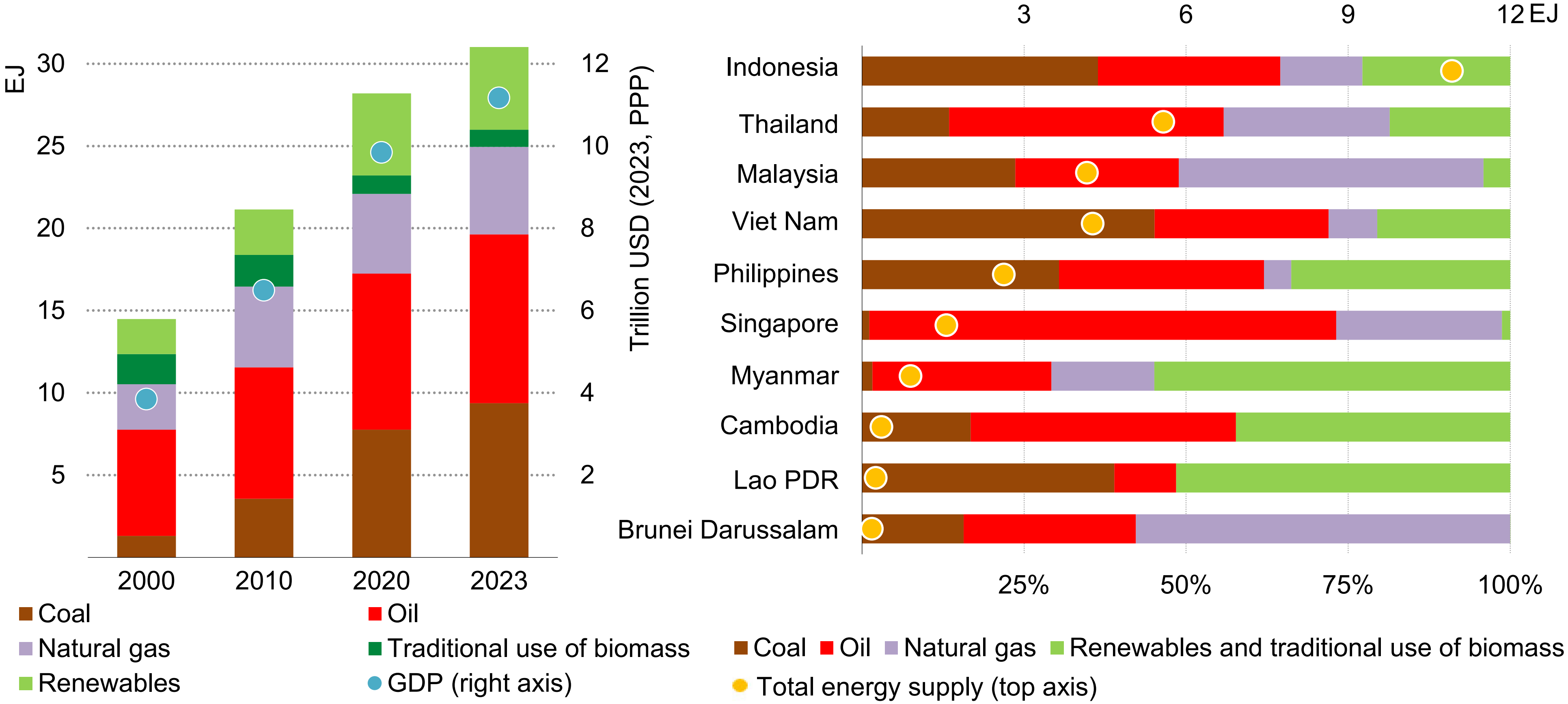
After a scene-setting discussion in the first chapter, the second chapter describes the scenario projections across all fuels and technologies and considers their broad implications for energy security, affordability and emissions. The third chapter analyses three key areas in depth. It explores what the outcomes of the COP 28 meeting in Dubai (2023) mean for Southeast Asia, notably regarding the global targets to triple renewable capacity by 2030, double the pace of energy efficiency improvement, and significantly reduce methane emissions. It also examines some emerging issues for clean energy transitions for electricity security and clean energy supply chains, and concludes with a discussion on how to scale up investment and finance in line with the region's energy and climate goals.

Energy in Southeast Asia

1.1 Today's energy trends

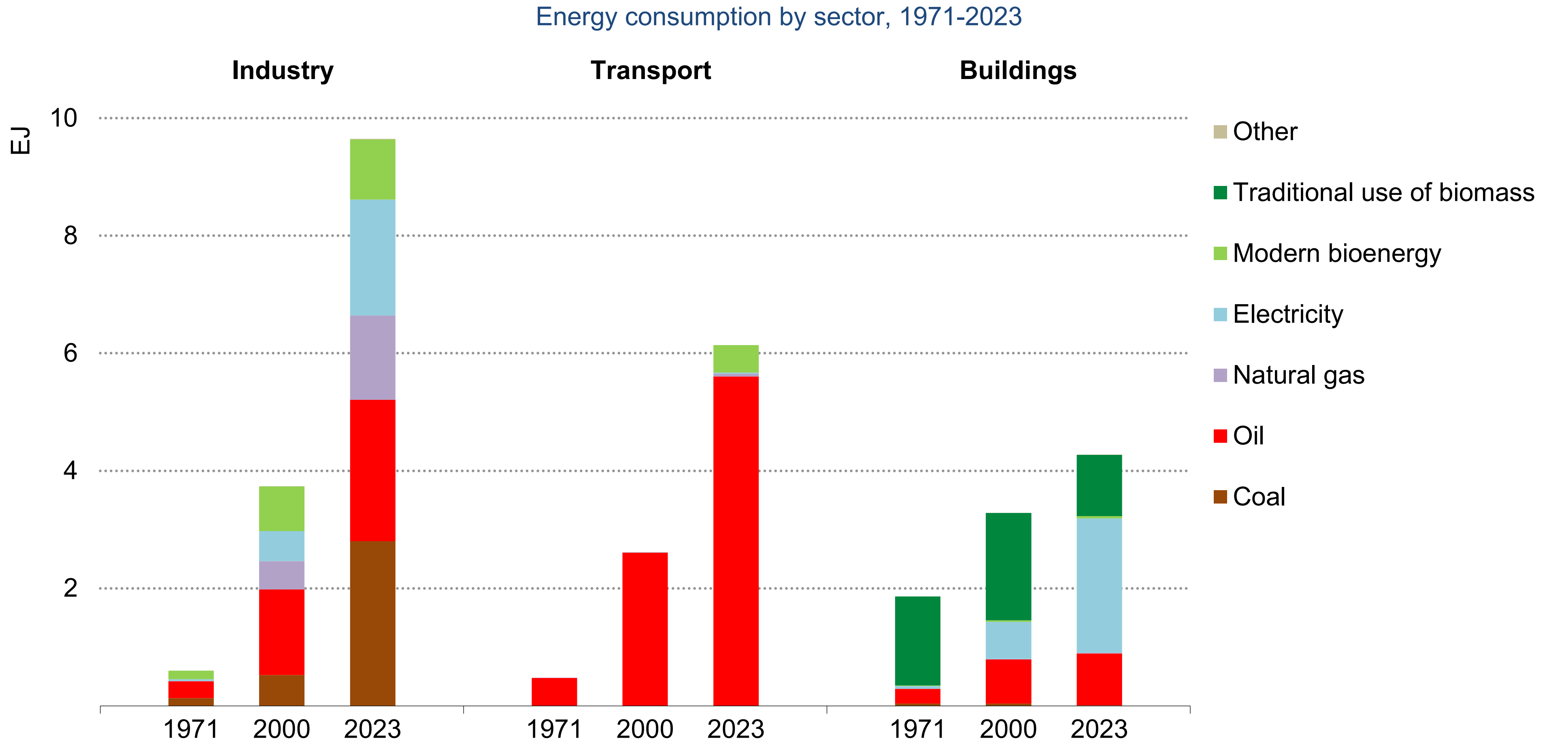
Southeast Asia's economies and energy systems have experienced rapid growth over the past two decades, with strong country-by-country variations in the energy mix

Energy demand by fuel in Southeast Asia, 2000-2023 (left) and by country in 2022 (right)



Notes: PPP = Purchasing Power Parity. EJ = Exajoules.

Industry and transport have driven strong growth in energy consumption



Notes: “Transport” excludes international bunkers. “Other” fuels cover geothermal, solar thermal, district heating and non-renewable waste.

Although the contribution of clean energy is growing, fossil fuels – led by coal – have met the lion's share of growth in Southeast Asia's energy use over recent decades

Southeast Asia is a dynamic part of the global economy, generating around 6% of global GDP. Despite the damaging effects of the Covid-19 pandemic and the global energy crisis triggered by Russia's full-scale invasion of Ukraine, its economy expanded by more than 45% over the last ten years. A growing economy and rising population have had strong implications for the region's energy demand which has more than doubled since 2000 – most of this growth was met by the rising use of fossil fuels. Coal was the main beneficiary, increasing its share in the regional energy mix from 9% in 2000 to 28% today. Indonesia accounts for almost 90% (as of 2022) of the region's coal production and is a major global exporter; Viet Nam is the next largest producer and consumer.

The region's oil demand has risen by 60% since 2000, and even though the share of oil in the energy mix has declined somewhat, it remains the largest element in the mix at above 30%. Indonesia, Malaysia and Thailand are the leading producers, but overall output in Southeast Asia peaked in the 1990s and has fallen by more than a third since 2000. Rising consumption has therefore required a large increase in imports, which have increased 2.5 times since 2000, with implications for the balance of payments and for energy security.

Natural gas accounts for around 20% of Southeast Asia's energy mix. Historically the region has been a significant net supplier of gas to international markets. For two decades Indonesia was the world's largest LNG exporter, until overtaken by Qatar in 2006, and Malaysia was likewise a major exporter. However, this surplus has gradually been eroded as the region's demand (which has almost doubled since 2000) outpaced increases in production (a total increase of around 20% over the same period). Growing reliance on imports exposed consumers to price spikes during the global energy crisis; this shook confidence in natural gas as a reliable and affordable fuel for the future. Gas demand rose in 2023, recovering to its 2018 levels.

The contribution of renewable energy sources to meeting the region's energy needs almost tripled between 2000 and 2023. Solar PV and wind have increased rapidly in recent years, especially in Viet Nam, but modern bioenergy, geothermal energy and hydropower still make up 96% of total renewable energy supply in the region today.

Regional trends hide large variations among individual countries. The share of fossil fuels ranges widely across Southeast Asia, depending on resource endowments, the structure of the economy and policies. For example, over the last decade, energy demand has grown fastest in Lao PDR and Cambodia, albeit from a low base. In Cambodia, this growing demand has almost exclusively been supplied by fossil fuels, while in Lao PDR, hydropower has played a key role.

While transport has been the major source of oil demand growth, industry has pushed up energy consumption across the board, and rising incomes drive higher demand in buildings

As recently as 2000, the shares of the three main end-use sectors – industry, transport and buildings – in Southeast Asia's final energy consumption were roughly equal. Since then, however, energy demand in the industry and transport sectors has sky-rocketed, while that in the buildings sector has been much more modest as modern sources of energy replaced the highly inefficient use of biomass as a cooking fuel.

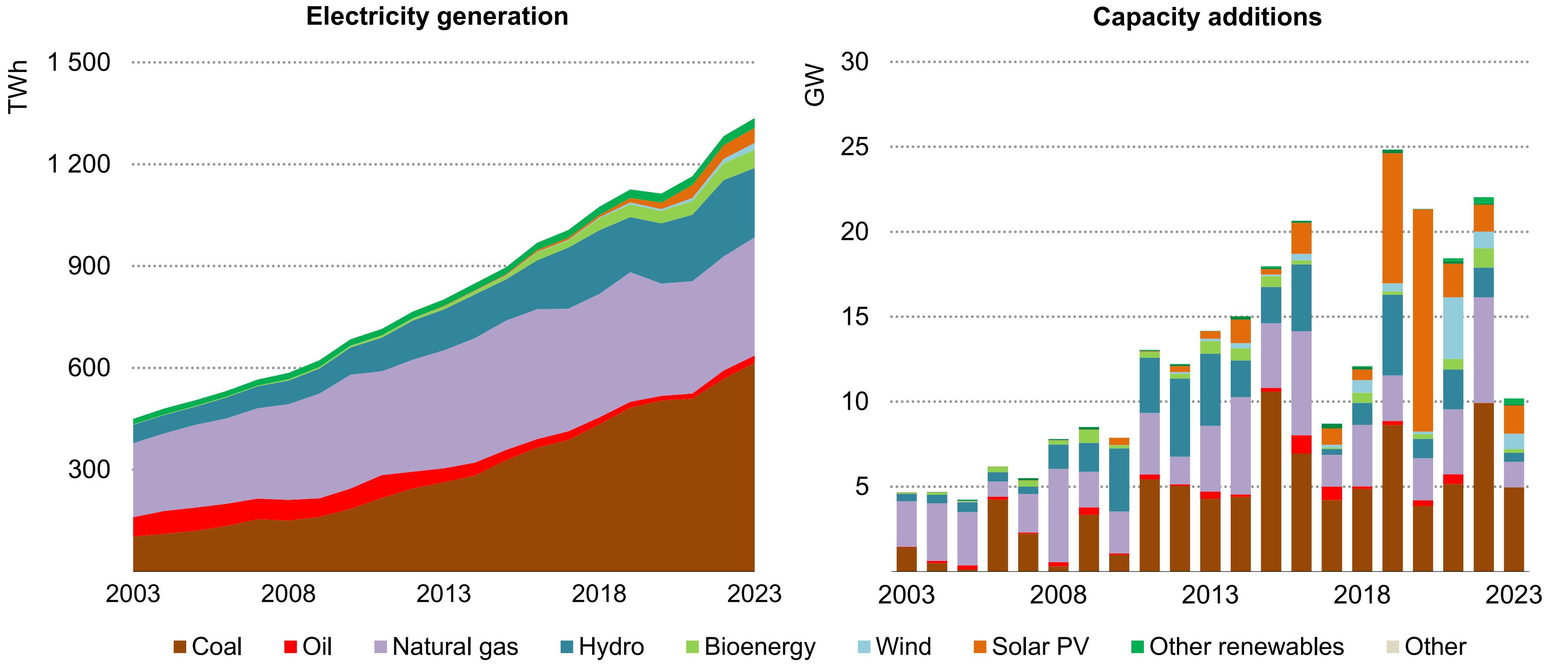
The industry sector has contributed to increases in demand for all the major energy sources with steel production rising sharply, including output of stainless steel that benefits from the region's significant nickel resources; this is one factor driving the rapid rise in regional coal consumption. Southeast Asia is also a major manufacturing centre, well integrated into global value chains for a wide range of goods, from food and textiles to consumer electronics and cars – industries which tend to rely more heavily on electricity and natural gas. Furthermore, the region is expanding its presence in service provision, including logistics and financial services, which tend to be significantly less energy-intensive sources of growth. Southeast Asia's integration into global value chains has been a source of its economic dynamism; however, the trend towards global economic fragmentation and higher barriers to trade also therefore exposes the region to some future risks.

The transport sector has driven the region's increase in oil demand: oil consumption in transport has more than doubled from 1.3 mb/d in 2000 to 2.8 mb/d today. Over this period, car ownership has risen from 30 vehicles per 1 000 inhabitants in 2000 to 75 per 1 000 in 2023. Truck freight activity has also grown rapidly as a result of the region's industrial rise. A shift towards electric mobility is only just beginning in Southeast Asia, but there are already some striking data points: the share of electric cars in total sales reached 15% in Viet Nam in 2023 and 10% in Thailand. Viet Nam's electric car sales grew from less than 100 in 2021 to more than 30 000 in 2023, largely thanks to a domestic front-runner VinFast. Electric two-wheelers are another major potential source of growth, but for the moment they account for only around 3% of total sales.

Energy consumption trends in the buildings sector have been shaped by rising living standards and incomes, pushing up demand for cooling and appliances, and by significant progress in energy access. More than 95% of households across the region now have electricity and around three-quarters have clean cooking options such as liquefied petroleum gas and improved cook stoves. However, these shares remain very low in Lao PDR, Cambodia and Myanmar, and the surge in commodity prices during the global energy crisis was a setback for efforts to reach universal access.

Growing electricity use has been met mostly by coal, which now accounts for about 45% of the electricity mix, although capacity additions have diversified over the last five years

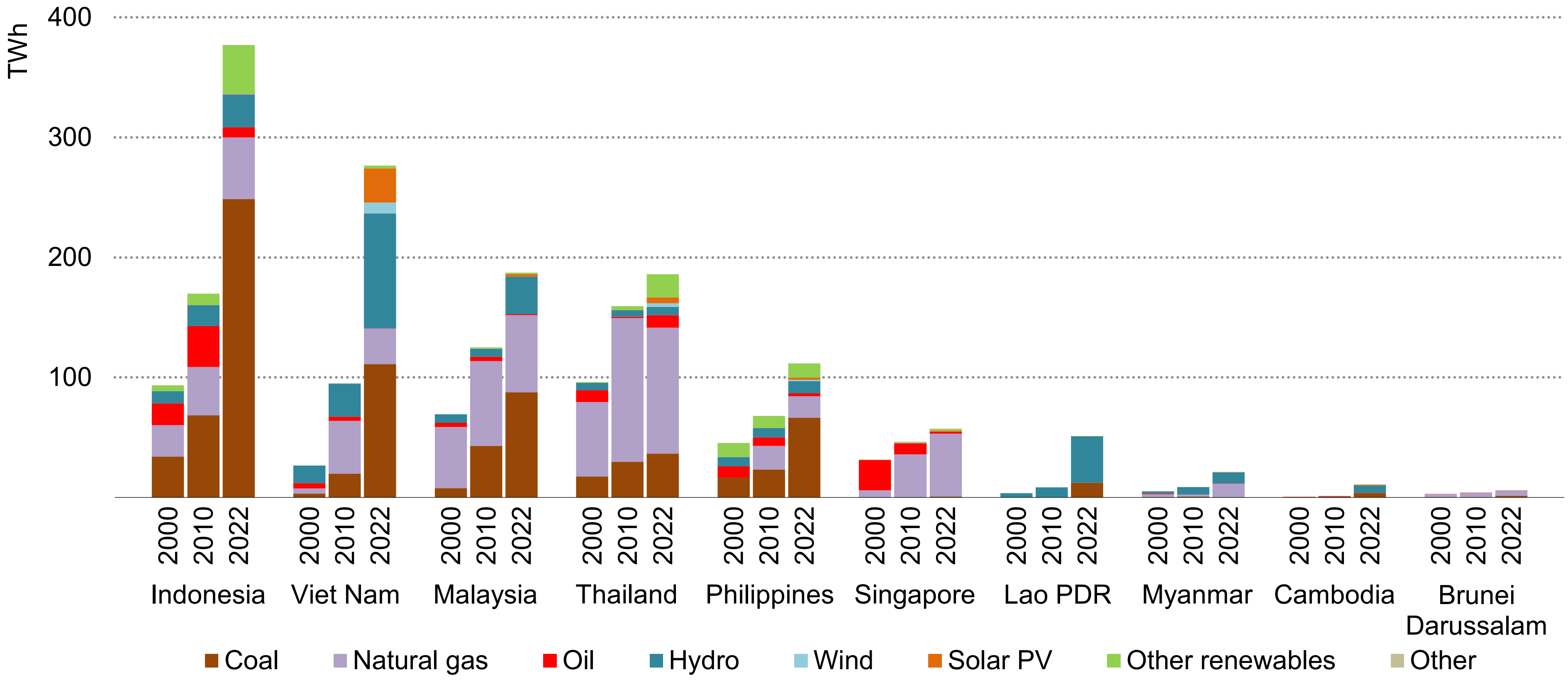
Electricity generation and annual electricity generation capacity additions by source, 2003-2023



Notes: GW = gigawatts. TWh = terawatt-hours. “Other renewables” include geothermal, concentrating solar power and marine power. “Other” includes non-renewable waste and other sources.

Rapid growth in demand has seen Indonesia and Viet Nam become Southeast Asia's largest electricity markets

Electricity generation by country and energy source, 2000-2022



Notes: TWh = terawatt-hours. "Other renewables" include bioenergy, geothermal, concentrating solar power and marine power. "Other" includes non-renewable waste and other sources.

Electricity generation has tripled over the past 20 years, mostly from coal-fired power plants, while recent years have seen an uptick in wind and solar deployment

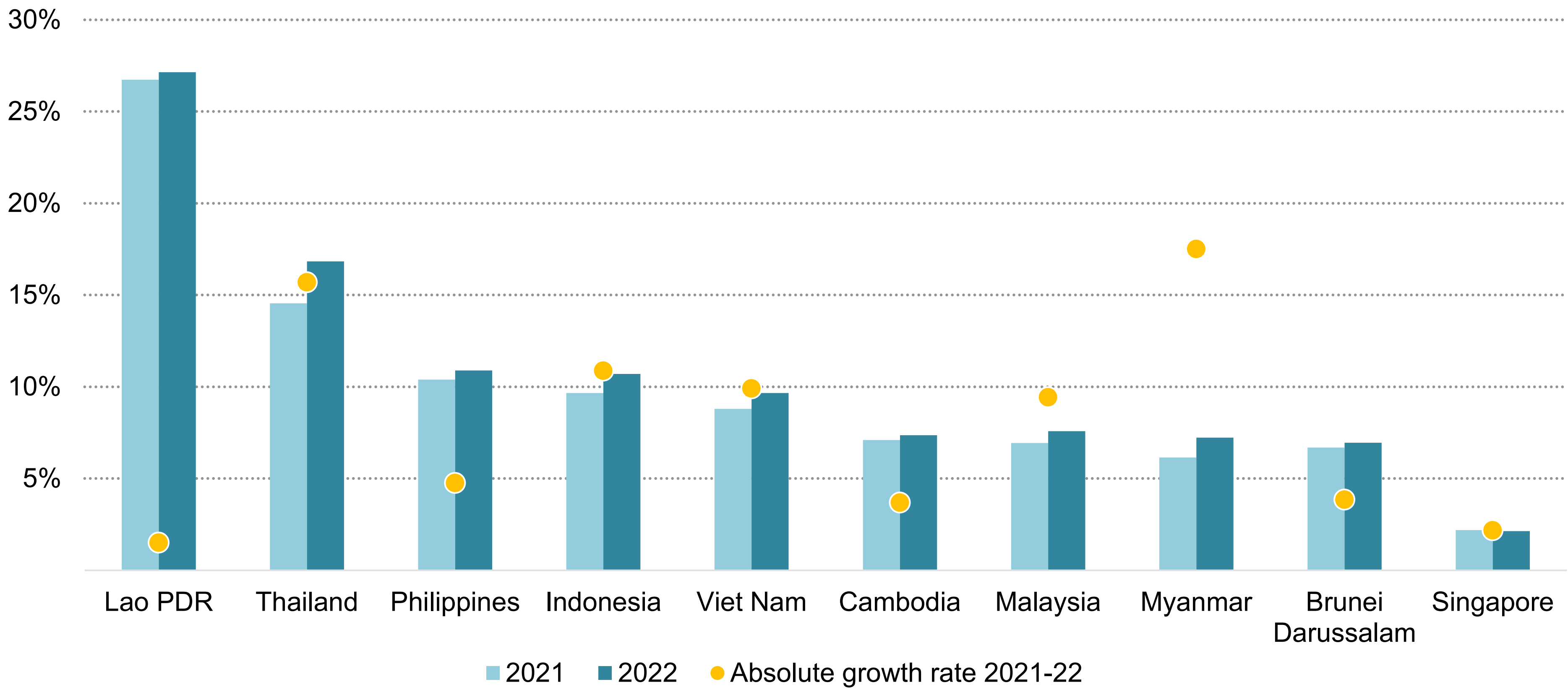
Electricity demand in Southeast Asia has tripled over the past 20 years, boosted by strong economic growth and millions gaining access to electricity. Most of the countries in the region have seen electricity generation increase by more than 5% per year on average since 2000, with some – notably Cambodia, Lao PDR and Viet Nam – seeing annualised growth in excess of 10% per year.

Much of the additional electricity has been supplied by coal-fired power plants. The expansion of coal-fired power generation accelerated from 2010 onwards, with annual coal capacity additions growing by about 5 GW per year on average over the period to 2023, the third-fastest rate globally, putting Southeast Asia right behind the People's Republic of China (hereafter "China") and India in terms of new coal additions. In Indonesia, which has become the largest producer of electricity in the region, and in the Philippines, coal now accounts for nearly two-thirds of the electricity supply. Coal's share has grown to nearly 50% in Malaysia and over 40% in Viet Nam. Although gas-fired capacity has also expanded, growing at an average rate of about 2.7 GW per year over the past 20 years, the strong growth of coal has seen it overtake natural gas to become the largest source of electricity in the supply mix of several large Southeast Asian economies, including Viet Nam, Malaysia and the Philippines. Hydropower has also grown significantly in several countries, with most additional capacity coming online in Viet Nam, followed by Lao PDR (some of it to increase exports of electricity to neighbouring Thailand and Viet Nam), Malaysia and Indonesia. Growth in solar PV and wind power has picked up over the past five years, with several countries seeing an increase in capacity additions. Viet Nam – which has overtaken Malaysia and Thailand to become Southeast Asia's second-largest producer of electricity – experienced a solar boom from 2019 to 2021, supported by a generous feed-in tariff, which saw the addition of 20 GW of capacity. Solar PV now accounts for about 10% of Viet Nam's electricity supply, though the withdrawal of support as well as bottlenecks in the transmission and distribution systems have since led to a virtual halt in new developments.

The energy crisis triggered by Russia's full-scale invasion of Ukraine in 2022 had a significant impact on power systems in Southeast Asia, exposing their vulnerability to external shocks. Record-level coal and gas prices put severe financial pressure on utilities and independent power producers and increased the difficulty of securing thermal coal and LNG supplies. Fuel shortages impacted the reliability of power supplies. Viet Nam, for example, had to grapple with coal shortages, a doubling of coal import bills, as well as difficulty in securing LNG supply contracts, while a drop in domestic gas production and difficulty sourcing additional coal exacerbated an electricity supply crunch in the Philippines.

The global energy crisis was a major shock for Southeast Asia, but governments provided a measure of protection for the region's households

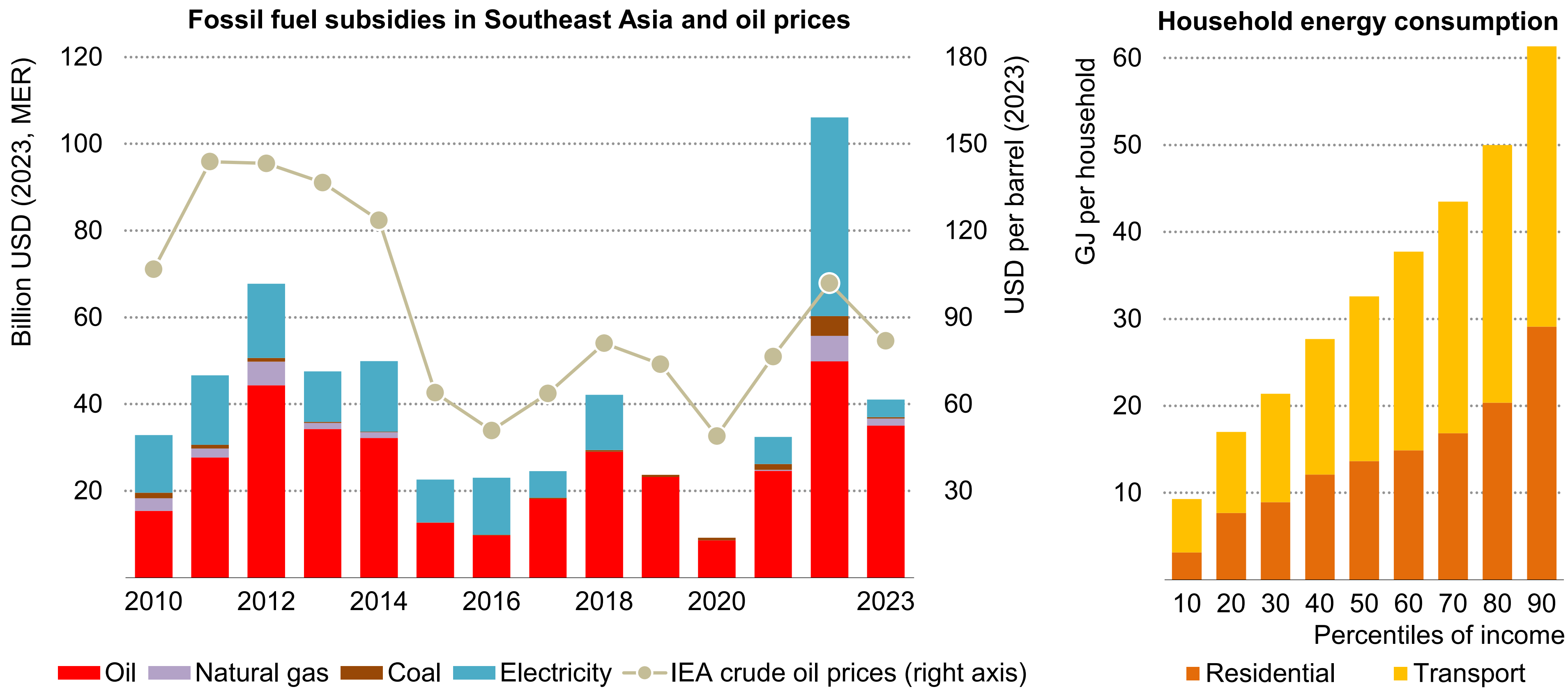
Household energy expenditure as a portion of average household income by country, 2021-2022



Notes: This analysis considers government subsidies that directly affect the energy prices paid by consumers. It does not include direct payments to households such as energy assistance cheques.

This protection came at a cost: fossil fuel consumption subsidies reached a record high in 2022, posing significant fiscal risks

Evolution of fossil fuel subsidies and oil prices, 2010-2023, and household energy consumption by income bracket, 2023



Note: MER = Market Exchange Rate.

The global energy crisis exposed significant vulnerabilities in the security and affordability of Southeast Asia's fossil fuel-dominated energy supply

The sharp rise in fossil fuel prices during the global energy crisis exposed vulnerabilities in Southeast Asia's energy system. Over the last two decades, the region has remained highly reliant on fossil fuels and on imported oil in particular. This has strained public resources as well as low-income household budgets and has come with serious consequences for emissions and air quality.

The surge in natural gas prices and the limited availability of LNG cargoes were particularly challenging for countries in the region that rely on LNG imports, such as Thailand and Singapore. Indonesia has been diverting LNG to meet domestic demand and importing cargoes as needed. LNG import facilities also recently began operations in Viet Nam and the Philippines. The crisis has generated a range of policy responses, including greater attention to domestic production as well as a renewed look at alternative sources of power, including renewable technologies.

Consumer exposure to higher prices varied across the region. Poorer countries and communities are at high risk from price spikes, as energy can account for a large share of their overall spending. Our analysis suggests that households in Lao PDR spend almost one-third of their income on energy (including both residential use and for transportation). However, consumers also had a degree of protection from international market volatility, as end-user energy prices – notably for electricity but also for transport fuels – are typically regulated. In some cases they are held well below the international market prices (IEA: Energy Subsidies).

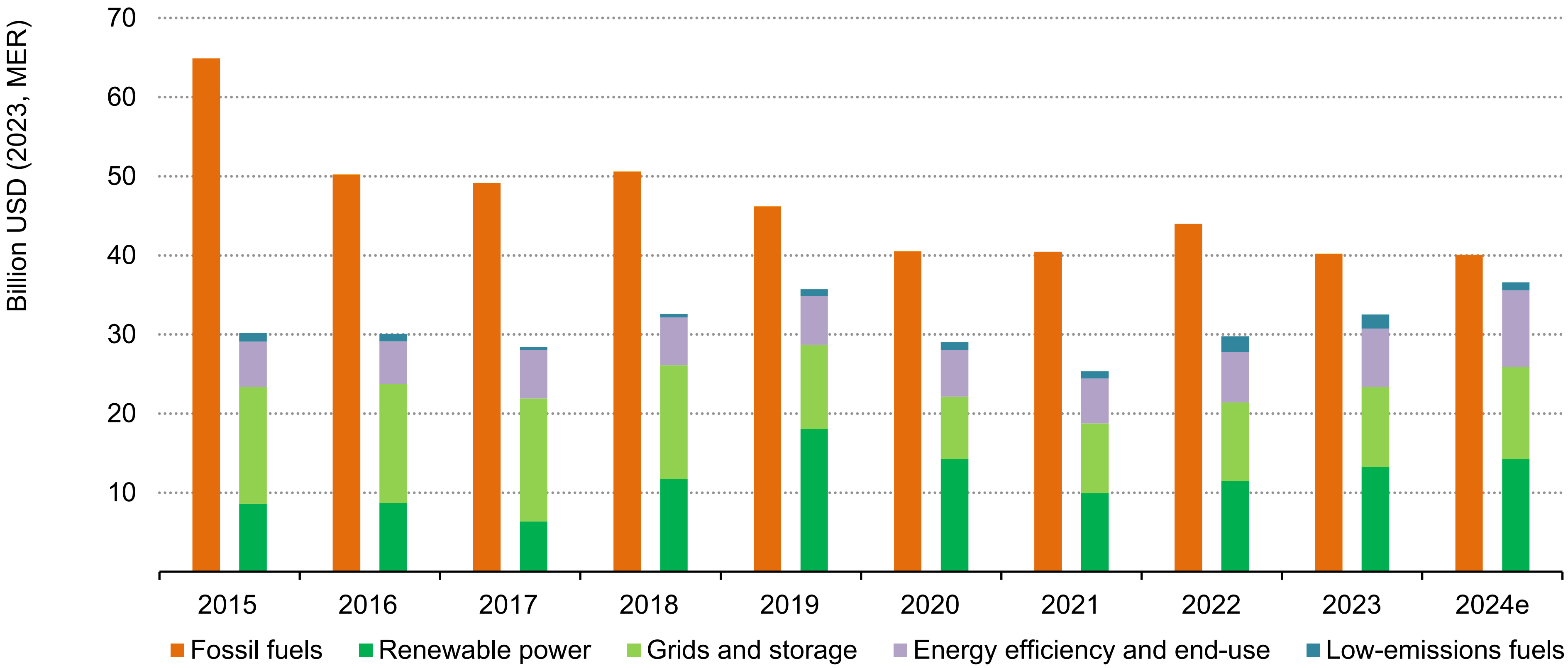
This meant that the crisis produced a sharp increase in import bills and fossil fuel consumption subsidies in Southeast Asian countries. The latter reached a record USD 105 billion in 2022, nearly 60% higher than the previous record. As wholesale fossil fuel prices decreased in 2023, subsidies also declined, returning closer to the average level seen in the past decade.

These consumption subsidies are rarely well-targeted, which means that they typically benefit higher-income households because they use more energy: on average across the region, the richest 10% of households consume six times more energy than the poorest 10%. In Indonesia, for example, middle- and upper-income households account for about 20% of the population but consume 42-73% of the subsidised diesel and almost 30% of subsidised liquified petroleum gas (LPG) (World Bank, 2022).

The global energy crisis provided powerful reasons for Southeast Asia to move towards a cleaner and more diversified energy mix. It also highlighted the need for careful and transparent pricing reform – with adequate provision for the impacts on the poorest households – to bolster the case for investment in cleaner and more efficient technologies and to relieve strains on public budgets.

The composition of energy investments in Southeast Asia is gradually shifting, pointing in the direction of a cleaner energy mix in the future

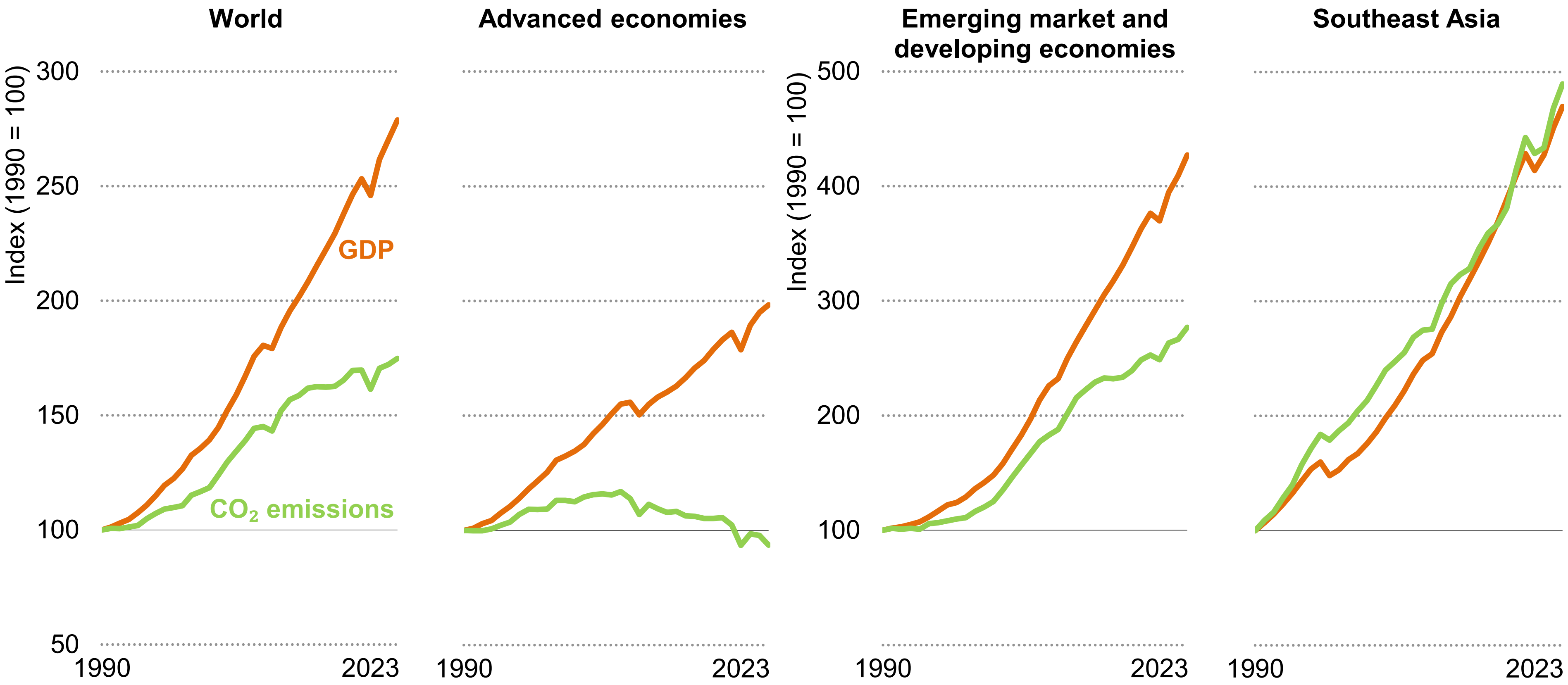
Investment in clean energy and fossil fuels in Southeast Asia, 2015-2024e



Notes: "Low-emissions fuels" = modern bioenergy, low-emissions hydrogen-based fuels, and fossil fuels with CCUS; it also includes direct air capture. 2024e = estimated values for 2024. MER = Market Exchange Rate.

However, for the moment, Southeast Asia shows a continued strong relationship between its GDP and CO_2 emissions, which are rising in parallel

GDP and CO_2 emissions by region, 1990-2023



Note: GDP expressed in year-2023 US dollars in purchasing power parity terms (PPP).

Southeast Asia's ability to meet its energy and climate goals in a secure and affordable way will depend on its success in mobilising energy investment

Energy investment flows are a crucial measure of Southeast Asia's energy outlook. For the moment, there are significant gaps between investment trends and the region's development and climate goals. Overall investment in all parts of the energy sector has yet to rebound to pre-pandemic levels, making the region an outlier from the broader global trend. The amount of capital going to fossil fuel supply projects is higher than that going to clean energy: for every dollar invested in fossil fuels today, around 80 cents is invested in clean energy. In contrast, the global ratio is almost 1:2 in favour of clean energy. Overall, the region's spending on clean energy represents only around 2% of the global total, significantly below the region's weight in the global economy (6%), global energy demand (5%) and population (9%).

Total energy investment in Southeast Asia in 2023 was just over USD 70 billion, of which capital flows to clean energy projects represented around USD 32 billion. Investments in the region were affected by some headwinds from higher borrowing costs and policy uncertainties but are generally on a rising trend. Our latest estimate suggests that almost all of the USD 5 billion increase in 2024 is set to be devoted to clean energy. Policy frameworks for energy investment are being strengthened, notably through initiatives like Indonesia's Comprehensive Investment and Policy Plan, released in 2023 under the Just Energy Transition Partnership (JETP).

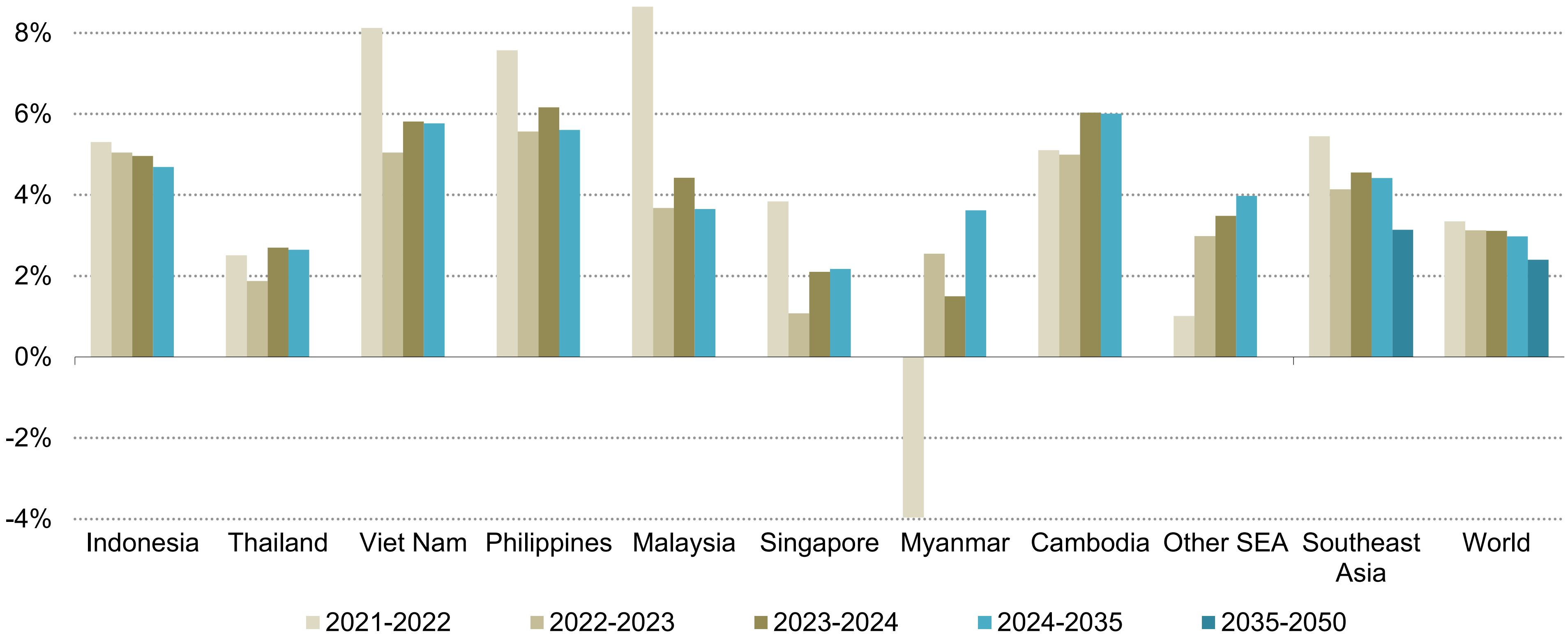
Offshore gas projects and biofuels are two of the more dynamic sectors for fuel investments. Clean power and grid expansion projects have made up the majority of the clean energy investments in recent years. From 2022 to 2023, installed capacity of solar PV and wind grew by 7%, accounting for nearly 25% of capacity additions in 2023. Investments in energy efficiency and electrification of end-uses account for less than 10% of the total, a relatively low share compared with other countries and regions.

The combination of relatively high growth in energy demand and the sluggish pace of clean energy investment is reflected in the data for Southeast Asia's emissions. At the global level and in most other parts of the world, the relationship between growth in the economy and growth in emissions has gradually been loosening. This trend extends well beyond advanced economies: in China, for example, the economy has seen fifteen-fold growth since 1990, but CO_2 emissions are only five times higher. Southeast Asia has been one of the few regions where GDP and emissions continued to march shoulder to shoulder (the Middle East is another). This is largely due to the high coal intensity of the region's economic growth, with a rising share of coal in power generation and industrial energy demand.

1.2 Economic and demographic prospects

GDP growth in Southeast Asian countries is picking up after the pandemic and the global economic crisis, and is assumed to remain well above the global average to 2050

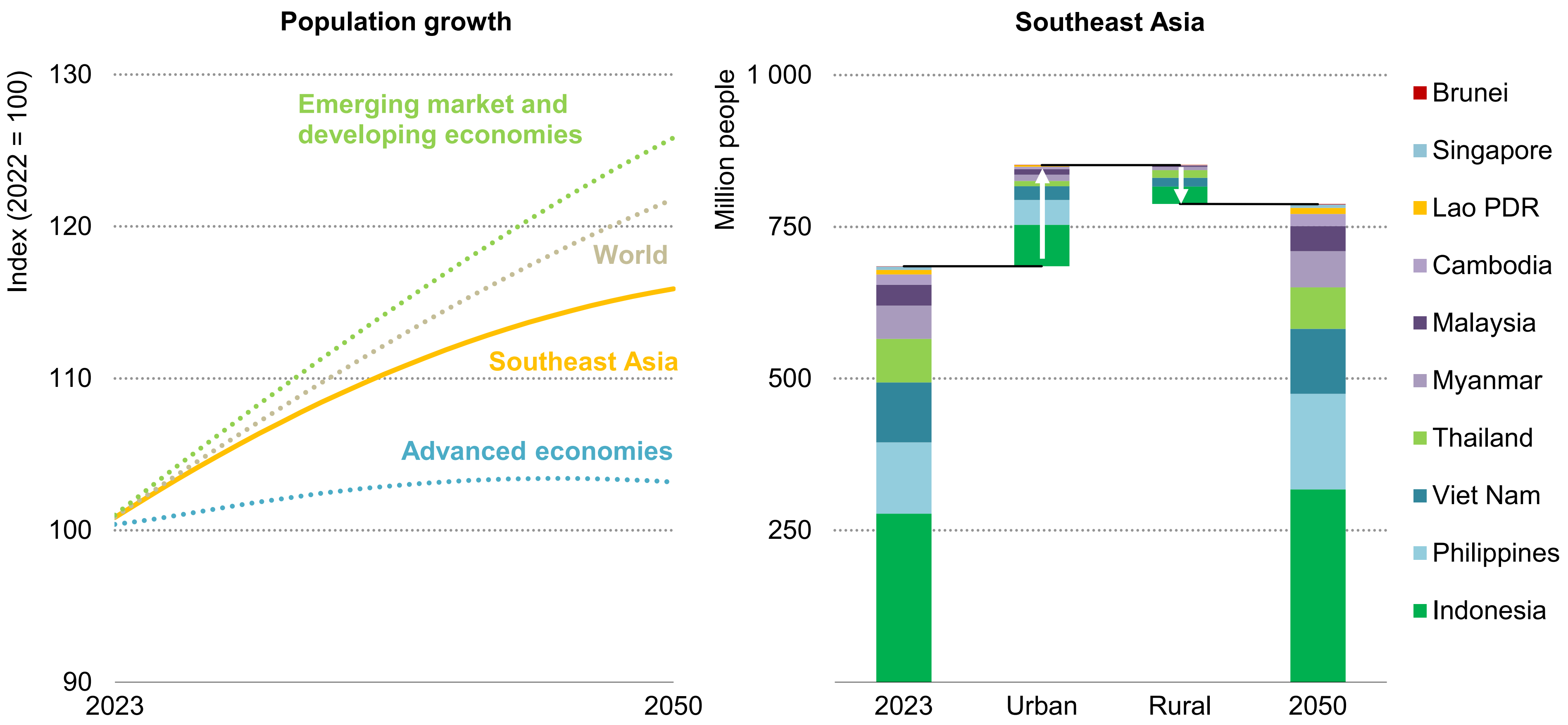
Average annual GDP growth by country and on a regional and global level, 2021-2050



Note: GDP expressed in 2023 US dollars in purchasing power parity terms (PPP). "Other SEA" is Brunei Darussalam and Lao PDR.

The region's population is expected to rise towards 800 million by mid-century, with all of the increase in urban areas

Population growth by economic grouping and country, 2023-2050



Sources: UN DESA (2022); IEA databases and analysis.

Economic growth and demographic trends are fundamental underlying forces shaping our outlook for the energy sector in Southeast Asia

Southeast Asia is a diverse region whose economic performance has proved to be quite resilient in recent years. Economic growth in the coming years is expected to be robust, although the region faces risks from higher borrowing costs, trade fragmentation and an increasingly complex geopolitical context. More so than many other parts of the world, Southeast Asia is also exposed to the effects of extreme weather events and climate-related risks, which could affect food as well as energy security.

The region has historically been successful in attracting investments in manufacturing and has started to position itself also in some clean energy manufacturing supply chains. This is notable for solar PV in Cambodia, Lao PDR, Thailand and Viet Nam, and for critical mineral production and processing, mainly related to nickel in Indonesia. For the moment, these investments are largely from Chinese companies expanding overseas.

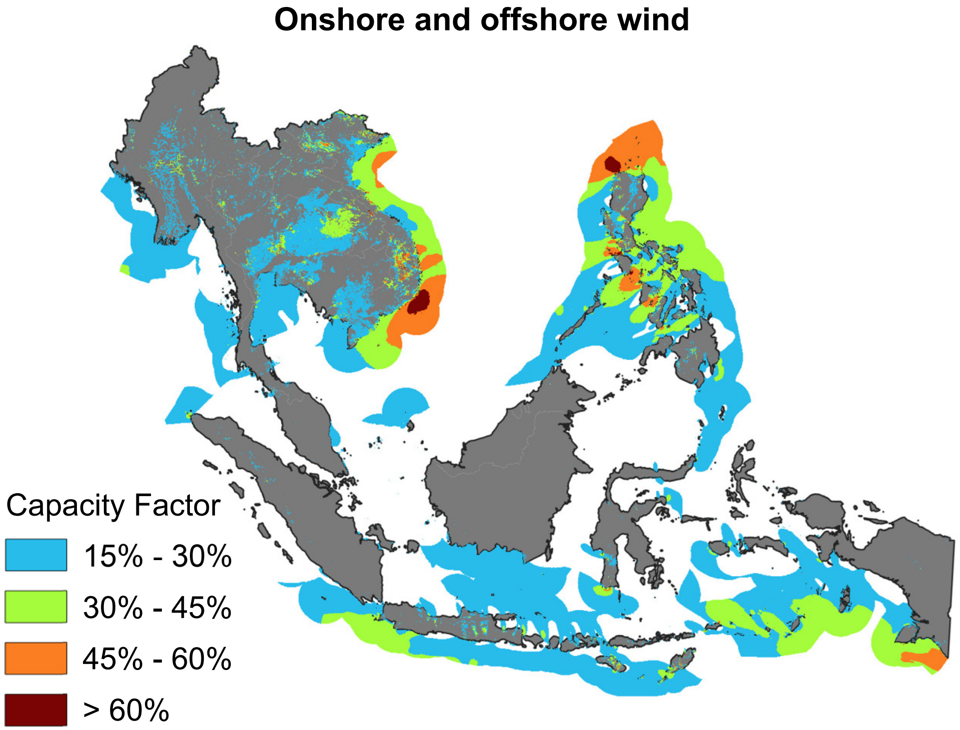
In our scenarios, we assume that the annual average real GDP growth in Southeast Asia is 4.4% between 2024 to 2035, slowing to 3.1% between 2035 and 2050. We hold these assumptions constant across the different scenarios examined. Cambodia, the Philippines and Viet Nam exhibit the highest anticipated rates of economic growth.

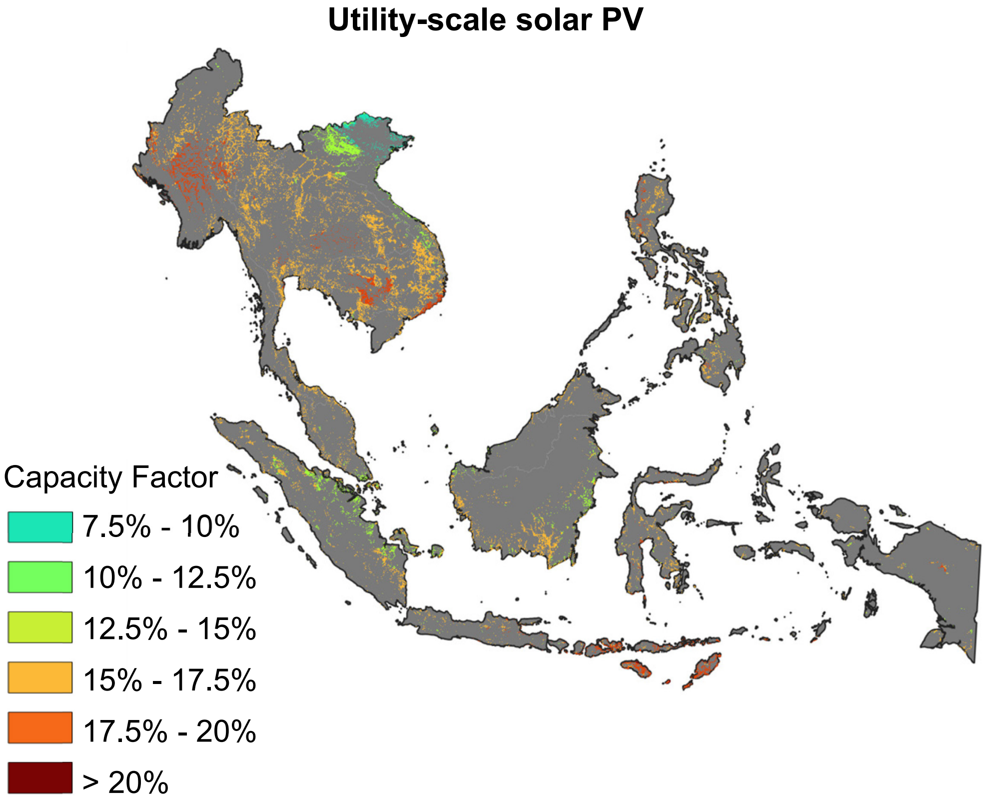
The population of the region is projected to increase from today's 685 million to 745 million by 2035 and then to almost 790 million by 2050. The median age of Southeast Asia's population is currently around 30, eight to ten years lower than that in the United States or China. Regional trends mask some very different national circumstances, with population density ranging widely between Singapore (the highest) and Lao PDR (the lowest).

Today, just four countries – Indonesia, the Philippines, Viet Nam and Thailand – account for more than 80% of the region's population. The Philippines and Lao PDR are expected to experience the highest population growth rates up to 2050, while the population in Thailand is the only one expected to decrease slightly. More than half of the region's population already live in urban areas, which see all the anticipated growth to 2050 (an additional 170 million people). The design of these cities is a crucial variable in terms of energy use and sustainability: while today many urban settlements in the region face significant challenges related to informal housing and a lack of basic services, there are huge gains to be made from investment in electricity distribution networks, construction of safe and sustainable public transit and energy-efficient buildings, as well as in making cities more resilient in the face of a changing climate.

1.3 Resources and geography

Despite some technical and spatial limitations, Southeast Asia is home to accessible solar and wind energy resources that could be much more widely exploited





Note: These maps show the distribution of wind and solar energy potentials in the region, quantified as the energy yield by the capacity factor, meaning the electricity produced from one unit capacity of solar PV or wind turbine in an average year. Only areas technically suitable for the deployment of renewables and not otherwise used or restricted are included. Offshore wind resources with a capacity factor below 20% are not included.

Source: IEA analysis based on data obtained from Global Wind Atlas, Global Solar Atlas, ESA (land cover), USGS (slopes), WDPA (protected areas).

Tapping substantial clean energy potentials will be crucial in meeting rising energy demand and achieving goals for emissions reduction

The natural environment of Southeast Asia includes significant natural resources that have been developed as energy assets. These include fossil energy sources like coal, oil and gas, critical mineral deposits, and renewable energies such as solar, wind, hydro, geothermal and bioenergy resources.

Southeast Asia's fossil energy sources generally originate from relatively young geological formations (from about 50 million years to the present) which consist of organic-rich sediments derived from terrestrial or shallow marine environments. As the sediments age under natural heat and pressure, large coal and petroleum deposits form. Indonesia is particularly rich in accessible coal and petroleum resources and supplies 90% of the region's coal as well as 30% of world exports. Indonesia also holds 50% of the total oil and gas in place (more than 200 000 mb total). Malaysia hosts the second highest hydrocarbon in place, at more than 100 000 mb or 27% of the regional total. Brunei Darussalam, Viet Nam and Thailand together make up most of the remaining balance.

Southeast Asia is rich in natural reserves of critical minerals, such as nickel and rare-earth elements. Today, Indonesia and the Philippines are the world's two largest producers of nickel, together accounting for about 65% of global mined production. Myanmar is the second largest producer of rare earths and – together with Lao PDR, Thailand and Viet Nam – makes up 20% of global production. Further investment is needed to facilitate mining of untapped reserves across the region.

The region's resources also include large potentials of renewable energy: solar, wind, hydro, geothermal and bioenergy.

Thanks to its lush tropical climate, Southeast Asia is home to considerable bioenergy resources. Bioenergy is currently the largest developed renewable energy source in the region, with significant potential for further expansion. Although nearly all biofuel production in Malaysia and Indonesia is derived from palm oil feedstocks, the region also has access to large quantities of agricultural and forestry residues and municipal waste.

Southeast Asia has significant hydropower potential, with countries in the northern mainland benefitting from their proximity to the Himalayas, which feed water in large rivers such as the Mekong and Irrawaddy, and from mountainous terrain facilitating the development of reservoir and pumped storage hydro. Viet Nam and Lao PDR produce the largest amounts of hydroelectric power in the region. Hydro not only provides clean electricity but also contributes important flexibility to power systems (see page 138). Nonetheless, hydro output can vary across seasons and years, and future development of untapped potential on the mainland as well as on Southeast Asia's islands is contingent on the ability to meet high upfront investment costs and to avoid negative environmental and social impacts, as well as geopolitical tensions.

Indonesia and the Philippines, which sit on the Pacific Ring of Fire, hold considerable potential for the development of geothermal resources using conventional methods, with national plans announcing further expansion of geothermal power generation towards 2030. While resources are abundant, high upfront investment costs make project development challenging.

Southeast Asia is home to large solar PV and wind energy resources. The tropical climate provides plenty of sunshine for solar PV across the region, mostly during the dry season. While the average solar potential in Southeast Asia is of slightly lower quality compared to hot and dry climatic zones like southern Europe and India, potentials are better than in temperate climate zones like northwestern Europe or Japan, which have nonetheless seen significant growth in solar in recent years. Areas with more pronounced dry seasons – Myanmar, Thailand, Cambodia, Viet Nam and Lao PDR – have the best potentials, benefitting from abundant sunshine at these times of the year.

While the quality of the solar resources is relatively consistent across the region, the quality of wind resources is unevenly distributed. Wind speeds are generally low, so average wind energy potentials are poorer than in Europe, North America and China. However, Viet Nam and the Philippines have excellent offshore wind resources, which could support capacity factors of around 60%, though due to a rapid drop in seabed depth, floating turbines are required to unlock this potential. Thailand, Cambodia, Viet Nam and Myanmar benefit from good onshore wind resources close to urban centres, where electricity demand is growing.

Harnessing the potential of wind and solar depends on resource quality, available land, accessibility and technology costs. Not all of the theoretical potential is available for development or economical to develop. Only a small fraction of land is available for wind or solar farms due to competing uses, like agriculture, or restrictions imposed by land use regulations protecting forests and nature reserves. Topographical challenges like rough terrain, remote locations and seabed depth increase construction costs and necessitate specific technical solutions; for example, built-up areas might support rooftop solar, but not utility-scale projects. However, even considering these restrictions, the technical potentials are very large, with the onshore wind potential (by far the smallest of the three resources) alone being twice the region's projected electricity demand. Overall, Southeast Asia's combined technical potential for utility-scale solar PV, onshore and offshore wind exceeds 20 TW. This highlights that wind and solar PV can play a key role in the region's future electricity supply, which is reflected in our outlook to 2050 (see Chapter 2).

1.4 Energy and climate policies

Increasing policy momentum in Southeast Asia could reinforce energy security and accelerate clean energy deployment, but only if pledges translate into actions

Recent years have seen a major strengthening of long-term energy and climate ambitions in Southeast Asia. Governments across the region have also started to put in place detailed measures that are designed to shift energy development onto a different track. But this process is far from complete. The scenarios in this report provide important insights into what has been achieved so far, and what more remains to be done.

The scenario trajectories for Southeast Asia incorporate the latest data on energy markets, region-specific technology costs, investment and infrastructure projects, and a detailed assessment of energy and climate policies. The table, Key announced energy and climate pledges in Southeast Asia, shows the extent of the ambitions announced by countries across the region, as well as some sectoral policy frameworks and targets. In addition, there are collective targets agreed in the ASEAN context, notably the ASEAN Plan of Action for Energy Cooperation (APAEC) Phase 2 (2021-2025).

As detailed in the Introduction to this *Outlook*, the Announced Pledges Scenario (APS) is modelled on the bold assumption that governments will meet, in full and on time, all the key economy-wide pledges that they have made. As such, it outlines a pathway for governments to achieve these goals.

But most countries' policy frameworks and deployment trends are far from aligned with the APS. This is illustrated by the Stated Policies Scenario (STEPS), which is grounded in a detailed assessment of what is actually in place. This scenario, reflecting today's policy settings, points the energy system in a different direction. The gap between the STEPS and APS trajectories highlights the need for additional efforts to implement national and regional goals.

Higher levels of ambition and implementation are needed to reach the requirements of a scenario that limits the rise in global average temperatures to 1.5 °C (the NZE Scenario). The implications of such a scenario for Southeast Asia are used as a point of reference throughout the report, and key points are then analysed in more detail in the section examining the implications of COP 28 for the region in Chapter 3.

Key announced energy and climate pledges in Southeast Asia

Sector		Policies and targets
Emissions commitments		Conditional commitments to net zero emissions by 2050 (Brunei Darussalam, Lao PDR, Malaysia, Singapore, Viet Nam), by 2060 (Indonesia) and by 2065 (Thailand). Commitment to carbon neutrality by 2050 (Cambodia). Signatories to the Global Methane Pledge (Cambodia, Indonesia, Malaysia, Philippines, Singapore, Viet Nam) commit to work together to collectively reduce methane emissions by at least 30% below 2020 levels by 2030.
Demand (Transport/Industry/Buildings)		Indonesia: Target to phase out conventional two-wheelers starting in 2025 and to have 2 million electric vehicles in passenger light-duty vehicle stock and 13 million electric motorcycles in the fleet by 2030. Malaysia: 100% of cars to be electrified or fuelled by compressed natural gas (CNG), LPG or biofuels by 2030, 80% of four-wheelers and two-wheelers to be electrified by 2050, including hybrids; minimum energy performance standards (MEPS) and labelling for washing machines, refrigerators and air conditioners. Singapore: Target to phase out passenger vehicles with internal combustion engines (ICE) by 2040; enhancements to MEPS for light bulbs. Thailand: Target for 100% zero emission vehicles in new sales from 2035. Viet Nam: Net zero GHG emissions in the transport sector by 2050, with a goal of 100% of road transport using electricity and clean energy; MEPS and labelling for appliances and lighting in residential and commercial buildings.
Power	Coal phase-out	Commitments to phase out coal from power generation by 2044 (Malaysia) and 2050 (Thailand). Indonesia aims to phase out coal by 2056 under the National Electricity General Plan (RUKN), which can be accelerated to 2050 with JETP support. Viet Nam also intends to phase out coal by 2050 with JETP support.
	Renewables	Brunei Darussalam: Target for at least 30% of electricity generation from renewables by 2035. Indonesia: The draft version of state electricity company PLN's Electricity Supply Business Plan (RUPTL), which refers to the RUKN, has a target of about 30 GW of additional renewables in power generation by 2033. Malaysia: National Energy Transition Roadmap has a target of 59 GW of solar PV capacity by 2050 to achieve 70% installed renewable capacity in power generation.

Sector		Policies and targets
Power (continued)	Renewables (continued)	The Philippines: National Renewable Energy Program aims for a 35% share of renewables in power generation by 2030, and at least a 50% share by 2040. Viet Nam: Power Development Plan 8 (PDP8) aims to boost installed utility-scale solar PV capacity to around 13 GW and installed wind capacity to around 28 GW by 2030.
Low emission fuels		Hydrogen: Malaysia is planning for 0.9 Mt/y of low-emissions hydrogen production by 2030. Viet Nam intends to develop hydrogen under its PDP8. CCUS: Regulatory frameworks are under development in Malaysia and Thailand. In Indonesia, existing ones are being extended beyond upstream oil and gas working areas. Singapore plans to support R&D projects through its Low-Carbon Energy Research Funding Initiative. Bioenergy: Indonesia's B35 biodiesel blending mandate increases to B40 from 2025. Malaysia has a target of B30 biodiesel blending by 2025. Singapore will require departing flights to use Sustainable Aviation Fuel with a minimum blend of 1% from 2026. Viet Nam mandates 20% biomass blend rates and ammonia co-firing in coal power plants after 20 years of operation, increasing to 100% by 2050.

1.5 International context

Some co-operative frameworks are in place, but Southeast Asia will require sustained, large-scale support if it is to achieve its energy and climate goals in full

Achieving a just, equitable and orderly transition to a net zero emissions energy system in Southeast Asia requires actions at the national and regional levels, and strong international financial and technical support. This is explicitly recognised in many policy and strategy documents.

Scenarios that align with the Paris Agreement all have in common a strong degree of international cooperation. There is a growing number of international initiatives in Southeast Asia that seek to implement financing and other mechanisms to accelerate clean energy transitions. These include the scaling up of renewable energy and other clean energy technologies, as well as supporting the early retirement or retrofitting of coal-fired power plants and the phasing out of coal.

In a crowded space for international donors, coordination among partners and policy coherence is essential to managing risks around duplication, contradictory advice and overwhelming host government bandwidth to engage. Regular donor engagement, programmatic coordination and identifying and harnessing the comparative advantage of different partner organisations can enable the most effective and comprehensive support to the region. International support for resilience and adaptation will also be critical to countries in Southeast Asia that are particularly vulnerable to the impacts of climate change.

At the same time, the international context has become more challenging for Southeast Asia in recent years. Financing conditions for energy projects have become more complicated with the rise in interest rates and borrowing costs, while concessional public financial commitments are not yet materialising at a large scale. Energy markets also remain vulnerable to geopolitical events. The initial price shocks from the global energy crisis and Russia's full-scale invasion of Ukraine abated during 2023 and into 2024, but market balances remain fragile and prone to disruption.

Clean energy supply chains are also subject to geopolitical risks and rivalries, with China having an outsized role in all areas of clean energy manufacturing, as well as in the production and processing of many critical minerals. International barriers to trade are on the rise, creating risks for a region like Southeast Asia that has traditionally sought open cross-border cooperation and integration into global value chains.

Key international cooperation frameworks

Initiatives	
ASEAN Plan of Action for Energy Cooperation (APAEC)	The APAEC (Phase 2) 2021-2025 was adopted by the ASEAN Ministers of Energy and details targets and objectives to enhance the security and sustainability of the region's energy systems. Implementation is led by the ASEAN Centre for Energy (ACE) with support from the international community.
ASEAN Power Grid (APG)	The APG is a regional initiative aiming to support regional power interconnection, enabling greater regional energy security and higher integration of renewable energy. Although the process long precedes the Memorandum of Understanding (MoU) signed in 2007, it has accelerated recently with the presentation of the results of the ASEAN Interconnection Masterplan Study (AIMS) III to ASEAN Ministers on Energy Meetings (AMEMs) in 2021 and 2023. As a major, multi-year, multi-stakeholder project, the APG is supported by the ASEAN member States, the ASEAN Secretariat, ACE, and ASEAN Sectoral Bodies including the ASEAN Power Grid Consultative Committee, Heads of ASEAN Power Utilities/Authorities and ASEAN Energy Regulators' Network (AERN), and other international technical supports.
Asia Zero Emission Community (AZEC)	The AZEC, proposed by Japan, was launched by 11 partner countries in 2023. The platform seeks to support policy development and public-private partnerships to bolster clean energy technology in Asia, including hydrogen, ammonia, carbon capture utilisation and storage, as well as establishing green industrial supply chains. There are currently more than 420 AZEC MoUs and projects underway.
Just Energy Transition Partnership (JETP)	JETP is a financing and political cooperation framework between international financers and coal- dependent emerging market and developing economies which commit to ambitious emissions reduction targets and define a credible national transition pathway towards net zero to be supported by a combination of public and private finance. Initial fund mobilisation is meant to be catalytic, creating the conditions for a dramatic scaling up of infrastructure and project financing. Two JETPs have been established so far in Southeast Asia. Indonesia's JETP aims to mobilise an initial USD 20 billion to kick start the country's push to reach net zero emissions in 2060 or earlier, while Viet Nam's seeks to mobilise USD 15.5 billion to support its goal to attain net zero emissions by 2050.
Transition Credits Coalition (TRACTION)	Launched in 2023, Singapore's Transition Credits Coalition (TRACTION) is led by the Monetary Authority of Singapore (MAS) and has about 30 members including financing and knowledge partners. It focuses on supporting the early retirement of coal-fired power plants through the use of high-integrity carbon credits. Two pilot programmes are currently being explored in the Philippines.

A new framework for international collaboration: The Just Energy Transition Partnerships (JETPs) with Indonesia and Viet Nam

Two ambitious JETPs were established in Southeast Asia in 2022, one with Indonesia and the other with Viet Nam. Launched in 2021 at COP 26 in Glasgow, JETPs are a financing cooperation mechanism between an International Partners Group (IPG) of advanced economies and multilateral financing institutions and a coal-dependent country which commits to ambitious emissions reduction targets and defines a credible national net zero 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.

The JETP between Indonesia and the IPG – which comprises Canada, Denmark, France, Germany, Italy, Japan, Norway, the United Kingdom, European Union and United States – aims to help Indonesia strengthen its ambitions and achieve net zero emissions by 2060 or earlier. The JETP aligns Indonesia's energy sector pledges with the Energy Sector Roadmap to Net Zero Emissions. The partnership commits an initial USD 20 billion – USD 10 billion from IPG funding aiming to attract an additional USD 10 billion from private financing institutions. In this context, the Glasgow Financial Alliance for Net Zero (GFANZ) is meant to play a key role in facilitating and mobilising private investors. It seeks to support policy reforms along with investments in the power sector to meet targets: peaking power sector emissions at 290 Mt CO_2 by 2030, achieving net zero power emissions by 2050, and ensuring renewables make up at least 34% of power generation by 2030.

In 2023, the Indonesia JETP issued its first Comprehensive Investment and Policy Plan (CIPP), outlining an energy and emissions pathway and priorities to support JETP goals. The CIPP targets on-grid emissions to peak at 250 Mt CO_2 by 2030 with a 44% share of renewables. Achieving these targets requires investments in five focus areas: transmission and grids, managed coal phase-out, dispatchable renewable power, variable renewable power and renewable energy supply chains, amounting to USD 97 billion from 2023 to 2030 and USD 580 billion from 2023 to 2050.

Since the issuance of the CIPP in 2023, the Indonesia JETP has shifted to its implementation phase, addressing initial gaps. It focuses on clarifying financial modalities and mechanisms, and aligning funds with CIPP investment areas. In early 2024, a new working group on Energy Efficiency and Electrification was added, which is analysing systems efficiency, buildings, appliances, transport and industry, and identifying priority projects in these sectors. The partnership is also developing a plan for clean energy transitions in Indonesia's off-grid captive power sector, driven by the growth of energy-intensive industries, especially critical minerals processing.

A planned CIPP update is underway for 2024, which adds energy efficiency to the investment focus area and aims to reflect these efforts, as well as recent market developments and policy priorities including signals from the government to ease some barriers (e.g. local content requirements) inhibiting the development of renewables. Nevertheless, achieving a flexible and renewables-rich power system will require sustained investment and policy efforts over time, including actions to accelerate the deployment of clean power, especially variable renewables, and transition from a heavy reliance on coal in a secure and affordable manner.

The JETP between Viet Nam and the IPG was developed to support the country's goal of accelerating its transition to a carbon neutral energy system and reach net zero emissions by 2050. The JETP reflects Viet Nam's targets to bring about a peak in power sector CO_2 and total GHG emissions by 2030; to cease issuing permits for the construction of new coal-fired power plants and peak coal capacity at 30 GW by 2030; to promote the development of renewables, so that they account for at least 47% of the electricity mix in 2030, up from 44% in 2021; and to 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 – will be public sector finance backed by the IPG. As with Indonesia, the aim is for international funding to catalyse additional private sector finance that at least matches the level of public sector finance, and to help Viet Nam attract the capital it requires to meet its ongoing investment needs as its clean energy transition moves forward. A major milestone was the release of the Viet Nam JETP Resource Mobilisation Plan (RMP) at COP 28 in December 2023. The RMP sets out investment needs and priorities, defines policy actions and regulatory reforms designed to enable and boost investments into renewables and other JETP-related projects, and establishes a framework for progress monitoring and evaluation.

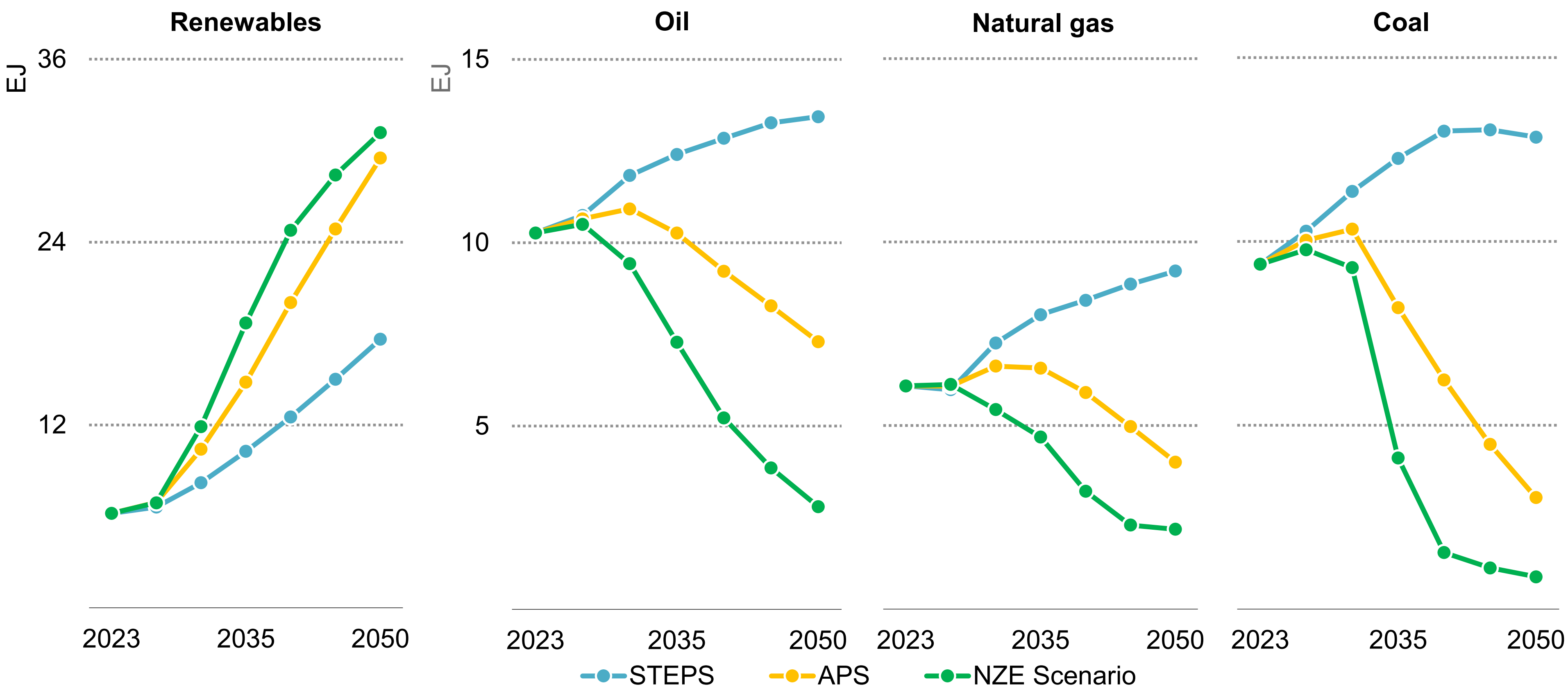
The Power Development Plan, approved in May 2023 (PDP8), is an important element of Viet Nam's strategy to achieve its energy and emissions reduction objectives. It sets out increased ambitions and details a pathway for power sector development to 2030. It also includes a longer-term vision to 2050. In line with JETP commitments, coal-fired capacity is planned to peak at about 30 GW in 2030, down from 55 GW in the previous PDP. Beyond 2030, coal plants will be retired when they are 40 years old unless converted to run on ammonia or biomass. Another key component of the plan is to significantly raise the share of variable renewables in the electricity mix, accompanied by a recognition that substantial investment in grids is needed to facilitate this.

Southeast Asia's energy outlook to 2050

2.1 Total energy demand

Demand for all major energy sources continues to grow in the STEPS, while faster build-out of clean energy in the APS and NZE Scenario pushes fossil fuel use into decline

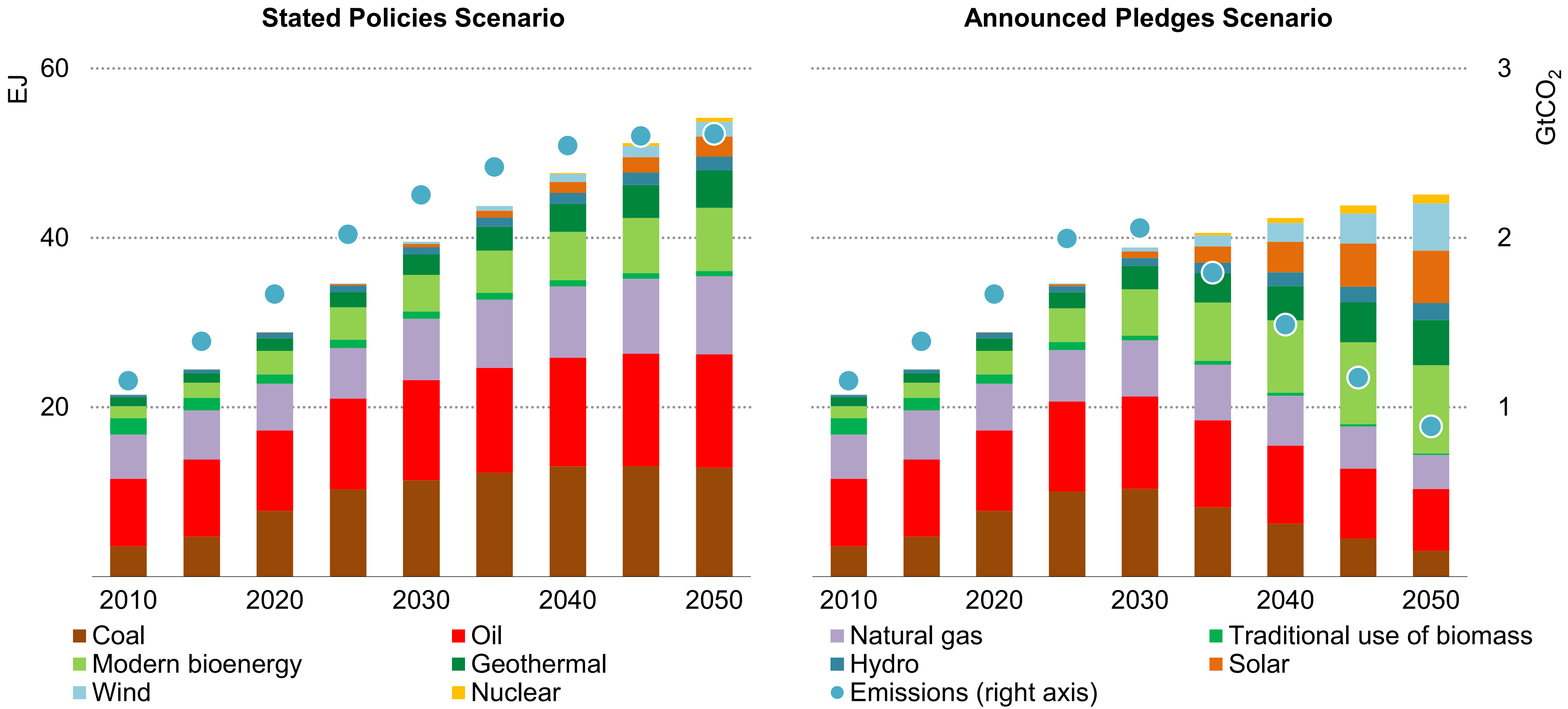
Energy demand by fuel and scenario, 2023-2050



Note: "Renewables" include solar PV, solar thermal, wind, hydro, modern bioenergy, geothermal, marine and renewable waste.

Southeast Asia's future energy mix will be dramatically re-shaped by mid-century if countries achieve their announced national climate goals

CO_2 emissions and energy demand by fuel and scenario, 2010-2050



More energy is needed in all scenarios to support Southeast Asia's growth, but the mix of fuels and technologies remains open, as do the implications for energy security and emissions

Southeast Asia is a very dynamic region and the energy outlook reflects its expected growth over the coming decades, with demand expanding rapidly in all of our scenarios. In the STEPS, energy demand increases by a third to 2035 and about two-thirds to 2050. In this scenario, just under half of the growth in demand is met by fossil fuels, which is enough to keep the quantity of each fuel – and emissions – on a rising trajectory; the share of fossil fuels in the total energy mix falls from 78% today to 65% in 2050. However, the rise in clean energy deployment produces a significant drop in the emissions intensity of GDP, falling by more than 2% per year.

In the APS, the region's energy demand grows to a lesser extent, by around 40% to 2050, reflecting accelerated efficiency improvements, electrification and fuel switching which affect energy demand. Determined progress towards meeting the region's climate ambitions in this scenario brings the share of fossil fuels in the energy mix down to around 30% in 2050, by which time around 15% of fossil fuel use is for feedstock and around another 5% is deployed with CCUS technologies. In the NZE Scenario, additional efficiency gains limit the growth of demand to a quarter of the growth seen in the STEPS. Fossil fuels decline to 45% of the energy mix in 2035 and 15% in 2050. Around a fifth of this fossil fuel use is with CCUS, while 40% is used for non-energy purposes.

Oil is the largest energy source today with coal just behind; each make up just under 30% of the energy mix in 2035 in the STEPS. Natural gas use increases in the STEPS to meet growing demand, though its share of energy demand remains at just under a fifth. Demand from the industry and power sectors drives increasing coal use, so it makes up 25% of the energy mix in 2050. In the APS, however, coal and gas demand peaks in the early 2030s, declining to 2050, and renewables take over as the largest source in the energy mix from around 2030. The NZE Scenario highlights the possibility of an even lower share of coal, at around 2% in 2050.

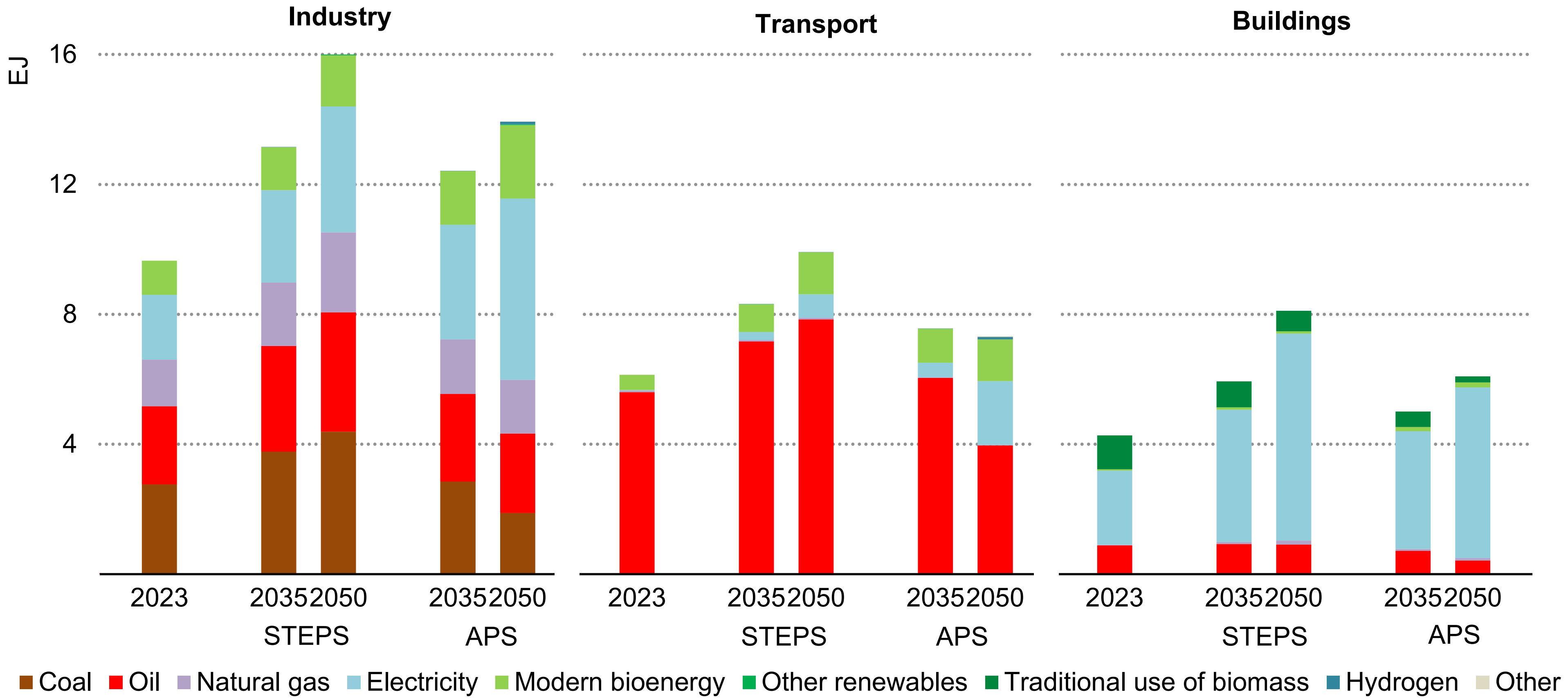
Renewables already account for just under a fifth of the energy mix, mainly through hydropower, geothermal and modern bioenergy. In the future, rapid expansion of wind and solar PV, alongside continued momentum in bioenergy and geothermal, lead to renewable output increasing over 1.5 times by 2035 in the STEPS and more than doubling in the APS. Significant improvements in energy efficiency put downward pressure on demand, so renewables energy demand is only 6% higher in the NZE Scenario than in the APS in 2050.

Nuclear power is not a large part of today's energy mix in Southeast Asia, but we project some nuclear power in the region by 2050 in all scenarios, led by countries such as Indonesia and Viet Nam that are already exploring nuclear power deployment options.

2.2 Total final energy consumption and emissions

Industry maintains its leading role among the end-use sectors and faster electrification of mobility leads to declining long-term energy demand in transport in the APS

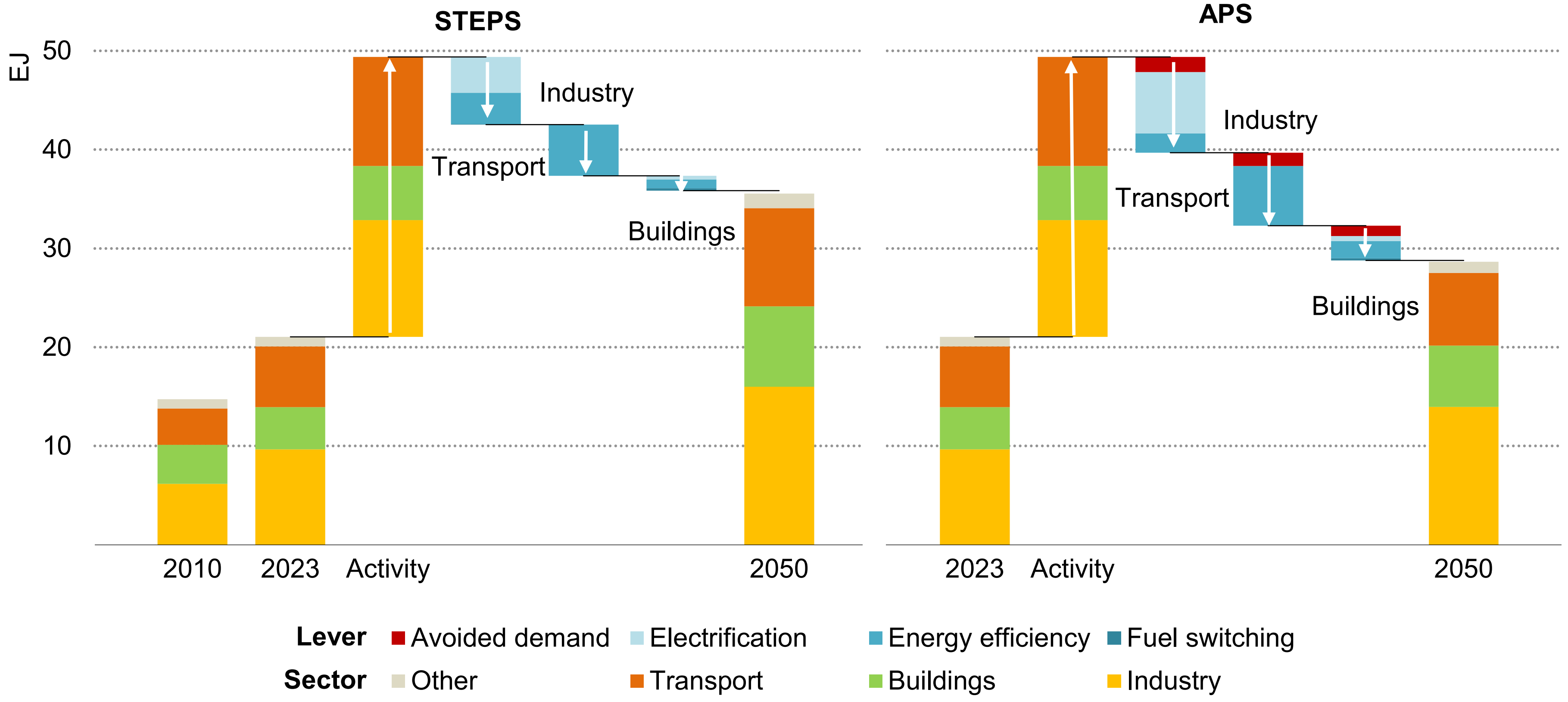
Total final energy consumption by sector and scenario, 2035 and 2050



Notes: "Hydrogen" includes low-carbon gaseous hydrogen and hydrogen-based fuels such as ammonia and synthetic hydrocarbons. "Transport" excludes international bunkers. "Other renewables" include concentrating solar power and geothermal. "Other" includes synthetic fuels and district heat.

Efficiency gains and electrification moderate the impact of rising energy demand in the STEPS; deeper modal, material and behavioural shifts in the APS result in demand being avoided

Changes in final energy consumption by lever, sector and scenario, 2010-2050



Notes: "Avoided demand" includes shifts in mobility patterns as a result of price elasticity in transport, material efficiency in industry through measures such as reduced vehicle production or improved building design, climate effects in buildings, as well as behavioural changes across sectors. "Other" includes agriculture and other energy transformation sectors.

Today's policy settings leave significant untapped potential to reduce growth in final energy demand in all end-use sectors and to tackle the challenge of industrial decarbonisation

Final energy consumption in the main end-use sectors – industry, transport and buildings – in Southeast Asia today is 21 EJ, growing by almost 3% per year to 2035 in the STEPS. The industry sector is the largest source of energy demand, accounting for half of total energy consumption from end-use sectors. Industry consumes almost 10 EJ per year and growth is expected in all scenarios, driven by rising production of iron, steel and chemicals, as well as growth in the light manufacturing sector (e.g. automobiles). In the STEPS, while natural gas and electricity serve most of the demand growth, there remains a risk of locking in coal use in industry, highlighting the need for investments in hard-to-abate sectors to reduce emissions.

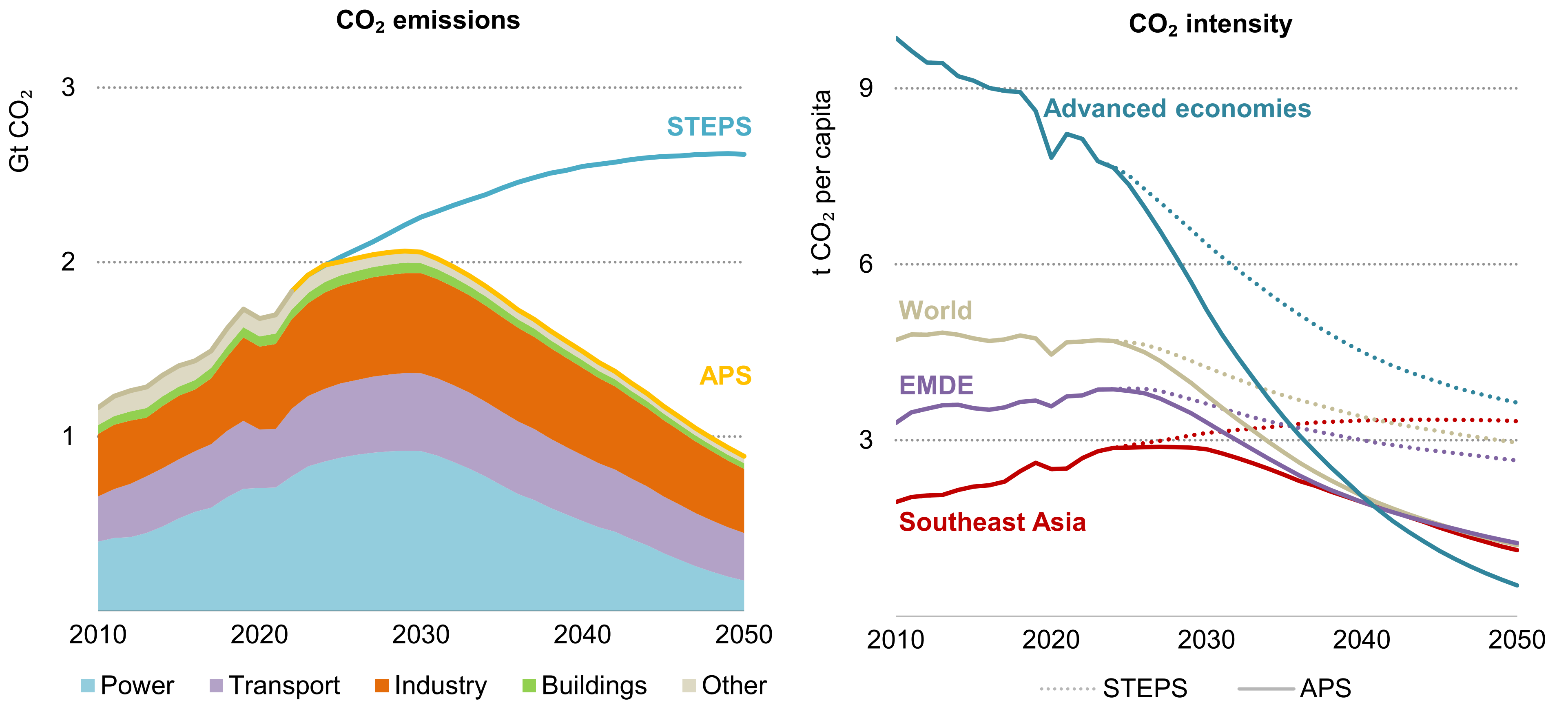
Transport sees a large rise in service demand to 2050, driven by an expanding car and two/three-wheeler fleet. However, if current policy and market trends persist with private vehicle ownership growth, this could exacerbate traffic issues in major cities such as Bangkok, Jakarta and Kuala Lumpur. Therefore, careful consideration of traffic management and the development of public transit is needed in parallel with improved access to personal mobility as part of the clean energy transition. Today, oil accounts for over 90% of regional transport fuel consumption, at over 2.8 mb/d – roughly equivalent to total transport oil consumption in the Middle East (2.9 mb/d). In the STEPS, policy and infrastructure support for the electrification of mobility are less pronounced than in the APS and oil retains its dominance, although the use of biofuels increases to 2050, meeting almost 15% of demand. In the future, modal shift through increased public transport could temper transport energy demand.

The buildings sector sees energy consumption almost double by 2050 in the STEPS, reflecting rising incomes and living standards in terms of housing and appliances. While energy demand in buildings is met mostly by electricity, traditional use of biomass still accounts for almost 10% of energy consumption in 2050 in the STEPS due to the lack of significant progress on clean cooking access.

Energy efficiency and electrification in all sectors as well as a fuel shift away from traditional biomass in Myanmar and Cambodia moderate energy demand growth; additions in final energy consumption in the STEPS are halved by 2050. In the APS, these efforts are strengthened, and the implementation of climate pledges bring additional savings, negating three-quarters of service demand growth to 2050. In transport, service demand is reduced because changes in fuel pricing and policies enable modal shifts. In turn, this influences declining material production in industry, alongside other material efficiency measures (e.g. in buildings construction). Such energy demand reductions mean that total final consumption in the APS is 29 EJ in 2050, compared to 36 EJ in the STEPS.

Implementing announced pledges leads to decreasing CO_2 emissions, but emissions per capita fall more slowly than in other regions and rise above the global average in the STEPS

CO_2 emissions by sector and scenario, and CO_2 intensity by economic grouping and scenario, 2010-2050



Notes: Gt CO_2 = gigatonne of carbon dioxide; “Other” includes agriculture and other energy transformation sectors.t CO_2 = tonne of carbon dioxide. “EMDE” = emerging market and developing economies.

Stronger policy action is required to put the region on track to reach its decarbonisation pledges

Energy-related CO_2 emissions in Southeast Asia totalled just under 2 Gt CO_2 in 2023. In the STEPS, CO_2 emissions increase by around one-fifth over the coming decade. Today, the power sector accounts for about 45% of direct energy-related CO_2 emissions, with coal-fired power plants alone accounting for 34%. With the accelerated deployment of renewables, the emissions intensity of electricity generation falls by one-fifth over the course of the next decade in the STEPS. However, the absolute amount of power-related CO_2 emissions rises by a quarter over the same period, as demand increases substantially. Increasing industrial activity and mobility also lead to higher emissions from end-use sectors. Emissions continue to rise after 2035 in the STEPS, reaching 2.4 Gt CO_2 in 2050.

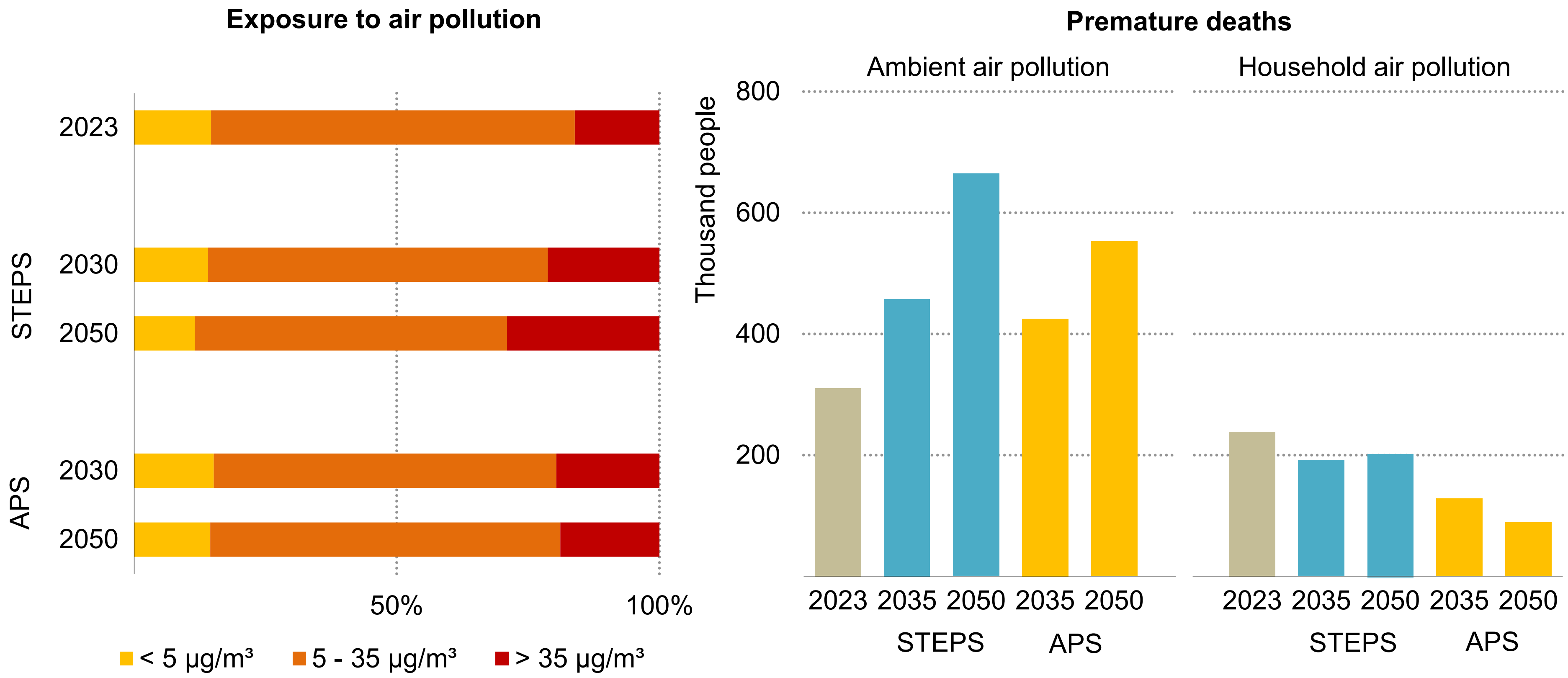
Of the ten countries in ASEAN, six have pledged to reach net zero emissions by 2050, with Indonesia targeting 2060 and Thailand targeting 2065. However, no updates have been submitted yet in terms of the nationally determined contributions (NDCs) for COP 30 in 2025 outlining the countries' increased ambitions, as required under Article 4 of the Paris Climate Agreement. Under existing NDCs, almost every country in the region sees their emissions rise by the end of this decade compared to their NDC reference year. Measures to implement the region's net zero pledges are already starting to decouple economic growth from increases in CO_2 emissions – such as accelerating renewables expansion and the electrification of end-use sectors – but an implementation gap remains. In the APS, emissions decrease by 8% from today to 1.6 Gt CO_2 in 2035, which is 0.6 Gt CO_2 lower than under the STEPS. This implementation gap widens to 2050, when CO_2 emissions in the APS are less than half of today's level. To achieve these pledged reductions, annual CO_2 emissions need to fall by about 40 Mt CO_2 every year, compared to the annual increase of over 60 Mt CO_2 seen over the last 10 years.

The power sector contributes 65% of emissions reductions in the APS. Emissions in end-use sectors also decline with faster progress in electrification, energy efficiency and avoided demand. However, almost 1 Gt CO_2 of residual emissions remain in 2050. Many countries have pledged to offset remaining emissions outside the energy sector.

CO_2 emissions per capita in Southeast Asia currently stand at 60% of the global average but rise to slightly above this average in the STEPS by 2050: CO_2 emissions per capita remain roughly constant to 2050 at around 3.3 t CO_2 per capita, compared to a global average of 3 t CO_2 per capita by 2050. Full delivery of announced pledges and NDCs in the APS leads to emissions intensity in the region decreasing to 1.1 t CO_2 per capita in 2050, just below the global average of 1.2 t CO_2 per capita.

The APS sees almost 100 000 fewer premature deaths in 2035 than in the STEPS, largely due to faster progress in clean cooking that reduces exposure to particulate matter

Share of population exposed to PM2.5 concentrations and premature deaths from air pollution by scenario, 2023-2050



Notes: "PM2.5" = particulate matter of 2.5 microns or less in width; "µg/m^3" = microgrammes per cubic metre of air. "Exposure to air pollution" is the long-term exposure to concentrations of > 5 micrograms/m^3.

Exposure to polluted air worsens in the STEPS to 2050, driven by delays in clean cooking progress and the slow development of clean transport for an urbanising population

In 2023, at least 85% of the population in Southeast Asia breathed polluted air, typically exceeding the safe concentration limits recommended by the World Health Organization by a large margin, notably in big cities. The air pollution burden of the region is among the highest in the world, cutting average life expectancy in the region by 1.5 years (WRI, 2023). Around 300 000 people died prematurely from ambient (outdoor) air pollution in 2023 and almost 240 000 died from breathing polluted household (indoor) air. Air pollution also leads to multiple serious diseases, placing an extra burden on healthcare systems, with significant economic costs.

In the STEPS, the continued heavy reliance on oil-based products in the transport sector, relatively weak pollution controls and expanding coal use in power generation lead to a sharp rise in ambient air pollutant emissions over the next decade, with associated deaths reaching over 450 000 in 2035 and continuing to grow to over 650 000 in 2050. Premature deaths from household air pollution decrease by around 20% to 2035 as the traditional use of solid biomass for cooking diminishes. However, progress on cutting premature deaths stalls to 2050, as lack of access to clean cooking remains acute in some countries, including Lao PDR, Myanmar, Cambodia and the Philippines. Affordability is a significant issue: solid biomass is often free, except for the time spent gathering it, while alternatives such as wood pellets or LPG can cost a poor household several weeks of income, not taking into account the cost of purchasing the cookstove itself. In cities, people often have to buy charcoal instead, cutting into household incomes. Therefore, the STEPS sees the number of premature deaths from household air pollution in Southeast Asia falling only marginally to around 200 000 people per year.

In the APS, the full implementation of announced pledges means that a lower reliance on traditional use of biomass for cooking and heating improves household air quality and reduces concentrations of PM2.5, despite a rise in energy demand. This results in almost 100 000 fewer premature deaths per year than in the STEPS by 2035, while also reducing GHG emissions and other climate-forcing agents (e.g. black carbon). However, premature deaths from poor ambient air quality remain significant in 2035 in Southeast Asia, largely due to pollution from vehicles and industrial processes. Although in some countries, a concerted effort to accelerate the uptake of EVs and mandate tailpipe standards, particularly for trucks, helps to bring about notable reductions in nitrogen oxide (NO_X) and PM2.5 emissions, overall progress is limited. With 60% of Southeast Asia's population projected to live in cities by 2035, an increasingly urban population means that premature deaths linked to ambient air pollution continue to rise to over 420 000 by 2035 in the APS, only marginally lower than in the STEPS, though the APS sees a slower rate of increase to 2050.

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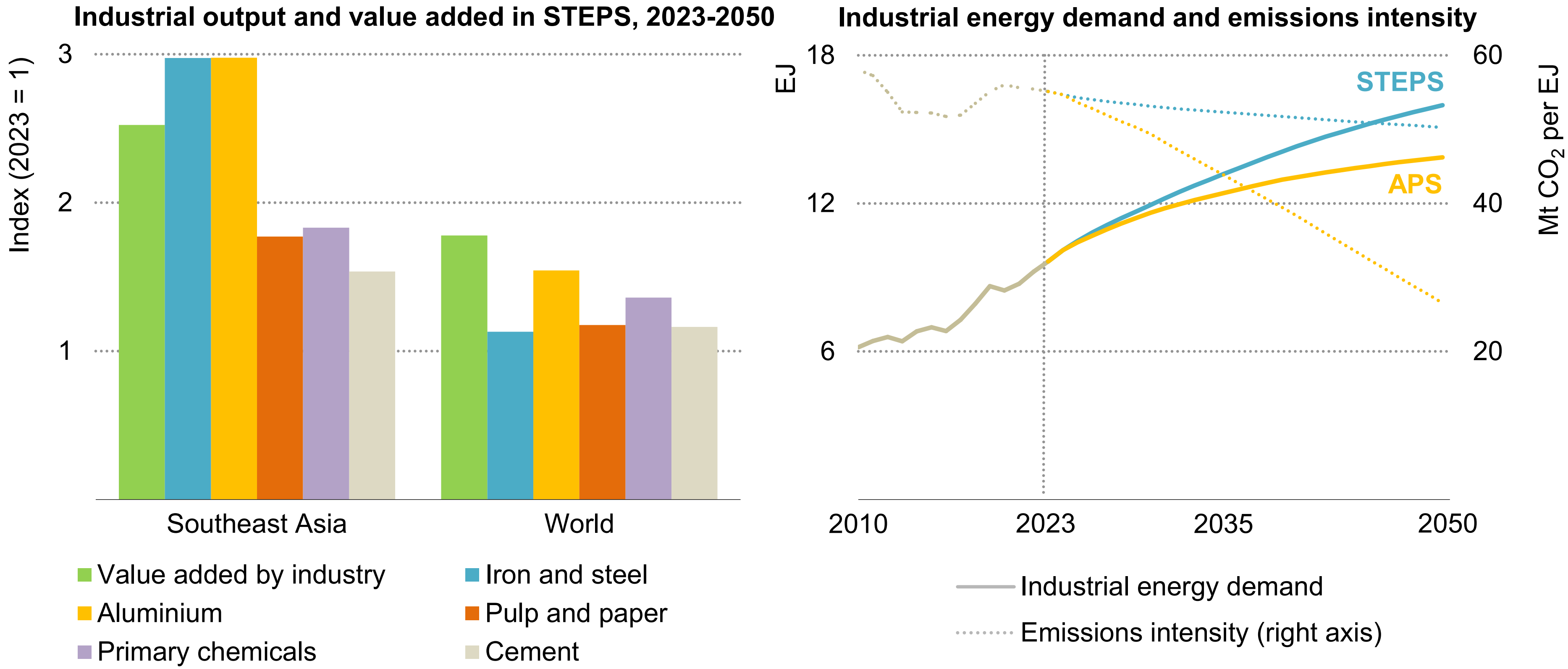
2.3 End-use sectors

Industry

All industrial sectors grow faster than the global average to 2050, as Southeast Asia expands as a manufacturing hub, driving up energy demand with implications for CO_2 emissions

Growth in industrial output by selected material in the Stated Policies Scenario, 2023-2050, and industrial CO_2 emissions intensity by scenario, 2010-2050



Note: "Primary chemicals" include ammonia, methanol, ethylene, propylene and aromatics.

Urbanisation and infrastructure projects underpin rising demand in energy-intensive industries, while manufacturing grows due to trade openness and relatively low costs and skilled labour

Southeast Asia's rapidly expanding industry sector is a source of economic dynamism in the region and the world. Across scenarios, the industrial value added in the region is projected to grow annually by an average of 3.5% per year to 2050, higher than the world average of 2.2%.

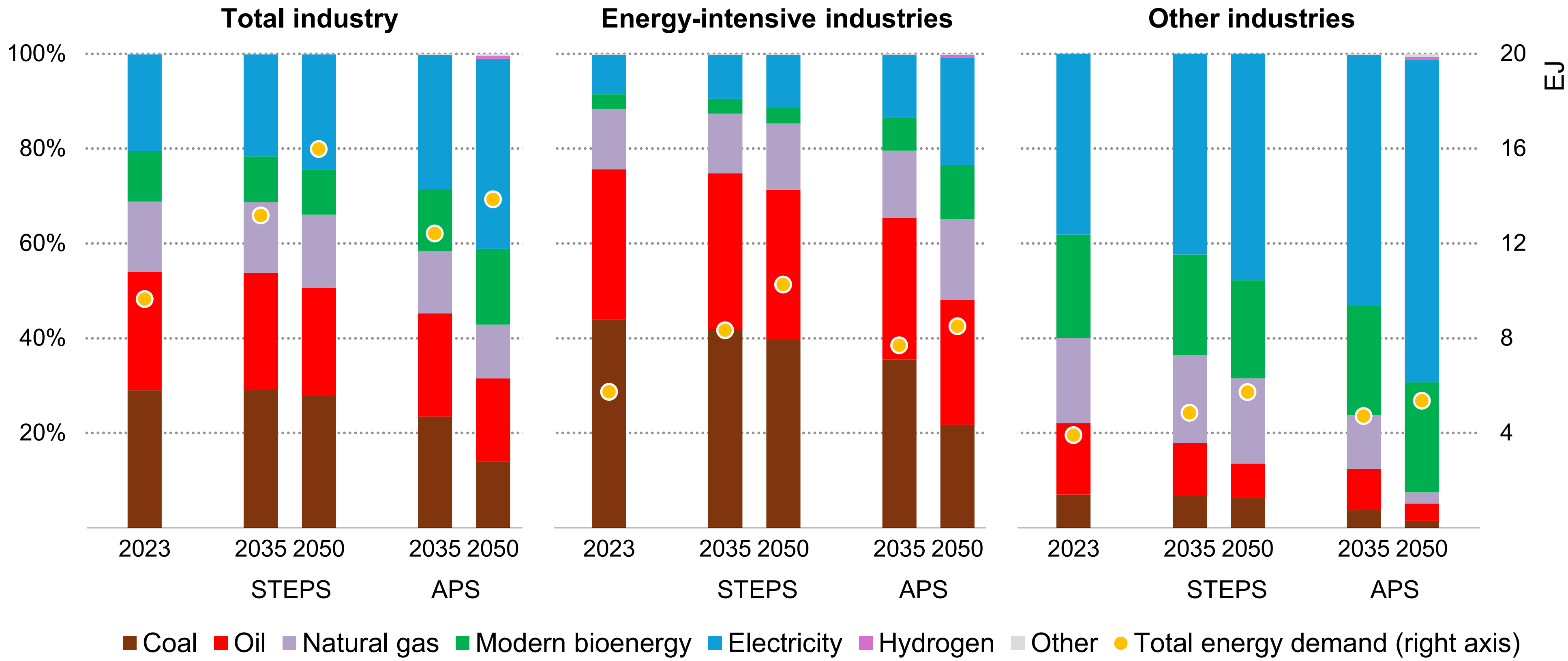
While all industrial subsectors in Southeast Asia are expected to exceed the average growth in global output, the pace varies significantly by material and country. In the STEPS and APS, iron and steel production almost triples by 2050, driven by rapid urbanisation and industrialisation, the availability of coal resources, as well as reducing import dependencies. Indonesia and Viet Nam are poised to lead regional growth in this sector, with large infrastructure projects planned and supportive government policies. Non-ferrous metals production (mainly aluminium and nickel) is also set to increase, especially in Malaysia and Indonesia. Indonesia is leveraging its abundant natural resources and developing significant midstream capacity, notably in nickel, in part by restricting raw material exports (see box). The chemical sector is expected to expand strongly, almost doubling in size by 2050, with Thailand building on its well-established industry presence and robust infrastructure. Indonesia ranks among the top three global exporters of ammonia, while Malaysia has ambitious plans for methanol production. The non-energy-intensive industry sector – which contributes the largest share of value added in the industrial sector – is also set for strong growth. Viet Nam is emerging as a major global manufacturing hub, particularly in textiles, capitalising on its low labour costs and multiple free trade agreements. Urbanisation and infrastructure projects are projected to boost the region's cement production by 50% by 2050, with Viet Nam again at the forefront.

Growing output drives a 65% increase in industrial energy demand from 10 EJ today to 16 EJ in 2050 in the STEPS, representing an average growth rate of 2.6% per year up to 2035 and 1.3% thereafter, reflecting a slowdown in the demand growth of energy-intensive industries towards mid-century. In the APS, a more decisive implementation of energy and material efficiency measures tempers the growth in industrial demand, which reaches 14 EJ by 2050.

In the STEPS, Southeast Asia's industrial CO_2 emissions intensity remains above the global average (10% higher in 2035) and declines slowly to 2050. This relatively high emissions intensity is linked to the growth of energy-intensive industries which rely heavily on coal for high-temperature heat provision, with the fuel providing 28% of the industrial energy mix in 2050, compared to 19% globally. In the APS and the NZE Scenario, the region's coal share goes down to 14 and 4% in 2050, respectively, leading to a faster drop in industrial emissions intensity.

The fuel mix meeting industrial demand does not evolve significantly in the STEPS and a strong push will be required to shift major energy users onto a lower-emissions path

Energy demand in the industrial sector by fuel and scenario, 2023-2050



Notes: "Energy-intensive industries" include iron and steel, chemicals, non-ferrous metals, non-metallic minerals and pulp and paper. "Other industries" include construction, food processing, mining, textiles etc. "Other" fuels include geothermal, solar thermal, district heating and non-renewable waste.

Electrification is the major option to reduce the CO_2 emissions of industry, complemented by low-carbon fuels and CCUS for more energy-intensive sectors

With its current fuel mix, Southeast Asia's industrial sector generates 28% of the region's energy-related CO_2 emissions; however, with greater action to decarbonise industrial processes and fuel inputs, the sector's contributions to emissions can be mitigated. Today, energy-intensive industry accounts for 60% of industrial energy consumption, and these sectors see the strongest energy demand growth in the future, accelerating to 2035 and increasing by a factor of 1.8 and 1.5 by 2050 in the STEPS and APS, respectively, compared to today's level. The energy demand of non-energy-intensive industries (other industries) also increases strongly, by a factor of 1.5 in the STEPS and 1.4 in the APS between 2023 and 2050.

Today, energy-intensive industries in Southeast Asia predominantly rely on coal – making up 44% of their energy demand – to meet the sector's high-temperature heat requirements. The other industry sector primarily utilises electricity (38%), complemented by substantial shares of gas (18%) and relatively high levels of bioenergy (22%). The overall industrial energy mix varies across the region, with countries such as Indonesia and Viet Nam relying on their large domestic coal resources, while industry in Thailand and Malaysia is fuelled by a more balanced mix with higher shares of natural gas and renewables.

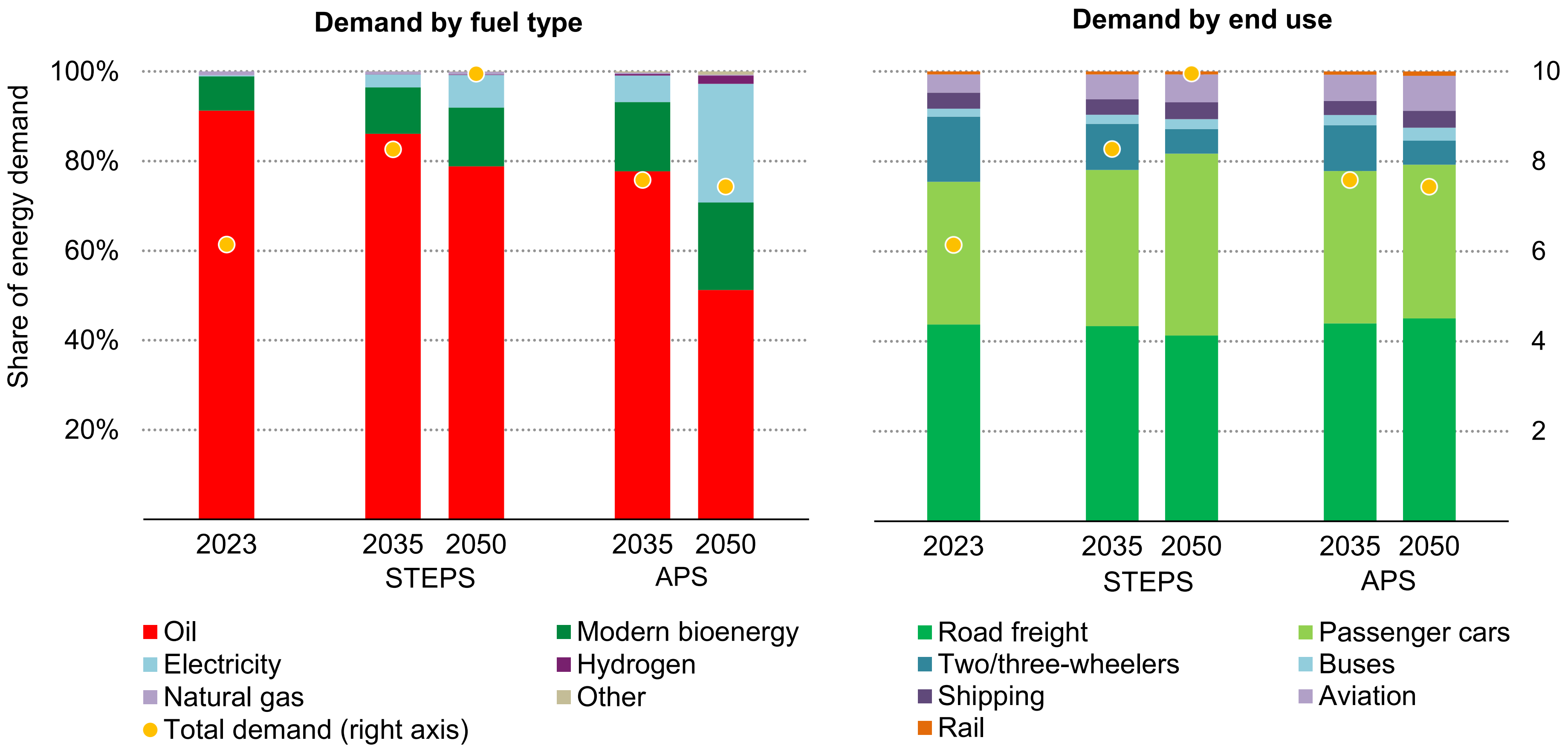
In the STEPS, the fuel mix changes marginally towards 2050, with the region maintaining its heavy reliance on fossil fuels in industry, dropping from 69% of the total industry demand in 2023 to 66% in 2050. The sector's rapid growth in output drives a strong increase in fossil fuel consumption in absolute terms, with coal use in particular increasing by more than 50% by 2050. In the APS, further action on decarbonisation moderates demand growth and brings about shifts in the fuel mix, with greater electrification of some processes in energy-intensive industries, such as iron and steel. Other hard-to-abate sectors, like cement, shift their consumption from coal to bioenergy, natural gas or, to a lesser extent, hydrogen and integrate CCUS to reduce the residual emissions. By 2050 in the APS, fossil fuels account for 65% of energy demand in energy-intensive industries, compared to 85% in the STEPS, and electricity meets more than a fifth of demand.

In the other industry sector, the widespread adoption of electrified heating technologies in the APS drives a higher share of electricity than in the STEPS, reaching almost 70% of energy demand by 2050; bioenergy makes up over 20%, with fossil fuels meeting the rest. In 2050, industry generates 50% fewer emissions in the APS than in the STEPS, highlighting the necessity of ramping up action to meet industrial decarbonisation goals and to participate in global supply chains.

Transport

Biofuels and electricity gradually reduce the dominance of oil in the transport sector

Energy demand in the transport sector by fuel type, end use and scenario, 2023-2050



Notes: Aviation and shipping excludes international aviation and shipping; “Other” = ammonia, synthetic oil products; “Road freight” = heavy and medium freight trucks, and light commercial vehicles.

Oil remains the predominant fuel for transport, although biofuel blending mandates and increasingly cost-competitive electrified options take increasing market share

Road transport accounts for over 90% of the more than 6 EJ of annual energy demand for transport, including international bunkers in Southeast Asia. Within road transport, road freight accounts for just under half of energy demand (48%), followed by passenger cars (34%), two/three-wheelers (16%) and buses (2%). Oil meets around 90% of Southeast Asia's energy demand in the transport sector, in line with the global average. The remaining transport demand is met almost exclusively by biofuels (8%). Electricity provides less than 1% of total transport demand today.

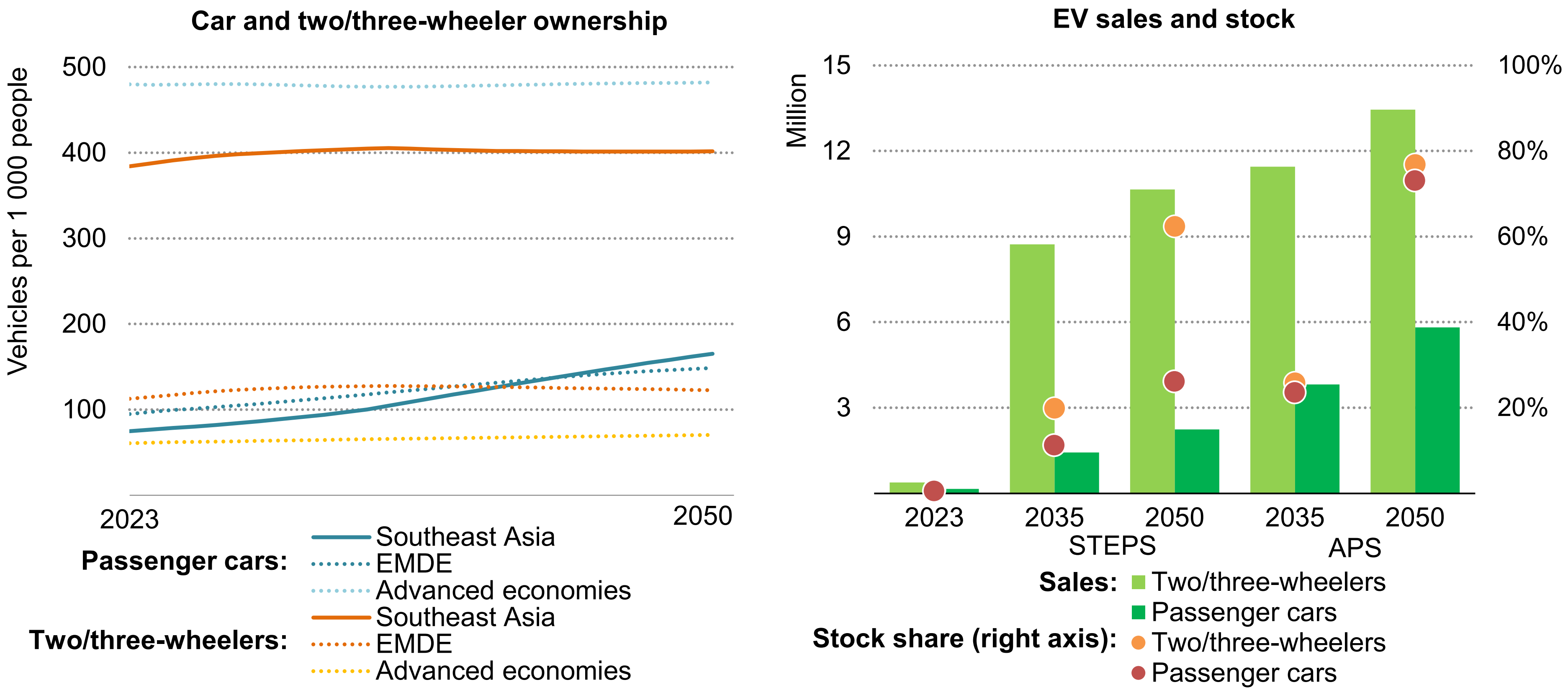
Growing incomes, higher rates of urbanisation and relatively limited public transport options in the region lead to rising ownership levels of cars and two/three-wheelers across scenarios, driving up energy demand. In the STEPS, energy consumption in the transport sector increases by 35% in 2035 from today's level. Beyond road transport, aviation demand doubles in the STEPS by 2035 and more than triples by 2050.

Looking ahead in the STEPS, oil's share in total transport consumption decreases to 85% in 2035. The reduction is mainly a result of biofuel blending mandates; biofuels meet 10% of energy needs by 2035. For biodiesel, Indonesia has a B35 (35% biodiesel) mandate in place, with additional plans to raise the biofuel share to 40% in 2025 – among the most ambitious targets in the world. Mandates also exist in Malaysia (for B20) and Thailand (for B7 and B20 blending), and in the Philippines (E10) and Viet Nam (E5) for ethanol. Palm oil is currently the main feedstock for biodiesel production, generating a high level of oil output per hectare, though raising land-use concerns. When developed sustainably, with efforts to limit impacts on biodiversity and food production, biofuels can reduce transport emissions and dependence on oil imports. In the APS, biofuels account for 15% of road energy consumption by 2035, and 20% by 2050.

Electricity serves 13% of road vehicle kilometre demand for passenger transport by 2035 in the STEPS, but makes up 8% of total road energy consumption due to the efficiency gains of electrification. For example, Thailand and Indonesia have recently introduced tax incentives for the purchase of EVs and subsidies for domestic manufacturing of EVs. In the APS, increased rates of EV adoption and fuel economy improvements reduce energy demand growth in transport to less than 25% in 2035 across Southeast Asia, compared to the 35% increase in the STEPS. Electricity consumption grows further to account for 6% of the total consumption by 2035, and over 25% of the total energy consumption in 2050. However, oil remains the dominant transport fuel in 2050, contributing to more than 50% of the transport energy mix in the APS, compared with the global average of 45%.

Two/three-wheelers are the most popular mode of transportation in Southeast Asia, and represent a major opportunity for electrification, but passenger car ownership is set to rise

Total ownership of cars and two/three-wheelers, and sales and stock of electric cars and two/three-wheelers, 2023-2050



Note: "EMDE" = emerging market and developing economies.

Electric car and two/three-wheeler transport is starting to gain momentum, supported by national policies and the availability of affordable models in the region

In Southeast Asia, rapidly growing demand for motorised mobility has been one of the key drivers of increased fossil fuel use. Over the last ten years, transport oil demand increased 25% mostly due to a rapid increase in the stock of cars, trucks and two/three-wheelers – by around 65% in total. Today, the ownership of two/three wheelers in Southeast Asia is exceptionally high – there are nearly four times as many two/three wheelers per capita as the world average. Even as ownership growth of two/three-wheelers stabilises over the coming years, they will remain a popular form of transportation. Ownership of cars in Southeast Asia, despite rapid growth in recent years, is today below the average for both advanced and emerging market and developing economies (EMDE). However, car ownership is expected to accelerate and surpass average levels in EMDE by 2050.

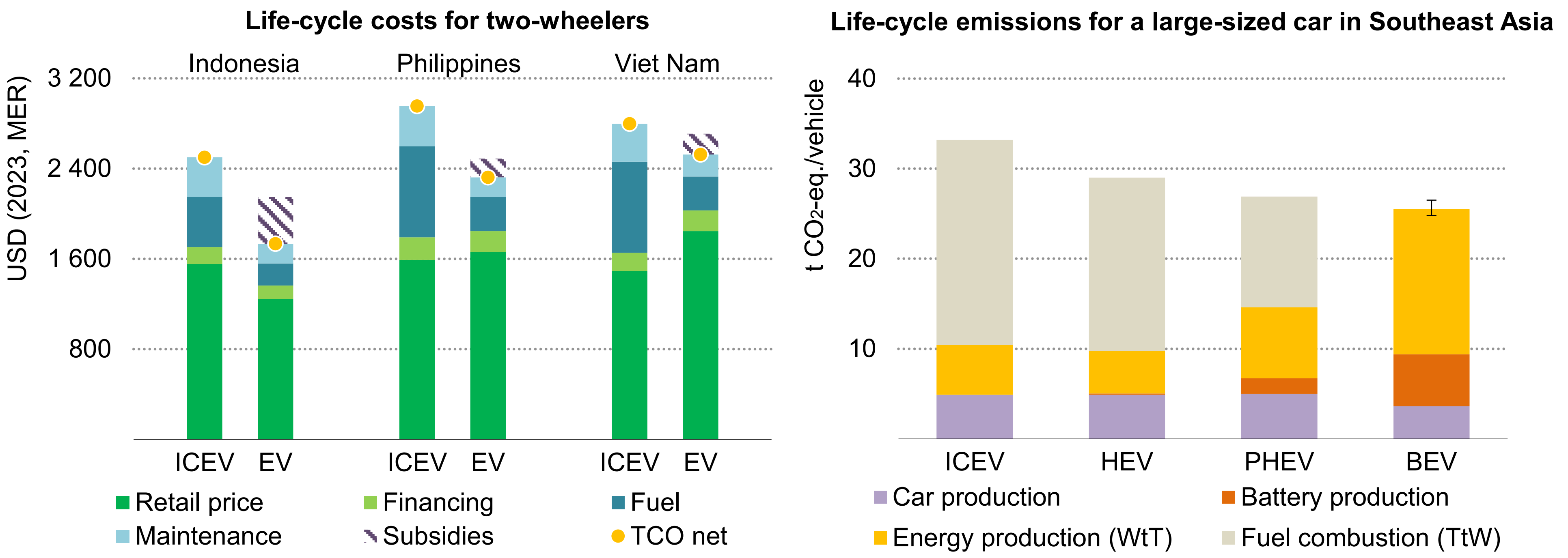
The high ownership rates of two/three-wheelers provide opportunities to think differently about infrastructure requirements for private transport relative to cars. Given the rapid growth of private vehicle ownership, establishing policies for the electrification of these vehicles is crucial to address the high levels of air pollution and CO_2 emissions in the region. The lower car ownership rate in Southeast Asia, relative to advanced economies, presents an opportunity for countries to avoid accumulating cars with ICEs and additional dependency on fossil fuel imports.

Today, 1 in 20 cars and about 1 in 40 two/three-wheelers sold are electric, though sales are seeing robust growth. In Thailand, electric car registrations more than quadrupled from 2022 to 2023 to nearly 90 000 (10% of total sales). Thailand has grants towards the purchase of cars and light commercial vehicles, and has set a target for 30% of all passenger cars and pickup trucks produced to be electric by 2030. In Malaysia, electric car registrations more than tripled to 10 000 in 2023, supported by tax breaks and import duty exemptions, and the country is targeting 100% of the private vehicle stock and 40% of all public transport to be electrified or fuelled by CNG/LPG/biofuels by 2030. Meanwhile, Singapore will cease registering new diesel cars and taxis from 2025, and have only cleaner energy models for all new cars and taxi registrations from 2030.

Such EV uptake targets, alongside a determined implementation of the region's NDCs, would help push the share of EVs to over 60% of new car sales and almost 75% of new two/three-wheeler sales by 2035 in the APS, compared to the respective shares in the STEPS of 23% for PLDVs and 56% for two/three-wheelers. To be aligned with a net zero trajectory, electrification rates need to reach nearly 100% for cars and two/three-wheelers by 2035, with the additional electricity demand being simultaneously matched with the decarbonisation of the electricity grid.

Total cost of ownership for electric two-wheelers is already lower than for ICEs in some places, and EVs have lower life-cycle emissions than their ICE counterparts across the region

Life-cycle costs of two-wheelers and life-cycle emissions of large-sized cars by technology type, 2023



Notes: **left figure:** “TCO net” = net total cost of ownership, “Two-wheelers” refer to vehicles with speeds greater than 50 km/hour and which fit the UNECE definition of L1 or L3. Assumed car and battery lifetime is 15 years, travelling 28 km per day; **right figure:** “BEV” = battery electric vehicle; “HEV” = hybrid electric vehicle, “PHEV” = plug-in hybrid vehicle, with 30% battery utility; “Fuel combustion (TtW)” does not include emissions from production of the energy source. “Energy production (WtT)” is defined as the emissions from producing and refining the fuel. Bioethanol blending is assumed to be 2% for ethanol, derived from the EV Life Cycle Assessment Calculator default setting. Calculated using the EV Life Cycle Assessment Calculator. ICEV consumption = 6.5 l/100 km; HEV fuel consumption = 5.5 l/100 km; 1 kWh/100 km; PHEV fuel consumption = 5 l/100 km; 5.8 kWh/100 km; BEV fuel consumption = 19.4 kWh/100 km. The BEV Error bar considers fluctuation in battery size (from 300-400 km range). Utility of PHEVs = 70% engine, 30% battery.

Lifetime costs of electric two-wheelers in the top markets in the region – Indonesia, the Philippines and Viet Nam – are about 15% to 45% lower than those of their ICE counterparts

Lower total costs of ownership for electric two/three-wheelers incentivise higher uptake rates. In the STEPS, the electric stock share of two/three-wheelers reaches over 60% in 2050, compared to just over 25% for passenger cars. Given the vehicles' light weight and limited daily driving distance, electrification is relatively easy and makes economic sense on a total cost of ownership basis in the region. Two/three-wheelers are also far more efficient in terms of energy consumption per passenger kilometre (pkm) compared to cars, with 60% less electricity consumption per pkm than that of an electric passenger car. They also require much smaller batteries (IEA, 2024).

Expanding public transport (where possible) can further support the transition away from ICE vehicles. Mass transit can also help address traffic issues impacting rapidly developing cities such as Manila and Jakarta. However, beyond the role of personal transit, a modal shift from cars to bus and rail can also enable fuel efficiency improvements. High-occupancy planned mass transit infrastructure in general uses less fuel per passenger kilometre than cars do, though slightly more than two/three-wheelers. For electrified transport, the EV battery capacities required per passenger kilometre of travel are lower for two/three-wheelers than for buses, and the battery capacities required for buses are lower than for cars. A modal shift among electrified vehicles can therefore temper rising demand for critical minerals.

However, for transport demand that cannot be otherwise met by public transport, walking, cycling or less energy intensive two/three-wheelers, electric cars can reduce GHG emissions when compared with ICE cars on a lifecycle basis. A large-sized car with a petrol (gasoline) engine bought in Southeast Asia today emits approximately 33 t CO_2-eq over a 15-year lifetime under the current policy setting, compared to 29 t CO_2-eq for an equivalent hybrid EV, and 27 t CO_2-eq for an equivalent plug-in hybrid EV; in other words, a respective 12% and 19% difference compared to an ICE vehicle over its lifetime. In contrast, an equivalent battery EV with a 350-km range would produce 25.6 t CO_2-eq, or 22% less over its lifetime than a conventional ICE vehicle. Despite higher manufacturing emissions associated with the respective battery production, the cumulative emissions of an EV's battery are lower than those of its internal-combustion equivalent after six years of operation; the dedicated EV Life Cycle Assessment Calculator enables the formulation and exploration of region-specific calculations. EVs are also effective in addressing air pollution issues arising from the use of ICE vehicles.

Zero emissions bunkering: maritime policies and partnerships at the Port of Singapore

Singapore is one of the busiest ports globally. It is the location of around 20-25% of global shipping re-fuelling sales today. As the world's largest bunkering port, it is a focal point for global decarbonisation efforts in the shipping sector. Singapore is a signatory – along with 26 other countries – of the Clydebank Declaration which aims for the maritime industry to achieve net zero emissions by 2050.

The Port of Singapore is pursuing several strategies to realise its decarbonisation ambitions.

The first is the development of green shipping corridors, a core part of the Clydebank Declaration, which is defined as a zero emissions maritime route between two or more ports. Three such corridors are: the Singapore–Los Angeles/Long Beach corridor partnership between their respective port authorities, the Singapore-Rotterdam corridor and the Singapore–Australia corridor.

Second, Singapore completed safety studies for ammonia bunkering pilots in 2023 and is also undertaking measures to enhance methanol bunkering capabilities. In early 2024, the world's first ammonia dual-fuel powered vessel was used in the Port of Singapore.

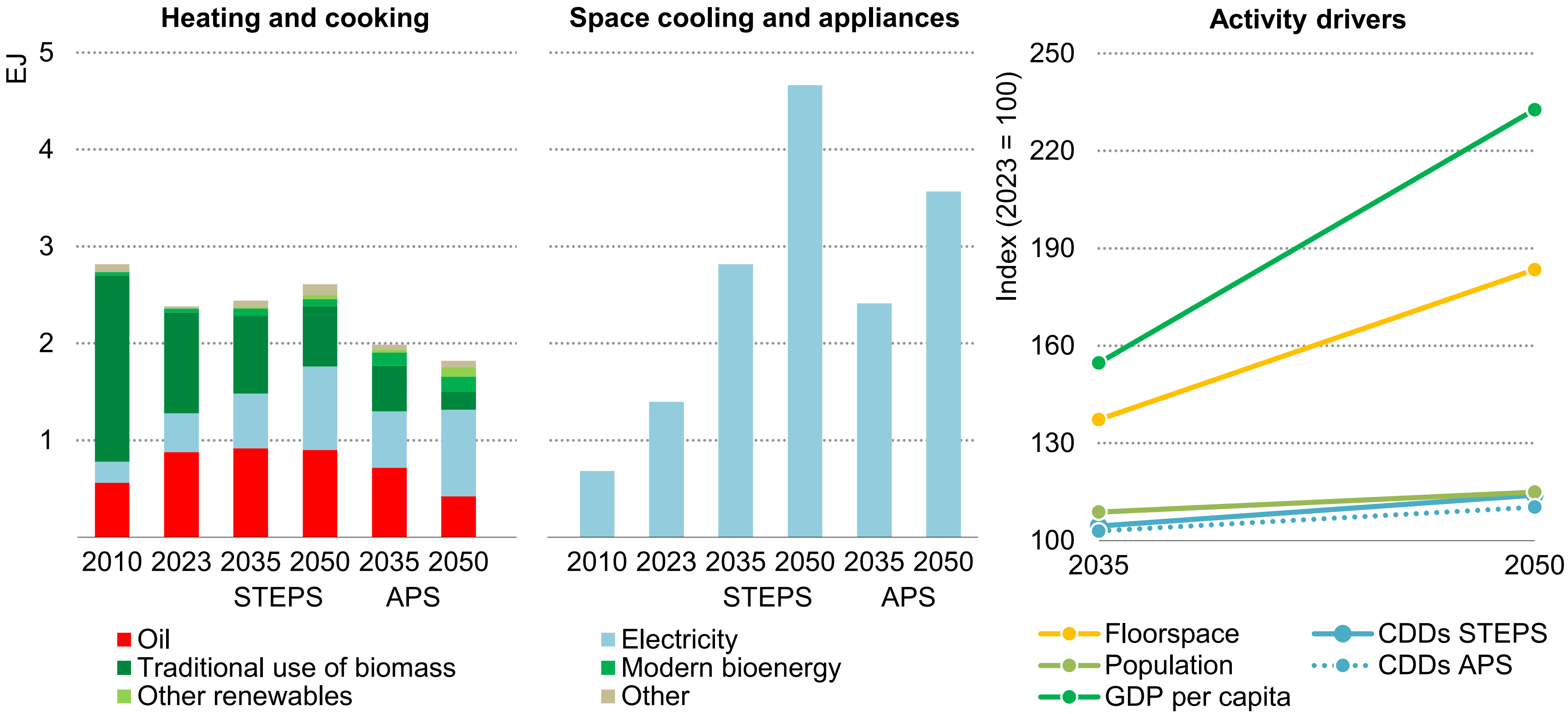
A third strategy includes registration incentives and purchase plans for low- and zero-emissions ships, which are likely to be influential as Singapore is home to approximately 5% of the world's registered shipping fleet. The Maritime and Port Authority (MPA) has established lower port dues and exemptions for green-certified ships, as well as additional tax incentives for ships that use low- or zero-carbon fuels, thus providing incentives for ships that exceed current environmental performance standards for shipping. In addition, the Singapore Registry of Ships is set to register its first four ammonia dual-fuel bulk carriers around 2026. And from 2030, new smaller harbour craft will be fully electric or compatible with net zero fuels.

These initiatives are critical in the transition to a net zero maritime industry by 2050, in line with the ambitions set out in the Clydebank Declaration for net zero green corridors and shipping by 2050.

Buildings

Total final energy consumption in Southeast Asia's buildings sector grows in all our scenarios, driven by rising incomes, increasing floorspace and population growth

Total final consumption in the buildings sector by source and scenario for selected end uses, 2010-2050, and change in activity drivers of buildings energy demand, 2035-2050



Notes: "Other renewables" includes solar thermal and geothermal. "Other" includes coal and natural gas. "CDDs" = cooling degree days. More details on the activity driver modelling can be found at the Global Energy and Climate Model documentation.

Surging electricity demand and reduced use of traditional biomass are key structural trends in buildings, with major potential for efficiency improvements and health co-benefits

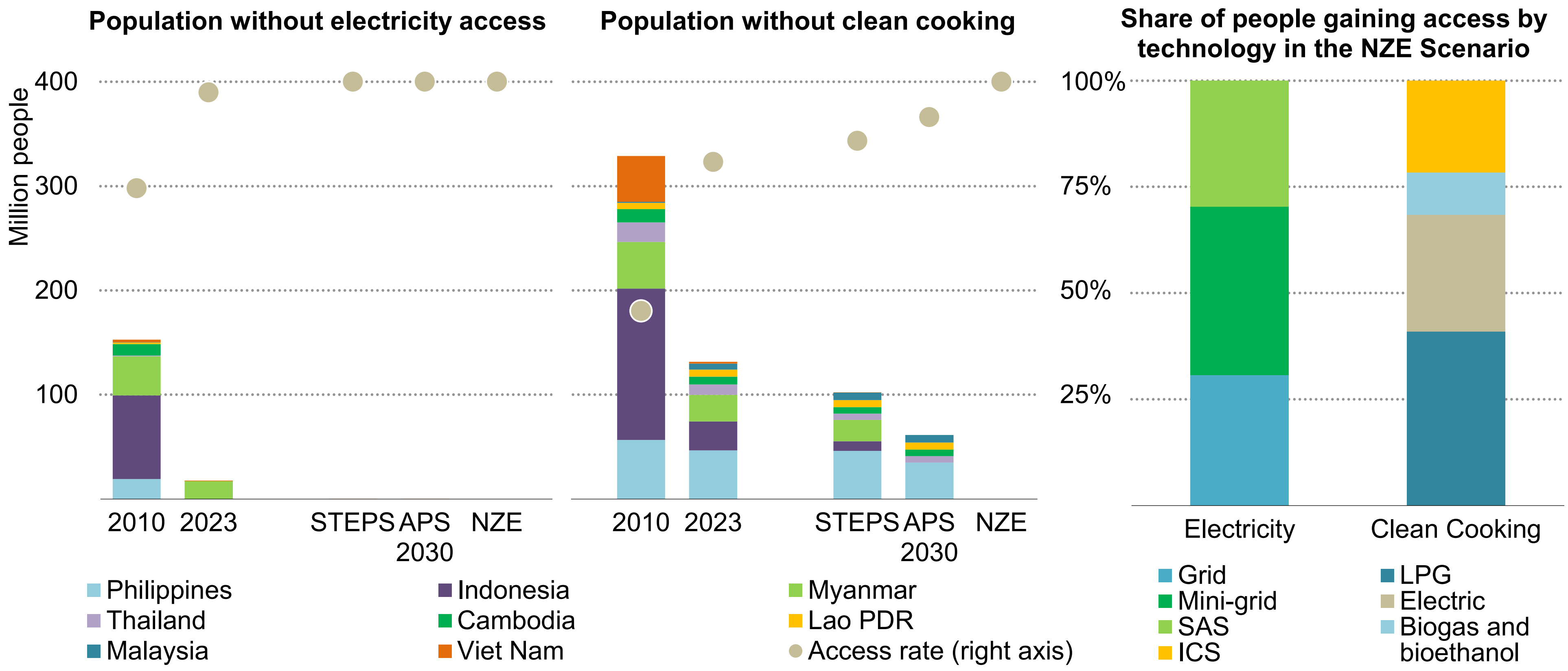
Households account for more than 70% of energy consumption in Southeast Asia's buildings sector, with the remainder used by service sector buildings. Today, appliances and space cooling account for more than 30% of the energy consumed in buildings, and their share is set to increase rapidly. Cooking makes up over 15% of the energy consumption, while water heating and lighting consume around 10% each. As the climate is relatively warm, space heating accounts for only around 5% of the energy consumption. The remaining energy use is mostly through the traditional use of biomass.

In the STEPS, energy consumption in buildings expands by around 2.8% per year to 2035, exceeding 8 EJ in 2050 (an increase of over 90% compared to today). Energy demand in buildings correlates with floorspace, which is projected to increase by more than 30% over the next 10 years and by over 83% between 2023 and 2050 – driven by rising incomes, as regional GDP per capita increases by 133% by 2050. In terms of the fuel mix, 46% of the energy needs in buildings in 2023 were met by fossil fuels or the traditional use of solid biomass. While most buildings in Southeast Asia have access to electricity, access to modern cooking technologies is less widespread, with the traditional use of biomass for cooking still accounting for nearly a quarter of energy consumption in buildings. In 2023, around 20% of Southeast Asia's population lacked access to clean cooking, with around 240 000 premature deaths resulting from indoor air pollution (see page 57). In the STEPS, just under 12% of the region's population lack access to clean cooking in 2035, reflecting some progress in this scenario with the uptake of more efficient cooking technologies which have lower emissions and bring health co-benefits. Electricity is the largest component of energy demand growth in buildings in the region, driven by the electrification of cooking and water heating, as well as rising incomes and temperatures, which increase the role of appliances and air conditioning (AC). In 2023, over half of energy consumption in buildings came from electricity, growing to nearly 80% by 2050.

In the APS, growth in energy demand is tempered by stronger energy efficiency measures to reach nearly 6.2 EJ in 2050 – an increase of 45% compared to 2023, but this is less than half the growth projected in the STEPS. Additionally, the impacts of climate change are lower than in the STEPS, reducing service demand for air conditioning. The electricity share is higher, while less oil and traditional solid biomass is used. Progress in providing access to clean cooking is more pronounced, as less than 7% of the population remain without clean cooking by 2035. This reduces overall demand growth. For heating and cooking, the share of direct renewable energy – which includes modern bioenergy, solar thermal and geothermal energy – increases almost fourfold in the APS by 2035. Renewable energy accounts for over 250 PJ in 2050.

Southeast Asia is on course to reach universal electricity access by 2030, but progress in providing access to clean cooking stalled due to the pandemic and higher fuel prices

Electricity and clean cooking access by scenario, 2010-2030, and share of access gained by technology in the Net Zero Emissions by 2050 Scenario, by 2030



Notes: “SAS” = standalone systems; “ICS” = improved cook stoves; “LPG” = liquefied petroleum gas.

Accelerated efforts and ambition are needed to bridge the clean cooking gap, as full implementation of government pledges will not achieve universal clean cooking access by 2030

Around 3% of the population in Southeast Asia – about 18 million people – still lack access to electricity, with almost all of them living in Myanmar. The number of people without access fell by 135 million between 2010 and 2023, although progress slowed between 2020 and 2022 due to the pandemic and the global energy crisis. Nine out of ten countries in the region have reached over 95% of their population with electricity access. About a third of the population in Myanmar, approximately 17 million people, has yet to gain access to electricity; however, since the launch of the National Electrification Project in 2015, significant progress has been made as the population with access to electricity has more than doubled, increasing the access rate from 30% in 2015 to almost 70% today.

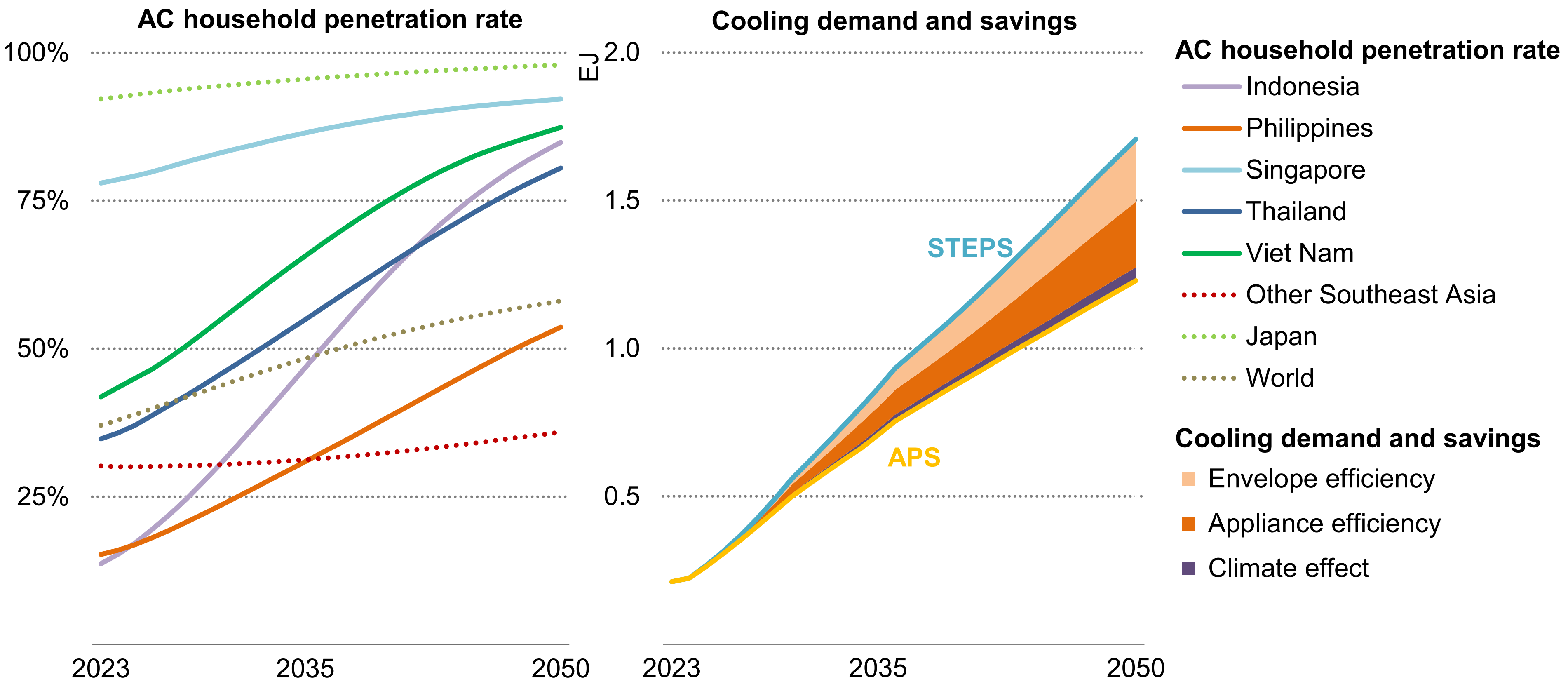
The region is on track to achieve universal access to electricity around 2030 as indicated in the STEPS, with remote populations gaining access via mini-grid and stand-alone systems, many powered by renewable sources.

Progress on clean cooking still lags, however, as more than 130 million people are still primarily cooking with harmful fuels such as traditional biomass, coal or kerosene. Countries with the lowest access rates include Lao PDR (11%), Myanmar (53%), Cambodia (57%), and the Philippines (60%), predominantly in rural areas. Access to clean cooking has significantly improved since 2010 from a 45% access rate to around 80% today, largely because of strong efforts to extend LPG access in Indonesia and Viet Nam. However, progress has remained slow in Lao PDR, the Philippines, and Malaysia. Regional progress slowed notably from 2020 to the end of 2022, due to a surge in fuel prices that drove some households to revert to traditional use of biomass, despite price supports implemented by governments. In response to price shocks, some countries are advancing electric cooking to reduce import and subsidy exposure, such as Indonesia.

Universal access to clean cooking by 2030 is achieved in neither the STEPS nor the APS, leaving about 15% and 9% (more than 100 and 60 million people) without access, respectively. The NZE Scenario highlights a pathway to achieve universal access by 2030, necessitating accelerated policy efforts and commitments. Of the total population gaining access, the NZE Scenario sees 41% gaining access through LPG, 22% via improved cook stoves, 27% from electricity, and 10% from biogas and bioethanol. To deliver universal access by 2030, 19 million people need to gain access every year, which means more than doubling the annual growth rate of the population with access to 4%, returning to the pre-pandemic rate of growth. This requires an annual investment in end-use cooking equipment of around USD 385 million and over USD 100 million in the required supply and distribution infrastructure.

Increasing AC ownership drives a surge in energy demand for residential cooling

AC penetration rate in households and residential cooling demand in the Stated Policies Scenario and Announced Pledges Scenario, 2023-2050



Note: “AC” = air conditioner. Climate effect reflects higher utilisation of ACs due to higher temperatures; lower projected emissions decrease this climate effect in the APS compared to the STEPS. “Other Southeast Asia” comprises Brunei Darussalam, Cambodia, Lao PDR, Malaysia and Myanmar.

Policies to improve the performance of building envelopes and AC efficiency reduce space cooling demand growth by more than a quarter in the APS by 2050 compared with the STEPS

The use of energy for space cooling is growing faster than for any other end use in buildings. However, AC ownership rates are highly unequal between countries in Southeast Asia despite the high temperatures and humidity experienced across the region. In 2023, Cambodia, Indonesia, Lao PDR, Myanmar and the Philippines had AC ownership rates of less than 20% of households compared to over 90% in Japan. The ACs across Southeast Asia vary greatly in energy efficiency and keeping them running consumes over 100 TWh of electricity every year. More than 16% of all the electricity used in buildings in the region is for space cooling, growing to over 35% in 2050 in the STEPS.

As incomes rise, major increases in AC ownership are projected, notably in Indonesia, where the share of households with air conditioning is set to increase from under 15% today to 85% in 2050. Without additional measures to mitigate climate change, the number of cooling degree days averaged across Southeast Asia rises by more than 10% by 2050 in the STEPS. The cooling demand in Southeast Asia is expected to grow sixfold by 2050, approaching the 635 TWh of total electricity consumed in buildings in 2023. This rise could cause significant growth in CO_2 emissions related to space cooling, considering the region's reliance on coal-fired power generation. Higher AC loads raise not only overall power needs, but also the need for generation and distribution capacity to meet demand at peak times, placing further stress on the power system.

Current or planned policies would have only a limited effect in slowing that growth, and strategies to improve the performance of building envelopes and ACs are crucial. Most countries in Southeast Asia have mandatory MEPS for ACs. Several countries also have mandatory energy codes for at least certain types of buildings, while Singapore and the Philippines have mandatory building energy codes for all newly constructed buildings. Sustainable construction methods are also encouraged, in part to mitigate the urban heat island effect. In Singapore, for example, the Green Mark Scheme incentivises strategies such as building with more reflective materials and integrating greenery into roofs and walls. Additionally, adopting certification and labelling standards for buildings is important for improving efficiencies and can unlock financing mechanisms such as green bonds. Efficiency measures reduce cooling demand growth by almost 30% compared to the STEPS in 2050, mostly resulting from better appliance efficiency, which would further benefit from harmonised standards between countries. While this highlights the impact of appliance efficiency policies, it also suggests potential to increase the coverage of building envelope efficiency in pledges and targets.

Southeast Asia presents a mixed picture for regulations and standards to support efficiency improvements in buildings, with some improvements since the last edition of this *Outlook*

Status and developments of key existing policy instruments to improve the energy efficiency of buildings and the appliances therein

Country	Buildings		Appliances			
	Building energy codes	Certification/ Labelling	MEPS for appliances		Labelling for appliances	
Brunei Darussalam	Mandatory for certain building types =	Mandatory for certain building types =	Mandatory =	AC	Under development =	AC
Cambodia	Under development =	Voluntary =	Under development =	AC, R	Under development =	AC, R
Indonesia	Mandatory for certain building types =	Voluntary =	Mandatory =	AC, R, L, F	Mandatory =	AC, R, L, F
Lao PDR	Under development =	No known policy =	Under development =	AC	Under development =	AC
Malaysia	Mandatory for certain building types =	Voluntary =	Mandatory =	AC, R, L, F	Mandatory ↑	AC, R, L, F
Myanmar	Voluntary =	Voluntary =	Under development =	AC	No known policy =	
Philippines	Mandatory for all buildings ↑	Voluntary =	Mandatory ↑	AC, R, L, F	Mandatory ↑	AC, R, L, F
Singapore	Mandatory for all buildings =	Voluntary =	Mandatory =	AC, R, L	Mandatory =	AC, R, L
Thailand	Mandatory for certain building types =	Voluntary =	Mandatory =	AC, R, L	Mandatory ↑	AC, R, L, F
Viet Nam	Mandatory for certain building types =	Voluntary =	Mandatory =	AC, R, L, F	Mandatory ↑	AC, R, L, F

AC - air conditioners

R - refrigerators/freezers

L - lighting

F - fans

= no change since SEAO 2022

↑ improvements since SEAO 2022

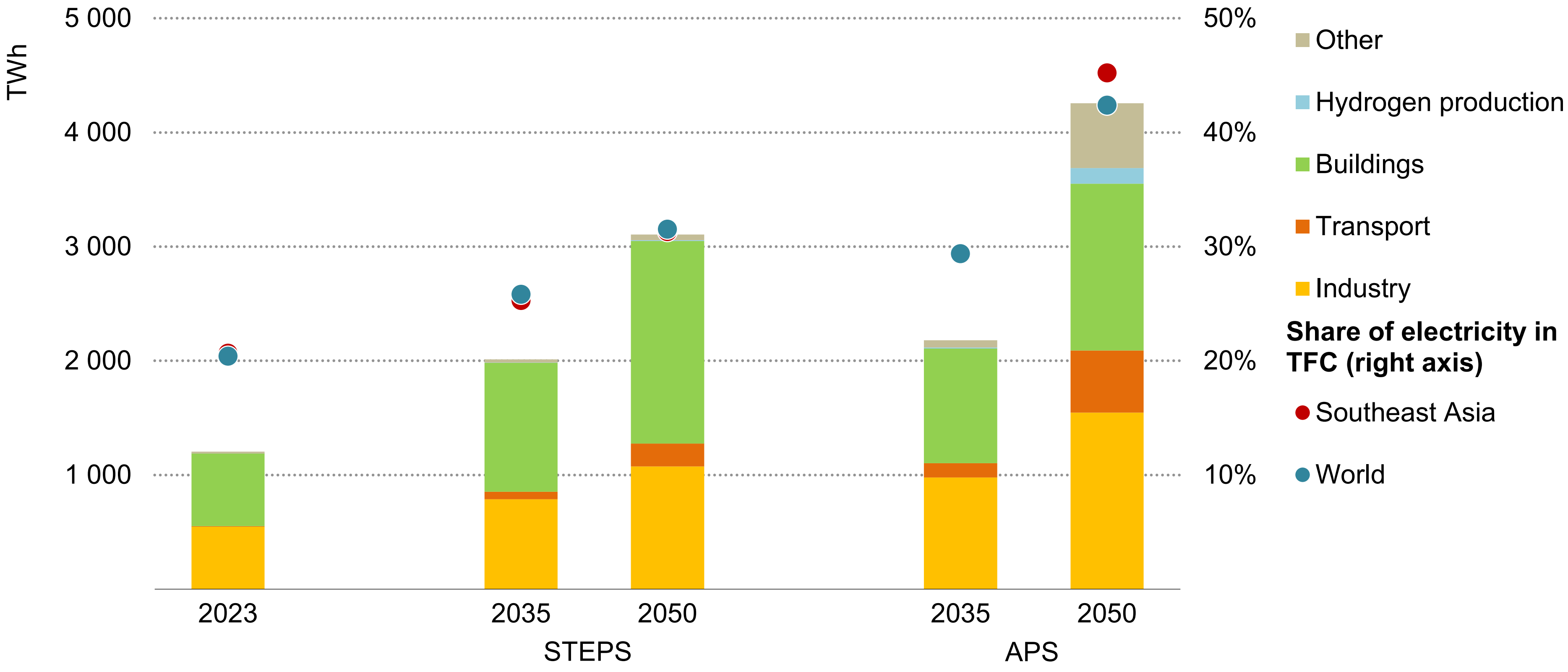
	Building energy codes, labelling, certification	Appliances
● (green)	Mandatory for all buildings	Mandatory
● (blue)	Mandatory for certain building types	-
● (yellow)	Voluntary	Voluntary
● (red)	Under development	Under development
● (grey)	No known policy	No known policy

Note: “Mandatory” status presumes that there is regulation in place that enforces energy efficiency requirements of the building energy code or certification; “Mandatory for all buildings” means that there are mandatory requirements for both residential and non-residential buildings; “Mandatory for certain building types” means that such requirements apply to a specified group of buildings, e.g. buildings owned by the government or buildings with a floor area larger than a certain threshold.

2.4 Electricity

The share of electricity in total final consumption rises by 50% in the STEPS and doubles in the APS by 2050, overtaking the world average under announced pledges in the long term

Electricity demand by sector and scenario and its share in total final consumption, 2023-2050



Notes: "Other" includes agriculture, energy sector own use and bioenergy processing, gas works, petroleum refineries, coal and gas transformation and liquefaction. "TFC" = total final consumption.

The strong increase in demand for cooling and appliances are the biggest drivers in electricity demand growth, but electricity use for transportation depends on the strength of policy support

The share of electricity in total final consumption (TFC) in Southeast Asia increases from about 20% today to almost 25% by 2035 and over 30% by 2050 in the STEPS. However, with an annual average increase of 4% until 2050, the growth of electricity demand in the STEPS is lower than the growth rates observed over the past decade.

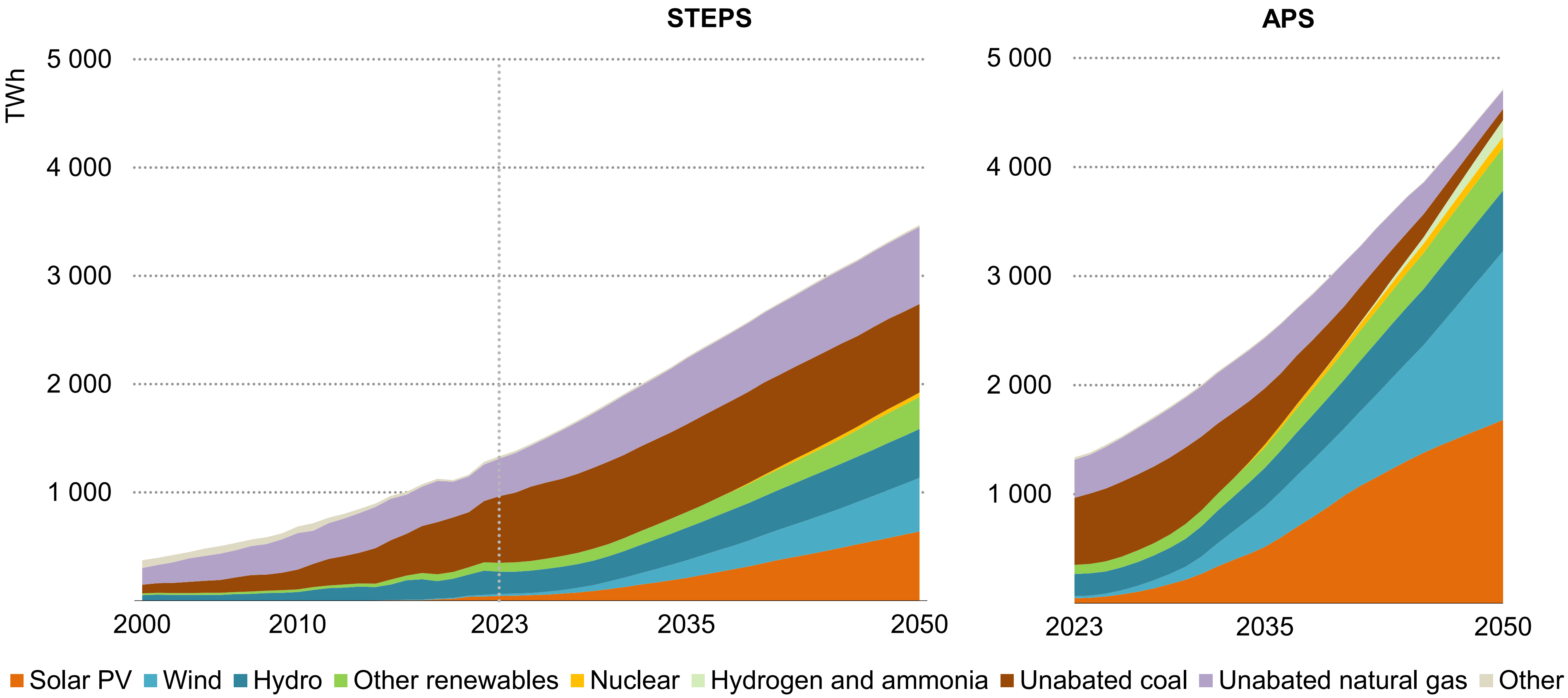
In sectoral terms, total electricity demand growth in the STEPS is driven primarily by buildings and industry. Today, transport accounts for less than 1% of consumption, and industry and buildings account for 90% of growth to 2035 and continue to do so to 2050. Buildings alone account for more than 60% of total electricity demand growth to 2035, due in large part to rising household incomes, which translate into higher appliance ownership and demand for air conditioning. Demand for cooling alone increases sixfold by 2050 in the STEPS, posing new challenges for peak demand management and the stability and reliability of the electricity system. Moreover, despite the setbacks of the global pandemic, most countries in Southeast Asia achieve near universal access to electricity by 2030 in the STEPS, connecting almost 2.5 million people every year. In industry, Southeast Asia's growing light manufacturing sector (e.g. automobiles) and electrification of low-temperature heat drive up demand. Although today the region is home to just around 3% of global data centre demand, its electricity demand for data centres is set to almost double by 2030.

The electrification of transport and the use of electricity for hydrogen production are less significant: despite rapid growth, they account for a combined 8% of total electricity demand growth to 2035, and 11% to 2050 in the STEPS. In the APS, however, policy and infrastructure support for the electrification of mobility is stronger, and demand growth is driven more heavily by transport and hydrogen production, which ramp up faster than in the STEPS: they are responsible for 15% of overall demand growth to 2035 and almost 35% to 2050.

In absolute terms, the APS sees electricity demand rising by 60% more than in the STEPS, and its share in total final consumption more than doubles to 45% to 2050. However, efficiency savings for electricity are also more significant in the APS. More stringent standards for electric motor systems and other industrial equipment, stronger buildings regulations and more stringent MEPS for appliances and cooling equipment, and a better fuel economy for cars and trucks, mean that by 2035, the APS avoids almost 1.5 EJ of total final consumption more than the STEPS (see page 131). Overall, Southeast Asia's share of electricity in total final consumption remains lower than in many other regions in both scenarios, as the region continues to rely heavily on fossil fuels, as well as bioenergy, to meet its growing energy demand.

Led by solar PV, renewables are set to enter a period of rapid expansion, supplying over 50% of Southeast Asia's electricity by 2050 in the STEPS and nearly 90% in the APS

Electricity generation by source and scenario in Southeast Asia, 2000-2050



Notes: "Other renewables" include bioenergy, geothermal, concentrated solar power and marine power. "Other" includes oil, non-renewable waste and other sources.

Both coal and natural gas use for electricity generation continue to grow in the STEPS, even as their shares in the electricity mix slowly come down

Total electricity generation is projected to increase rapidly in Southeast Asia, rising from 1 300 TWh in 2023 to over 2 200 TWh by 2035 in the STEPS and over 2 400 TWh in the APS. In 2050, it reaches 3 500 TWh in the STEPS and 4 700 TWh in the APS.

Renewables, led by solar PV, are poised for fast growth. Solar PV makes up 3% of electricity generation today, a share which increases to around 10% in 2035 and 20% in 2050 in the STEPS. In the APS, solar PV expands over elevenfold by 2035, constituting more than 20% of the electricity mix, rising to 35% by 2050. Growth in wind power also picks up in the STEPS. Its share in the mix – about 1% today – increases to 7% by 2035 and nearly 15% by 2050. In the APS, wind capacity growth accelerates after 2030, driven by onshore and offshore wind plans in Viet Nam's PDP8. Wind's share in the mix rises to 15% by 2035 and 33% by 2050. Increasing the flexibility of the coal fleet, reinforcing grids, and deploying new sources of flexibility such as battery storage and demand response will be key to integrating the rising shares of variable renewables. Other renewables also grow: hydro output expands as untapped potentials are developed, and generation from geothermal and bioenergy increases roughly in line with electricity demand growth.

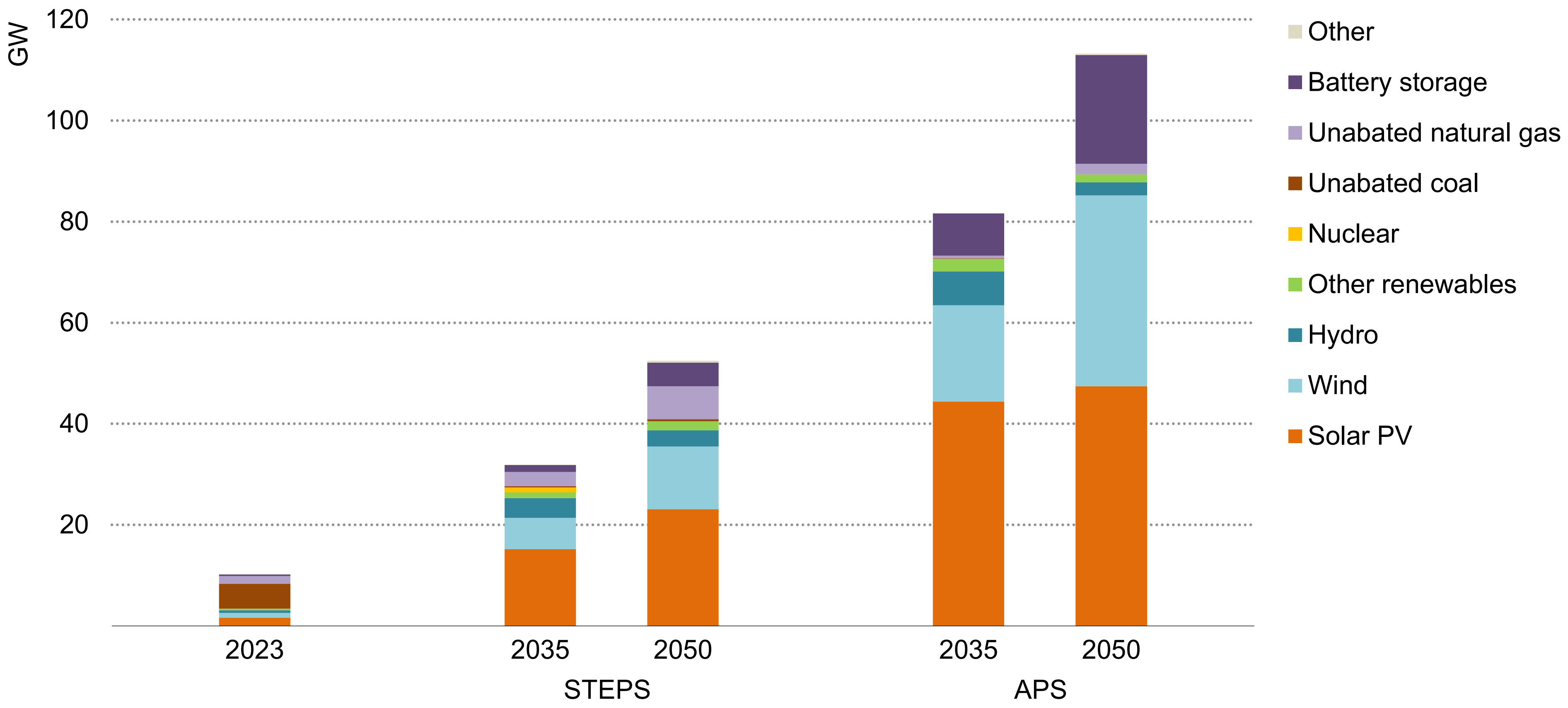
While coal-fired power generation increases at about 2% per year from 2023 to 2035 in the STEPS, its share in the electricity mix falls from 46% today to about 35% in 2035. Growth essentially stops around 2040 and coal's share in the mix drops to 25% by 2050. In the APS, coal generation peaks by 2030 and then declines as no new unabated coal plants are commissioned. From 2035, the progressive retirement of older plants reaching the end of their service lives and the conversion of some to co-fire ammonia or biomass leads to steep reductions in coal-fired electricity generation, to about 100 TWh by 2050, or around 2% of the electricity mix.

Low LNG prices narrow the cost gap to coal and support an acceleration of gas-fired power generation in the STEPS. Its share increases from about 26% today to nearly 30% by 2030. While this share drops to about 20% by 2050, in absolute terms gas-fired generation then is over twice as high as it is today. Due to the faster expansion of renewables, gas grows more slowly in the APS, peaking by 2035 before declining, its share dropping to less than 5% by 2050.

Nuclear becomes a part of the electricity mix around 2035 in both scenarios. However, its contribution remains relatively small, accounting for about 1% in 2050 in the STEPS and 2% in the APS. In the APS, hydrogen and ammonia also enter the mix after 2035 as some gas and coal plants are retrofitted to blend these fuels, although owing to their comparatively high cost, their combined share remains well below 5% in 2050.

In both the STEPS and APS, solar PV is set to become the largest and wind the second-largest source of new power generation capacity by 2030

Annual power generation capacity additions by scenario, 2023-2050



Note: "Other renewables" include bioenergy, geothermal, concentrated solar power and marine power. "Other" includes non-renewable waste and other sources.

In both scenarios, installed solar PV capacity is projected to eclipse that of gas and coal by 2035, while battery storage grows rapidly in the APS, helping integrate rising shares of solar PV

With over 110 GW, natural gas currently ranks first in terms of installed capacity in Southeast Asia today, followed closely by coal with just under 110 GW and hydropower with about 60 GW. Solar PV capacity has increased to more than 30 GW over the past five years, much of it due to a boom in additions in Viet Nam between 2019 and 2021. Across the region, there are currently less than 10 GW of wind connected to electricity grids.

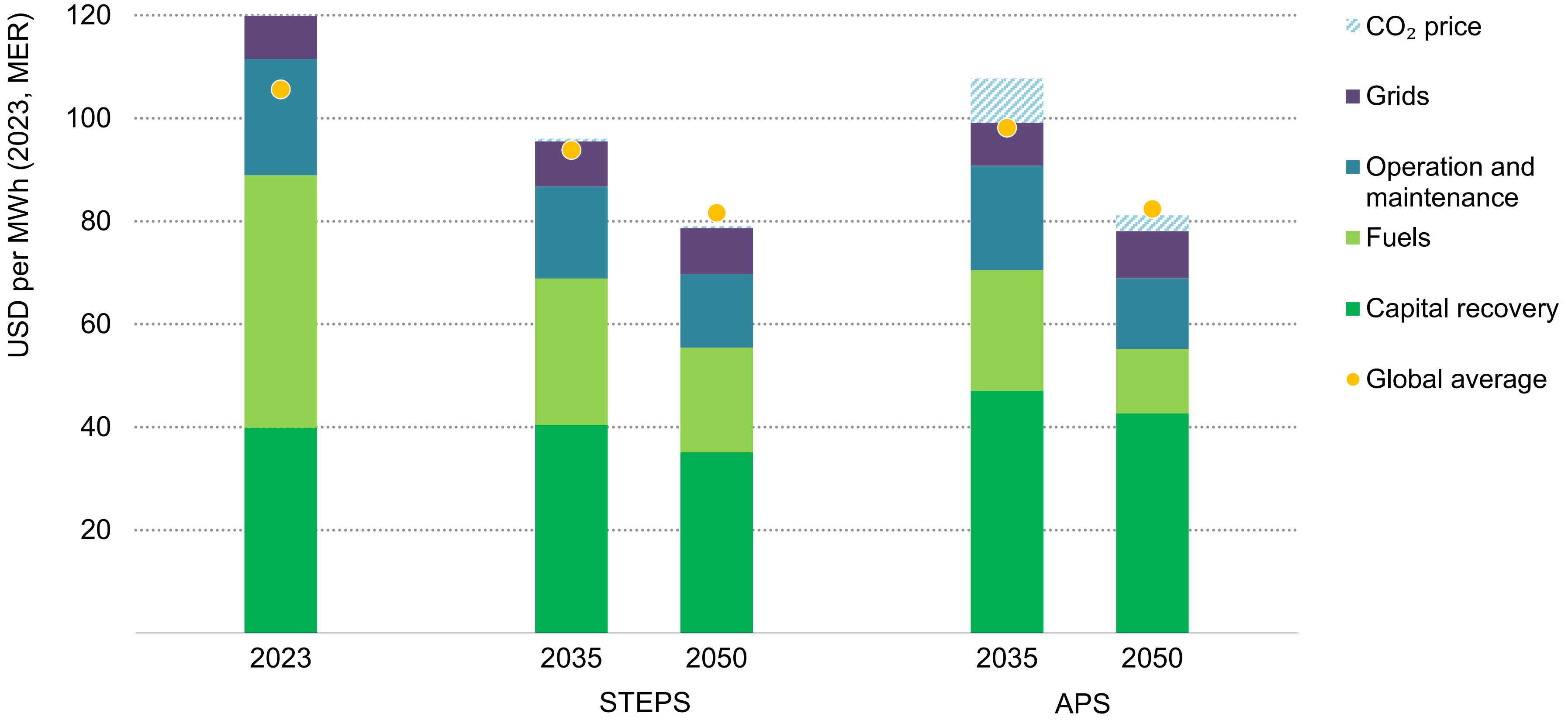
As the markets for solar PV and wind mature, there is a substantial increase in the pace of capacity additions of the two technologies, especially after 2030. Due to the low and falling cost of solar modules, solar PV capacity additions pick up considerably in both scenarios, increasing from about 2 GW per year in 2023 to 15 GW per year in 2035 in the STEPS and nearly 45 GW per year in the APS. Wind additions, by contrast, increase only slowly in the STEPS, rising from less than 1 GW per year in 2023 to 6 GW in 2035. In the APS, they increase faster, to nearly 20 GW per year by 2035, reflecting increased ambition, most notably Viet Nam's PDP8 and Indonesia's roadmap to net zero emissions. Hydropower capacity is also projected to continue to grow in both scenarios, reflecting the fact that there still is significant untapped potential that can be developed to supply low-emissions electricity and flexibility to power systems across the region. The installed hydro capacity rises from close to 60 GW today to nearly 95 GW by 2035 in the STEPS and 120 GW in the APS.

Installed coal-fired capacity is set to continue to grow to over 135 GW by 2035 in the STEPS before stabilising at this level to 2050. In the APS, coal capacity peaks at nearly 135 GW in 2030 and then starts to decline as older plants are retired, while gas-fired capacity peaks at close to 155 GW around 2035. By 2050, about 165 GW of unabated coal- or gas-fired capacity remains operational, together with about 50 GW of capacity retrofitted to blend ammonia or hydrogen. These plants continue to provide essential services in the form of secure capacity and seasonal balancing (see page 138). Beginning around 2035, several nuclear power plants are commissioned in both scenarios, primarily in Indonesia, increasing Southeast Asia's installed nuclear capacity to 6 GW by 2050 in the STEPS and 13 GW in the APS. Growth in utility-scale battery storage accelerates after 2025 in both scenarios as it is quick to deploy, easy to scale and costs are projected to continue to come down.

Battery storage plays a vital role in helping to integrate rising shares of solar PV into the region's electricity systems. In the APS, it becomes the third-largest source of additional capacity after 2035, behind only solar and wind, with annual additions increasing to over 20 GW per year until 2050.

Average costs per unit of electricity fall towards the global average in both scenarios, helping keep electricity affordable for consumers in Southeast Asia

Average cost per unit of electricity in Southeast Asia in the Stated Policies Scenario and Announced Pledges Scenario, 2023-2050



Note: The average cost per unit of electricity excludes taxes and subsidies.

Even as electricity demand grows, electricity costs moderate as fuel prices stay low and the rise of renewables helps insulate power systems from fuel price shocks

While electricity prices can differ significantly both between consumer groups and between countries depending on local regulations and taxes – with industrial consumers often 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. Across scenarios, the average cost per unit of electricity reflects the cost of building and running power systems. Total power generation costs include capital recovery (annuities paid over the economic lifetime of assets to recover upfront investment), fuel costs, operation and maintenance, and CO_2 prices (note that revenue from carbon taxes or emissions allowance auctions can be returned to consumers). Grid costs mostly reflect the capital recovery of investment in grid expansions and replacements.

In 2023, the average cost per unit of electricity stood at about USD 120 per MWh in Southeast Asia, slightly above the global average. Fuel costs accounted for over 40% of the total system cost, capital recovery for a third, and operation and maintenance and grid costs for the remainder. Up to 2035, the average cost per unit of electricity decreases relative to current levels in the STEPS and the APS, primarily because the price of natural gas, which has generally supplanted oil as the marginal fuel in electricity systems across Southeast Asia, is projected to trend downwards over the next few years and remain low by historical standards, largely due to a well-supplied LNG market. Until 2050, average costs fall further in both scenarios, to around USD 80 per MWh (close to the global average), due to growing solar PV and wind, which – already among the cheapest generation sources today – see further cost declines. As the shares of near-zero marginal cost wind and solar grow in the mix, fuel costs contribute less to total power system costs, while the relative importance of capital and fixed operation and maintenance costs increases. Although the APS sees a significant increase in investments in power generation – mostly solar and wind – and grids, with total annual investment spending rising from around USD 35 billion in 2023 to nearly USD 130 billion in 2035 and USD 140 billion in 2050, strong electricity demand growth dilutes these costs across greater volumes of electricity, contributing to the decline in average costs.

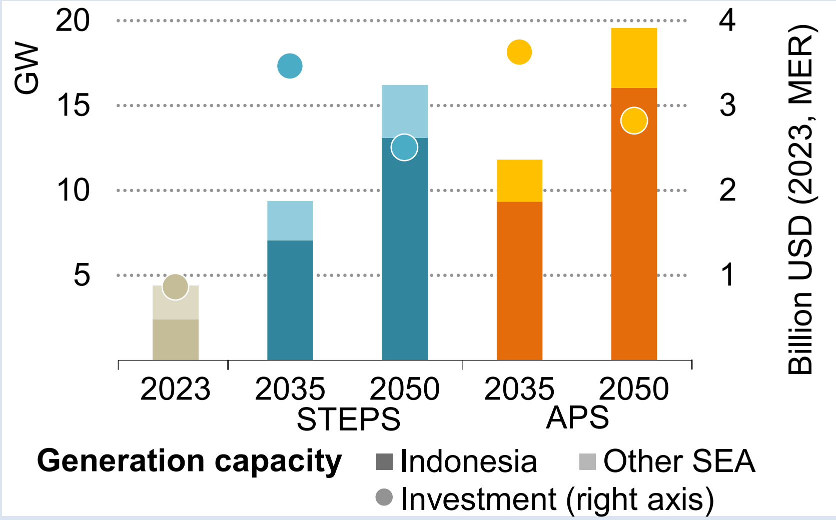
The decreasing share of fuel costs in the average cost per unit of electricity has the added benefit of shielding consumers from potential power price spikes triggered by price shocks on the coal or natural gas markets, such as the record-level prices seen in the wake of Russia's full-scale invasion of Ukraine. Nonetheless, it is important to consider that growing shares of variable renewables raise power system flexibility needs to maintain the security of the electricity supply (see page 138).

Untapped geothermal potential could boost flexibility and baseload capacity in power generation, but this requires government support to de-risk investment

Geothermal energy makes up 5% of Southeast Asia's total energy supply – above the global average of less than 1% – and this share is set to rise in all scenarios. The region is a global leader in geothermal development, with an existing geothermal electricity generating capacity of more than 4 GW, over half of which is in Indonesia, with the rest primarily concentrated in the Philippines. Indonesia alone ranks second globally in geothermal capacity, after the United States, with the Philippines close behind. Several projects in operation highlight the historic, albeit small, role of geothermal as a source of baseload power generation, such as Indonesia's Wayang-Windu and the Tiwi and Makban geothermal power plants in the Philippines, with their first units operational since 2000 and 1982, respectively. Past and existing projects have provided a reliable source of electricity and, in some cases, industrial heat. By 2030, the Philippines aims to increase geothermal power generation capacity by around 1.4 GW (from 2016 levels) and Indonesia anticipates additions of 3.4 GW (from 2021 levels).

Looking ahead, regional geothermal power generation capacity triples to reach over 9 GW by 2035 in the STEPS. Indonesia's ambitious targets are reflected in the STEPS and APS; total regional investment quadruples by 2035. In the APS, capacity almost triples to 12 GW in 2035, with a further increase to 20 GW in 2050. Across scenarios to 2050, geothermal represents around 1% of total power generation capacity, as growing capacity roughly keeps pace with expanding electricity demand. The value of geothermal, however, is its dispatchability – a key characteristic for ensuring the security of electricity supply in future energy systems with less coal-fired power generation and higher penetration of variable renewables.

Geothermal generation capacity and investment by scenario



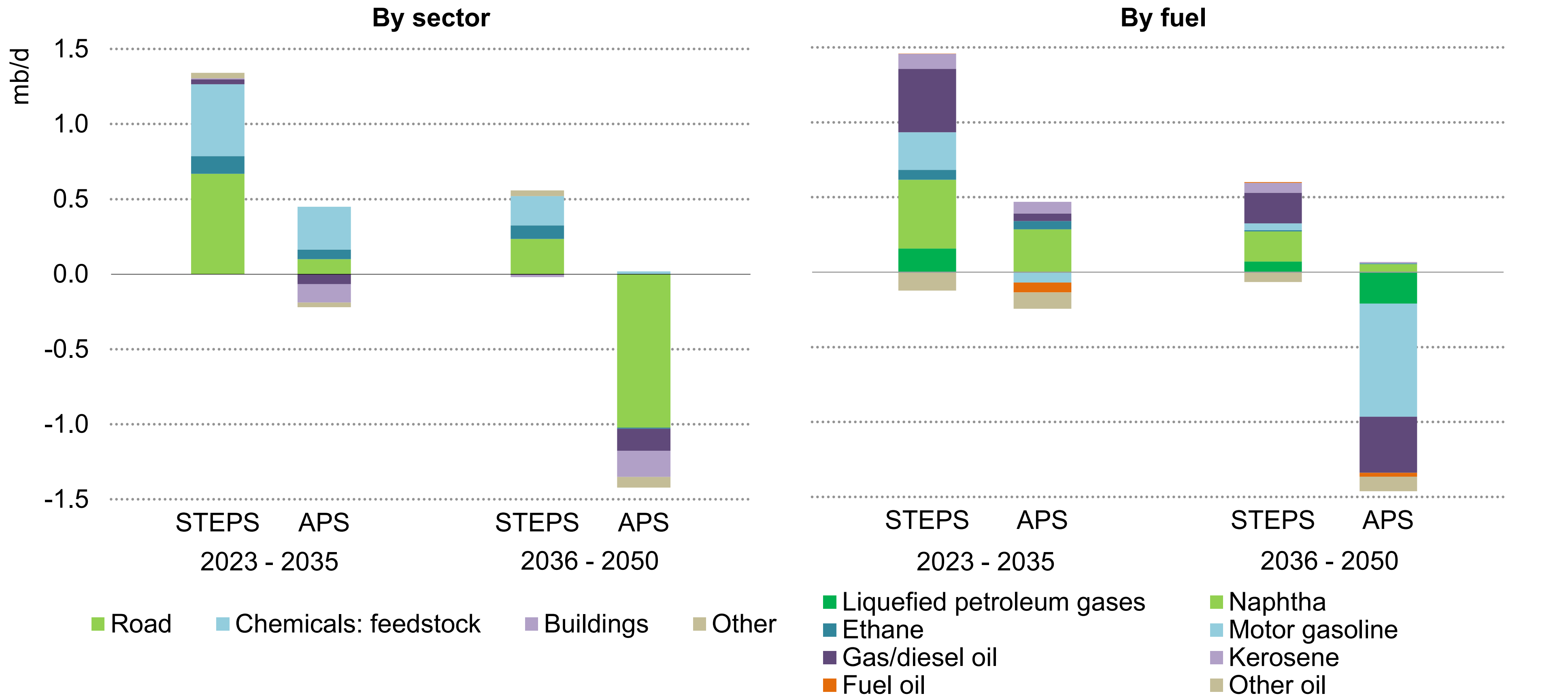
However, several obstacles impede the development of new geothermal resources, most notably the high upfront investment cost and risks associated with projects, especially during the development phase. Other challenges include the need for transmission infrastructure to unlock the development of geothermal resources in locations remote from demand centres; and lengthy permitting processes, for example, due to forest protection regulations.

Governments can facilitate the development of new geothermal resources by supporting the collection and sharing of data on geothermal resources; such availability helps to attract investors and presents opportunities for synergies with mining and petroleum industries. The Indonesia Geothermal Resource Risk Mitigation Project exemplifies how international financial institutions can also play a role in scaling up investment in geothermal, with the World Bank providing USD 465 million in financing for risk mitigation in exploration drilling.

2.5 Fossil fuels

Slowing but continuous growth in oil demand in the STEPS contrasts with a turnaround in the APS, with oil use for transport falling by over 30% to 2050

Changes in oil demand by sector and fuel



Note: "Other" includes agriculture, energy sector own use and non-energy uses excluding petrochemical feedstock.

Road transport drives rising oil demand in the STEPS, while in the APS, gasoline demand recedes and renders petrochemicals the sole source of oil demand growth

Southeast Asia's oil demand was around 5 mb/d in 2023, representing about 5% of global demand. This is set to increase to 6.4 mb/d in 2035 and 7 mb/d in 2050 in the STEPS. Chemical feedstock demand grows in both the STEPS and APS to 2050, but transport demand (in particular, road) peaks in the APS before 2040.

Under current policies and trends, gasoline and diesel consumption for road transport rises by around 30% by 2050, reaching nearly 1.6 mb/d. Such volumes and growth levels are like those seen in Central and South America but are much lower than the increases seen in Africa. The rising volumes used as chemical feedstock are met by doubling naphtha demand, rising from 8 to 16% of total oil demand.

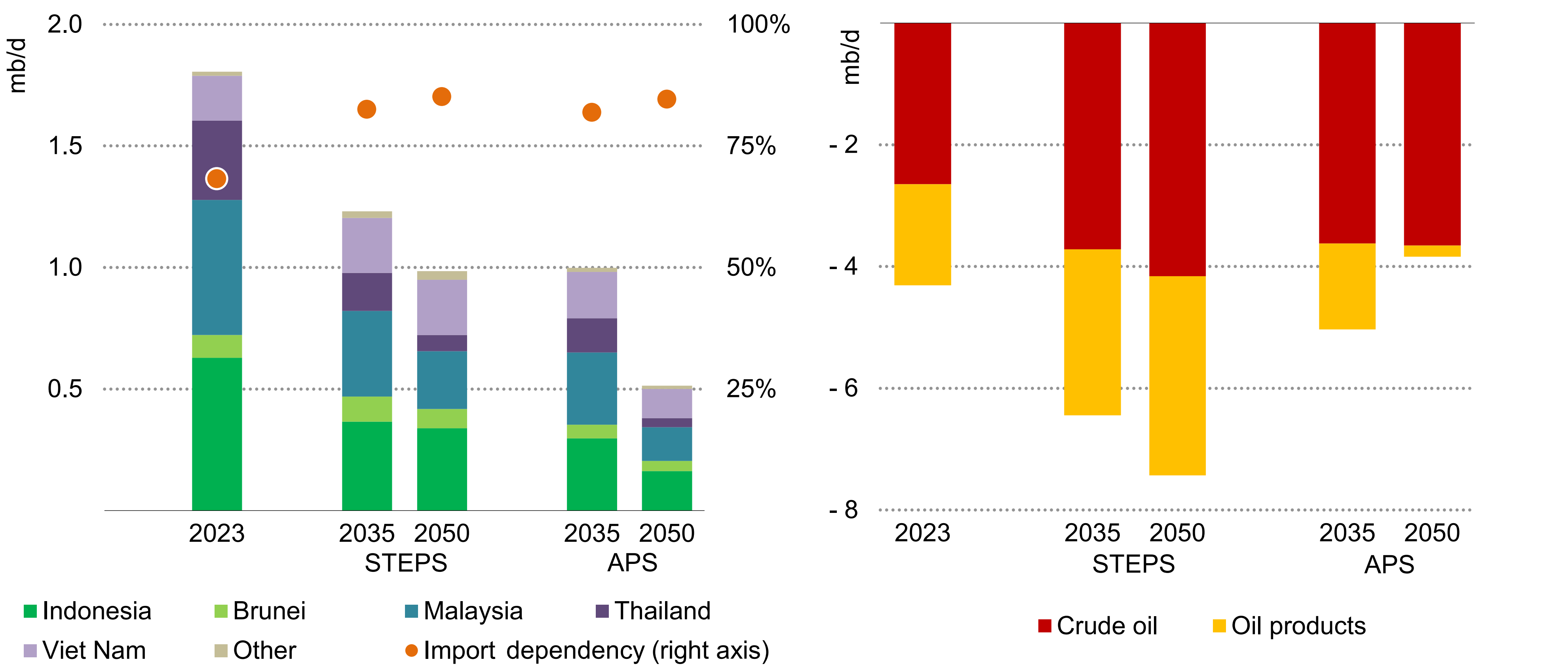
The APS yields different trajectories. Oil demand continues to grow, though only to 5.2 mb/d in 2035, and then falls to 3.8 mb/d in 2050. As in the STEPS, Southeast Asia reaches around 7% of global oil demand in the APS in 2050, driven by chemical feedstocks. Chemical feedstock demand stabilises at 1.1 mb/d by 2035, with increases only in naphtha feedstock demand to 2050.

By 2035, overall oil demand in the APS is 17% less than in the STEPS. In the STEPS, passenger vehicles and road freight account for just over 50% of total oil demand from 2023 to 2035. In the APS, the relative distribution of demand across sectors is similar but with lower volumes. The oil demand of two/three-wheelers declines over this period in both the STEPS and the APS as sales of EVs overtake ICE models by 2035 and 2031, respectively; the total cost of ownership of electrified two/three-wheelers is already lower than ICE vehicles in Indonesia, the Philippines and Viet Nam (see page 71). Thailand is experiencing a surge in EV adoption with a sales share higher than in many other Southeast Asian countries and comparable to the share in the United States, helping to temper oil demand growth.

Refining output and petrochemical demand are significant drivers of overall oil demand growth in all scenarios, with implications for the region's trade balance. In Indonesia alone, total refinery output increases by 130 kb/d in the STEPS by 2035 and continues to rise gradually to 2050 while also experiencing efficiency gains. LPG, naphtha, kerosene, and fuel oil show stability with minor increases over the years. In the APS, total refinery production peaks before 2040 at nearly 950 kb/d. Due to growing petrochemical feedstock demand, the region becomes ever more dependent on imports which increase by one-third to 2035 in the STEPS, to nearly 6 mb/d (Southeast Asia imported around 4mb/d of oil in 2023). Awareness and protection of trade chokepoints, such as the Strait of Malacca, will be important in meeting demand whilst maintaining affordability and energy security.

Continued declines in oil production throughout the region mean Southeast Asia's reliance on imports is growing

Changes in oil supply by country and scenario, and change in net trade by type and scenario, 2023-2050



Notes: "Other" includes the Philippines, Myanmar, Cambodia and Lao PDR. "Import dependency" = net oil imports divided by demand including international bunkers.

Oil production is set for continued decline as producers face strong competition for investment

Oil production in the region was less than 2 mb/d in 2023, with Indonesia accounting for one-third at around 630 000 b/d. The Indonesian national oil company (NOC), Pertamina, is responsible for most of this production, notably from the Rokan, Duri and Cepu fields which have been producing crude oil for over 80 years. Other companies participating in Indonesian oil production include BP, ExxonMobil and MedcoEnergi.

Malaysia is the second largest producer, with over 550 000 b/d produced in 2023. Production is diversified across many assets, with Petronas leading operations in the Malikai and Gumusut-Kakap fields. Shell is the most significant international stakeholder. Thailand's national petroleum exploration and production company PTTEP, along with Chevron, produced almost all of the country's 330 000 b/d crude oil in 2023.

In the STEPS, production tails off across much of Southeast Asia, except in Viet Nam in the near term, and by 2050 total output drops to around 1 mb/d. Declining production is accompanied by increasing dependency on imports to meet rising demand. In the APS, production declines even more, to below 1 mb/d in 2035 and to around 0.5 mb/d in 2050. However, import dependency does not wane even as overall import volumes decline.

Therefore, the trade balance of crude oil and oil products continues to run at a deficit, but the ratio and magnitude vary across scenarios.

Net trade of crude oil increases by 40% from 2023 to 2035 in the STEPS. Oil products account for a growing share of imports, rising from 38% to 42% in the STEPS to 2035. Net trade approaches -8 mb/d by 2050.

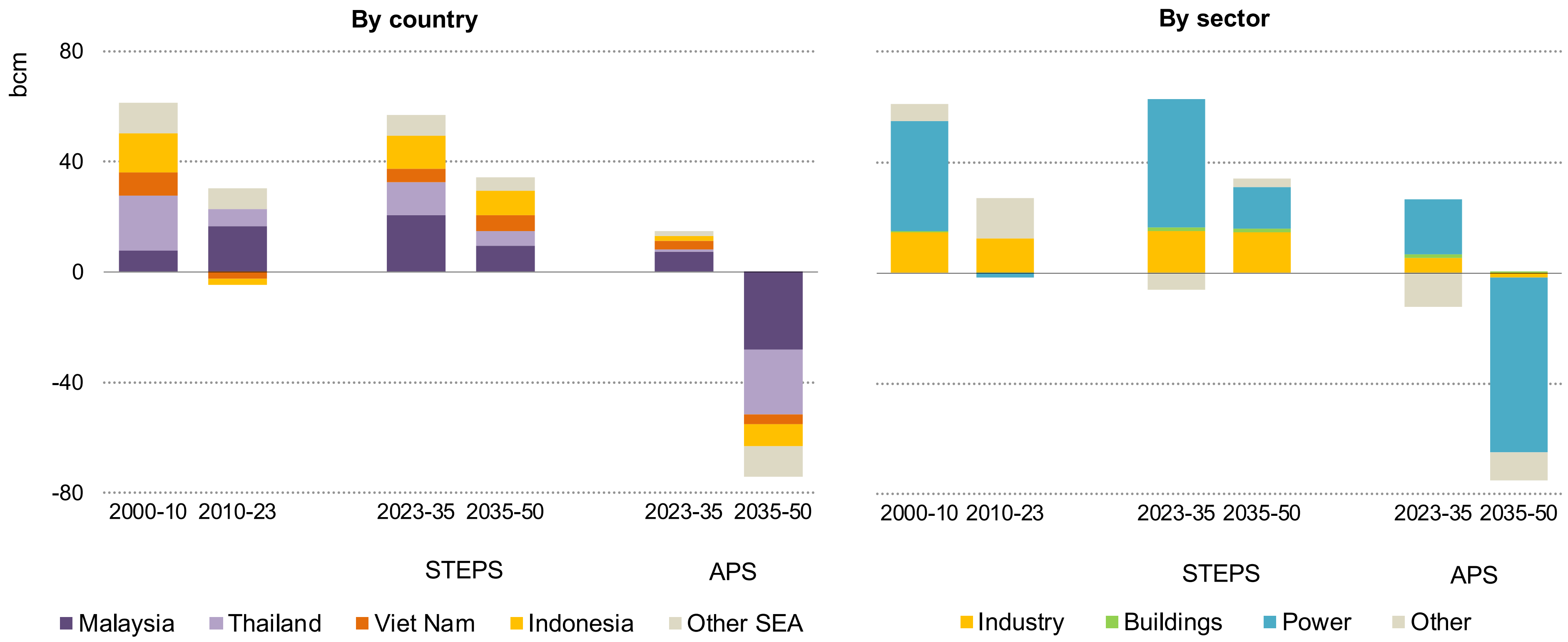
In the APS, the increase in imports is more muted by 2035 compared to the STEPS and falls back to below current levels by 2050. The contribution of oil products to the deficit contracts to 2050, with crude oil making up for 95% of the shortfall.

Investment, merger and acquisition activity is reframing the landscape of oil producing stakeholders in the region. Upstream oil investment in the region was USD 10 billion in 2023, a 11% increase compared to 2022. As production falls, investment drops by 30% to around USD 7 billion in 2035 in the STEPS, and by 40% and 60% in the APS and NZE Scenario, respectively.

Mergers, acquisitions and operational ownership changes are commonplace. In Indonesia, Petronas and PT Pertamina Huly acquired Masela Block from Shell for USD 650 million in July 2023. In Malaysia, SapuraOMV Upstream created a nearly USD 1 billion stake for TotalEnergies in January 2024. By contrast, in July, ExxonMobil announced transferring some operations to Petronas while maintaining the same ownership structure for the time being.

Policy makers and power and industrial consumers face some strategic choices as Southeast Asia shifts to become a net importer of natural gas

Change in gas demand by country, sector and scenario, 2000-2050



Notes: "Other SEA" = other Southeast Asia. "Other" (by sector) includes transport and the use of energy by transformation industries.

Gas follows a robust growth path in the STEPS but loses out to renewables in the APS

Natural gas has played an important role in meeting Southeast Asia's energy needs over the past three decades. From 2000 to 2010, a third of total energy demand growth in the region was met by gas, which is a similar share to coal. Since 2010, coal has overtaken gas, becoming the main fuel for power generation in 2014 and satisfying around 30% of the region's industrial energy demand in 2023, compared with 15% met by natural gas.

The 70% growth in natural gas demand from 2000 to 2010 was led by Thailand, Indonesia, Viet Nam, Malaysia and Singapore, which accounted for over 90% of the increase. Strong domestic production initially underpinned natural gas demand before the picture began to shift in 2010. Weakened competitiveness versus coal and more recently, renewables, has come alongside plateauing domestic production, leading to a slowdown in gas demand growth over the last decade, particularly since 2014.

Since 2022, gas demand has increased 5%. This recovery comes after a 4% fall in demand from 2019 to 2022 stemming from both the Covid-19 pandemic and a spike in LNG prices following Russia's full-scale invasion of Ukraine.

Since the last edition of this *Outlook*, gas prices have been extremely volatile, threatening the ability of countries to import gas at affordable prices to complement coal demand and domestic gas production. LNG spot prices in the region peaked in the third quarter of 2022 at around 73 USD/MBtu, before falling back to levels seen at the beginning of 2021, around 11 USD/MBtu.

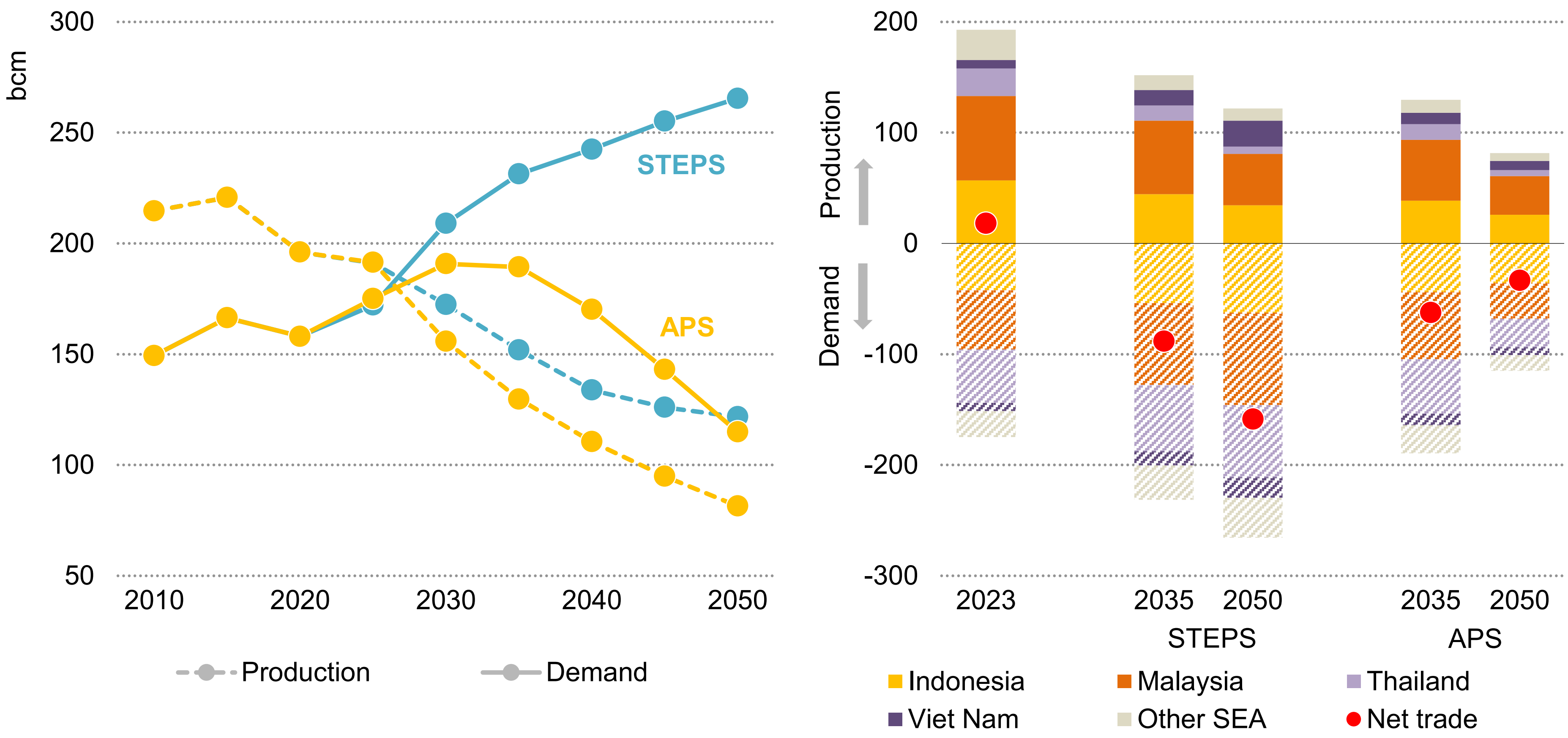
Gas demand increases by over 30% to 2035 in the STEPS, driven by industry, power generation and non-energy uses, such as chemical feedstocks. Projected growth in electricity demand drives a 5% annual increase in gas-fired power generation from today to 2035.

By contrast in the APS, industrial and power sector demand for gas plateaus as the acceleration of renewables offsets demand for gas in power generation. Overall demand for natural gas grows by only 8% to 2035, and gas in power generation increases on average by 2% a year.

From 2035 to 2050, the scenarios diverge further. In the STEPS, gas demand grows to 1.5 times today's level by 2050, with the power and industrial sector demand seeing continued robust growth. On the contrary, the APS sees a peak in gas demand before 2035 and a steady decline thereafter, by almost 40% between 2035 and 2050. Gas use in industry remains constant around today's levels, as growing activity is offset by efficiency improvements, but gas loses out in the power sector to renewables in power generation. Gas use for power falls to less than half of today's level by 2050 in the APS, and to 5% in the NZE Scenario.

Southeast Asia's gas sector is at a crossroads as natural gas demand soon starts to exceed domestic production

Natural gas demand and production by scenario, 2010-2050, and by country, 2023-2050, and net natural gas trade



Efforts to bolster the domestic supply of gas in Southeast Asia do not avoid long-term reliance on LNG imports

Natural gas production declined sharply in 2020 during the pandemic and picked up thereafter but remained below pre-pandemic levels despite the strong price signals during the global energy crisis in 2022-2023. Companies and policy makers are looking at ways to address the structural decline in gas production and reduce the rise in imports. After a period when relatively few projects went ahead, a number of new gas projects in Indonesia, Malaysia and Viet Nam are looking to take final investment decisions (FIDs) in the late 2020s.

The prospective investments could mitigate declines in gas production in the region and enable continued LNG exports from Indonesia and Malaysia (even as the region becomes a net importer of gas). But in a competitive environment for new gas projects, regional output is projected to continue its decline from 190 billion cubic metres (bcm) today to around 150 bcm in the STEPS by 2035 (and 130 bcm in the APS). This downward trend continues to 2050, with production reaching just 40% of today's levels in the APS. While Viet Nam adds to the regional balance, increasing output by over 15 bcm in 2050 in the STEPS, production in all the other major producing countries in the region declines, especially in Thailand and Indonesia, where output falls by 70% and 40%, respectively, to 2050.

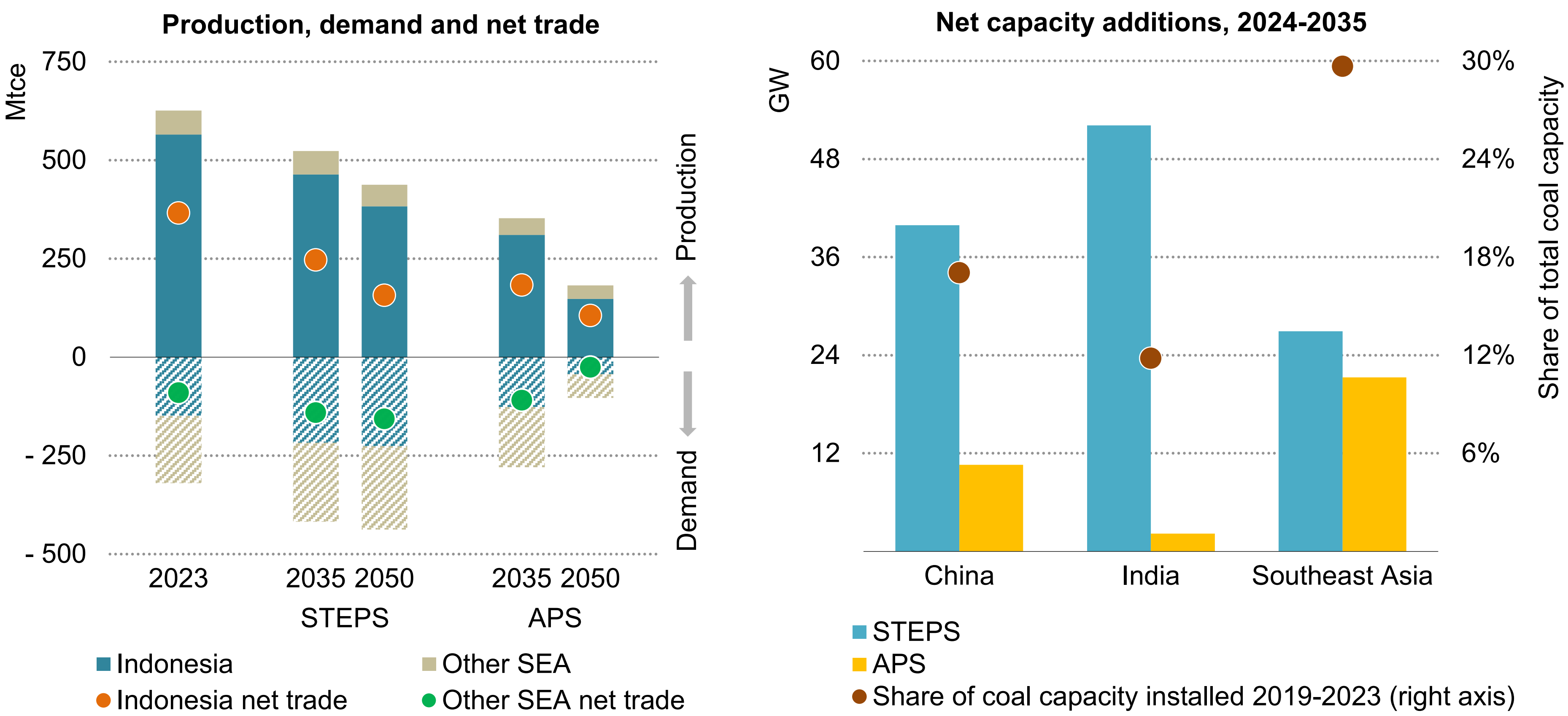
Against this backdrop, Southeast Asia becomes a net gas importer in the latter part of the 2020s in both the STEPS and APS. With limited opportunities for pipeline connections, LNG becomes an increasingly important part of future gas supply. LNG imports grow from 20 bcm in 2023 to around 165 bcm by 2050 in the STEPS, and to around 40 bcm in the APS. This is a significant shift for Malaysia and Indonesia, as major LNG exporting countries of the past.

Gas-fired power emits lower levels of CO_2 than coal and has the potential to substitute for coal-fired power, but bringing LNG to the region requires regasification infrastructure, which has often been subject to delays. During the global energy crisis, Floating Storage Regasification Unit (FSRU) projects were delayed or withdrawn as European customers jumped to secure import vessels in early 2022.

The projections in the STEPS and APS have gas prices ranging between USD 6/MBtu and USD 13/MBtu over the next decade. The wave of new international LNG projects starting operation in the late 2020s should help to maintain downward pressure on prices, but confidence in gas was shaken by the experience of 2022-2023 and there would be significant downside risks to the outlook for gas if price volatility were to return. Price-sensitive consumers and governments may struggle in any case to absorb the higher costs of imported LNG: Indonesian consumers pay regulated gas prices at a maximum of 6 USD/MBtu on average, which remains below the prevailing price of imports.

Indonesia continues to dominate coal production, while the region's relatively young coal assets make the transition to lower-emissions alternatives more challenging

Coal production, demand and net trade by scenario, and net change in installed coal power capacity by region/country and scenario



Note: "SEA" = Southeast Asia.

Coal production declines as the world transitions to lower-emissions alternatives, but despite falling demand for coal in the APS, it remains a source of flexibility to power systems

Today, coal is an important element of Southeast Asia's energy landscape, making up 28% of energy demand at around 320 million tonnes of coal equivalent (Mtce). In the STEPS, coal demand grows by almost a third to around 420 Mtce in 2035, and to 440 Mtce in 2050, underpinned by the expanding power sector which accounts for 60% of the rise in 2035, with industry driving most of the rest. Coal powered half the region's electricity generation in 2023 – accounting for nearly 80% of power sector emissions – and fuelled around 30% of industrial energy demand, such as nickel production. This share remains constant to 2050 in the STEPS, reflecting the slow pace of industrial decarbonisation, while coal use in power declines to around 30% as low-carbon generation sources grow in the mix.

The demand outlook diverges in the APS as coal demand peaks by 2030 at over 350 Mtce, falling to around 100 Mtce in 2050 – making up 7% of energy demand compared to 24% in the STEPS. Rapidly declining demand for coal in power generation and greater steps towards industrial decarbonisation drive this reduction in coal demand. The NZE Scenario highlights the possibility of an even lower share of coal in the energy mix, with 80% of this abated with CCUS.

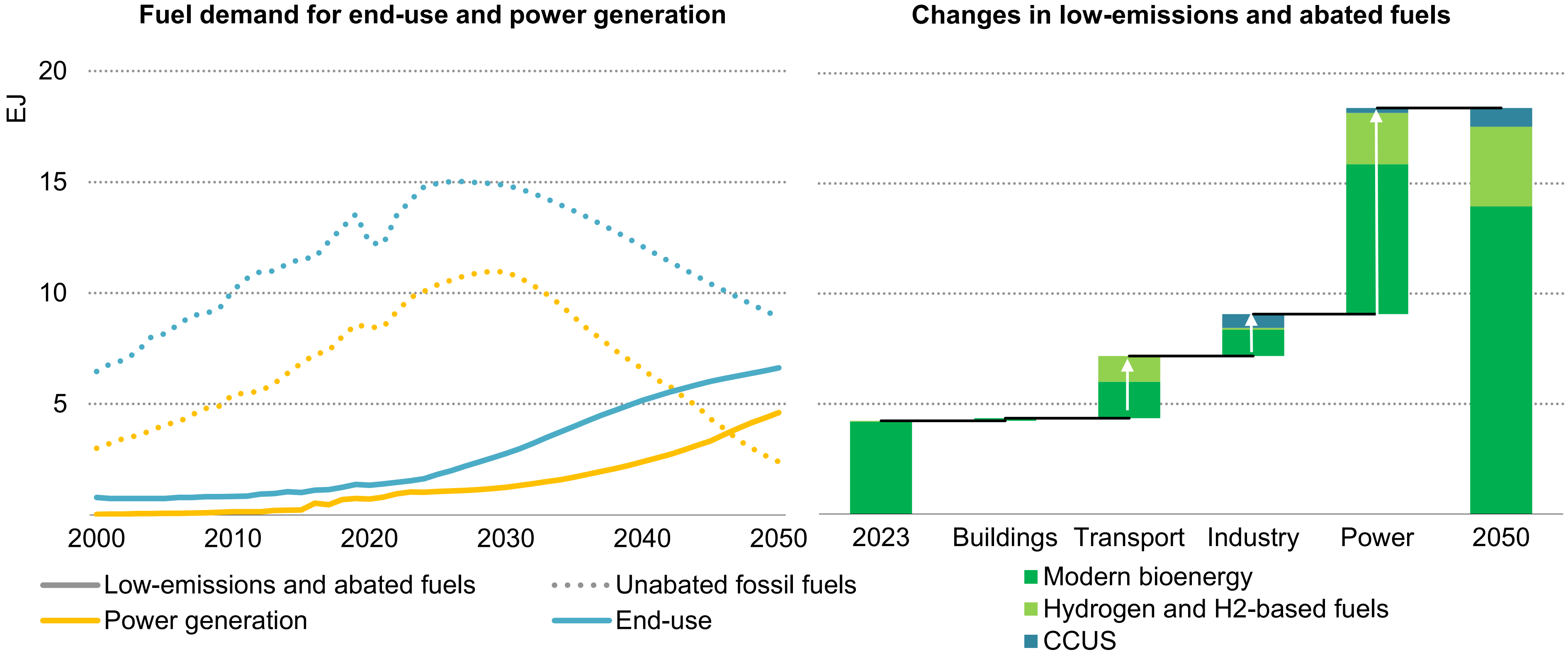
In 2023, coal production totalled 626 Mtce – led by Indonesia (90%) and Viet Nam (6%) – and continues to grow briefly in the short-term, though it declines in all scenarios by 2050: in the STEPS, production declines gradually by 30% to 2050; in the APS, output falls by around 70% and in the NZE Scenario, it declines to just 8% of today's levels. Investments in supply also decline in all scenarios, from over USD 5 billion today to around USD 1.4 billion in 2050 in the STEPS, and around USD 550 million in the APS. With declining regional production, net trade balances also shift. Today, Indonesia accounts for around 40% of global steam coal exports – largely to China and India – and almost all regional exports. As production declines, Indonesia's net trade balance contracts in all scenarios, while the rest of the region becomes more import dependent as demand continues to rise in the STEPS, with an opposite trend in the APS.

The next decade is crucial to developments in the APS which are contingent on the managed phase-out of coal-fired power generation, with delays risking supply lock-in. As electricity demand rises and coal remains cost-competitive, the STEPS sees net capacity additions of 27 GW to 2035. Net capacity rises to a lesser extent in the APS, but additions outpace those in both China and India. 30% of current coal capacity was installed in the last five years – compared to 12% and 17% in India and China, respectively – and while some of this can be repurposed for more flexible operation (see page 138), the need to recover investments on relatively young assets challenges the transition to low-emissions alternatives.

2.6 Low-emissions fuels

As potential substitutes for fossil fuels in hard-to-abate sectors of the economy, low-emissions fuels are essential building blocks of a low-emissions energy system

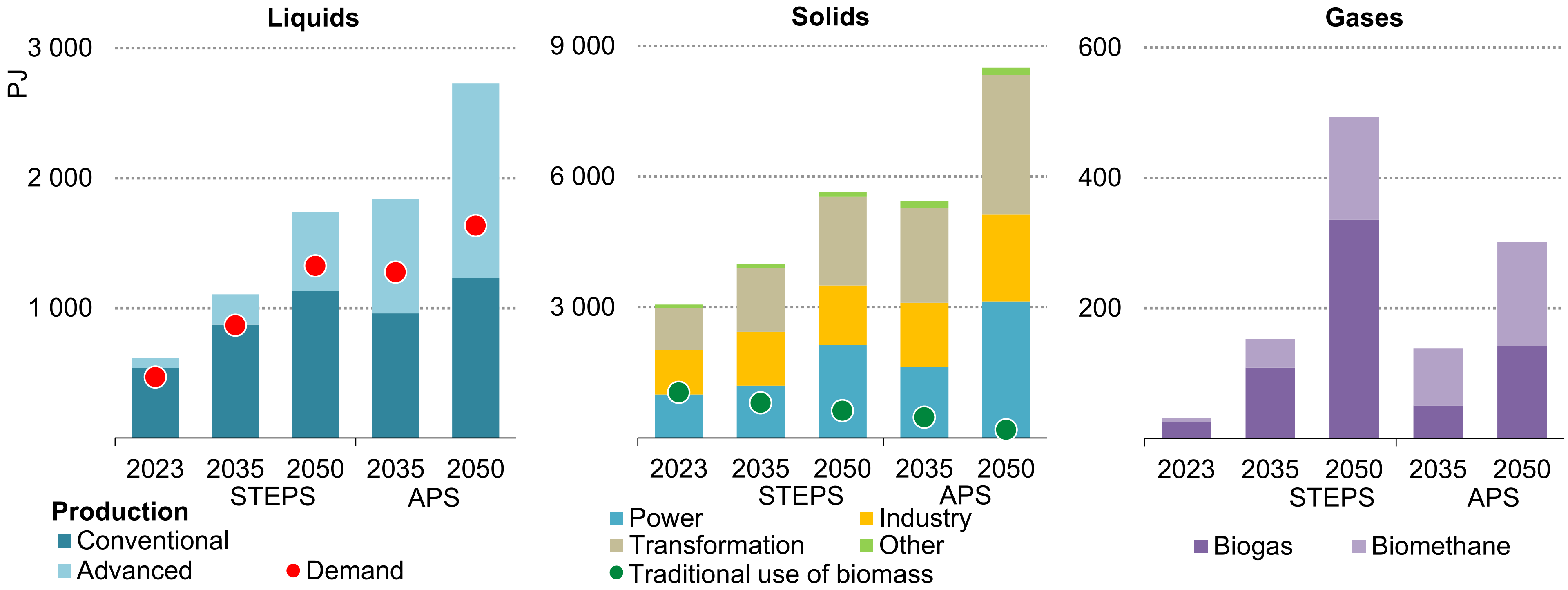
Comparison of fossil and low-emissions fuels demand, 2000-2050 and low-emissions fuels demand by sector, 2023-2050 in the Announced Pledges Scenario



Notes: "Low-emissions and abated fuels" include modern bioenergy and renewable waste, low-emissions hydrogen, low-emissions hydrogen-based fuels and fossil fuels with CCUS; "Transport" includes domestic and international bunkers; "H_2-based fuels" = hydrogen-based fuels; "CCUS" = fuels with carbon capture, utilisation and storage.

Solid bioenergy leads the growth of modern bioenergy with end uses in power and industry, while liquid biofuels are increasingly blended into transport fuels

Bioenergy demand in Southeast Asia by scenario and type, 2023-2050



Notes: "Conventional" liquid biofuels are fuels produced from food crop feedstocks, including sugar cane ethanol, starch-based ethanol, fatty acid methyl ester (FAME) produced from palm, rapeseed or soybean oil, straight vegetable oil (SVO) and hydrotreated vegetable oil (HVO) produced from palm, rapeseed or soybean oil. "Advanced" liquid biofuels are produced from non-food crop feedstocks. "Other" includes agriculture and buildings. "Solids" include all solid bioenergy products, except the traditional use of biomass which is shown separately. "Biogas" is a mixture of methane, CO_2 and small quantities of other gases produced by anaerobic digestion of organic matter. "Biomethane" is a near-pure source of methane produced either by "upgrading" biogas or through the gasification of solid biomass.

Modern sustainable bioenergy improves energy access, fortifies energy security and reduces greenhouse gas emissions in Southeast Asia

In 2023, demand for modern bioenergy in Southeast Asia was more than 3 500 PJ, making up 11% of total energy demand, much higher than the global average share of 6%. Thailand, the Philippines, Myanmar and Viet Nam are the largest producers after Indonesia, which made up just under a third of the region's bioenergy production in 2022 Malaysia is a major exporter of bioenergy alongside Indonesia, though both countries' exports have only recently recovered following a stark decline during the pandemic.

As substitutes for fossil fuels, modern forms of bioenergy are used in transport, industry, clean cooking and power generation. In 2023, 23% of bioenergy demand in Southeast Asia was traditional biomass use in household heating and cooking, a proportion which has more than halved since 2000. Replacing traditional biomass with modern solid bioenergy alternatives improves energy efficiency and avoids negative health and environmental impacts. Traditional use of biomass falls to 800 PJ by 2035 in the STEPS. In the APS, it declines even more to 470 PJ, or 6% of total bioenergy demand. Traditional biomass is substituted by modern solid bioenergy which increases by 30% to almost 4 000 PJ by 2035 in the STEPS and over 5 400 PJ in the APS, or 13% of regional energy demand, also meeting demand in the power and industry sectors.

Strategic use of solid biofuels, such as wood pellets, and ammonia co-firing plays a role in reducing power sector emissions and particularly ramps up after 2040, together reaching almost 4 000 PJ of inputs to the power sector in 2050 in the APS, equivalent to nearly 60% of regional coal power inputs today. However, higher fuel costs relative to coal mean that coal-fired plants are likely to vary blend rates according to fuel and retrofit costs for higher percentage blends, with co-firing plants generally running at lower capacity factors than unabated coal plants, reflecting their role as providers of flexibility rather than of baseload electricity. State-owned Indonesian utility PT PLN plans to co-fire biomass in 52 coal plants by 2025, up from 43 in 2023, while Viet Nam's PDP8 mandates coal plants to co-fire biomass and ammonia at a 20% blend rate after 20 years of operation, eventually increasing to 100% so as to phase out coal by 2050.

Southeast Asia produced 27% of the world's biodiesel in 2023. Most liquid biofuels production currently uses "conventional" feedstocks, such as sugar cane ethanol and palm oil. In contrast, advanced biofuels, as defined in this report, are produced from non-food crop feedstocks and do not compete with food consumption. The share of advanced liquid biofuels increases in all scenarios, shifting today's ratio of conventional to advanced liquid biofuels from 7:1 to 4:1 by 2035 in the STEPS. In the APS, this shift is accelerated, nearly reaching a 1:1 ratio by 2035. The NZE Scenario indicates the potential for advanced liquid biofuels to reach over three times the level of conventional production by 2050, with implications for emissions reduction and sustainability.

Liquid biofuels can be blended in transport fuels to displace fossil fuels and reduce emissions intensities. The share of biofuels in road transport today in Southeast Asia is twice the global average at 8%. Biofuels reach 10% of total liquid fuel transport demand by 2035 in the STEPS; and 16% in the APS, rising to 20% by 2050. Several countries already have blending mandates in transport fuels (see page 68), although Indonesia is most ambitious with 35% biodiesel blending, increasing to 40% from 2025. Such mandates require careful management to avoid biofuel competition with food consumption and emissions from land-use change. Biofuel blending can also offset the cost of fossil fuel imports, mitigating exposure to price volatility; for example, the Indonesian government estimates that the use of B35 biodiesel blending since 2023 has saved up to around USD 8 billion (2023, MER).

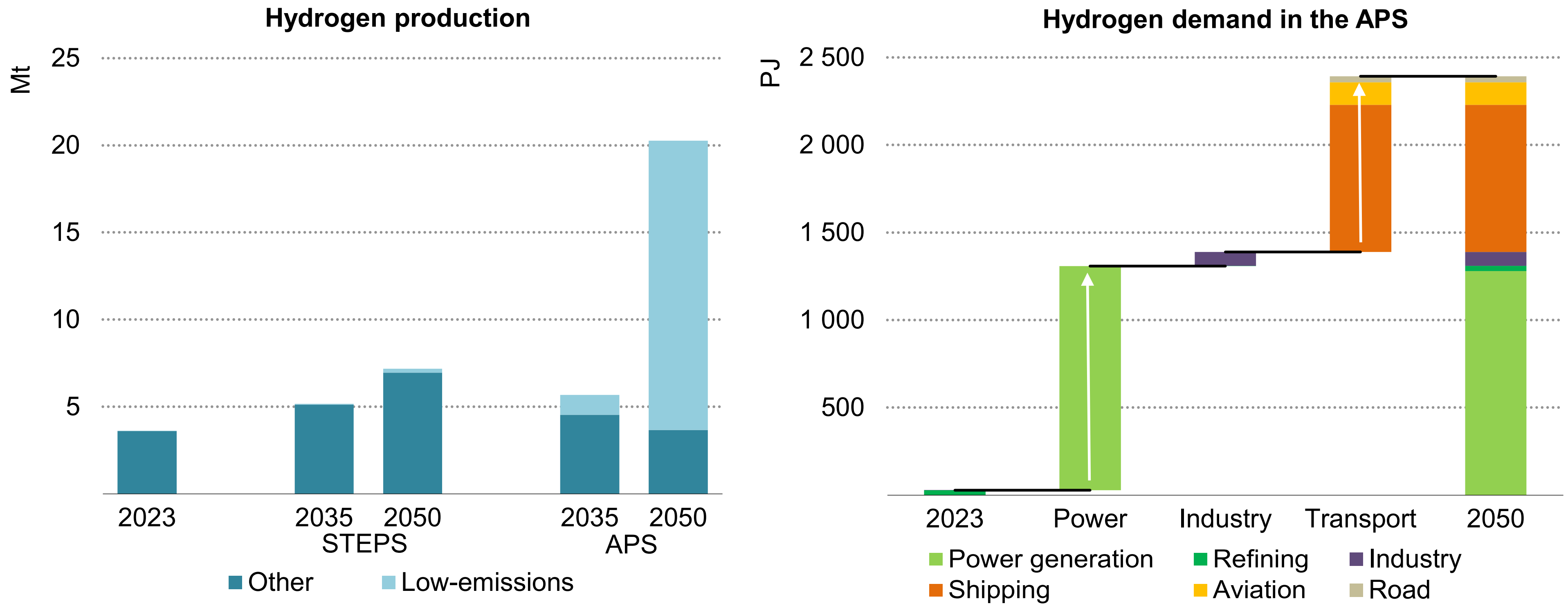
As hard-to-abate sectors, aviation and shipping also present Southeast Asia with opportunities to reduce emissions intensity through the deployment of liquid biofuels alongside low-emissions hydrogen. In the STEPS, biojet kerosene use increases marginally, while in the APS, it grows to 120 PJ in 2035, or 7% of total aviation fuel demand. The NZE Scenario underlines the potential of sustainable aviation fuels, reaching 40% of total aviation fuel demand in 2050. Regional initiatives include the launch of Singapore's sustainable aviation fuel (SAF) facility in 2023, and the Malaysia Aviation Decarbonisation Blueprint and Indonesia's SAF Action Plan, both launched in 2024.

Most gaseous biofuels are in the form of biogas, which is generated through methane recovery from wastewater resulting from palm oil processing among other sources, such as crop residues and municipal waste. Thailand is the main producer of biogas in the region (68% in 2022), followed by Indonesia (24%). Biogas is unprocessed, unlike biomethane, which is usable in natural gas infrastructure. In the STEPS, demand for biogas more than quadruples by 2035 and continues to rise to 2050. In contrast in the APS, biogas demand only doubles, with biomethane demand increasing 14 times by 2035. Biomethane demand continues to ramp up to 2050, highlighting this fuel as a long-term means of mitigating energy security risks associated with a reliance on imported natural gas.

Biofuel feedstocks need to be developed sustainably. In all scenarios, maximising the use of advanced biofuels helps to expand biofuel production in a way that has minimal impact on land use, food and feed prices. There are ongoing efforts to develop consistent and harmonised certification schemes, though more could be done to accurately reflect the lifecycle impacts of biofuels by adopting a greenhouse gas emissions intensity approach to certification. Countries can also develop modern bioenergy further by expanding and diversifying their feedstocks using sustainable farming practices.

Demand for hydrogen and hydrogen-based fuels expands beyond the refining sector in the APS, supplied by a ramp up in low-emissions hydrogen production

Hydrogen and hydrogen-based fuels production by scenario and demand by end use, 2023-2050



Notes: "Other" = hydrogen produced by steam methane reforming and other production processes which emit greenhouse gas emissions. "Shipping" and "Aviation" include domestic and international bunkers.

Hydrogen and hydrogen-based fuels can help to decarbonise hard-to-abate sectors, but firm indications of demand are required to incentivise low-emissions production

In 2023, Southeast Asia produced around 3.6 Mt of hydrogen. Hydrogen is mainly used in refining and chemical production, such as ammonia and methanol. Almost all current hydrogen production is fuelled by natural gas steam reforming without CCUS. However, transitioning to a low-emissions system necessitates ramping up low-carbon hydrogen production, as indicated in regional initiatives – such as the national hydrogen strategies in operation in Indonesia, Malaysia, Singapore and most recently, Viet Nam – as well as recently announced projects (see table). However, only 1% of this capacity has taken an FID, with most projects in the concept/feasibility stage. Indonesia's first green hydrogen project started production in October 2023 at Muara Karang Steam Gas Power Plant, which has a capacity of 51 t H_2/y (national hydrogen demand was around 1.75 Mt in 2021), and the country recently announced four green hydrogen clusters.

In the STEPS and APS, hydrogen production increases at a similar rate to reach over 5 Mt in 2035. However, the scenarios diverge to 2050: in the STEPS, production almost doubles from today's levels to over 7 Mt – mostly fuelled by unabated natural gas – while in the APS, it grows sixfold, reaching 20 Mt by 2050. This huge growth in hydrogen production in the APS is driven by a rapid ramp up of low-emissions hydrogen, accounting for 20% of total production by 2035 and rising to over 80% by 2050. In the APS, three-quarters of the hydrogen is produced from electricity in 2050, consuming the equivalent of around 10% of regional renewable generation.

The boost in low-emissions hydrogen production reflects its role in decarbonising the power sector and hard-to-abate sectors such as industry, aviation and shipping, together with its traditional use in oil refining. While international hydrogen trade is in its nascent phase, ammonia and methanol are already widely traded as chemical feedstocks. The maritime sector also poses considerable potential for hydrogen-based fuels in Southeast Asia, especially in light of the recently revised International Maritime Organisation's emissions strategy, which highlights the use of alternative fuels. Singapore – the world's largest bunkering hub – carried out the region's first ammonia trial and first successful methanol bunkering in 2023 (see box "Zero emissions bunkering: maritime policies and partnerships at the Port of Singapore").

In the APS, the demand increases are largest in the power sector, where hydrogen is mainly co-fired in the form of ammonia. Demand rises from the mid-2030s to reach almost 1 300 PJ by 2050, helping to displace coal and natural gas in regional power generation. Expanding demand is particularly driven by Viet Nam's PDP8, which foresees a strong increase in hydrogen-based generation in its vision to 2050. According to Singapore's national hydrogen strategy, hydrogen could meet up to 50% of its electricity demand in 2050.

Hydrogen projects highlight the region's natural endowment of renewable energy sources and the development of national strategies underway

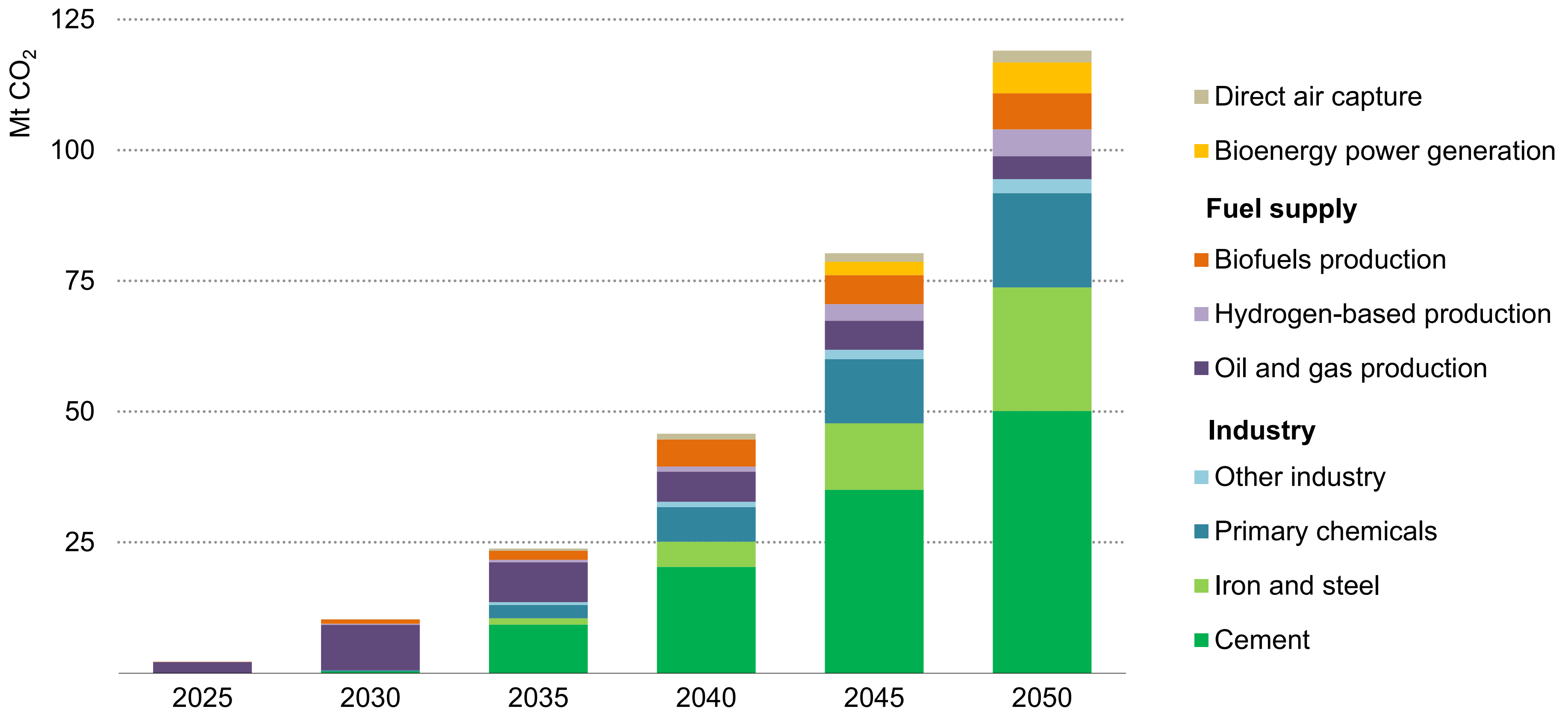
Selected early-stage low-emissions hydrogen and hydrogen-based fuels production projects

Project	Country	Partners	Date online	Electricity generation	Capacity ($kt\ H_2/y$)
E-methanol plant	Singapore	PTTEP, Air Liquide, YTL PowerSeraya, Oiltanking Asia Pacific, Kenoil Marine Services, and Maersk	2026	Renewable	19
Tra Vinh Green Hydrogen Plant	Viet Nam	The Green Solutions, Honeywell	2027	Wind, solar & BESS	90
H2biscus Phase 1	Malaysia	SEDC, Samsung, Lotte Chemical, Posco	2028	Hydropower	9
Batam Bintan Green Hydrogen Cluster	Indonesia	Pertamina, IGNIS, Sembcorp	2030	Floating solar	100
Sumatra Clean Hydrogen Cluster	Indonesia	Pertamina, Chevron, Keppel	2030	Geothermal	100
North Sulawesi Green Ammonia	Indonesia	Pertamina, TEPCO, Jera, NEDO	2030	Solar & geothermal	90
Sarawak Clean Hydrogen	Malaysia	SEDC, Sumitomo, ENEOS	2030	Hydropower	90

Notes: "Kt H_2/y": = kilotonnes of hydrogen or hydrogen-equivalent per year; "BESS" = Battery Energy Storage System; "SEDC" = Sarawak Economic Development Corporation.
Source: IEA (2024), Hydrogen Production and Infrastructure Projects Database.

Transforming climate pledges into action is key to ramping up CCUS deployment in more diverse applications from 2030 in the APS and requires huge investments

Total CO_2 captured by sector in the Announced Pledges Scenario, 2025-2050



CCUS can help to address emissions across Southeast Asia's energy system, well beyond the current focus on upstream oil and gas projects

There is significant potential for capturing CO_2 in Southeast Asia, especially during upstream oil and gas production which generates 4% of regional emissions. Depleted oil and gas reservoirs present opportunities for CO_2 storage capacity, and industrial clusters can connect multiple emitters. International collaboration and financial support are crucial to support CCUS deployment in key applications. The Asia CCUS Network was created in 2021 to this end, facilitating knowledge-sharing and capacity-building. Indonesia has already established a CCUS regulatory framework. A similar framework is under development in Thailand and in 2023, Malaysia proposed a tax incentive for companies implementing CCS.

A growing pipeline of CCUS projects are led by NOCs in partnership with private sector actors. Such projects focus on upstream oil and gas operations, where CO_2 is separated to meet natural gas standards for domestic use and export, captured and then used for enhanced oil or gas recovery. Nine out of 13 announced capture facilities involve CO_2 capture in natural gas processing, both for existing fields and for high CO_2 content gas fields, which would otherwise be left unexploited. In the STEPS, around 2.4 Mt CO_2 are captured in 2050, entirely in upstream oil and gas operations.

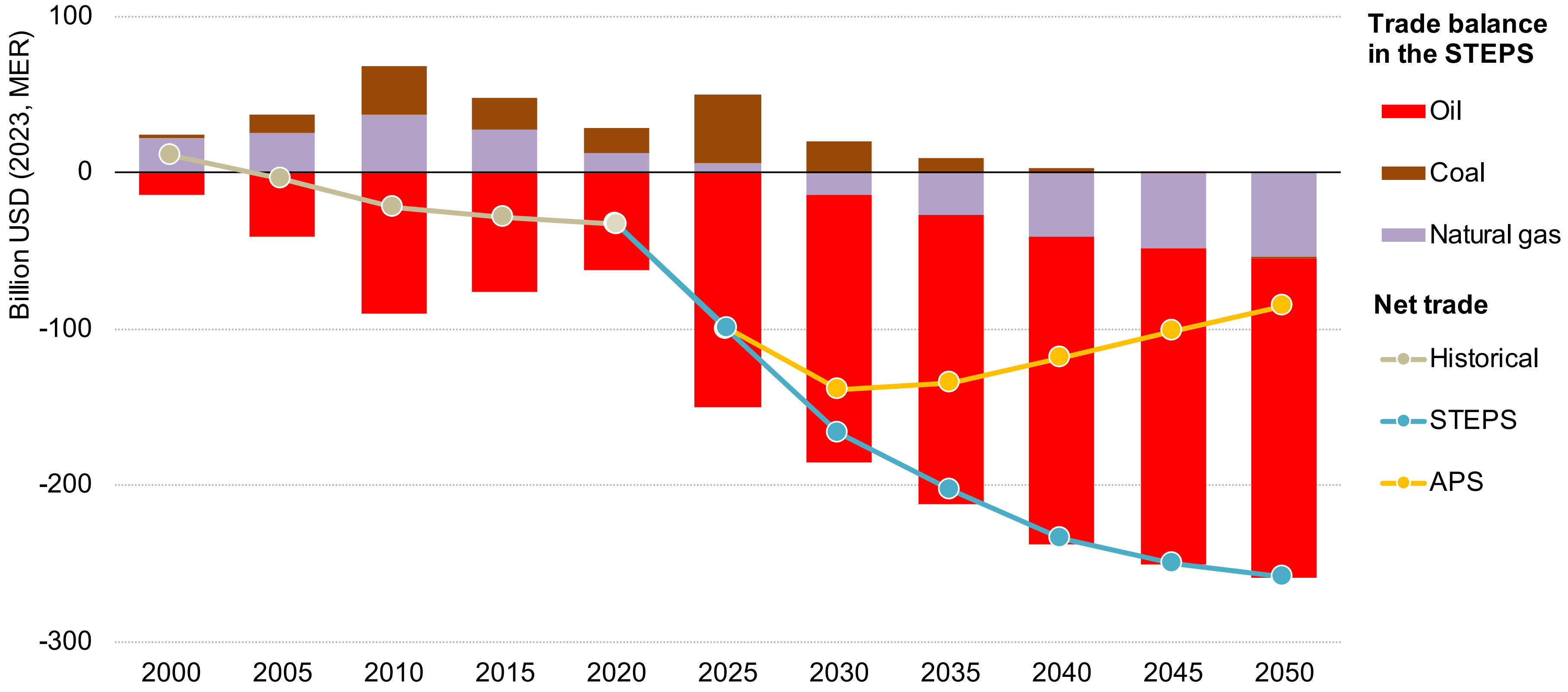
In the APS, CO_2 capture applications are broader, capturing around 120 Mt CO_2 in 2050, or 13% of regional emissions. Around 80% of emissions captured in 2050 are from the industrial sector, with cement production constituting half of this. Today, the combustion (40%) and process (60%) emissions of this subsector generate 10% of the region's CO_2 emissions; CCUS is one of the few technologies available to mitigate this, covering over 20% of cement plants by 2050. Around 15% of total industrial emissions captured in 2050 are from primary chemical processes. The remaining industrial emissions are captured during combustion, for example, of coal to generate high temperature heat for iron and steel production. In both the STEPS and APS, the power sector sees very little CCUS deployment, as national plans – particularly Indonesia – favour biomass and ammonia cofiring alongside renewables to meet net zero targets.

To realise CCUS projections in the APS, regulations will need to create a broader CCUS framework than currently exists. The London Protocol necessitates the use of robust classification for cross-border carbon trade. Investment will also need to ramp up: currently, only one project in the region has reached an FID; however, investment could increase to over USD 3 billion by 2035 in the APS if FIDs for the roughly 20 projects in the pipeline are reached in the next decade. From 2035 to 2050, annual investment in CCUS averages around USD 4.2 billion in the APS, facilitating around 2.5% of cumulative emissions to 2050 to be captured by CCUS technologies, with even greater potentials indicated in the NZE Scenario.

2.7 Energy security

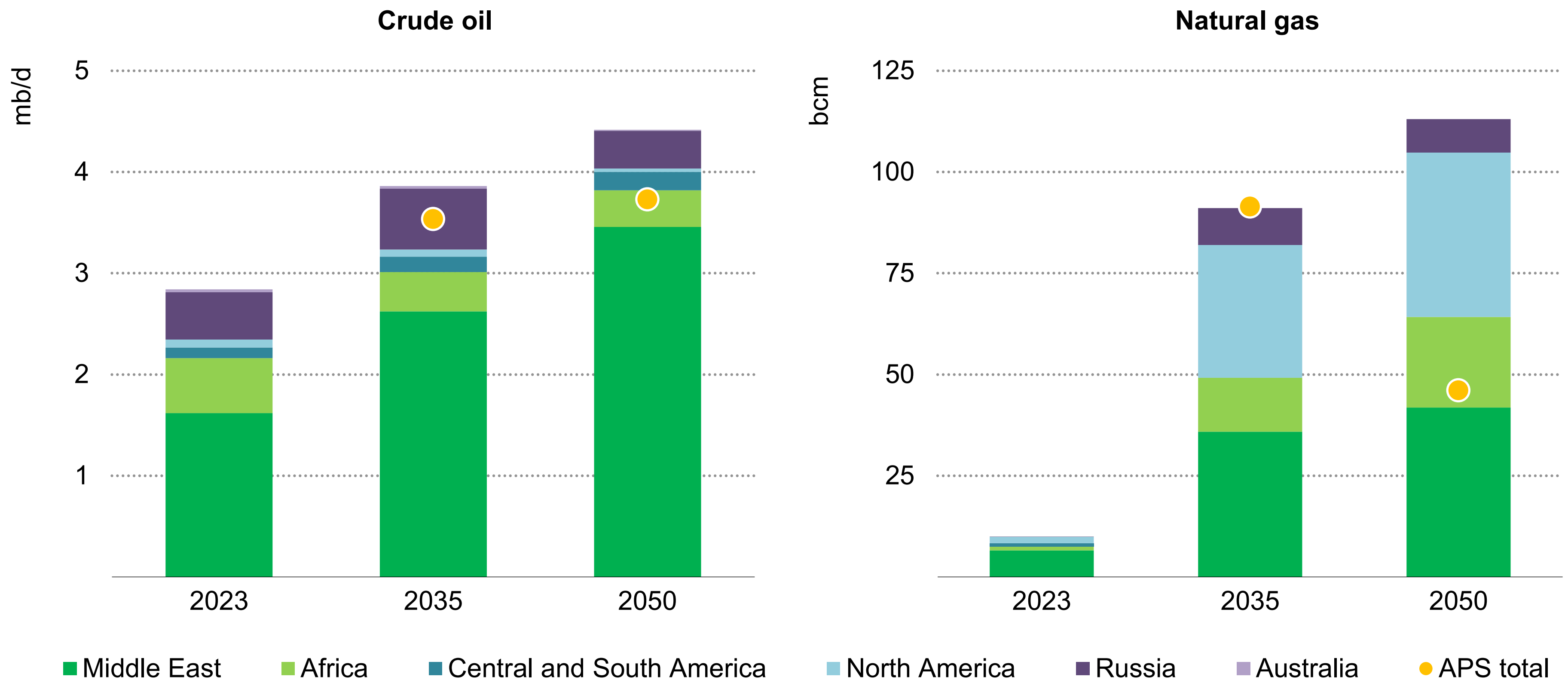
The outlook for Southeast Asia rings alarm bells for rising oil and gas import requirements, import bills and exposure to energy security risks

Fossil fuel trade balance in Southeast Asia by scenario, 2000-2050



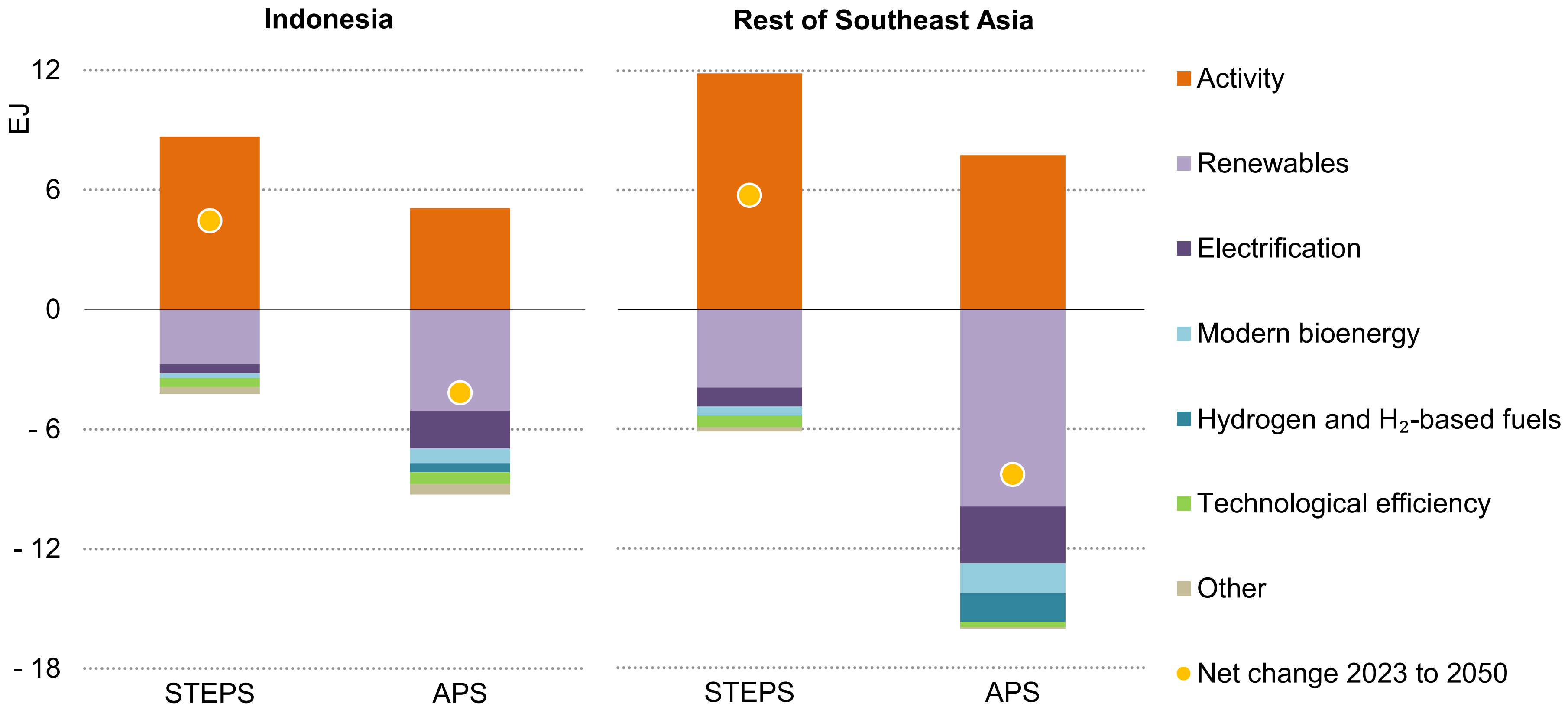
As natural gas supply sources evolve, the region is vulnerable to geopolitical events and disruptions in oil procurement

Crude oil and natural gas imports to Southeast Asia by origin in the Stated Policies Scenario and total in the Announced Pledges Scenario, 2023-2050



Clean energy and greater electrification offer the main avenues to mitigate the risks from rising fuel import dependence

Drivers of change in fossil fuels demand in Indonesia and other Southeast Asian countries, 2023-2050



Notes: "Activity" includes fossil fuels demand change in industry, transport and buildings; "Other" includes fossil fuel switching and nuclear energy.

Energy security concerns provide powerful reasons to accelerate structural changes in Southeast Asia's energy sector, even as some emerging security issues require attention

Our *Outlook* underscores that Southeast Asia faces a deepening structural supply deficit for oil and gas that will be met by imported fuels, despite efforts in many countries in the region to stimulate domestic investment and output. This comes with significant implications for import bills and the balance of payments. We estimate that Southeast Asia's import bill for oil was around USD 130 billion in 2023. In the STEPS, this balloons to over USD 200 billion by mid-century, a significant economic burden. The net trade balance for gas also shifts from surplus to deficit, adding another USD 50 billion to the import bill by 2050 in the STEPS. Aside from the financial implications, this exposes the region to risks of fuel price volatility on a scale much greater than seen during the recent global energy crisis, as well as the possibility of physical disruptions to supply in the event of geopolitical instability in key producing regions or around major chokepoints for international trade.

Faster progress with Southeast Asia's structural transformation – in line with the region's announced climate goals – would reduce these vulnerabilities. In the APS, the fossil fuel import bill peaks close to USD 140 billion around 2030 and falls back under USD 90 billion in 2050; this is about a third of the amount projected in the STEPS.

There are other spending and revenue considerations. Rising fossil fuel imports have strong implications for government expenditure on fossil fuel consumption subsidies (for those products that have regulated prices below their international market value). As noted in Chapter 1, these subsidies amounted to over USD 100 billion in 2022. However, there are also some consequences of declining fossil fuel use for government tax revenue. The aggregate revenue accrued from excise and value-added taxes on fossil fuels grows from USD 32 billion to USD 40 billion by 2050 in the STEPS. In the APS, this falls to about USD 20 billion over the same period. Therefore, structural changes need to be well-managed and well-sequenced to reduce fossil fuel use and secure smooth energy transitions.

There are also some new energy security issues that arise in energy transitions that require close attention from policymakers. Two of these are considered in detail in Chapter 3: the first issue concerns how policymakers can safeguard the security and reliability of electricity systems in the face of increased variability, both on the demand and supply sides. Second is the resilience of clean energy supply chains, including supplies of the critical minerals that are essential inputs to clean energy manufacturing. This is an area where Southeast Asia's manufacturing prowess and its resources can play a crucial role, bringing major potential benefits for the region's economy and employment by giving it a firm foothold in the new, clean energy economy.

Countries in Southeast Asia are on the front lines of climate change, facing increasing climate hazards such as heightened flood risks and more frequent heat waves

Level of climate hazard and exposure by country in Southeast Asia

Country	Warming	River flood	Coastal flood	Drought	Tropical cyclone
Brunei Darussalam	0.023	4.9	3.3	1.6	0
Cambodia	0.017	8.7	3.8	3.9	1.8
Indonesia	0.029	8.3	8.1	2.2	1.5
Lao PDR	0.041	8.2	0	2.4	1.4
Malaysia	0.027	6.8	6.4	2.8	0
Myanmar	0.032	8.8	8	0.6	5.8
Philippines	0.026	6.7	8.9	3.3	9.2
Singapore	0.021	0	1.9	0	0
Thailand	0.026	9.8	5.5	5.2	1.6
Viet Nam	0.032	9.9	9.6	3.4	5.9
World average	0.037	4.5	3.5	2.9	1.6

High

Medium

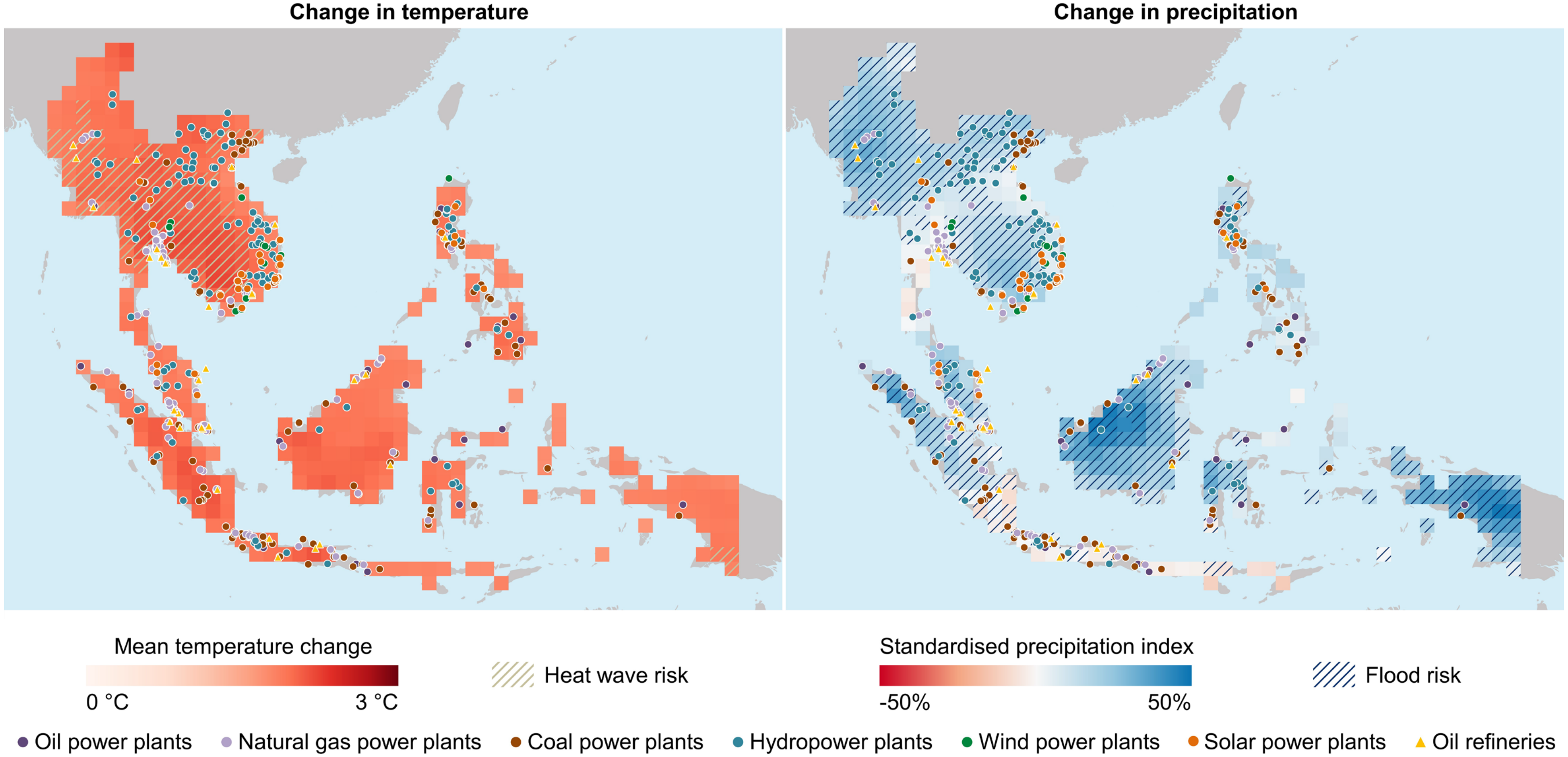
Low

Notes: Each cell colour indicates the level of climate hazard and exposure. For warming, the numbers indicate the slope of a linear regression line of average temperatures from 2000-2023. If warming exceeds 0.048 °C per year (+0.011 °C from the global average of 0.037 °C per year), the climate hazard level is considered High; if it is below 0.026 °C per year (-0.011 °C from the global average), it is considered Low. The levels of climate hazard and exposure for river flood, coastal flood, drought, and tropical cyclone, are assessed based on the indicators of the INFORM Risk Index 2024. In this report, the risk is defined as Low (0-2.99), Medium (3-6.99) and High (7-10).

Source: IEA (2024), Climate Resilience for Energy Security in Southeast Asia.

Climate hazards pose challenges to the operation and resilience of energy systems

Power plants and refineries exposed to climate hazards in the Stated Policies Scenario, 2041-2060 compared to the pre-industrial period (1850-1900)

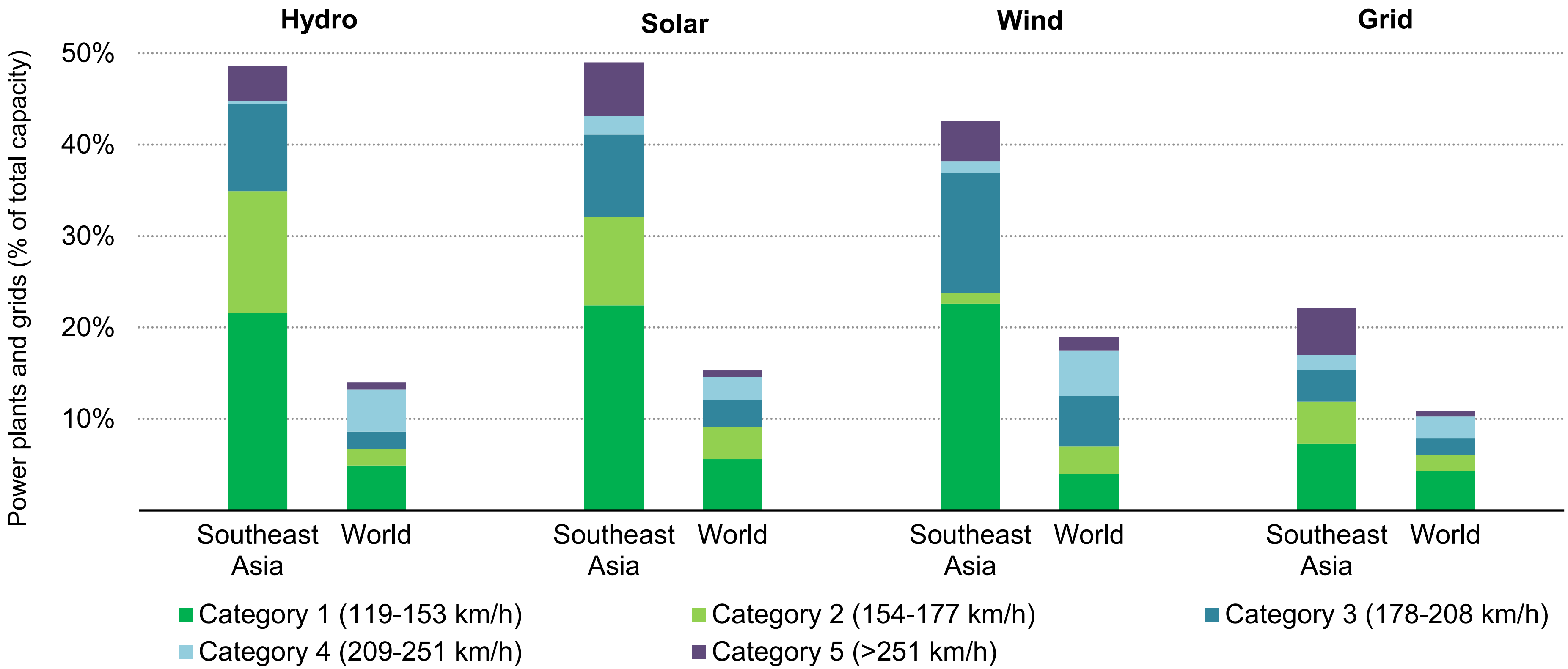


Notes: The heat wave risk areas see over 20 days more with maximum temperature above 35 °C in 2041-2060 compared to the pre-industrial period (1850-1900). Flood risk areas see at least 10% increase in one-day maximum precipitation. Only power plants with an installed capacity above 100 MW are shown on the map.

Sources: IEA analysis based on IPCC (2021), Working Group I Interactive Atlas; S&P Global (2021), Market Intelligence Platform (database); Global Energy Monitor (2023), Global Wind Power Tracker and Global Energy Monitor (2024), Global Solar Power Tracker.

Extreme weather events such as tropical cyclones can have a direct impact on the physical resilience of energy systems

Share of power plant and electricity grid capacity exposed to tropical cyclones in Southeast Asia and globally



Notes: A tropical cyclone is called a hurricane, typhoon, or cyclone, depending on geographic location. In this graph, tropical cyclones were categorised according to the Saffir-Simpson Hurricane Wind Scale, a 1 to 5 rating based on a hurricane's maximum sustained wind speed. In general, hurricanes at Category 3 and higher (> 177 km/h) are known as major hurricanes.
Sources: IEA (2024), Climate Resilience for Energy Security in Southeast Asia.

Building climate resilience is essential for energy security in Southeast Asia

Although adverse impacts of climate change are increasing in the region, they can be avoided or minimised by implementing climate resilience measures. A climate-resilient energy system can prepare for climate changes (“readiness”), adapt to and withstand the slow-onset changes in climate patterns (“robustness”), continue to operate under the immediate shocks from extreme weather events using alternative sources (“resourcefulness”), and restore the system’s function after climate-driven disruptions (“recovery”).

Coordinated efforts from diverse stakeholders, including the public and private sectors, regional organisations and international partners, could lead to a more resilient and secure future for the energy sector in Southeast Asia. Actions for climate resilience could start with building a robust climate database, conducting scientific assessments, and integrating climate resilience into energy policies. Despite notable progress in recent decades, the inadequate quality of observation data and climate projections in the region remains a major bottleneck for climate resilience, while the energy sector’s climate resilience is often neglected in climate change adaptation and resilience policies. As recently as 2021, only six out of the ten ASEAN countries had identified energy as a key sector for climate change adaptation and resilience. In some countries, the energy sector is still being discussed only from the mitigation angle despite the increasing impacts of climate change.

Mobilising private sector investment with public financing instruments, supportive policies and insurance is also required to support resilience measures to enhance robustness and resourcefulness. Technical and structural improvements of energy infrastructure, diversification of energy sources with distributed energy sources and storages, and adoption of innovative digital solutions can help address immediate impacts from extreme weather events while enabling fast recovery. Deployment of energy-efficient technologies and nature-based solutions contributes to coping with both slow-onset and extreme weather events, while addressing fundamental issues which have long-term horizons.

In-depth analysis of key priorities and implications

3.1 Implementing COP 28 outcomes in Southeast Asia

At COP 28 in Dubai (2023), countries agreed on global energy objectives to keep the 1.5 °C limit alive, but what does this imply for Southeast Asia's energy transition?

Nearly 200 countries made major collective pledges on energy at the COP 28 climate summit in Dubai with the aim of keeping within reach the Paris Agreement target of limiting global warming to 1.5 °C.

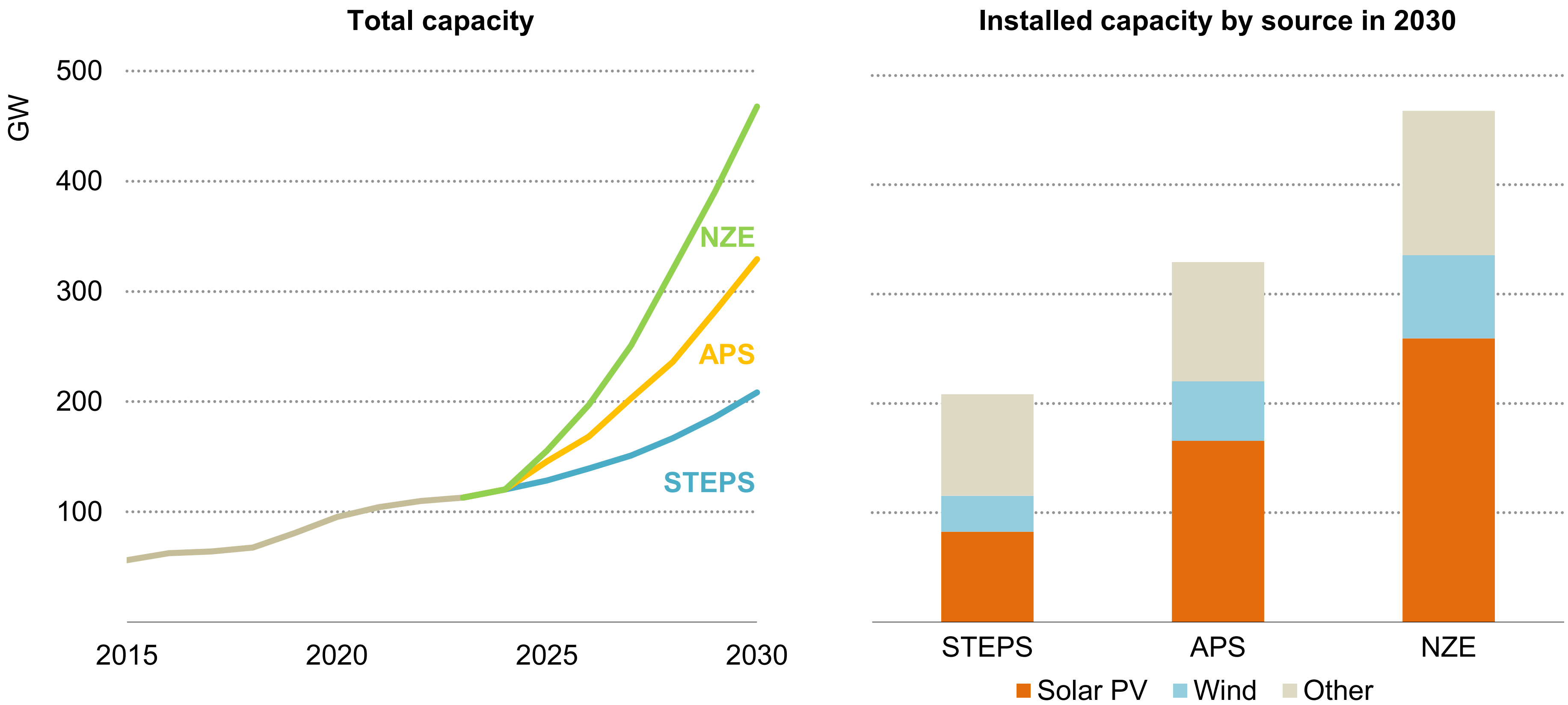
For the first time, governments recognised that to achieve this target, energy-related emissions need to reach net zero by 2050, and they set key goals to help meet this objective. These include tripling global renewable energy capacity and doubling global energy efficiency improvements by 2030; significantly reducing methane emissions; phasing out inefficient fossil fuel subsidies; accelerating the transition away from fossil fuels; and deploying emerging technologies, such as low-emissions hydrogen and carbon capture.

The COP 28 outcome is a non-binding document. Ultimately, its success depends on national implementation. However, the goals were specified only at the global level and have not yet been translated into national or regional targets. There is a strong possibility of imbalanced implementation, focused on a handful of major economies, that leaves many emerging market and developing economies without the means to harness clean technologies to meet rising demand for energy services. Therefore, to ensure that the world advances towards the 1.5 °C goal at sufficient pace, the focus must be on deployment of clean energy technologies in countries and sectors where fossil fuels can be displaced most effectively. Southeast Asia is one of such priority regions.

In this section, we discuss three of the major elements included in the UAE Consensus and consider what they might mean for Southeast Asia. The three are the targets for renewables and energy efficiency, and the goal to substantially reduce methane emissions. Tripling renewable capacity is a global target and does not imply that each individual renewables technology needs to triple, nor that renewable capacity in each country should increase by this amount only. In Southeast Asia, for example, an accelerated deployment of renewables – with installed capacity quadrupling rather than just tripling by 2030 – is necessary to meet the 1.5 °C goal, and this acceleration is reflected in the IEA NZE Scenario. This scenario provides a coherent and consistent approach to implement the COP 28 outcome in a way that puts the world on a pathway towards net zero emissions by mid-century while respecting different national circumstances. Since the global goals were derived in large part from the NZE Scenario, we report below the regional results of the NZE Scenario modelling to provide indicative guidance on the actions that would be required to align Southeast Asia with the COP 28 outcomes.

While Southeast Asia's renewables capacity doubles by 2030 in the STEPS, full alignment with national and global goals requires a much faster pace of change

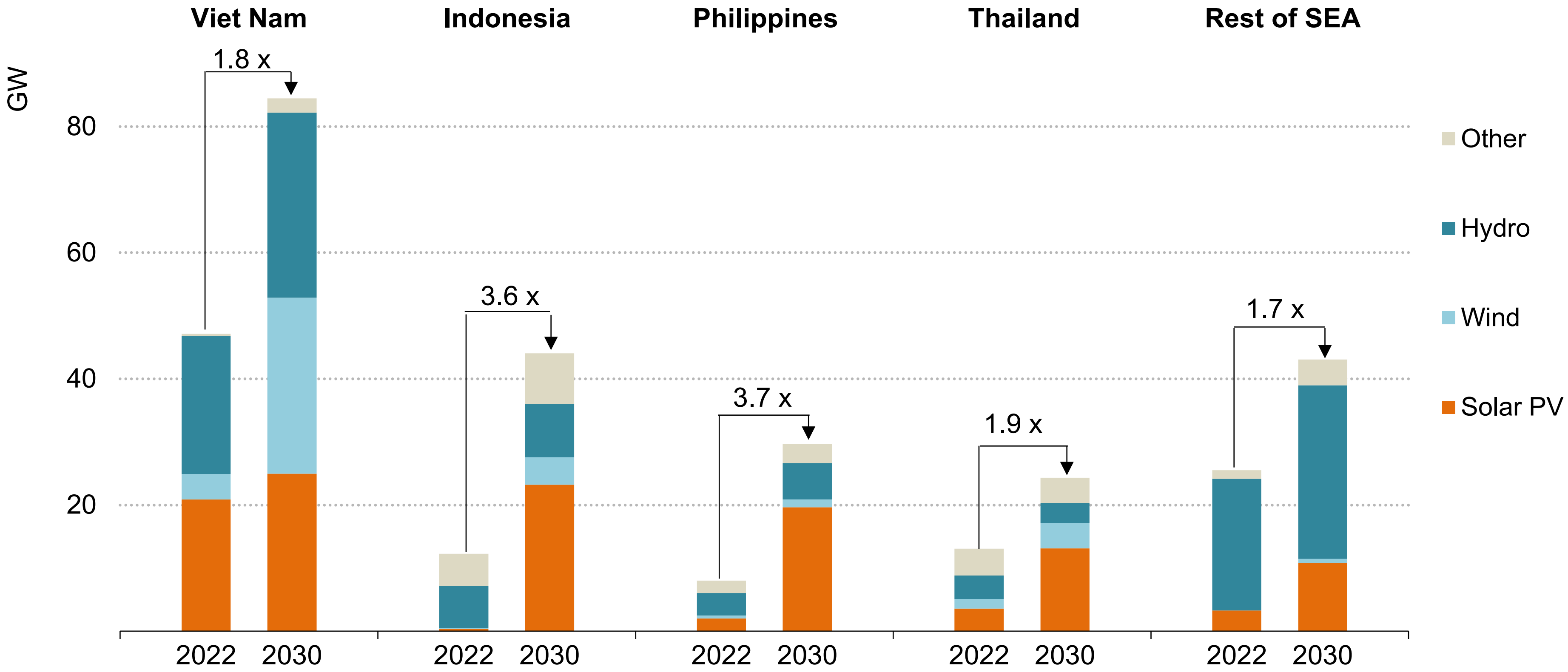
Installed renewables capacity in Southeast Asia by scenario, 2015-2030 and by source in 2030



Note: "Other" includes hydro, geothermal, bioenergy, marine and renewable waste.

Today's deployment plans indicate that Viet Nam is set to remain the largest renewable power market in the region, while the highest growth rate is seen in the Philippines

Installed renewables capacity in 2022 and policy targets for 2030 in Southeast Asia



Note: "SEA" = Southeast Asia; "other" includes geothermal, bioenergy, marine and renewable waste.
Sources: IEA (2023), Renewables 2023; IEA (2024), COP28 Tripling Renewable Capacity Pledge.

Alignment with COP 28 outcomes necessitates a concerted effort to accelerate renewables deployment across Southeast Asia, over and above current plans

Our analysis suggests that Southeast Asia is currently set to achieve a doubling in its renewables capacity by 2030. This represents an acceleration compared with historical trends, but not yet the step-change in deployment that would be required to align with national net zero goals and with the global 1.5 °C target. Renewables capacity in the NZE Scenario in Southeast Asia in 2030 is well in excess of 400 GW, compared with around 200 GW in the STEPS.

In Southeast Asia, full implementation of planned capacity additions would see renewables capacity increase from about 110 GW in 2022 to 225 GW by 2030. Almost one-third of the planned additions are in Viet Nam, followed by 27% in Indonesia and 18% in the Philippines. Solar PV would surpass hydropower to become the largest renewable technology (in capacity terms) in the region, driven by low costs and increasingly robust policy frameworks.

Some of the national plans and outlooks are as follows:

Viet Nam

In May 2023, Power Development Plan (PDP) 8 received government approval, establishing 2030 capacity targets and outlining the most substantial growth for wind (24 GW) and hydropower (7 GW). Utility-scale solar PV is projected to increase only modestly (4 GW), primarily due to grid integration challenges. Faster growth can be achieved by increasing grid investments and swift introduction of new policy support to fill the gap left since the expiration of the last feed-in tariff in 2021. Recently allowed Direct Power Purchase Agreements are expected to be an important driver of renewables expansion.

Indonesia

In September 2022, a presidential decree established a policy support framework for renewables, which, together with support from the Just Energy Transition Partnership, is expected to accelerate deployment. However, delays in introducing detailed regulations and in organising procurement processes are set to limit capacity growth in the short term. Deployment could be accelerated with faster implementation of support policies and attention to the challenges of existing overcapacity and inflexible power procurement contracts with fossil fuel generators.

The Philippines

In November 2022, the government updated the National Renewable Energy Program 2020-2040 to target a 35% share of renewable energy in the generation mix by 2030. The Green Energy Auction

Program and renewable portfolio standards are the main policy tools to achieve these goals. Also, higher foreign ownership of renewable energy assets was allowed in November 2022, which should encourage international investment. Increasing investments in grid infrastructure and streamlining permitting would allow the Philippines to accelerate renewables deployment.

Thailand

Thailand's new Power Development Plan aims for a 51% share of renewables in final energy consumption by 2037. The main driver for renewable energy growth continues to be fiscal incentives. Additionally, the Energy Regulatory Commission introduced a new feed-in-tariff regime to be in force until 2030, and the distributed PV net billing scheme which targets 10 GW of rooftop PV capacity by 2037. Higher investment in power grid system flexibility, support in securing land for investments and streamlining permitting procedures would facilitate faster development of renewable energy sources.

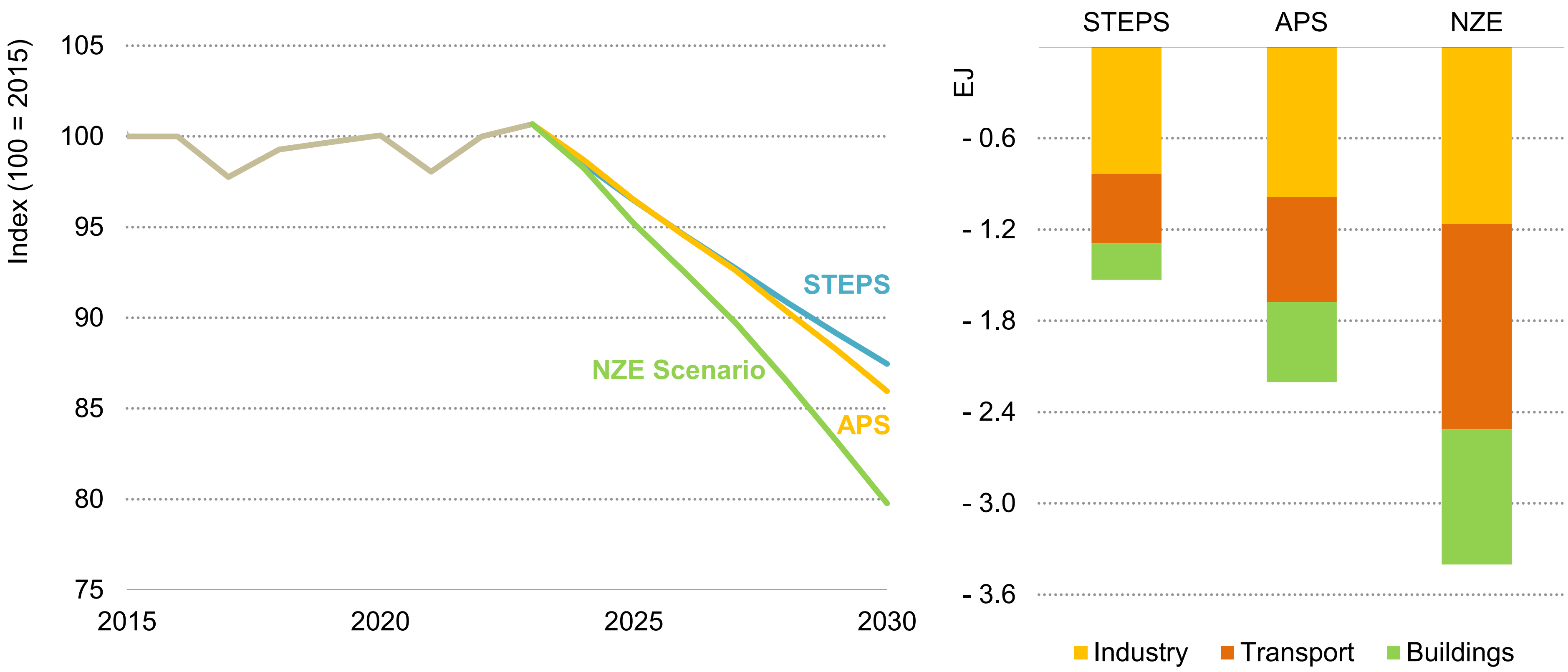
Policies to align deployment with the COP 28 goals

Supportive policy frameworks and strong international support are essential to support the achievement of national plans and, even more so, to allow for an acceleration that would align regional deployment with national and global climate goals. Key elements of these policy frameworks are:

- an ambitious long-term national vision for the transition to a low-emissions power sector, including generation, network infrastructure and storage
- integration of national plans with a regional approach to network development and trade, to optimise the development and use of renewable resources across the region
- streamlined permitting, with simplified rules and procedures: at present the permitting and licensing phase of project development is often longer than the construction phase
- adequate attention to reinforcing and expanding grids and deploying additional sources of flexibility, such as batteries and demand response (see next section)
- taking measures to enable the flexible operation of fossil fuel-fired plants and to accelerate their phase-down or repurposing, to allow for faster introduction of low-cost renewables
- phasing out inefficient fossil fuel subsidies to improve the investment case for clean energy technologies.

Southeast Asia's fluctuating energy intensity has been lagging declining global trends, but all sectors show potential for efficiency improvements to 2030

Annual energy intensity improvement in Southeast Asia by scenario, 2015-2030, and energy savings by scenario 2023-2030



Efficiency investments are lagging far behind the level that would be consistent with the COP 28 outcomes, with significant gains to be made in buildings and appliances by 2030

The COP 28 commitment to double the annual rate of global energy efficiency improvements from around 2% to over 4% every year until 2030 is ambitious, but achievable. In Southeast Asia, the regional rate of annual improvement needed in the NZE Scenario (to be in line with the global doubling target) is slightly lower at 3%. Nonetheless, it requires a step-up in ambition and implementation, which remains challenging for the region's emerging economies.

Annual energy intensity improvements have varied among ASEAN countries; however, since 2011 every country has reached above 4% at least once. Average annual change in energy intensity for 2000-2022 has been roughly in line with global trends at just over 1%, with some countries outperforming such trends (e.g. Indonesia). From 2022 to 2023, while global energy intensity declined (partly due to the global energy crisis and strong energy intensity improvement in some regions such as Europe), it increased on average in Southeast Asia. This means that progress in the next few years will be crucial to contribute to global COP 28 outcomes.

The regional energy intensity reduction target of 32% by 2025 (based on the 2005 level) will be updated for the 2025-2030 ASEAN Plan of Action for Energy Cooperation (APAEC), which is an opportunity to increase regional ambition and contribute to global goals, though this will necessitate a ramp up in investment. In 2023, regional investment in energy efficiency and end-use electrification was around USD 7 billion. In the STEPS, this more than doubles to around USD 19 billion in 2030. In the APS, investment almost quadruples from today's levels to USD 29 billion by 2030, and in the NZE Scenario, investment in the efficiency and end-use electrification accelerates even faster, increasing to around USD 64 billion in 2030. Recognising the need for further investment in efficiency, Indonesia's JETP launched the Energy Efficiency and Electrification Working Group in early 2024.

The three main components of energy intensity improvements are upgrading the technical efficiency of equipment and appliances; electrification and fuel switching; and structural changes in the economy (e.g. higher relative growth in less energy-intensive sectors than in others).

Of the transport, industry and buildings sectors, it has been the buildings sector which has seen the largest increase in 2023 in electricity consumption driven by population growth, rising living standards and rapid urbanisation. These have led to increased floor space per person and greater appliance ownership. Cooling represents almost 16% of the electricity used in buildings, and the region's AC stock is projected to be fifteen times higher in 2050 than it was in 2020, a period during which heat waves are expected to be more common. Southeast Asia experienced another crippling heat wave in 2024, during which, Thailand saw record power demand, and

Viet Nam's state-run utility made appeals to the public to reduce their electricity consumption due to the unprecedented peak demand. Appliance policy can help mitigate this demand in the future. In April 2024, Singapore introduced a USD 225 voucher for efficient appliances, and household water heaters and commercial storage refrigerators will be subject to mandatory MEPS and labelling in 2025.

Fuel switching and electrification are also key drivers of efficiency in the buildings sector. The share of the population in the region with access to electricity rose from around 60% to 97% from 2000 to 2023. The number of people using traditional biomass for cooking decreased almost 70% across the same period, but around a fifth of the population still lacks access to clean cooking (see page 58). Indonesia launched a clean cooking programme in 2007. While this successfully reduced kerosene use by 92%, the LPG subsidies weigh heavily on the public purse. Since 2021, the government has piloted programmes to transition to induction stoves and electric rice cookers.

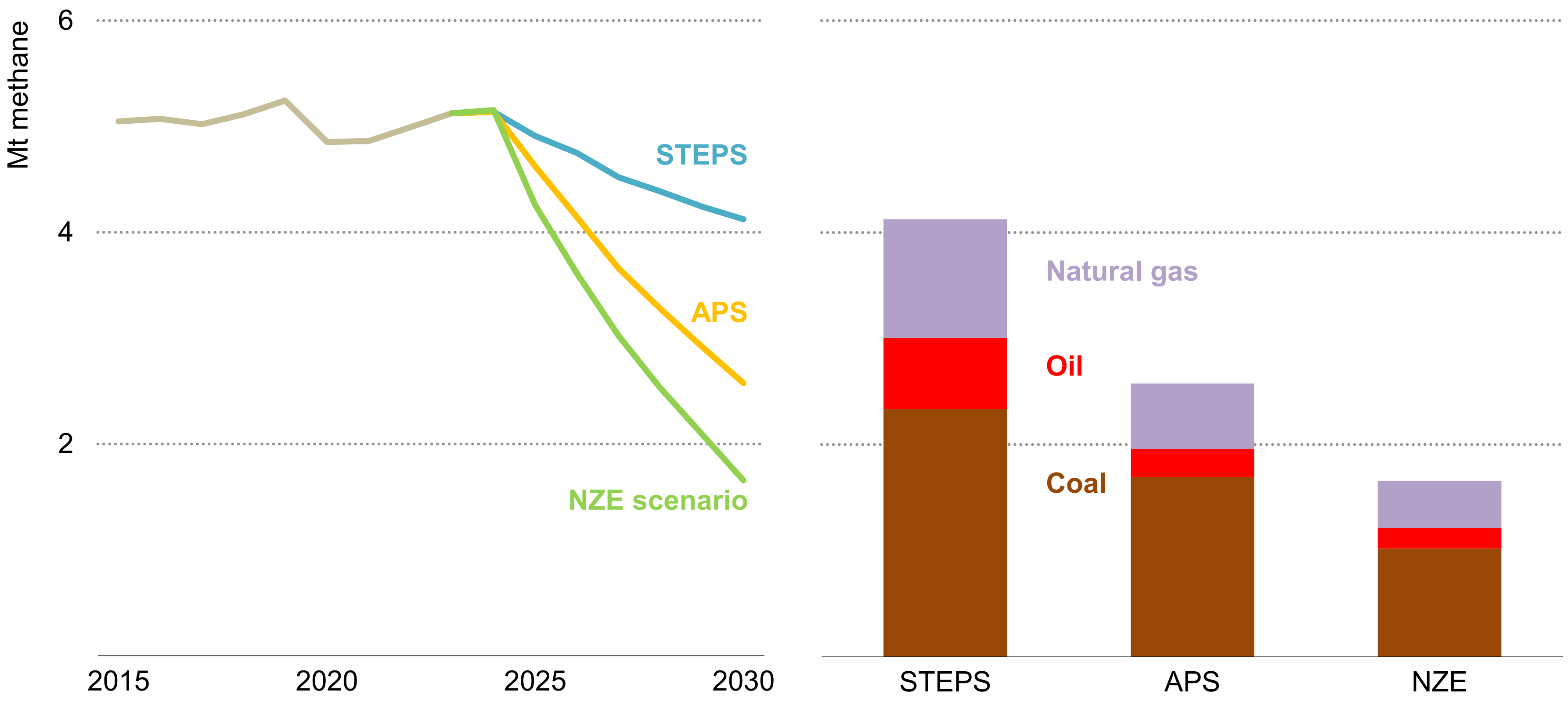
The industry sector accounts for almost half of total energy consumption from end-use sectors. Growth is expected in all scenarios, mainly driven by the region's rising production of iron, steel and chemicals, and growth in light manufacturing (see page 63). MEPS and labelling of equipment, especially motors, remain relatively low (e.g. at IE1 or IE2 levels) or voluntary in Southeast Asian countries, except for Singapore. Industrial energy audits and reporting requirements, recently expanded in Indonesia, are also key tools to increase efficiency.

In the STEPS, transport demand is expected to grow, with biofuel blending and electrification of road transport gradually reducing oil's dominance in the sector (see page 68). Indonesia is currently developing fuel economy standards for heavy-duty vehicles with the support of the IEA while a recently issued regulation reducing the value-added tax for electric vehicles could improve EV uptake in the country. Malaysia recently expanded consumer subsidies for the purchase of electric 2-wheelers with a means-tested incentive of up to about USD 530 per person, boosted incentives for investments in EV charging and invested in 150 electric buses.

To accelerate efficiency progress across sectors, policy makers can develop a robust policy package of regulation, information and incentives. In Southeast Asia, key tools to drive efficiency include developing and strengthening building energy codes, setting stringent MEPS for ACs, refrigerators and motors, introducing incentives for building retrofits, encouraging efficient appliances, industrial equipment and processes, and transitioning to EVs. The implementation of measures to improve energy efficiency – such as fuel switching and electrification – is hindered by government support for inefficient fossil fuel alternatives, for example, through consumption subsidies. Therefore, policy packages promoting energy efficiency in end-use sectors can be implemented alongside measures to phase out inefficient subsidies for fossil fuels.

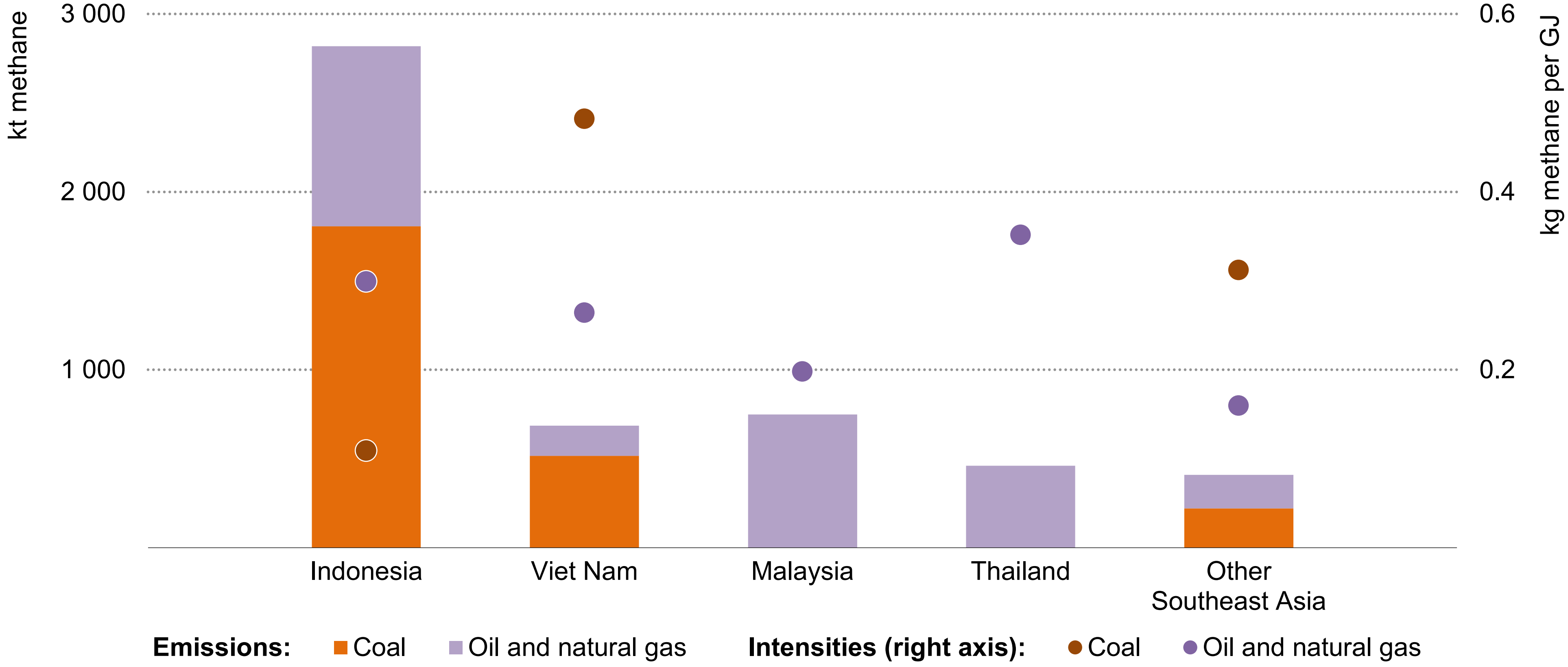
Methane emissions have remained stubbornly high over the past decade, but targeted country and company efforts improve the outlook to 2030

Methane emissions from fossil fuel operations in Southeast Asia by scenario, 2015-2030 (left), and by fuel in 2030 (right)



Methane emissions in the region are evenly split between coal mines and oil and gas facilities, with four countries accounting for over 90% of the total

Methane emissions from fossil fuel supply and related methane intensities in 2023



Note: "Other Southeast Asia" is Brunei Darussalam, Cambodia, Lao People's Democratic Republic, Myanmar, the Philippines and Singapore.

Tackling methane emissions from fossil fuel operations is key to limiting near-term global warming

The COP 28 outcome calls for substantial reductions in methane emissions by 2030 but does not specify a quantitative target. Methane abatement is vital for climate goals and can improve energy security by bringing additional gas to market, while providing health benefits. We estimate that Southeast Asia's oil, gas and coal industries emitted around 5 Mt of methane in 2023. This represents 8 bcm of natural gas that was lost in pipelines, coal mines and other parts of energy supply chains.

The energy sector holds the largest potential for cost-effective near-term methane abatement. Our analysis of Southeast Asia suggests that a reduction in methane emissions of around 70% by 2030 in the region would be consistent with the 1.5 °C goal: this is what is achieved in the NZE Scenario. This requires that all available methane abatement measures are deployed across fossil fuel supply chains. Well-known solutions include the use of vapour recovery units that direct waste flows of methane to productive uses, the replacement of leaky equipment and the abatement of mine ventilation air methane.

Indonesia is responsible for over half of fossil fuel methane emissions in Southeast Asia, which are mainly associated with its coal mines. The average amount of methane released per unit of coal or oil and natural gas produced in the region is around the same as the global average (0.2 kg methane/GJ), but performance varies and generally has much room for improvement in all countries. The abatement potential is higher in the oil and gas industry, where methane reductions can often be achieved at no net cost. This is because the required outlays for abatement measures are less than the market value of the additional methane gas captured and sold or used.

Barriers to methane abatement include a lack of awareness about the scale of the problem or the solutions available; the absence of regulations and policies compelling companies to act; the risk of split incentives, where the owner of the equipment does not directly benefit from reducing leaks, or the owner of the gas does not see its full value; the difficulty in deploying sufficient staff or obtaining the services needed to tackle the problem; and the lack of pathways or businesses to bring captured gas to productive use.

Investing in methane abatement can also require significant upfront capital expenditure, and this often faces competition within companies for available funds. If methane abatement projects have low internal rates of return, they may lose out to other investments deemed more important to the company's core business. National oil companies (NOCs) face additional constraints given competing priorities for domestic spending, especially in low- and middle-income countries, potentially limiting the amounts available to invest.

Detailed methane abatement plans can take Southeast Asia from pledges to actions

In the STEPS, methane emissions from fossil fuel operations fall by around 20% to 2030, mostly due to targeted action in the oil and gas industry where low-cost methane abatement measures can be readily deployed. This includes measures such as leak detection and repair programmes in the upstream segment and the use of low-emissions devices like electric pumps. The STEPS however takes the region along a path far from the reductions needed to deliver on climate goals.

In the APS, Southeast Asia's emissions fall by 50% due to broader efforts in the oil and gas sector as well as measures to reduce coal mine methane emissions, such as the use of drainage systems to capture methane from mines. Several major emitters in Southeast Asia have joined the Global Methane Pledge, committing to contribute to a 30% reduction in global methane emissions (from all anthropogenic sources) by 2030. Participants include Indonesia, Viet Nam and Malaysia, which together account for around 80% of the region's estimated energy-related methane emissions.

Many oil and gas companies active in the region have joined the Oil and Gas Decarbonisation Charter, pledging to end routine flaring and reach near-zero upstream methane emissions by 2030. These include both NOCs – such as Pertamina (Indonesia), Petronas (Malaysia) and PTTEP (Thailand) – and major international oil companies, like ExxonMobil and Shell.

Countries in the region have an opportunity to firm up methane abatement plans in the next round of NDCs in 2025. Viet Nam and Thailand have action plans to deliver methane cuts but have yet to include methane targets in their NDCs. Malaysia is in a similar position, with no specific action in its NDC to cut methane, while Petronas launched the ASEAN Energy Sector Methane Leadership Program in collaboration with Japan's Organization for Metals and Energy Security and other partners, such as PTTEP (Thailand), Pertamina (Indonesia), the United States Agency for International Development (USAID) and the United Nations Environment Programme (UNEP). Other countries in the region could follow suit, taking advantage of low-cost opportunities to cut methane emissions in the energy sector.

Stronger action on methane may facilitate access to capital and markets, limit regulatory risks and address some of the concerns of civil society. The inclusion of the first-ever methane standard on oil, gas and coal imports in the European Union methane regulation (2024) highlights the role methane management will play in conditioning access to markets. In 2023, Japan and Korea, two other major natural gas importers, along with trade partners, formed the Coalition for LNG Emission Abatement toward Net-zero (CLEAN) project, under which large purchasers of LNG will collect information from suppliers on the status of methane reduction efforts to enhance the availability of information on LNG-related emissions.

3.2 Emerging issues for clean energy transitions

Safeguarding the security and reliability of power systems

Tackling rising flexibility needs, ensuring the adequacy of supply and reinforcing grids are critical to guaranteeing the security and reliability of Southeast Asia's power systems

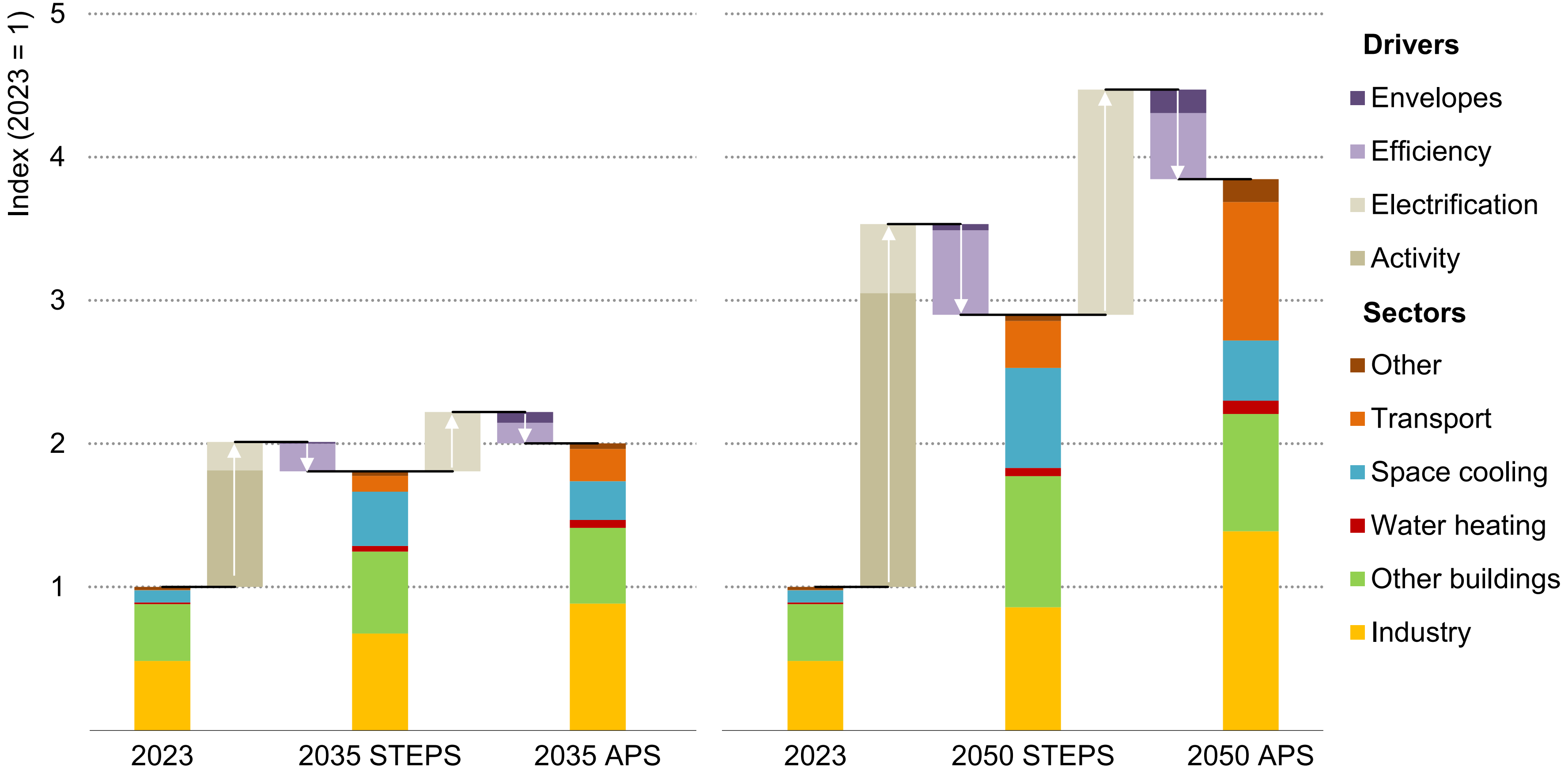
Electricity demand is projected to continue to grow strongly in Southeast Asia, driven in part by the rising uptake of air conditioners and electric vehicles. At the same time, the combined share of variable wind and solar PV in the electricity mix is set to increase significantly, most notably in the APS after 2030. These factors combined raise the variability of electricity demand and supply, contributing to rising power system flexibility needs across all timescales – from hours to days to seasons.

Today, flexibility needs across the region are met mostly by thermal power plants and hydro. The projected sharp increase in flexibility needs and the imperative to reduce power sector CO_2 emissions call for the deployment of new technologies and approaches to provide flexibility and ensure the adequacy and reliability of the electricity supply. As the share of variable renewables increases, thermal power plants, including coal-fired power plants, will have to be operated more flexibly to accommodate swings in supply and demand. This will require updating operational practices and contracts to incentivise flexible operations, and may, in older units, require targeted equipment upgrades. Over the next three decades, thermal power plants and hydro will increasingly be complemented by batteries and demand response, which are set to become crucial providers of hourly and daily balancing and ancillary services, such as voltage control, to power systems. Together with hydro, thermal power plants will remain a key pillar of the seasonal flexibility supply, even as thermal plants will run less and less each year as the share of wind and solar PV increases in the electricity mix. Together with batteries, thermal power plants also remain essential providers of secure capacity that can be relied upon to supply electricity in critical hours with low renewables generation and high load. In the long run capacity remuneration mechanisms could be an effective way to ensure that thermal power plants remain financially viable even as they run less and less frequently. Beyond 2030, the introduction of hydrogen, ammonia and biomass co-firing can provide opportunities to further reduce emissions from the thermal power plant fleet.

In addition, expanding and reinforcing power grids, including increasing interconnections between countries across the region, will be essential to meet growing demand and integrate rising shares of variable renewables. The electricity system is complex, with many moving parts. To prevent grid development from lagging behind, integrated planning of the energy supply and grid infrastructure, including internationally, is essential, as are accelerated permitting and the provision of sufficient capital for grid expansion.

Peak demand increases in both the STEPS and the APS, driven by higher activity and strong electrification, but energy efficiency gains and better building insulation mitigate the growth

Peak electricity demand by sector and driver in Indonesia in the Stated Policies Scenario and the Announced Pledges Scenario, 2023-2050



Note: "Envelopes" refers to building insulation. "Efficiency" refers to technical efficiency. "Other" includes agriculture. "Other buildings" includes appliances, lighting and cooking.

Peak demand increases faster than total demand in both the STEPS and the APS, driven by strong electrification, increased use of air conditioners and EV charging

Most countries in Southeast Asia continue to see strong electricity demand growth in the STEPS and APS. However, peak demand is set to grow even faster, driven primarily by the growing proliferation of air conditioners and electric vehicles, as well as the progressive electrification of industry.

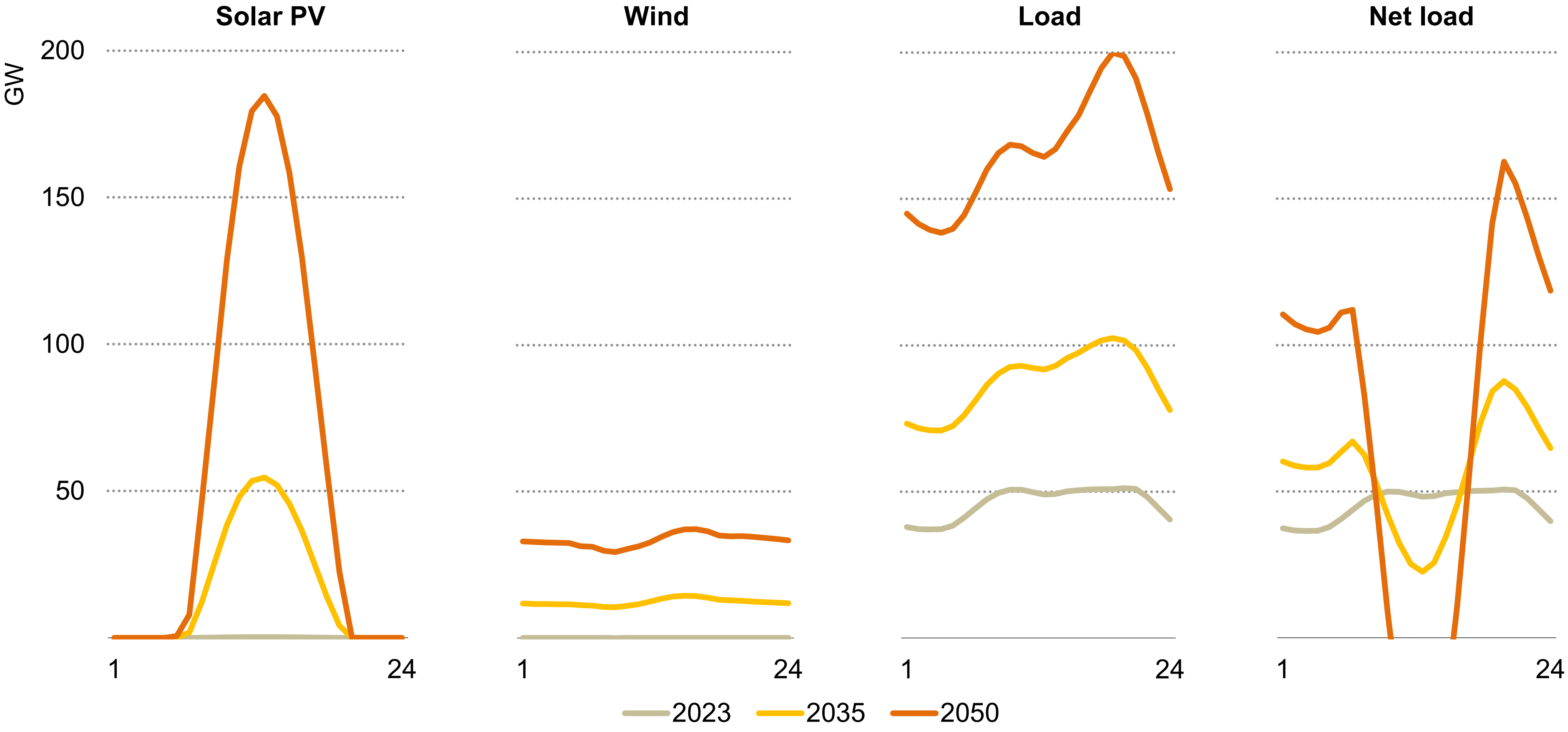
Indonesia, Southeast Asia's largest power system, provides a good example of the causes and magnitude of these changes. The country's electricity demand increases threefold to 2050 in the STEPS, driven by an increasing population, rising standards of living and rapid urbanisation. Air conditioner ownership in Indonesia has been rising steadily along with growing incomes and reached around 20 units per 100 households in 2023. It is estimated to expand tenfold by 2050, outpacing the growth of every other major household appliance. Indonesia has enacted policies to support EV uptake, such as reduced value-added tax and subsidies. It also aims to strengthen clean energy technology manufacturing, joining the ranks of producers and exporters of key clean energy equipment such as solar PV modules.

As a result, peak electricity demand almost doubles to 2035 in the STEPS, mostly driven by higher activity, with two-thirds from buildings, and the remainder mostly from industry. Electrification of transport and light industries adds nearly another 20% to peak demand, which is compensated for by energy efficiency gains in industry. The APS features a similar peak demand level, yet with a more pronounced contribution of industry because of higher electrification rates and nascent demand from EVs. Higher MEPS for appliances, notably air conditioners, and more stringent energy codes for buildings reduce the contribution of buildings and cooling to peak demand.

Peak demand triples by 2050 in the STEPS and quadruples in the APS. The largest increase comes from activity, driven by more floorspace/households and industrial output, though there are significant efficiency gains in these same sectors. Electrification is still limited, with electrification rates in industry and transport 8 percentage points lower than the average for EMDE. In the APS, additional electrification comes equally from transport and industry, and efficiency savings (two-thirds from buildings and cooling) help mitigate the peak increase. Due to Indonesia's tropical climate with smaller variations in average temperatures across the year, compared to other Southeast Asian countries, there is little seasonality in the average load. This limits the impact of cooling on peak demand, as it is distributed over the year instead of being concentrated over a limited number of weeks.

Across the day, the net load becomes much more variable, especially after 2030, due to the strong growth in solar PV, the proliferation of air conditioners and rising EV uptake

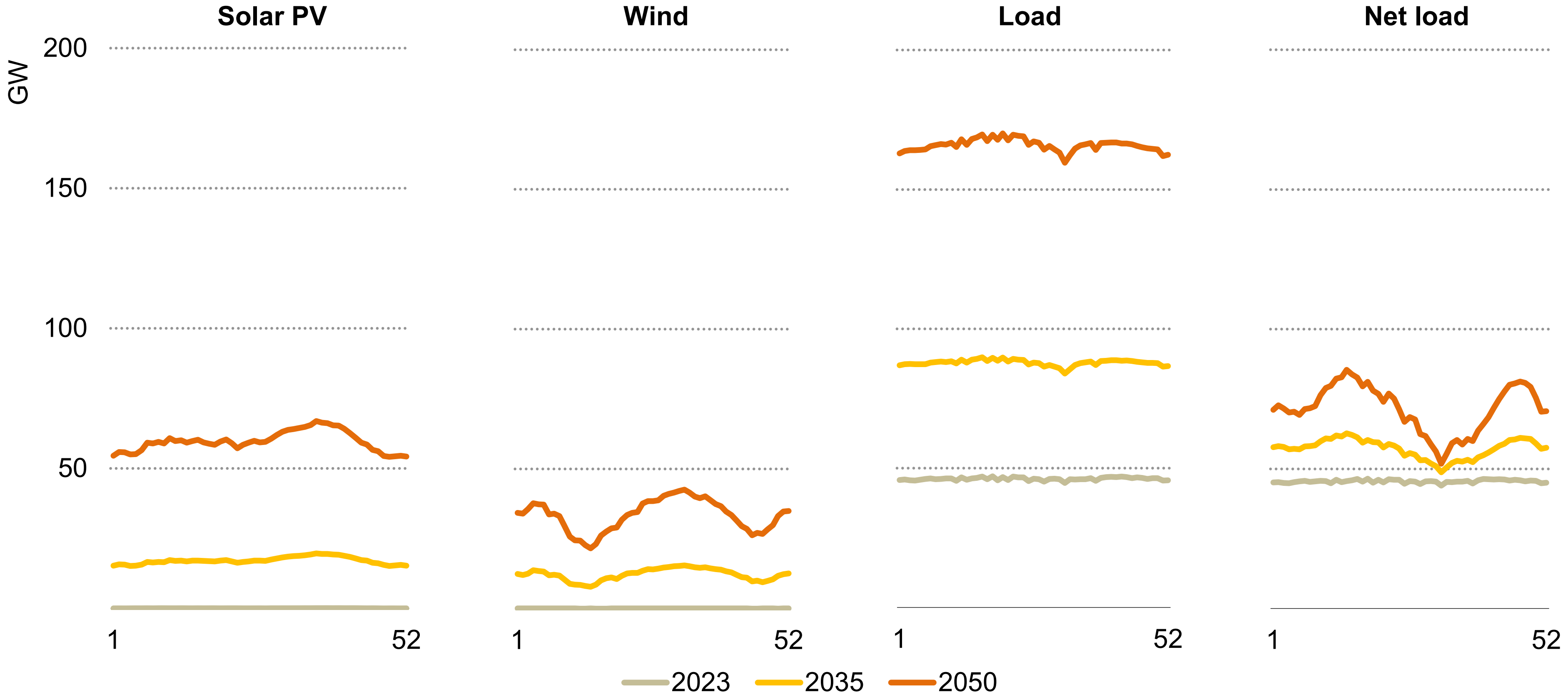
Average hourly solar PV and wind power output, load and net load across the day in Indonesia in the Announced Pledges Scenario, 2023-2050



Note: "Net load" is electricity demand (load) less the contribution of wind, solar PV and run-of-river hydro.

Due to seasonal swings in the output of wind and solar PV, as well as rising air conditioner usage, the variability of the net load across the year also increases

Average weekly solar PV and wind power output, load and net load across the year in Indonesia in the Announced Pledges Scenario, 2023-2050



Note: "Net load" is electricity demand (load) less the contribution of wind, solar PV and run-of-river hydro.

The variability of the net load increases with rising shares of wind and solar PV in the electricity mix and growth in electricity demand from air conditioning and electric vehicles

The variability of the net load – the load that remains when deducting the contribution of wind, solar and run-of-river hydro from the total load – is projected to increase over the 2023-2050 period, across all timescales, from hours to days and across seasons. This increase is produced by the rising shares of variable wind and solar PV in Southeast Asia's electricity systems, together with the growing and increasingly variable electricity demand driven by growing numbers of EVs and by rising air conditioner uptake, which makes electricity consumption more temperature sensitive. This variability is most strongly felt in the APS after 2030, which sees the combined share of wind and solar PV in the region's electricity mix grow to nearly 70% by 2050, alongside strong electricity demand growth connected to cooling and electric vehicles.

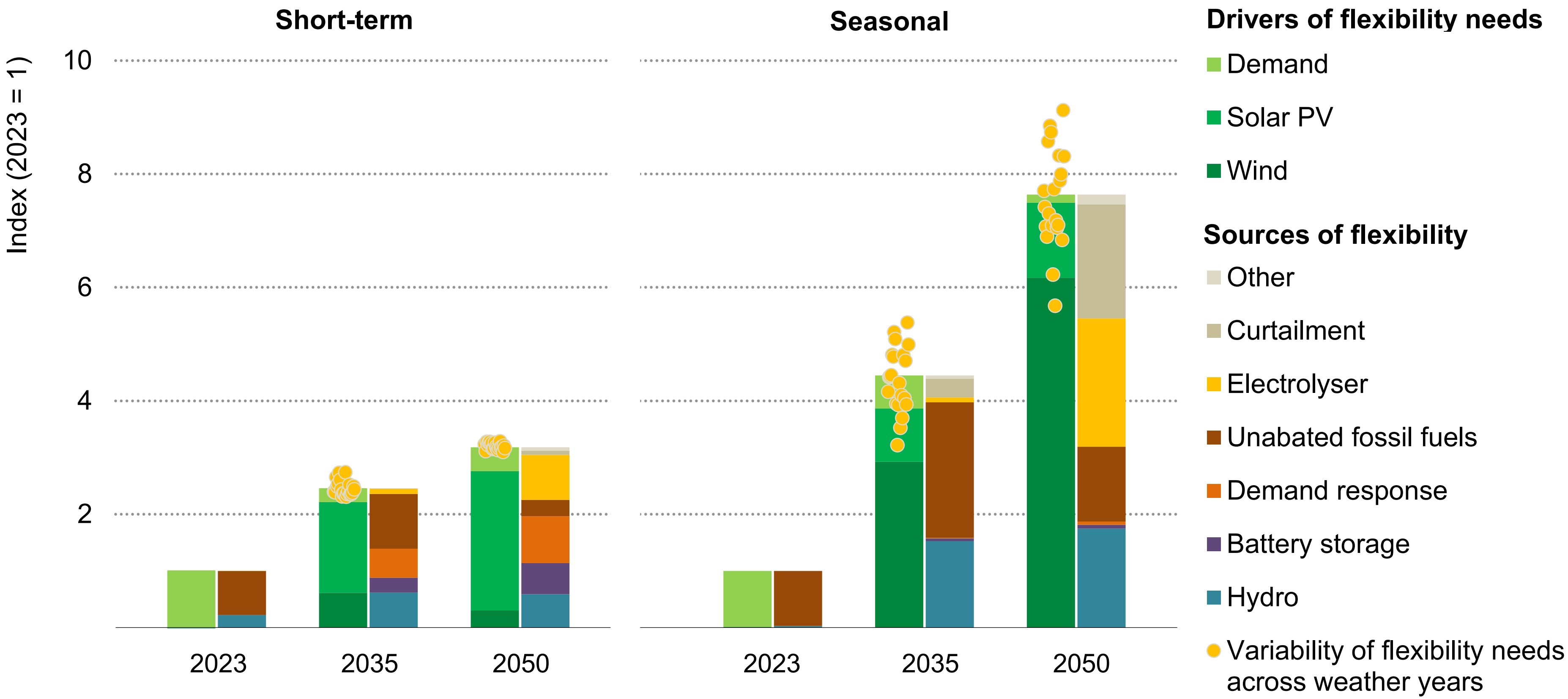
In Indonesia in the APS, for example, the daily variability of electricity supply and load increases substantially between 2035 and 2050. Rising solar PV generation leads to the emergence of a very prominent "duck curve" in the net load, with the daytime peak in solar PV output exceeding demand on most days. This is followed by a sharp increase in the net load as solar PV output drops off towards the evening and growing cooling needs and EV charging in the late afternoon and evening raise the overall load. This daily pattern would look similar in other Southeast Asian countries with high shares of solar PV in their electricity systems.

The seasonal variability of the net load also increases significantly to 2050 in Indonesia in the APS, driven almost exclusively by the rising share of wind and solar PV in the electricity mix. Indonesia's climate is characterised by wet and dry seasons determined by the Australian-Asian monsoon. Cloud cover tends to peak between October and March in most of the country, while drier conditions prevail during the other half of the year. Average wind speeds are also higher during the dry season, which means that both wind and solar PV generation tend to peak in this period, with a secondary peak for wind at the height of the rainy season.

As a result, the net load transforms from being virtually flat across the year today to exhibiting two distinct peaks, with a pronounced low during the dry season. Due to Indonesia's near equatorial climate with only small variations in average temperatures across the year, there is little seasonal variation in the average load. However, this would be different in other parts of Southeast Asia where there are higher annual variations in temperatures, such as Viet Nam, Lao PDR or northern Thailand. Here, fluctuations in electricity demand for space cooling would have a bigger impact on the seasonal variability of the net load than in the equatorial parts of the region.

In Indonesia in the APS, short-term and seasonal flexibility needs increase substantially to 2050, underpinned by rising shares of wind and solar PV in the electricity mix

Short-term and seasonal flexibility needs and supply by technology in Indonesia in the Announced Pledges Scenario, 2023-2050



Notes: A weather year is a set of annual weather parameters such as temperature, solar radiation, wind speed and precipitation compiled from historical records to create curves of hourly loads and renewables output. "Other" includes nuclear, hydrogen and ammonia, geothermal, solar thermal, bioenergy, marine and waste to energy.

Power system flexibility needs are set to increase, and new technologies like batteries and demand response will join thermal power plants and hydro to meet this challenge

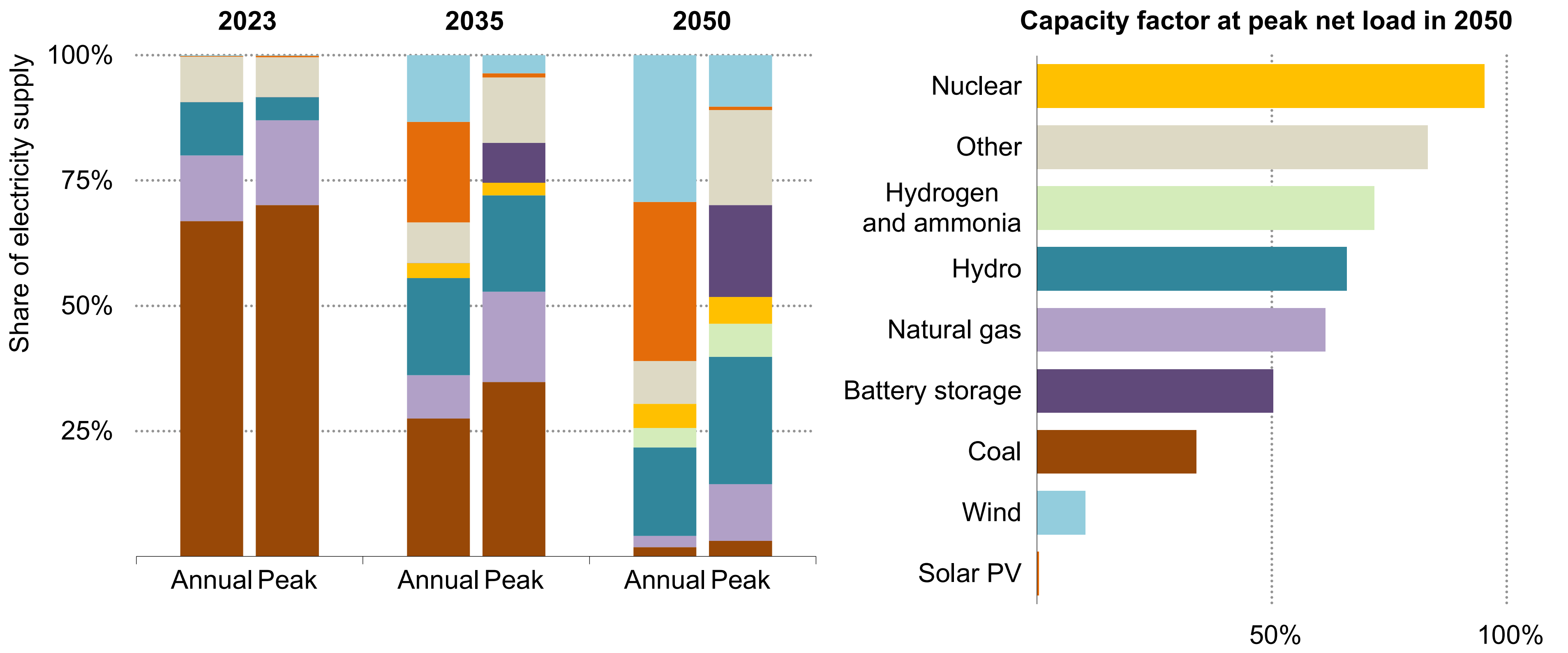
Both short-term (measured here as the largest hour-to-hour changes in the net load) and seasonal flexibility needs (measured as the highs and lows of the net load across the year) are expected to rise significantly in power systems across Southeast Asia as the share of variable renewables in the electricity mix increases and the net load becomes much more variable.

In Indonesia in the APS, short-term flexibility needs rise on average 3 times to 2050, while seasonal flexibility needs grow nearly 8 times, albeit from a low base. While today, both short-term and seasonal flexibility needs are almost entirely determined by variations in electricity demand, the rising share of variable renewables in the electricity mix means that they become the primary drivers of growing flexibility needs after 2030. Solar PV – with its distinct but predictable daily cycle – drives short-term flexibility needs. Wind generation, which tends to remain more stable across a day but can vary considerably across longer time periods, drives seasonal flexibility needs alongside solar PV, which also exhibits seasonal fluctuations in output linked to variations in average cloud cover. As flexibility needs are increasingly shaped by renewables, their sensitivity to year-to-year variations in weather patterns – linked to variations in cloud cover and monsoon intensity – also grows. This can result in substantial differences in the need for seasonal balancing across different years.

Currently, coal and gas-fired power plants provide around 80% of the short-term flexibility and nearly all of the relatively small seasonal flexibility required, with the remainder provided by hydropower plants. Until 2035, battery storage and demand response become important additional sources of short-term flexibility in the APS, with batteries able to take advantage of the daily pattern of solar PV electricity generation, shifting electricity from the daytime into the evening. A significant share of the demand response potential is provided by the smart operation of air conditioners. After 2035, electrolysers emerge as additional providers of short-term flexibility. EVs now make up the bulk of demand response contribution by shifting charging to the daytime, thus attenuating the sharp increase in the net load in the evening. Unabated fossil fuel-fired power plants remain important providers of seasonal flexibility well into the 2040s. By 2050 however, their share in the mix is reduced by the emergence of other flexibility providers, most notably the flexible operation of grid-connected electrolysers, with small but growing contributions from nuclear and from coal plants retrofitted to co-fire ammonia or biomass. Additionally, the strategic curtailment of surplus wind or solar PV generation becomes an increasingly important tool to manage longer-term variations and balance the system in a cost-effective manner. Curtailment accounts for a quarter of the seasonal flexibility provided to the Indonesian electricity system in 2050.

Variable renewables generate over 60% of Indonesia's electricity in 2050 in the APS, but dispatchable sources remain essential to meet demand in all hours

Annual and peak net load electricity supply mix (2023-2050) and capacity factor at peak net load in 2050 in Indonesia in the Announced Pledges Scenario



Notes: This figure shows the average electricity supply mix over a day and the electricity supply mix, as well as average plant capacity factor, in the 100 hours with the highest net load (electricity demand less the contribution of wind, solar PV and run-of-river hydro) averaged across 30 weather years. "Other" includes oil, bioenergy, geothermal, marine and waste to energy.

Batteries become and thermal power plants remain crucial in ensuring security of supply at times of peak net load, when high electricity demand is not met by renewables output

In addition to meeting rising flexibility needs, making certain that systems retain sufficient dispatchable generating capacity to guarantee the adequacy of supply at all times is critical. Traditionally, the assessment of power system adequacy has been based on its ability to meet peak demand. In systems characterised by high shares of variable renewables, the times during 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. In these hours, dispatchable sources tend to produce near the maximum of their available capacity.

As the share of variable renewables increases, the supply mix at peak – the hours of the year with the highest net load – increasingly diverges from the annual average electricity mix. In Indonesia in the APS in 2050, for example, wind and solar PV account for around 60% of the annual electricity supply, but at peak, this share drops to 10%, with almost no contribution from solar PV. Instead, fossil fuel and low-emissions thermal power plants and battery storage ramp up to provide 65% of the electricity at peak, with most of the remainder being supplied by hydro, and with many of these plants running at close to their full available capacity. In countries like Indonesia, where solar power is projected to become a major component of the electricity mix, battery storage in particular becomes a crucial provider of secure capacity at peak. Batteries can be charged during the day when solar power generation is at its maximum. The charged batteries can then supply electricity during the evening when demand typically peaks and solar generation is not available. Their ability to fulfil this role is facilitated by the significant increase in battery storage projects with longer durations (four to eight hours) that is projected to occur in regions with high shares of solar PV. A similar role is played by demand response, which, by shifting electricity consumption, helps limit the increase in demand even at peak net load.

Thermal power plants remain crucial to ensure security of supply, with many running at close to their maximum available capacity when the net load peaks. In Indonesia in the APS in 2050, some are still coal- or gas-fired since the country's power sector is not yet fully decarbonised. However, they are increasingly complemented by plants that co-fire ammonia, reducing emissions. Since ammonia is relatively expensive, these plants predominantly serve to provide secure capacity, focusing operations on critical hours. Alongside Indonesia, other countries in the region also plan to rely on hydrogen and ammonia to provide secure capacity in their long-term energy plans, including Viet Nam, Malaysia and Cambodia.

Efficient grid-interactive buildings can reduce energy demand, provide demand response and enhance power system flexibility in Southeast Asia

In 2023, the IEA prepared a study to map opportunities and challenges for efficient grid-interactive buildings (EGIBs) in ASEAN. EGIBs are energy-efficient buildings with high-performance building envelopes and efficient appliances and equipment. They are smart, optimising energy performance through the use of sensors and controls and sending/receiving signals to respond to the grid. They are flexible, balancing energy loads through behind-the-meter generation, demand response and energy storage. These features, alongside smart grid-side solutions, can increase power system flexibility and help integrate variable renewable electricity (VRE).

The study found that green-building certified buildings in ASEAN had 20-70% lower energy use intensities. Several ASEAN countries have adopted building energy codes and all have some MEPS and labelling for different appliances in force or in development. However, countries need to increase the stringency, scope and enforcement of these policies. The ASEAN building digitalisation market is expected to grow significantly. Several ASEAN countries are supporting the uptake of smart meters, mainly driven by utilities. In 2022, there were around 30 million smart meters installed across ASEAN. While the use of smart inverters for solar PV systems is currently limited, there are several pilot projects. Smart charging for EVs in buildings could also offer flexibility benefits, but its use is currently limited in ASEAN. Many countries in the region have developed smart grid plans and the ASEAN Power Grid (APG) will establish cross-border transmission lines. Interoperability between buildings and the grid is crucial, but currently very limited in the region. A promising trend is the emergence of virtual power plants and peer-to-peer solar energy trading projects.

VRE integration is enabled by investments in grid infrastructure and energy storage in buildings. ASEAN countries can also consider dynamic electricity tariffs and demand response programmes to reduce and shift demand from peak hours, avoid grid congestion and mitigate higher electricity costs.

The IEA analysed EGIB opportunities in each ASEAN country and grouped countries into three categories: Explorers, Adopters and Innovators. Despite regional progress, especially on pilot projects, none of the countries made it to the Innovators group, indicating opportunities for improvement. The report provides recommendations for each group, and to ensure robust policy-making, the IEA recommends countries adopt a policy package approach combining regulation, information and incentives.

Recommendations for ASEAN countries based on the assessment of enablers for efficient grid-interactive buildings

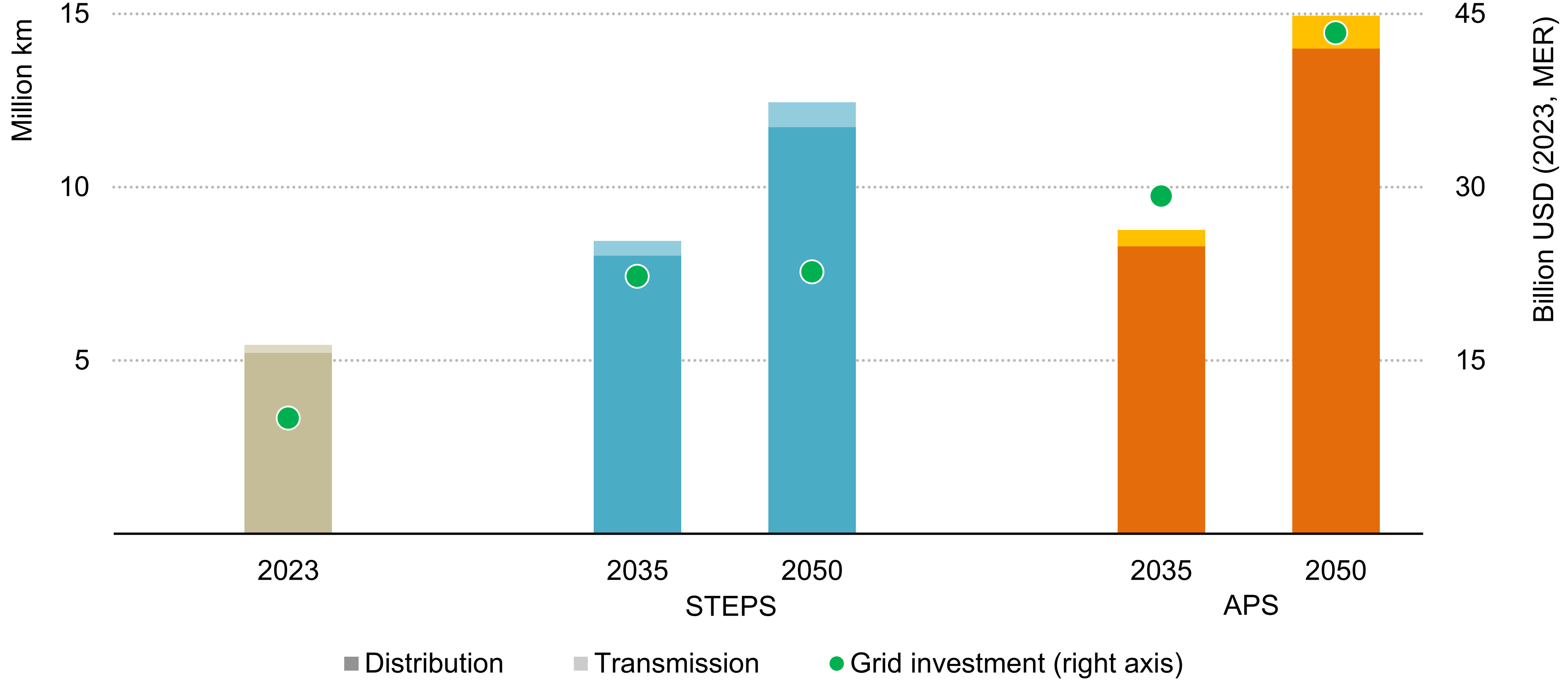
	Explorers: Countries that are in the beginning of the process of discovering and researching the opportunities for EGIBs	**Adopters**: Countries that have identified some opportunities for EGIBs and are implementing pilot projects and sandboxes to test their benefits and potential
	Brunei Darussalam, Cambodia, Lao PDR, Myanmar	**Indonesia, Malaysia, Philippines, Singapore, Thailand, Viet Nam**
Energy efficiency	Develop and implement building energy codes with mandatory EE requirements Introduce MEPS and supporting policies for appliances (can be voluntary first)	Make regular updates and more stringent mandatory EE requirements in building energy codes and MEPS
Decarbonisation	Introduce voluntary requirements for on-site solar PV in buildings Promote battery storage systems	Introduce mandatory requirements for onsite renewable generation and storage
Smartness	Develop voluntary smart buildings standards and requirements for smart solutions	Adopt and implement smart buildings standards and requirements for smart solutions in large buildings
Building-to-grid interaction	Conduct feasibility study on open interoperability standards and grid-readiness requirements in building energy codes and MEPS Develop pilot projects for demand response and virtual power plants	Introduce voluntary requirements for grid-readiness which transition to mandatory Develop mandatory requirements for demand-response readiness in MEPS, scale up virtual power plant projects

Note: EE = energy efficiency, MEPS = minimum energy performance standards.

Source: IEA (2023) Efficient Grid-Interactive Buildings.

Grid expansion and cross-border interconnection are key to meeting growing demand for access to clean electricity and require an increase in investment to deliver announced targets

Installed transmission and distribution line length, and annual average investment in grids by scenario, 2023-2050



Grid expansion enables the integration of affordable, indigenous renewable energy by connecting the resource-rich areas to demand centres

Significant growth in both transmission and distribution grids is expected in Southeast Asia, driven by rising electricity demand which roughly doubles from today's levels by 2035 and again by 2050 in the APS. Governments in the region indicate a strong desire to enhance electricity security through grid expansion by facilitating access to a larger diversity of resources and reducing dependency on specific energy sources. For instance, recent gas supply constraints and droughts affecting hydro capacity highlighted the need to diversify the generation mix and expand the geographical balancing area.

Another driver for grid expansion is the need to increase resilience against climate change impacts including extreme winds, rainfall and heat, which affect the performance of grids and power supply. Increasing grid resilience involves modernising and reinforcing infrastructure, replacing old equipment prone to failure, and enhancing remote monitoring and control for rapid response and restoration.

Finally, grid expansion is also recognised globally as a means to facilitate access to cheaper generation to more people. It enables the integration of affordable, indigenous renewable energy by connecting resource-rich areas to demand centres. For example, in Viet Nam, reinforcing the north-south interconnection would allow faster integration of substantial southern solar power to northern demand centres. Integration of regional and subregional power systems can reduce overall dispatch costs by accessing a larger and more varied pool of generation resources. For instance, Europe saved EUR 34 billion in 2021 through stronger regional electricity integration measures.

By 2035, to securely meet the APS targets, the transmission network length will need to more than double compared to 2023 levels. Additionally, the distribution network will need to grow by 60% over the same period. Looking further ahead to 2050, network lengths will need to be almost triple compared to current 2023 levels. This will call for an increase in annual investments in grids from around USD 10 billion today to USD 29 billion in 2035 and USD 43 billion in 2050.

Unlike the United States, Europe or Japan, where much grid investment is driven by replacement of ageing grids, in Southeast Asia most of it is expected to be for new builds as only 27% is older than 20 years. Furthermore, it is expected that some of the growth will take place in the form of microgrids, especially in countries like Indonesia and the Philippines with many remote islands.

Microgrids with renewable power can provide sustainable access to electricity and accelerate decarbonisation, but technical, financial and business model challenges remain

Microgrids are small, local energy systems that generate and distribute electricity. They can function independently or connect to the main grid and are often used to provide power in areas without reliable access to electricity. Traditionally powered by diesel or gasoline generators, many microgrids are now shifting to renewable sources like solar panels, mini hydro plants and battery storage.

Renewable-based microgrids offer a sustainable solution for providing electricity to the approximately 18 million people in Southeast Asia who still lack access. In remote areas and islands, they present a viable alternative to extending the main grid, which is often not economically feasible. Microgrids can supply power for entire villages and towns, supporting both households and productive uses. In island nations like Indonesia and the Philippines, microgrids are already in operation. For example, the "Solar Para Sa Bayan" initiative in the Philippines launched Southeast Asia's largest solar-battery microgrid in 2018, bringing electricity to the town of Paluan, which was previously denied a grid connection due to limited supply from the main grid.

Despite their potential, several challenges remain. While solar PV and battery costs have dropped significantly, making renewable microgrids cheaper to operate than diesel-based ones – at levelised costs of 0.40-0.61 USD/kWh compared to diesel's 0.92-1.30 USD/kWh– the upfront capital investment for renewable technologies remains high. High interest rates and perceived risks with new technologies further complicate access to finance, hindering widespread adoption. Regulatory clarity and supportive policies are critical to overcoming these barriers. Governments can create frameworks that attract private investment and ensure grid compatibility, such as Indonesia's "Accelerating Electrification in Rural Areas" policy, which promotes rural microgrid deployment.

Technical challenges also arise from the region's diverse geography and climate, which demand tailored microgrid solutions. Island microgrids must withstand typhoons and high humidity, while inland systems face challenges from dense forests and mountainous terrain. Proper system design is crucial to ensure microgrids are resilient and fit for local environmental conditions. Notably, microgrids can enhance resilience in disaster-prone areas like the Philippines and Thailand. In remote area like Siesangtham in southeast Thailand, a grid-connected microgrid provides local power and increases resilience by its ability to disconnect from the main grid during outages, ensuring continuity for critical loads through batteries.

A major stumbling block to microgrid implementation is establishing a sustainable business model. Determining a cost recovery mechanism is difficult without clear regulations, but organisations like GET.transform are jumping in to fill this gap and are developing mini-grid regulation templates to accelerate regulatory processes and implement proven cost recovery schemes.

Another hurdle is assessing the right service level for microgrids, particularly in remote areas where market data is scarce, and community expectations shift as they gain access to reliable electricity. Identifying "anchor consumers" – large customers who can ensure consistent electricity demand and revenue – can help underpin both electricity demand and financial viability. For instance, a 3 MWp solar hybrid plant installed in Bonang, Indonesia, in 2019 provides power to a local mine, securing a steady load and revenue stream.

Once revenue is stabilised, the focus shifts to building a reliable operation and maintenance framework, an often overlooked barrier to implementing microgrids. This responsibility often falls to the host community, but remote locations face logistical difficulties, such as sourcing spare parts, which can delay repairs and raise costs. Additionally, local technicians may be in short supply, complicating the timely inspection and resolution of issues.

The village of Muara Enggelam in Indonesia has tackled this challenge by managing its solar-based microgrid through local technicians trained by the government and international organisations. Due to the economic growth benefits associated with electrification, the community not only decreased its dependence on government support but has also managed to cover all its operational and maintenance costs. This shows that empowering communities with the necessary tools, technical training and support systems is essential to ensuring the long-term sustainability of microgrids.

Despite the broad agreement on the benefits of grid expansion, challenges remain for its accelerated development for a secure energy transition

There are issues of global relevance pertaining to rapid grid expansion, which are also applicable to Southeast Asia and require enhanced attention. Grid development planning and access to capital should align with long-term national and regional decarbonisation targets so that undue risk is managed, and investors can be confident lending at internationally competitive rates. Regulation is key to ensuring project bankability and in setting appropriate tariffs for cost recovery. Industry readiness – including supply chains and skills – is crucial. However, novel circumstances highlight the need for Southeast Asia to find unique solutions that suit the region.

First, innovative approaches to financing are needed to mobilise the anticipated step-change increase in investment. They are also needed to grapple with the unconventional cross-border aspect of interconnectors, which are likely to be shared assets such as subsea cables. Unconventional funds and blended finance can be explored to extend the funding base, as these may respond to risk in a different way than fund providers do for conventional grids; however, this necessitates the reform of risk assessment approaches and agreement of cost sharing methodologies.

The bankability underpinning the projects will also be important to attract investment. It will be helpful to put in place a market design that enables interconnector projects to reap the intended benefits of cross-border trade. Even without complete harmonisation of market liberalisation across the region, price arbitrage between market areas (which could be countries) can create a clear monetisation strategy for investors of interconnectors. Explicitly valuing domestic spot prices (even as a shadow price without an actual market) can quantify interconnector benefits, allowing usage fee recovery in relation to them. Common asset financing facilities can also support investment in an environment with different market structures across borders.

Furthermore, planning a grid at a regional level and for a diverse set of scenarios strengthens business cases for transmission projects. Highlighting grid utilisation under a range of scenarios supports the business case for cost recovery because this is the basis for tariffs. Currently, Southeast Asian grid development tends to follow domestic PDPs, rather than regional scenarios. This approach overlooks the potential benefits of regional integration, which could reduce the need for extensive domestic grids and consolidate higher utilisation to fewer grid assets.

Finally, particularly for regional interconnection, responsibilities and accountability for cross-border assets need to be made more explicit. Supranational entities responsible for mapping out the steps and driving implementation forward need to be formalised, empowered and adequately resourced. They should prioritise and coordinate initiatives, drive action and track progress so that interconnection moves at a steady pace in the desired direction.

Regional, subregional and bilateral grid interconnection initiatives are increasing, with infrastructure development and power integration high on the agendas of ASEAN governments

The ASEAN Power Grid (APG) initiative envisions the interconnecting of all the power grids in all ten ASEAN countries. The regional agreement in the form of a Memorandum of Understanding (MoU) was signed in 2007 and expired in 2023; a Joint Declaration on interconnectivity was signed at the 41st ASEAN Ministers on Energy Meeting, prolonging the region's commitment to implement the APG. The reference master plan for infrastructure development for the APG is outlined by the ASEAN Interconnection Master Plan Study (AIMS). The latest plan (AIMS III) consists of 18 transmission projects with various target completion dates.

The Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP), initiated in 2014, is the most advanced multilateral power trading arrangement of the region. In 2022, it began trading 100 MW of hydropower from Lao PDR to Singapore via Thailand and Malaysia using existing transmission infrastructure. This is based on a power purchase agreement (PPA) between the power producer in Lao PDR and the off-taker in Singapore, and a wheeling agreement among the four involved countries. The current agreement runs until 2024, with potential plans to increase trade to 200 MW and extend the agreement for some years.

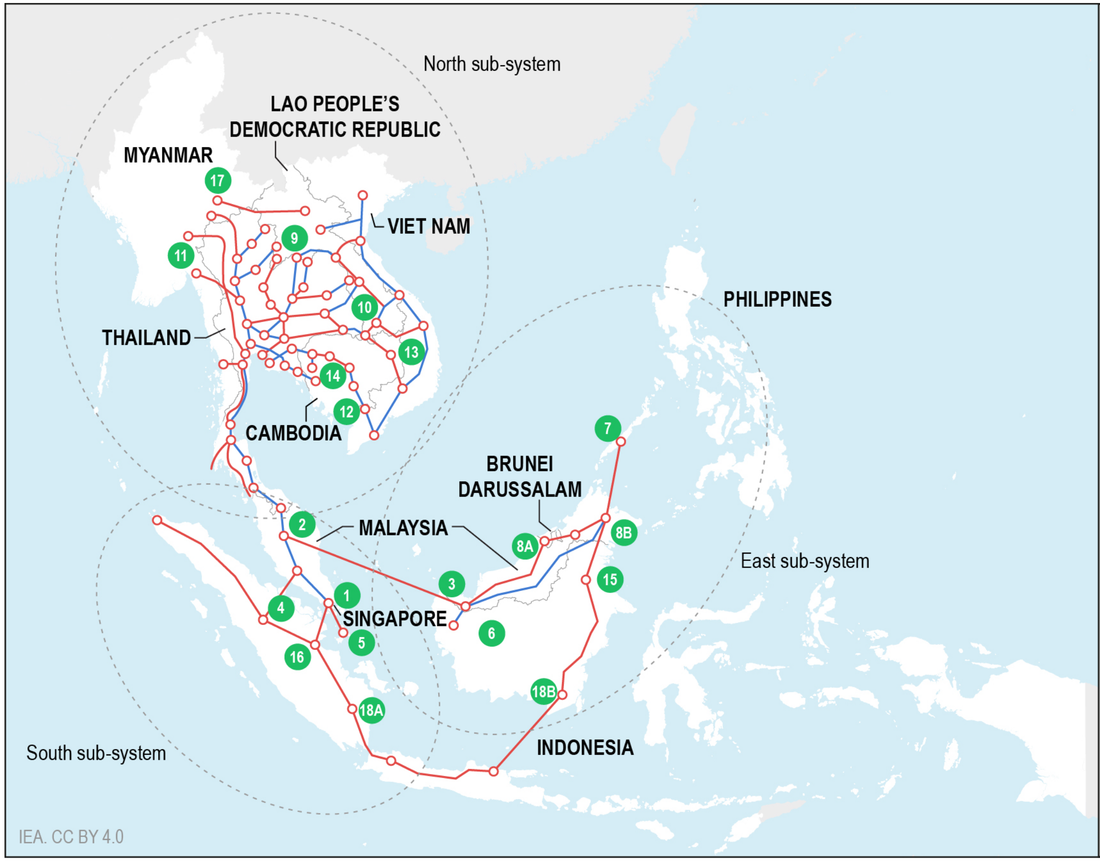
In contrast, the Brunei Darussalam, Indonesia, Malaysia and the Philippines Power Integration Project (BIMP-PIP) – launched in 2023 – requires new infrastructure. It will interconnect countries on Borneo with Palawan Island, the Philippines, through both onshore and offshore links. A feasibility assessment is currently being undertaken to study the project in detail.

Additionally, an intergovernmental agreement, followed by two MoUs for power trade among the six Greater Mekong Subregion (GMS) countries, was signed in 2004 to continue development towards the envisioned multilateral power trade initiative. It involves six countries: Cambodia, China, Laos, Myanmar, Thailand and Viet Nam, and aims to establish a regional power market, creating regulatory and technical standards for cross-border electricity trading. Infrastructure development focuses on developing and upgrading transmission lines to support cross-border electricity flows. While there have been agreements on certain technical and regulatory frameworks, full-scale implementation is yet to be realised. In 2022, the GMS Energy Transition Taskforce was established to advance implementation activities towards the multilateral power trade initiative.

Singapore aims to import up to 6 GW of low-carbon electricity by 2035, and this ambitious goal includes bilateral connections with multiple countries including Cambodia, Indonesia, Viet Nam, Sarawak (Malaysia), Australia and India.

The ASEAN Power Grid seeks to connect all ten countries through several interconnection projects, reflecting regional cooperation in ensuring security of electricity supply

ASEAN Power Grid Map



- Existing interconnection
- Planned interconnection
- Sub-systems

Status	MW
Existing	7 700
Ongoing project (up to 2025)	1 245
Grand total (up to 2040)	17 550

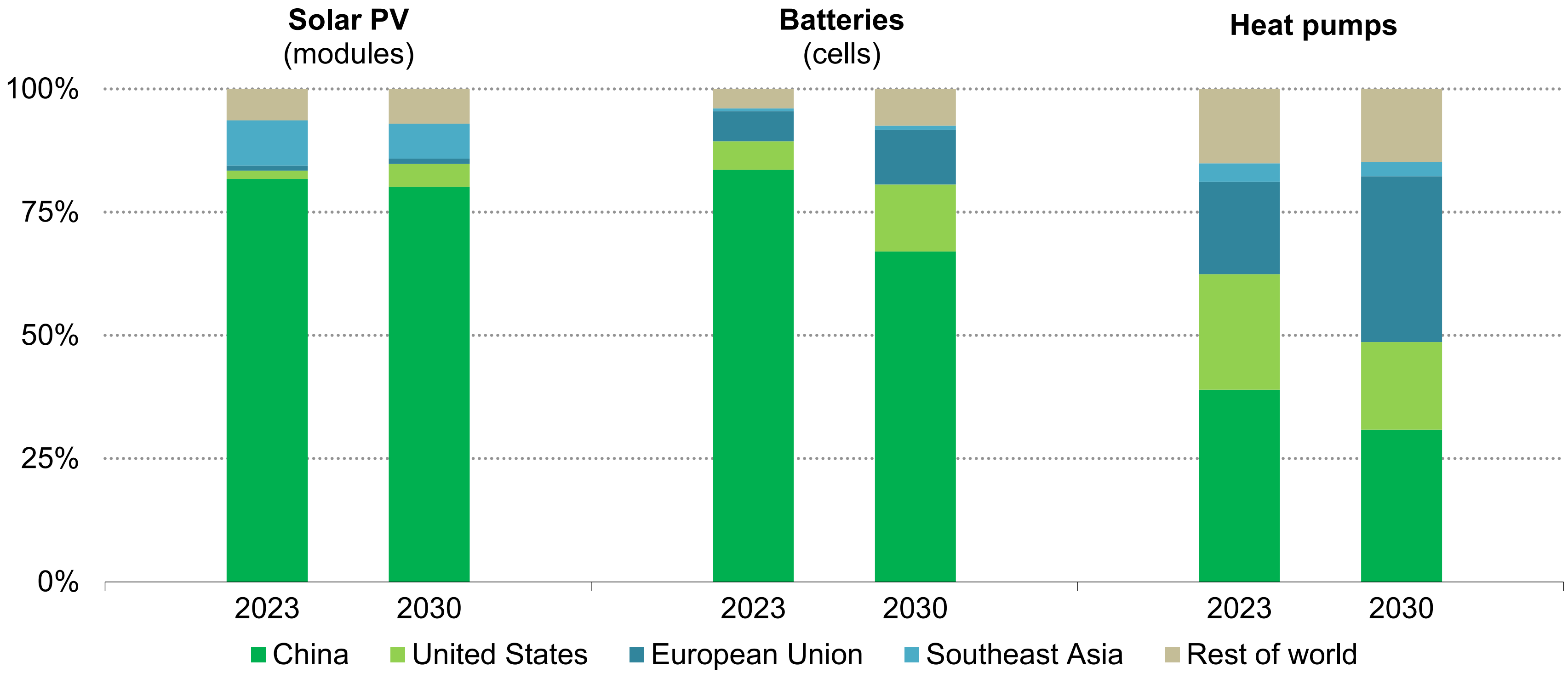
1. 275 kV Plentong - Senoko | 9.2 km
   Existing 1 050 MW
2. 110 kV Gurun - Khlong Ngae | 110km
   Existing 300 MW
4. 500 kV Telok Gong Malaka to Perawang | 234 km (50 km subsea)
   Year connect 2030 | 2 000 MW
5. Singapore - Batam subsued to Sumatra - Singapore Interconnection
6. 275 kV Mambong - Bengkayang | 126 km
   Existing 230 MW | Expand to 830 MW
7. 275 kV Kudat - Palawan 230 km (190 km subsea)
   Year to connect 2040 | 200 MW
8A. 275 kV Kuala Belait to Miri/Tudan | 45 km
   Year to connect 2025 | 100 MW
8B. 275 kV Lawas - Mengalong Sipitang | 31 km
   Existing 100 MW | Expand to 150 MW
9. 1. 115 kV Nong Khai - Dongphosy
   2. 115 kV Bueng Kan - Pakxan
   3. 115 kV Nakhon Phanom - Thakhek
   4. 115 kV Mudhakan - 2 Pakbo
   5. 115 kV Sirindhom - Bangyo
   6. 115 kV Tha Li - Paklay
   115 kV Mae Chan - Ton Phueng | 60 km
   Year to connect: 2025 | Expand 900 MW
   up to 1 300 MW
10. 220 kV Nam Mo - Ban Ve | Existing 570 MW
    500 kV Hax Tan - Pleiku | 94 km
    Year to connect : 2040 | Expand to 620 MW
11. 500 kV Hutgyi (Myanmar) to Phitsanulok | 300 km
    Year to connect : 2040 | 1,250 MW
12. 220 kV Chau Doc to Takeo| Existing 400 MW
    500 kV Savy Antor - Tay Ninh
    Year to connect: 2035 | 250 MW
13. Bypass at Lao Border from Don Sahong generation
    Exisiting 300 MW
    New: Banhat to Stung Treng | 85 km
    Year to connect: 2030 | Expand up to 200 MW
14. 115 kV Aranyaprathet to Poi Pet| Existing 240 MW
    500 kV Prachin Buri to Siem Reap | 300 km
    Year to connect: 2025 | Up to 250 MW
15. 275 kV Malinau - Kalabakan | 140 km
    Year to connect: 2030 | Up to 200 MW
16. 250 kV Paranap - Singapore| 260 km (100 km subsea)
    Year to connect : 2030 | Up to 1 600 MW
17. 115 kV Tonpheun to Tachilcik | Existing 30 MW
    230 kV from Muang Long to Ken Tung | 300 km
    Year to connect: 2035 | Up to 350 MW
18A. 500 kV Muara Enim (Sumatra) to Bogor 500 km
    (40 km subsea)
    Year to connect: 2030 | Up to 6 200 MW

Source: ASEAN Centre for Energy 2024, 8th ASEAN Energy Outlook.

Clean energy technology supply chains

Southeast Asia looks set to retain a stake in global solar PV manufacturing capacity even as leading economies also expand their facilities

Geographical concentration of current and announced manufacturing capacity for selected technologies, 2023-2030



Notes: The 2030 capacities are calculated as the sum of existing capacity at the end of 2023 and announced manufacturing capacity; an assessment of potential retirements is not included. Shares are based on manufacturing capacity.

Sources: IEA analysis based on data from Benchmark Mineral Intelligence, Bloomberg New Energy Finance, EV Volumes, InfoLink, S&P Global Commodity Insights, UN Comtrade, Wood Mackenzie, as well as announcements by manufacturers and personal communications.

The growing market for clean energy technologies presents fresh opportunities for Southeast Asia's strong manufacturing base

Clean energy technology manufacturing is surging worldwide, driven by growing consumer demand and new industrial strategies designed to ramp up capacity for key technologies, especially solar PV and EV batteries. The sector accounted for a record 4% of global GDP growth in 2023, and nearly 10% of global investment growth.

Around USD 200 billion was invested globally in clean energy technology manufacturing in 2023 – up 75% from the previous year. In Southeast Asia, investment amounted to almost USD 6 billion, more than double the amount invested in 2022, although there are big differences between countries, with Viet Nam and Thailand attracting the largest shares. The majority of investment in 2023 was for solar PV manufacturing (USD 5 billion), and around USD 800 million for EV battery cells and components.

Southeast Asia already has a strong manufacturing base, with manufacturing representing more than one-fifth of GDP – above the global average – in most countries in the region in 2022. However, in some countries, such as Indonesia, the share has declined over the past two decades as other sectors have outpaced the growth in manufacturing. However, the region's existing manufacturing strengths and the consumer power of its growing middle class point to opportunities to tap into the emerging markets for key clean energy technologies.

At the end of 2023, Southeast Asia had 106 GW solar PV module manufacturing capacity, more than three times the capacity in the European Union and United States combined. However, announced projects already committed – those that have reached an FID or are under construction – combined with anticipated plant retirements, are expected to cause capacity to remain unchanged or even contract to around 85 GW by 2030. Despite the lack of growth, capacity remains more than sufficient to meet the 28 GW of regional PV capacity additions expected based on announced policies, demonstrating the continuing importance of the export market.

While clean tech manufacturing creates new opportunities for the region, other countries are also stepping up manufacturing by onshoring or "friend-shoring" steps of the supply chain to build resilience. In this context, the relative positions of some Southeast Asian countries look set to change. In 2023, Viet Nam, Thailand and Malaysia were the world's largest solar PV manufacturers after China. However, based on announced additions, they will have less capacity than the United States and India by 2030. With price declines and concerns about surplus capacity globally, it may become more challenging for the region's solar PV manufacturers to remain competitive.

Southeast Asia can play to strengths in solar PV and EV battery supply chains

Many of Southeast Asia's solar PV manufacturing plants are owned by companies headquartered outside the region, particularly in China, partly due to cost advantages, but also because location in the region previously allowed them to circumvent import tariffs imposed on Chinese manufacturers in the United States. Such practices have since been limited, and in October 2024 the US government announced countervailing duties on imported solar PV panels from certain Southeast Asian countries in an effort to prevent stockpiling.

Major solar PV and EV battery manufacturing facilities operating in Southeast Asia, 2023

Company (solar PV)	Location	Country of company HQ	Production capacity (GW)
LONGi	Viet Nam	China	9
Runergy	Thailand	China	9
Canadian Solar	Thailand	Canada	7.46
JA Solar	Viet Nam	China	5
Trina	Viet Nam	China	5
Company (EV battery)	**Location**	**Country of company HQ**	**Production capacity (GWh)**
Samsung SDI	Malaysia	Korea	11
Energy Absolute	Thailand	Thailand	1 (Plans to expand to 4 by 2025)
Murata	Singapore	Japan	4

While the majority of existing solar PV capacity is for module manufacturing, project announcements look set to strengthen capacity across the supply chain. Based on committed project announcements, Southeast Asia will have 87 GW of solar cell manufacturing capacity by 2030, up from 79 GW at the end of 2023. An additional 17 GW for wafers is also expected by 2030, a 65% increase on the capacity installed at the end of 2023. Polysilicon capacity should increase to 16 GW by 2030, up from 14 GW at the end of 2023.

In the APS, EV adoption accelerates in Southeast Asia, reaching an EV demand equivalent to almost 120 GWh of batteries by 2030. This is a steep rise from demand in 2023 (10 GWh). Accelerating manufacturing of EV batteries and their components is therefore a strategic target of policy initiatives in several countries.

The region was home to 16 GWh of EV battery cell manufacturing capacity at the end of 2023, and this is expected to expand, with 39 GWh of committed planned additions by 2030, and a further 23 GWh in preliminary announcements. The leading countries are Malaysia, Viet Nam and Indonesia, with around 1% of committed battery manufacturing capacity globally in 2030.

Notable too are planned additions for upstream battery components – the cathode and anode active materials needed for the manufacture of lithium-ion batteries. As estimated from committed and preliminary announcements, cathode manufacturing could grow to over 160 GWh in 2030, a more than sixteen-fold increase from 10 GWh of installed capacity in 2023, although only 18 GWh is committed. Anode manufacturing could also mushroom, from zero capacity in 2023 to more than 200 GWh by 2030, although only half of the announced projects have reached an FID or begun construction.

Indonesia is set to become one of Southeast Asia's largest manufacturing hubs for lithium-ion batteries, and by far the largest for components, thanks to its abundant raw material resources, particularly nickel. Scale-up in Southeast Asia is underpinned by partnerships with manufacturers from outside the region. In 2024, Indonesia announced the start-up of an EV battery cell plant with 10 GWh capacity developed through a partnership between Hyundai, LG Energy Solution and the Indonesia Battery Corporation, backed by a USD 9.8 billion investment.

In addition, the local content ruling introduced in 2023 in Indonesia which limited purchase incentives to only EV models with at least 40% local content has been relaxed until 2026 to give manufacturers more time to invest locally. The ruling has encouraged international companies to set up EV manufacturing facilities in the country, such as BYD (China) and VinFast (Viet Nam), which are expected to open plants in the coming years.

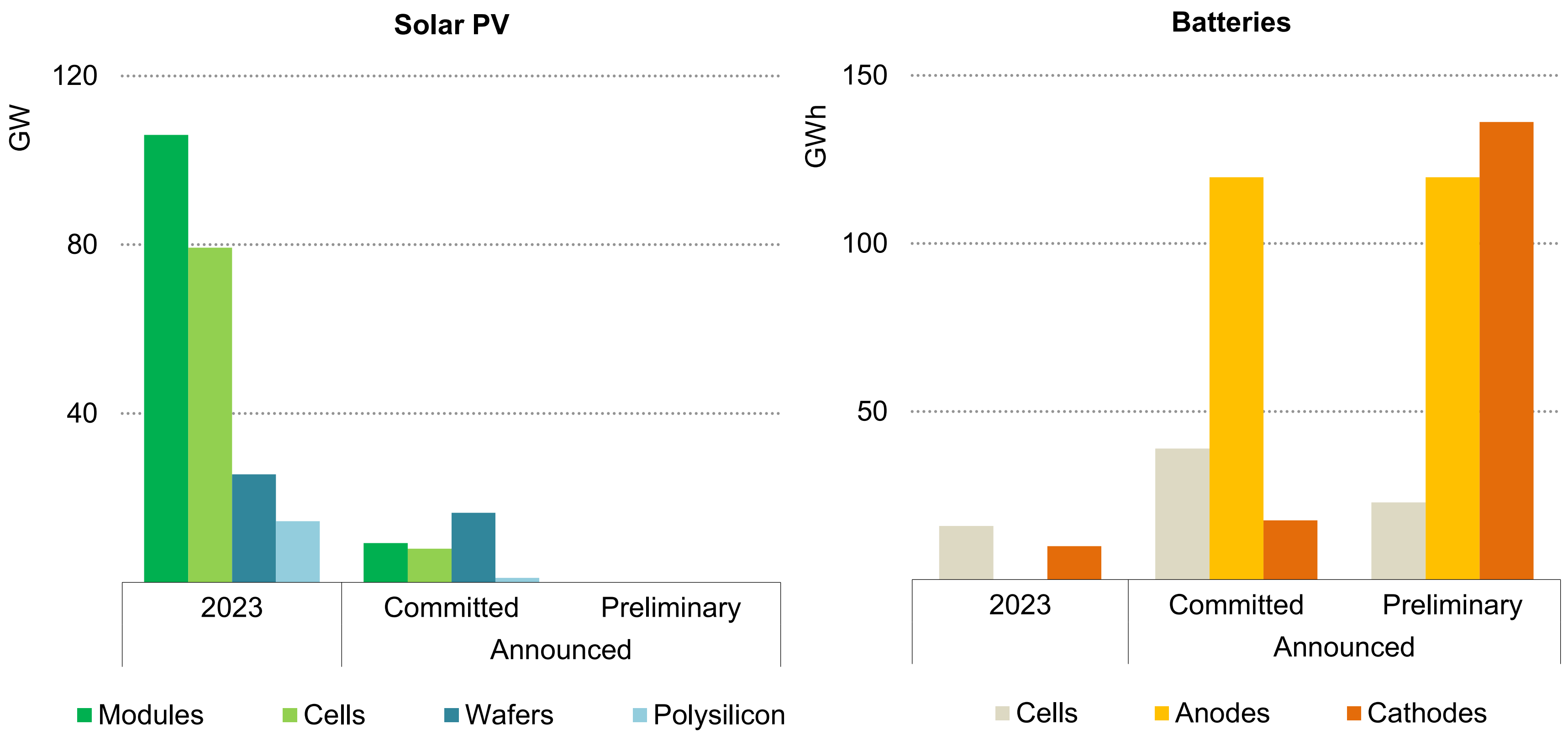
In Indonesia, the 10 GWh of battery manufacturing capacity announced for 2025, and the 20 GWh for 2030, is all in plants belonging to companies headquartered in Korea. Likewise, all 11 GWh of existing capacity in Malaysia is owned by Korean companies. Announced additions would imply that by 2030, this will have increased to 29 GWh, while plants owned by Chinese companies will account for 15 GWh. All additions announced for Singapore (4 GWh in 2030) are from companies headquartered in Japan, while in Viet Nam, they are from companies headquartered in China (5 GWh). In Thailand, which has implemented a USD 700 million subsidy scheme to reduce the cost of producing EV batteries domestically, Thai companies are expected to account for 4 GWh of capacity by 2030, while US-headquartered companies will account for 1 GWh. The region's first lithium-ion battery gigafactory was established in Thailand.

Elsewhere, changing import restrictions in the rest of the world could have mixed effects for Southeast Asian clean technology manufacturers, especially in the short-term. Regional and international cooperation, and transparency in the supply chain, will be key to ensuring minimal disruption.

The region is also attracting venture capital (VC) investments in novel battery chemistries, such as Singapore's VFlowTech, which raised USD 10 million in 2023 for its work on vanadium redox flow batteries, a technology that has the potential to offer multi-day stationary storage.

Announced projects could lead to strong upstream growth in EV battery component manufacturing

Projected maximum output from existing and announced projects for solar PV and EV battery component manufacturing, 2023-2030



Notes: 2023 production values reflect estimates of actual utilisation rates. A utilisation rate of 85% is used for both existing and announced manufacturing capacity in 2030. Cathode and anode refers to active materials.
Sources: IEA analysis based on data from Benchmark Mineral Intelligence, Bloomberg New Energy Finance, EV Volumes, InfoLink.

Critical minerals offer Southeast Asia opportunities to be a major contributor to global supply chain diversification

In recent years, Southeast Asia has become a global powerhouse for the supply of critical minerals essential for the clean energy transition. The rapid growth in the supply of minerals such as nickel and rare earths has alleviated global supply tensions, despite the substantial demand growth driven by clean energy technologies. Rare earth mining in the region has more than doubled over the past five years. For nickel, global demand increased by 30% (750 kt) over the same period, while mined output ramped up much faster, increasing by 1 200 kt.

Due to the lack of downstream value chains, Southeast Asia's mining outputs currently integrate with incumbent downstream industrial players, reinforcing existing supply chain structures. Myanmar's rare earth extraction occurs close to the border with China and is directly exported there. Similarly, while Indonesia is the dominant nickel mining and refining country, domestic transformation into nickel sulphate – a key battery compound – remains limited. China dominates nickel sulphate production globally, using Indonesia's intermediate products. In 2023, 1.4 million tonnes were refined in Indonesia, while only 12 kt were transformed into nickel sulphate.

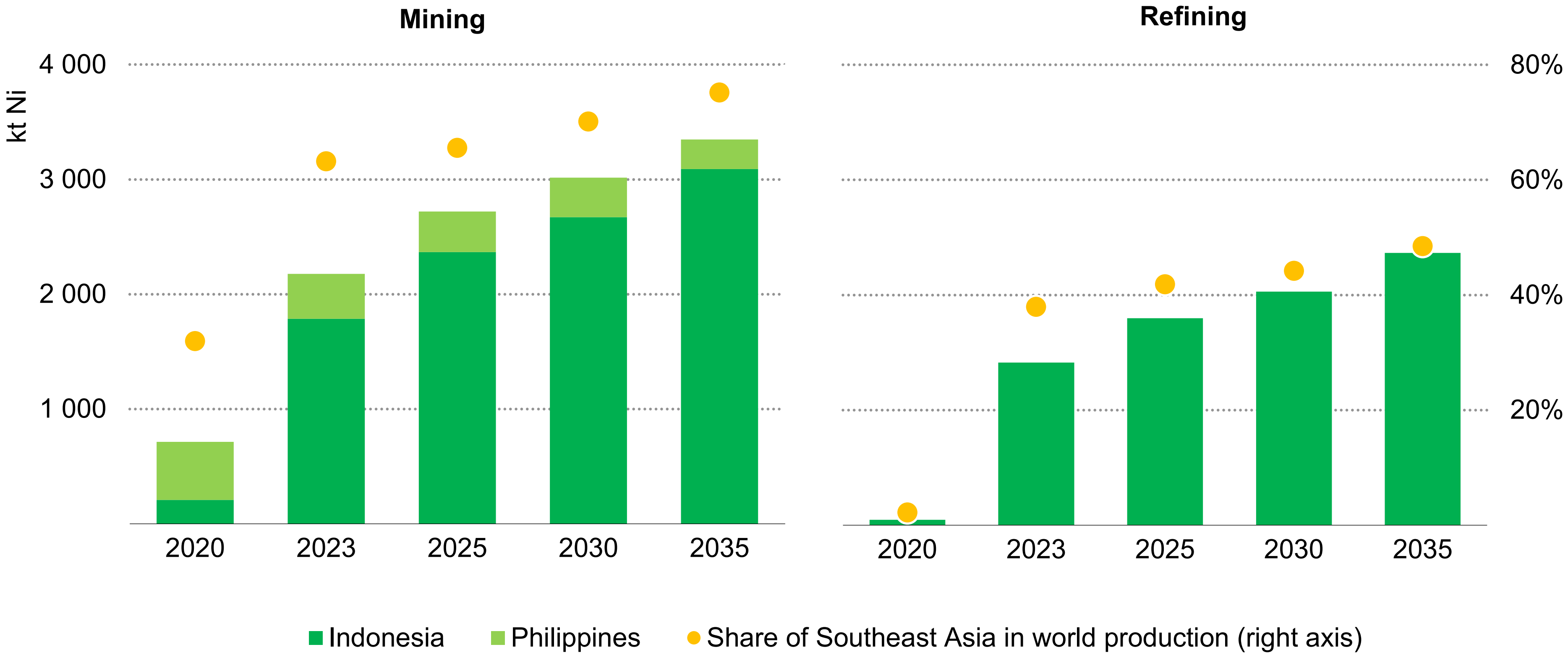
However, Southeast Asia has potential as an attractive region to diversify global critical mineral supply chains. Malaysia hosts rare earth refining capacities, owned by the Australian company Lynas. With plans for further expansion, Malaysian production of rare earth oxides is expected to grow to 10% of global production by 2030. Viet Nam, endowed with the world's second-largest rare earth resources, has ambitions to increase domestic production and attract investments from diverse sources. In the Philippines, strategies aim to leverage nickel resources to attract investors pursuing diversification.

Indonesia is a success case in developing midstream and downstream value chains. Cobalt is extracted as a by-product of nickel mining and the country's strong push to strengthen nickel refining has also recently positioned it as the world's second largest cobalt supplier, providing an option to diversify global supply. Indonesia is also expanding into lithium refining and anode material production to supply the battery industry, including domestically.

Malaysia is developing polysilicon manufacturing capacity, increasing from 35 kt to 56 kt, corresponding to about 17 GW solar capacity. Malaysian polysilicon is expected to find buyers among Vietnamese solar PV manufacturers, responding to regulations to access the US market.

The rapid growth of nickel supply from Southeast Asia fuels global production of batteries, and offers the potential to build a regional downstream manufacturing value chain

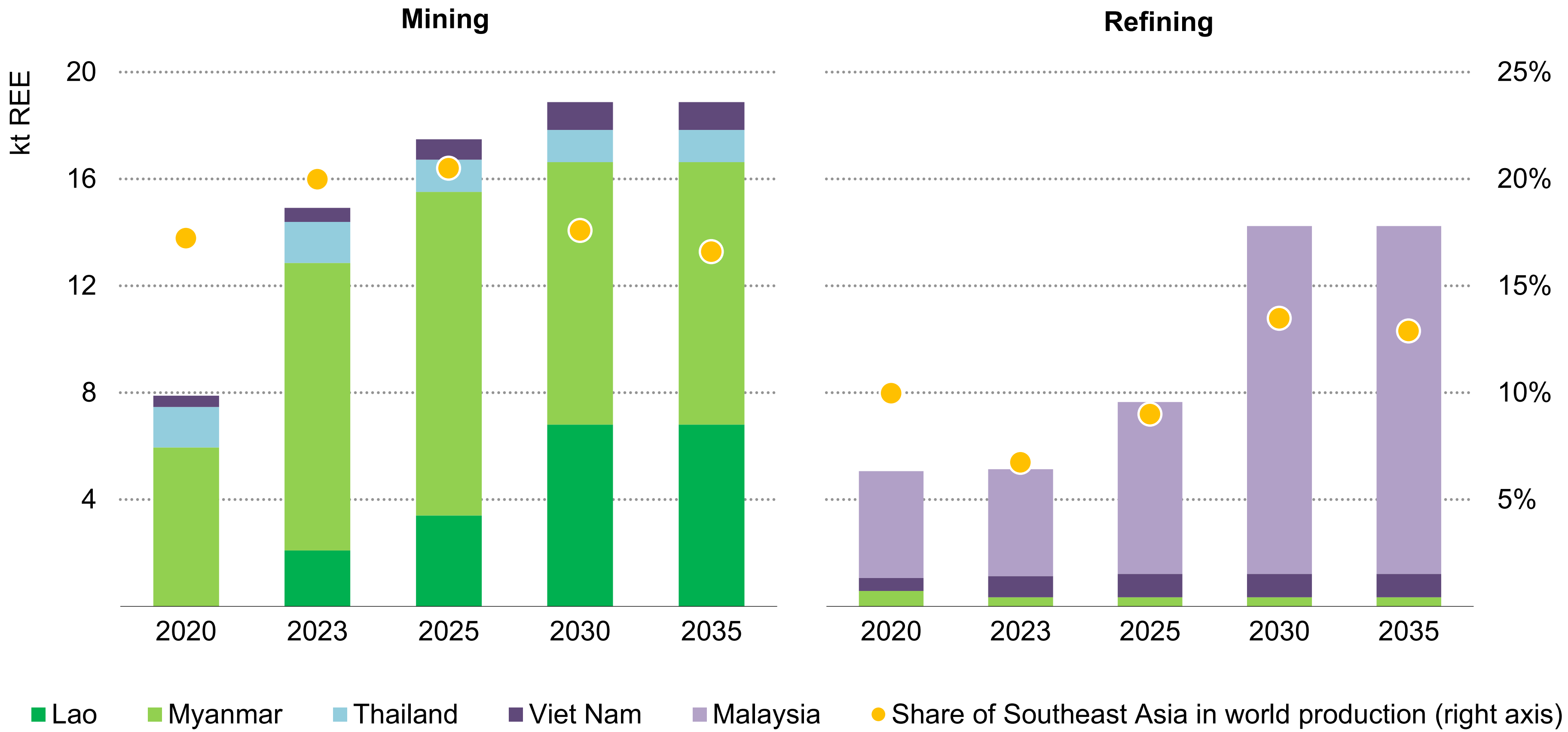
Nickel production in base case supply scenario, 2020-2035



Note: Nickel refining includes nickel that is processed into either a metal, oxide, nickel pig iron (NPI), ferronickel, or sulphate and excludes outputs from intermediate. For more information on the base case supply scenario, see the Global Critical Minerals Outlook 2024.

Southeast Asia is becoming a key rare earth supplier, both of raw materials for established manufacturers and as a region to diversify refining operations

Share of Southeast Asia in global magnet rare earth production, base case supply scenario, 2020-2035



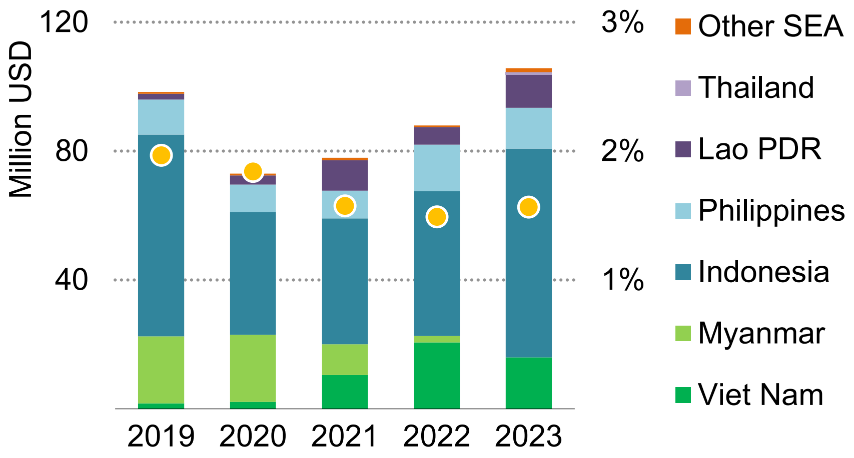
Notes: "REE" = rare earth elements. The figures are for magnet REE only (neodymium, praseodymium, dysprosium and terbium). For more information on the base case supply scenario, see the Global Critical Minerals Outlook 2024.

Opportunities exist to boost critical minerals exploration and bolster environmental, social and governance (ESG) performance

Exploration and mineral development

Southeast Asia's potential in the mining and refining of critical minerals presents significant challenges and opportunities. Exploration spending in the region lags behind other resource holders globally, even on minerals of which the region appears as a key supplier and resource holder. After a significant fall in the 2010s, exploration investment in the region has been growing steadily since 2020, though at a slower pace compared to global industry trends. Geological surveys and data access play key roles in attracting private investment in mineral exploration.

Exploration spending by country, excluding gold and diamonds



Source: IEA analysis based on S&P Global.

Innovation

Fostering innovation and developing skills in key areas such as mining engineering and environmental management can further increase the competitiveness of the mining and metals sector, while also helping the industry reduce its environmental and social impacts. The development of high-pressure acid leaching (HPAL) technology, helped by Indonesia's downstream policy to develop domestic value chains, was integral to the boom of Indonesian nickel production. Southeast Asia can continue to advance the latest extraction and processing technology through collaboration, leveraging its attractiveness to international mining and refining companies and investors.

Regional and international cooperation

Critical minerals are identified as a key area of regional cooperation. The ASEAN Minerals Cooperation Action Plan Phase 2 (2021-2025) aims to enhance trade and investment and strengthen capacity building for sustainable mineral development. Activities include supporting international partnerships, including those with South Africa and Korea. These dialogues can facilitate the integration of Southeast Asian resources, local manufacturing capacities and global clean energy supply chains. Other topics may involve sharing best practices in resource and environmental management as well as consolidating regional data on supply, trade and demand. In 2023, ASEAN Ministers adopted the Principles on Sustainable Minerals Development, which called for the development of an ASEAN Minerals Development Vision.

Improving ESG performance and due diligence

Improving environmental, social and governance (ESG) performance is key to supporting the development of sustainable and responsible supply chains in Southeast Asia. The rapid growth of mining and metals activities can result in ESG performance lagging behind. Increased energy requirements may create concerns about emissions levels. There are environmental challenges such as biodiversity impacts and risks relative to tailings management. Engaging local communities in decision-making processes for land use planning, mining and refining activities is essential to identifying, avoiding and minimising risks. Corruption risk is also relevant for countries with existing local governance challenges.

Existing frameworks at both the national and company levels can support best practices for countries and companies aiming to improve ESG outcomes. For example, the Extractive Industries Transparency Initiative tracks progress in governance and data availability. Some countries in the region have made significant strides, such as Indonesia, which has made "meaningful progress" since 2017 and the Philippines, which has achieved a "moderate" overall score. Myanmar, however, was delisted in March 2024 due to "ongoing political instability and conflict". Industry-led initiatives, such as the Initiative for Responsible Mining Assurance standard, have supported efforts to provide detailed third-party audits available in Africa and the Americas, but mines in Southeast Asia have yet to follow through.

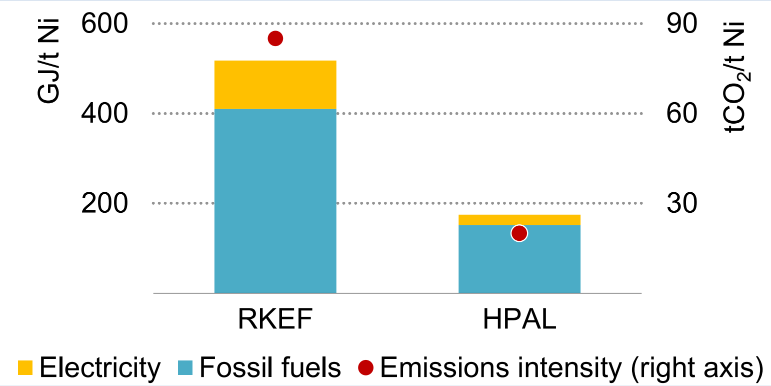
In Myanmar, most rare earth mining operations are carried out close to the Pang War-Tengchong border crossing with China in Kachin State, which is under the control of various groups such as the Kachin Independence Organisation (KIO), and also other conflicting militias. Recent developments include closures of the border, environmental protests, pledges from the KIO to regulate extraction as well as increased ambitions from Chinese authorities to regulate imports and refining of rare earths. These mining activities, in areas where environmental governance is weak, are associated with significant pollution, and also risk fuelling conflict. The complex set of ESG challenges in this high-risk area and its critical importance to permanent magnet supply chains highlight the need for increased downstream transparency and enhanced due diligence efforts, in alignment with OECD guidelines. Efforts to identify and assess risks in the supply chain would then allow mitigation measures and improvement tracking, in alignment with Annex III of the OECD guidelines.

Options to reduce emissions associated with Indonesia's carbon-intensive nickel production

Nickel is crucial for batteries and the global energy transition, with demand and production expected to surge in the coming decades. Indonesia's recent growth in nickel production positions it to become a leading supplier. From 2018 to 2023, annual mined nickel production in the country tripled from 0.6 Mt to 1.8 Mt and could grow to over 3 Mt by 2035 in the base case supply scenario. Production of refined nickel products has increased more than fivefold in the country in the last five years, mainly due to the Indonesian ban on nickel ore exports. Much of this growth has come from the energy-intensive processing of lower-grade nickel ores through rotary kiln electric furnaces (RKEF) to intermediates suitable for use in batteries. In 2023, energy demand for the refining of nickel in Indonesia was more than 700 PJ, primarily met by coal. High-pressure acid leaching (HPAL) process, which recovers nickel from laterite resources, is becoming increasingly popular in Indonesia. The process of using HPAL results in high waste production but lower emissions, compared to RKEF processing. If unchecked, growing nickel production in Indonesia could drive an increase in CO_2 emissions associated with this sector by more than 50% in 2035 in the STEPS. Indonesia is working to reduce the carbon footprint of its nickel operations but achieving the long-term goal of net zero emissions by 2060 will require substantial efforts and additional policy incentives.

Chief among such efforts is the shift from captive coal plants to renewable power generation. More than 7 GW of captive coal power capacity in Indonesia is operated for nickel refining, with around another 10 GW in the pipeline. There is scope to partially replace coal with natural gas, bioenergy and other low-emissions fuels for heat or as reductant in the refining process. Emissions can also be mitigated by developing less energy-intensive refining processes and promoting electrification, for example by increasing the share of HPAL refining plants compared to RKEF.

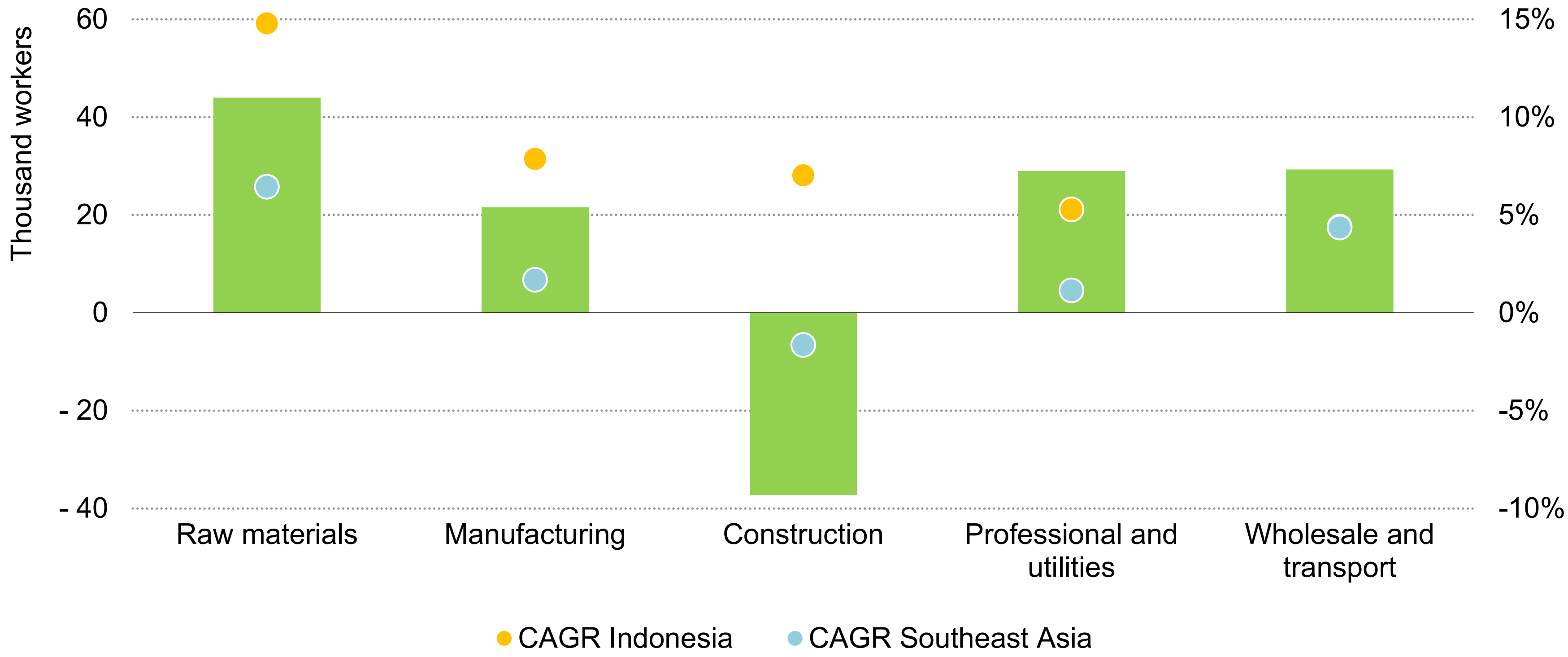
Energy and CO_2 emissions intensity of nickel refining processes



Notes: Global averages. Emissions intensity includes both direct and indirect CO_2 emissions from electricity generation.

With efforts to establish the region as a global manufacturing and industrial hub, clean energy transitions have created more than 85 000 jobs in Southeast Asia over the past five years

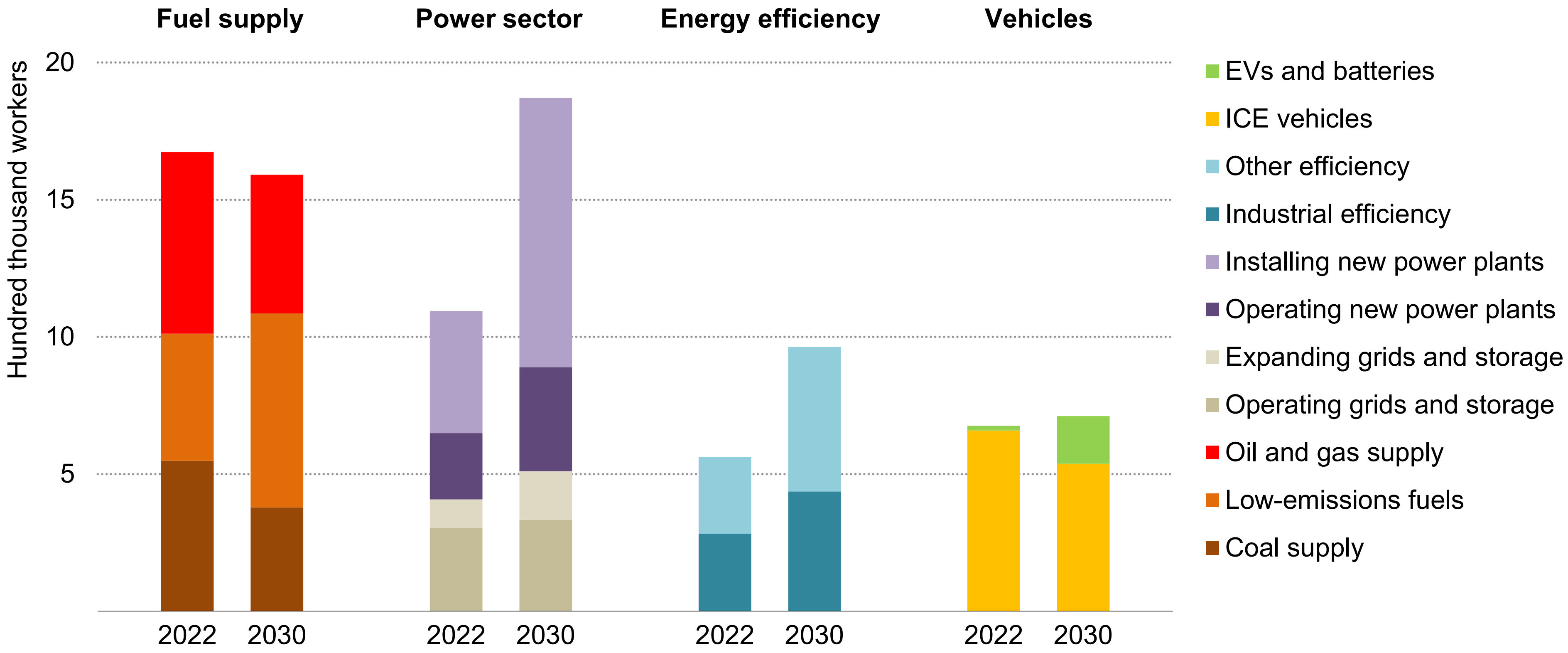
Clean energy employment change by economic activity in Southeast Asia, 2019-2023



Notes: "CAGR" = Compound annual growth rate. "Raw materials" employment includes workers engaged in the mining and extraction of fuels and critical minerals, and agriculture to produce bioenergy. Construction employment in clean energy technologies decreased between 2019 and 2023, largely due to a surge in solar PV installations in 2019. Increased deployment in that year was driven by generous feed-in-tariff programmes in countries like Viet Nam, which have since then been revised. Other factors include grid infrastructure limitations, delayed policy implementation and disruptions in supply chains following the Covid-19 pandemic.

The energy transition is a net creator of jobs but requires all parts of the energy sector to pivot their workforce to different segments

Energy employment in Southeast Asia by technology in the Announced Pledges Scenario, 2022 and 2030



Notes: “ICE vehicles” = internal combustion engine vehicles; “EVs” = electric vehicles. “Other efficiency” includes building retrofits, heat pumps and other equipment, and appliances. “Low-emissions fuels” include bioenergy supply, nuclear supply, hydrogen supply and critical minerals.

Clean energy employment has grown by 4% since 2019, led by strong growth in clean manufacturing employment, while fossil fuel jobs decreased over the same period

Over 4 million workers were employed in the energy sector in Southeast Asia in 2022, with Indonesia accounting for 1.6 million of these jobs. Between 2019 and 2022, fossil fuel jobs decreased by 1.5% in the region, while clean energy jobs increased by almost 4%. Clean energy employment is set to surpass fossil fuel jobs in the coming years, already accounting for 48% and 52% of total energy sector employment, respectively, in 2022. Clean energy investment reached nearly USD 30 billion in 2022 in the region and is set to more than double by 2030 in the STEPS.

Around 30% of clean energy job growth in Southeast Asia can be attributed to the manufacturing sector. Manufacturing employment increased by more than 20 000 jobs between 2019 and 2022. This growth in employment reflects efforts to establish the region as a global hub for clean manufacturing in a number of energy sectors, including solar PV modules and EV batteries. In 2021, the Indonesian government set a target to manufacture 140 GWh of battery capacity by 2030 through the Indonesia Battery Corporation in an attempt to become a leading supplier of EV batteries; various policies have been introduced since then in the country to support EV use, such as reduced value-added tax and subsidies. In addition, Viet Nam and Indonesia joined the ranks of exporters of solar PV modules in 2022.

More factories are opening up in the region, solidifying Southeast Asia's place as a global manufacturing hub. Hyundai and LG Energy opened Indonesia's first battery cell factory in 2023, a USD 1.1 billion project. Malaysia also witnessed a significant boom in recent years, with a number of new manufacturing plants, including Samsung's USD 1.3 billion battery manufacturing project in Seremban. China's BYD, the world's largest EV maker, opened a USD 490 million EV factory in Thailand, its first in Southeast Asia.

Together, mining and manufacturing accounted for over two-thirds of total clean energy job growth in Southeast Asia between 2019 and 2022. Notably, employment in the extraction of critical minerals increased by over 30%, with Indonesia leading the way as the largest producer of nickel in the world. In recent years, Indonesia has attracted billions of dollars of investment from battery makers and auto manufacturers, with Chinese companies dominating its nickel industry.

Though coal supply jobs decrease by 2030 in the STEPS, the growth in jobs (around 40%) in clean energy sectors over the same period, including low-emissions power, EV and batteries, and industrial efficiency, ensures that the energy transition is a net creator of jobs in Southeast Asia over the coming years.

Improved labour productivity drives near-term decline in coal employment, signalling long-term uncertainties over the implications of energy transitions for the sector

Coal supply employment in Southeast Asia totalled over 540 000 jobs in 2022. Indonesia, one of the three largest coal producers in the world, accounted for more than 80% of these jobs. Coal mining jobs, which do not include jobs in coal power generation, represent a significant share of total employment in the region, accounting for almost 30% of total energy jobs in Indonesia. Formally employed coal miners tend to be relatively well-paid in the region, amplifying the importance of employment in the coal industry to local economies. Coal miners are paid over one and half times the average wage of industrial workers (in manufacturing, construction and utilities) in the country. However, pay and working conditions are poor for informal workers, especially in illegal mining operations, where such miners generally earn a fraction of what a formal worker makes.

The average number of workers per tonne of coal extracted is much higher than the averages in advanced economies but is declining due to mechanisation. In the Quang Ninh province of Viet Nam, longwall mining using mechanised shearers, automated conveyor systems and hydraulic roof supports, has had significant impacts on labour productivity: for certain operations, the workforce required has decreased by 30-50% over the last decade. As a result of labour productivity improvements among the large coal producers in Southeast Asia, coal mining employment decreased by 2% between 2019 and 2022 and is projected to further contract by 2030 in the STEPS even though coal production climbs over the same time period.

Highly coal dependent countries like Viet Nam and Indonesia are particularly at risk of challenging transitions, with social implications often concentrated in specific regions. For instance, while coal mining represented around 1% of national employment in Indonesia in 2022, coal mining jobs accounted for around 9% of the total in the coal-intensive region of East Kalimantan. The provinces of Kalimantan totalled 6% of the country's population but around 90% of its coal production, with the coal sector's share of regional GDP reaching 35%, compared to 2% at the national level. Although not all the wealth embodied in regional GDP remains in the region, the share of coal mining in local employment is a meaningful metric as workers are likely to spend their income locally.

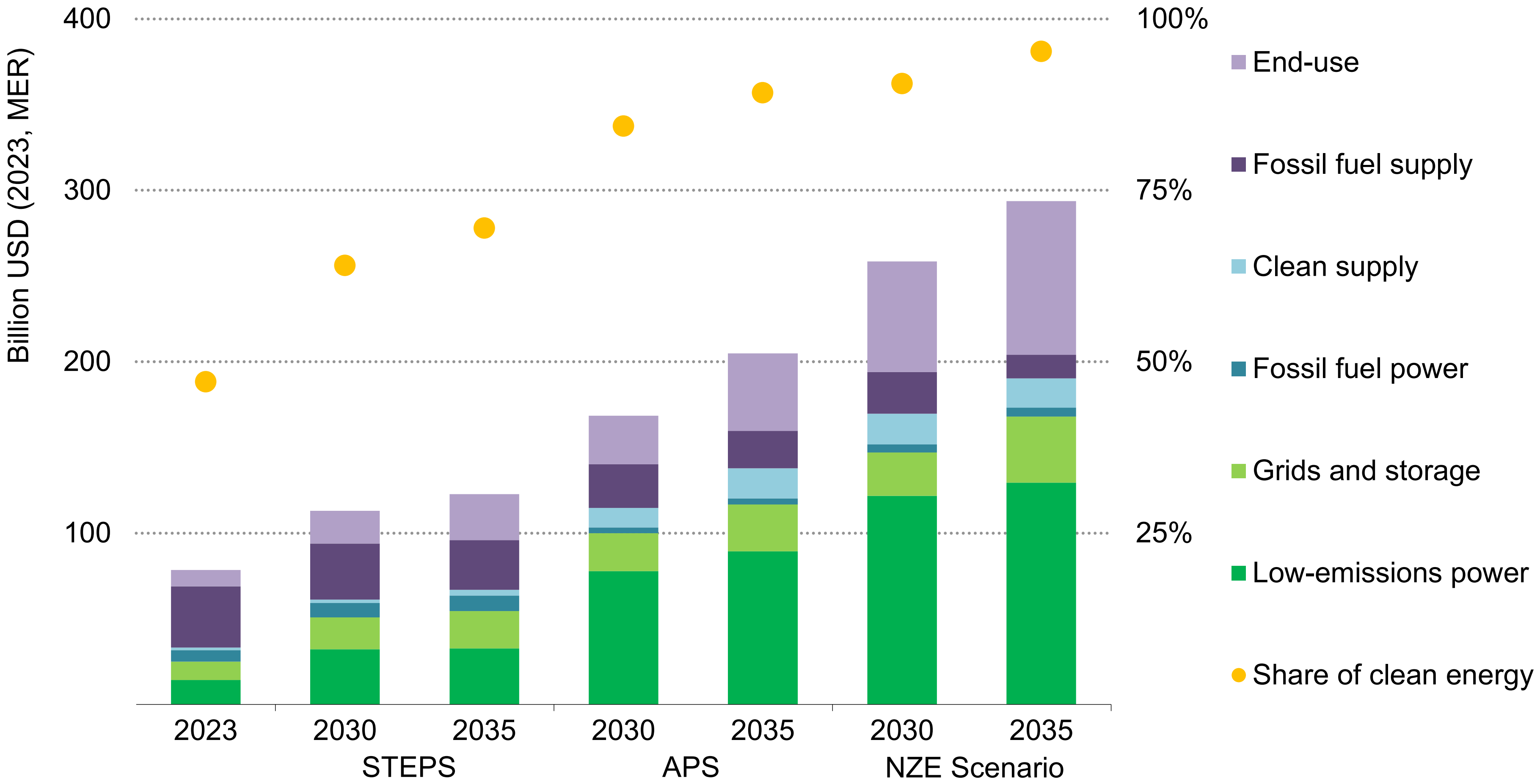
Coal employment is set to fall in all scenarios, but only slightly faster than the natural retirement rate in key locations. In Indonesia, the decline in coal miners in the APS is more rapid than the natural retirement rate at 60 years old but shifting the retirement age from 60 to 55 would align closely with the employment needs, assuming no new hiring. Accordingly, assuring a just and orderly transition involves focusing resources on workers who are likely to remain economically active after leaving the sector through redundancy.

It is critical to begin planning early as training workers for alternate employment can take years. Support for coal workers can take the form of retraining programmes, vocational schools, economic diversification measures, local re-hiring, job reallocation services, and retirement plans. Measures to boost economic development and diversification will be especially important in Southeast Asia, with countries like Indonesia relying heavily on coal mining activities in their economy and energy mix.

3.3 Investment and finance

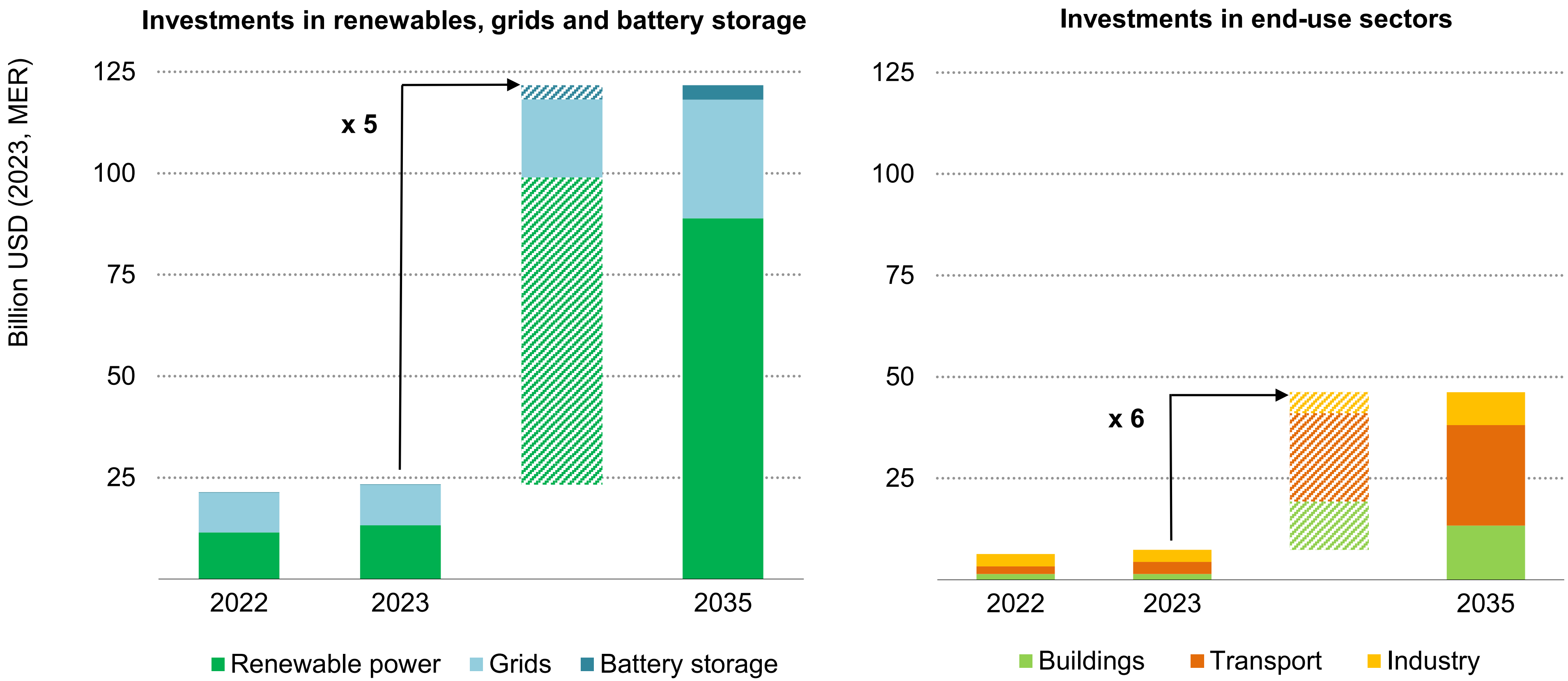
While most countries in Southeast Asia now have ambitious long-term clean energy goals, the investments required to meet these targets are not yet on track

Total energy investment and share of clean energy investment in the total in Southeast Asia by scenario, 2023-2035



Current clean energy spending for renewable power, grids, battery storage and energy efficiency needs to scale up rapidly to meet announced energy and climate pledges

Investments in renewable power, grids and battery storage, and in end-use sectors in Southeast Asia in the Announced Pledges Scenario, today and 2035



Note: To 2030, investments in renewables, grids and battery storage increase just under fivefold in the APS, and investments in end-use sectors increase fourfold.

National efforts to mobilise investment need to be complemented by enhanced international finance and support

In the STEPS, annual clean energy investment more than doubles in 2035, compared to 2023 levels, reaching over USD 90 billion. The APS requires a steeper increase, to nearly six times today's levels, with clean energy spending exceeding USD 190 billion in 2035. Two-thirds of this spending in the APS is allocated to clean electricity, while efficiency and end use continue to constitute around a quarter of the total, because rising urbanisation and the need for more efficient buildings, cooling appliances and transport alternatives raise required investment costs. In the APS, the stock of air conditioners rises from 40 million units today to over 190 million units by 2035, and this increases energy consumption by an average of 14 TWh or 8% per year over this period. EVs currently represent around 5% of passenger cars sold in the region and increase to 60% by 2035 in the APS. Investment in low-emissions fuels is limited in the STEPS but reaches almost USD 18 billion annually by 2035 in the APS.

The major challenge ahead for the region will be to invest in energy security with a focus on clean energy. To support the expansion of capital flows, Development Finance Institution (DFI) financing can play an important role in de-risking projects, while transition finance can provide funding for energy transitions in energy intensive sectors.

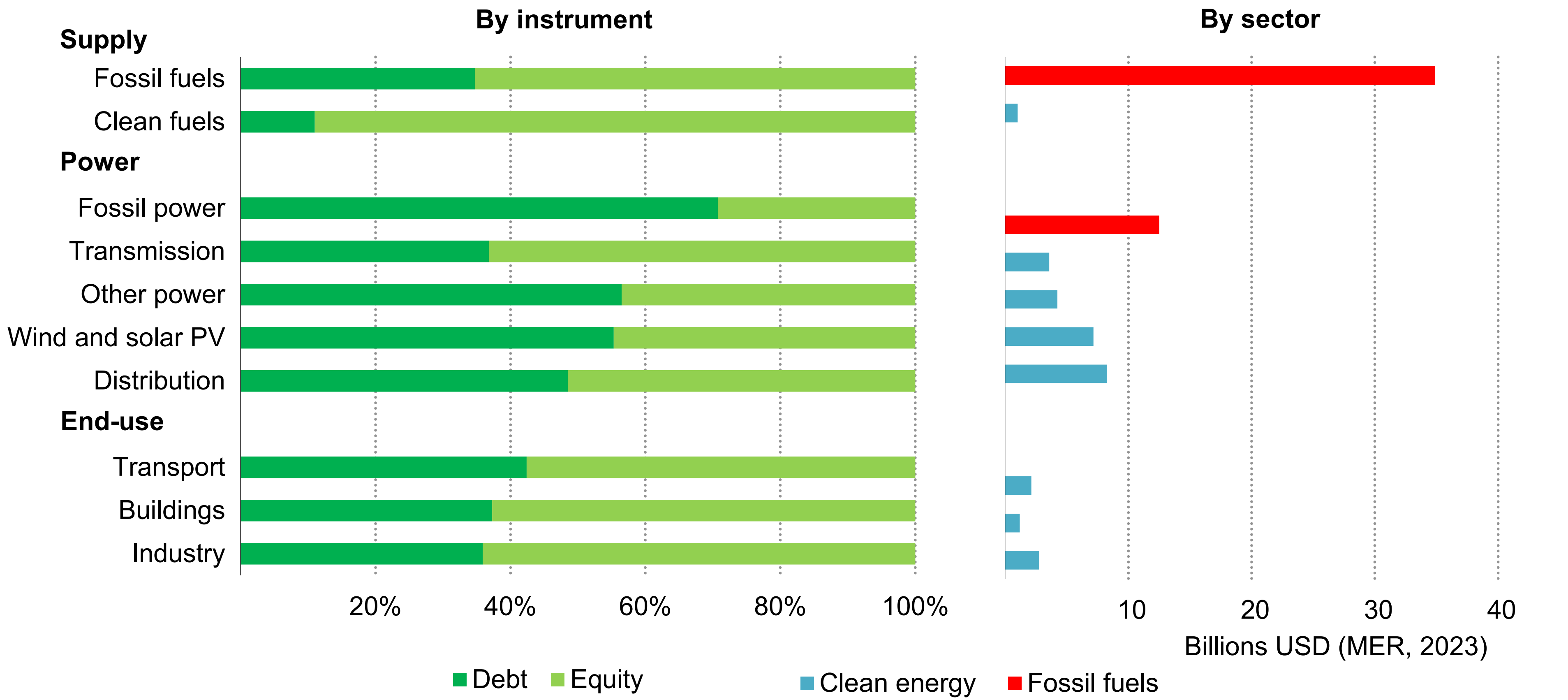
Some countries are signalling a shift in priorities, for example, Viet Nam's PDP8 reflects ambitions to reshape its electricity system, including by extensive development of renewables, the use of low-emissions hydrogen and ammonia and a reduced reliance on unabated coal. However, the implementation plan is not yet fully clear and over 10 GW of new coal-fired capacity remains in the pipeline.

Updated expansion plans for low-emissions power and infrastructure and changes in power purchase agreements are important signals to investors. However, uncertainties remain in many countries over remuneration mechanisms for renewable output, affecting risk perceptions and the cost of capital.

International development finance and support are crucial to Southeast Asia's energy transitions. JETPs provide a framework to mobilise capital for investments in clean energy and support the phasing out of coal-fired power generation. The release of Indonesia's Comprehensive Investment and Policy Plan in November 2023 was an important milestone for the JETP and is expected to mobilise USD 97 billion in power sector investments by 2030. The AZEC initiative by Japan provides financial support of up to USD 8 billion to 2030 for energy projects. The ASEAN Taxonomy, individual country taxonomies for Indonesia and Singapore among others, the ASEAN Transition Finance Guidance, and the Asia Transition Finance Guidelines by ATF SG provide a framework to improve credibility and transparency for all market stakeholders.

Debt financing is more prominently used in power and distribution assets, while larger equity stakes are seen in fossil fuels and end-use technologies

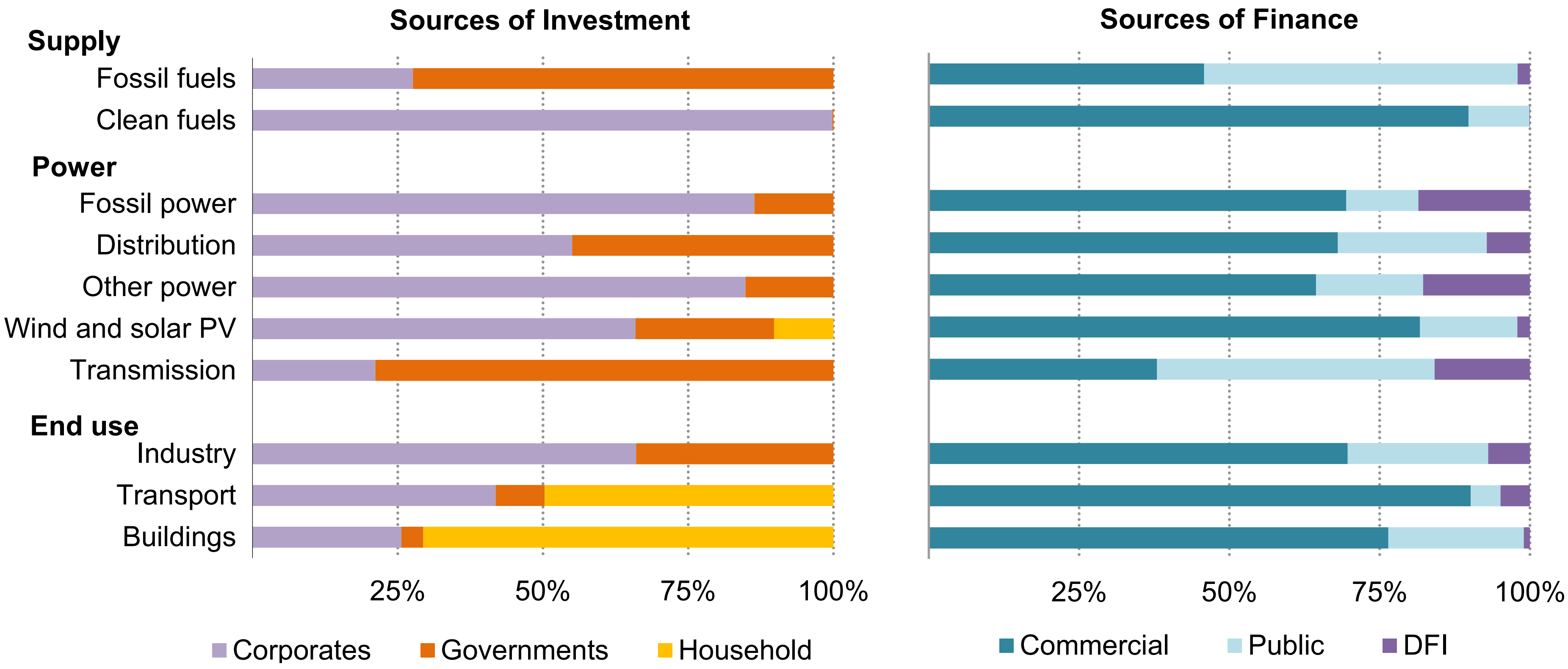
Average annual energy-related investment in Southeast Asia by instrument and sector, 2015-2023



Source: IEA analysis using data from S&P Capital IQ, IJ Global, World Bank PPI, Rystad, OECD CRS, AidData's Global Chinese Development Finance Dataset, Version 3.0.

Government investments dominate in fossil fuels, underscoring the role of state-owned enterprises, while households drive investment in buildings efficiency and transport

Average annual energy-related investment in Southeast Asia by investor and financier, 2015-2023

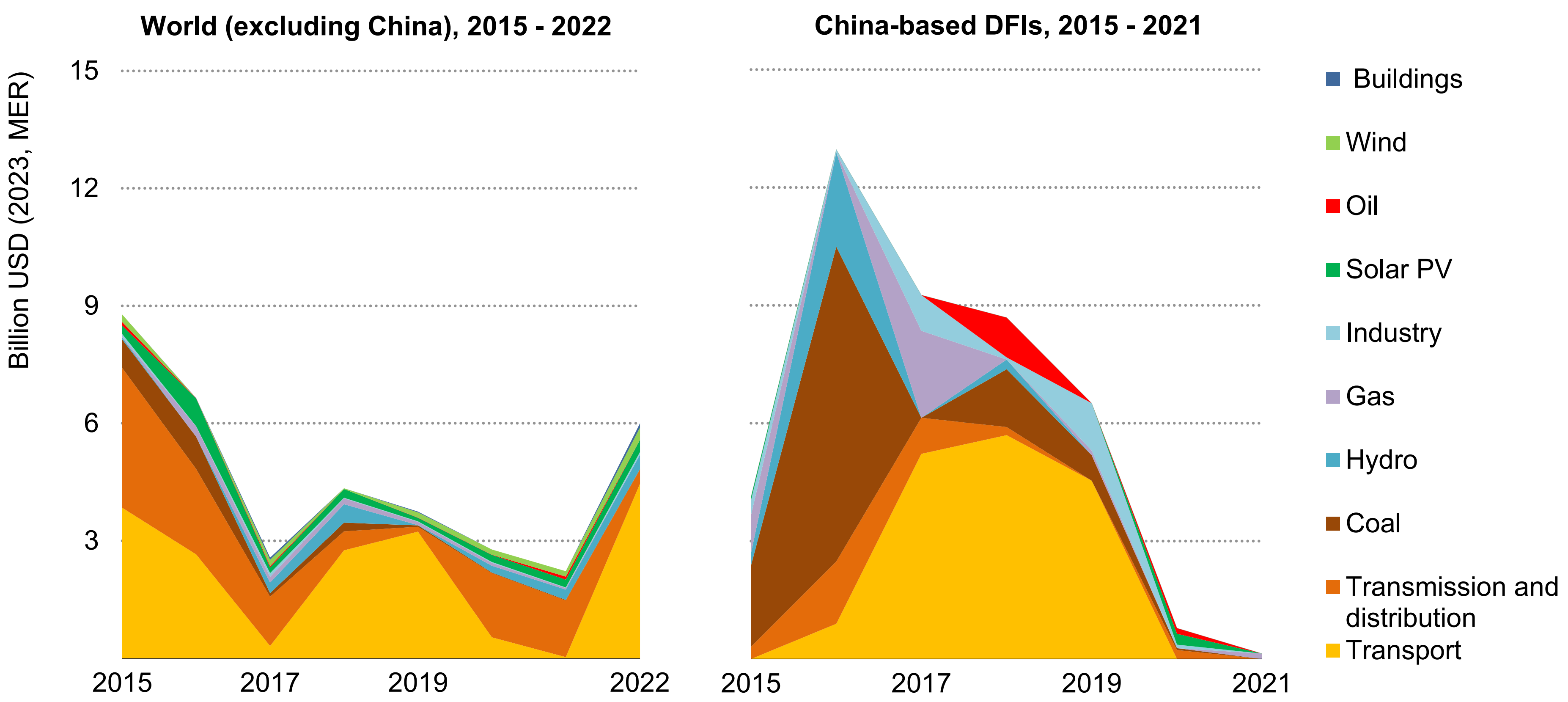


Notes: Commercial finance includes equity investments made by private enterprises and households, alongside debt from commercial financial institutions. It also includes some finance from state-owned banks, sovereign wealth funds and pension funds, that may include a degree of state-directed lending, especially in emerging economies with strong industrial policies. "DFI" = development finance institutions.

Source: IEA analysis using data from S&P Capital IQ, IJ Global, World Bank PPI, Rystad, OECD CRS, AidData's Global Chinese Development Finance Dataset, Version 3.0

DFIs prioritise investments in renewable energy and end-use sectors, reflecting a transition away from fossil fuels

Global and China-based DFI financing by technology in Southeast Asia



Note: "China-based" DFI (Development Finance Institution) = China Development Bank and the Export-Import Bank of China. Based on yearly commitments. Oil, gas and coal include fuel supply and power generation.
Source: IEA calculations based on OECD CRS and AidData's Global Chinese Development Finance Dataset, Version 3.0.

Commercial finance remains the dominant source of financing in the region, while DFI financing plays an important role in power supply and end-use sectors

The share of debt finance in energy investment is around 45% in Southeast Asia. The region is dominated by fossil fuel supply financing that has relatively lower leverage (35%) compared to the power sector and end-use sectors. High energy prices following the pandemic and Russia's full-scale invasion of Ukraine have enabled fossil fuel companies to reduce their debt levels in more recent years. In 2022 alone, net income for fossil fuel producers is estimated to have neared USD 4 trillion. Consequently, they have been able to finance investments primarily through retained earnings, while returning cash to shareholders via generous buybacks and record dividends.

NOCs are quite prevalent in Southeast Asia. They rely less on debt spending than their peers, tapping it for around 35% of total investment. Since NOCs typically generate sufficient income from upstream assets to cover their capital requirements, they tend to use debt either to finance a rapid increase in production or to grow new business areas, though their strategic and financial autonomy is shaped by their governments.

In clean power, where upfront costs are high and margins are lower, the share of debt financing is currently around 50% and as high as 70% for fossil fuel power generation. Meanwhile, debt financing in end-use sectors, including industry, buildings and transportation, is close to the 45% average. This indicates a balanced approach to financing across different sectors within the region. In contrast, the share of equity is close to 90% for clean fuels and other emerging technologies, such as battery storage or hydrogen supply. These nascent technologies are associated with higher risks, so developers tend to obtain financing through venture capital (VC) rather than debt markets.

Beyond fossil fuel investment, which is strongly supported by public and commercial finance in the region, commercial finance drives energy investment in Southeast Asia. Commercial finance supports at least 60% of investments in sectors like industry end-use, wind and solar PV, as well as for fossil fuel power and other renewables due to their mature, lower-risk profiles. Conversely, public finance is crucial for fossil fuel supply and transmission, covering about half of the financing due to their high upfront costs and longer payback periods. In Southeast Asia, the significant role of public finance in clean energy reflects a commitment to sustainable energy and highlights strategic government interventions to foster innovation and achieve long-term energy security and emissions-reduction goals.

While limited in numbers, high-income households in Southeast Asia are an emerging force supporting clean energy end-use technologies, notably EV and energy efficient buildings, and to a lesser extent in rooftop solar. However, the upfront costs of these investments are beyond the means of most households. Well-designed policies, such as affordable financing options, low-interest loans, or government-backed incentives, can enable household consumers to adopt clean energy technologies without bearing an unsustainable financial burden, helping to bring these technologies to underserved communities.

Despite its small overall share, development finance plays a crucial role in mobilising commercial finance, particularly for clean energy investment in Southeast Asia. Public finance also plays a significant role in these economies, accounting for 33% of spending in 2023, compared with 19% in advanced economies. DFIs help de-risk projects and attract private investment, particularly in sectors like transport, solar PV and hydro. China-based DFIs have provided significant overseas financing to the energy sector in Southeast Asia, particularly for transport and coal-fired power plants, although their financing has declined sharply since its peak in 2016, including an end to overseas coal financing. This reliance on DFIs and public finance underscores the need for strategic financial interventions to support the region's energy transition.

Given the critical role that DFIs play in mobilising investments, increasing the availability of concessional financing is essential, including a range of guarantees, senior or subordinated debt and equity, performance-based incentives, viability gap funding, and other investment grants. Estimates suggest that to meet the region's energy transition goals, concessional financing from DFIs will need to increase substantially together with blended finance such as the Financing Asia's Transition Partnership. This type of financing can lower the cost of capital and make clean energy projects more financially viable, particularly in emerging and high-risk markets. In the NZE Scenario, an estimated USD 12 billion in concessional finance will be needed by the early 2030s to support an accelerated uptake in clean energy technologies. This strategic infusion of concessional financing will be crucial to help de-risk projects and overcome financial barriers that can be used to crowd in investments from the private sector and ultimately ensure a sustainable and secure energy future for the region.

Persistent perceived risks for clean energy projects translate into a high cost of capital in Southeast Asia, a key impediment to higher investment and private capital

The cost of capital is the minimum return that a company requires to justify an investment. It is a measure of real and perceived risks: the larger the risks, the higher the rate of return required.

The cost of capital is especially important for clean energy projects due to their capital intensity: projects require relatively high upfront expenses (as a share of total project costs). For example, utility-scale solar PV and wind projects demand significant initial spending but are then cheap to run. The cost of capital for solar PV and storage projects in EMDE other than China is at least twice the average in advanced economies, according to data collected by the IEA Cost of Capital Observatory initiative. Mobilising much more capital for clean energy projects in Southeast Asia will depend largely on reducing the risks that push up the cost of capital.

The latest data from the Observatory show that the cost of capital for utility-scale solar PV in Indonesia has fallen slightly, from 9.0-9.5% (nominal post-tax) in 2019 to an average of 8.0-8.5% for projects for which final investment decisions were reached in 2022, driven in part by lower interest rates (though these have since edged up). Adding utility-scale batteries to these projects in Indonesia increases the cost of capital by about 150 basis points.

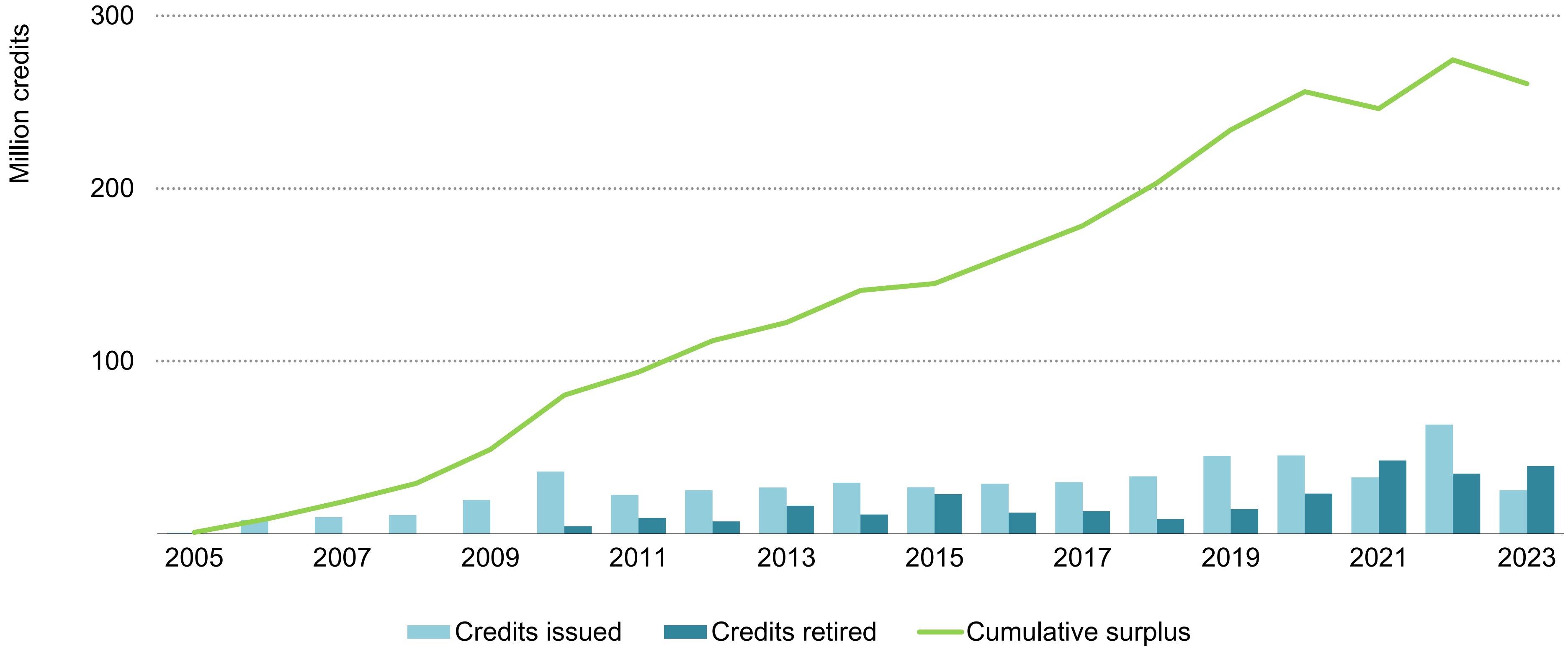
Indicative data for Viet Nam shows a cost of capital in the range of 9.0-10.5% in 2022.

Financing future energy investments in Southeast Asia will require a larger role from private capital, particularly from domestic financial institutions. Alignment with the APS in 2035 requires an additional USD 100 billion from private sources, compared to 2023 levels. Mobilising this capital will depend on addressing cross-cutting and sector-specific issues, and a need for more local currency financing.

During the 2023 survey, stakeholders were asked to identify the top risks that should be prioritised to achieve reductions in the cost of capital in each country. For Indonesia, the top risk mentioned by investors and financiers was regulatory, followed by political and off-taker risks. In the case of Viet Nam, the top risk mentioned was political risk, followed by regulatory and then transmission risks. Viet Nam attracted considerable investment in utility-scale solar until about 2022, thanks in part to a generous feed-in tariff, but the renewable deployment boom was not matched with increased investment in transmission, which – together with other issues around infrastructure planning and regulations – led to curtailment and a slowdown of new investment.

Carbon pricing instruments have so far played a marginal role in decarbonising the Southeast Asia energy system, but most countries are experienced with carbon credit markets

Issuance and retirement of energy-related carbon credits in Southeast Asia, 2005-2023



Notes: Data on carbon credits relates to the following voluntary carbon markets registries: American Carbon Registry, Climate Action Reserve, Gold Standard, Verra's Verified Carbon Standard, California Air Resources Board and Washington State Climate Commitment Act. The categories considered under energy-related carbon credits are: renewable energy, industry, transport, energy efficiency, and carbon capture and storage. "Credits retired" are carbon credits issued from projects in Southeast Asia that have been retired by buyers.

Source: IEA analysis based on data from the Goldman School of Public Policy at the University of California, Berkeley, 2024.

Countries in the region are increasingly exploring a mix of compliance carbon pricing instruments and carbon credits to decarbonise their power and industry sectors

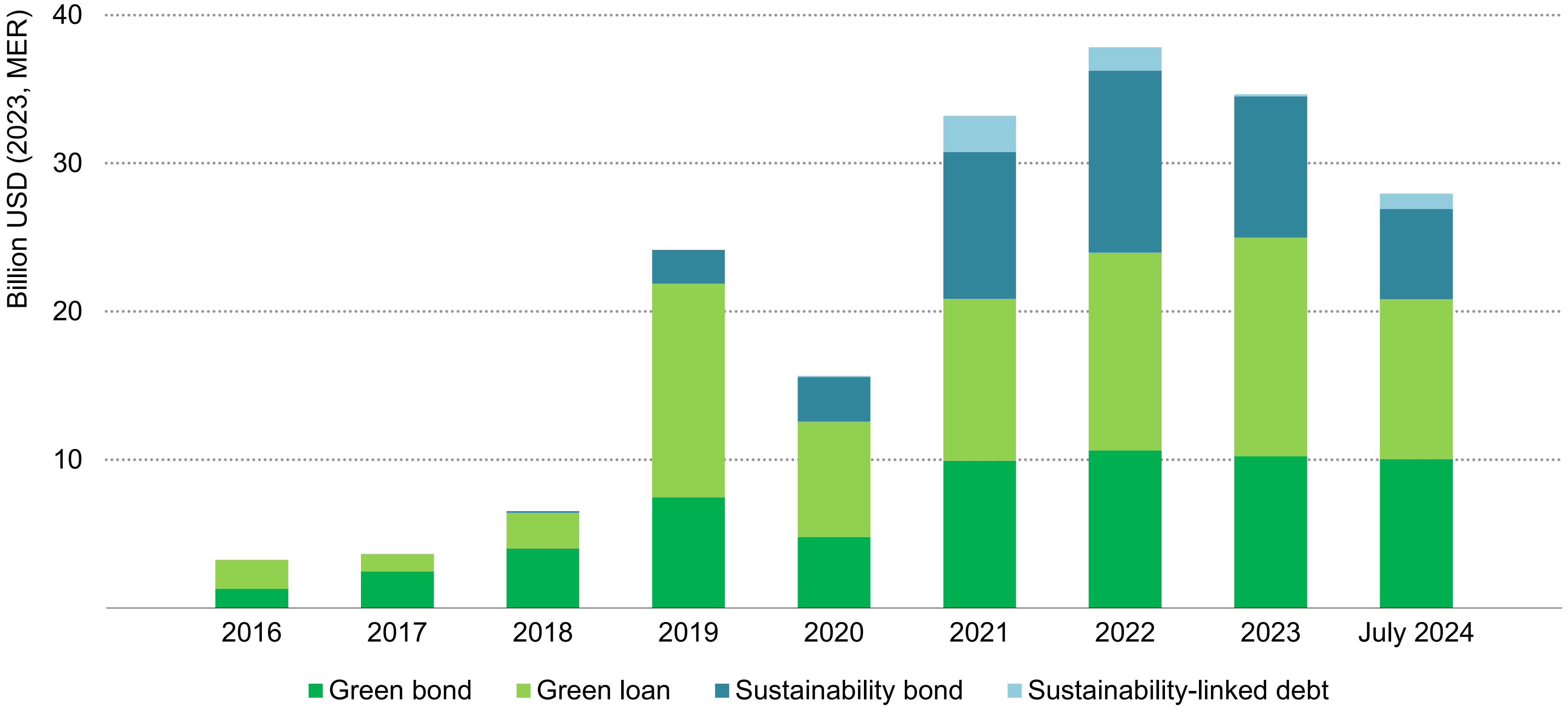
Carbon pricing can be an important tool for mitigating emissions, as it can encourage investment in low-carbon technologies and reduce demand for emissions-intensive activities. One form of carbon pricing is represented by compliance carbon pricing instruments (CCPIs), which include carbon taxes and emissions trading systems (ETS). Another form is baseline and credit systems, which generate carbon credits from emissions reductions or removals.

As of October 2024, only two countries in Southeast Asia – Singapore and Indonesia – have adopted CCPIs. Since 2019, Singapore implemented a carbon tax applying to the power, manufacturing and waste sectors, and covering 80% of the country's GHG emissions. During an initial transitional period from 2019 to 2023, the carbon tax was set at SGD 5/tCO_2-eq (USD 3.7/tCO_2-eq). At the beginning of 2024, this was raised to SGD 25/tCO_2-eq (USD 18.6/tCO_2-eq) and is scheduled to gradually increase to SGD 50-80/tCO_2-eq (USD 37.2-59.5/tCO_2-eq) by 2030. Since January 2024, covered entities can also use international carbon credits compliant with Article 6 of the Paris Agreement that meet defined environmental integrity criteria to offset up to 5% of their taxable emissions. In February 2023, Indonesia launched an intensity-based ETS initially covering 99 grid-connected coal-fired power plants, representing 80% of its power capacity, and the country plans to introduce a carbon tax that will operate alongside the ETS from 2025. Other Southeast Asian countries are also considering implementing CCPIs. Viet Nam plans to implement a pilot ETS from 2027 in the power, steel and cement sectors, moving to full implementation by 2030. Thailand is developing a voluntary ETS, alongside a domestic carbon market framework. Malaysia and the Philippines are also exploring the implementation of their own ETSs.

Most Southeast Asian countries have experience with carbon credit markets. Issuance and retirement of energy-related credits under voluntary carbon markets have been inconsistent over the years, and a significant surplus has accumulated. A few initiatives such as the Transition Credits Coalition (TRACTION, led by the Monetary Authority of Singapore) and the Energy Transition Accelerator (led by the US Department of State, Bezos Earth Fund and Rockefeller Foundation) have set up frameworks to issue transition finance credits for the early retirement of coal-fired power plants and their replacement with cleaner energy. Several countries in the region are also active in Article 6 cooperation. The first ever transaction under Article 6 was carried out in January 2024 between Thailand and Switzerland through an electric bus programme. Singapore, the Philippines, Myanmar, Lao PDR and Indonesia are also engaged or are exploring international cooperation under Article 6.

Despite well-established green and sustainable debt markets, Southeast Asia represents a mere 3% of global issuances

Sustainable debt issuances in Southeast Asia by type, 2016-2024



Source: IEA analysis based on data from Bloomberg (2024).

Transition finance: Further efforts are needed to increase finance to the sectors and countries which are struggling with energy transitions

Transition finance is a key tool to support a broad range of investments to address the energy transition in Southeast Asia. Investments are required not only in clean energy, but also in technologies that are necessary to provide or enable zero emissions energy or energy services, and in technologies that provide emissions reductions but do not themselves deliver zero emissions energy or energy services. Enablers of zero emissions energy amount to 30%, and the technologies for emissions reductions amount to 9% of regional total investments in the 2035 APS. In addition, due to the concentration of young coal-fired power plants, securing funds for managed phase-out are essential for the region.

Important progress has already been made, including the release of the ASEAN Taxonomy, national taxonomies for Indonesia, Singapore, among others, ASEAN Transition Finance Guidance, and Asia Transition Finance Guideline by ATF SG. While transition-related bonds have been issued in Japan, Italy, China, and others, there has been almost no issuance in Southeast Asia under this instrument.

To expand financial flows for the transition, three issues will need to be addressed. First are interventions that can help lower country risks which drive up financing costs in Southeast Asia. Only two of the ten ASEAN economies have an A rating and half are below investment grade. To reduce financing costs, strategic use of concessional finance targeted at mitigating project risks will be an important enabler of much higher multiples of commercial finance. Japan's experience with transition finance through the Climate Transition Bonds scheme in February 2024 may have potential lessons for use in Southeast Asia.

Second is enhancing the "interoperability" and "equivalence" of regional taxonomies and road map with other regions. Southeast Asian financial markets are not as developed as those of advanced countries and considering the urgent financing needs, capital flows from advanced countries are essential. Developing regional energy transition pathways and attracting international capital flows to the region can be facilitated by aligning taxonomies and enhancing cooperation among finance industry and stakeholders.

Finally, the reputational value of transition finance for stakeholders needs to be improved. Generally, in a financed emissions perspective, transition finance is valued as less attractive than green labelled products. However, the region's high reliance on fossil fuels requires careful attention to facilitate a just transition, and green finance and transition finance have a complementary role to play in achieving the region's orderly energy transition. The intrinsic value of transition finance that mobilises capital to the sectors where emissions reductions are challenging should be taken into consideration.

Managed phase-out of unabated coal-fired power plants is vital to achieve the energy transition with capital recovery of young power plants in Southeast Asia

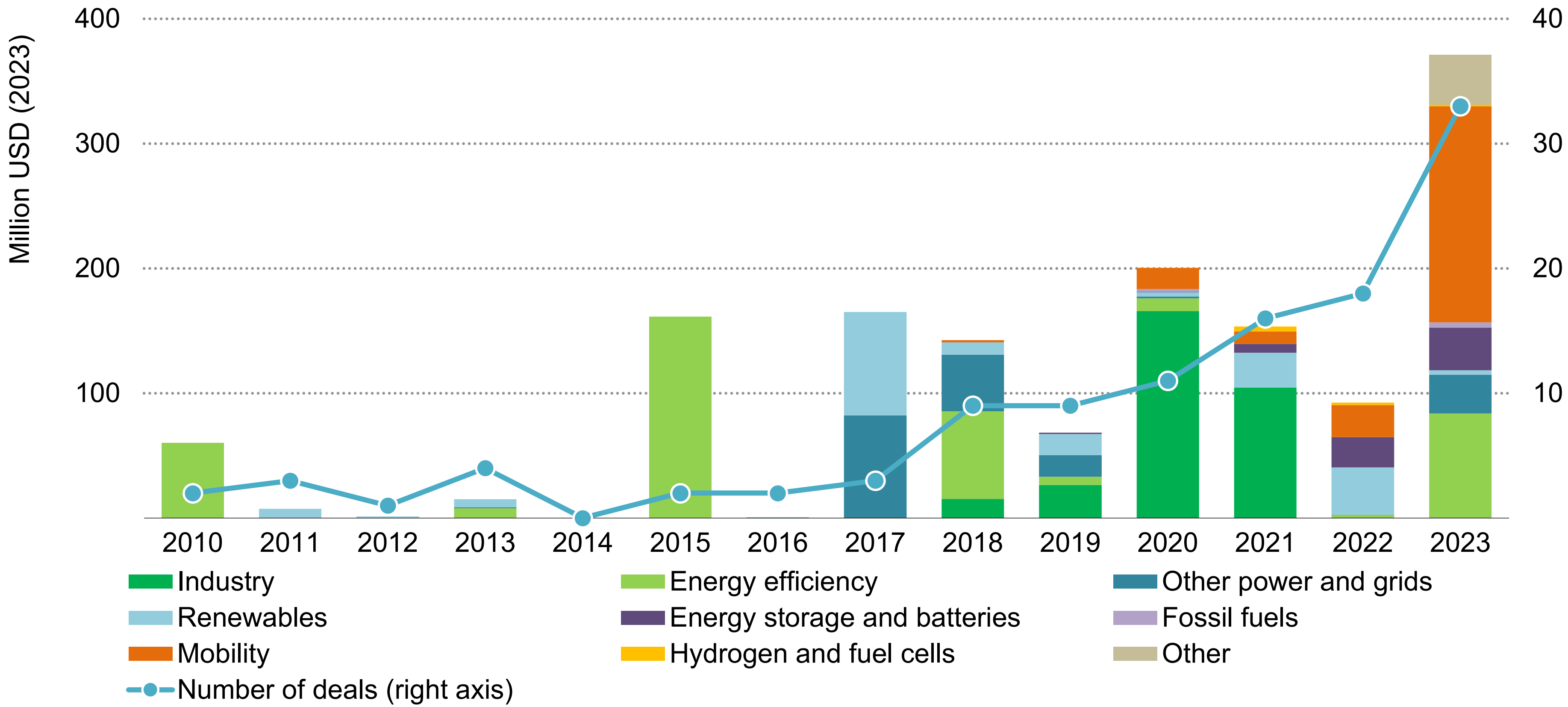
Reducing the emissions from unabated coal-fired power plants will be an important contributor to emissions reductions in the region. Under the APS, the region's CO_2 emissions in 2035 are just three-quarters those in the STEPS, with lower emissions from coal power contributing 50% of the reduction. There are four major approaches to enable this reduction: repurposing plants to provide load balancing services rather than baseload power, retrofitting coal plants with CCUS technologies, co-firing with low-emissions fuels such as ammonia or biomass, and retiring plants early and converting existing sites for low-emissions power. To reduce emissions through early retirement, alternative power sources need to be developed to meet rapidly growing power demand. In addition, it usually takes 20-30 years for coal-fired plants to recover the invested capital and given that the plants in developing economies in Asia are on average under 15 years old, many have not yet recovered their capital investments. Therefore, innovative solutions are needed to enable plant owners to recoup their capital through alternative revenue models.

Managed phase-out is one promising option in the approach to support early retirement. The Rocky Mountain Institute published guidelines for financing a credible coal transition in 2021. The GFANZ described managed phase-out as one of the key transition strategies and issued guidance for financial institutions in 2023. The Coal to Clean Credit Initiative (CCCI), announced by Rockefeller Foundation and Global Energy Alliance for People and Planet, is developing a world-first carbon credit methodology, and ACEN announced the world-first market-based Energy Transition Mechanism with CCCI and MAS at COP 28. MAS's TRACTION aims to identify system-wide barriers and develop solutions for transition credits to be used as a credible tool. The US Energy Transition Accelerator, a buyer-seller coalition of carbon credit, focuses on developing markets for power sector decarbonisation in EMDE, including early coal retirements.

To develop a managed phase-out scheme, several areas need to be addressed. Reliable credit methodologies and procedures that ensure an adequate demand for credits are essential, and the pilot projects that MAS announced in December 2023 provide a valuable opportunity to test the feasibility. Under the ASEAN Taxonomy classification, managed phase-out is classified into "Green" or "Amber", and other taxonomies will also need to ascertain the transition value of such investments. To foster a holistic approach to emissions reductions from coal, activities related to repurposing and retrofitting with CCUS and low-emissions fuels such as ammonia or biomass might also be considered as part of a managed phase-out with the meticulous application of the methodology for measuring emissions reductions and the guardrails.

Venture capital (VC) can support Southeast Asia's energy transition by financing innovative clean energy technologies and taking on early-stage investment risk

Energy-related venture capital investment in Southeast Asia by technology and number of deals, 2010-2023



Source: IEA analysis based on Cleantech Group (2024).

VC investment in energy start-ups in Southeast Asia has grown but remains under-represented compared to other sectors and regions

VC fundraising for energy start-ups in the region has grown over the past decade, with a doubling of funds raised between 2020 and 2023 compared with 2016 to 2019, covering a variety of technologies. Despite a dip in investment from 2020 to 2022 reflecting macroeconomic conditions and high interest rates, 2023 saw a surge in investment to USD 370 million, with 33 deals struck – almost twice as many as the year before. Nevertheless, the region's share of global energy-related VC remains around 1%.

Energy VC fundraising in the region is led by start-ups based in Singapore (66% of the total in 2023) – supported by a favourable business environment – while the rest are based in Indonesia (33% in 2023). The growth of energy-related VC in 2023 goes against the flow of overall VC funding in the region, which declined that year. Energy-related VC, however, remains a modest share of the total at 15%; in contrast to other areas, clean energy technologies often lack a near-term market and sufficient capital in the development stage.

Mobility emerged as the largest contributor to energy VC fundraising in 2023, representing almost half of the investment, driven by six large deals by electric motorcycle makers and charging infrastructure start-ups, including Ion Mobility in Singapore, and Maka Motors and ALVA in Indonesia. VC investment in energy efficiency and industrial sectors has been significant over the past decade, accounting for almost half of total investment since 2018, mostly at the growth stage. Especially in the early stages, energy storage, batteries and hydrogen have been gradually attracting more VC over recent years, led by battery recycling businesses, indicating strengthening links between scientific research and clean energy market expectations.

Around three-quarters of capital comes from investors based in other regions, roughly equally split between the rest of Asia, Europe and North America. Among local investors, over 70% of recent funding came from Singapore. Singapore has established itself as a VC hub; Enterprise Singapore supports local start-ups through StartupSG, providing funding and access to facilities. EcoLabs, in collaboration with universities, connects innovators to commercial opportunities and global testbeds, offering labs and energy innovation support. Funding growth in Indonesia has also been supported by easing investment regulations and policy funding for founders and incubators.

To foster expertise and drive energy innovation in other countries in the region that attract less VC, it is crucial to send strong market signals in conjunction with energy policy frameworks, support R&D and establish start-up ecosystems that connect innovators with mentors, companies, investors, and facilities. Broader economic regulations can help mobilise capital for risky, early-stage ventures.

Southeast Asia's energy start-ups raised substantial funding for electric mobility, renewable energy, waste-to-energy and energy management, driving regional clean energy innovation

Selected energy start-ups in Southeast Asia raising USD 10 million or more in venture and private equity since 2019

Company	Country	Funding (million USD [2023])	Area
RWDC Industries	Singapore	297	Fossil fuel-free chemicals
ALVA	Indonesia	60	Electric motorcycle manufacturing
Ion Mobility	Singapore	43	Electric motorcycle manufacturing
Green Li-ion	Singapore	41	Lithium-ion battery recycling
Blue Planet	Singapore	40	Biogas and waste-to-energy developer
Maka Motors	Indonesia	38	Electric motorcycle manufacturing
Volta Indonesia	Indonesia	35	Electric motorcycle manufacturing
Xurya	Indonesia	33	Solar PV project development
Yoma Micro Power	Myanmar	32	Renewable energy microgrids development
Sun Energy	Singapore	24	Solar PV project development
Cleanedge Resources	Singapore	19	Biogas and waste-to-energy technology and project developer
REDEX	Singapore	18	Renewable energy certificate marketplace
Dat Bike	Viet Nam	16	Electric motorcycle manufacturing
Scorpio Electric	Singapore	15	Electric motorcycle manufacturing
SensorFlow	Singapore	14	Smart management of building cooling, heating and lighting
VFlowTech	Singapore	13	Redox flow battery manufacturing
Amperesand	Singapore	12	Solid state transformer developer
OYIKA	Singapore	11	Battery swapping and charging infrastructure for EVs

Annex

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Abbreviations and acronyms

AC	air conditioning
AE	advanced economies
AERN	ASEAN Energy Regulators' Network
APAEC	ASEAN Plan of Action for Energy Cooperation
APG	ASEAN Power Grid
APS	Announced Pledges Scenario
ASEAN	Association of Southeast Asian Nations
AZEC	Asia Zero Emission Community
CCPI	compliance carbon pricing instrument
CCUS	carbon capture, utilisation and storage
CIPP	Comprehensive Investment and Policy Plan
COP 28	2023 Conference of the Parties of the UNFCCC
CO_2	carbon dioxide
CNG	compressed natural gas
DFI	development finance institution
EGIB	efficient grid-interactive buildings
EMDE	emerging market and developing economy
ESG	environmental, social and governance
ETS	emissions trading system
EUR	Euro
EV	electric vehicle
FID	final investment decision
GDP	gross domestic product
GFANZ	Glasgow Financial Alliance for Net Zero
GHG	greenhouse gas
GMS	Greater Mekong Subregion
HAPUA	Heads of ASEAN Power Utilities/Authorities
ICE	internal combustion engine
IEA	International Energy Agency
IPG	International Partners Group
JETP	Just Energy Transition Partnership
LDV	light duty vehicle
LNG	liquified natural gas
LPG	liquified petroleum gas
KIO	Kachin Independence Organisation
MEPS	minimum energy performance standards
MER	market exchange rate
MPA	Maritime and Port Authority
NDC	Nationally Determined Contribution
NOC	national oil company
NO_X	nitrogen oxide
NZE Scenario	Net Zero Emissions by 2050 Scenario
PDP	power development plan
PLDV	passenger light duty vehicle
PPP	purchasing power parity
PV	photovoltaic
R&D	research and development
RMP	Viet Nam JETP Resource Mobilisation Plan
RUKN	Indonesian National Electricity General Plan
RUPTL	PLN's Electricity Supply Business Plan
STEPS	Stated Policies Scenario
TRACTION	Singapore's Transition Credits Coalition
UNFCCC	United Nations Framework Convention on climate change
USD	United States Dollar
VC	venture capital
VRE	variable renewable electricity

Units of measure

bcm	Billion cubic metres
EJ	Exajoule
GJ	Gigajoule
$GtCO_2$	Gigatonnes of carbon dioxide
GW	Gigawatt
GWh	Gigawatt Hour
kg	Kilogramme
mb/d	Million barrels of oil per day
kb/d	Thousand barrels of oil per day
MBtu	Million British thermal units
Mt	Million tonnes
Mtce	Million tonnes of coal equivalent
MW	Megawatt
MWh	Megawatt hour
pkm	Passenger kilometre
t CO_2-eq	Tonnes of carbon dioxide-equivalent
TWh	Terawatt hour

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