An Energy Sector Roadmap to Net Zero Emissions in Indonesia

International Energy Agency

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International Energy Agency Special Report

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Joint IEA-MEMR High-Level Statement on Net Zero Emissions

Indonesia announced its ambitious objective to reach net zero emissions by 2060 during the UN Climate Change Conference (COP 26) in 2021. Since then – at the request of the Government of Indonesia – the country's Ministry of Energy and Mineral Resources (MEMR) and the International Energy Agency (IEA) have been working collaboratively on detailed scenario and policy analysis of what this target means for Indonesia's energy sector. Both institutions have conducted robust and granular modelling of the pathways to net zero for Indonesia's energy sector. The key findings of this collaborative project are summarised here.

Indonesia's development is an extraordinary success, though largely underpinned by conventional energy sources. Indonesia has sustained very rapid growth over half a century, ranking as the fourth-fastest growing large economy in the world, following Korea, Singapore and China. Exports of coal and natural gas have contributed to this growth, and to Indonesia's positive trade balance. Indonesia achieved almost full electrification of households in 2021, and the share of the population below the national poverty line has dropped from 60% in 1970 to less than 10% today. Indonesia is the world's fourth-most populous country; seventh-largest economy; twelfth-largest energy consumer and the largest coal exporter.

Indonesia's net zero objective is ambitious and achievable. Despite the more than doubling of Indonesia's energy sector emissions over the last two decades and substantial growth in the emissions intensity of its energy mix, its per capita energy sector emissions remain half the global average. Nonetheless, both MEMR and IEA analysis find that Indonesia's net zero target is achievable through the deployment of renewable energy resources, energy efficiency, electrification and grid interconnection.

Energy efficiency and electrification are the immediate priorities. Indonesia is set to add huge amounts of appliances, cars, machines and infrastructure this decade. In the scenario in which Indonesia reaches net zero by 2060, ownership rates for air conditioners and the country's stock of cars increase significantly by 2030. Both MEMR and IEA modelling shows that enforcing energy performance standards, especially for air conditioners, and supporting electrification of transport and cooking are critical to lower energy costs and emissions at the same time.

In the near term, a policy push is needed to drive the growth of renewables. The MEMR and IEA roadmaps project that solar PV will provide as much as 50-60% of the installed electricity generation capacity needed to serve the much bigger demand for electricity by 2060. Important policy reforms can help to achieve this renewables expansion in a smooth and timely manner. Most importantly, policy needs to establish a stable, substantial and multi-year pipeline of auctions for renewables with competitive and transparent tariff-setting.

At the same time, action needs to be taken to address the current huge overcapacity of coal-fired power plants (CFPP). The capacity margin in Indonesia, particularly in the Java-Bali system, is around 57% in 2022. This exceeds PLN's targeted capacity margin (30%), and is three to four times higher than international benchmarks.

Both MEMR and IEA modelling analyses indicate no need for new coal-fired power plants (CFPP) after the current project pipeline, and project the phase out of unabated CFPP by the 2050s. Coal power continues to provide 50% of peak capacity in 2030 in the net zero by 2060 pathway. However, contractual adjustments are needed to allow coal and gas power plants to operate more flexibly and at lower annual capacity factors, but these adjustments need to be conducted carefully to preserve investor confidence. Investors should be appropriately remunerated for coal plants' continued role in electricity security. Accelerated retirements can help to reduce overcapacity in the system, and international support, based on a detailed assessment of plant balance sheets, should be provided to help cover possible unrecovered capital.

The pathway to net zero emissions by 2060 can increase affordability and energy security for Indonesia. Both the MEMR and the IEA analyses show that, with the right policies in place, the total production cost for electricity would be stable in the net zero by 2060 pathway. Total household energy bills as a share of disposable income would fall by 2030 compared with current levels, thanks to the benefits of energy efficiency and electrification.

The energy security benefits of the transition are even more attractive in the context of today's global energy crisis. Indonesia's annual oil import bill is expected to rise above USD 35 billion in 2022 as world prices spike. And by 2030, net imports of oil are set to reach more than USD 50 billion in the business-as-usual scenario, meaning that even as a share of growing GDP Indonesia would spend more on imported fossil fuels than it does today. But in the net zero by 2060 pathway, the oil import bill is close to one-third lower in 2030 relative to the business-as-usual scenario.

Indonesia is home to some of the most coal-dependent regions in the world, but it is also the world's largest producer of nickel and second-largest producer of tin, both of which are critical inputs for clean energy technologies. In the net zero by 2060 pathway, the total value of Indonesia's critical minerals production reaches more than USD 30 billion annually by 2030, more than the largest ever value of coal exports. Indonesia is already taking steps to deepen domestic value added, for example through the establishment of a domestic battery manufacturing industry. Driving further development of clean energy value chains also requires a robust domestic market for clean energy technologies.

International support and co-operation are needed. While the near-term actions for net zero are built around current commercially available and cost-effective technologies, financial and technology co-operation are still critical. Indonesia will need about USD 8 billion in additional investment per year by 2030 in the net zero by 2060 pathway. By 2050, around one-quarter of the reductions need to be achieved through technologies that are currently not commercially available in Indonesia, including hydrogen and hydrogen-based fuels, nuclear, and carbon capture, utilisation and storage. Deployment of these options requires innovation at the global level to bring down technology costs. In Indonesia, their deployment requires co-ordinated, cross-sectoral and long-term planning across supply, infrastructure and demand, and large investment in infrastructure and demonstration projects. International co-operation, technology transfer and financial support will be essential.

Indonesia's net zero ambition can drive the next stage in its economic transformation. Indonesia has established a goal to become an advanced economy by 2045 – marking 100 years since its declaration of independence. For an upper-middle income country today, this is an ambitious objective, requiring rapid, sustained and inclusive economic growth; diversification of its current resource-intensive development pathway; and advances in its innovative and technological capacity. The development of clean energy value chains can diversify Indonesia's economy, and offers new opportunities to its fossil-fuel dependent regions. The drive towards net zero emissions can promote the adoption, domestic development and export of innovative clean energy technologies, such as batteries, critical minerals, and renewables equipment — all of which have large growth potential.

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The report was developed upon the request of the Minister of Energy and Mineral Resources of the Republic of Indonesia. This study was prepared by the World Energy Outlook team in the Directorate of Sustainability, Technology and Outlooks in co-operation with other directorates and offices of the International Energy Agency (IEA). It benefited from inputs and reviews from experts within the Ministry of Energy and Mineral Resources of the Republic (MEMR) of Indonesia, Perusahaan Listrik Negara (PLN), Badan Pusat Statistik (BPS) of Indonesia and the National Energy Council of Indonesia.

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Valuable input to the analysis was provided by David Wilkinson (independent consultant).

We are grateful to our Indonesian partners, including

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Sagap Aliktipo	BPS
Florencia Satwika Genah	BPS
Infaz Rizki Adawati	BPS
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Valuable comments and feedback were provided by other senior management and numerous colleagues within the IEA. In particular, Mary Warlick, Keisuke Sadamori, Tim Gould, Alessandro Blasi, Paolo Frankl, Masatoshi Suguira, Sara Moarif, Brian Motherway, Rebecca Gaghen, and Timur Gül.

Thanks go to the IEA's Communications and Digital Office for their help in producing the report and website materials, particularly to Jad Mouawad, Jethro Mullen, Astrid Dumond, Grace Gordon, Tanya Dhin, Therese Walsh, Merve Erdem, Allison Leacu, Robert Stone and Clara Vallois. Ivo Letra and Ben McCulloch provided essential support to the production process. IEA's Office of the Legal Counsel, Office of Management and Administration and Energy Data Centre provided assistance throughout the preparation of the report.

The work could not have been achieved without the support and co-operation provided through the IEA Clean Energy Transitions Programme, in particular, this report has been produced with the financial assistance of the European Union and the Australian Government.

Peer reviewers

Many senior government officials and international experts provided input and reviewed preliminary drafts of the report. Their comments and suggestions were of great value. They include:

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Rebecca Collyer	European Climate Foundation
Lamberto Dai Pra	Enel
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The individuals and organisations that contributed to this study are not responsible for any opinions or judgments it contains. All errors and omissions are solely the responsibility of the IEA.

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Annexes

Indonesia is an extraordinary development success story

When Indonesia declared independence in 1945, its GDP per capita was more than ten-times lower than today. Since then, its economic development has been an extraordinary success story. From 1968 to today, Indonesia has been the fourth-fastest growing large economy in the world, joining Korea, Singapore and China in sustaining very rapid growth over half a century. The share of the population below the national poverty line has fallen from 60% in 1970 to less than 10% today. Today, Indonesia is the world's fourth-most populous country, seventh-largest economy, twelfth-largest energy consumer, and the largest coal exporter.

With growth has come transformation

Indonesia's GDP fell by nearly 15% in the wake of the Asian Financial Crisis in 1997. In response, the country unleashed a wave of reforms, and over the next two decades, its economy changed substantially. Indonesia shifted from a net oil exporter to a net oil importer in 2003. The share of the oil and gas sector in GDP fell from 10% in 2000 to around 2.5% in 2021, accompanied by a fourfold decrease in the share of government revenues from the sector. No longer an oil exporter, Indonesia is still highly dependent on fossil fuels. Exports of coal and natural gas make up nearly 20% of net goods exports.

Growth has led to more CO_2 emissions

Indonesia's total energy supply increased nearly 60% from 2000 to 2021. As energy demand rose, coal stepped in to fill the gap. Per unit of energy consumed, its energy sector now emits one-third more CO_2 than in 2000. Total energy sector emissions have grown faster than energy demand, more than doubling over the last two decades. In 2021, energy sector emissions were around 600 million tonnes of carbon dioxide (Mt CO_2) – making Indonesia the world's ninth-largest emitter. Yet, per capita energy CO_2 emissions are only 2 tonnes, half the global average.

Moving toward net zero emissions is a key part of Indonesia's path to becoming an advanced economy

Indonesia's ambitious target of reaching net zero emissions by 2060 or sooner is an integral part of its overarching development goal of becoming an advanced economy by 2045. Despite the country's achievements, a long path to this stated goal remains. GDP per capita at purchasing power parity today is 30% lower than the world average, and economic development is regionally imbalanced and highly resource dependent. The islands of Java and Bali are home to 60% of the country's population and 75% of manufacturing GDP. Other regions specialise in natural resource extraction. Indonesia's net zero emissions target needs to be seen as part of its necessary transformation on the path to becoming an advanced economy by 2045. This includes: economic diversification from a concentration in natural resources; economic development across the archipelago driven by knowledge, technology and innovation; and leveraging its competitive advantage in many clean energy value chains.

IEA's contribution to achieving net zero emissions

As part of its long-standing co-operation with the Government of Indonesia, the International Energy Agency (IEA) prepared this report "*An Energy Sector Roadmap to Net Zero Emissions in Indonesia*" in close collaboration with the Indonesian Ministry of Energy and Mineral Resources (MEMR). The IEA's contribution complements – and has benefited from – the high-quality modelling and analysis that is already being conducted in Indonesia to flesh out its net zero emissions target. This roadmap comes at a historic moment for Indonesia as it holds the G20 Presidency for the first time in 2022 – and at a time of severe turbulence in world energy markets.

There is no one path to net zero emissions for Indonesia. This report presents *a* pathway to reach this goal, not *the* pathway. The IEA and MEMR's joint work on this roadmap has identified a number of clear near-term priorities for Indonesia on its journey to net zero emissions by 2060, or sooner. Our analysis is centred on the IEA's Announced Pledges Scenario (APS), in which Indonesia reaches net zero emissions on an economy-wide basis by 2060, with deep cuts in energy sector emissions. The report also develops an accelerated scenario, the Net Zero Emissions by 2050 Scenario (NZE).

Efficiency, renewables and electrification are the near-term pillars

Achieving net zero emissions by 2060 is a long journey that requires immediate and sustained action. Energy efficiency, renewables in the electricity sector, and the electrification of transport need to be kick-started now. To 2030, these three levers provide around 80% of the emissions reductions from the energy sector needed to put Indonesia on the road to net zero emissions. The technologies for efficiency, electrification and renewables are commercially available and cost-effective, provided that the right policies are put in place.

Efficiency brings multiple benefits but requires substantial policy reform

Between now and 2060, Indonesia will add huge quantities of energy consuming appliances, machines, factories and infrastructure to its capital stock. More than 2 billion square metres of new residential floor area are constructed between 2021 and 2030 in the APS, increasing Indonesia's residential building stock by close to four-times the total land area of the Special Capital Region of Jakarta. There are 22 million additional air conditioners in 2030 compared with today, as ownership rates rise from only one-in-ten households to more than one-in-three. Steel production increases by 5 million tons (Mt), with the equivalent of 30% of today's production capacity added by 2030. The stock of passenger cars increases from 11 million today to 23 million by 2030.

In this context, it is imperative that energy efficiency policies be strengthened robustly, including pricing and subsidy reform. In the APS, mandatory minimum energy performance standards for buildings, appliances and equipment, combined with policies to rapidly electrify motorbikes and passenger cars, reduce final energy demand by almost 10% in 2030 relative to a business-as-usual scenario, increasing to 33% by 2060. Subsidy reform provides effective incentives to boost the efficient use of energy, including switching to electricity in some end-uses. Consumers save an average of USD 100 per household on energy bills in the APS in 2030 relative to a business-as-usual scenario. The savings increase to USD 500 in 2050.

Electricity sector rigidity risks holding back the transition

More than 25 gigawatts (GW) of solar PV and wind capacity are installed by 2030 in the APS, up from around 0.4 GW today. Early growth of renewables is essential to lay the foundation for the industry to scale up strongly after 2030. This is a path to transform the current power mix in which coal provides 60% of generation and solar PV and wind account for less than 1%. Today's generation mix is characterised by substantial over-capacity, which is the result of overly optimistic electricity demand projections in the past.

Solar PV and wind for power generation have a large role to play in achieving the net zero pathway, but policy reforms are essential for them to fulfil that role. Without effective reforms, solar PV and wind projects risk being economically uncompetitive relative to coal and natural gas power plants. Recent auction results in Indonesia for solar PV and wind revealed costs twice as high as those in comparable emerging market and developing economies.

A high-level policy push is needed to overcome hurdles for renewables

The critical challenge for the transition today is to create opportunities for renewables to expand their contribution to the electricity generation mix. Four key policy reforms are needed in the near term:

- **Contract adjustments** to allow coal and natural gas plants to operate more flexibly and at lower capacity factors. IEA analysis suggests that this kind of contract reform can save more than 5% of costs across the electricity system in 2030, reducing curtailment of available renewables capacity and avoiding the dispatch of high cost, emissions-intensive power plants. Reforms of existing contracts need to be done in a manner that ensures that investors receive an adequate return and that confidence in the sector is not compromised.
- **Remunerate system services** provided by coal, other power plants and eventually battery storage and demand side flexibility. Coal continues to play an important role in electricity security to 2030, providing 50% of peak capacity.
- **No new coal beyond the current pipeline and retire ageing coal capacity**. Retirements should accelerate after 2030 and the need for planned coal plants should be revaluated.
- **A favourable regulatory environment for development and operation of renewables capacity.** This includes clear schedules for substantial competitive auctions, transparent and attractive tariffs, effective provisions for land and transmission system access, and guaranteed priority dispatch.

Deep decarbonisation of the energy sector requires a broad suite of options

While efficiency, electrification and renewables can deliver much of the needed cuts in emissions, reaching deep emissions reductions calls for deploying additional clean energy technologies. For example, around a quarter of the emissions reductions needed by 2050 in the APS are delivered by hydrogen and hydrogen-based fuels, nuclear, electrification of some industrial processes, and carbon capture, utilisation and storage (CCUS). By 2060, around 190 Mt CO_2 is captured with CCUS – almost one-third of today's emissions. Total electricity generation devoted to hydrogen production is around 220 terawatt-hours by 2060, almost as much as current total demand in all sectors.

Energy demand centres in Indonesia are not close to its ample renewable energy resources. Inter-regional undersea transmission capacity is needed to interconnect electricity generation in resource rich areas to Indonesia's demand centres. By 2050 in the APS, Java is importing nearly half of its electricity from neighbouring islands.

Deploying the needed technologies requires innovation at the global level to bring down costs; co-ordinated, cross-sectoral and long-term planning across supply, infrastructure and demand in Indonesia; and large investments in infrastructure and demonstration projects. International co-operation, technology transfer and financial support will be essential.

Investment in clean energy technology goes hand-in-hand with policy reform

Historically, Indonesia has invested around USD 20 billion per year in its energy sector. With growing GDP and energy demand, this is set to increase in any outlook. However, a pathway to net zero emissions is more capital intensive. By 2030, investment is around USD 8 billion higher per year in the APS than in a business-as-usual scenario, with investment in renewables generation and grids (USD 25 billion) more than the current investment in the entire energy sector. Investment in energy efficiency climbs to USD 10 billion annually by 2030, a fivefold increase on today. Mobilising this level of investment will require significant policy reforms as well as international support.

Energy security is strengthened in the transition

Indonesia spent about USD 24 billion on net oil imports in 2021, and this is expected to rise to around USD 35 billion in 2022 as world prices spike. By 2050, net imports of oil and gas reach USD 100 billion in a business-as-usual scenario. This implies that Indonesia spends a higher share of GDP on imported fossil fuels than it does today. In the APS, electrification and efficiency dampen consumption of imported fossil fuels, and the oil and gas import bill is more than three-times lower than in a business-as-usual scenario by 2050. The difference in import bills between the two scenarios to 2050 is bigger than the difference in investment in clean energy technologies. This means that the clean energy transition delivers lower total energy system costs for Indonesia.

Energy remains affordable, despite higher investment requirements

Despite the challenge of raising large amounts of additional energy sector investment, energy remains affordable. Wholesale electricity generation costs amount to about USD 80 per megawatt-hour (MWh) today. In the APS, these fall to around USD 70/MWh when CO_2 prices are excluded. Electricity generation costs rise in the APS compared with today if CO_2 prices are included, but CO_2 costs are fundamentally different because carbon pricing revenues can be used to compensate consumers or to drive growth by lowering other taxes. Total household energy bills are lower in the APS than in a business-as-usual scenario by 2030, thanks to investment in clean energy technologies such as more energy efficient appliances and air conditioners, electric motorbikes, and increasingly, electric cars.

Workers should not be left behind in the transition from coal to clean energy

Indonesia is the world's largest producer of nickel and second-largest producer of tin, both of which are critical for making various clean energy technologies. Indonesia is attracting growing investment into the business of transforming these minerals, with USD 30 billion invested in the nickel value chain in the last few years (mostly from Chinese companies). In the APS, the total value of Indonesia's critical minerals production reaches more than USD 30 billion annually by 2030, more than the peak historical value of coal exports. By 2050, this could rise to more than USD 70 billion if Indonesia expands its market share beyond today's level.

Indonesia is home to some of the most coal-dependent regions in the world, but around 85% of its coal exports go to countries with net zero emissions targets, casting doubt over long-term export prospects. The clean energy transition holds large opportunities for Indonesia to diversify its economy. But critical minerals production is substantially less labour intensive than coal mining, and by itself will be insufficient for regional economic diversification. The full benefits can only be seized if Indonesia can develop activities across the full value chain, with steps already being taken in this direction via the development of a domestic battery manufacturing industry. Driving further development of clean energy value chains in Indonesia will require international investment and partnerships, a commitment to upholding more stringent environmental standards, and also a robust domestic market for clean energy technologies.

An accelerated pathway brings additional challenges – but also benefits

Cumulative renewables capacity additions to 2030 in the NZE are nearly triple the level seen in the APS. To accommodate this growth, development is halted for several coal-fired power plants that are part of the active pipeline. By 2030, the coal fleet is about 10% smaller in the NZE than in the APS. But this accelerated transition comes with benefits. In the period to 2050, lower domestic fossil fuel consumption and lower international prices in the NZE reduce oil imports by more than half compared to the APS. Total revenues from critical minerals are nearly three-times higher than today's levels in 2030, and nearly one-third higher than in the APS in that year.

Indonesia's clean energy transition offers the path to a new success story

Indonesia's past success in transforming its economy gives it an excellent foundation for the clean energy transition. And in many respects, the country encapsulates the opportunities and challenges of the global transition to net zero emissions. Indonesia is the world's largest coal exporter, but also one of the world's largest producers of the critical minerals necessary for clean energy technologies. It is a net oil importer, and energy security concerns are pushing the government to search for solutions. It has tremendous renewable energy resources including solar, wind, hydropower, geothermal and bioenergy. Above all, Indonesia is a rapidly growing, urbanising and still industrialising economy. A transition to net zero emissions offers the opportunity to usher in prosperity built on the emergence of a diversified, technologically advanced and high-value-added economy.

An Energy Sector Roadmap to Net Zero Emissions in Indonesia aims to provide Indonesian and international stakeholders with a clear outline of how Indonesia can achieve net zero emissions, the role the energy sector can play, and the needed actions and investments. The report lays out *a* pathway, not *the* pathway, for Indonesia to achieve net zero emissions by 2060. Using scenario analysis, it illustrates a pathway that is based on: a detailed understanding of national and regional circumstances; the most recent analysis of global market for fuels and technologies; recognition of Indonesia's development objectives; and robust incorporation of the key drivers of energy service demand.

- Chapter 1 provides an overview of Indonesia today; the role of energy in the economy, the recent evolution of energy demand and emissions, and the country's energy and climate policy landscape.
- Chapter 2 presents the scenarios used in the analysis, with a focus on the central net zero emissions by 2060 scenario, its energy and emissions trends and key mitigation levers.
- Chapter 3 examines the pathways to net zero emissions by 2060 on a sector-by-sector basis for electricity generation, low emissions fuels and the end-use sectors: industry, transport and buildings.
- Chapter 4 considers an accelerated pathway that aims for net zero emissions by 2050, analysing the actionable steps required to achieve such a pathway, and how the pathway differs from a net zero emissions by 2060 scenario.
- Chapter 5 highlights the anticipated key implications along the energy transition pathway, such as just transitions, regional electricity system integration and integration of a high share of renewables in the electricity system, energy security and the outlook for Indonesia's energy trade balance and finally, investment needs for the transition.

Chapter 1

Indonesia today

State of play

SUMMARY

- Indonesia has been the fourth-fastest growing large economy in the world over the course of the last five decades, behind Korea, Singapore and China. In 2021, Indonesia's poverty rate was less than 10% of the population, notable progress from the 60% level in 1970. Today, Indonesia's place in global rankings include: fourth-most populous country; seventh-largest economy; twelfth-largest energy consumer and ninth-largest emitter of CO_2 from fuel combustion.
- Indonesia's GDP per capita was around USD 13 000 (PPP) in 2021, 70% of the global average. In the 2000s, Indonesia shifted from a net oil exporter to a net importer, with the share of the oil and gas extraction sector in GDP declining from around 10% in 2000 to about 2.4% in 2021. Coal mining accounted for 2.4% of GDP in 2021, and exports of coal and natural gas represented on average about one-quarter of total net goods exports over the last five years.
- Indonesia's population, economy and energy resources are spread unevenly across its many islands. Java, the main island, accounts for around 60% of the population and GDP, and 75% of electricity consumption, and is extremely densely populated. Yet, Java accounts for just 4% of the country's solar PV potential and 14% of its onshore wind potential.
- The total energy supply in Indonesia increased by more than one-and-a-half-times from 2000 to 2021. Coal surged from less than 10% in 2000 to almost one-third in 2021 and surpassed oil as the largest component in total energy supply. Access to modern forms of energy also increased substantially, with electricity access increasing from around 55% in the early 1990s to almost 100% in 2021.
- Indonesia's total energy sector CO_2 emissions were 600 Mt in 2021, almost as much as from Korea's energy sector. Indonesia's total energy sector CO_2 emissions more than doubled between 2000 and 2021, of which coal is responsible for over 70% of the increase.
- Indonesia submitted its updated Nationally Determined Contribution and first Long-Term Low Emissions Strategy to the UNFCCC in 2021. The strategy states that Indonesia has the opportunity to "progress towards net zero emissions in 2060 or sooner". Achieving this ambitious target would require strong action across the whole energy sector.

1.1 Overview

Indonesia is the world's largest archipelago country, with a landmass that spans more than 17 000 islands, a unique diversity of ecosystems and landscapes, and more than 90 000 kilometres of coastline. Indonesia was a very poor country when it declared independence in 1945. Since the 1970s, it has been one of the fastest growing economies in the world, with a very impressive record of poverty reduction. Measured since 1968, Indonesia has recorded the fourth-fastest rate of growth in per capita GDP among all large- and medium-size economies, behind only Korea, Singapore and the People's Republic of China (hereinafter China).[1] Indonesia has set the goal of reaching advanced economy status by 2045, marking one hundred years of independence.

Indonesia's population growth rate has been about 1.4% per year, from around 180 million people in 1990 to almost 280 million people in 2021, making it the fourth-most populous country in the world. Indonesia is the seventh-largest economy in the world measured at purchasing power parity (PPP) and the seventeenth-largest economy measured at market exchange rates. Today, Indonesia is the world's twelfth-largest energy consumer and ninth-largest emitter of CO_2 from fuel combustion.

Indonesia has made notable progress in reducing its poverty level – from 60% in 1970 to less than 10% in 2021 (BPS, 2022b; Hill, 2021). Large regional disparities remain, however, with the poverty rate as high as 27% in Papua Province and below 5% in provinces such as Bali and DKI Jakarta (Box 1.1).[2] The government has conducted an annual national socio-economic survey since the mid-1960s, the *Survei Sosio-Ekonomi Nasional*, which has enabled comprehensive and relatively consistent estimates of the national poverty rate since 1970.

1.2 Economic and social context

Indonesia's economy sustained a very severe hit during the Asian financial crisis in 1997, with GDP falling nearly 15% from its peak in 1997 and only regaining that level six years later. Recovering from the financial crisis, Indonesia's GDP increased 4.9% per year from 2000 to 2021, although it experienced a 2.1% decline in 2020 owing to the Covid-19 pandemic. In 2021, GDP expanded by 3.7%, lower than the historical average, as uncertainty around the pandemic lingered and the country experienced continued public health-related restrictions. Nonetheless, in 2021 GDP recovered to above the pre-pandemic level.

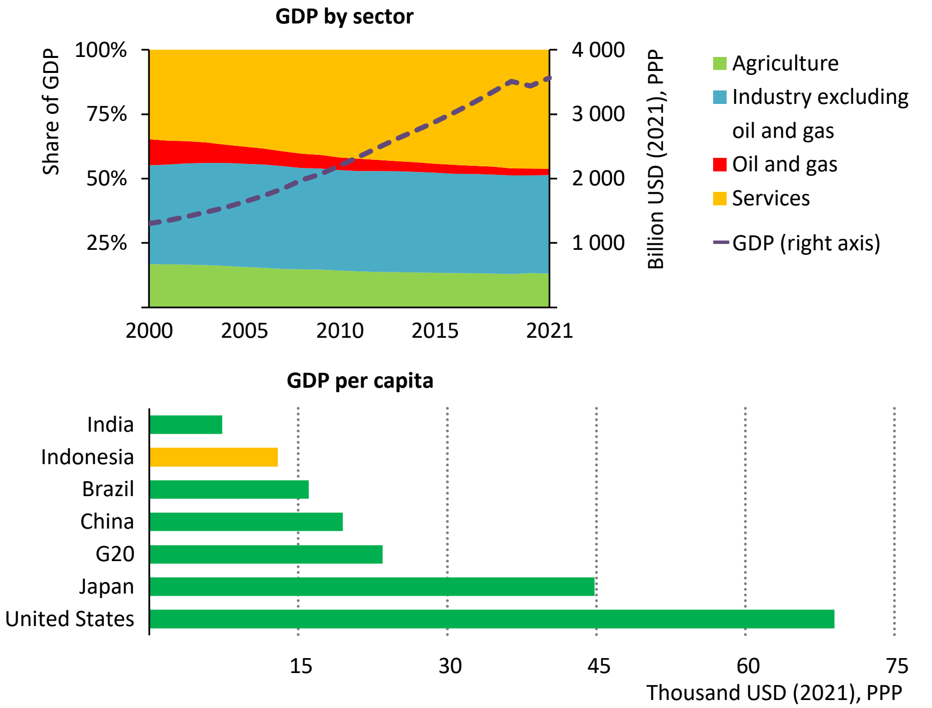
GDP per capita was around USD 13 000 (PPP) (equivalent to about Indonesian Rupiah [IDR] 62 million per capita in 2021 at current prices). This puts GDP per capita in Indonesia at 70% of the global level and 55% of the G20 level (Figure 1.1). Indonesia is classified in the World Bank income classification as a lower middle-income country, alongside economies such as

[1] For the purposes of this analysis, a large- or medium-size economy is considered as one with more than 0.05% of world GDP in 2019.

[2] The national poverty line in 2021 was about USD 3.5 per capita per day for urban areas and USD 3.25 per capita for rural areas, measured at PPP.

Egypt and Tunisia. Despite its strong historical economic advances, Indonesia still requires strong economic growth to deliver high standards of welfare to its citizens.

Figure 1.1 ▹ GDP by sector, 2000 – 2021, and GDP per capita in 2021 in Indonesia relative to selected countries



Despite very strong economic growth since 2000, Indonesia remains a lower middle-income country and its GDP per capita is well below the level of the G20 group

Notes: In national accounts, oil and gas extraction is considered as a part of the industry sector. In this figure, it is shown separately to underscore the significance of the transition in its share of GDP. The members of the G20 are: Argentina, Australia, Brazil, Canada, China, European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, Saudi Arabia, South Africa, Türkiye, United Kingdom and United States.

1.2.1 Economic transition

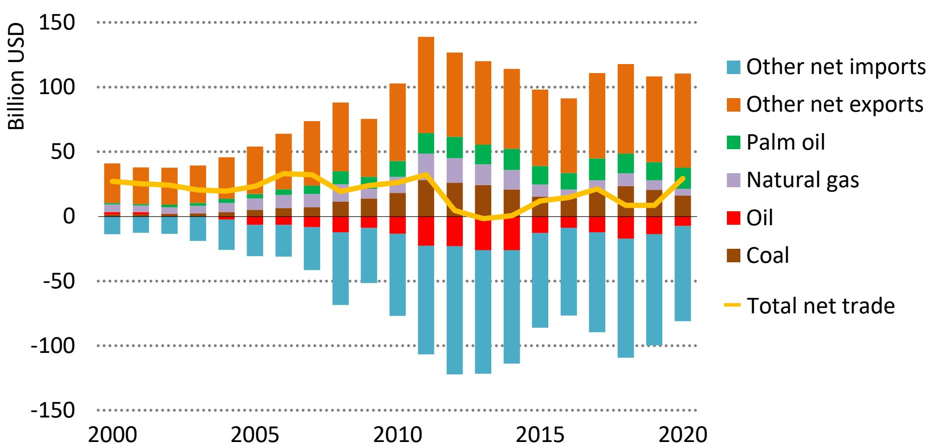
Over the last two decades, the structure of the Indonesian economy has shifted. In 2000, agriculture accounted for about 17% of GDP and industry for almost 50%. By 2021, the share of agriculture had fallen by around five percentage points and the share of industry in GDP (including oil and gas extraction) had fallen by eight percentage points. The share of the services sector in GDP increased from around a third in 2000 to almost half in 2021. As Indonesia shifted from a net oil exporter to a net importer, the share of the oil and natural gas sector in GDP declined from 10.1% in 2000 to 2.4% in 2021, measured at constant prices.

This was accompanied by a decline in government revenues from the oil and gas sector, from over 35% of fiscal revenues in the early 1990s to around 6% by 2020 (Masdi A., 2021).

1.2.2 Energy in the economy today

Despite the decline in the oil and gas sector, the commodities sector remains significant for the Indonesian economy. In 2021, the coal mining sub-sector accounted for about 2.4% of GDP at constant prices, slightly down from the peak of 3.1% in 2013 during the China-driven commodities supercycle.[3] Taken together, coal, oil and natural gas extraction accounted for about 5% of Indonesian GDP in 2021, measured at constant prices. However, measured in current prices, the extraction of oil, gas and coal accounted for about 6.5% of GDP in 2021, down from a peak of 9.1% in 2011 during the high price period of the commodities supercycle.

Figure 1.2 ▹ Oil, natural gas, coal and palm oil in goods trade in Indonesia, 2000 – 2020



Export of coal, natural gas and palm oil make up about one-third of Indonesia's total net exports

Looking at the structure of Indonesia's goods trade further highlights the significance of commodities (Figure 1.2). Coal accounted for around 15% of Indonesia's net goods exports in 2020 compared to a peak of around 20% in the 2011-13 period. The net value of coal exports was about USD 16 billion in 2020 compared with about USD 21 billion in 2019. Natural gas represented 5% of Indonesia's net exports in 2020, down from around 15% in the 2011-13 period. Although not principally an energy commodity, palm oil accounted for 15% of Indonesia's net exports in 2020, as much as coal. Indonesia is the world's largest

[3] The commodities supercycle refers to the broad boom in commodities prices from 2000-14, driven by rising demand in emerging market and developing economies, particularly in China.

producer of nickel and second-largest producer of tin, both of which are important metals for energy transitions (see Chapter 5, section 5.2.2).

From a small net oil exporter in the early 2000s, Indonesia became a net importer in the mid-2000s. In the high oil price period of 2011-14, oil accounted for around one-fifth of Indonesian net goods imports, and contributed to driving its net goods trade into a small deficit in 2013. Other net imports tend to be higher value technology products, such as machinery and electrical equipment, which alone account for more than one-third of its net imports. While today coal and natural gas exports are sufficient to offset the expense of oil imports, this may no longer be the case in coming years (see Chapter 5, section 5.2). This risk underscores the government's high priority on reducing energy imports.

Exports of coal, natural gas and agricultural commodities such as palm oil have allowed Indonesia to maintain a surplus in goods trade over the last two decades (except 2013), even while imports of other goods increased, in particular higher value technology products. Over the last decade, Indonesia's goods surplus has been offset by net import of services and net outflow of external investment income resulting in a current account deficit (although it swung back into surplus in 2021 based on strong goods exports).

1.2.3 Labour market

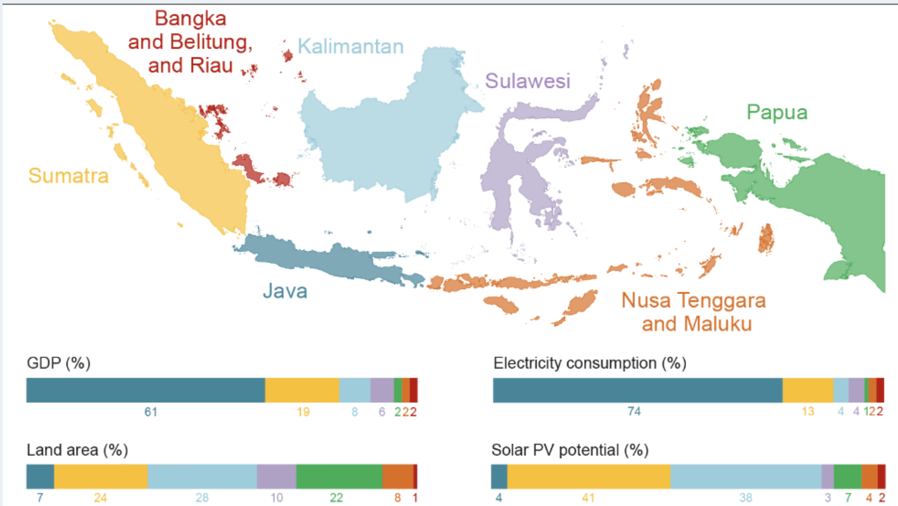
Several characteristics of Indonesia's labour market – informality, large number of low paid and low skilled jobs, and relatively low participation rates of women – are not dissimilar to countries at a similar level of development. About three-quarters of Indonesia's 131 million total working population in 2019 are in informal jobs (World Bank, 2021a). A substantial share of job growth in the last twenty years has been in relatively low productivity sectors of services and agriculture still accounts for a substantial share of employment. As a consequence, only about 15% of jobs pay enough to be classified as middle-class jobs (World Bank, 2021a). In 2019, the services sector accounted for about half of total employment, agriculture for about 27% and industry for about 23% (BPS, 2019). The mining sub-sector, despite its significant share of GDP, accounts for only around 1% of total employment, although its level is much higher in mining areas (see Chapter 5, section 5.1.1 on the role of energy sector employment).

Box 1.1 ▹ Economic and social geography of Indonesia

The 37 provinces of Indonesia are spread across five main islands, (Java[4], Sumatra, Kalimantan [on the island of Borneo], Sulawesi and Papua), and four island groups, (Bangka and Belitung, Riau Islands, Nusa Tenggara and Maluku). Population, economy and energy resources are unevenly distributed across the archipelago nation – the largest in the world. This economic geography has important implications for the net zero emissions pathway (Figure 1.3).

[4] Including the island of Bali.

Figure 1.3 ⊳ Economic geography of Indonesia: key indicators



Population and economic activity are mainly centred on the island of Java, while land and resources, including solar, are concentrated elsewhere

Sources: IEA analysis based on data from Statistics Indonesia (BPS, 2021a and 2016).

The islands of Java and Bali account for around 60% of Indonesia's population and GDP. Java is extremely densely populated (about 1 150 people per square kilometre, comparable to the density of Bangladesh and the most densely populated states of India such as Bihar). Java is the powerhouse of the country's non-resource dependent economy, accounting for nearly three-quarters of manufacturing GDP and about 70% of services sector GDP. As a consequence, Java dominates energy demand, accounting for around three-quarters of the country's electricity consumption.

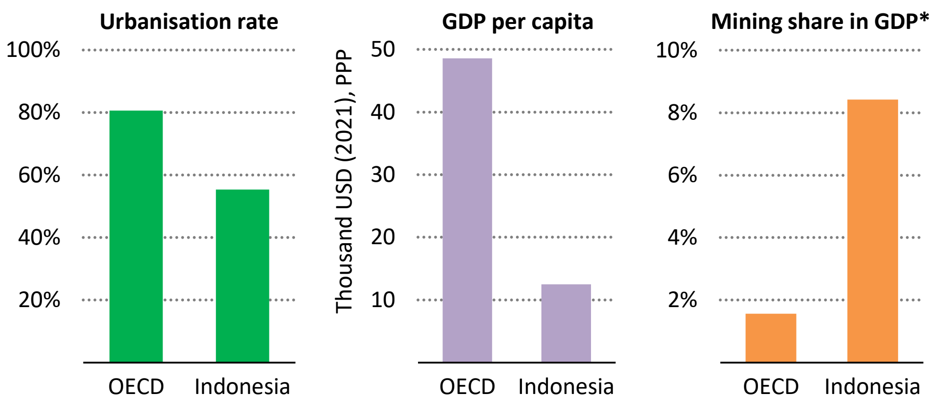
Adjacent to Java, Sumatra is far less densely populated. Agriculture accounts for a higher share of Sumatra's GDP than the national average. Sumatra is home to more than half of the land area under palm oil plantation in the country. Oil and natural gas extraction and coal mining account for nearly 10% of Sumatra's GDP. Similar to Sumatra, the economy of Kalimantan is very resource dependent, with coal mining accounting for 22% of the province's GDP (see Chapter 5, section 5.1.1 for details on Kalimantan's economy).

Indonesia's technical potential for utility-scale solar photovoltaics (PV) generation is about 1 500 gigawatts (GW) and 500 GW for onshore wind power. Both Sumatra and Kalimantan have about 40% of this solar PV potential, while the economic powerhouse of Java has just 4% of the solar PV potential and 14% of wind power. Java does have important hydropower and geothermal resources, but the province's path to net zero emissions from power generation is likely to require low emissions electricity that exceed the estimated renewables capacity. (Chapter 5 discusses the implications and opportunities such as inter-island transmission and rebalancing economic development.)

1.2.4 Socio-economic indicators

There is a large development gap in Indonesia relative to advanced economies and Organisation of Economic Development and Co-operation (OECD) member countries (Figure 1.4). In general, a country's urbanisation rate is highly correlated with its development level. Slightly more than half of Indonesia's population live in cities, an urbanisation rate that is broadly in line with the level expected of a country with Indonesia's level of GDP per capita. However, this is 25 percentage points lower than the aggregate urbanisation rate of OECD member countries, where eight-out-of-ten people live in cities. As Indonesia develops, its urbanisation rate will increase further, driving up demand for materials and energy.

Figure 1.4 ▹ Key socio-economic indicators for Indonesia relative to OECD countries, 2018



Indonesia has a large development gap compared to OECD countries, and an economy that is far more dependent on resource extraction

* Mining represents all mineral resource extraction, including oil and gas production.

Note: Data are for 2018 to facilitate comparison with the OECD countries.

Sources: IEA analysis based on data from BPS (2022a); OECD (2022) and World Bank (2022).

Indonesia's GDP per capita level at PPP is about four-times lower than the level of the OECD countries. Indeed, Indonesia's current level of economic development, as measured by GDP per capita, is comparable to that of some OECD member countries in the early 1960s. Today, Indonesia's economy is also more dependent on resource extraction, with the mining and quarrying sector, including oil and gas extraction, accounting for about 8% of GDP. On average the mining and oil and gas sub-sectors make up about 1.5% of OECD country GDP.

As Indonesia develops, far reaching structural change will be required to transform its economy from the current high reliance on commodities towards one based on technology, infrastructure, regional integration and human capital development. The transformation of its energy system towards a net zero emissions pathway should be seen within this broader context of its development model as the country moves toward higher income levels over the coming decades.

1.3 Energy and emissions trends

1.3.1 Energy supply

Since 2000, Indonesia's GDP has risen by more than two-and-a-half-times while total energy supply has increased about one-and-a-half-times from around 6 500 petajoules (PJ) in 2000 to almost 10 400 PJ in 2021 (Table 1.1).[5] This relative decoupling of GDP and energy demand reflects significant improvements in the energy intensity[6] of the economy largely driven by two factors.

Table 1.1 ▻ Key socio-economic and energy indicators for Indonesia, 2000 – 2021

	2000	2010	2021	Change 2000-2021	CAAGR 2000-2021
Population (million)	212	242	276	31%	1.3%
GDP (Billion USD [2021], PPP)	1 302	2 202	3 566	174%	4.9%
GDP per capita (USD [2021], PPP)	6 154	9 104	12 904	110%	3.6%
Poverty rate (%)	19%	13%	10%	-9 pp	n.a.
Electricity access (%)	53%	67%	100%	47 pp	n.a.
Clean cooking access (%)	6%	41%	82%	76 pp	n.a.
Total energy supply (PJ)	6 518	8 546	10 422	60%	2.3%
Total energy supply per capita (GJ)	31	35	38	22%	1.0%
Oil import dependency (%)	-23%	30%	53%	76 pp	n.a.
Energy sector CO_2 (Mt CO_2)	270	410	598	122%	3.9%
Energy intensity (MJ per USD, PPP)	5.	3.9	2. 9	-42%	-2.5%
Energy intensity excl. TUOB (MJ per USD, PPP)	3. 7	3. 1	2. 8	-24%	-1.3%
Carbon intensity of TES (t CO_2/MJ)	39.	45. 7	54. 2	39%	1.6%

Notes: CAAGR = compound average annual growth rate; PPP = purchasing power parity; PJ = petajoule; GJ = gigajoule; MJ = megajoule; Mt = million tonnes; TUOB = traditional use of biomass; TES = total energy supply; n.a. = not applicable. In the change column, pp = percentage points. Oil import dependency is calculated as net trade, i.e. the difference between the absolute value of imports and exports, divided by the total energy supply of primary and secondary oil products. Therefore, a negative sign indicates exports and a positive sign indicates imports. The oil dependency data for 2021 are provisional.

First, extending the provision of modern energy services to the vast majority of the population substantially reduced the traditional use of biomass for residential cooking. In 2021, almost 85% of Indonesian households used liquefied petroleum gas (LPG) as their primary cooking fuel, while around 12% used wood (BPS, 2022b). The traditional use of

[5] Total energy supply is equivalent to total primary energy demand.

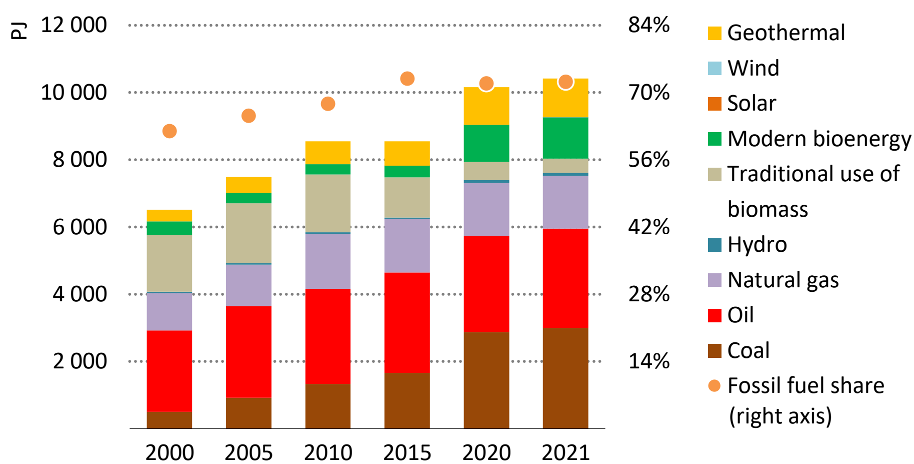
[6] Energy intensity is defined as the ratio of energy supply to GDP in PPP terms.

biomass is very inefficient, so shifts to LPG improved energy intensity. Second, the energy intensity of the Indonesian economy improved by almost a quarter from 2000 to 2021 even without counting the shift from traditional biomass burning. This equates to an annual rate of improvement of around 1.3%. This is about 15% faster than the rate of energy intensity improvement for the emerging market and developing economies as a group.

The shift from the traditional use of biomass boosted the CO_2 emissions intensity of TES by about 50% between 2000 and 2021, as the share of fossil fuels increased.[7] This shift from the traditional use of biomass has had many positive socio-economic benefits. However, even without this effect, the emissions intensity of Indonesia's TES has increased over the last two decades, as the share of coal in the fossil mix has risen.

Indonesia has also seen a significant shift in its oil trade balance. In 2000, its net oil exports were equivalent to almost a quarter of domestic consumption. This had changed dramatically by 2021, with net imports accounting for more than half of domestic oil consumption.

Figure 1.5 ▹ Total energy supply by source in Indonesia, 2000 – 2021



Coal use surged as Indonesia transitioned from the traditional use of biomass; the share of fossil fuels in total energy supply has expanded by ten percentage points

Indonesia's total energy supply mix has undergone significant change over the last two decades (Figure 1.5). In 2000, oil occupied by far the largest share, accounting for 37% of TES. Oil increased modestly in absolute terms while its share has been falling and reached less

[7] The IEA estimates the traditional use of biomass based on the number of households without access to modern cooking fuels and includes these estimates in its energy balances. The traditional use of biomass is not included in the energy balance statistics produced by the Indonesian Ministry of Energy and Mineral Resources.

than 30% in 2021. Over the same period, the share of natural gas has been comparatively stable, falling by a few percentage points to around 15% in 2021. Coal, however, has surged from a less than 10% share in 2000 to around 30% in 2021, and surpassed oil as the largest contributor to TES.

As noted, extending the provision of modern energy services to the majority of the population substantially reduced the traditional use of biomass in the buildings sector. It declined from more than a quarter of TES in 2000 to less than 5% in 2021. Over the same period, the share of modern renewables – modern bioenergy, solar, hydro, wind and geothermal – increased from slightly more than 10% to nearly 25% in 2021. This particularly reflects the increase in liquid biofuels in transport and geothermal in electricity generation (Box 1.2). The share of fossil fuels in Indonesia's total energy supply has increased by more than ten percentage points since 2000, although this trend shows recent signs of plateauing with the growth of modern renewables.

Box 1.2 ▹ Implications of energy accounting conventions

The IEA follows the International Recommendations for Energy Statistics to convert electricity generation from wind, solar and hydropower into primary energy inputs and uses the physical energy content method (UN, 2018). This method converts electrical output from non-thermal generation into primary energy input on a one-to-one basis: 1 kilowatt-hour (kWh) of electrical output equates to 1 kWh of primary energy input. For non-combustion thermal conversion process (nuclear, solar thermal and geothermal), the IEA follows a primary heat approach, which accounts for losses in converting the primary heat input into electrical energy, based on available data, or an assumed conversion efficiency. Reported statistics for Indonesia indicate the current average efficiency of geothermal plants in operation is 5%: 1 kWh of electricity output requires 20 kWh of primary geothermal heat input. For new geothermal capacity, this conversion efficiency is assumed to be 5%, in line with international standards (UN, 2018). This accounting convention increases the share of geothermal in total energy supply compared to its share in electricity generation.

Total energy supply can therefore be an imperfect metric for understanding the role of various energy sources. For example, in Indonesia in 2021 hydropower and geothermal made up similar shares of total electricity generation. However, the share of geothermal in the TES was around ten-times larger than the share of hydro because of the accounting conventions employed.

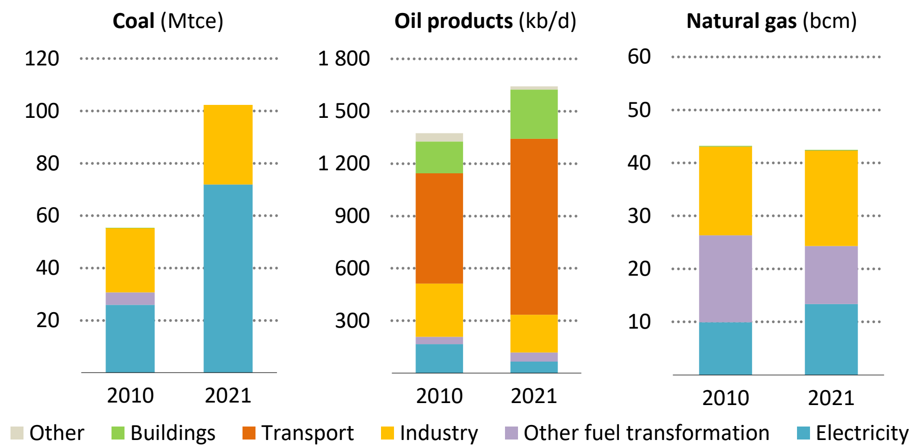
The impact of accounting conventions such as these needs to be kept in mind, particularly because the net zero emissions pathway for Indonesia sees an important role for geothermal. Sometimes understanding the role of various energy sources requires selecting the right perspective. For example, the significance of geothermal resources is better understood through its share in electricity generation rather than total energy supply.

1.3.2 Energy demand

1

The surge in coal demand has been driven by the electricity sector. Coal inputs to electricity generation more than doubled in the 2010-21 period, increasing by over 45 million tonnes of coal equivalent (Mtce) (Figure 1.6). Over this period, oil demand was squeezed out of the industry and electricity sectors, though its use in transport rose by over one-third to reach 1 million barrels per day in 2021. Oil product use in the form of LPG increased by over 50% in the buildings sector. Natural gas demand was stable over the period, although this masks shifts in demand at the level of different sectors.

Figure 1.6 ▷ Fossil fuel demand by type and sector, 2010 and 2021

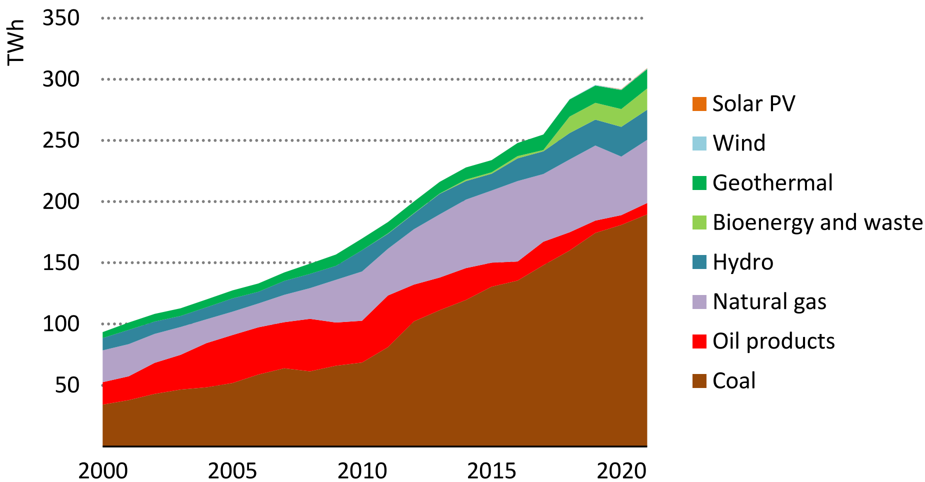


The electricity sector drove the surge in coal demand, while transport substituted industry and electricity as the driver for oil product demand

Note: Mtce = million tonnes of coal equivalent; kb/d = thousand barrels per day; bcm = billion cubic metres.

Coal emerged as the dominant fuel for electricity generation in Indonesia over the last two decades (Figure 1.7). Coal-fired generation increased more than five-times from around 35 terawatt-hours (TWh) in 2000 to nearly 190 TWh in 2021, accounting for nearly two-thirds of Indonesia's electricity generation. In the same period, oil use for power generation halved in absolute terms and its share shrunk from nearly a third in the mid-2000s to about 3% in 2021. Natural gas use in power generation has doubled since 2000, although in recent years it has stagnated and declined slightly. Electricity generation from hydro, bioenergy and geothermal increased by nearly four-times over the two decades. Combined, these sources provided nearly 60 TWh of generation in 2021, almost a fifth of total electricity production. Wind and solar, on the other hand, are currently negligible in the generation mix, contributing only 1 TWh of electricity production in 2021.

Figure 1.7 ▷ Electricity generation mix by source, 2000 – 2021



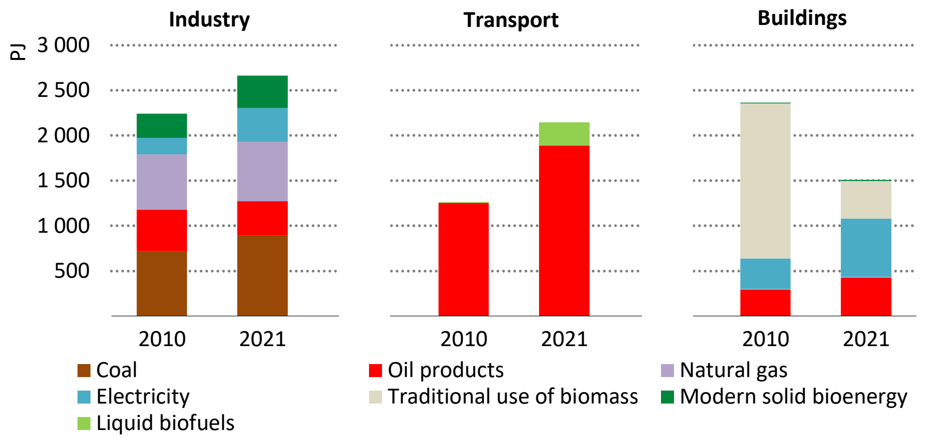
Coal's share in electricity generation has almost doubled since 2000 and bioenergy, geothermal and hydro boosted the share of renewables in generation

Coal is less dominant in total final consumption (Figure 1.8). In aggregate across all end-use sectors, coal provided about 15% of total final consumption in 2021, an increase of a few percentage points since 2010. Coal in final energy consumption is exclusively in the industry sector. In the 2010-21 period, the share of oil products in total final consumption declined substantially in industry. This was counterbalanced by an increase oil consumption in transport. The net effect of these two trends was that the overall share of oil in the total final energy consumption mix has only risen marginally and remains by some margin the largest share. Natural gas has also remained broadly stable at around a 10% share with consumption concentrated in the industry sector.

The share of electricity in total final consumption has increased from a low level in 2010 to reach about 15% in 2021. In this period, electricity consumption in industry doubled and almost doubled in the buildings sector, driven in particular by rising demand for space cooling. By contrast, the traditional use of biomass in the buildings sector decreased by around three-quarters as clean cooking access increased. Biodiesel in transport dominates the increase of modern renewables in final consumption, with liquid biofuels expanding 35-times in the 2010 to 2021 period to now account for more than 10% of final energy consumption in the transport sector – one of the highest shares in the world.

This analysis highlights three significant trends in the Indonesian energy sector in the period since 2000. One was the shift from being a net oil exporter to a net oil importer. This drove a fall in oil use in the industry and electricity sectors, where easy substitutes were available. Another is the notable transition to supplant the traditional use of biomass with modern energy sources, mostly LPG and electricity, which was enabled by rising incomes and government support programmes. The third trend is an increase in CO_2 emissions. The emissions profile is driven not just by an increase in the total quantity of energy supplied to the economy, but also by a 30% increase in the quantity of CO_2 emitted per unit of total energy supply.

Figure 1.8 ▹ Final consumption by fuel and sector, 2010 and 2021



Electricity consumption increased in the industry and buildings sectors; biofuels supplemented significant increased oil use in transport

1.3.3 Energy sector emissions trends

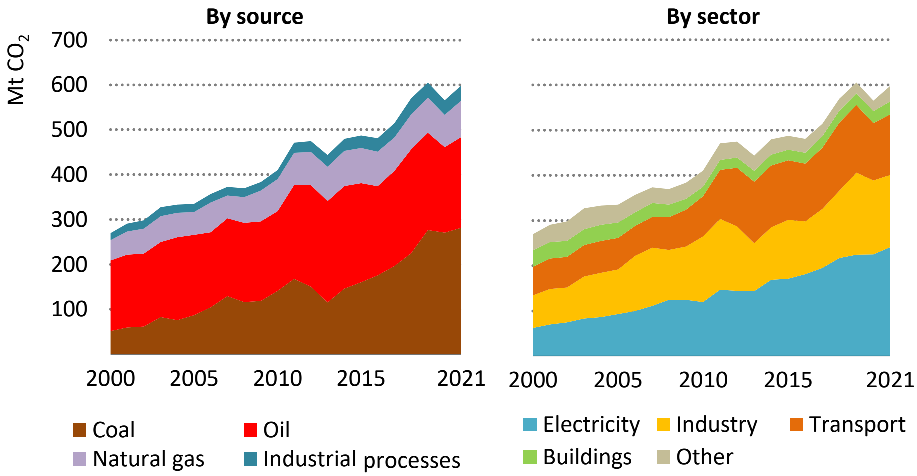
Over the 2000-21 period, Indonesia's CO_2 emissions from the energy sector increased by slightly more than two-times and GDP increased by a little more than two-and-a-half-times.[8] The growth of CO_2 emissions has therefore been relatively tightly coupled to the growth of GDP. Coal, by far, is the largest driver and accounted for almost three-quarters of increased emissions. More oil and natural gas demand, in roughly equal measure, account for the additional increase in emissions. By sector, power drove about half the emissions increase and industry, including process emissions, about one-fifth. The transport sector contributed about a fifth of the increased CO_2 emissions in this period.

Indonesia's total energy sector emissions were around 600 million tonnes of carbon dioxide (Mt CO_2) in 2021, slightly less than from Korea's energy sector. After declining by 6% in 2020 due to the Covid-19 lockdowns, Indonesia's total energy sector CO_2 rebound in 2021,

[8] Unless otherwise specified, energy sector emissions refers to emissions from fuel combustion and industrial processes in this report. When not specified, CO_2 emissions refer to emissions from the energy sector; it is explicitly specified throughout the report when CO_2 emissions from other than the energy sector are included, for example from agriculture, forestry and other land use.

approaching its 2019 level. A little less than half of the emissions were from coal combustion, one-third from oil, and the remainder from natural gas combustion (around 15%) and process emissions (around 5%). The power sector made up about 40% of total CO_2 emissions in 2021, while transport and industry each accounted for around one-quarter of total emissions (Figure 1.9).

Figure 1.9 ▷ Energy sector CO_2 emissions in Indonesia, 2000 – 2021



Growth in coal-fired electricity generation contributed more than half of the doubling of CO_2 emissions from the energy sector since 2000

Notes: Mt CO_2 = million tonnes of carbon dioxide. Other includes agriculture and other fuel transformation.

Looking at CO_2 emissions by sector and sub-sector provides useful information about the opportunities and challenges for the net zero emissions pathway (Figure 1.10). In the power sector, coal-fired electricity generation accounts for the lion's share of CO_2 emissions. Natural gas is the primary source of CO_2 emissions in the other fuel transformation sector. However, Indonesia's growing coal-to-chemicals sub-sector risks increasing the emissions from coal combustion in the other fuel transformation sector (see Chapter 5, section 5.5).

Half of CO_2 emissions from fuel combustion in the industry sector are from heavy industries: chemicals, iron and steel and cement. The other industry grouping accounts for 30% of the industry total. (Chapter 3, section 3.3. discusses energy consumption in industry). These other industries typically use coal and natural gas to provide low- to medium-temperature process heat. CO_2 emissions from the iron and steel sub-sector have substantially increased in recent years, driven by growth of emissions-intensive blast-furnace, basic oxygen furnace output in steel. The surge in nickel smelting has increased emissions from the non-ferrous metal subsector. Road transport accounts for almost 90% of total CO_2 emissions in the transport sector, with the remainder emanating from the domestic aviation and shipping sub-sectors.[9] Within road transport, passenger transport accounts for about 60% of total CO_2 emissions. Indonesia's very large stock of two/three-wheel vehicles means that they account for almost half of total passenger CO_2 emissions, despite their lower emissions intensity per kilometre relative to cars. For the road freight sub-sector, most emissions are from light- and medium-duty vehicles.

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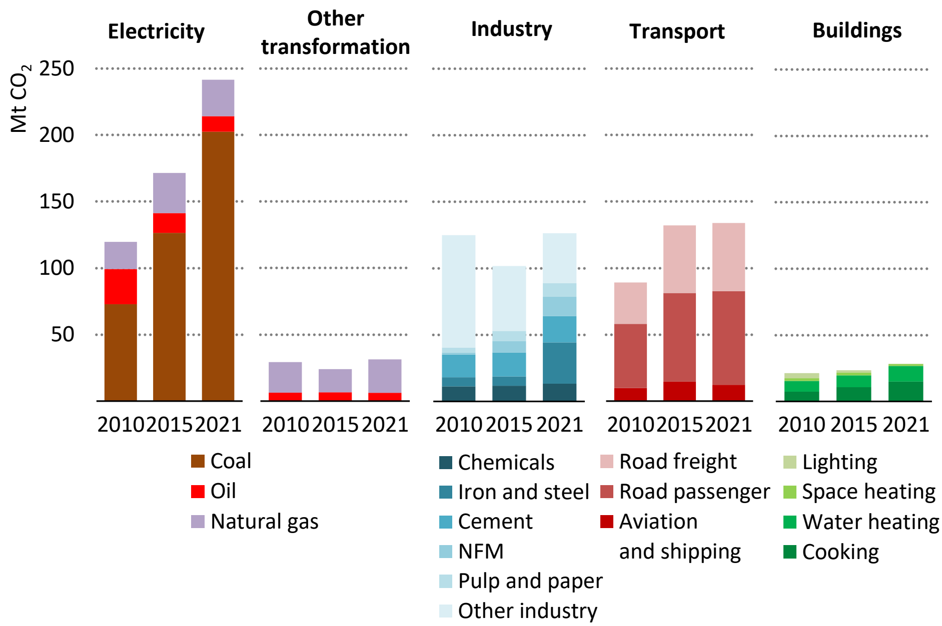
Figure 1.10 ▷ CO_2 emissions from fuel combustion by sector and sub-sector, 2010 – 2021



Coal-fired generation dominates CO_2 emissions in the power sector; emissions from end-uses are from a range of sub-sectors

Notes: NFM = non-ferrous metals. This figure shows direct emissions from fuel combustion by sector. Indirect emissions, for example from electricity production used to power air conditioning in buildings, are allocated to the sector of production. Other transformation refers to other fuel transformation such as oil refining. Other industry includes construction, food processing, machinery, mining, textiles, wood processing and industries otherwise not categorised

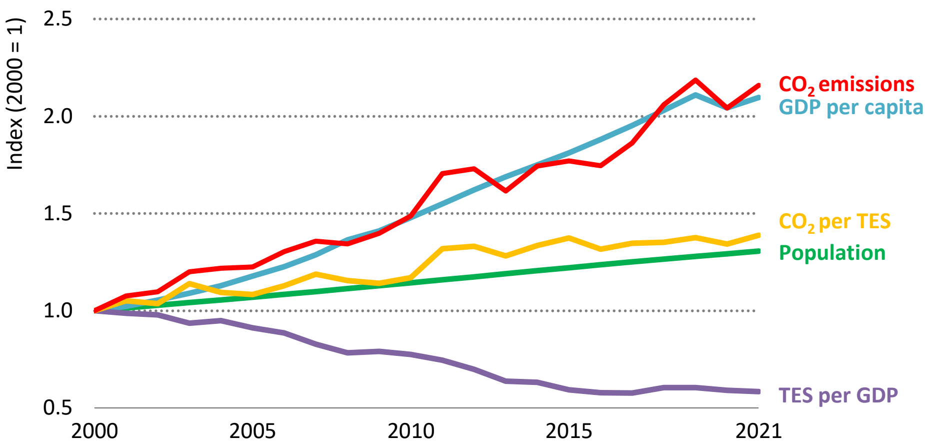
Direct CO_2 emissions in the buildings sector, not including those from electricity generation, are dominated by cooking and water heating in households, reflecting Indonesia's minimal need for space heating. Thanks to the progress in improving access to electricity, emissions from lighting with kerosene and other combustible fuels have been largely eliminated over the last decade. According to the most recent annual socio-economic survey, only 0.8% of

[9] Emissions from the combustion of bunker fuels for international aviation and maritime transport are not allocated to national emissions totals.

households reported using a non-electrical source as their main source of lighting (BPS, 2022b). Household appliances such as refrigerators and air conditioners operate on electricity and therefore do not have direct CO_2 emissions. The key challenge to decarbonise the buildings sector will be to shift cooking and water heating to electricity and other low emissions fuels, while raising the energy efficiency of appliances and building envelopes to reduce the rate of electricity demand growth.

Growing economic activity is the key driver of Indonesia's increasing CO_2 emissions (Figure 1.11). As the country's population increased over the last two decades, welfare and consumption grew and economic output boomed. Population growth alone is responsible for about one-fifth of the increase in emissions. But the primary driver of the substantial rise in CO_2 emissions was the growth of GDP per capita, which accounted for more than half the increase in emissions. The increase in the carbon intensity of energy supply was responsible for about a quarter of the growth in emissions. However, the energy intensity of Indonesia's GDP improved which helped to avoid a much bigger increase in emissions. Absent improved energy intensity, CO_2 emissions would have almost quadrupled instead of the doubling that took place in the 2000-21 period.

Figure 1.11 ▷ Key drivers of energy sector CO_2 emissions in Indonesia, 2000 – 2021



Growth in emissions is due to increases in population, per capita GDP and the emissions intensity of energy supply

Note: TES = total energy supply.

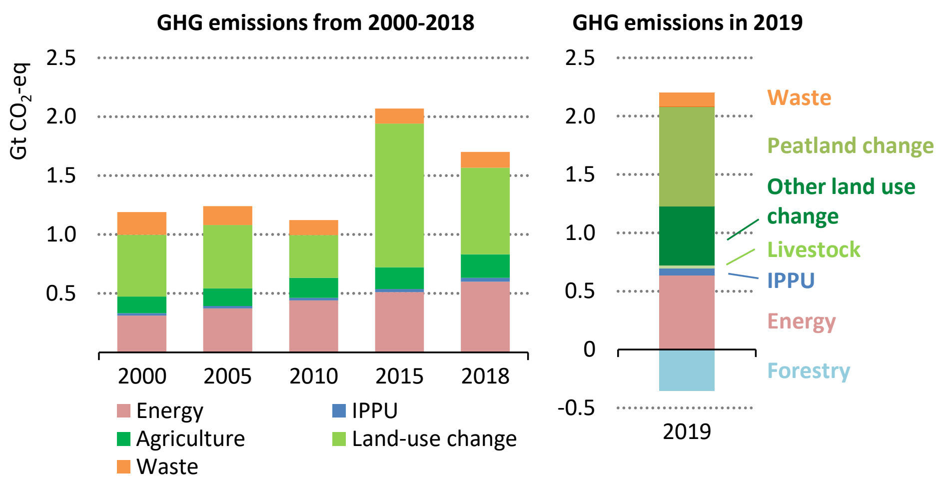
1.3.4 Emissions from other sectors

This report focuses on CO_2 emissions from the energy sector. In addition to the significant increase in emissions from the energy sector, Indonesia emits large quantities of greenhouse house gas (GHG) emissions from other sectors, in particular CO_2 from the agriculture, forestry and other land use (AFOLU) sector. AFOLU includes GHG emissions from existing activities, such as methane emissions from rice cultivation, and CO_2 emissions from land-use change, such as deforestation or peatland degradation. Indonesia's energy sector emissions need to be considered in the context of its overall GHG emissions profile.

1

Total net GHG emissions amounted to about 1.8 gigatonnes of carbon-dioxide equivalent (Gt CO_2-eq) in 2019 – ranking Indonesia the sixth-largest GHG emitter in the world, (considering the European Union as a single entity).[10] The energy sector, including fugitive emissions of methane, accounted for about one-third of Indonesia's total net emissions in 2019. Peatland fires and degradation account for slightly less than half of Indonesia's total emissions and show high variability from year to year (Figure 1.12). Other land uses, including grassland and cropland management, accounted for about a quarter of net emissions. Forest management contributed a net sink of 355 Mt CO_2-eq. Taken together, the AFOLU sector accounted for about 1 Gt CO_2-eq of net emissions in 2019.

Figure 1.12 ▷ Total greenhouse gas emissions by sector, 2000 – 2019



Emissions from the energy sector have increased rapidly with economic activity, while AFOLU emissions show considerable year-to-year variations due principally to fire

Note: GHG = greenhouse gas emissions; Gt CO_2-eq = gigatonnes of carbon-dioxide equivalent; IPPU = industrial process and product use.

Sources: Emissions from the 2000-2018 period are from Climate Analysis Indicators Tool, which provides a consistent annual time series (Climate Watch, 2022). Emissions for 2019 are from the Third Biennial Update Report of Indonesia to the United Nations Framework Convention on Climate Change (Government of Indonesia, 2021a).

[10] Emissions from the AFOLU sector are subject to high uncertainty. Indonesia's position in rankings of largest emitters has changed in recent years depending on annual variations in its emissions and those of Brazil. From an emissions perspective, the European Union can be considered as a single entity given that it submits a joint Nationally Determined Contribution to the UNFCCC under the Paris Agreement.

1.4 Indonesia's energy policy landscape

Indonesia's development goals are outlined in its *National Long-Term Development Plan* (RPJPN 2005-2025). It is divided into four phases. Each phase has a National Medium-Term Development Plan (RPJMN). Each medium-term plan provides the strategic basis for all Indonesian ministries and government agencies for the period.

The government's energy law (2007) was supplemented by the *National Energy Policy* (Kebijakan Energi Nasional, [KEN]) in 2014.[11] It set a goal of reaching a 23% share of renewables in total energy supply (TES) by 2025 and 31% by 2050, based on TES of more than 16 exajoules (EJ) in 2025 and 42 EJ in 2050. It further set targets to increase electricity demand to 2 500 kilowatt-hours (kWh) per capita by 2025 and 7 000 kWh by 2050. The policy also targets a reduction in final energy intensity of 1% per year in the 2015-25 period.

To put these targets in perspective on the basis of the most recent data, in 2021 electricity consumption was slightly less than 1 000 kWh per capita and TES was around 10 EJ. Total final energy intensity of GDP, excluding the traditional use of biomass, improved about 2% per year over the last decade.

For the energy sector, the *National Energy Plan* (Rencana Umum Energi Nasional [RUEN]) established in 2017 is the current strategic document. The plan, prepared by the Ministry of Energy and Mineral Resources (MEMR), aims to achieve the objectives of the KEN and national goals for economic growth, energy independence and energy security, and serves as a guideline for energy planning.

The National Energy Plan presents two scenarios for the energy sector; the business-as-usual scenario and the RUEN scenario which defines targets for the evolution of the energy sector. The RUEN scenario largely restates the central targets of the KEN, notably regarding electricity consumption per capita, the share of renewables in TES and the volume of TES in 2025 and 2050.

The National Energy Plan is incorporated in sectoral and regional planning documents, notably:

- *National Electricity General Plan* (Rencana Umum Ketenagalistrikan Nasional) which establishes long-term goals for the electricity sector, and the *Regional Electricity Plan* (Rencana Umum Ketenagalistrikan Daerah), developed by the MEMR.
- *Electricity Supply Business Plan* (Rencana Umum Penyediaan Tenaga Listrik [RUPTL]) of the state-owned electricity corporation, Perusahaan Listrik Negara (PLN). It is considered the guiding document for the development of the national electricity system. It details investment plans and the power plant construction pipeline.
- *Regional Energy Plans* (Rencana Umum Energi Daerah) developed for each province.

The KEN targets for the share of renewables in TES are reiterated in Indonesia's updated Nationally Determined Contribution (NDC) submitted to the UNFCCC in 2021. Assessing

[11] Law No. 30/2007 on Energy in 2007 and Presidential Regulation No. 79/2014 in 2014.

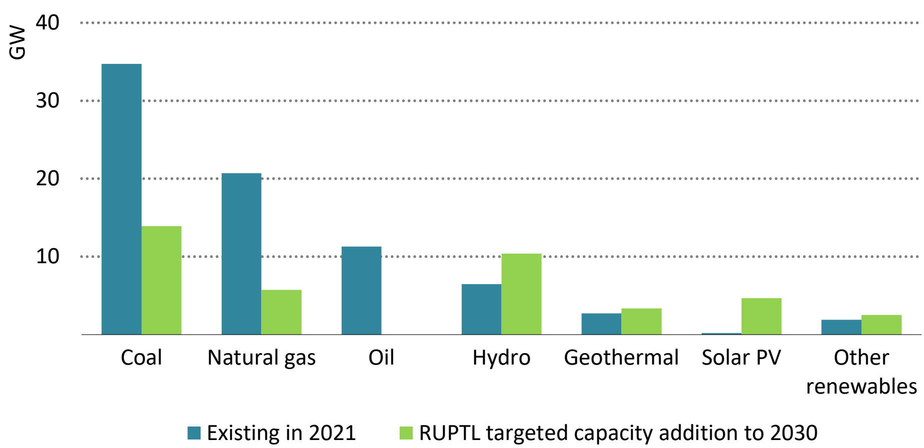
progress toward the KEN targets, in part, depends on the approach to accounting for renewables in total energy supply (Box 1.2). The share of renewables in TES was about 12% in 2021 according to the most recent energy balance by the MEMR (MEMR, 2022). The MEMR and IEA use different conventions to account for the primary energy input to renewables-based electricity generation, notably for geothermal. In addition, the IEA accounts for the traditional use of biomass, whereas the national energy balance produced by the MEMR does not. According to the IEA energy balance for Indonesia, the share of renewables in TES was around 24% in 2021 (IEA, 2021a).

1.4.1 Renewable energy policies

Renewables in electricity generation

In the current electricity supply plan (RUPTL 2021-2030), PLN envisages substantial growth in renewables generation capacity (Figure 1.13). Between 2021 and 2030, renewables are planned to make up more than half of capacity additions. Targeted renewables capacity additions include 10 GW of new hydro capacity – nearly half of the total – and about 3 GW from geothermal. The planned capacity additions of wind (0.4 GW) and solar PV (4.7 GW) are relatively modest in absolute terms. In the same period, coal accounts for about one-third of the targeted capacity additions (about 14 GW). The government and PLN have stated that after the current pipeline to 2030, as defined in the RUPTL, no new coal capacity should be built. Natural gas is expected to account for about 14% of new capacity additions.

Figure 1.13 ▷ Targeted capacity additions by 2030 relative to current generation capacity



Targeted capacity additions in the electricity supply plan see the coal-fired generation fleet expand by 14 GW, or 40%, with modest additions of renewables capacity

Notes: Other renewables include wind and bioenergy; RUPTL = Electricity Supply Business Plan.

Despite increasing government efforts to accelerate deployment of electricity generation from renewables in Indonesia, the National Electricity Law requires the prioritisation of domestic products and services when developing generating assets. This local content requirement, and the limited domestic renewable energy technology industry results in higher prices and in difficulty for project developers to obtain the necessary equipment. In addition to local content requirements, limited transparency of the process and contractual specifics of power purchase agreement negotiations for renewables projects increases both uncertainty for developers and risk premiums for project financing.

Further, current electricity tariff regulations do not favour wind and solar. PLN and MEMR uses the main indicator *biaya pokok produksi* (BPP), based on the average cost of production, as a measure of cost-effective performance of the power sector. Fossil fuel subsidies, such as the domestic market obligation that requires coal producers to supply power generators, with a maximum price of USD 70 per tonne for greater than 6 000 kilocalorie per kilogramme (kcal/kg) coal, keep the cost of coal to the power sector low. Regulation sets a maximum purchase price of 100% of the BPP for hydro and geothermal, biomass and ocean wave and 85% of the BPP for solar PV and wind.[12] Current tariff levels are viewed by most industry players as too low to spur growth in capacity additions, notably given the local content requirements and high capital costs. A long proposed presidential regulation on renewables is intended to correct this tariff disadvantage for renewables and other barriers to deployment, its implementation, however, has not yet been realised.

Bioenergy

Renewable energy programmes announced by the MEMR aim to maximise the use of bioenergy. The avenues laid out include: bioenergy use in waste-to-energy plants (with construction of plants proposed in 12 cities); co-firing in existing coal generators; and for use as liquid biofuel.

The rapid growth in palm oil production in Indonesia over the last two decades has fuelled the increase of biofuel blending in diesel fuel. The National Energy Law (KEN) of 2007 promoted the use of biofuels as an energy diversification measure, with subsequent policies establishing blending mandates, and subsidy and pricing mechanisms. Mandatory biofuel blending rates were set by regulation in 2015.[13] Biodiesel has been required to make up 30% of total diesel demand as from January 2020, up from the previous blending target of 20% achieved in 2019. Bioethanol blending requirements vary by sector, with a 10% blending target for transport in 2020, increasing to 20% by 2025, however, efforts to increase bioethanol use have been less successful than biodiesel. Recent government statements suggest an ambition to further increase biodiesel blending requirements, including testing of B40. Blending mandates are supported by subsidies to cover the price differential between fossil fuels and biofuels. The subsidies are financed by levies on palm oil exports. The

[12] Regulation 50 of 2017 (MEMR, 2017) amended by Regulation 4 of 2020 (MEMR, 2020).

[13] MEMR Regulation No. 12/2015 updates MEMR Regulation No. 32/2008.

government is also supporting construction of refineries to convert waste bioenergy into biofuels, and other renewable fuels, such as bio-based LPG and naphtha.

1.4.2 Electrification policies

Electromobility

The government has outlined ambitions to accelerate the deployment of electric vehicles (EVs). As part of the upcoming National Energy Grand Strategy (slated for release during the G20 summit in late 2022), the indicated target fleet is 2 million electric cars and 13 million electric motorbikes by 2030. This would equate to about 9% and 12% of the respective stocks in 2030, compared to well under 0.1% in 2021. Only 800 electric cars and 10 000 electric motorbikes were sold in 2021. To support deployment, the Presidential Regulation on Battery Electric Vehicles and the Battery Electric Vehicle Roadmap sets targets for the share of low-carbon emission vehicles including battery EVs, plug-in hybrid vehicles, flex-fuel engine and low cost green cars in local production. The roadmap sets targets for low-carbon emission vehicles to reach 20% of domestic car production in 2025 and 30% in 2035. The government has also promoted the establishment of the Indonesia Battery Corporation, a partnership of four state-owned companies (Pertamina, PLN, Mind.Id and ANTAM), each with a 25% share.

The government has mandated that PLN co-operate with state-owned enterprises as well as privately owned business entities in the development of EV charging infrastructure. The Provision of Electric Charging Infrastructure for Battery Based Electric Motor Vehicles regulates the types of charging infrastructure and electricity charging tariffs.

Cooking

It is a government policy objective to reduce use of LPG for household cooking in favour of electric induction cooking. It is motivated by the weight of LPG subsidies on government balance sheets and the LPG trade deficit. However, current subsidisation of LPG (covering the vast majority of LPG sales) creates headwinds for the electrification of cooking, tipping the economic balance in favour of LPG. Announced policy proposals to date are unlikely to create sufficiently strong incentives for households to switch to electric cooking methods while the LPG subsidies remain in place. In addition, low power capacity electricity connections in many low-income households hamper the uptake of electric stoves (Christian, 2021).

1.4.3 Energy efficiency policies

Indonesia's *National Master Plan for Energy Conservation* (RIKEN) sets a goal of decreasing energy intensity 1% annually between 2015 and 2025. In order to reach this goal, energy demand reduction potentials relative to a business-as-usual baseline have been identified by sector: industry 15-30%; commercial buildings 25%; households 10-30%. The plan to achieve these targets includes fiscal incentives (tax deductions and soft loans) together with other instruments such as training and educational programmes as well as energy audits. Notably, the primary and final energy intensities of the Indonesian economy have been improving considerably faster than 1% annually in recent years, highlighting an opportunity for national energy planning to set more ambitious targets for energy intensity improvements.

At a more granular level, Indonesia has passed a number of energy efficiency laws and regulations, mostly in the industry and buildings sectors. Recent regulations build on the 2009 regulation[14] that decrees energy conservation to be the responsibility of national and regional governments, businesses and citizens. It establishes a framework to incentivise energy conservation practices and requires large energy users to undertake energy conservation practices. The details of the required energy management practices were provided in subsequent regulation in 2012.[15]

The Regulation on Energy Conservation establishes requirements for industries that use more than 6 000 tonnes of oil equivalent (toe) or 70 gigawatt-hours (GWh) per year. In 2021, it applied to more than 300 industrial facilities. It is expected that the energy threshold level for the industry sector will be lowered from 6 000 toe/year to 4 000 toe/year, expanding the number of sites covered. Further to these requirements, the Ministry of Industry has developed 31 green industry standards that regulate the limit of energy and emissions intensity by product type or process. Standards cover the paper industry and glass packaging.[16] Between 2017 and 2021, 44 industries were certified as green industries. The Ministry of Industry estimates that the green industry programme in 2021 avoided over 360 PJ of energy demand, saving IDR 3.2 trillion (around USD 225 million) in energy bills.[17]

In the buildings sector, projected electricity demand growth from home appliances, in particular from air conditioners, has encouraged the development of national mandatory regulations on energy use in buildings which were promulgated in 2021 by the Ministry of Public Works and Housing.[18] The regulations set standards for site management, energy efficiency, water use efficiency, indoor air quality and waste management. The regulations are mandatory for most residential buildings of at least four storeys, mixed-use residential buildings, office buildings with a floor area of more than 50 000 square metres (m^2), hospitals with a floor area of more than 20 000 m^2 and other buildings with a floor area of more than 10 000 m^2. The new regulations set minimum performance standards for building envelopes, cooling equipment, lighting and other building systems.

[14] Government Regulation No. 70/2009 on Energy Conservation.

[15] Regulation of MEMR No. 14/2012 on Energy Management.

[16] Green Industry Standard for Paper Industry and Corrugated Paper (Regulation of the Minister of Industry Regulation 49/2020) and Green Industry Standard for Glass Packaging (Regulation of the Minister of Industry Regulation 48/2020).

[17] Presentation of the Ministry of Industry on the Achievement of Green Industry 2021, presented on 5 January 2022.

[18] Government Regulation No.16/2021 on Buildings and subordinate regulation Government Regulation No.21/2021 on the Assessment of Green Building Performance.

The national building code and green building performance regulations expand on existing building energy codes in some jurisdictions, such as Jakarta, Bandung and Semarang that have mandatory codes for certain building types.

Building codes and green building performance regulations complement minimum energy performance standards (MEPS) and mandatory energy labelling for products. Building on previous requirements for energy efficiency labelling for compact fluorescent lamps and air conditioners, the MEMR established MEPS for appliances and equipment in 2021.[19] The regulation defines the scope of products, testing methods, rating criteria and label designs. Subsequent subordinate regulations establish or strengthen the MEPS and labelling criteria for four appliances: air conditioners, fans, refrigerators and rice cookers. MEPS for air conditioners require that units with a cooling capacity less than 7.9 kilowatts (kW) have a cooling seasonal performance factor (CSPF) of at least 3.1, a level in line with most other Association of Southeast Asian Nations (ASEAN) markets, but well below the minimum of CSPF 8 in Japan (IEA, 2022). The standards immediately came into force for air conditioners and are scheduled to come into force in September 2022 for the other three appliance types. The MEMR plans to introduce MEPS for 11 additional appliance and equipment types, covering lighting, televisions, washing machines and inductions stoves, among others.

From high level regulations to specific product standards, challenges remain in effective and comprehensive enforcement of existing regulations, as well as in access to the financing required to implement energy efficiency improvements.

1.4.4 Domestic fuel supply and use policies

The government aims to provide continued support to maintain current levels of coal production. In addition, it aims to accelerate development of coal downstream industries to transform low grade coal into products such as dimethyl ether (DME) and methanol. State-owned coal producer, Bukit Asam, and state-owned oil and gas corporation, Pertamina, signed a joint venture with Air Products to develop a coal gasification plant to produce DME as a substitute for imported LPG in cooking. A second announced plant, to be located in East Kalimantan, will produce methanol (Chapter 5, Box 5.2 covers emissions of coal downstream processes).

Coal demand is also supported by targets to continue to expand coal-fired electricity with 14 GW of capacity slated to be developed in the period to 2030 according to the national electricity supply plan. Existing and expanding coal-fired generation capacity is supported by a domestic market obligation (DMO) policy by which domestic coal miners must supply 25% of their annual production to PLN at a price capped at USD 70 per tonne for >6 000 kcal/kg coal, which is well below current international market prices. Coal prices for coal consumers in industry, such as cement and fertiliser plants, are currently capped at USD 90 per tonne

[19] Government Regulation No.14/2021 on the Implementation of Minimum Energy Performance Standards for Energy Consuming Appliances and Equipment.

for >6 000 kcal/kg coal. The government in the past has enforced the DMO by banning coal exports until supplies to domestic power plants have been assured.

Government ambitions to increase domestic production of natural gas parallel targets to expand domestic use to replace imported LPG and to connect 4.7 million households to natural gas (city gas) networks by 2025. Continued subsidisation of LPG for households reduces the incentive to switch to natural gas for cooking and other uses, plus delays in the expansion of domestic supply jeopardise the economic and energy security benefits to Indonesia of shifting to natural gas for cooking to replace imported LPG.

1.4.5 Energy affordability and access policies

Energy subsidy reform has been a target of the current presidential administration since taking office in 2014. Electricity subsidies were somewhat reformed in 2014 when the government reintroduced automatic electricity tariff adjustment mechanisms, shifting away from the requirement for legislation to change electricity tariffs. As part of this process, several categories of consumers were moved to tariffs considered to be unsubsidised. However, the automatic mechanism was suspended in 2018 and tariffs frozen, in advance of presidential elections.

In 2020, in order to counter the shock of the Covid-19 pandemic on the incomes of poor households, the government provided targeted electricity bill relief subsidies to low income citizens from April to June, providing full relief for electricity bills for around 35 million households.

LPG subsidies have not yet been reformed, though it remains high on the political agenda. Several reform options to eliminate wealthy households from subsidy eligibility are being tested, notably using biometric recognition. However, the Covid-19 pandemic and subsequent inflationary pressure has stalled progress on LPG subsidy reform.

Transport fuels for consumers are also subsidised, via the products premium gasoline (RON 88) and pertalite gasoline (RON 90). Pertamina announced plans to progressively phase out subsidies for oil consumption in transport, however, these plans are on hold in 2022.

According to IEA analysis, fossil fuel and electricity subsidies for consumers in Indonesia in 2020 amounted to USD 6.9 billion, or about 0.6% of Indonesia's GDP. With higher prices in 2021, subsidies increased USD 19 billion, or about 1.6% of GDP (Chapter 5, section 5.1.2 discusses energy affordability in the net zero emissions pathway).

1.5 Evolution of climate policy in Indonesia

Indonesia's first commitment to mitigate GHG emissions was in 2009 at the Copenhagen climate summit. It pledged to reduce emissions by 26% by 2020 relative to a business-as-usual baseline and by up to 41% premised upon international support. This pledge was translated into domestic policy via the *National Action Plan for Reducing Greenhouse Gas*

Emissions (RAN-GRK), approved by presidential regulation in 2011. Indonesia's Intended NDC under the Paris Agreement, submitted in 2015, pledged to reduce CO_2 emissions by 29% in 2030 relative to a business-as-usual baseline. Indonesia ratified the Paris Agreement in 2016, reiterated the 29% target and assigned the MEMR responsibility to achieve 11 percentage points of the target emissions reduction from the energy sector. The Ministry of Environment and Forestry was assigned responsibility to achieve 17 percentage points of the target emissions reduction from the AFOLU sector, underscoring its predominant role in Indonesia's total GHG emissions.

Indonesia's initial NDC submission and wider energy policy landscape lacked actionable steps and policy frameworks to reduce emissions from the energy sector. However, its GHG emissions reduction objectives were integrated into the national economy-wide development and domestic policy agenda in 2017 with the Indonesia Low Carbon Development Initiative, presented by the Ministry of National Development Planning. Further to this, policies to address AFOLU emissions included moratoriums on forest clearing, revoking concession permits in forests, creating the Peatland Restoration Agency and developing a plan for social forestry.

Indonesia's updated NDC was submitted to the UNFCCC in July 2021. It reiterated the unconditional target to reduce CO_2 emissions by 29% in 2030 relative to a business-as-usual baseline and also included a reduction target of up to 41% in 2030, conditional on the provision of international assistance. The updated NDC sets targets for the shares of fuels in the energy mix: 77% share of fossil fuels in 2025, comprised of 25% oil, 30% coal and 22% gas; and by 2050 a reduction of the fossil fuel share to 69% (20% oil, 25% coal and 24% gas).

The government is developing the *National Grand Energy Strategy* to integrate the targets set out in the NDC with its energy sector strategic planning. It is planned for release in association with the G20 summit in November 2022, of which Indonesia currently holds the presidency.

1.5.1 Emissions trading and carbon pricing

Decarbonisation of its energy sector forms a cornerstone Indonesia's efforts to achieve its emissions related goals. The development and implementation of a domestic emissions trading system (ETS) for the power and industry sectors is one of the government's key policy mechanisms to help meet its NDC targets and to foster low-carbon sustainable development.

A presidential regulation to provide a national framework for carbon pricing instruments, including an ETS, was signed in October 2021.[20] It extends the Government Regulation on Environmental Economic Instruments, which was introduced in November 2017 and provides a first mandate for an emissions and/or waste permit trading system to be implemented by 2024.

[20] Government Regulation 98/2021.

A voluntary and intensity-based pilot ETS for the power sector was tested between March and August 2021. Participants traded allowances and offset credits stemming from renewable energy generation. Initially, 84 coal-fired plants, both public and private, were invited to participate, with 26 eventually taking part. According to government plans, the pilot programme is set to continue with new phases, including the integration of the industry sector, over the coming years before transitioning to a mandatory ETS, which is expected by 2024 in line with the presidential regulation.

The ETS will function as a hybrid "cap-trade-and-tax" system alongside a carbon tax that was imposed in April 2022 and be regulated by the broad Law of the Harmonization of Tax Regulations. The new law stipulated that carbon taxes will be implemented first in the power sector in 2022, then gradually expanded to other sectors from 2025, depending on sector readiness. Once the mandatory ETS is in place, installations that fail to meet their obligations under the system will be subject to the carbon tax, at a rate linked to the price of the domestic carbon market, but with a minimum price threshold of IDR 30 000/kg CO_2 (USD 2/t CO_2) (Kementerian Keuangan, 2021).

Sectoral coverage and cap setting

The voluntary ETS trial covers only power sector emissions. Coal-fired power plants with a capacity greater than or equal to 100 megawatts (MW) directly participate in the cap and trade system, while renewable and other power plants participate indirectly by means of offsets. The 2019 intensity cap is calculated using the weighted average emissions of each plant category. Plants receive free allowances based on the intensity cap, which means that those that emit less than the average will have an allowance surplus, while those that emit more than the average will have an allowance deficit.

Table 1.2 ▹ Coal-fired power plant CO_2 emissions cap by category, 2019

Power plant category	Capacity (MW)	Emissions cap (t CO_2/MWh)
Coal-fired power plant	> 400	0.918
Coal-fired power plant	100 < x ≤ 400	1.013
Mine mouth coal-fired power plant	100 < x ≤ 400	1.094

During the trading phase, plants with an allowance surplus can sell their excess allowances only if they have made energy efficiency and emissions mitigation efforts, such as adding renewable energy. Plants can trade no more than 70% of their allocated emissions allowance. Those with an allowance deficit can purchase allowances from other plants or use offsets to achieve compliance. Coal plants that have not surrendered a sufficient amount of allowances or offsets under the scheme will be subjected to the carbon tax. The carbon tax is expected to act as a price floor for Indonesia's ETS market.

Box 1.3 ▹ Indonesia's vulnerabilities to climate change

The Earth's mean surface temperature increased by about 0.02 °C every year from 2000 to 2020, and stood around 1.2 °C above pre-industrial levels in 2020 (IPCC, 2021). In the IEA's Stated Policies Scenario, which is based on the assessed impacts of current and announced policies, this warming trend continues, with the median temperature rise reaching 1.5 °C by 2030, about 2 °C by 2050 and 2.6 °C by 2100. Due to uncertainties in the physical response of the climate to GHG emissions, such projections of future levels of warming are probabilistic in nature: for example, in the Stated Policies Scenario there is a 10% chance of a temperature rise above 3.5 °C in 2100 (IEA, 2021b).

The effects of climate change are already apparent in Indonesia. Monsoon patterns are changing, with shorter wet seasons now the norm in South Sumatra, Java and Kalimantan. Extreme rainfall events intensified between 1981-2015, especially in Sulawesi and Papua, increasing the risks of flooding and landslides (Government of Indonesia, 2017).

Various extreme weather events have impacted energy infrastructure. For example, extreme rainfall in 2013 led to the shutdown of the Muara Karang gas-fired power station; the tropical cyclones in 2019 and 2021 damaged power transmission networks with storm surges flooding coastal power plants; an extreme heatwave in 2019 triggered rolling blackouts on Lombok Island over several weeks due to the combined effects of higher peak electricity demand for cooling and lower production capacity.

A recent study ranked Indonesia in the top one-third of countries exposed to climate-related risks, with particular exposure to coastal and rain-induced flooding, and extreme heat (World Bank and Asian Development Bank, 2021).

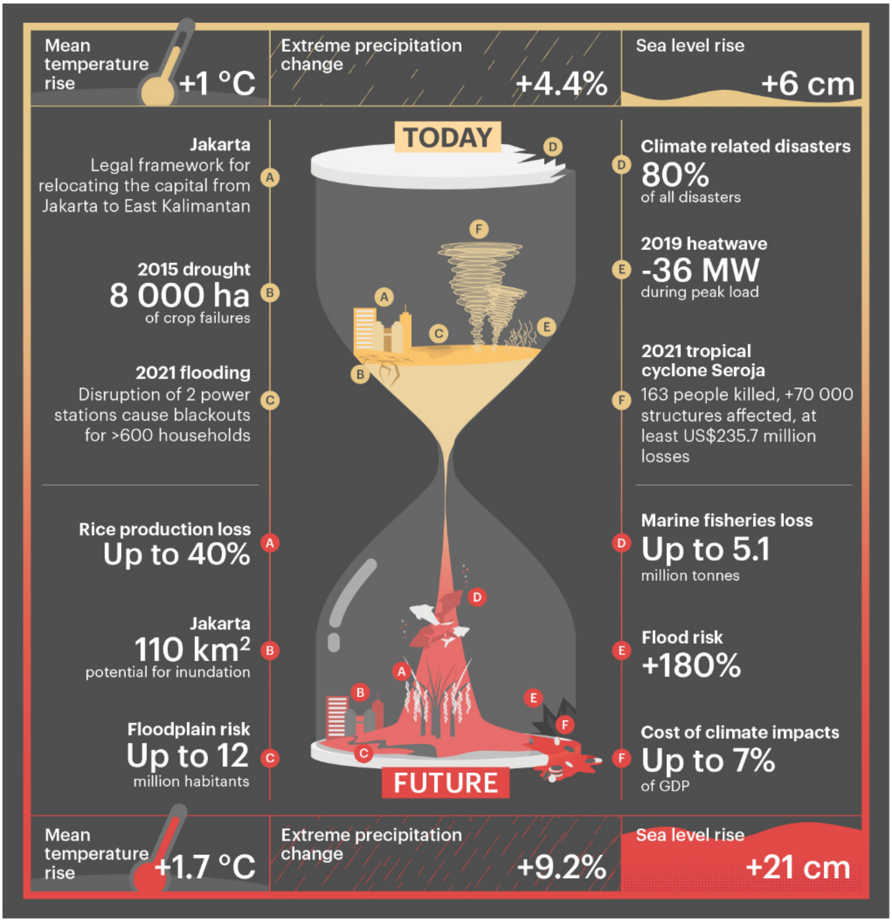
Currently, with a mean temperature rise in Indonesia of 1 °C, the effects of climate change are already being felt in heatwaves, droughts and flooding events (Figure 1.14). By 2050, in the Stated Policies Scenario, the mean global temperature rise is around 2 °C, and the temperature rise in Indonesia is estimated to be around 1.7 °C. At this level of warming, key physical hazards for Indonesia and/or Southeast Asia include (IPCC, 2021):

- A 20-30% decrease in mean rainfall in some regions, such as Java, Sumatra and Kalimantan.
- An increase in the frequency and intensity of heavy and intense precipitation events in South, Southeast and East Asia, alongside a large increase in flood frequency in monsoon regions.

Consequential impacts of these and other physical hazards include (IPCC, 2022):

- A 15-40% increase in the extent, severity and duration of peatland fires, leading to loss of habitats and biodiversity risk.
- A 180% increase in flood risk in Jakarta and a 55% increase in flooding on agricultural land.
- Loss of up to 40% of rice production potential.

Figure 1.14 ⊳ Climate-related physical hazards and consequential impacts



A 1.7 °C temperature rise occurs around 2050 in Indonesia in the Stated Policies Scenario, leading to increased risks of physical hazards and consequential impacts

Note: Future mean temperature rise, extreme precipitation change and sea level rise correspond to median values for Southeast Asia over the period 2041-2060 taken from the IPCC Working Group 1 Interactive atlas (IPCC, 2022).

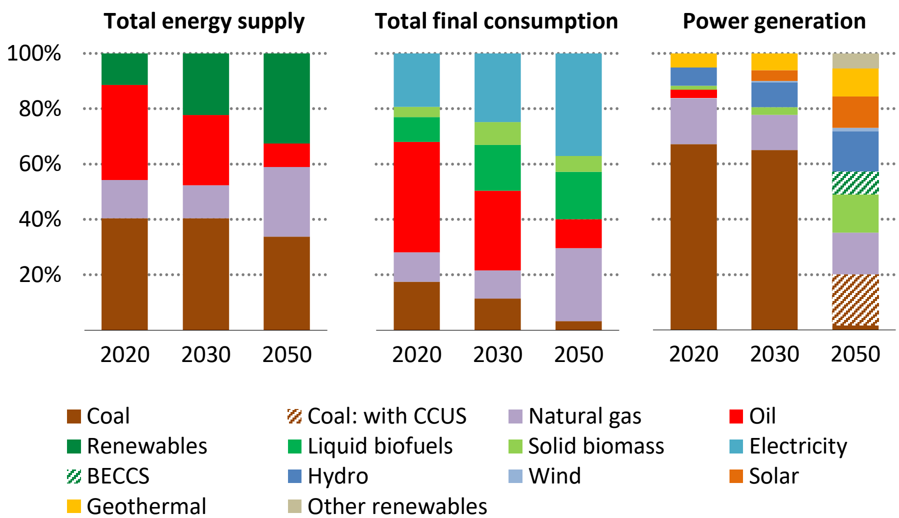
The impacts of the physical hazards brought about by climate change will be felt across all sectors of Indonesian society, including on energy-related infrastructure. During extreme heat events, the rise in cooling demand can be challenging for the electricity sector, while electricity supply is also affected. Climate change impacts, such as reduced rainfall, are projected to reduce Indonesia's hydropower capacity factor by around 5-7% between 2060-2100 (IEA, 2021c). This would impact electricity generation from the 6.5 GW of existing and more than 10 GW of planned hydropower capacity in Indonesia.

1.6 Net zero emissions target

Indonesia submitted its first Long-Term Low Emissions Strategy (LTS) along with its updated NDC to the UNFCCC in 2021. The LTS sets out three long-term development scenarios. The most aggressive mitigation scenario, the Low Carbon Scenario Compatible with the Paris Agreement (LCCP), envisages total GHG emissions peaking around 2030 and declining thereafter. Under the LCCP, "Indonesia is expected to gain optimistically [the] opportunity for more rapid progress towards net zero emission in 2060 or sooner" (Government of Indonesia, 2021b). This forms the basis for Indonesia's target of reaching net zero emissions by 2060.

The projections for the LTS are based on a slower long-term rate of GDP growth than those of the National Energy Policy (KEN). GDP is projected to grow at around 5% between 2025 and 2040, moderating to 4.5% between 2040 and 2050. This results in a lower projection for total energy supply in 2050 of around 25 EJ versus 42 EJ in the KEN.

Figure 1.15 ▷ Total energy supply, final consumption and power generation mix in the LCCP scenario of Indonesia's Long-Term Low Emissions Strategy



Coal retains a substantial share of total energy supply including a large uptake of coal-fired generation equipped with CCUS

Notes: LCCP = Low Carbon Scenario Compatible with the Paris Agreement; BECCS = bioenergy equipped with CCUS; CCUS = carbon capture, utilisation and storage. Renewables in total energy supply is given as an aggregate and includes all renewable sources. Coal in total energy supply includes coal with CCUS in power generation; coal with CCUS in total energy supply is not given as a separate data series.

Sources: IEA analysis based on data from Government of Indonesia (2021b).

In the LCCP, renewables account for the largest share of electricity generation in 2050, while unabated coal generation is almost eliminated and the remaining coal-based generation is equipped with carbon capture, utilisation and storage (CCUS) (Figure 1.15). The use of bioenergy equipped with CCUS (BECCS) would provide some negative emissions. Total GHG emissions from the energy sector, but excluding process emissions, would peak by 2030 and decline to 570 Mt CO_2-eq in 2050.

The overarching cross-sectoral framework provided in the LTS is intended to provide guidance for individual sectors to develop their own vision of the pathway to Indonesia's goal of reaching net zero emissions by 2060. At COP26 in late 2021, the MEMR presented an initial analysis of the pathway for the energy sector. This envisages reaching net zero emissions in the power sector in the 2050s, while still allowing for coal-fired power plants to reach the end of their expected technical lifetimes. Total energy sector emissions would reach around 400 Mt CO_2-eq by 2060, driven by emissions in the transport and industry sectors. These emissions would be offset by GHG emissions removals from the land-use sector, which is modelled separately by the Ministry of Environment and Forestry. Since COP26, the MEMR has been working on revising this analysis as part of the process of developing a concrete pathway for the energy sector.

A pathway to net zero emissions by 2060

Energy sector on the road to net zero emissions

SUMMARY

- This report presents *a* pathway, not *the* pathway, for Indonesia to meet its economy-wide goal of net zero emission by 2060. It is informed by the Announced Pledges Scenario (APS) which assumes the energy sector contributes to the economy-wide goal.
- Indonesia's GDP is projected to grow at more than 5% per year to 2030, when its GDP per capita is around 50% higher than in 2021. It reaches the GDP per capita level of today's advanced economies by the mid-2040s. With continued economic growth, by 2060 the average Indonesian is more than three-times wealthier than today, with a level of GDP per capita similar to that of Japan today.
- Given this projected scale of economic expansion, achieving economy-wide net zero emissions by 2060 in Indonesia will require comprehensive, immediate and sustained action. In the APS, energy sector CO_2 emissions peak around 2030 at 20% above the level of 2021, but about 10% lower than in the Stated Policies Scenario (STEPS) in the same year. By 2040, energy sector emissions are 20% lower than today in the APS. By 2060, those emissions amount to just over 100 Mt, predominantly from heavy industry and long-distance, heavy-duty transport.
- Indonesia's total energy supply expands in the APS, from less than 10 500 PJ today to 14 400 PJ by 2030 and almost 19 000 PJ by 2060. Even with this growth, total energy supply is 16% lower than projected in the STEPS by 2060, thanks to the benefits of energy efficiency and electrification. In total energy supply, the share of fossil fuels drops from more than 70% today to 22% by 2060 and renewables overtake fossil fuels before 2040.
- Total final energy consumption peaks around 2040 in the APS, thanks to stringent energy efficiency policies and savings from electrification. By 2060, electricity meets half of total final energy consumption; low emissions fuels meet one-fifth.
- Progress on the net zero emissions pathway requires concerted mitigation action in all sectors. Energy efficiency is front-loaded in the APS and provides almost half of the emissions savings between the STEPS and the APS in 2030, with this share declining towards 2050. Electrification and hydrogen emerge as key levers for decarbonising end-uses post-2030, delivering 30% of savings in 2050. But it is renewables that do the heavy lifting, providing nearly half of the energy sector emissions savings in 2050, dominated by their role in replacing coal in electricity generation. CCUS plays a smaller, though still critical, role in reducing emissions in the industry and fuel transformation sectors, and in electricity generation, while sources of low emissions electricity such as nuclear, ammonia and hydrogen also play a role.

2.1 A pathway to net zero emissions

There is no one pathway to achieve net zero emissions for Indonesia. Policies or technologies may exceed or fall short of expectations, energy prices and economic conditions will fluctuate and unexpected shocks are likely. Although there are many cost-effective clean energy technologies that can be implemented today with the right policies, Indonesia's transition will also partly depend on global progress to demonstrate, commercialise and diffuse key low emissions technologies. Today Indonesia is an exporter of coal and natural gas, and a major producer of energy-related critical minerals such as nickel and tin, therefore its energy sector and economy will also be influenced by international clean energy transition efforts.

Indonesia has unique circumstances for which a net zero emissions pathway must be tailored. These include a high reliance on coal in both its economy and its energy system; concentration of economic activity and energy demand on the island of Java; distinctive resource endowments of solar, geothermal, hydropower and bioenergy; and significant development needs that require substantial increases in energy consumption relative to today.

With this in mind, the objective of this analysis is not to present *the* pathway to net zero emissions, but rather *a* pathway that is:

- Embedded in a detailed understanding of Indonesia's national and regional circumstances.
- Linked to the latest analysis of global markets for fuels and technologies.
- Robust in its incorporation of key drivers of energy services demand and uncertainties.

The chapter presents an energy sector pathway to economy-wide net zero emissions in 2060, building from the IEA's Announced Pledges Scenario. It provides an overview of the main inputs to the scenario, emissions trends by sector and an analysis of the transition in energy supply and consumption. (Chapter 3 provides sector-by-sector details.)

2.1.1 Scenario design and modelling approach

Scenarios

Indonesia has set a target to achieve net zero greenhouse gas (GHG) emissions by 2060. It guides the central scenario – the Announced Pledges Scenario (APS) – used in this report. The APS was introduced into the IEA's scenario framework in 2021 to reflect the growing number of countries with announced net zero emissions targets (IEA, 2021a). The APS assumes that net zero emissions pledges are met in full and on time, regardless of whether they are currently backed by detailed implementing laws, policies and regulations. It also takes into account how countries envisage different sectors such as energy and agriculture, forestry and other land use (AFOLU) contributing to the goal of net zero emissions.[1]

[1] The mitigation potential of AFOLU is derived from removals of greenhouse gases as well as a reduction of emissions through management of land and livestock.

In the case of Indonesia, this means that in the APS its energy sector gets close to, but does not achieve, net zero CO_2 emissions. Consistent with Indonesia's *Long-Term Strategy for Low Carbon and Climate Resilience 2050* (LTS), submitted to the United Nations Framework Convention on Climate Change in July 2021, these residual energy sector emissions would be offset by removals and mitigation measures in other sectors (Government of Indonesia, 2021). The APS assumes that other countries meet their net zero pledges, and that the fuel and technology markets modelled in the IEA's Global Energy and Climate Model evolve accordingly.

Indonesia's LTS states that the country aims to "rapidly progress towards net zero emissions in 2060 or sooner" (Government of Indonesia, 2021). The possibility of an earlier transition is reflected in an accelerated outlook, our Net Zero Emissions by 2050 Scenario, as discussed in Chapter 4. The Net Zero Emissions by 2050 Scenario assumes that Indonesia contributes to a global pathway to net zero energy sector emissions by 2050, subject to the availability of financial support and cost-effective low emissions technologies.

Our analysis also uses the Stated Policies Scenario (STEPS) as a reference against which to explore the implications of the APS or the Net Zero Emissions by 2050 Scenario. The STEPS takes a more conservative and granular approach, integrating sector-by-sector analysis of the impacts of established and announced policies and regulations. Outside of these policies, the evolution of the energy system in the STEPS is driven by infrastructure and equipment lifetimes, energy technology costs, fuel prices and consumer preferences.

Modelling approach

Each of the scenarios have been modelled using the latest version of the IEA's Global Energy and Climate Model (GEC-M).[2] Modelling for this report was done in the context of the preparation of the IEA's *World Energy Outlook-2022* and therefore uses a consistent global scenario framework, encompassing macroeconomic developments, energy and climate policies, and energy prices and technology costs.[3] Notably, it includes the effects of the Russian Federation's (hereinafter Russia) ongoing invasion of Ukraine on global energy markets.

The GEC-M is a large-scale energy system simulation model, which represents Indonesia as an individual country within a connected framework of global energy markets. The IEA has modelled Indonesia as an individual country for over two decades, and updates its analysis and assumptions regarding Indonesia annually. The GEC-M is a bottom-up energy model, with rich detail regarding stocks of energy-consuming appliances and equipment, power plants, and other infrastructure for energy production, transformation and transport. The GEC-M also calculates investment and fuel costs for various sectors and technologies, and in

[2] Building on the modelling work completed for *Net Zero by 2050: A Roadmap for the Global Energy Sector* (IEA, 2021b), the IEA modelling teams merged and upgraded the World Energy Model and Energy Technology Perspectives models, naming the combined modelling framework the Global Energy and Climate Model in 2022.

[3] Interested readers are directed to the forthcoming edition of the *World Energy Outlook-2022* for more details about global assumptions and outcomes of the scenarios used in this report.

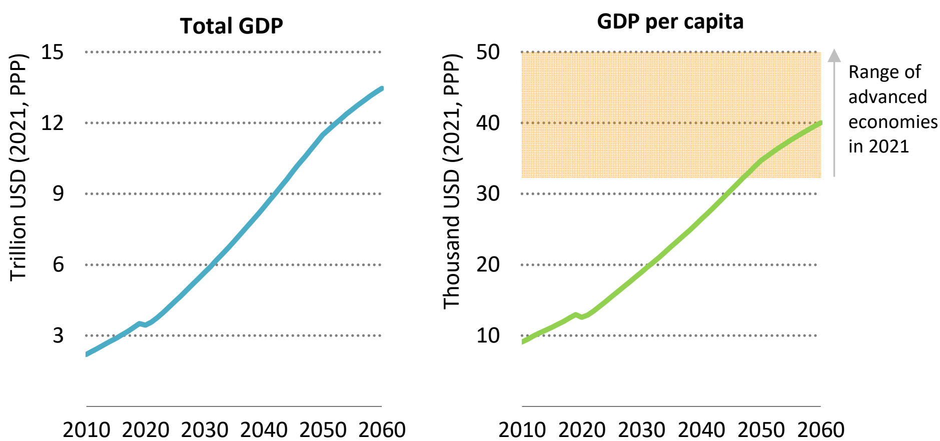
aggregate for the whole energy system. The GEC-M includes modules to assess the development of global trade for conventional fossil fuels, emerging hydrogen and hydrogen-based fuels, and bioenergy. For this report, the GEC-M has been complemented with a new, specially developed model to analyse the operation of the Indonesian electricity sector at an hourly level (see Chapter 5, section 5.3).

2.1.2 Socio-economic evolution and demand for energy services

Indonesia still faces large development needs to further reduce poverty and enhance the welfare of its citizens. Strong and inclusive long-term economic growth is critical to achieve its development goals.

Our scenarios assume that Indonesia's population growth rate moderates from 1.3% per year over the last 20 years to around 0.6% per year in the period to 2050, and then 0.2% per year to 2060. Its population increases from slightly more than 275 million today to 330 million in 2050 and 336 million in 2060. Its urbanisation rate increases from 57% today to nearly 80% in 2060, consistent with the current level seen in advanced economies as a group.

Figure 2.1 ▷ Total GDP and GDP per capita in Indonesia, 2010 – 2060, and relative to advanced economies in IEA scenarios



Strong projected economic growth brings Indonesia into the ranks of the advanced economies on a GDP per capita basis by the mid-2040s

Notes: The range of GDP per capita for the advanced economies is delimited at USD 50 000 per capita to facilitate formatting of the chart. In 2021, the richest advanced economy was Luxembourg with a GDP per capita of over USD 130 000 PPP, while the median was USD 50 0000 PPP.

In the near term, GDP growth in our scenarios is in line with the latest projections from the International Monetary Fund (IMF, 2022). In our scenarios, Indonesia maintains a steady growth rate over the next few years, despite the impacts of the current global economic uncertainty. Between 2021 and 2030, the real GDP growth rate is above 5%, making

Indonesia one of the fastest growing large economies in the world. In the longer term, the economic projections are based on a well-established macroeconomic model integrating variables such as labour supply, investment and capital stock.

After 2030 in our three scenarios, Indonesia's GDP per capita starts to converge with today's level of the advanced economies (Figure 2.1). Between 2030 and 2050, the annual GDP growth rate is around 4% per year, moderating to around 2% between 2050 and 2060. By 2050, Indonesia is the fifth-largest economy in the world (if the European Union is accounted for as a single economy). Indonesia's GDP per capita is USD 35 000 (2021) PPP, comparable with that of Slovakia today. This robust economic growth almost quadruples the size of Indonesia's economy from 2021 to 2060. By 2060, Indonesia's GDP per capita rises to more than USD 40 000 (2021), PPP per capita, around 90% of Japan's GDP per capita today.

Box 2.1 ▷ Indonesia's long-run economic growth rate projections in a historical context

To add perspective to the projections for Indonesia's long-run GDP growth outlook, we consider 70 years of global macroeconomic experience. The annualised real GDP growth rate by decade achieved by all medium- and large-size economies since 1950 are depicted in Figure 2.2.[4] Countries are classified according to their GDP per capita at the start of each decade analysed. Countries with similar levels of GDP per capita are grouped into income categories by increments of USD 5 000 PPP per capita (e.g. less than USD 5 000 per capita, USD 5 000 to USD 10 000 per capita, and so on).

At low development levels of less than USD 5 000 PPP per capita, the median growth rate over a decade was less than 2% per year and there is a wide range of outcomes between countries. Some remain trapped in poverty and some manage to progress.

As institutional performance improves at slightly higher levels of development, the median growth rate rises. In the income category of USD 5 000 - 10 000 PPP per capita, the median growth rate was around 3% per year. In the USD 10 000 - 20 000 PPP per capita income category, it was around 4% per year. At this stage of development, well-performing countries are able to combine relative institutional stability while tapping the drivers of fast catch-up growth, e.g. investment in infrastructure, urbanisation and a structural transition away from agriculture to manufacturing and services.

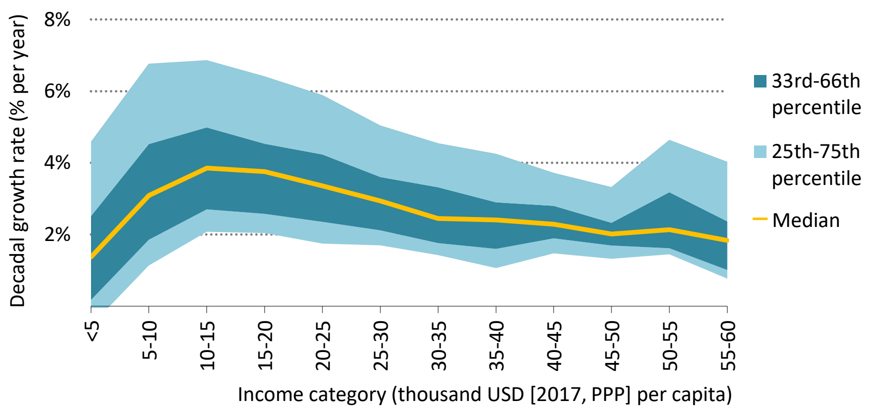
At higher levels of development, drivers of fast catch-up growth are progressively exhausted. Growth at higher levels was characterised by two facts. First, growth is more consistent, i.e. the range between the best and worst performers narrows and growth is more consistent across time. Second, growth slows. Above USD 30 000 PPP per capita, the median growth rate was around 2.5% per year, while above USD 40 000 PPP per capita it falls closer to 2%. At high levels of development, easy catch-up options are

[4] For the purposes of this analysis, a large- or medium-size economy is one with more than 0.05% of world GDP in 2019, 100 countries have a share of GDP above this threshold.

exhausted and growth is driven by rates of technology-driven productivity improvements and very high levels of human capital, notably education and health.

This historical experience informs the macroeconomic assumptions for Indonesia in the scenarios. The IEA scenarios envisage a continuation of robust growth rates of around 4-5% per year as Indonesia moves towards the ranks of the advanced economies. In the long term, however, the projected GDP growth rate slows to 2-3% per year, as Indonesia progresses to the level of an advanced economy, catch-up growth options are progressively exhausted, and the drivers of growth come to depend on global, long-run rates of technology-driven productivity improvements.

Figure 2.2 ▷ GDP growth rate per capita by decade versus starting GDP per capita in each decade, 1950 – 2019



As countries get richer, GDP growth rates tend to slow as easy opportunities to achieve fast growth are exhausted

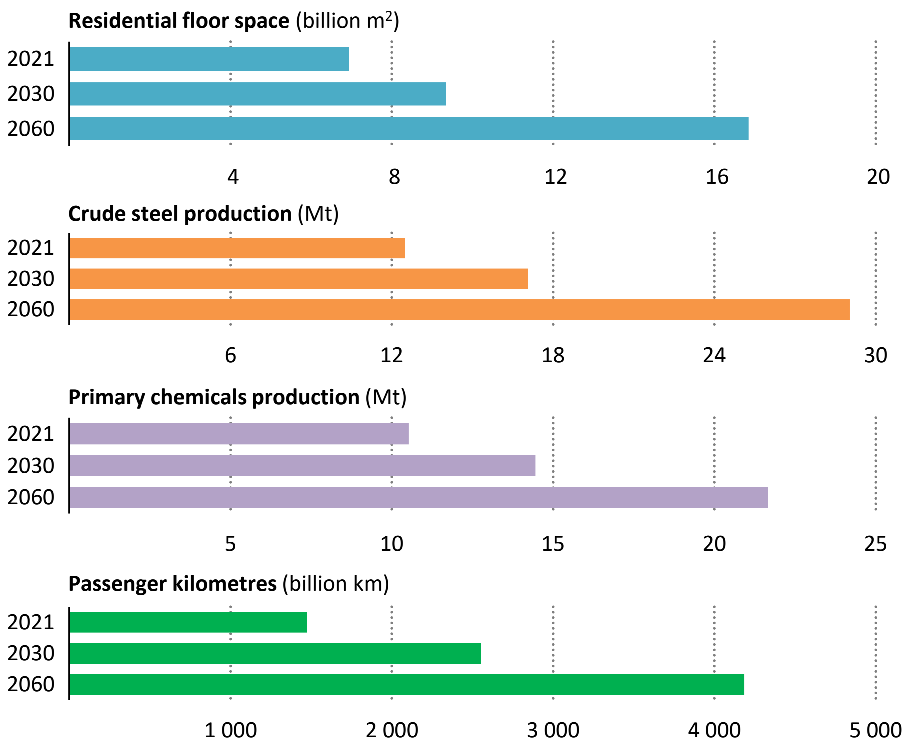
Sources: IEA analysis based on data from the 2021 version of the Penn World Tables. (Feenstra, Inklaar and Timmer, 2015).

Indonesia is a relatively "frugal" country in terms of its level of demand for energy services relative to its GDP per capita. For example, its steel consumption per capita, adjusted for imports and exports, is almost two-times lower than the level of countries with a comparable GDP per capita. Its rate of car ownership is relatively low compared to countries with a similar level of GDP per capita. For example, an aggregate of twelve major emerging market and developing economies[5] that have a GDP per capita similar to Indonesia, but a rate of car ownership (about 115 vehicles per 1 000 people) that is almost triple that of Indonesia (about 40 vehicles per 1 000 people).

[5] Brazil, Chile, China, Colombia, India, Indonesia, Mexico, Philippines, South Africa, Thailand, Türkiye and Viet Nam.

Demand for energy services nonetheless increases substantially over the coming decades, underpinned by the projected strong economic growth (Figure 2.3). For example, pushed by expanding urbanisation, rising incomes and decreasing average household occupancy, total residential floor space increases by around 35% between 2021 and 2030, and by a further 80% between 2030 and 2060. This drives a large increase in demand for materials. For instance, more steel is required to expand cities, infrastructure and industries, and to support increasing household consumption. Steel output increases by almost 75% from 12.5 million tonnes (Mt) in 2021 to 17 Mt in 2030. Indonesia is projected to remain a net steel importer with output of 29 Mt in 2060 in the APS. The output of chemicals, such as ammonia, ethylene and propylene, expands by 37% between today and 2030, and continues to increase thereafter. The number of road transport passenger kilometres increases by more than 70% between 2021 and 2030, and by another 60% by 2060 in the APS.

Figure 2.3 ▹ Key drivers of energy services demand growth in Indonesia in the Announced Pledges Scenario, 2021 – 2060



Growing GDP and incomes drive large increases in energy services demand in the period to 2060

Notes: m^2 = square metres; Mt = million tonnes; km = kilometres. Primary chemicals include ethylene, propylene, benzene/toluene/xylene, ammonia and methanol.

By 2060, the average Indonesian is more than three-times wealthier than the average today. The average Indonesian travels two and a half-times further every year across all modes of transport compared to the average today, lives in a dwelling that is 60% larger, and their welfare will be supported by an economy that produces more than two-times more steel than today. Such metrics represent real improvements in average living standards and a continuation of Indonesia's progress. Nonetheless, delivering this boost in living standards and materials consumption while reducing emissions to net zero is a substantial challenge.

2.1.3 Energy and CO_2 prices

Energy prices in international and domestic markets, and CO_2 prices over time are important factors that shape Indonesia's pathway to net zero emissions. Projections of international energy prices are highly uncertain. Today's global geopolitical situation and high prices for key energy commodities, further compounds the uncertainty of price projections.

Energy price projections in IEA scenarios are designed to achieve equilibrium between supply and demand. In the short term, reduced flows of oil and gas from Russia to major energy importers are projected to maintain pressure on the supply and demand balance. In this case, Indonesia spends more on oil imports, but benefits from higher export revenues from coal and to a lesser extent, natural gas. In the longer term, less demand for fossil fuels in the APS means that pressure on global fossil fuel supply eases, and prices decline to 2060. The international oil price declines to around USD 64 per barrel by 2030 and USD 60 per barrel in 2050 in the APS, falling well below the price levels in the STEPS. Projected coal prices for Indonesian exporters are USD 50/tonne in 2030 in the APS, before declining to USD 40/tonne in 2050 as demand from importers in the Pacific Basin falls (Table 2.1).

Table 2.1 ▷ International fossil fuel and domestic carbon prices in the Announced Pledges Scenario

Real terms (USD [2021], MER)	2010	2021	2030	2040	2050
IEA crude oil (USD/barrel)	94	69	64	63	60
Natural gas (USD/MBtu)					
Japan	8	10.1	9.7	8.0	7.5
China	13	10.2	10.0	7.9	7.4
Steam coal (USD/tonne)					
Japan	139	164	75	69	64
China (coastal)	129	153	84	65	61
Indonesia carbon price in electricity, industry and energy production (USD/tonne)	0	0	40	110	160

Notes: MER = market exchange rate; MBtu = million British thermal units. The IEA crude oil prices are a weighted average import price among IEA member countries. Natural gas prices are weighted averages expressed on a gross calorific-value basis. China natural gas prices reflect a balance of pipeline and liquefied natural gas (LNG) imports, while Japan gas prices solely reflect LNG imports. Steam coal prices are weighted averages adjusted to 6 000 kilocalories per kilogramme. Coastal China steam coal price reflects a balance of imports and domestic sales, while the Japanese steam coal prices are solely for imports.

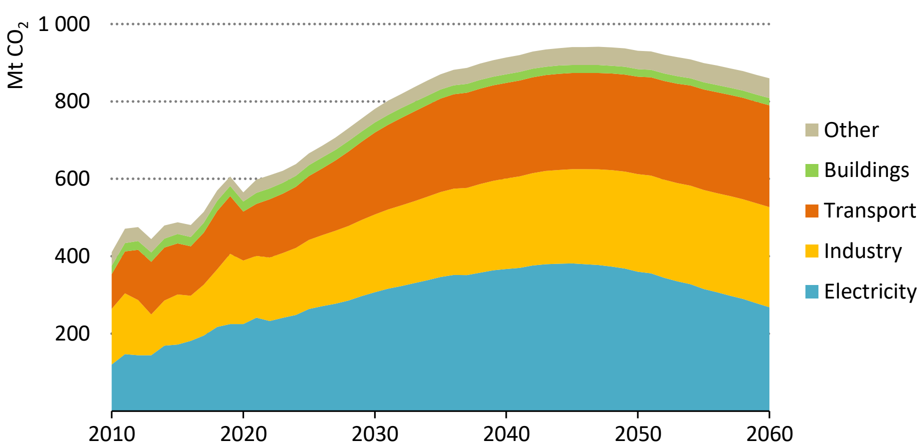
Indonesia has established the legal framework for an emissions trading system (ETS) and a carbon tax to act as its floor price. The APS builds upon this framework and Indonesia's experience from pilot ETS programmes, and expands CO_2 pricing to all electricity sector actors, as well as heavy industry and energy transformation industries, such as refiners or coal processing plants. CO_2 prices in the APS rise from the current announced price of USD 2/tonne to USD 40/tonne in 2030 and to USD 160/tonne in 2050. CO_2 emissions reductions in Indonesia in the APS are driven by direct policies to encourage the adoption of low emissions technologies and to send clear signals regarding the transformations required in each sector. CO_2 prices compliment these direct measures, assisting in aligning price signals with policy objectives.

2.2 Emissions trends

2.2.1 Emissions trends in the Stated Policies Scenario

This section presents a brief overview of emissions trends in the STEPS, in order to use these trends in comparison with the APS. In the STEPS, Indonesia's total CO_2 emissions from energy and industrial processes increase by almost 60% by 2050 relative to current levels, peaking at around 950 Mt in the late 2040s before beginning a slow decline (Figure 2.4). Indonesia's peak total energy sector emissions in the STEPS are equivalent to over 90% of those of Japan today, or around 90% of the net GHG emissions from Indonesia's AFOLU sector in 2019.

Figure 2.4 ▷ Total energy CO_2 emissions by sector in Indonesia in the Stated Policies Scenario, 2010 – 2060



Total energy sector CO_2 emissions peak at 950 Mt in the late 2040s, with growth driven initially by electricity generation and then increasingly by industry and transport

The end-use sectors of industry, buildings and transport account for more than half of the growth in energy sector CO_2 emissions to 2050 in the STEPS. Because of the peak in electricity sector emissions around 2045, and subsequent decline, by 2060 the end-use sectors account for more than 80% of Indonesia's total emissions growth in the STEPS. The transport sector is the largest contributor, accounting for almost half of the total emissions growth to 2060, as freight and passenger transport demand grows strongly and electricity and low emissions fuels are insufficient to offset transport-related emissions. The industry sector also accounts for more than 35% of emissions growth, due to expanded output of emissions-intensive products such as iron and steel, cement and chemicals.

In the STEPS, the emissions intensity of electricity generation declines progressively, falling from more than 750 grammes of carbon dioxide per kilowatt-hour (g CO_2/kWh) today to around 235 g CO_2/kWh in 2060. However, this reduction, driven in particular by an increased contribution of renewables such as solar and wind in the electricity generation mix, is initially not sufficient to counteract the increase in electricity demand, and as a consequence electricity sector emissions continue to increase to 2045, albeit with growth slowing over time. The electricity sector accounts for about 35% of the growth of emissions in the period to 2050, and remains the largest emitting sector through to 2060.

2.2.2 Emissions trends in the Announced Pledges Scenario

Indonesia's energy sector CO_2 emissions continue to grow over the coming decade in the APS, before peaking around 2030 and starting to decline (Figure 2.5). The electricity sector leads the way, with emissions peaking and plateauing around 2030, and by 2050 emissions are more than 90% below their peak. By 2030, electricity sector emissions are around 20% higher than in 2021, compared to a 30% increase in the STEPS. After the peak, the decline of emissions from electricity generation accelerates, as older generation units are retired and output is reduced from remaining units. Between 2030 and 2040, emissions from electricity generation drop by 40% and approach zero by the 2050s.

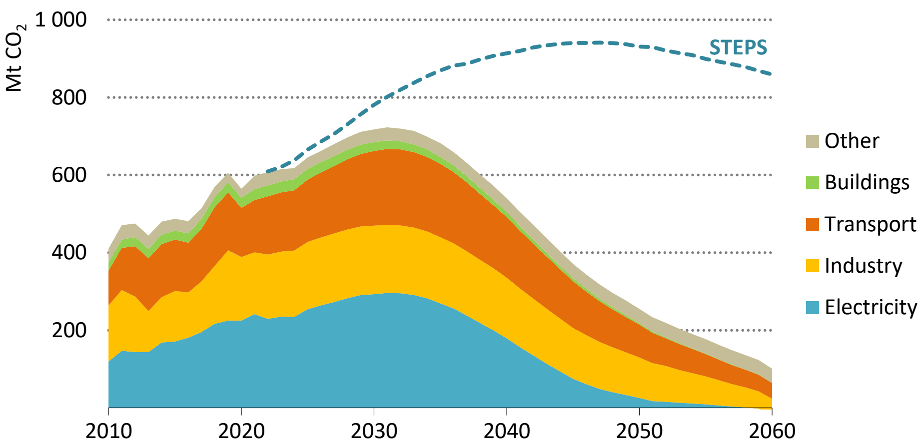
CO_2 emissions from industry have a relatively longer plateau around their peak, and only start to decline substantially in the second-half of the 2030s. Nonetheless, aggressive near-term action on energy and materials efficiency, and fuel switching in other industry, ensures that the increase of industry sector CO_2 emissions between today and 2030 is far lower than in the STEPS. In 2060, there are still around 40 Mt CO_2 emissions from the industry sector, in particular from the heavy industry sectors that face challenges in reducing emissions to net zero.

CO_2 emissions in the transport sector increase in the period to 2030 in the APS, albeit at a lower rate than in the STEPS. Income growth drives up the demand for transport services, and the speed at which clean energy technologies can be rolled out is limited by the inertia of the existing vehicle stock, restrictions in the scale up of sustainable biofuels, and the lower level of maturity of some low emissions technologies in transport. CO_2 emissions from transport peak after 2030, after which the speed of emissions reductions accelerates quickly.

Between 2030 and 2040, CO_2 emissions from transport are reduced by a fifth. By 2060, CO_2 emissions from transport are around 40 Mt, predominantly from aviation, shipping and road freight.

The buildings sector, including both residential and services buildings, accounts for less than 5% of total energy sector CO_2 emissions in 2021, far less significant than those in the electricity, industry and transport sectors. Opportunities for emissions reductions in buildings are rapidly deployed in the APS, supported by strong policies to incentivise the purchase of low emissions technologies and equipment (see Chapter 3, section 3.6). Emissions in the buildings sector peak in the next several years, and see an absolute decline by 2030. By 2060, emissions from the buildings sector are essentially zero, with all household end-uses electrified or based on low emissions fuels.

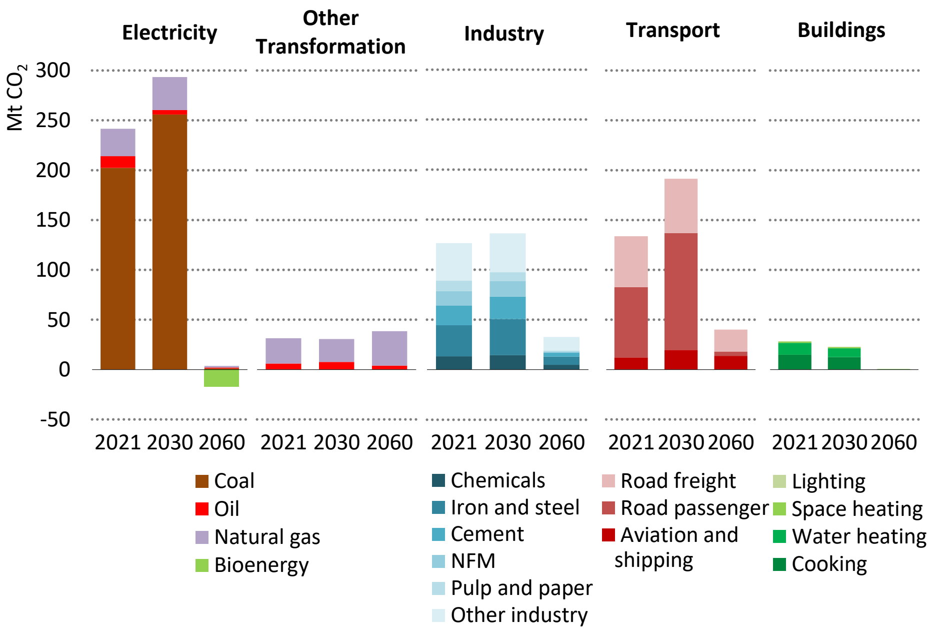
Figure 2.5 ▹ Total energy CO_2 emissions by sector in Indonesia in the Announced Pledges Scenario, 2010 – 2060



Total CO_2 emissions peak around 2030 in the APS at a level that is about 10% lower than in the STEPS in the same year; by 2040 emissions are 10% lower than today

The CO_2 emissions trajectory in the APS differs substantially by fuel and end-use (Figure 2.6). In the period to 2030, emissions from coal-fired electricity generation are almost a third higher than in 2021, as coal plants in the pipeline are brought online. Nonetheless, CO_2 emissions from coal-fired electricity generation are 5% lower than in the STEPS in 2030, which may require adjustments to existing contract structures (see Chapter 5, section 5.3). CO_2 emissions from oil-fired generation decline by 60% by 2030 compared to today's level, while use of natural gas-fired generators increases, assisting with the integration of the rising output from variable renewables.

Figure 2.6 ▻ **CO_2 emissions from fuel combustion by fuel, sector and sub-sector in the Announced Pledges Scenario**



Reducing emissions from coal-fired electricity generation is critical to reach net zero emissions, plus ambitious actions need to be taken in all sectors

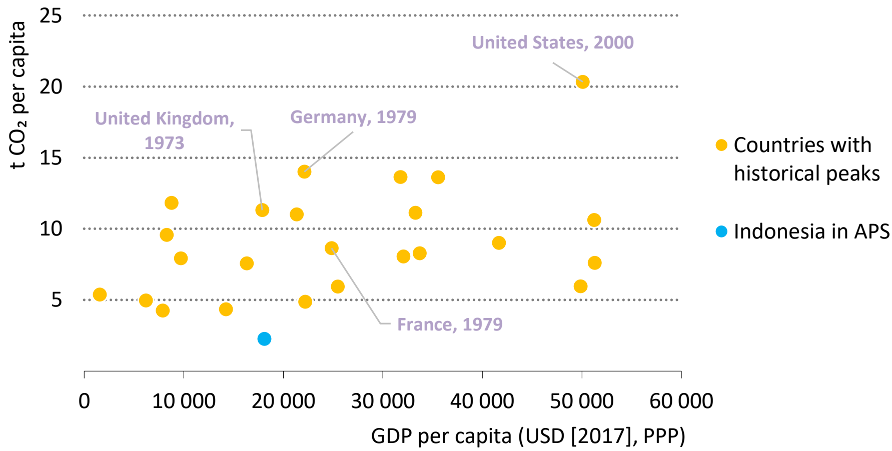
Notes: NFM = non-ferrous metals. Other transformation includes losses from hydrogen production, bioenergy transformation, gas works, petroleum refineries, coal and gas transformation and liquefaction. It also includes energy own use in coal mines and in oil and gas extraction. Other industry includes construction, food processing, machinery, mining, textiles, wood processing and industries otherwise not categorised.

In the industry sector, CO_2 emissions from the large other industry grouping peak first, and are already on the decline by 2030. Emissions from heavy industries – chemicals, iron and steel, and cement – decline after 2030. In the transport sector, CO_2 emissions from both road passenger and road freight increase in the period to 2030. It is not until 2035 that low emissions technologies help to reduce emissions in both road passenger and freight transport in earnest. Aviation and shipping then account for most of the residual CO_2 emissions in transport, as well as heavy trucks, which are not easily electrified.

Box 2.2 ▻ How does the timing of Indonesia's emissions peak compare with other countries?

The short term increase in Indonesia's CO_2 emissions, before they peak in the early 2030s in the Announced Pledges Scenario, may seem substantial for a pathway to net zero emissions. It should be considered, however, that Indonesia's per capita emissions from fuel combustion[6] today are significantly below the world average – about 2 tonnes per capita compared to the world average of 4.3 tonnes. Historically, countries where CO_2 emissions have peaked did so at much higher levels of emissions per capita and GDP per capita (Figure 2.7).

Figure 2.7 ▷ Per capita CO_2 emissions from fuel combustion and GDP per capita at peak emissions in selected countries



If Indonesia peaks emissions as projected in the APS, it would be at one of the lowest levels of CO_2 emissions per capita experienced historically

Such comparisons need to be viewed in context. Technologies change over time, opening opportunities for cleaner energy production and consumption that were not available in past decades. National circumstances are different and change over time. For example, Indonesia has a negligible need for heating in buildings, but large demand for cooling, and a large share of light industries in its economy. It is highly dependent on coal both for its energy supply and for export. In a historical perspective Indonesia's reliance on coal is not exceptional. For example, when the United Kingdom was at its peak of CO_2 emissions, the share of coal in total energy supply was about 6 percentage points higher than the share in Indonesia today.

In the APS, CO_2 emissions from fuel combustion in Indonesia would peak at a level of emissions per capita that is substantially lower than has been achieved historically. On the other hand, in the APS, emissions peak at a GDP per capita level in Indonesia comparable to that at which emissions peaked in some advanced economies, such as the United Kingdom.

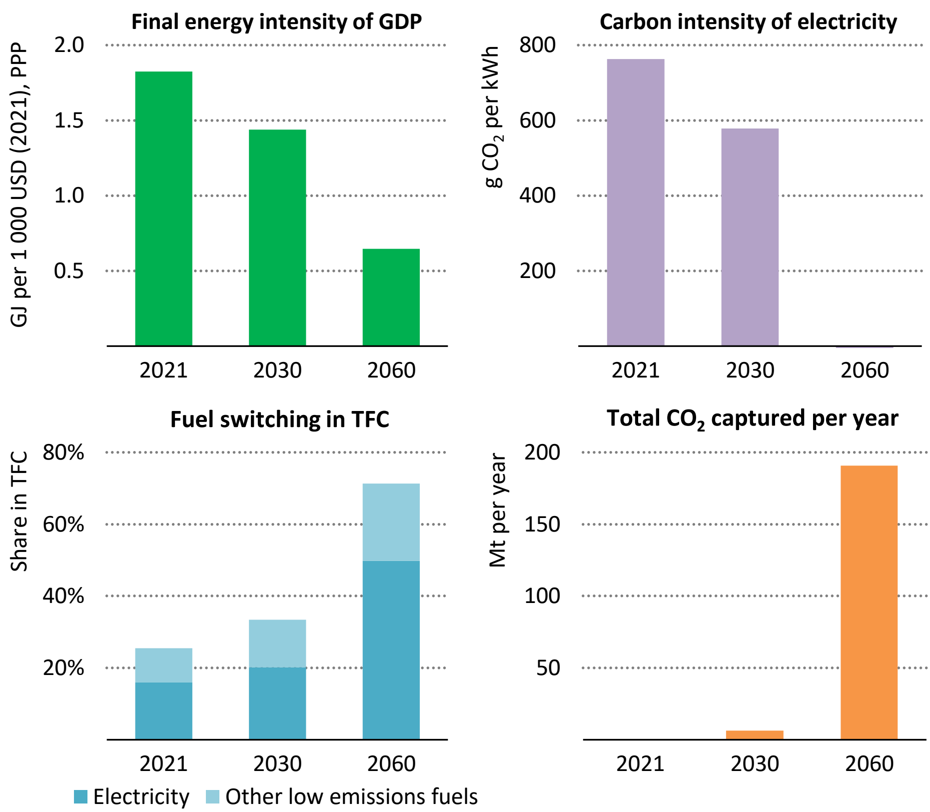
[6] In order to obtain a long historical time series, we exclude process emissions from this analysis.

2.3 Energy trends

2.3.1 Key pillars of the transition pathway

The transition towards net zero emissions requires strong and sustained action across the entire energy sector, and the deployment of a wide range of clean energy technologies and practices. Broadly, the required changes can be categorised around four pillars: energy intensity improvements, decarbonising electricity generation, switching to low emissions fuels in end-uses and carbon capture, utilisation and storage (CCUS) (Figure 2.8). Each pillar is necessary to reach net zero emissions, but they play different roles at different stages in the pathway.

Figure 2.8 ▷ Four key pillars of the energy transition to net zero emissions in Indonesia, 2021 – 2060



Pulling the key levers of efficiency, low-carbon electricity generation, fuel switching and carbon capture is required to reach net zero emissions

Note: TFC = total final consumption.

Energy intensity of the economy is improved substantially in the APS, with final energy intensity improving 20% by 2030 and more than 60% by 2060, relative to 2021 levels. Strong action to improve energy intensity helps to reduce the costs of the transition, by lowering the investments required to meet energy demand, saving on fuel expenditures and reducing the need to rely on more expensive mitigation options. However, achieving improvements in energy efficiency will require sustained and comprehensive policies, and energy pricing reform. (See section 2.3.4.)

The *CO_2 emissions intensity of electricity generation* improves substantially, both to reduce emissions directly in the electricity sector as well as to facilitate the use of low-carbon electricity to substitute for burning fossil fuels in end-use sectors. Today, Indonesia has one of the most emissions-intensive electricity sectors in the world at over 750 g CO_2/kWh. This compares to just under 600 g CO_2/kWh in China and 710 g CO_2/kWh in India in 2021. In the APS, early action in the electricity sector reduces the carbon intensity of electricity generation by almost a quarter by 2030, relative to current levels. By 2060, the electricity sector essentially has been completely decarbonised in the APS, and electricity serves as a low emissions energy carrier to the end-use sectors.

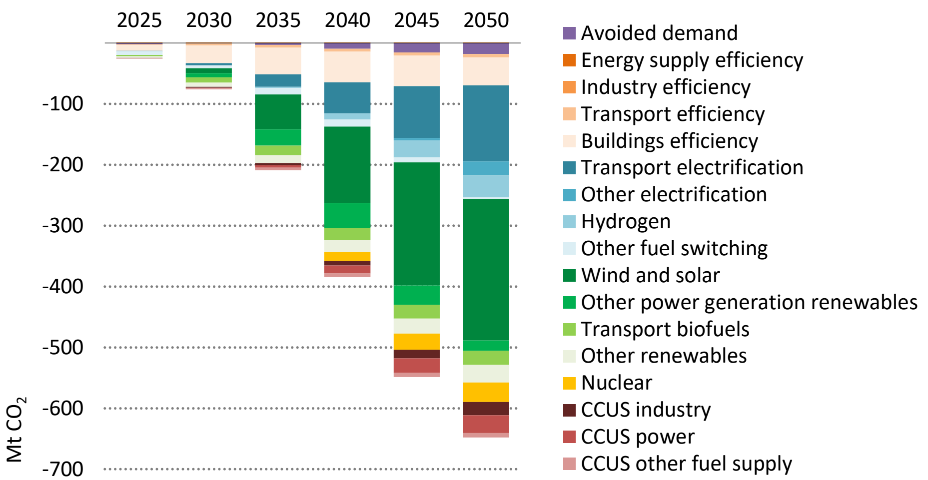
Widespread *switching to low emissions fuels in end-uses*, such as electricity, bioenergy, solar thermal, and hydrogen and hydrogen-based fuels,[7] reduces emissions in total final consumption (TFC) of energy. This transition takes more time initially than improved energy intensity of the economy and decarbonised electricity generation because some of the technologies required to shift end-use sectors to low emitting fuels are less mature. In the longer term to 2050 and 2060, electricity makes wide inroads to serve demand in end-uses, reaching half of total final consumption. By 2060, low emissions fuels and electricity account for almost three-quarters of TFC, with fossil fuel use with CCUS in industry accounting for another 5%. Oil retains a role in transport.

A low emissions energy system needs to be able to *capture, use and store carbon dioxide*. CCUS plays a role in reducing emissions from industrial processes like cement, steel and chemical production; offers the option to use fossil fuels in applications where it remains cost effective to do so; and provides a low emissions source of carbon[8] for synthetic fuel production, or atmospheric carbon dioxide removal to offset unavoidable emissions from the use of unabated fossil fuels. By 2060, around 190 Mt CO_2 per year are captured across Indonesia's energy system. (Chapter 5, section 5.5 discusses the role of CCUS.).

[7] Hydrogen-based fuels refers to ammonia and synthetic hydrocarbons, such as synthetic methane and synthetic oil products.

[8] In other words, atmospheric carbon, either captured directly through direct air capture or indirectly through bioenergy with carbon capture.

Figure 2.9 ▷ Decomposition of CO_2 emissions reductions from fuel combustion by measure, Announced Pledges Scenario versus Stated Policies Scenario, 2021 – 2050



A wide range of emissions reduction measures are required to reach net zero, with low-carbon electricity and efficiency significantly contributing in the near term

Decomposition of the change in emissions from fuel combustion in the APS versus the STEPS is depicted in Figure 2.9. The role of the emissions reductions options are summarised below.

- *Avoided demand* refers to technology-driven interventions that lower the amount of energy services demand needed to meet the same level of output or welfare. Examples include light weighting of vehicles, enhancing materials recycling or extending product or building lifetimes to reduce demand for materials. Avoided demand practices take time to be implemented at scale, providing only 1% of the combustion emissions reductions achieved in the APS relative to the STEPS in 2030, but by 2050 this ramps up to 3%. Avoided demand plays a particularly important role in the industry and transport sectors, where it helps to curb emissions and to avoid locking in high emissions assets, while emerging low emissions technologies are developed and deployed.
- *Energy efficiency improvements* in the technical efficiency of appliances, industrial equipment and vehicles provides almost half of the combustion CO_2 emissions reductions in the APS relative to the STEPS in 2030. As 2050 approaches, the potential for further CO_2 savings from efficiency gains in the APS is exhausted as electricity is decarbonised and efficiencies approach best available technology levels, while emissions reductions from efficiency are increasingly drowned out by gains from renewables and fuel switching. The largest potential emissions reductions from efficiency gains are in the buildings sector, where robust appliance efficiency standards,

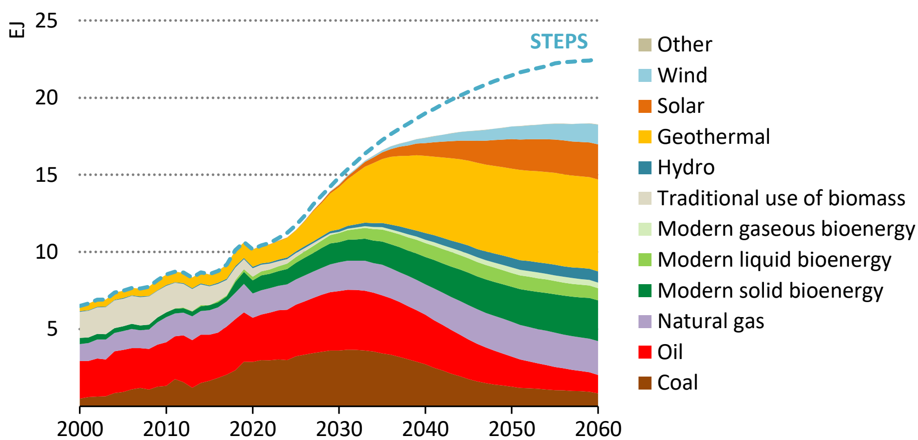
energy pricing reforms and building energy codes and standards help to avoid 225 terawatt-hours (TWh) of electricity demand growth to 2050. Energy efficiency improvements in transport and industry are also important contributors to reducing emissions, although electrification and use of renewables has a larger impact on emissions in these sectors.

- *Electrification of transport* is boosted by the rising penetration of electric vehicles (EVs) that help to cut emissions, but the effect is only visible after 2030 due to the slow turn-over of the vehicle fleet. By 2050, electrification of transport is responsible for 20% of emissions reductions in the APS relative to the STEPS.
- *Hydrogen and other fuel switching* provide about 8% of the emissions reductions relative to the STEPS in the near term, a share that stays relatively constant to 2050. (Chapter 3, section 3.2.2 discusses the role of hydrogen.).
- *Renewables* deployment provides the lion's share of emissions reductions, as they substitute for the largest source of emissions today – coal in the power sector. In the near term, around half of the contribution from renewables-based electricity generation is from hydro and geothermal (included in other power generation renewables in Figure 2.9) and the remainder from solar PV and wind, together they provide a quarter of the emissions reductions achieved in the APS relative to the STEPS by 2030. Thereafter, wind and solar PV take a bigger share of electricity generation, and hence emissions reductions. By 2050, wind and solar PV together provide more than one-third of the total emissions reductions, while other renewables in electricity generation provide less than 5%. (Chapter 5, section 5.3 discusses balancing an inter-regional, high renewables electricity sector.) Biofuels in transport are significant in the near term to cut emissions from transport. By 2030, the higher level of biofuel use in transport relative to the STEPS provides 15% of emissions reductions in the APS relative to the STEPS, which is more than twice the level of emissions reductions from electromobility, which is slower to be deployed. By 2050, however, electrification of transport overtakes biofuels as a clean energy technology in the sector, due to the increasing competitiveness of EVs and limits to the supply of sustainable biofuels. By 2050, biofuels for transport provide almost 5% of the required emissions reductions in the APS relative to the STEPS.
- *Nuclear* power features within Indonesia's net zero strategy and the APS, contributing 5% to the emissions reduction between the APS and STEPS in 2050. Due to the long project timelines, this lever becomes effective after 2040.
- *Carbon capture, utilisation and storage* also plays a critical role to cut emissions from fuel combustion and to reduce industrial process emissions. A few plants that burn or transform bioenergy also use CCUS and capture around 25 Mt CO_2 by 2060. The largest role for CCUS in Indonesia is to reduce emissions from industry, followed by the power sector, and then in other fuel transformation. CCUS provides 10% of the emissions reductions required in the APS relative to the STEPS by 2050.

2.3.2 *Total energy supply*

Total primary energy supply in Indonesia in the APS increases from less than 10 500 petajoules (PJ) today to 14 400 PJ by 2030 and 19 000 PJ by 2060 (Figure 2.10). This 8 500 PJ increase in demand to 2060 in the APS is well below the 12 000 PJ added by 2060 in the STEPS, largely thanks to accelerated efforts to improve energy efficiency and electrify end-uses. By 2030 energy demand in the APS is 3% below the level in the STEPS, with this gap widening to around 15% by 2060.

Figure 2.10 ▷ Total energy supply in Indonesia in the Announced Pledges and Stated Policies scenarios, 2000 – 2060



Transformation of the energy supply mix in the APS is driven by rapid growth of renewables and the phase-out of unabated coal use in the electricity sector

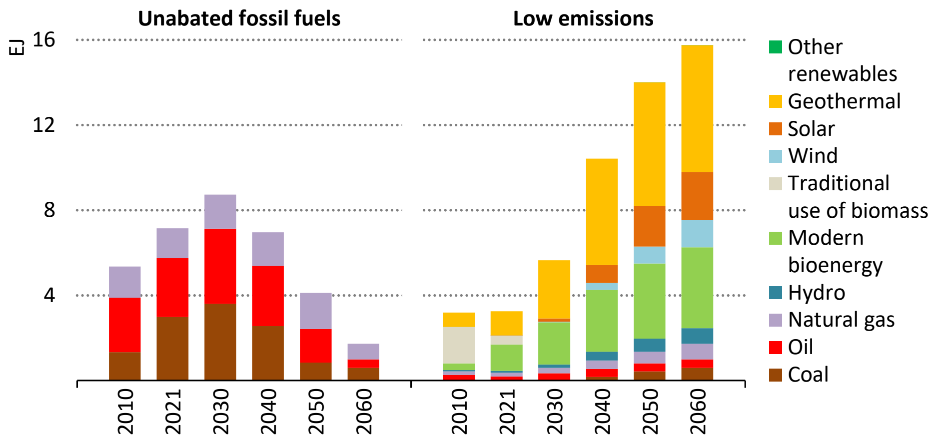
Notes: EJ = exajoules. The representation of geothermal in total energy supply is influenced by the International Recommendations for Energy Statistics, used by the IEA to convert geothermal electricity generation into primary inputs. (Details in Chapter 1, Box 1.2.)

The energy supply mix is rapidly transformed in the APS, with the share of fossil fuels dropping from 72% in 2021 to 65% by 2030 and 22% by 2060. Coal demand declines the most as its use in electricity generation is reduced after 2030. Thereafter, the decline of coal accelerates, dropping a further 2 800 PJ to account for only 4% of total energy supply in 2060. Demand for oil, but particularly natural gas, is more resilient, largely due to their uses as feedstock in chemicals processing and the challenges related to deploying alternative fuels for use in aviation and shipping. In the short term, demand for both oil and gas continues to rise in the APS, to meet rapid demand growth in the industry and transport sectors. Oil's share in the primary energy mix falls slightly from 28% in 2021 to 27% by 2030, but then drops to 6% by 2060. The share of natural gas declines from 15% today to 13% in 2030. After

2030, the use of natural gas in non-emitting processes, including hydrogen production with CCUS, sees demand increase slightly from 2030 levels.

Indonesia has subsidised liquefied petroleum gas (LPG) stoves and LPG cylinder refills for more than a decade. This has been instrumental in extending clean cooking solutions to most of its population. The number of people relying on the traditional use of biomass for cooking declined by 60 million between 2010 and 2021. As a consequence, the traditional use of biomass declined from 1 700 PJ in 2010, representing 20% of total energy supply, to 420 PJ in 2021, 4% of supply. Looking forward in the APS, progress on access to clean cooking continues, with universal access achieved by 2030 in line with Sustainable Development Goal 7, driving down the traditional use of biomass to zero by 2030. Unlike the profusion of LPG in the 2010s, in the 2020s in the APS, households that gain access to clean cooking do so with a more diverse set of technologies. While LPG remains dominant as a relatively cheap and accessible fuel, modern bioenergy solutions and electric cooking are used by almost 40% of those gaining access, with their share increasing over time. Households using LPG eventually shift to low emissions fuels in the APS.

Figure 2.11 ▹ Unabated fossil fuels and low emissions sources in total energy supply in Indonesia in the Announced Pledges Scenario

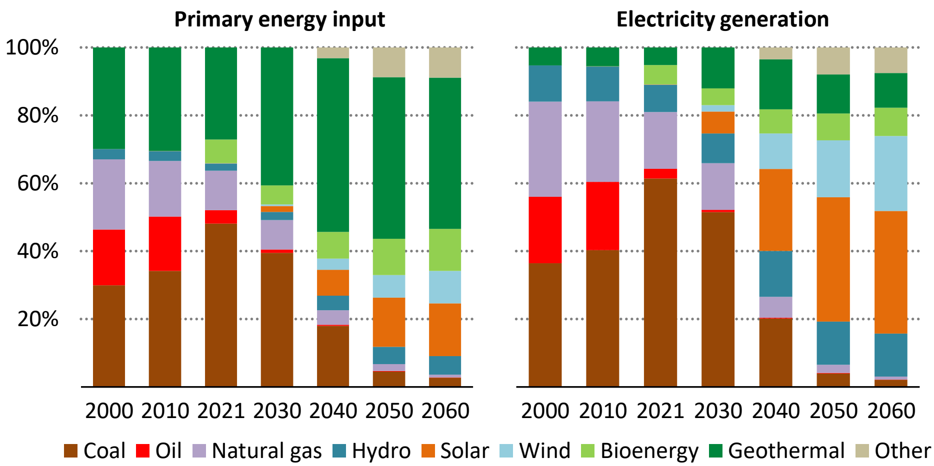


Unabated combustion of fossil fuels drops by almost 5 500 PJ to 2060, while renewables increase by 11 500 PJ, a 550% increase on 2021 levels

Notes: EJ = exajoules. The representation of geothermal in total energy supply is influenced by the International Recommendations for Energy Statistics, used by the IEA to convert geothermal electricity generation into primary inputs. (Details in Chapter 1, Box 1.2.)

Renewables contribute the biggest share of the increase in total energy supply in the APS, increasing by almost 2 600 PJ to 2030 and 11 500 PJ to 2060, relative to 2021 levels. By 2030, renewables increase their share in the energy supply mix to 35%, 11% higher than 2021 levels, by 2060 they account for 74% of total energy supply, with more than 80% of renewables used in the power sector, 2% in industry and 4% in transport. Geothermal accounts for the biggest share of growth from a total energy supply perspective, when the International Recommendations for Energy Statistics, used by the IEA, are used to convert geothermal electricity generation into primary inputs. However, when looking at increases in electricity generation, output from solar photovoltaics (PV) increases the most, followed by wind, hydro, and then geothermal (Figure 2.12).

Figure 2.12 ▻ Primary energy inputs to the power sector and electricity generation by fuel in the Announced Pledges Scenario



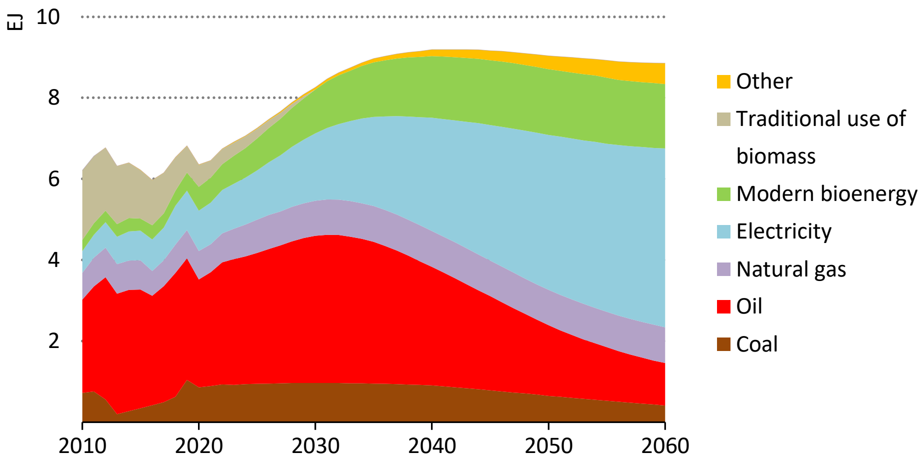
Solar PV and wind represent a small share of primary energy inputs into electricity generation due to accounting standards, but a much larger share of output, the opposite is true for geothermal

Notes: Other includes hydrogen and hydrogen-based fuels such as ammonia and marine renewable energy. The representation of geothermal in total energy supply is influenced by the accounting standards used to convert geothermal electricity generation into primary inputs. (Details in Chapter 1, Box 1.2.)

2.3.3 Final energy demand

Total final consumption in Indonesia increases from around 6 450 PJ in 2021 to around 8 300 PJ in 2030 in the APS, with an average demand growth rate of 2.8% to 2030 (Figure 2.13). Final energy demand growth slows post-2030, peaking in the early 2040s at close to 9 200 PJ before declining to 8 850 PJ by 2060. This peak and slight decline in final energy demand is achieved thanks to stringent energy efficiency policies across all sectors and savings driven by large-scale electrification of transport. The share of fossil fuels in final energy demand declines from 68% today to around 25% in 2060. In absolute terms, oil demand declines by an average of 2.5% per year to 2060; coal demand by 2% per year, while natural gas differs with demand rising in the short term before plateauing over the following decades to 2060. Electrification is the defining narrative for end-use sectors; its share in final energy demand rising from 15% today to 50% by 2060.

Figure 2.13 ▷ Final energy demand in the Announced Pledges Scenario



Fossil fuels in final energy demand decline from around 70% in 2021 to around 25% in 2060, while electricity increases from 16% of demand to 50% by 2060

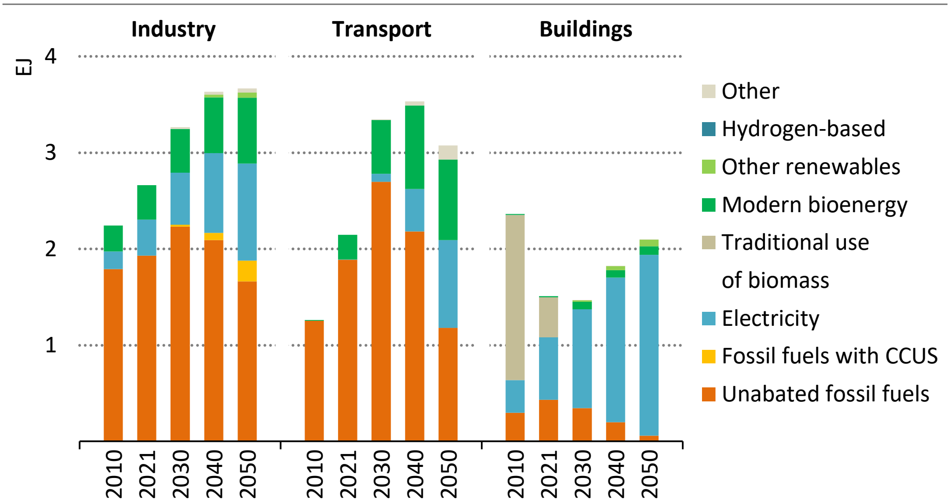
Industry is the largest final energy-consuming sector in Indonesia today. Energy demand in the sector rises on average 2.3% per year to 2030 then 0.4% to 2060, pushing total demand up from 2 700 PJ in 2021 to 3 700 PJ by 2060 (Figure 2.14). The industry sector accounts for all of final energy demand for coal, and almost all final energy demand for natural gas demand in 2021, and this trend endures throughout the APS outlook. In the short term, increasing natural gas use in industry mitigates demand growth for coal. Indonesia leverages domestic natural gas resources as they become available in areas where industrial clusters are close to gas fields or in proximity to pipelines. Natural gas demand in industry rises by 4 billion cubic metres (bcm), or 23%, and peaks in the mid-2030s. Emissions from coal, and to a lesser extent from natural gas, are mitigated by CCUS in some industrial facilities, with CO_2 captured from both combustion and industrial process emissions. As 2060 approaches, bioenergy and hydrogen-based fuels are increasingly used to meet high-temperature industrial heat needs in the APS, displacing coal and to a lesser extent gas, while lower temperature heat needs are met by electric heat pumps and low emissions sources. As a result, despite a more than threefold increase in industrial value added, use of unabated fossil fuels falls more than 60% by 2060 relative to current levels.

In *transport*, energy demand growth is driven by increases in passenger vehicle ownership and freight activity. Averaging a growth rate of more than 5% to 2030, demand rises over

1 200 PJ above current levels to reach 3 350 PJ. Beyond 2030, demand rises until the mid-2030s before entering a slow decline to 2060. By 2060 demand is almost 500 PJ below 2030 levels, a decline induced by efficiency gains associated with electrification (with EVs on average three-times more energy efficient than an internal combustion engine (ICE) vehicle), as well as increasing modal shifts from private to public transport as public transport infrastructure is further developed, both within and between cities. Without electrification, energy efficiency and modal shifts in the APS, transport energy demand would be more than 15% higher in 2030 and 80% higher in 2050.

In line with Indonesia's domestic biofuel production and blending targets for biodiesel and bioethanol, biofuels are critical to mitigate oil demand growth to 2030, and beyond then to displace oil demand from the remaining ICE vehicle fleet, particularly in heavy trucks where the penetration of electric models is considerably lower than for light-duty vehicles. Biofuel use increases by more than 9% per year to 2030 in the APS to reach 650 PJ. Beyond 2030, demand growth slows, then begins to decline as more of the passenger vehicle fleet is electrified, but demand continues to increase in aviation and shipping.

Figure 2.14 ▷ Final energy consumption by sector and fuel in the Announced Pledges Scenario, 2010 – 2050



Energy efficiency and electrification dampen demand growth, facilitating a reduction in unabated fossil fuels to 2050 of 15% in industry, 40% in transport and almost 90% in buildings

In the *buildings* sector, the traditional use of biomass represents almost 30% of energy demand in 2021, but this drops to zero by 2030. This delivers a 3% drop in total energy demand in the buildings sector relative to 2021 levels. In the APS, the majority of the population transitioning from the traditional use of biomass and gaining access to clean cooking do so with LPG stoves, due to the availability and current subsidisation of LPGs. However, those using LPG for cooking and heating increasingly transition to electric cooking and water heating in the APS as subsidies for LPG are supplanted by support for households to electrify cooking. By 2050, oil use is almost completely phased out from the buildings sector. In parallel, ownership of electrical appliances and equipment, notably air conditioners, rises rapidly. As a result, by 2030 electricity demand in the buildings sector is 60% higher than in 2021, with growth continuing after 2030. By 2050, electricity accounts for over 90% of energy demand in the buildings sector, up from nearly 45% today.

2.3.4 Leveraging energy efficiency

Energy efficiency is the first fuel in Indonesia's pathway to its net zero emissions target, and is key to also achieving its socio-economic growth aspirations. Energy efficient appliances, motors, boilers and vehicles are mature technologies available in global markets today. In many cases such technologies offer attractive returns on investment. Energy efficiency is front-loaded in the APS to ensure that equipment added to the energy system in the coming decades is as efficient as possible. Efficiency is especially important to cut emissions from transport and industry, where conventional technologies that use fossil fuels continue to be sold over the next two decades, albeit with shrinking market shares as low-carbon alternatives emerge. In the buildings sector, energy efficiency's biggest impact is to curb growth of electricity demand, facilitating the decarbonisation of the power sector.

Potential for energy efficiency improvements

Mandatory minimum energy performance standards (MEPS) are the principle means of driving adoption of more energy efficient technologies. Recent regulations in Indonesia have strengthened mandatory MEPS for air conditioners and refrigerators and expanded MEPS to rice cookers and fans. However, MEPS and energy consumption comparative labels are still lacking for key end-uses in the industry and transport sectors, with Indonesia and more broadly, the Association of Southeast Asian Nations (ASEAN), lagging behind other economies in Asia (Table 2.2).

Space cooling in residential and services buildings is the fastest growing source of electricity demand in Indonesia. It accounted for 15% of electricity demand in buildings in 2021, almost 30 TWh, up from 10% in 2010. Energy use for space cooling is set to increase even faster in coming years as rising incomes render air conditioner ownership affordable for most households and businesses. A regulation in 2021 establishes new MEPS and energy efficiency labels for air conditioners, with the aim of mitigating future electricity demand growth related to space cooling.[9] The new regulation rates air conditioners by efficiency performance. The top rating – five stars – is awarded to an air conditioner with a cooling seasonal performance factor (CSPF) of 5 or greater. At the other end of the range, a one star rating is set for a CSPF of 3.1, which is more than 10% higher than the previous standards.

[9] Ministry of Energy and Mineral Resources Regulation No. 103.K/EK.07/DJE/2021.

Table 2.2 ▻ **Mandatory minimum energy performance standards and comparative labels for key end-uses in Indonesia and selected Asian countries, 2021**

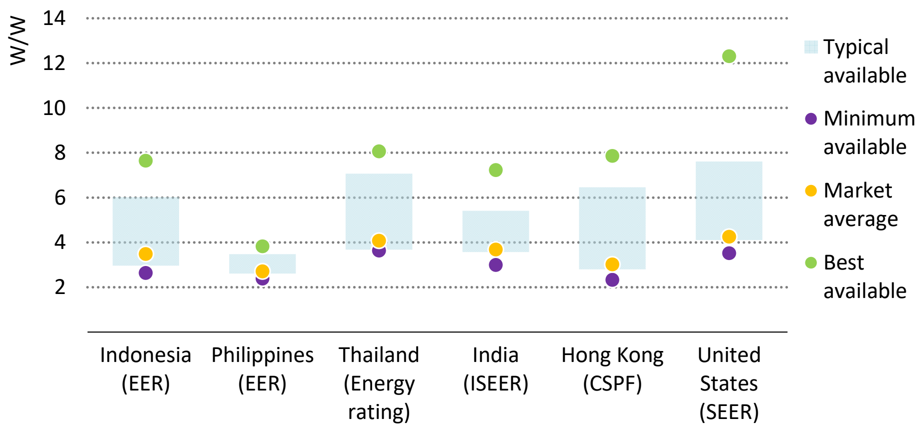
	Residential air conditioners		Residential refrigerators		Residential lamps		Industrial motors		Passenger light- duty vehicles	
	MEPS	CL	MEPS	CL	MEPS	CL	MEPS	CL	MEPS	CL
Southeast Asia										
Indonesia	In force	In force	In force	In force	In force	In force	None	None	None	None
Brunei Darussalam	In force	Under development	None	None	None	None	None	None	None	None
Cambodia	Under development	Under development	None	None	None	None	None	None	None	None
Lao PDR	Under development	Under development	None	None	None	None	None	None	None	None
Malaysia	In force	In force	In force	In force	In force	None	None	None	None	None
Myanmar	Under development	Under development	None	None	None	None	None	None	None	None
Philippines	In force	In force	None	In force	In force	In force	None	None	None	Under development
Singapore	In force	In force	In force	In force	In force	In force	In force	None	None	In force
Thailand	In force	In force	In force	None	In force	None	None	None	None	In force
Viet Nam	In force	In force	In force	In force	In force	None	In force	In force	None	None
Other Asia										
China	In force	In force	In force	In force	In force	In force	In force	In force	In force	In force
India	In force	In force	In force	In force	In force	In force	In force	None	In force	In force
Japan	In force	In force	In force	In force	In force	In force	In force	None	In force	In force
Korea	In force	In force	In force	In force	In force	In force	In force	None	In force	In force

Level of implementation: None Under development In force

Note: MEps = minimum energy performance standards; CL = energy consumption comparative label.

Nevertheless, there remains considerable scope to increase the stringency of both the minimum standard and efficiency ratings (Figure 2.15). For example, 100% of models sold were already at the minimum standard when they came into force in 2021, while 16% of air conditioners sold met the five-star standard. Certain models on the market in Indonesia today achieve a CSPF of almost 8, but they are given the same star rating as a unit with a CSPF of 5. MEPS should aim to close the gap between the average efficiency of units sold and the best available technology on the local market. Experience from other countries suggests that labelling can have the biggest impact in facilitating uptake of the most efficient models when top ratings correspond to or exceed the efficiency of the best available technology in the market.

Figure 2.15 ▷ Efficiency ratings of available air conditioners in selected countries, 2020



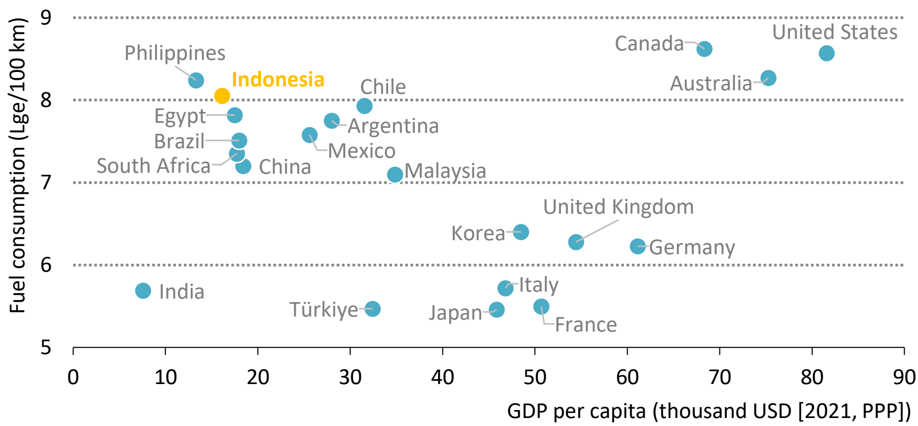
Indonesia, like many markets, has a major opportunity to increase the efficiency of air conditioners, while new MEPS will help, they are insufficient to tap the larger potential

Notes: W/W = Watt of cooling output per Watt of electricity input. EER = energy efficiency ratio. ISEER = Indian seasonal energy efficiency ratio. CSPF = cooling seasonal performance factor. SEER = seasonal energy efficiency ratio. Energy efficiency ratings for air conditioners refers to the ratio of heat removed from a space to the amount of energy the equipment requires to cool it. The higher the rating, the more efficient the equipment. Efficiency rating indicators differ by country depending on climate weighting, which can be altered by, for example, assuming different temperature ranges or requesting different numbers of testing data points.

Stringent energy and emissions-related elements in building codes are another key measure to tap the extensive potential for efficiency improvements in the buildings sector. Strengthening regulations for the envelope of new buildings, as well as for deep renovations of existing ones, are essential to improve comfort, and to reduce cooling loads and peak electricity demand. The enforcement of building code regulations presents significant challenges.

In the *transport* sector, there is significant potential for progress. There are no efficiency or CO_2 emissions standards for cars, trucks, buses, motorbikes or any other forms of transport, plus certain grades of diesel and gasoline are subsidised. Indonesia has high average fuel consumption intensities relative to other countries (Figure 2.16). Further, it risks becoming a dumping ground for less efficient vehicle models not permitted for sale in other markets. The passenger light-duty vehicle stock in Indonesia has an average fuel economy of 8.8 litres of gasoline equivalent (Lge) per 100 km. The fuel economy of a new vehicle sold today in Indonesia offers only marginal improvements, averaging 8.1 Lge/100 km, which is considerably less efficient than in India (5.7 Lge/100 km) or Malaysia (7.1 Lge/100 km). Fuel economy standards, and even more so, CO_2 emissions standards, are important drivers to facilitate the uptake of EVs. Standards are principal policy tools to enable Indonesia to achieve the levels of efficiency improvement and electrification in transport needed to achieve the APS trajectory.

Figure 2.16 ▷ Fuel consumption in new passenger cars relative to GDP per capita in selected countries, 2019



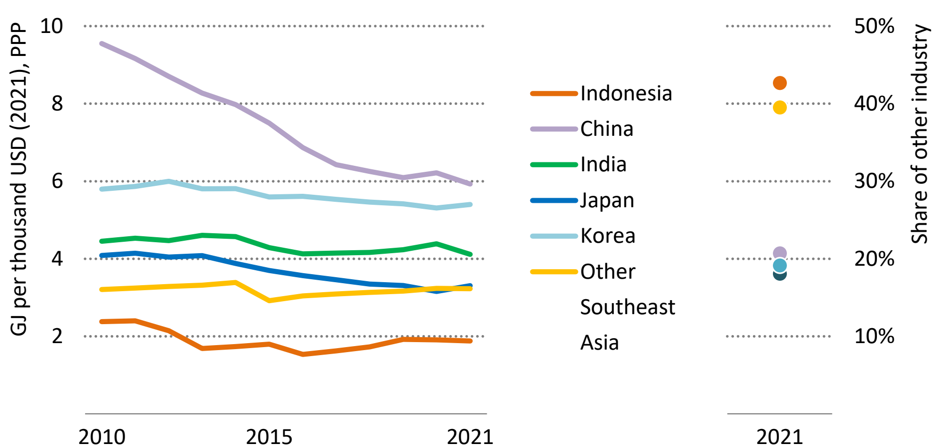
Average fuel consumption for new cars is 8.1 Lge/100 km in Indonesia – considerably higher than many countries at similar income levels and 40% higher than in India

Note: Lge = litres of gasoline equivalent.

Worldwide, nearly 80% of heavy trucks sold in 2020 were in markets where fuel economy standards or vehicle efficiency regulations covered at least some vehicle categories. In Indonesia, however, the lack of fuel economy standards impedes progress in improving the energy efficiency of freight transport. Energy demand for trucks over the last decade has grown 60% - much faster than the growth of overall transport demand. With the stock of heavy trucks vehicles set to expand even faster in coming decades, energy efficiency standards as well as complementary measures such as improving freight logistics and training drivers to operate in a more fuel-efficient manner will be critical to mitigate increases in fuel demand in the freight segment.

In the *industry* sector, there are no mandatory MEPS even for common equipment such as electric motors. Major industrial energy consumers are required to implement energy management systems and to report their energy use. However, there are no mandatory targets or government incentives for industries to improve their performance. Nonetheless, the average energy intensity of industry value added in Indonesia is below many other comparable economies (Figure 2.17). Indonesia's low average energy intensity today is primarily due to the structure of its industry sector rather than use of more efficient equipment and processes. While the share of other industry in total industry energy demand in Indonesia is on par with the rest of Southeast Asia and India, its other industry sector is dominated by the food and beverage sub-sector, including the processing of agricultural products. Accounting for 60% of other industry value added, the food and beverage branch uses little energy relative to many other industry segments, lowering the industry sector wide average energy intensity. There is nonetheless major scope for energy efficiency improvements in this segment, with a shift to more efficient electric motors for milling and other uses, and a switch to heat pumps or solar thermal for drying and other processes with low-temperature heat needs. While Indonesia's metal processing industry is small by current standards, the high share of coke oven blast furnaces in steel making and relatively low use of scrap make iron and steel production in Indonesia highly energy intensive. This impacts its international competitiveness compared with other principle industrial product producers.

Figure 2.17 ▷ Energy intensity of industry in selected countries and share of other industry in industry energy demand, 2021



Industry in Indonesia, on average, uses less energy per dollar of value added by the sector than most comparable economies, largely due to the high share of other industry

Note: Other industry includes construction, food, machinery, mining, textiles, transport equipment, wood processing and industries otherwise not categorised.

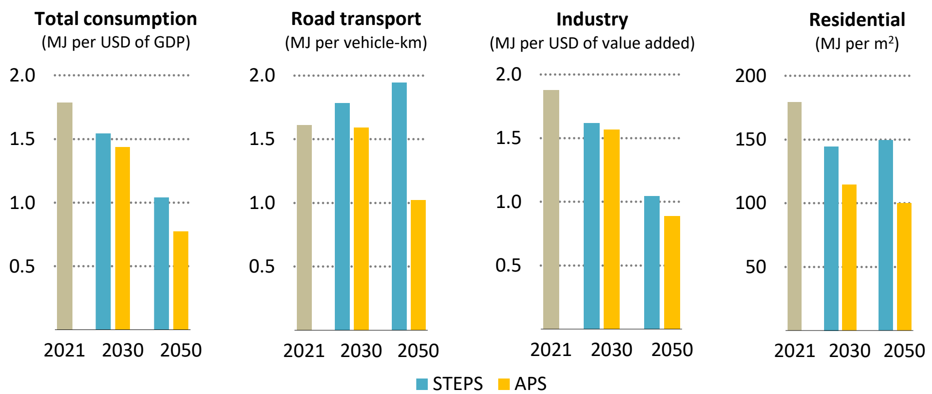
Energy efficiency in the Announced Pledges Scenario

Tapping Indonesia's significant potential for energy efficiency improvements is essential to achieve its economic development objectives as well as the net zero emissions target. Decisive policy actions to accelerate energy efficiency improvements in the APS, including to unlock efficiency gains from electrification and avoided demand, and to decouple increased access to energy services from energy demand. At an economy-wide level, Indonesia achieves advanced economy status in the 2040s. Yet with the decoupling, per capita final energy consumption declines marginally by 2060.

Looking at key end-uses, by 2050 Indonesia achieves a comparable level of energy services consumption as in many advanced economies today. For example, air conditioner ownership increases from an average of one unit per every ten households today to almost two units per household by 2060, yet thanks to step changes to improve the energy efficiency in air conditioning units and building envelopes, household electricity use for cooling increases sevenfold compared to the more than thirty-fold increase in the air conditioner stock.

Mandatory MEPS across all end-uses drive a rapid shift in sales toward the most efficient industrial electric motors and boilers, air conditioners, appliances and vehicles. Parallel policies to encourage electrification, achieve universal access to clean cooking and construct more efficient and comfortable buildings further drive reductions in the overall energy intensity of economic activity.

Figure 2.18 ▷ Energy intensity by sector in Indonesia in the Announced Pledges and Stated Policies scenarios, 2021 – 2050

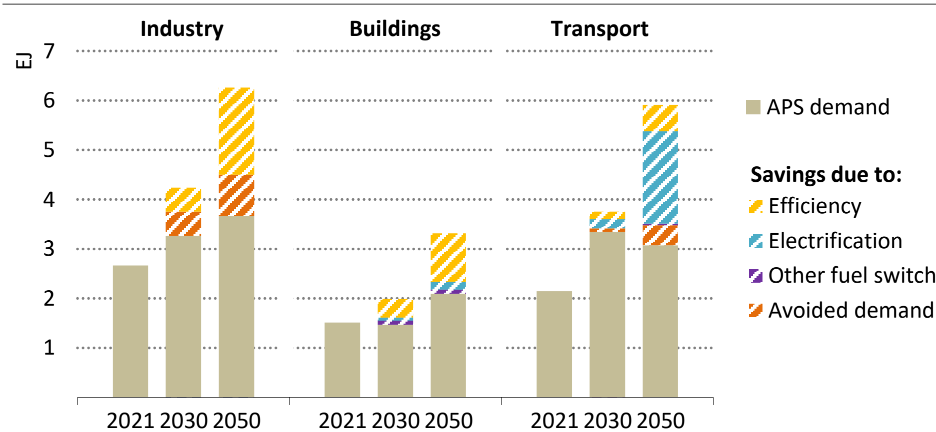


Energy efficiency improvements and electrification drive declines in energy intensity in end-use sectors, with an overall decline of 60% by 2050

Final energy intensity of Indonesia's GDP declines 20% by 2030 in the APS relative to today (Figure 2.18). By 2050, 60% less energy is needed per dollar of GDP relative to today. By 2050, the average energy intensity of the road transport vehicle fleet is more than 40% lower than today, reaching 3 Lge/100 km for passenger cars. In industry, the shift to more efficient production routes, as well as the adoption of energy and materials efficiency measures in existing plants, results in a decline in average energy intensity of over 50% by 2050. Consequently, energy demand increases by only 40% from 2021 levels, while industrial value added more than triples. In households, eliminating the traditional use of biomass for cooking delivers immediate efficiency gains with the uptake of cooking devices that are five-to-ten-times more efficient than basic wood-fired stoves. Increasingly stringent MEPS for air conditioners and household appliances, as well as building energy codes, curb energy demand growth to 40% by 2050 while residential building floor area more than doubles in the same period.

Final energy consumption in 2030 would be almost 2 000 PJ higher without increased energy efficiency gains, electrification, avoided demand and other fuel switching in all sectors relative to current levels. Direct improvements in the energy efficiency of equipment deliver more than half of these savings in 2030, underscoring the critical role of energy efficiency to mitigate energy demand growth in the short term. Energy efficiency in industry reduces demand by almost 500 PJ to 2030 in the APS. In the transport sector, fuel economy standards introduced by 2025 and accelerating electrification avoid over 350 PJ of oil demand in 2030 (Figure 2.19). Greater material efficiency and increased use of public transport also pay dividends in the APS, avoiding over 500 PJ of energy demand by 2030.

Figure 2.19 ▷ Total final energy consumption and demand savings by mitigation measure and sector in Indonesia in the Announced Pledges Scenario, 2021 – 2050



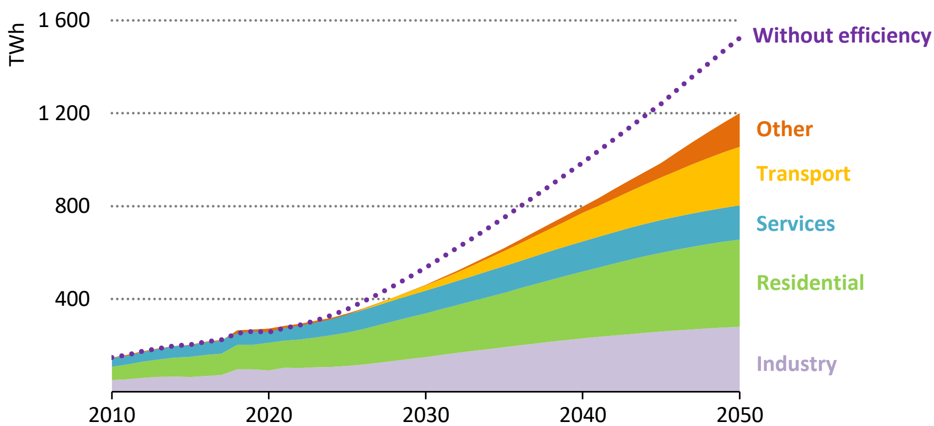
Energy efficiency, electrification and other measures avoid nearly 2 EJ of demand by 2030 and 7 EJ by 2050; efficiency is crucial to curb energy demand growth in the short term

Notes: EJ = exajoules. The buildings sector includes energy used in residential, commercial and institutional buildings. Avoided demand includes materials efficiency, structural and economic effects (such as the response of consumers to higher prices) and behavioural changes.

Looking beyond 2030, efficiency gains from electrification deliver an increasing share of total energy demand savings, reaching 30% by 2050. EVs are around three-times more efficient than comparable ICEs, and heat pumps offer an efficient alternative for low-temperature industrial process heat. In the buildings sector, electrification of cooking and water heating energy demand saves over 150 PJ by 2050, but the biggest gains are in efficiency improvements of building envelopes, electric appliances and air conditioners to subdue growth in electricity demand.

Energy efficiency is a key measure in the APS to mitigate rising demand for electricity. Absent efficiency improvements, electricity demand would be over 70 TWh higher by 2030, and 320 TWh higher by 2050 (Figure 2.20). Electricity demand in the APS increases at an annual average of 5.2% to 2050. Absent efficiency gains, that rate of growth would average 6.1% per year. By mitigating demand growth, better efficiency for electricity consuming equipment significantly reduces the need to build new generation assets.

Figure 2.20 ▷ Electricity demand with and without energy efficiency improvements in the Announced Pledges Scenario



Energy efficiency improvements reduce electricity demand by 320 TWh in 2050

In the APS, avoided electricity demand due to efficiency gains offsets 80% of the increased electricity demand related to electrification of transport, industrial process heat, cooking and water heating. Electricity demand savings are most significant in the buildings sector, at 180 TWh by 2050. Absent the efficiency gains, electricity demand in the buildings sector would be more than one-third higher in 2050.

Sectoral pathways to net zero emissions by 2060

Driving change across the energy system

SUMMARY

- Electricity demand in Indonesia increases more than fivefold from 2021 to 2060 in the Announced Pledges Scenario (APS), driven in part by new uses such as electromobility and hydrogen production, but moderated by strong efficiency policies. By 2060, per capita electricity demand rises to around 4 400 kWh, while consumption of electricity services exceeds the average level of advanced economies today. Renewables capacity increasingly replaces unabated coal and natural gas, whose combined generation share falls from nearly 80% in 2021 to 65% in 2030 and essentially zero in 2060. A broad range of cost-effective renewables generate 90% of electricity by 2060, tapping Indonesia's excellent solar PV, geothermal and hydro resource potential. Other low emissions options help make many existing power plants compatible with net zero emissions, including CCUS, hydrogen and ammonia.
- Bioenergy use doubles by 2060 in the APS playing a crucial role in decarbonising both heavy industry and transport, and providing a source of low-carbon flexibility to the power system. Over 70% of the bioenergy in 2060 is from sustainable waste streams.
- Hydrogen produced in areas with good solar conditions could reduce in cost by 2050 to below that of unabated production from natural gas. Hydrogen and ammonia account for half of fuel demand in shipping in the APS in 2060. Hydrogen use accounts for 7% of road transport energy demand.
- By 2060, industry sector value added more than triples in the APS and yet its CO_2 emissions peak around 2030 and are cut from around 160 Mt in 2021 to below 40 Mt by 2060. In the near term, energy demand growth is dampened by energy and material efficiency gains. Electricity meets 30% of energy demand in industry by 2060, with direct use of renewables meeting a quarter of demand, and fossil fuels equipped with CCUS and hydrogen together accounting for about 15%.
- Today, the average Indonesian travels 5 500 km per year, with this distance lengthening to 14 000 km by 2060 in the APS. With expanding electromobility and better energy efficiency, transport energy demand in 2060 is only one-third higher than in 2021. Electricity accounts for nearly half of transport energy demand by 2060, biofuels and hydrogen account for a third. Oil use persists in aviation and shipping.
- Residential floor area expands the equivalent of fifteen-times the area of the Special Capital Region of Jakarta by 2060 and the number of air conditioners surges by more than 200 million as incomes and population increase. In the APS, building energy codes and ambitious minimum energy performance standards subdue electricity demand growth. By 2030 savings equate to around 50 TWh, or the output of around 20 coal-fired power plant units. Savings rise to around 200 TWh by 2060. Average electricity use per air conditioner in 2060 is one-quarter of the 2021 average.

3.1 Context

This chapter presents sectoral pathways aligned with net zero emissions by 2060. Presented sector-by-sector, it provides an overview of the energy and emissions trends for key end-uses; exploring the evolution of service demand, energy efficiency opportunities, the emerging role of new technologies and their costs.

The pathways presented are based on the IEA's Announced Pledges Scenario (APS), a scenario that achieves Indonesia's stated economy-wide target of net zero CO_2 emissions by 2060, as well as Indonesia's target to increase GDP per capita to advanced economy levels by the mid-2040s. In some cases, comparisons are presented relative to the Stated Policies Scenario (STEPS), which is based on existing policies and measures, as well as those under development. Unlike the APS, the STEPS does not take for granted that governments will reach all announced goals.

The chapter first explores the pathway for the electricity sector; the role of Indonesia's coal-fired generators in the transition to net-zero emissions, the steps needed to accelerate deployment of renewables and how costs evolve. In addition, the chapter discusses the role of low emissions fuels; how Indonesia can leverage its unique bioenergy potential in the energy transition, while respecting sustainability constraints, and the role for hydrogen and hydrogen-based fuels such as ammonia. It analyses transition pathways for the industry, transport and buildings sectors in turn, exploring the specific barriers and opportunities for emissions reduction in end-uses, while ensuring that wealth and access to energy services increases for Indonesians.

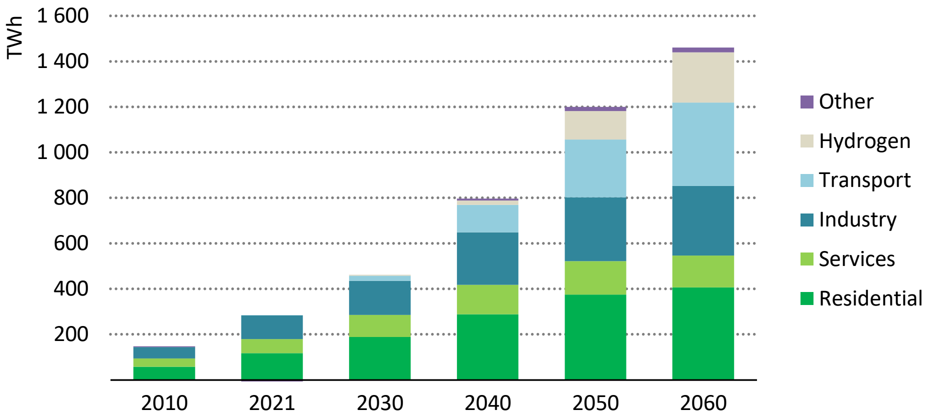
3.2 Electricity sector

3.2.1 Electricity demand

Electricity demand in Indonesia is set for rapid growth over the next four decades as the population expands, incomes rise, demand for energy services increases and energy transition policies drive the electrification of end-uses. In the APS, electricity demand rises at an average rate of more than 4% per year, increasing more than fivefold from 2021 to 2060. This is faster than the projected average rate of economic growth. Average per capita electricity demand rises from under 1 000 kilowatt-hours (kWh) in 2021 to more than 1 500 kWh in 2030 and around 4 400 kWh in 2060, ranking Indonesia comfortably in the range of developed economies today in terms of energy service demand (Spotlight).

Electricity demand growth is driven by expanding activities and increasing electrification in all sectors. The largest absolute increase in electricity demand is for electromobility, with transport the second-largest component of electricity demand in 2060 (Figure 3.1). Today the residential sector accounts for the largest share of electricity demand and it retains this rank in 2060 as higher incomes push up demand for more energy services, particularly space cooling. Electricity demand for households more than triples in the period to 2060, though this growth is mitigated by improvements in energy efficiency. The services sector also sees strong growth in the APS, though efficiency gains help to offset electricity demand growth relative to activity expansion. Projected demand for electricity for hydrogen production sees a huge increase by 2060, nearly equal to total electricity demand in Indonesia today, as hydrogen is put to use to reduce emissions in multiple sectors.

Figure 3.1 ▷ Electricity demand by sector in Indonesia in the Announced Pledges Scenario, 2010 – 2060



Electricity demand increases fivefold to 2060 as the population increases and incomes rise which underpins more demand for energy services

Notes: TWh = terawatt-hours. Other category includes electricity demand in agriculture and in other energy transformation, such as refineries.

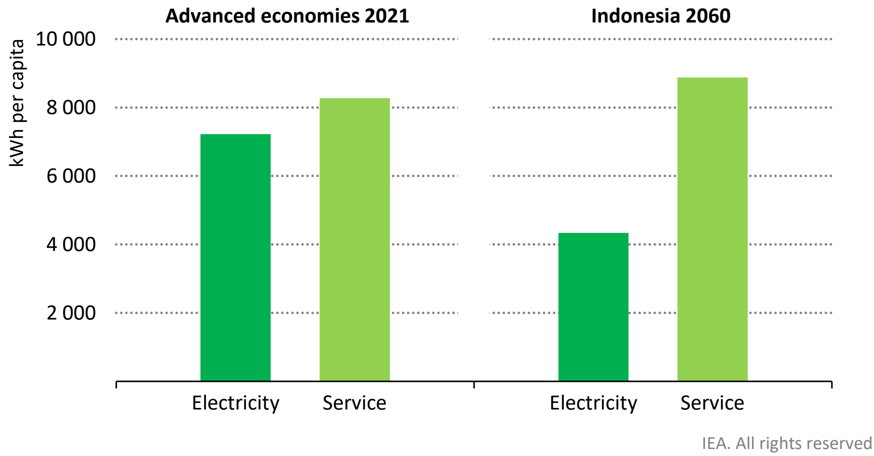
S P O T L I G H T

Consumption of electricity services in Indonesia by 2060 exceeds levels in advanced economies today

The consumption of energy services, not energy itself, improves human welfare. For example, a household benefits from the cooling service of an air conditioner, not the electricity it runs on. Improving efficiency creates the possibility of relative decoupling of energy demand and service provision.

The transition to net zero emissions by 2060 is a path for Indonesia to achieve decarbonisation objectives and to significantly increase the multitude of services provided by electricity. Examples of services include air conditioned buildings, passenger transport, lighting, motors and dryers. In the APS, the use of electricity services increases eightfold in the period to 2060, driven by increases in demand for cooling and appliances in the buildings sector, as well as electromobility. By 2060, the consumption of electricity-based services in Indonesia would exceed the average level of consumption per capita in advanced economies today (Figure 3.2)

Figure 3.2 ⊳ Electricity demand and electricity service demand per capita



Electricity services consumption expands eightfold to 2060 bringing levels in Indonesia to those of advanced economies in 2021, though gains in efficiency conserves electricity demand to 4 400 kwh per capita

If Indonesia's electricity demand per capita increased in line with the growth in the provision of electricity-based services, then per capita demand would approach 7 000 kWh by mid-century, in line with the target in Indonesia's National Energy Policy, and by 2060 it would approach 8 000 kWh. However, thanks to determined efforts to tap the potential for energy efficiency in the APS and the increasing role of electricity use for transport and cooling, Indonesia is able to deliver energy services aligned with advanced economies, with only a fourfold increase in electricity per capita to around 4 400 kWh.

The biggest savings in electricity demand come from the buildings sector, where shifting sales of air conditioners to the most efficient models available increases the average seasonal coefficient of performance from just over 2.5 today to almost 8 by 2060. This means that only 1 kWh of electricity is required to deliver 8 kWh of useful service in the form of cooling. Improvements in building envelopes performance further increase savings. Electric vehicles (EVs) also contribute to decouple electricity demand growth from the increase in service provision. On average, EVs are three-times more efficient than internal combustion engine vehicles, meaning it takes three-times less energy to travel a kilometre than travelling the same distance in a conventional car.

The share of highly efficient air conditioners in Indonesia's equipment stock in 2060, as well as the large-scale electrification of passenger transport, means that electricity use has an average efficiency of around 200%. This is much higher than the average efficiency of electricity use in advanced economies today, where the share of highly efficient EVs, air conditioners and heat pumps in the total electric equipment stock is just sufficient to raise average electricity efficiency above 100%.

3.2.2 Electricity supply

Indonesia's electricity generation mix undergoes a major transition in the APS. Today's high share of unabated fossil fuels – 80% of generation in 2021 – is progressively reduced in favour of low emissions generation sources. Displaced by renewables, unabated fossil fuels are two thirds of total generation in 2030 and only a few percent in 2060. Utility-scale solar photovoltaics (PV) and onshore wind are the most significant renewables contributors in the long term, complemented by hydropower, bioenergy and geothermal. Strengthening and integrating the electricity grid are also important components on the pathway. Other low emissions sources such as nuclear, coal and gas equipped with CCUS, and small amounts of ammonia- and hydrogen-fired generation, pave the way towards net zero emissions in the electricity sector. In the APS, CO_2 emissions intensity of electricity generation declines from 760 grammes of carbon dioxide per kilowatt-hour (g CO_2/kWh) in 2021 to 580 g CO_2/kWh in 2030 and to near zero in 2060.

3

Coal

Coal-fired power – the foundation of Indonesia's electricity system at about 60% of total generation in 2021 – undergoes multiple transitions in the coming decades. Its fleet of coal plants is young in age and more plants are under construction or planned. This continues the reliance on coal in any scenario for a number of years. It will be critical to reduce emissions from the fleet of coal-fired power plants and provide opportunities for low emissions sources to progress on the path to net zero emissions, facilitated by electricity market reforms and adjustments to existing contracts (Box 3.1). The path in the APS sees the contribution of unabated coal drop to just over 50% by 2030. This is in line with recent announcements from the state-owned electricity corporation, Perusahaan Listrik Negara (PLN), that the use of unabated coal in power generation is fully phased out before 2060.

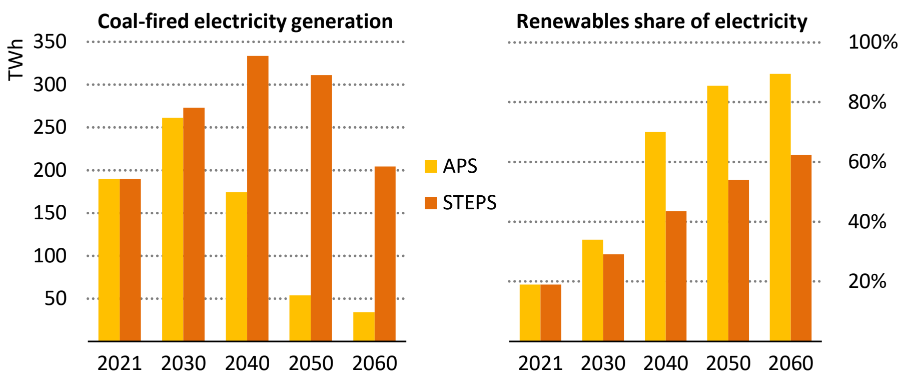
Reliance on coal and coal-fired power plants is maintained in the transition, facilitated by several strategies to reduce emissions. Equipping coal plants with carbon capture, utilisation and storage (CCUS), co-firing with low-carbon ammonia and repurposing plants to focus on flexibility, allow them to retain a key role in the electricity system while contributing to meeting emissions reduction targets. Older plants that are less suited for such transformations may be retired early as low emissions sources scale up.

Box 3.1 ▷ Modifying coal power plant operations to accelerate the transition

Indonesia's fleet of coal-fired power plants is young and there are 14 GW of new plants in the PLN 2021-2030 project pipeline, as defined by the Electricity Supply Business Plan (Rencana Umum Penyediaan Tenaga Listrik [RUPTL]). Coal-fired power capacity should peak at just above 45 GW by 2030. This represents about one-third of total installed capacity projected in 2030. How these plants are operated over the coming decades is instrumental to the pace of the clean energy transition. Adjusting the way they are operated is critical to cut their CO_2 emissions and to provide opportunities for renewables to gain share in the power generation mix.

Implementation of a number of measures assumed in the APS modifies coal plant operations before 2030 with more significant changes in subsequent years. In recent years Indonesia's coal plants have operated with a capacity factor of around 60%.[1] By 2040 in the APS, the fleet of coal plants has an average capacity factor of around 50% and produces 175 terawatt-hours (TWh), which is 25 TWh less than if past operations were maintained and just over half of electricity generation from coal in the STEPS (Figure 3.3). As the share of coal fades, renewables and other low emissions sources step in and their share of generation expands from under 20% in 2021 to three-quarters in 2040.

Figure 3.3 ▷ Electricity generation from coal and share of renewables in Indonesia in the Stated Policies and Announced Pledges scenarios, 2021 – 2060



As output from coal-fired power plants declines, renewables and other low emissions generation sources scale up and accelerate the transition

Note: APS = Announced Pledges Scenario.

Significant changes in the underlying framework are required to shift coal-fired power plant operations. For instance, today coal plants operate based on long-term contracts for power purchases at set prices, which does not give operators appropriate incentives to adapt operations when renewables-based generation is available. Further complicating ways to operate coal plants more flexibly are long-term fuel contracts. Coal plants should be able to operate flexibly to integrate rising shares of solar PV and wind generation assets. Modified contractual arrangements and market reforms are key to unlocking this flexibility and accelerating the transition. The need for reforms is even more pressing given that independent power producers have signed long-term contracts with PLN, which will increase their share in power generation in coming years.

The remaining output from coal-fired power plants will need to be abated or avoided in order to minimise emissions. One way is by equipping about 7 GW of coal plants with

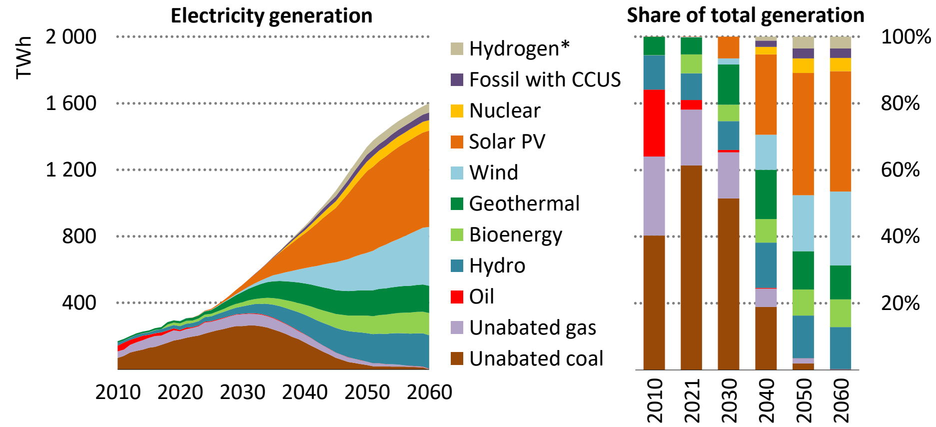
[1] Capacity factor refers to total output divided by theoretical maximum output over the period.

CCUS by 2060 in the APS, with storage locations near several clusters of large emitters (see Chapter 5, section 5.5). CCUS enables the continued use of domestic coal resources in Indonesia. However, the projected costs make CCUS a relatively expensive option relative to renewables (the picture changes somewhat when the added costs of inter-regional transmission are included). Co-firing coal with ammonia is another option, which reduces coal use and therefore the volume of emissions that require abatement. As ammonia is projected to remain a much more expensive fuel than coal, its use would change the underlying economics of plant operation, with generation targeting only the highest value times, when renewables are least able to meet electricity demand.

Natural gas

Natural gas-fired power plants provide another dispatchable source of electricity in Indonesia, albeit significantly smaller than coal. Through to 2060, natural gas use in power generation transitions from unabated to a lower emissions technology profile, both through the inclusion of CCUS and by co-firing with hydrogen. The changing availability of domestically produced natural gas limits its role in terms of generation. Overall, the share of unabated natural gas in total generation falls by a few percentage points between 2021 and 2030 before decreasing to less than 1% in 2060 in the APS (Figure 3.4). Gas-fired power plants also play an important role to support electricity security, providing flexibility and contributing to the reliability of the system.

Figure 3.4 ▷ Electricity generation by type and share of total generation in Indonesia in the Announced Pledges Scenario, 2010 – 2060



As a cornerstone of achieving net zero emissions by 2060, electricity supply transitions away from unabated fossil fuels to renewables and other low emissions sources

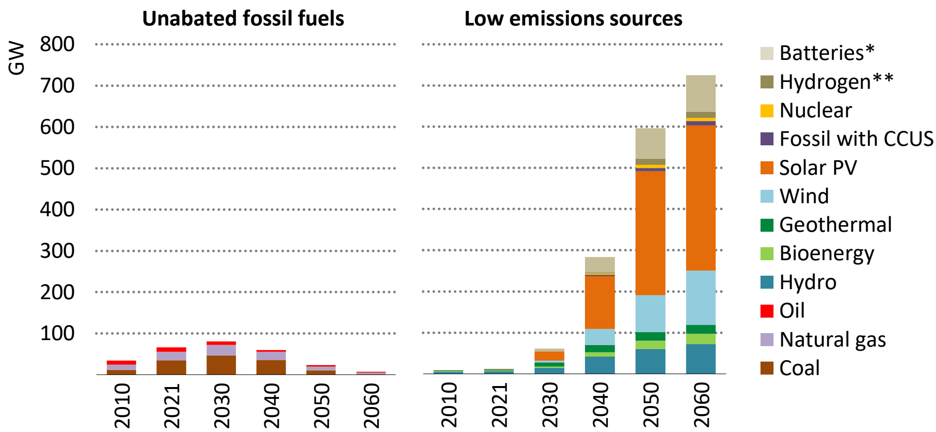
* Hydrogen includes hydrogen and ammonia, both produced exclusively from low-carbon sources in the APS.

Note: TWh = terawatt-hours. Fossil with CCUS = fossil fuel-fired generation equipped with carbon capture, utilisation and storage technology.

Carbon capture, utilisation and storage

Due to the availability of domestic fossil fuels in Indonesia, the use of coal and natural gas-fired generation continues to 2060 in the APS, albeit with increasing levels of assets fitted with CCUS. By 2040, 2 GW of coal plants are equipped with CCUS, representing 6% of the total coal fleet. By 2060, 7 GW of coal-fired capacity is equipped with CCUS (Figure 3.5). Gas-fired capacity with CCUS reaches 1 GW and 5% of the fleet by 2040 and 3 GW by 2060. Retrofits of coal and gas plants accelerate significantly after 2035, capturing and storing a total of almost 1 Gt CO_2 emissions between 2035 and 2060. A critical factor in the ability to deploy carbon capture technologies is the availability of geologic storage sites, fortunately many existing power plants are located near suitable CO_2 storage locations (see Chapter 5, section 5.5).

Figure 3.5 ▻ Installed capacity by type in Indonesia in the Announced Pledges Scenario, 2010 – 2060



Solar PV, hydro and other renewables capacity scale up rapidly in the APS, while the fleet of unabated fossil fuel power plants peaks around 2030

* Batteries are included in low emissions sources as they have no direct emissions. ** Hydrogen also includes ammonia, both produced exclusively from low emissions sources in the APS.

Notes: GW = gigawatts. Fossil with CCUS = fossil fuel-fired generation equipped with carbon capture, utilisation and storage technology.

Co-firing in fossil fuel power plants

Co-firing with low-carbon hydrogen and its derivative, ammonia, in its existing fossil fuel plants can provide Indonesia with an additional tool to lower emissions from its electricity sector. In coal plants without CCUS, co-firing with ammonia picks up quickly around 2040, with blending rates rising to nearly 60% ammonia by volume in 2050 and nearing 100% by 2060 in the APS. For natural gas-fired power plants without CCUS, co-firing with hydrogen reaches over one-third hydrogen by volume in 2050 and nearly 80% by 2060 in the APS.

Renewables

A broad range of cost-effective renewables generate 90% of electricity by 2060 – up from nearly 20% in 2021 and one-third in 2030 – tapping Indonesia's excellent solar PV, geothermal and hydropower resource potential. Electricity generation from renewable energy technologies expands rapidly in the APS, almost tripling from 2021 to 2030. Solar PV makes strides from less than 1 GW of capacity in 2021 to more than 20 GW in 2030 and reaches 300 GW by 2050, tapping the enormous solar resources available throughout Indonesia (see Chapter 5, Box 5.2). Wind power complements the roll-out of solar PV, though it is limited by wind speeds in most locations. The availability of low-speed wind turbines, for both onshore and offshore installations, is necessary. In the APS, wind capacity rises from under 1 GW in 2021 to 90 GW by 2050, of which a significant portion is offshore, predominantly off the coast of Kalimantan, based on the IEA's assessment of offshore wind potential (IEA, 2019).

In addition, a suite of dispatchable renewables is deployed to cut emissions, provide flexibility and maintain the security of electricity supply. Hydropower is the most significant accounting for more than 70 GW in 2060. Geothermal accounts for 22 GW and bioenergy for 25 GW in 2060 in the APS.

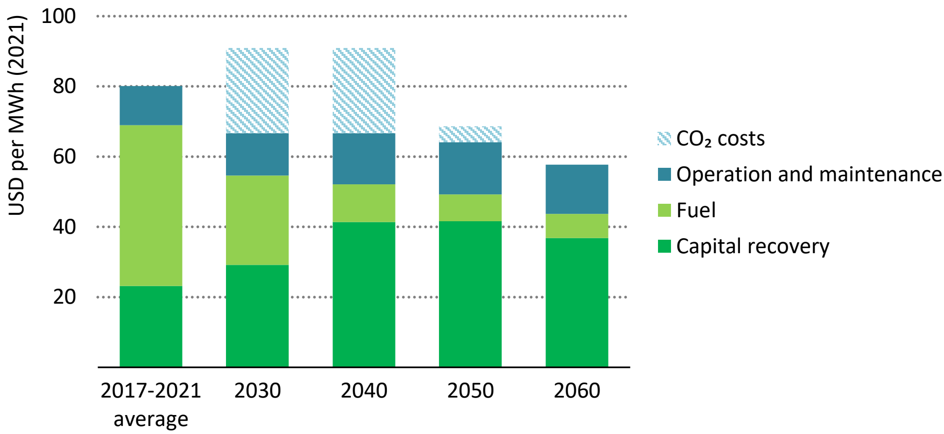
Nuclear

Indonesia has no nuclear power today, but its deployment could be another option in the net zero emissions path. Nuclear power can provide a dispatchable source of electricity without adding emissions, and support the reliability and stability of the grid. In the APS, Indonesia's first nuclear reactor begins producing electricity just after 2035 and a total of 8 GW of nuclear capacity is operational by 2050. In doing so, Indonesia would join several countries projected to develop their first nuclear reactors in the APS, including Türkiye, Poland and Egypt. To support the introduction of nuclear power to Indonesia, the necessary regulatory structure would have to be developed, with independent safety checks a core element. If small modular nuclear reactors are successfully developed and if they are economic, they could present opportunities to further contribute to Indonesia's energy transition.

3.2.3 Electricity generation costs

Average electricity generation costs on a per unit basis in Indonesia increase by 10% in the period to 2030 compared with recent years, rising from about USD 80 per megawatt-hour (USD/MWh) in 2021 to USD 90/MWh in 2030. Average costs are broadly stable to 2040 before starting a long-term structural decline to below USD 60/MWh in 2060 (Figure 3.6). With increasing output, the total costs of electricity generation doubles by 2030 from just about USD 22 billion on average in 2017-21 to almost USD 45 billion, and nearly double again to USD 85 billion by 2050.

Figure 3.6 ⊳ Average electricity generation costs by category in Indonesia in the Announced Pledges Scenario, 2017 – 2060



Average electricity costs rise about 10% by 2030, but fall by almost 30% by 2060; in the interim CO_2 revenues can compensate consumers or benefit the economy

Note: CO_2 costs refer to those associated with a carbon price for emissions from fossil fuel power plants.

Rising CO_2 prices are the main driver for increasing electricity generation costs over the next decade. By 2030, CO_2 costs reach about USD 12 billion, accounting for over one-quarter of total electricity generation costs. However, these CO_2 costs are fundamentally different than other types of electricity cost, as they can provide revenue for the government to compensate consumers for higher electricity prices or to bolster the economy in a multitude of ways. Total CO_2 costs (or revenues) peak in 2040 at around USD 20 billion, before rapidly declining as the decarbonisation of the electricity sector overtakes the effect of rising CO_2 prices. Excluding CO_2 costs, the remaining costs of electricity generation decline by almost 20% to 2030, offering an opportunity for electricity to be more affordable in the near term in the APS.

Falling average electricity costs in Indonesia is primarily the result of the cost effectiveness of renewables relative to fossil fuels. Renewable energy technologies can soon become the least expensive new sources of electricity in Indonesia, as they have in many other regions. With policies to drive improved financing conditions and the development of the market, the levelised cost of electricity (LCOE) of solar PV falls significantly in Indonesia in the APS, with utility-scale projects dropping below USD 40/MWh by 2030. At this level, they would become the cheapest new source of electricity. Rooftop solar PV installations would also decline, to about USD 100/MWh.

The cost of onshore wind power declines by 10% to about USD 90/MWh in 2030, with costs for offshore wind in the same range by 2030. To complement energy technology innovation from global industries, policy support in Indonesia can help achieve these cost reductions by expanding its market and limiting risks to unlock low cost financing for new renewables projects. In doing so, a large amount of cost-effective deployment could replace unabated fossil fuels at no costs to consumers.

The costs of dispatchable renewables in the APS are more stable as the technologies are more mature, as exemplified by the costs of hydropower which are stable at USD 80 - 90/MWh throughout the APS projection. The LCOE of bioenergy power plants span a wide range, though generally above USD 150/MWh, depending on the delivered cost of biomass, which is expensive to transport.

Re-shaping Indonesia's electricity mix changes the nature of the underlying costs, as the electricity sector becomes more capital intensive. Capital recovery accounts for a rising share of the total costs, from about 30% in recent years up to nearly half in 2040 and almost two-thirds in 2060. This mainly due to the rapid growth of renewables, particularly solar PV, wind, hydropower and geothermal, where the majority of costs are incurred during construction, fuel costs are zero and operation and maintenance costs are relatively low. Fuel costs currently make up close to 60% of total electricity costs, but this is cut to under 30% by 2030 and under 15% by 2040, as the use of coal, natural gas and oil all decline sharply. This new cost structure also offers more predictability in the long term for average electricity costs.

As the generation mix shifts in Indonesia, renewables will also begin to represent the largest portion of total electricity costs. Fossil fuel power plants currently account for about 85% of total electricity costs in Indonesia, with coal-fired power plants costs about USD 10 billion per year to fuel, maintain and recover capital. Recently renewables accounted for just 15% of total costs, mainly split between hydropower and bioenergy. By 2040 in the APS, fossil fuels and renewables reach parity, each accounting for nearly half of total electricity costs, complemented by nuclear and hydrogen. By 2060, renewables dominate the system and represent 80% of total electricity costs, with just over 10% for fossil fuels, 6% for nuclear power and the remaining few percent for hydrogen and ammonia.

3.3 Low emissions fuels supply

3.3.1 Bioenergy

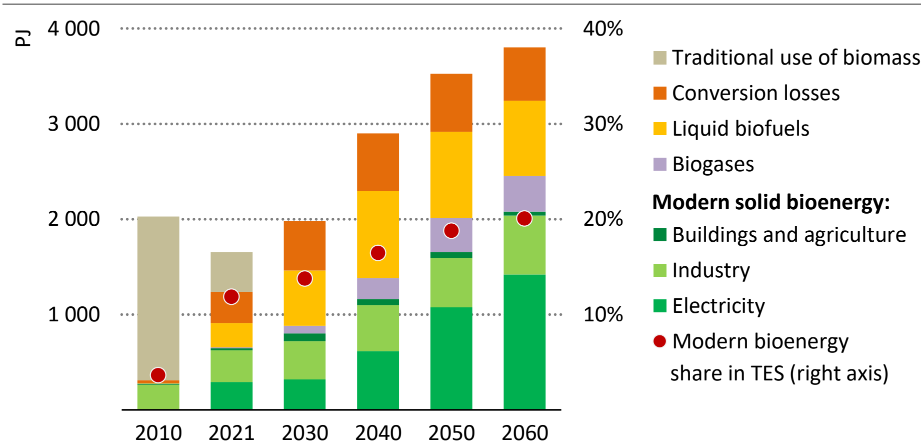
With half of Indonesia covered by forests and cropping practised on one-fifth of its land area, biomass is an abundant resource (FAO, 2020). It has historically been the principal source of energy for cooking and heating needs in households across Indonesia, but as access to modern alternatives such as liquefied petroleum gas (LPG) has rapidly increased, bioenergy use has increasingly shifted use in the transport, industry and electricity generation sectors. Recognising it as a means to reduce reliance on imported fossil fuels, the government has promoted the use of modern bioenergy, particularly for transport and aims to propel the country to the status of a global leader in both the production and use of biofuels.

In the APS, Indonesia leverages its vast bioenergy potential to reduce emissions from existing assets and to decarbonise some of the hardest to abate sectors. However, not all of its biomass is suitable to use as bioenergy – caution must be used to ensure that bioenergy uses are sustainable and do not lead to net positive greenhouse gas (GHG) emissions, destruction of biodiversity or competition for food production.

Bioenergy demand

Bioenergy demand in Indonesia in 2021 totalled almost 1 700 petajoules (PJ), 16% of total energy supply. Total bioenergy demand has dropped around 20% since 2010, although this decline is solely due to improvements in access to clean cooking that reduced the traditional use of biomass for household cooking. Demand for modern bioenergy increased by 920 PJ in the 2010-21 period, almost quadrupling. Over 560 PJ of modern bioenergy is used to produce liquid fuels predominantly for use in transport, this includes 300 PJ of conversion losses. The electricity and industry sectors are also major consumers of modern bioenergy, mostly in the form of combustion of waste residues from agricultural processes and forestry.

Figure 3.7 ▻ Total bioenergy demand by type and by end-use sector in Indonesia in the Announced Pledges Scenario, 2010 – 2060



Modern bioenergy use triples from 2021 to 2060; fuelled by use in long-distance transport, high-temperature heat in industry and generating electricity

Notes: PJ = petajoules; TES = total energy supply. Bioenergy demand excludes exported biofuels but includes the conversion losses associated with biofuels production for export. Modern solid bioenergy refers to the use of all forms of solid biomass, including agricultural and other organic waste, combusted in improved cookstoves or boilers and therefore excludes the traditional use of biomass.

In the APS, bioenergy is critical to reduce emissions from the existing transport fleet, to decarbonise end-uses that are not easily electrified, such as heavy trucking, aviation and shipping, to assist in the integration of variable renewables generation, and as a source of negative emissions via bioenergy carbon capture and storage (see Chapter 5, section 5.5.1). Use of bioenergy increases to almost 2 000 PJ in 2030, reaching just over 3 800 PJ in 2060, with growth slowing in the last decade to 2060 as the transport fleet is increasingly electrified (Figure 3.7). The share of bioenergy in the total energy mix reaches 20% in 2060, while its share in total final consumption rises from 16% today to plateau at 18% in the 2050s.

Indonesia is a world leader in the production and use of *liquid biofuels*. It was the largest producer of biodiesel in 2021 at 265 PJ, 18% of global production, of which 235 PJ was consumed domestically. In 2019, Indonesia met its initial 20% blending target for biodiesel and is now on track to meet its current 30% biodiesel blending mandate – the world's highest. Recent announcements suggest the government is considering an increase in the target to a 40% blending rate, a decision that will be influenced by the evolution of international oil prices and prices of domestically produced biodiesel. Any cost differences between diesel and biodiesel are currently covered by the Crude Palm Oil Fund, which collects export levies from palm oil producers, therefore avoiding any price burden on consumers of rising biofuels use. The biodiesel blending mandates also cover diesel use in industry and electricity generation, with current blending share at around 22%. In addition to biodiesel, in 2020 the government established ethanol blending targets of 10% for transport and 5% for small businesses and agriculture, increasing to 20% by 2025. While domestic ethanol production has increased to 4 PJ, it is primarily used in the industrial sector rather than in transport, leaving blending targets unmet (USDA FAS, 2021a).

Demand for liquid biofuels in the APS sees the largest growth in the period to 2040. With an annual growth rate of 13%, demand more than triples to 910 PJ by 2040, 95% of which is for use in the transport sector. Biofuels have an advantage in the transport sector given existing infrastructure and vehicle technologies that allow for rapid uptake that deliver near-term emissions reductions while other clean energy technologies, notably electric vehicles, are slower to scale up and penetrate the market.

In the APS, the share of biofuels in transport energy demand increases from 12% today to 17% by 2030. Demand increases to a peak of 880 PJ in the mid-2040s; at this point liquid biofuels meet 25% of total transport energy demand. The vast majority of liquid biofuels are used in road transport, with biodiesel used predominantly in road freight transport, and lesser amounts of ethanol used in passenger vehicles. Blending shares of biodiesel in road freight transport reach over 50% in 2040. As electrification of road transport accelerates after 2040, total transport biofuel use declines to 700 PJ by 2060. Demand for liquid biofuels, however, continues to increase in harder to electrify end-uses particularly heavy trucking (around 50% of heavy trucking energy demand in 2060), shipping (10%) and aviation (20%).

The *traditional use of solid biomass* in Indonesia accounts for 25% of bioenergy use and 4% of total energy supply in 2021, down from 85% of bioenergy use and 20% of total energy supply in 2010. Traditional use of bioenergy for cooking and other household demand is inefficient and polluting, resulting in negative environmental, health and social impacts. Indonesia has demonstrated tremendous progress: access to clean cooking has increased from 40% in 2010 to more than 80% of the population today. Most have gained access with

LPG, reflecting generous and ongoing government subsidises for LPG stoves and fuel (see section 3.5.3). In the APS, LPG continues to play a central role to deliver clean cooking access, while improved solid biomass cook stoves, ethanol and domestic biogas digesters also contribute to achieve a full phase out of traditional use of biomass by 2030.

Modern solid bioenergy is used principally in the electricity and industry sectors, in almost equal shares today. Solid bioenergy accounts for 7% of electricity sector energy use (290 PJ), and 5.5% of generation, up from almost zero in 2010. Bioenergy in electricity generation increases more than sevenfold in the APS, from 17 TWh in 2021 to 130 TWh in 2060. Solid bioenergy provides crucial support to balance increasing shares of variable renewables. Bioenergy also provides opportunities to make use of existing infrastructure, such as coal-fired power plants, both via co-firing with coal, or converting plants to operate on 100% bioenergy. Bioenergy also crucially provides carbon dioxide removal (CDR) when coupled with carbon capture and storage (BECCS), offsetting residual emissions from other portions of Indonesia's energy system. Power plants using BECCS remove almost 20 million tonnes of carbon dioxide (Mt CO_2) in 2060.

Today, industry is the major user of modern solid bioenergy. It is used predominantly in light industries within the other industry branch, but also in cement production. Bioenergy use in industry steadily rises in the APS from 360 PJ in 2021 to 650 PJ in 2060, or 18% of total energy consumed by industry. Use of solid bioenergy remains concentrated in the other industry branch, but sees rapid demand increases in cement kilns, non-ferrous metal production and pulp and paper to provide medium- to high-temperature heating with minimal need to invest in new processes and technologies. Bioenergy accounts for almost one-quarter of energy demand in cement by 2060 in the APS. Around 95% of cement capacity is fitted with CCUS in 2060, providing 6 Mt CO_2 of CDR when used in conjunction with bioenergy.

Indonesia has significant potential to tap organic waste to produce *biogas*, e.g. municipal waste or waste water. Biogas can be directly combusted to provide dispatchable electricity generation. In the APS, biogas used for electricity generation rises from 7 PJ in 2021 to 55 PJ in 2030 before climbing to 230 PJ by 2060. In rural areas, direct use of biogas produced from small-scale bio-digestors and fuelled by resources like manure and crop residues increases in the APS. Biogas is used directly for cooking or other heat needs in homes and businesses. Direct use of biogas jumps to 5 PJ by 2030, providing a clean cooking solution for more than 400 000 rural households. By 2060, demand increases to 10 PJ.

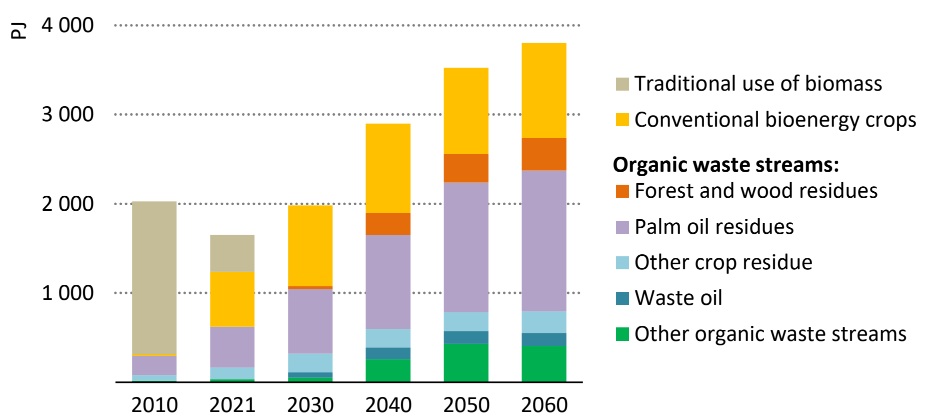
Biogas can also be upgraded to biomethane, which has the same molecular basis as natural gas. Biomethane demand in the APS increases twelve-fold to 20 PJ by 2030 and 125 PJ by 2050, plateauing at this level. Industry dominates demand for biomethane, with 115 PJ consumed via the gas grid in 2060 (3 billion cubic metres) contributing around 3% to industry energy demand. The remainder is used in the buildings sector, with urban gas networks almost completely decarbonised thanks to high shares of biomethane blending.

Sustainable bioenergy supply

The majority of Indonesia's bioenergy supply has come directly from its forests as fuel wood, or wood transformed into charcoal. With the phase down of traditional use of biomass in the last decade, sources of bioenergy shifted to bioenergy crops and organic waste streams, each representing close to 40% of bioenergy supply in 2021. Bioenergy crops are primarily used to produce biofuels, with palm oil representing virtually all biofuels production in Indonesia.

Use of conventional bioenergy crops, notably palm oil, grows by almost 50% to 900 PJ by 2030 in the APS, before stabilising at around 1 000 PJ after 2040, in order to not expand the land footprint of palm oil for energy. While direct use of bioenergy crops plateaus by 2060, the APS sees a rapid ramp up in the utilisation of organic waste to produce biofuels and biogas, and for use as a solid fuel (Figure 3.8). Organic waste streams and residues tapped in the APS include biogenic municipal waste, wastewater sludge, forestry and wood residues, waste oils and agricultural waste streams, including by-products of palm oil production. The prevalence of organic waste streams in Indonesia, the low opportunity cost when using them for energy purposes, and the ability to tap many of these streams without impacting sustainability outcomes elsewhere, means that waste streams in close geographic proximity to sources of demand are prioritised in the APS and supply over 70% of bioenergy by 2060.

Figure 3.8 ▷ Bioenergy supply by source in Indonesia in the Announced Pledges Scenario, 2010 – 2060



Bioenergy supply transitions from traditional forms to a variety of waste and residue resources, particularly from sustainable palm oil production

Notes: Bioenergy supply excludes supply that is then exported, but includes conversion losses associated with liquid biofuel production for export. Palm oil residues mostly consist of empty fruit bunches (EFB) in addition to fibres, shells and other woody residues. Other organic waste streams include the organic fraction of municipal solid waste, wastewater sludge and agricultural waste such as livestock manure. The share of specific waste streams in the total organic waste supply in the historical period are estimated.

Sources: IEA modelling and analysis based on ICCT (2021a).

Palm oil use for biofuel production increases by 50% in the period to 2030, but only rises a further 20% in the next 30 years to 2060 in the APS. This trajectory is driven by the need to achieve rapid emissions reductions from transport in the period before the use of waste streams for electricity generation and advanced biofuels reach sufficient scale. In order to guarantee that expanding use of palm oil does not negatively impact biodiversity, total GHG emissions and other sustainability indicators, the APS is consistent with no new land being converted to palm oil plantations for domestic biofuel use. Meeting the increased demand for palm oil-based biofuels to 2030 in the APS relies on increasing the yield from existing plantations, ensuring that this major industry can be a valuable pillar to achieve the net zero emissions target without compromising on wider sustainability goals (Box 3.2) (IRENA, 2017).

Box 3.2 ▹ Palm oil and biodiesel production

Palm oil is a major commodity for Indonesia; it accounts for one-fifth of global vegetable oil trade as well as conventional biodiesel production (Reuters, 2022) (IEA, 2021a). Palm oil production contributed 4.5% of Indonesia's GDP in 2019 and directly employed 2 million people (UNDP, 2019).

Indonesia is the world's largest palm oil producer with over 45 million tonnes (Mt) per year representing more than 50% of global supply. Almost two-thirds of its palm oil production is exported, mostly to India, China and Europe. Another 7.3 Mt are used domestically to produce fatty acid methyl esters biodiesel, while the remaining 8 Mt is used domestically for cooking oil and other food product (USDA FAS, 2021b).

Palm oil is one of the most land-efficient oilseed crops; producing on average around 3 tonnes of vegetable oil per hectare (ha), over six-times higher than the average for soybean oilseeds (Our World in Data, 2018). Palm oil trees can be harvested every few weeks year-round, further contributing to high productivity. The attractiveness of palm oil as a cash crop has fuelled a doubling of plantation land area over the past ten years to 12 million ha in 2021 (USDA FAS, 2012; USDA FAS, 2021b).

The rapid expansion of palm oil plantations has significantly impacted forests and biodiversity. The industry is under increasing local and international pressure to improve sustainability outcomes. The government has taken major steps in this direction. It has committed to protect its remaining natural forests: a permanent moratorium on developing forest lands and peatlands for other uses was established in 2019.[2] The government enacted mandatory certification for sustainable forest management and will soon require all plantations to be certified under the Indonesia Sustainable Palm Oil standard.

These measures underpin the need to increase production from existing plantations in order to deliver Indonesia's targets for palm oil production and forest protection. Today, productivity levels of plantations vary considerably reflecting the genetics of the oil

[2] Presidential instruction 5/2019.

palms, farming practices, fertiliser application and climate. Many plantations have significant potential to increase yields. Small land holders control about 40% of palm oil plantation areas in Indonesia, yet they produce only 30% of total palm oil (Ardana, Wulandar and Hartati, 2022). The government's Smallholders Oil Palm Plantation Replanting (PSR) scheme (2016), provides financial support to small land holders to replant fields with higher quality, higher yielding seedlings. The PSR aims to replant 180 000 ha per year; however, since 2016 this annual target has not been met (Coordinating Ministry for Economic Affairs, 2021). In the APS, expanding such programmes to increase productivity from existing plantations allows for increased palm oil to produce biodiesel without impinging on palm oil use for food products or requiring additional land area.

Waste from palm oil production offers longer term possibilities to expand its contribution to bioenergy supply while freeing up crude palm oil for domestic food use or for export. Empty fruit bunches (EFB), i.e. the bunches left over after palm oil seeds are removed, offer significant potential. A small portion of EFB is currently used as a secondary fertiliser, but the majority could be available to use in advanced biofuels via gasification routes. As EFB are residues of palm oil processing, they are already centralised at the processing facility, leading to relatively easy collection compared to residues left in fields. Other palm oil residues (e.g. fibre, shells) are already used to provide heat and electricity onsite at plantations, while palm fatty acid distillate is used to make soap and animal feed as well as biodiesel.

In addition to conventional crop-based biofuels, increasing bioenergy use in Indonesia and supplying more bioenergy crops for food will require scaling up biomass resources from waste and residues. Unlocking these advanced feedstocks will facilitate decarbonisation of some of the hardest to abate transport end-uses (heavy-duty trucking, shipping and aviation) and industrial sub-sectors (cement, iron and steel), while also providing a sustainable and locally available input into electricity generation.

Indonesia is home to a variety of waste and residue feedstocks that can have low impact on the environment when collected responsibly and little to no impact on land-use change. The APS assumes contributions from the following waste streams:

Palm oil residues, including empty fruit bunches (EFB), fibres, shells, palm oil mill effluent (POME), spent bleaching earth oil (SBEO) and palm fatty acid distillate (PFAD). EFB, fibres and shells are woody residues that either can be burned directly for heat and power or converted into advanced biofuels via gasification followed by Fischer-Tropsch synthesis. Additionally, POME contains both palm oil that can be siphoned off into sludge palm oil and used in fatty acid methyl esters (FAME) biodiesel as well as other organic material than can be anaerobically digested into biogas and upgraded to biomethane. PFAD and SBEO are waste oils that can also be converted into FAME biodiesel or hydro processed esters and fatty acid (HEFA) renewable diesel. In the APS, use of palm oil residues, mostly EFB, for bioenergy increases to 1 600 PJ by 2060, providing more than one-quarter of Indonesia's total bioenergy supply.

Agricultural residues come from maize, sugar cane, rice and livestock, such as rice husks and manure. Crop residues are dispersed within the field, requiring additional incentives and resources to collect them for use as bioenergy; their utilisation is low in the APS relative to centralised waste streams such as palm oil residues. Crop residues can either be gasified or converted to advanced liquid biofuels or, along with manure, converted into biogases via digestion. Agricultural residues, other than from palm oil, provide around 250 PJ of bioenergy supply by 2060 in the APS.

The organic fraction of *municipal solid waste* (MSW) includes food and yard scraps, waste water, and paper and cardboard. These can be anaerobically digested into biogas for direct use in heat, power and clean cooking or subsequently upgraded to biomethane and injected into gas networks. MSW provides over 260 PJ of bioenergy supply, mostly in the form of biogas, by 2060 in the APS.

Waste oils include used cooking oil, inedible animal fat, waste fish oils, tall oil (a by-product of pulp and paper production) and palm oil residues. These can be converted into FAME biodiesel or drop-in renewable diesel via the HEFA process. Waste oils provide around 150 PJ of bioenergy by 2060 in the APS.

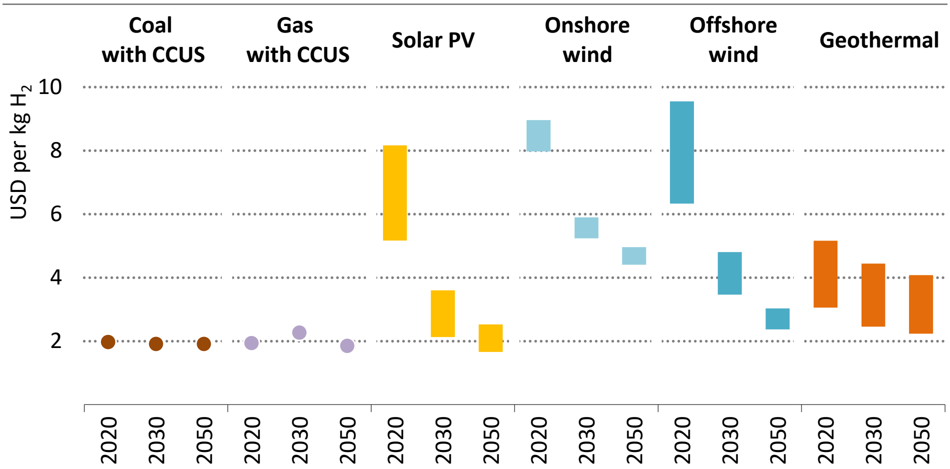
3.3.2 Hydrogen and hydrogen-based fuels

Hydrogen demand in Indonesia was around 1.75 million tonnes of hydrogen (Mt H_2) in 2021, almost completely for the chemical and refining sub-sectors and largely based on the unabated use of natural gas. Indonesia's significant renewable energy resources offer opportunities to produce low-carbon hydrogen via water electrolysis using renewables-based electricity. Thanks to the potential for CO_2 storage, producing hydrogen from natural gas or coal in combination with CCUS is another low emissions production option.

Current costs for low emissions hydrogen are higher than production from unabated fossil fuels (Figure 3.9). However the outlook for cost reductions for electrolysers, renewables-based electricity and CO_2 capture technologies can make low emissions hydrogen competitive. Hydrogen production costs from solar PV could fall to USD 1.7 per kilogramme hydrogen (kg H_2) by 2050 in regions with good solar conditions, such as in East Nusa Tenggara with an annual average capacity factor of 22%, and assuming that policies are put in place to lower the current high costs of solar PV (see Chapter 5, section 5.4). These cost levels are lower than the unabated production from natural gas at USD 2.6/kg H_2. Producing hydrogen from offshore wind locations with a capacity factor of over 40% results in costs below USD 2.5/kg H_2 in 2050.

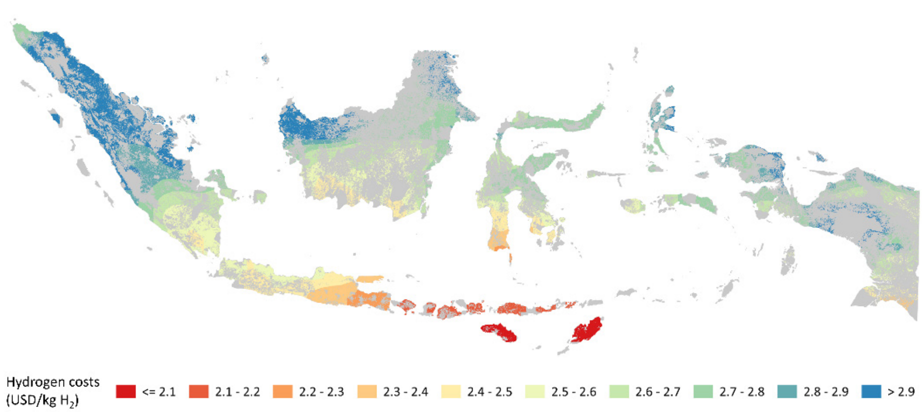
Using electricity produced from geothermal for hydrogen production would result in similar costs (USD 2.5/kg H_2 based on geothermal electricity costs of USD 45/MWh), while also providing a stable hydrogen supply on a daily and annual basis. Further synthesis steps such as the production of ammonia can benefit from such a stable hydrogen supply, which reduces the need for hydrogen storage compared to when production is based on variable renewables generation. Hydrogen from coal in combination with CCUS also allows for stable hydrogen production at projected costs of USD 1.9/kg H_2 by 2050 (based on a coal price of around USD 40/tonne in the APS by 2050). Natural gas with CCUS is another option, but with declining domestic gas production would have to rely on imports after 2030, making this route less attractive under energy security and domestic value chain considerations.

Figure 3.9 ▷ Hydrogen production costs in Indonesia in the Announced Pledges Scenario



Hydrogen production costs from solar PV could fall substantially to USD below USD 2/kg H_2 by 2050 in regions with good solar conditions

Figure 3.10 ▷ Hydrogen production costs from hybrid solar PV and wind systems in Indonesia in the Announced Pledges Scenario, 2030

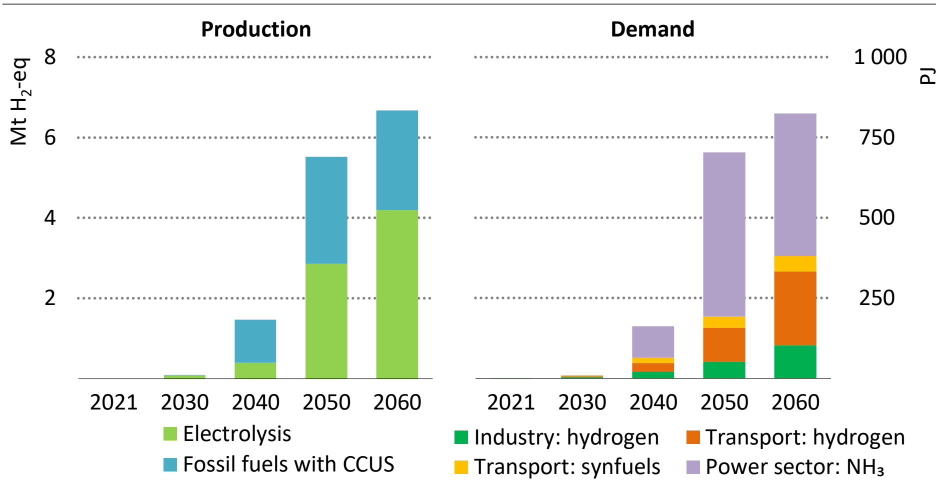


Some regions – Nusa Tengara in particular – could see renewables-based hydrogen production costs at around USD 2/kg H_2 in 2030

Hydrogen production costs are higher in Indonesia compared to other parts of the world with better renewable resources, such as Australia or the Middle East. However, shipping hydrogen from these regions to Indonesia results in additional costs of USD 1-2/kg H_2, making most hydrogen imports less attractive than domestic production.

Several projects or co-operation agreements to produce low emissions hydrogen have recently been announced in Indonesia. For example, Pertamina, a state-owned oil and gas corporation, plans to build a pilot plant to produce hydrogen using geothermal electricity at its Ulubelu site. Samsung and Hyundai announced a collaboration with the Global Green Growth Institute on a USD 1.2 billion project to produce green hydrogen from geothermal electricity in North Sumatra. A consortium, involving PT Panca Amara Utama, a chemical company, Mitsubishi and the Institut Teknologi Bandung announced plans to produce ammonia (660 kilotonnes of ammonia [kt NH_3] per year) in combination with CCUS in Central Sulawesi. Fortescue Future Industries, an Australian company, in co-operation with the provincial government of North Kalimantan, is conducting feasibility studies for a 3.7 Mt NH_3/year ammonia production plant using renewables-based electricity.

Figure 3.11 ▷ Low emissions hydrogen production and demand in Indonesia in the Announced Pledges Scenario, 2021 – 2060



Low emissions hydrogen is mostly produced from renewables-based electricity, and is mainly transformed into ammonia for co-firing in coal-fired power plants

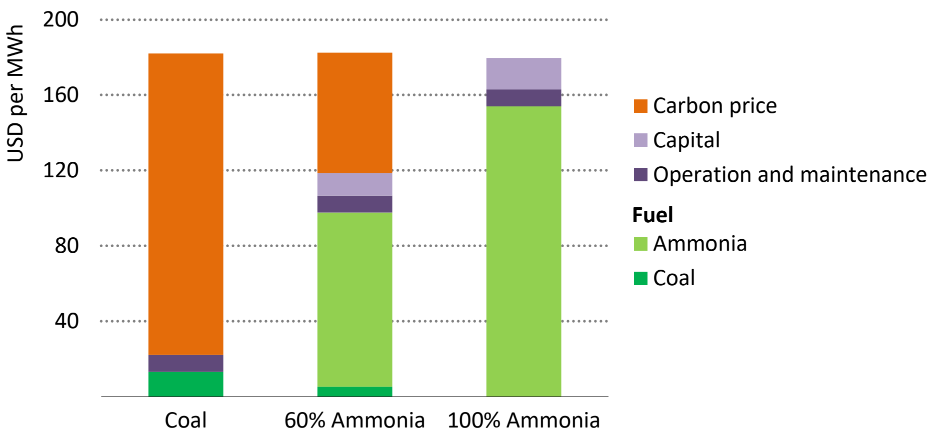
Notes: Mt H_2-eq = million tonnes of hydrogen equivalent. 1 Mt H_2-eq has an energy content of 120 PJ, based on the lower heating value of hydrogen. NH_3 = ammonia. Transport - Synfuels = synthetic oil or synthetic methane used in transport.

Hydrogen can be an option to decarbonise parts of the energy system where other mitigation approaches such as direct electrification are technically more difficult or more costly. Total demand for hydrogen and hydrogen-based fuels reaches almost 7 Mt by 2060 in the APS, covering just under 4% of the final energy demand in Indonesia (Figure 3.11). But, hydrogen and hydrogen-based fuels play an important role in long-distance transport and heavy industry. By 2060 in the APS, ammonia and hydrogen cover half of domestic shipping fuel demand and hydrogen accounts for 7% of road transport, in particular for trucks.

Co-firing of ammonia can reduce CO_2 emissions from existing coal power plants in the near term. In the longer term, plants converted to operating completely on hydrogen could provide flexibility to the electricity system. In the APS, ammonia and hydrogen account for around 4% of electricity generation in Indonesia by 2060. However, the economics of this option will strongly depend on the electricity system needs for long duration energy storage.

An ammonia cost of USD 350/t NH_3 (domestically produced from hydrogen at USD 1.8/kg H_2 using solar electricity) and a CO_2 price of at least USD 170/t CO_2 would be needed to make co-firing or 100% ammonia-firing competitive with generation from unabated coal at electricity costs of USD 180/MWh (Figure 3.12). However, given that ammonia plants are used infrequently at the times of highest value to the electricity system, they nonetheless can provide options for delivering flexibility to the power system based on existing generation assets.[3]

Figure 3.12 ▻ Levelised cost of electricity for an existing coal plant with co-firing of ammonia in Indonesia in the Announced Pledges Scenario, 2050



Economic viability of ammonia co-firing at an existing coal plant strongly depends on the costs of low emissions ammonia and the CO_2 price

Notes: Carbon price = USD 170/t CO_2 .Capital = plant retrofits. Ammonia costs = USD 350/t. Existing coal plant capacity factor = 15%.

[3] These aspects are discussed in more detail in The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector (IEA, 2021b).

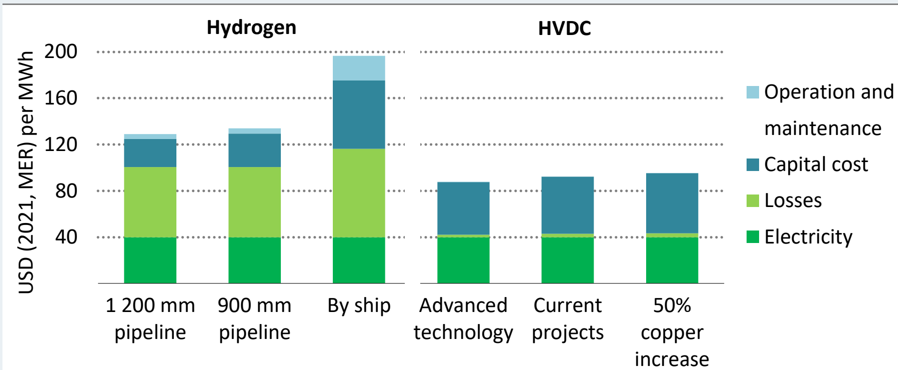
Low emissions hydrogen demand in Indonesia reaches almost 7 Mt H_2 and more than 60% is produced in electrolysers using renewables-based electricity in the APS in 2060. Hydrogen production from fossil fuels with CCUS (mainly coal) supply almost 40% of demand. Electrolyser capacity reaches 50 GW by 2060 and requires around 225 TWh of renewables-based electricity, or 14% of total electricity generation in 2060. The production of hydrogen and ammonia in combination with CCUS results in over 30 Mt CO_2 being captured and stored annually in 2060 in the APS.

Box 3.3 ▷ Economics of HVDC electricity transmission versus hydrogen as an energy carrier

In Indonesia, the areas rich in renewable energy resources are not co-located with centres of energy demand. This spatial mismatch raises the need to transfer energy among its many islands.

The relative economics of directly transferring electricity via an inter-regional high-voltage direct current (HVDC) transmission network relative to using electrolytic hydrogen as an energy carrier by transporting it via pipeline or ship and converting it to electricity are considered here. Both cases assume electricity generated from solar PV with a levelised cost of USD 40/MWh. For hydrogen, conversion losses are far higher, as the electricity must be converted to hydrogen and hydrogen converted back to electricity, with a round trip efficiency of around 40%. By contrast, losses on a long-distance HVDC line are less than 10%, i.e. a round trip efficiency of over 90%. For a HVDC transmission line, the capital costs are higher per MWh of delivered energy.

Figure 3.13 ▷ Levelised costs of electricity for a 600 km transfer project in Indonesia: HVDC versus hydrogen as an energy carrier



Energy transfer between Indonesia's regions with high renewables and its load centres is more cost effective by HVDC link than by hydrogen as an energy carrier

Notes: HVDC = high-voltage direct current; MER = market exchange rate. Advanced technology mainly includes a higher transmission voltage, leading to lower material needs for the conductor and lower system losses.

The analysis shows that the total levelised cost of electricity of the HVDC transmission line option is substantially lower than using hydrogen as an energy carrier, largely because of its much better round trip efficiency, even taking sensitivities into account (Figure 3.13). Accordingly, hydrogen in the APS is either transported and used directly in end-use sectors in the form of hydrogen or ammonia, or is used to generate electricity in the area where the hydrogen is produced. The resource constraints of a regional, high renewable power system are solved predominantly with HVDC transmissions links.

3.4 Industry

Today the industry sector accounts for more than 40% of final energy consumption in Indonesia, and more than half of CO_2 emissions from the three main end-use sectors – industry, transport and buildings. Since the turn of the millennium, industrial energy consumption has increased by 85% and is mostly supplied by fossil fuels. Coal leads at 33% in the industry sector energy mix with natural gas at 25%, bioenergy at 14% and electricity at 14% in 2021.

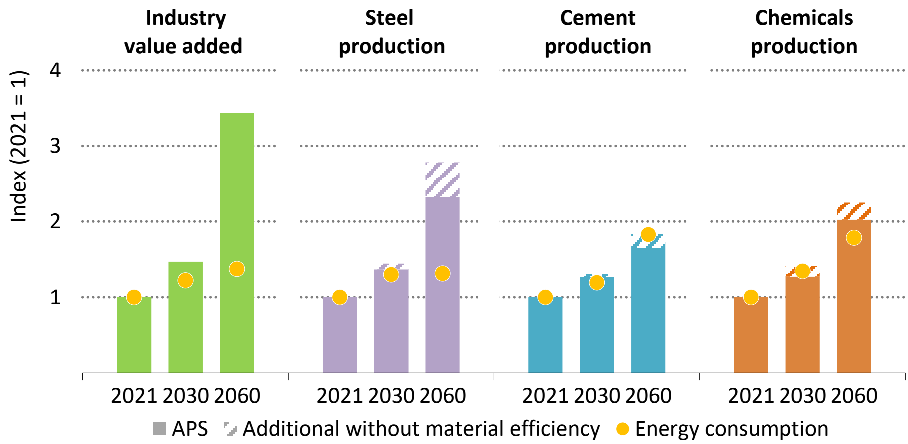
The other industry category includes industrial branches such as manufacturing, food processing, construction and textiles. The other industry category accounts for more than 40% of industrial energy demand in Indonesia, compared to a global average of 29% in 2021. Industries in this category tend to have energy processes and equipment that are easier to decarbonise with existing technologies than do heavy industries such as steel, cement and chemicals. Output from Indonesia's heavy industries is projected to increase substantially in the coming years, so the transition to net zero emissions will require deploying clean energy technologies and practices in the heavy industries too. Current coal consumption in industry is mostly in the heavy industry subsectors of cement and steel production.

3.4.1 Activity drivers

Indonesia is a major global industrial producer; it is the second-largest producer of stainless steel and among the top-twenty producers of crude steel. It is also a major producer of ammonia, which is used as fertiliser and for other industrial applications, e.g. plastics, explosives and fibres. With rising incomes and a growing population increasingly moving to urban centres, industrial output is projected to continue to increase rapidly. Indonesia's Master Plan of National Industry Development (RIPIN) sets very ambitious targets for industrial deployment up to 2035, in particular in the chemicals sub-sector.

Value added by industry is almost 50% higher in 2030 than today and more than triple the current level by 2060 in the APS (Figure 3.14). Driven by a dynamic automotive industry and increasing demand in the construction sector, steel output doubles before 2050 and reaches almost 30 Mt in 2060 in the APS. Ammonia production increases by a quarter by 2030 and almost doubles by 2060. Similarly, cement production rises steadily and surpasses 100 Mt in 2060.

Figure 3.14 ▷ Industrial output and total final consumption by sub-sector in Indonesia in the Announced Pledges Scenario



Despite rapid growth of industrial output, materials and energy efficiency curb industry energy demand

Note: APS = Announced Pledges Scenario; STEPS = Stated Policies Scenario.

3.4.2 Energy efficiency and avoided demand

Despite strong growth in the output of industrial products, they do not rise as fast as value added. This decoupling is enabled by two factors. First, as Indonesia develops and moves up industrial value chains, the value added of its industrial output increases faster than the physical output. Second, in the APS there are concerted efforts to adopt policies and practices that promote the efficient use of materials. This enables a lower material output in the APS than in the Stated Policies Scenario (STEPS), even while the industrial sector caters to the same level of GDP and welfare in the two scenarios. In the APS, the output of steel is close to 20% lower than in the STEPS in 2060, ammonia output is 5% lower and cement output is 10% lower. Material efficiency is particularly important in the industry sector because heavy industries are already highly incentivised to be energy efficient – due to the significance of energy in production costs – and low emissions technologies are less mature in these sectors.

These reductions are achieved through measures such as light weighting, life extension and improved design practices, e.g. modular construction, in downstream applications such as buildings, vehicles and infrastructure. Increased collection for recycling and re-use of steel, aluminium and plastic reduces the need for more energy-intensive primary production, having knock-on benefits for energy efficiency and the potential for electrification.

Industrial energy demand does not rise as quickly as the increase in industrial material production, due to increases in energy efficiency and switching to less energy-intensive process routes. Total industry sector energy use rises from 2 700 PJ today to 3 300 PJ in 2030 and 3 600 PJ in 2060 in the APS, only 40% higher than 2021 levels.

In the APS, financial barriers are removed so Indonesia can build and replace its industrial facilities with the best available technologies, which leads to incremental reductions in energy intensity for key heavy industry facilities. Conversely, the use of certain technologies – notably CCUS – increases the energy intensity of production while reducing emissions. This partly offsets the gains in efficiency achieved from the adoption of best available technologies. Nonetheless, industry sector energy intensity[4] decreases by an average of 2% annually to 2030 – similar to the rapid decline between 2010 and 2021 – and continues to decline at an average of 2% from 2030 to 2060. By 2060, the energy intensity of industrial value added in the APS is 20% lower than the in the STEPS.

In the other industry category, increased energy efficiency plays an important role in decarbonisation. Some efficiency gains are inherent to the technology shifts that are undertaken in the APS, such as the provision of heat via heat pumps, which can be three- to four-times more efficient than fossil fuel sources of heat for industrial applications. The use of highly efficient electric motors[5] also leads to reductions in electricity consumption in industry, which does not lead directly to emissions savings, but increases efficiency and reduces the burden placed on the electricity sector. Incremental improvements in the efficiency of conventional heating technologies, achieved via equipment upgrades and increased levels of process integration also contribute modest gains to efficiency levels, despite a shift away from the use of these technologies over time in the APS.

3.4.3 Electrification and low emissions fuel switching

Indonesia's industry sector realises a transformation away from unabated fossil fuels and towards electricity and renewables in the APS. This concerns all industrial sectors – such as the production of steel, cement, fertilisers and textiles – and requires a significant uptake of clean energy technologies such as heat pumps, CCUS, electrolysis, pyrolysis and ethanol dehydrogenation units. Further electrification enables higher demand-side responses that enhance the reliability of the electricity system.

The other industry category moves first to low-carbon fuels. In 2030, electricity in other industry accounts for almost 30% of energy demand in the APS compared to less than a quarter today. This is mainly driven by further deployment of electrical equipment to provide heat in the textile and food processing industries as well as ramping up of heat pumps for some low-temperature uses (Figure 3.15).

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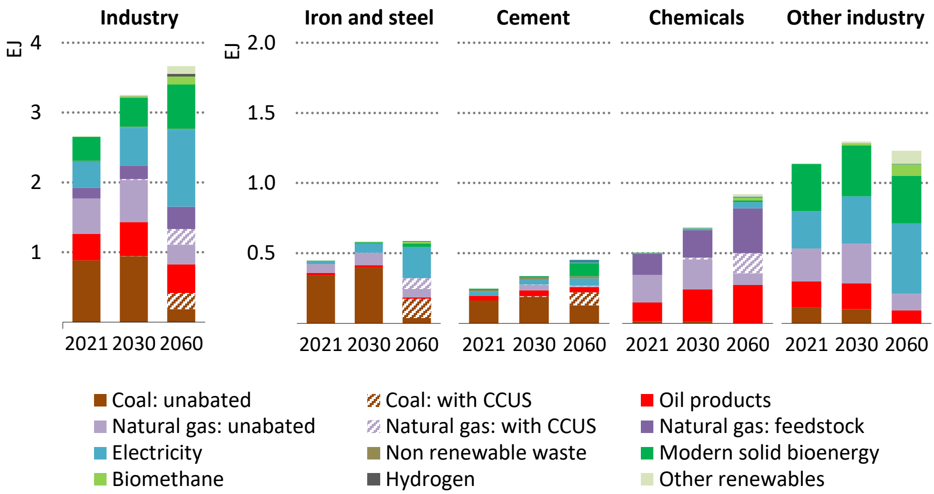
[4] Expressed as the ratio of final energy consumption in industry and the value added by industry in power purchasing parity terms.

[5] Motors with efficiency classes of IE2 and above.

Figure 3.15 ▷ Energy use by fuel and sub-sector in Indonesia in the Announced Pledges Scenario, 2021 – 2060



Electrification, renewables and CCUS are key to reduce CO_2 emissions from industry: more than 85% of industry energy use is non-emitting by 2060

Notes: EJ = exajoules. Industry includes iron and steel, chemicals, non-metallic minerals (which includes the cement sub-sector), non-ferrous metals, paper and other industry. Other industry branches include construction, food processing, machinery, mining, textiles, transport equipment, wood processing and industries otherwise not categorised. Other industry does not include non-ferrous metals and pulp and paper.

Energy-intensive sub-sectors also quickly electrify low-temperature heat demand, with the share of electricity increasing from 6% today to 20% by 2060.[6] But with most of their thermal needs being above 200 degrees Celsius (°C) – for which electricity-based technologies are expensive or not available today – bioenergy gains ground in the short term, alongside hydrogen in the longer term.

Indonesia's current stock of heavy industry assets is at the younger end of the age spectrum in global comparisons. Around half the country's total installed capacity for crude steel production has been added over the past ten years and the majority is emissions-intensive blast furnace-basic oxygen furnace capacity. A gigantic plant, more than twice the size of any existing installation in Indonesia, has been proposed by Shaanxi Iron and Steel, a Chinese state-owned company. There are around 30 major cement plants in Indonesia, with a combined clinker production capacity of around 80 Mt. As with its steel plants, these assets are young, with around two-thirds of steel plants being less than 20 years old, relative to a typical average lifetime of around 40 years.

[6] Energy-intensive sub-sectors include iron and steel, chemicals, non-metallic minerals, non-ferrous metals, and paper, pulp and printing industries.

Coal represents the lion's share of fuels used for *steel production* today, almost three-quarters, but its contribution decreases steadily, to reach two-thirds by 2030 and less than a third in 2060 in the APS. This ongoing shift from coal is the result of energy efficiency improvements of the fleet – with improvements in existing plants and new construction of plants with efficiency on par with the best available technologies – and electrification of downstream processes and auxiliary services. In the longer term, innovative technologies for primary steel production, such as CCUS-equipped blast furnaces, natural gas-based direct reduced iron electric arc furnaces with CCUS, hydrogen-based direct reduced iron and secondary production continue to increase.

In *cement manufacturing*, which needs to reduce almost 30 Mt of process-related CO_2 emissions from the clinker production process, the preferred option in the APS is to equip dry kilns with CCUS technologies. The share of unabated coal in cement manufacturing is stable in the period to 2030, but with decreases of CCUS costs and industrial-scale deployment globally, CCUS-equipped kilns are deployed afterwards. Innovative processes such as electric kilns able to capture process emissions make inroads in the 2040s, albeit in relatively small amounts.

Energy use for the production of *chemicals* is less carbon-intensive than for iron and steel or cement, as 55% of fuel use serves as feedstock today. But the sub-sector also requires important technology shifts to curb CO_2 emissions from fossil fuels and production processes. Ammonia production plants are progressively equipped with CCUS technologies, able to capture both combustion and process emissions: around two-thirds of plant capacity captures CO_2 in 2060. Ethylene production from bioethanol also makes inroads, displacing oil use.

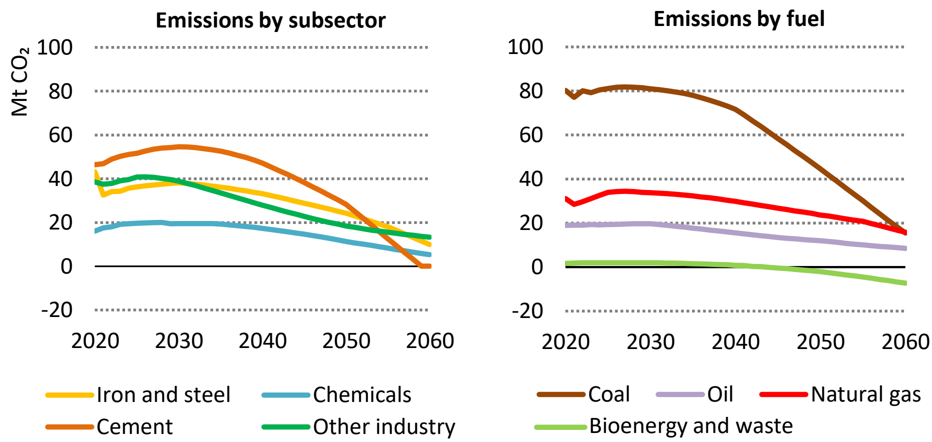
3.4.4 CO_2 emissions trends

In the APS, total industry CO_2 emissions peak around 2030, and then start to decline (Figure 3.16). Reductions are led by the other industry branches, such as manufacturing and food processing, where energy efficiency and clean energy technologies can be rolled out earlier than in the heavy industries. When comparing the APS with the STEPS, industry contributes almost 40% of the total emissions reductions achieved by 2030.

CO_2 emissions from the heavy industry sub-sectors peak and plateau around 2030. In these industries, energy efficiency is already widely pursued because of the weight of energy in production costs. In addition, low emissions technologies for heavy industries are less mature and take time to be commercialised and widely deployed.

By 2060 in the APS, the industry sector as a whole achieves emissions reductions of 75% from today's level even while more than tripling the sector's value added. Yet, the industry sector accounts for 40 Mt of residual emissions in 2060 largely from the iron and steel, cement and chemicals sub-sectors.

Figure 3.16 ▷ Total CO_2 emissions from industry in Indonesia in the Announced Pledges Scenario, 2020 – 2060



CO_2 emissions from the industry sector peak around 2030, led by the numerous other industry branches, while heavy industries take longer to peak

Note: Other industry branches include construction, food processing, machinery, mining, textiles, transport equipment and wood processing and industries otherwise not categorised. Other industry does not include non-ferrous metals and pulp and paper.

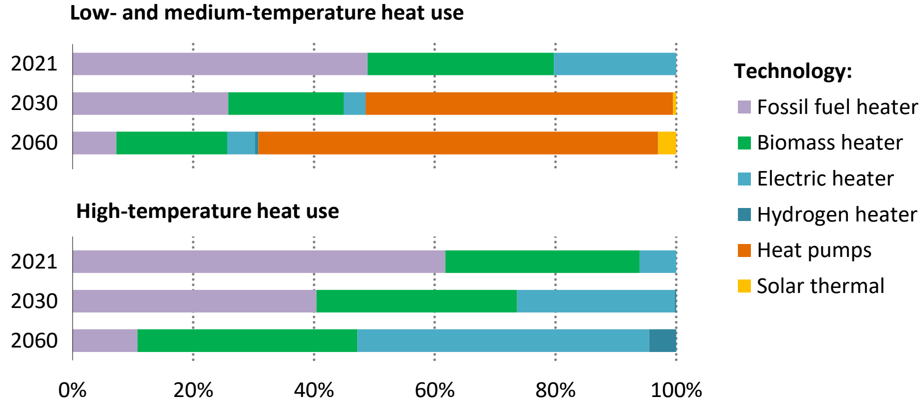
3.4.5 Technology performance and costs

Emissions from the *other industries* category account for around one-quarter of total industry emissions. These sub-sectors see CO_2 emissions fall by more than 60% by 2060 in the APS, with electrification and other fuel switching being the main vectors for decarbonisation. In contrast to the heavy industries, low-carbon technologies to provide heat in other industry branches are readily available. Their uptake is slowed by technology costs, financing hurdles and insufficient incentives for adoption.

Energy use in other industries can be broadly divided along two main lines of energy services: mechanical work (provided by electric motors) and heat (largely provided by burning fossil fuels). While switching to more efficient electric motors can reduce the burden placed on a rapidly decarbonising electricity sector, direct CO_2 emissions reductions are achieved mainly by replacing the use of fossil fuels to provide heat.

Today more than half of heat demand in other industries is met with fossil fuels, while heat supplied from biomass and electricity make up the balance (Figure 3.17). It is estimated that 45% of heat needs are for low-temperature demand (at or below 100 °C), 50% for medium-temperature needs (100-400 °C) and the remainder for high-temperature demand (above 400 °C). These shares remain relatively stable in the APS even as production in other industries expands rapidly. However, the way heat is generated undergoes a profound shift in the APS, moving away from natural gas and coal boilers to low emissions heating technologies.

Figure 3.17 ▷ Share of heat demand by technology and temperature level in other industry branch in Indonesia in the Announced Pledges Scenario

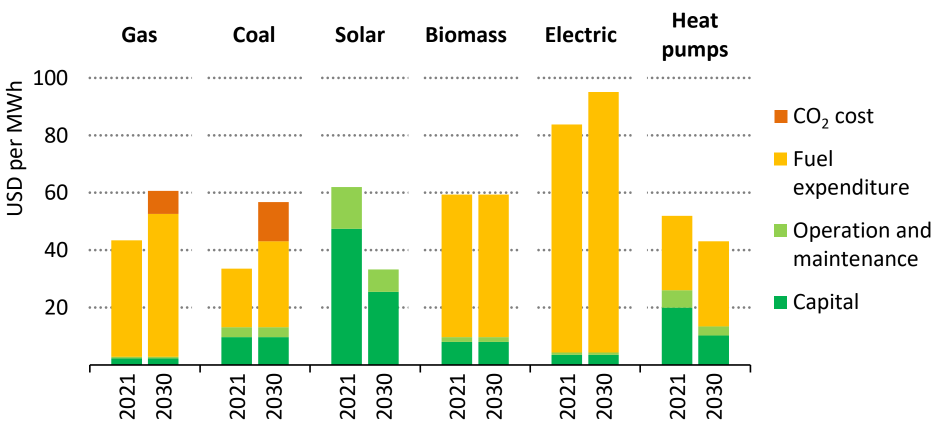


Low-temperature heat demand is rapidly electrified and surplus bioenergy shifts to serve medium- and high-temperature heat demand

Low emissions technologies to supply heat are deployed rapidly in the APS and by 2030 they meet more than 70% of all heat demand. By 2060, these shares are over 90%. Heat pumps are a particularly efficient way of decarbonising low-temperature heat; output temperatures of around 150 °C have been demonstrated at commercial scale. To serve higher temperature needs, technologies such as direct electric resistance heating and electric boilers are deployed, though they have a lower efficiency profile. Electro-magnetic technologies to provide heat can achieve very high temperatures, but have not yet been demonstrated at commercial scale for large industrial applications.

Coal-fired boilers and furnaces are among the cheapest options to serve demand for heat in other industries today in Indonesia given the advantage of cheap domestic coal supply (Figure 3.18). In the APS, the cost of heat supplied by coal rises by a factor of 1.7 and natural gas by 40% relative to 2021 levels, in part due to the imposition of a progressively increasing CO_2 tax (USD 40/tonne in 2030). Solar thermal technologies and industrial heat pumps are projected to undergo the most substantial cost declines over the coming decade, reflecting improvements in technology performance and economies of scale as deployment ramps up. Biomass and electric boilers and furnaces are mature technologies, so their capital costs do not decline as much. Hydrogen generated onsite with an electrolyser, or consumed as a blended component of network gas, plays a marginal role in decarbonising medium- and high- temperature heat in the APS.

Figure 3.18 ▷ Levelised costs of key technologies to provide heat for other industries in Indonesia in the Announced Pledges Scenario, 2021 and 2030

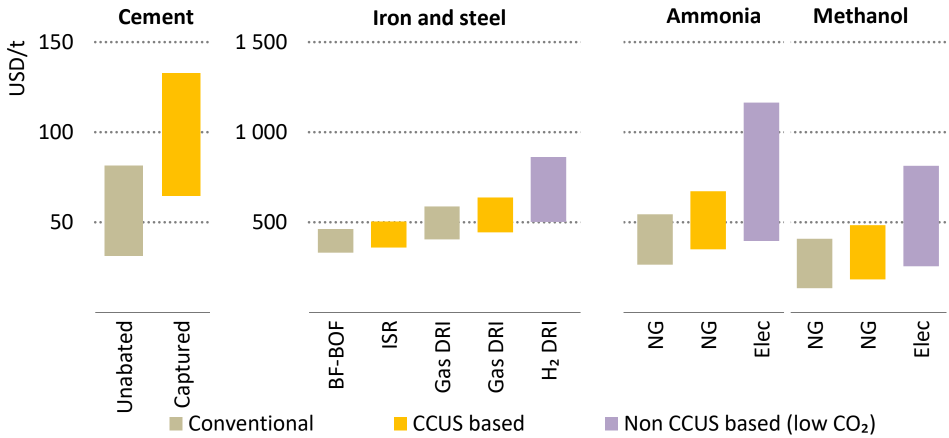


Low-carbon options to provide heat such as heat pumps and solar thermal become the most economic option by 2030 as their costs decline while fuel and CO_2 prices rise

In *heavy industry*, the cost gap between conventional and innovative low emissions technologies is more difficult to close before 2030 than in other industries. However, after 2030 the accelerating deployment of emerging low-carbon technologies for heavy industry significantly improves the economics of decarbonising energy use in heavy industry. Bringing these technologies to market commercialisation is a global effort, with advanced economies and leading industrial players such as China, already taking steps to deploy innovative technologies such as hydrogen-based direct reduced iron with electric arc furnaces, or blast furnaces with CCUS.

Figure 3.19 highlights the range of costs for key heavy industry sub-sectors when they reach commercialisation. This analysis does not include any CO_2 costs imposed by regulation, such as from a CO_2 tax or an emissions trading system, nonetheless, key low-carbon production routes already achieve cost competitiveness with conventional processes in certain markets. In Indonesia, the imposition of the CO_2 price in the APS would allow low-carbon technologies in cement, steel and chemicals production to achieve cost competitiveness leading up to 2060. In addition to CO_2 pricing, the decarbonisation of heavy industry in Indonesia will require collaboration with industrial sector stakeholders and other governments to allow Indonesia to seize the opportunities from global progress in low-carbon industrial technologies.

Figure 3.19 ⊳ **Global levelised costs of materials production in heavy industry by route at commercialisation**



In a number of heavy industry sub-sectors, processes equipped with CCUS are the most cost-effective options compared with other low emissions processes

Notes: BF-BOF = blast furnace-basic oxygen furnace; ISR = innovative smelting reduction; Gas DRI = natural gas-based direct reduced iron/electric arc furnace route; H_2 DRI = 100% electrolytic hydrogen-based; NG = natural gas; Elec = electrolytic. Costs are shown as a range across all global markets. The costs do not include CO_2 prices or taxes. Costs are shown for the year the technology reaches commercialisation, or for current costs if the technology is already commercial.

Source: IEA (2020).

3.5 Transport

Indonesia's transport sector accounts for one-third of final energy consumption and around 40% of CO_2 emissions from final energy consumption. Energy consumption for transport has surged by 70% over since 2010 to around 2 150 PJ. Oil supplied 100% of this demand in 2010, but its share shrank to below 90% in 2021 as biofuel blending increased. Close to 90% of CO_2 emissions (120 Mt CO_2) in the transport sector, as well as 90% of oil demand, are from road transport. The 11 million cars on Indonesian roads today account for slightly more than 35 Mt CO_2 emissions, while trucks emit over 50 Mt CO_2. Shipping and aviation each account for about 5% of total transport sector energy demand and emit a combined total of almost 15 Mt CO_2.

3.5.1 Activity drivers

A more than 50% increase in economic output over the last decade drove large increases in demand for transport services, notably for road transport. Passenger road transport activity, measured in passenger-kilometres (pkm), increased by almost 50% over the decade. Freight activity measured in tonne-kilometres (tkm) increased 70%. In the APS, total road passenger transport pkm increases nearly 75% on 2021 levels by 2030, and triples by 2060. By 2060, the average Indonesian travels 14 000 km domestically per year, up from 5 500 km in 2021. Increasing economic output goes hand-in-hand with rising transport needs for industrial, commercial and agricultural goods; freight transport increases by around 50% by 2030 and more than triples by 2060.

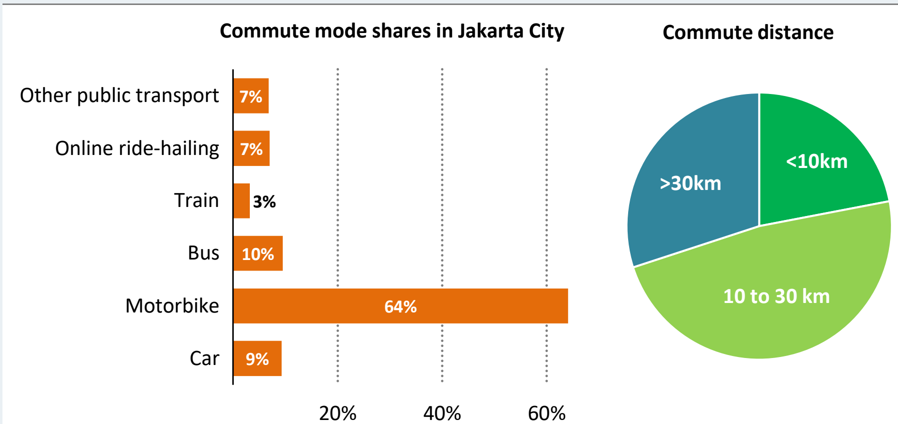
Motorbikes are the main transport mode for Indonesians today. At 325 motorbikes per 1 000 inhabitants, the ownership rate is well above the 160 motorbikes per 1 000 inhabitants in India, and more than triple the global average of 93 per 1 000 people (Box 3.4). Car ownership in Indonesia is about 40 cars per 1 000 inhabitants – a quarter the global average.

Box 3.4 ▷ Commuting in urban Jakarta

In the megacity of Jakarta, motorbikes are by far the most common mode of transport for commuting, accounting for 64% of daily trips (Figure 3.20) (Sofiyandi and Siregar, 2020). More than two-thirds of daily commutes are for distances of less than 30 km and 22% are under 10 km (BPS, 2015).

The prevalence of motorbikes and relatively short daily travel distances offer an attractive opportunity for Indonesia's largest city to shift to electromobility. The average home-to-work commuting distance of under 20 km can be easily served with battery-powered two/three-wheelers available in markets today (Sofiyandi and Siregar, 2020). Electrifying Jakarta's motorbike fleet could be achieved at limited additional cost and would benefit residents with improved air quality. Electric motorbikes are much more energy efficient than those that burn gasoline and so would help to reduce CO_2 emissions in the near term even with Indonesia's coal-intensive electricity system. Maximising the mitigation benefits of electromobility requires decarbonising electricity generation.

Figure 3.20 ▷ Commuting by mode and distance in Jakarta

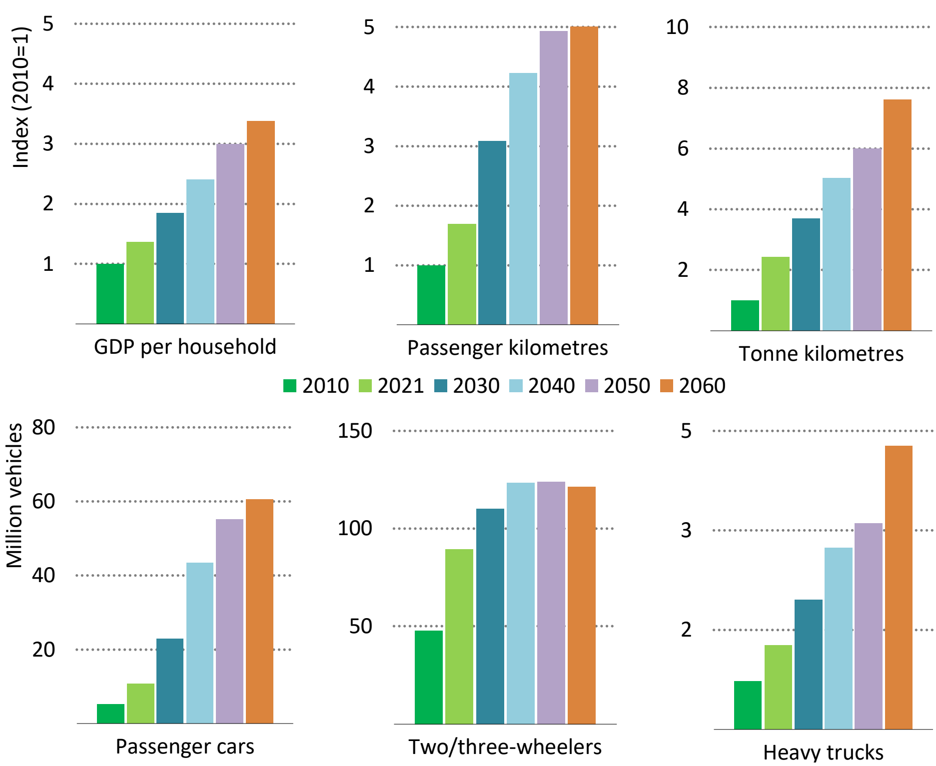


Motorbikes dominate commuter trips in Jakarta with typical distances that could easily be met by today's electric two/three-wheelers

Sources: IEA analysis based on data from Sofiyandi and Siregar (2020) and BPS (2015).

In the APS, income growth spurs the preference for and accessibility of car ownership over motorbikes, in line with trends observed in many emerging economies. Ownership of motorbikes and other two/three-wheeler vehicles increases by almost 15% by 2030, but peaks just before 2040 and then begins to decline. By 2060, the total two/three-wheeler stock is only around 35% larger than today. On the other hand, car ownership jumps to over 75 vehicles per 1 000 people in 2030 and 180 cars per 1 000 inhabitants in 2060, multiplying the total stock of passenger cars more than fivefold (Figure 3.21).

Figure 3.21 ▷ Evolution of key activity metrics for selected road transport modes in Indonesia in the Announced Pledges Scenario, 2010 – 2060



Income growth drives significant changes in the structure and scale of transport demand, with a more than fivefold increase in the number of cars by 2060

Freight transport needs rise as Indonesia's economic output expands and markets integrate further across provinces and internationally. Use of heavy trucks triples by 2060 compared to the current level, with activity concentrated in the existing economic centres of Java and Sumatra, but also increasing markedly in Kalimantan as the region develops rapidly, spurred by the move of the national capital to East Kalimantan. Growth of the road freight transport fleet and average distances travelled nonetheless are constrained by Indonesia's archipelago geography, with shipping and port infrastructure playing a major in the integration of markets across Indonesia and internationally.

Average distance travelled for passenger cars increases 10% by the end of this decade and almost 15% for two/three-wheelers in the APS. This increase in mileage reflects increases in wealth and urban expansion. As income levels rise people purchase newer vehicles that are driven more compared to older ones. However, in the APS, total pkm are nearly 15% lower by 2060 than in the STEPS due to a modal shift to public transport.

Consistent with Indonesia's position as an emerging economy, the APS does not assume substantial policies to reduce flying. *Aviation* activity levels are similar in both the STEPS and APS. Additionally, in line with Indonesia's expected economic growth, freight tkm activity increases one-and-a-half-times by 2030 and more than triples by 2060 in both scenarios.

Almost 40 million passengers took domestic flights in Indonesia in 2021. Increasing connectivity of Indonesia's islands and rising average incomes drive a quadrupling of total aviation activity to 230 billion pkm by 2030, increasing to more than 450 billion pkm by 2060 in the APS, nine-times today's level of 50 billion pkm.

Shipping accounts for around 90% of Indonesia's internationally traded goods, with around 700 Mt of cargo volume in 2021. Despite being an archipelago, growth in domestic shipping activity has been relatively low. Prioritising sea over land transport could reduce transportation energy demand and yield economic benefits.

3.5.2 Energy efficiency and avoided demand

Total final energy consumption in the transport sector rises by around 55% in the period to 2030 in the APS, yet it falls below the 2030 level by 2060 thanks to energy efficiency improvements and electrification. Energy demand for passenger road transport in the APS rises at a similar rate to the increase in distances travelled by road passengers to 2030, with the impact of the shift to cars from more fuel-efficient motorbikes offset by efficiency improvements and electrification in both cars and motorbikes. For freight, energy demand increases at a 50% slower pace than the rate of increase in in the metric of tkm, thanks to efficiency improvements in trucks. Decoupling of transport activity and energy consumption is driven by substantial improvements in energy efficiency in transport modes, and by the efficiency benefits of electrification. As noted in Chapter 2, Indonesia has large potential for energy efficiency improvements across the transport sector, given the current lack of fuel economy standards and relatively poor average fuel economy values for passenger and freight vehicles.

With average passenger light-duty vehicle (LDV) fuel economy of 8.8 litres of gasoline equivalent (Lge) per 100 km, Indonesia's passenger car fleet is considerably less efficient than in India (6.5 Lge/100 km). In the APS, Indonesia implements fuel economy standards before

2030 for sales of new cars and trucks. This puts the average fuel economy at 5.9 L/100 km for new internal combustion engine (ICE) cars sold in 2030, compared to 6.6 L/100 km in the STEPS. Fuel economy standards are put in place for trucks in the APS and are critical given the slower pace of electrification of heavy vehicles. By 2030, the average fuel economy of heavy trucks in Indonesia is 29 L/100 km in the APS, compared to 35 L/100 km in 2021 (Figure 3.22). After 2030, the technical opportunities for further gains in fuel economy for heavy trucks are increasingly limited, yet the impact of standards enacted in proceeding years continues to transform the stock over the following two decades. The biggest long-term impact on fleet wide fuel economy is from electrification, as EVs are around three-times more efficient than ICE vehicles (Figure 3.22).

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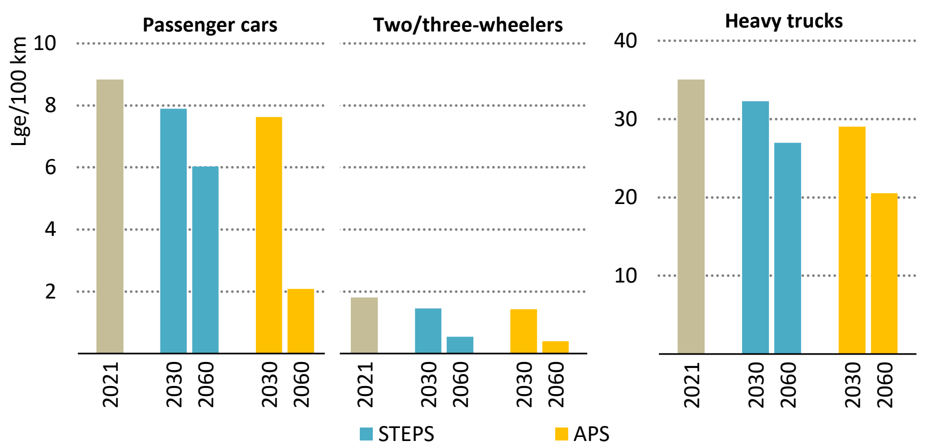
Figure 3.22 ▷ Evolution of fleet fuel economy in selected road transport modes in Indonesia in the Stated Policies and Announced Pledges scenarios, 2030 and 2060



Fuel economy standards in the APS increases the efficiency of ICE vehicles, while electrification of cars and motorbikes delivers a step change in efficiency

Note: Lge = litres of gasoline equivalent; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

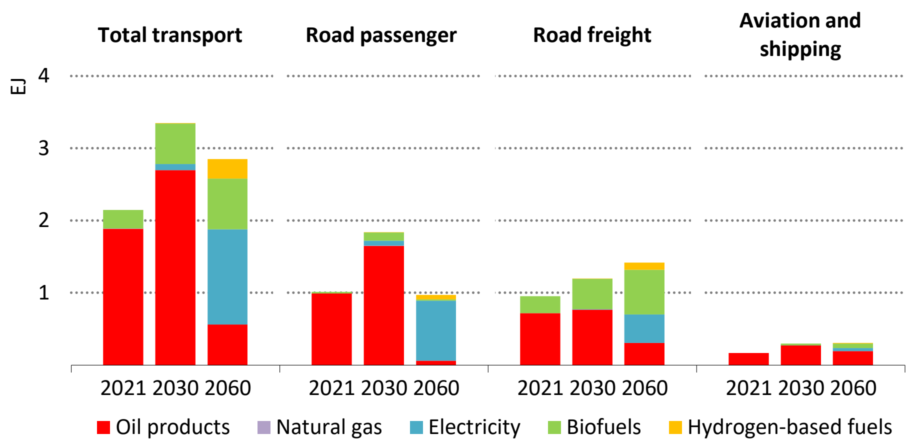
Targets set by the International Maritime Organisation and the International Civil Aviation Organisation reduce the energy intensity of aviation and large vessel maritime transport since global manufacturers dominate plane and ship building. The average energy intensity of a passenger kilometre for domestic aviation in Indonesia is reduced by almost 20% by 2030 relative to 2021, and a further 30% by 2060 in the APS.

3.5.3 Electrification and low emissions fuel switching

The energy mix for transport shifts significantly in Indonesia already by 2030, and by 2060 the changes are stark; the share of oil falls from almost 90% today to 80% by 2030 and to only 20% by 2060 in the APS. Biofuels play a near-term role to displace oil demand in today's vehicle fleet: the share of biofuels increases from slightly more than 10% in 2021 to around 20% in 2030, an increase of 300 PJ. Beyond 2040, biofuels play a declining role in energy demand for LDVs as electric vehicles (EVs) become more common. Electricity has a minimal role in total energy demand for road transport today, with the stock of light-duty EVs estimated at around 1 500, the share of electricity in road transport increases to only 3% by 2030, but takes off post-2030 to reach around half of energy demand for road transport by 2060 (Figure 3.23).

Biofuels continue to play a growing role in freight transport. In 2060, demand for biofuels in total road transport is around 100 PJ higher than in 2030 in the APS.

Figure 3.23 ▷ Energy consumption in transport by fuel and by mode in Indonesia in the Announced Pledges Scenario, 2030 and 2060



Biofuels suppress oil demand growth in the short term and in the longer term electrification pushes down oil use in all road transport modes; while liquids remain key for aviation

Note: EJ = exajoules.

Passenger cars consume 27% of total energy demand for road transport in Indonesia today and are fuelled almost entirely by gasoline, plus a small share of biofuels and diesel. In the APS, oil decreases from a 93% share today to 85% in 2030, and to less than 5% by 2060. The uptake of EVs in the passenger car segment boosts the average fleet fuel economy by 14% in 2030 and by 76% in 2060. EVs account for 8% of the total car fleet by 2030 and 90% by 2060 in the APS, requiring EVs to account for more than a fifth of total new car sales in 2030, up from essentially zero today.

Two/three-wheeler motorbikes almost exclusively run on gasoline today, accounting for almost one-quarter of total energy consumption in road transport in Indonesia. By 2030, the average fuel consumption of the two/three-wheeler stock decreases by over 20% and by almost 80% in 2060 in the APS. This impressive improvement is underpinned by their rapid electrification as their availability and economic attractiveness increase. By 2030, 20% of the stock is electrified and almost 100% by 2060 in the APS.

Buses account for just over 1% of total energy demand in road transport today in Indonesia. Buses have a relatively high share of biodiesel blending in the fuels they run on today. The bus fleet almost doubles in size by 2030 in the APS and electrification helps to improve the fleet fuel economy by over 15% in 2030 and over 60% by 2060 in the APS. In 2060 over 85% of the bus stock is electric, up from less than 1% today.

Light commercial vehicles (LCVs) use double the share of biofuels in energy demand for road transport compared to passenger cars today. This is due to the larger number of LCVs that use diesel fuel, with a mandated blending rate of 30%, which may increase to 40%. By 2030 in the APS, the LCV segment is projected to see its share of biofuels increase to over 10% of its total energy consumption. Similarly as for other vehicle types, the share of biofuels falls well below today's level by 2060. This reflects a progressive shift to EVs, with electricity accounting for over 90% of the energy demand for LCVs by 2060. Fuel economy improves by 10% in 2030 and 70% in 2060 in the APS.

Heavy trucks (medium and heavy freight trucks) account for almost 40% of total energy consumption in road transport. Today, trucks run on diesel and biodiesel, with biofuels meeting around 30% of their total liquids demand. The heavy truck fleet expands by over 50% to 2030 and more than triples by 2060 in the APS. Yet, the emissions intensity of heavy trucks decreases by over 30% in 2030 and over 80% in 2060 due to biodiesel blending mandates, fuel economy improvements and electrification.

Aviation remains reliant on oil to 2030, but nonetheless cedes 5% of its market share to sustainable aviation fuels (SAFs). By 2060, the share of oil in aviation energy demand falls below 60%, as bio jet kerosene increases to meet more than 15% of demand and synthetic kerosene and electricity cover an additional 25%.

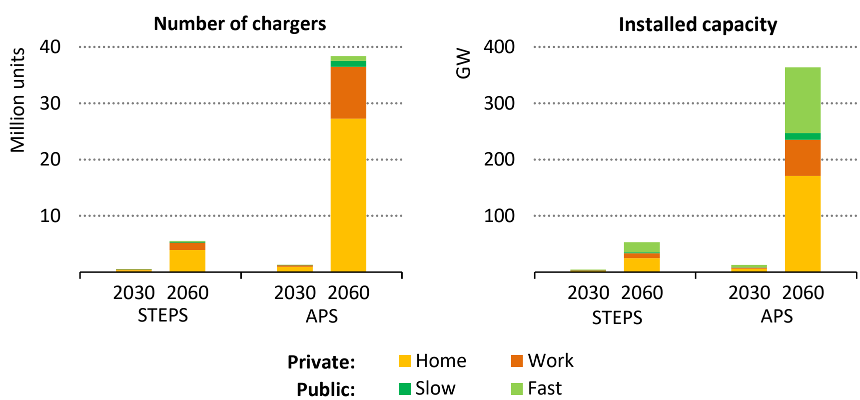
Maritime shipping sees further diversification of its fuel consumption in the APS. Oil currently meets all shipping demand (123 PJ), yet its share decreases to around 80% by 2030, and a third by 2060. Hydrogen and ammonia emerge as the dominant energy sources for shipping, with each accounting for about a quarter of total demand in 2060. The high share of biodiesel blending in the country also impacts shipping, meeting almost 15% of demand, mostly used in smaller vessels that today run on diesel.

S P O T L I G H T

Supporting EV deployment with chargers and battery manufacturing

Access to convenient and affordable EV charging infrastructure – both public and private chargers in households and workplaces – is crucial to enable the deployment of EVs in order to support the government's target of 2 million electric LDVs and 13 million electric two/three-wheelers by 2030. PLN, the state-owned electricity company, estimates that it would require more than 31 000 publicly accessible charging stations, with over a third in Jakarta. Challenges to develop the needed infrastructure include the high upfront costs of charging stations (in particular direct current fast chargers), the lack of standardised charging specifications, the lower power capacity of many household connections as well as subsidised electricity tariffs. In the APS, the number of public charging points[7] reaches 45 000 slow chargers and 35 000 fast chargers, with 5 GW of charging capacity installed by 2030 (Figure 3.24).

Figure 3.24 ▷ Charging infrastructure for electric LDVs in Indonesia in the Stated Policies and Announced Pledges scenarios, 2030 and 2060



The total number of charging points is expected to be 1.3 million by 2030 in the APS, 90% of which are private chargers, although public chargers have higher average capacity

Note: LDV = light-duty vehicles; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

The global momentum to electromobility provides opportunities for Indonesia to take advantage of its large nickel reserves. The Indonesia Battery Corporation is a recently

[7] Charging points refer to the number of sockets that can charge vehicles at the same time. One charging location can have several charging stations, which in turn can have several charging points.

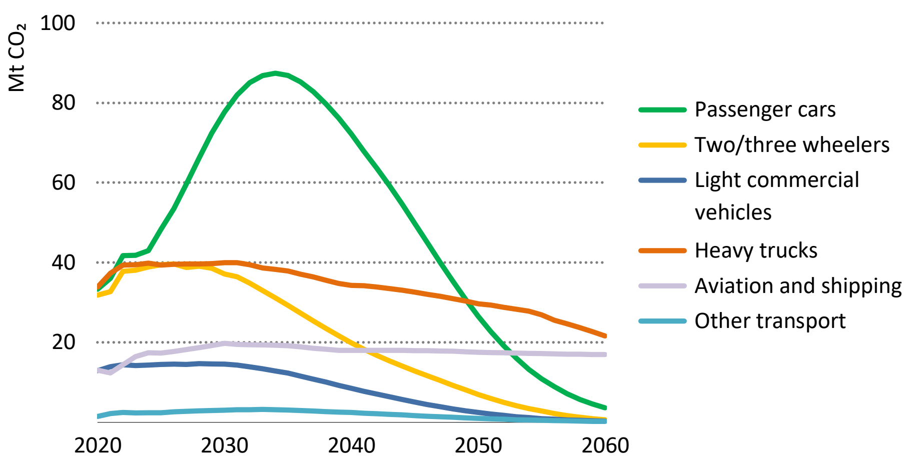
established state-owned enterprise that aims to produce 140 gigawatt-hours (GWh) of battery cells by 2030, of which 50 GWh will be for export. This target equates to about 16% of current total global battery production today. These plans were advanced with a Memorandum of Understanding (MoU) between the Ministry of Investment and the Hyundai Motor Company for construction of a 10 GWh factory with a price tag of USD 1.1 billion. The factory, to be built with the LG Group, aims to incorporate battery precursor production with pack production, as well as mining, smelting and recycling facilities. This is a part of a larger MoU signed by Indonesia's government and a consortium led by the LG Group for USD 9.8 billion to develop integrated EV supply chains.

3

3.5.4 CO_2 emissions trends

CO_2 emissions from passenger cars rise rapidly until around 2035 due to more cars on the road and continued sales of ICE vehicles. The share of EVs in passenger vehicle sales only ramps up in the 2030s. By the early 2050s, sales of new ICE vehicles end. The combination of energy efficiency improvements, biofuel blending, and especially increasing penetration of EVs drive CO_2 emissions down in the passenger car segment by 2060 in the APS (Figure 3.25).

Figure 3.25 ▷ CO_2 emissions from selected transport modes in Indonesia in the Announced Pledges Scenario, 2020 – 2060



CO_2 emissions from all road transport modes peak by the mid-2030s and decline sharply to 2060, emissions from aviation and shipping are relatively consistent

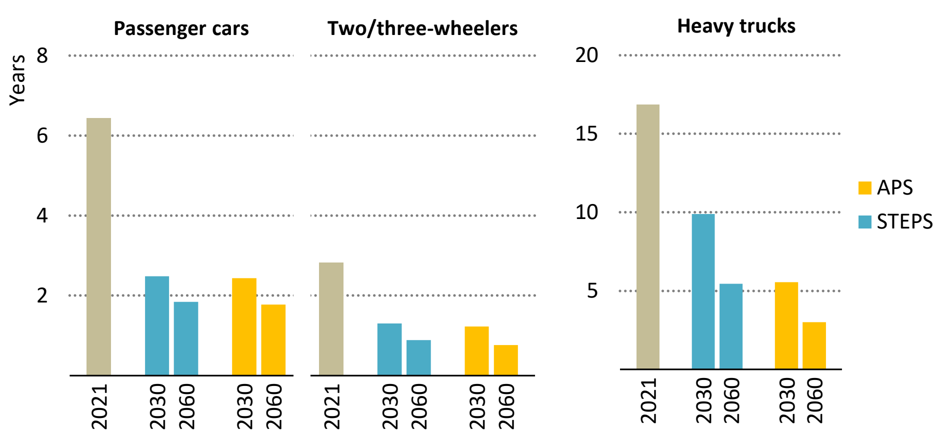
Heavy trucks rapidly increase biodiesel blending which enables plateauing of CO_2 emissions in the 2020s, while beyond 2030 the combined effect of increasing electrification of smaller trucks and continued increases in biodiesel use are enough to drive down emissions to around half of 2021 levels, despite a more than tripling of the number of heavy trucks on the road.

3.5.5 Technology performance and costs

Today, in Indonesia a battery electric two/three-wheeler costs on average USD 1 000-2 000 more than a conventional one. Notably, however, the payback period for the higher investment is less than three years today and declines to around one year in the APS by 2030. Total cost of ownership for some electric models is lower than for conventional two/three-wheelers today and becomes lower by 2025 for most models, even without government incentives, since their operating costs are cheaper (ICCT, 2021b).

Buying a battery electric car can cost upward of USD 10 000 more than an ICE car today in Indonesia, due predominantly to the limited market offering. Nonetheless, the average payback period is close to 6.5 years. The APS projects the payback period to contract to just 2.5 years by 2030 (Figure 3.26). Battery electric cars are more energy efficient and have lower operating and maintenance costs than conventional ICE cars which improves their economics.

Figure 3.26 ▷ Payback period for battery EVs in the Stated Policies and Announced Pledges scenarios, 2030 and 2060



Payback periods for battery EVs decline sharply by 2030 in the APS and even trucks have attractive payback periods

Note: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

3.6 Buildings

The buildings sector represented 23% of final energy consumption in Indonesia in 2021, but due to the significant role of electricity and, polluting but not CO_2 emitting, traditional use of biomass, the sector accounts for only 9% of emissions from final energy consumption.[8] Residences dominate at 83% of energy demand in the buildings sector in 2021. The services segment, i.e. commercial, institutional and non-specified buildings, accounted for the rest. While CO_2 emissions from residential and services equate to only 27 Mt CO_2 and 1.8 Mt CO_2 respectively, the buildings sector nonetheless has a critical role to play in Indonesia's pathway to net zero emissions. Buildings account for two-thirds of today's electricity demand, 80% of which is generated with unabated fossil fuels, and this demand is set to grow rapidly in the coming decades.

3.6.1 Activity drivers

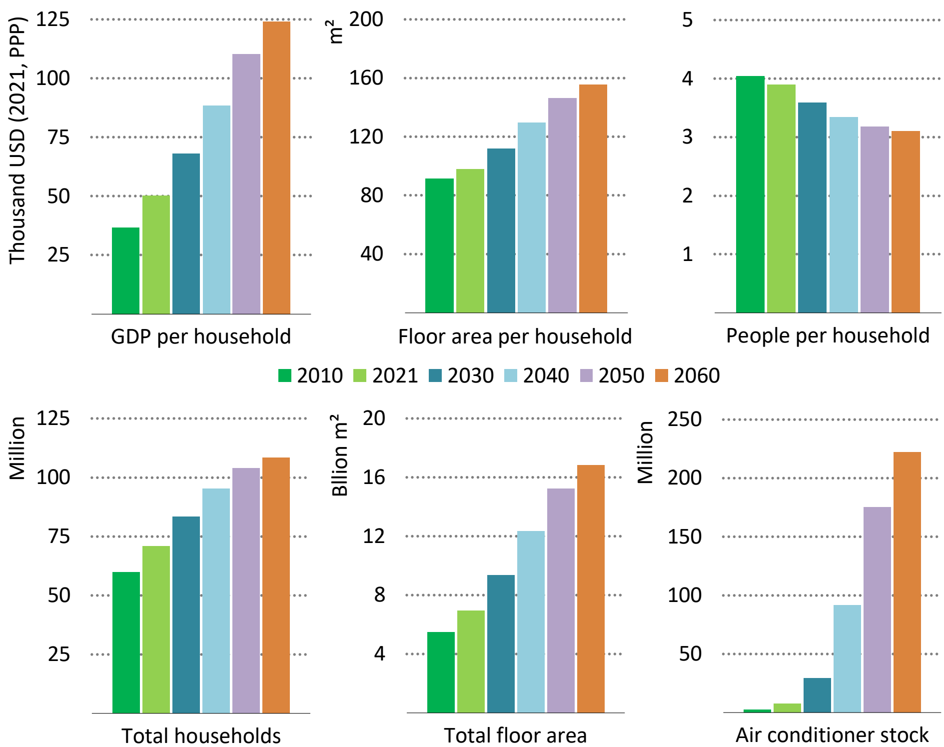
Expanding demand for energy services in the buildings sector in Indonesia is underpinned by a growing population with access to energy, rising levels of household income and services sector activity. Indonesia has made strong strides in recent years to provide energy access; the share of its population with access to electricity increased from 67% in 2010 to essentially 100% today, resulting in an additional 110 million electricity consumers. Progress has also been rapid in improving access to clean cooking, with the share of the population relying on traditional use of biomass, kerosene or coal for cooking dropping from almost 60% in 2010 (76% in rural areas) to less than 18% in 2021. Nonetheless, this still leaves almost 50 million Indonesians without access to clean cooking. In the APS, all households have access to clean cooking by 2030, with significant beneficial implications for health, the environment and energy demand.

Population growth is expected to slow to below 1% per year in the 2030s, and 0.4% from 2030 to 2060. Indonesia's population increases by 60 million in the period to 2060, reaching 300 million in 2030 and 336 million in 2060. Population growth drives an increasing need for housing as well as increases in the stock of basic energy-related goods. Compounding the impact of population growth, Indonesia is rapidly urbanising; its urban population is projected to increase by 100 million in the next 40 years and to reach an urbanisation rate of almost 80% by 2060. Jakarta is already a global megacity with its urban area home to 35 million people – it is the world's second-largest urban area. Urban households in Indonesia are typically wealthier and consume more energy than rural households. Rapid urbanisation also impacts needs for new buildings, transport systems and other infrastructure, all of which impact energy demand. Efforts to ease the pressures of growing and emerging megacities in Indonesia, and their vulnerability to climate change, include a plan to move the national capital to a planned city in East Kalimantan, Nusantara. Whether

[8] The buildings sector includes energy used in residential and services buildings. Services includes commercial and institutional buildings and non-specified other. Building energy use includes space heating and cooling, water heating, appliances and cooking equipment.

living in megacities, provincial centres or rural areas, households in Indonesia grow much wealthier in the APS, driving up demand for energy services. By 2060, average GDP per household in Indonesia is projected in the APS to reach USD 124 000, compared to USD 50 000 today (Figure 3.27).

Figure 3.27 ▷ Residential activity metrics in the Announced Pledges Scenario, 2010 – 2060



Income growth drives up household size and appliance ownership; residential floor area added by 2060 is fifteen-times the land area of the Special Capital Region of Jakarta

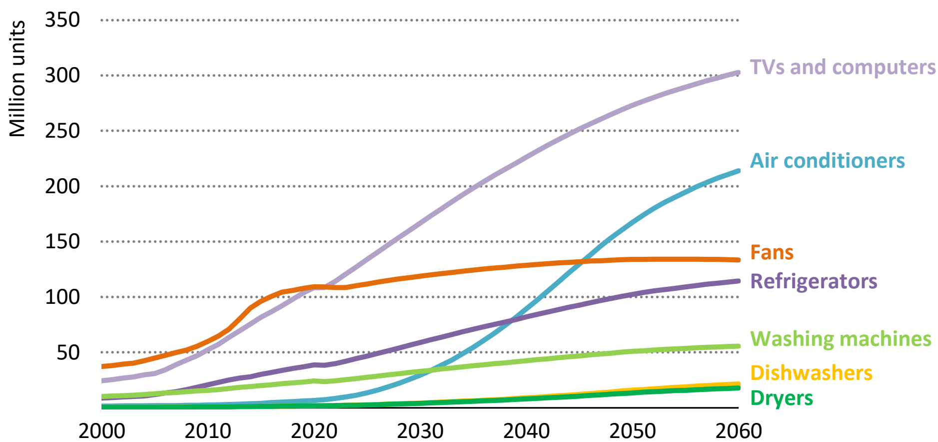
With average gross national income and GDP per household converging to levels in advanced economies by the 2040s, household size and composition evolve; Indonesians increasingly prefer larger houses and live in smaller family units. At almost 100 square metres (m^2), the average dwelling size in Indonesia is among the largest in emerging market economies today, and is on par with European economies, Japan and Korea. Average floor area rises to 112 m^2 by 2030, and 155 m^2 by 2060 in the APS. In parallel, the number of people per household falls with growing incomes from 3.9 today to 3.1 in 2060, remaining higher than today's average of 2.4 in the European Union and 2.7 in China.

Larger homes and fewer people per household result in residential floor area increasing at an average of 2.3% over the period to 2060, four-times the rate of population growth. Almost 10 billion m^2 of new residential floor area is constructed between 2021 and 2060 in the APS, more than doubling Indonesia's residential building stock and equivalent to fifteen-times the total land area of the Special Capital Region of Jakarta.

Activity in the services sector (commercial and public buildings) also expands rapidly in the APS, with its value added more than quadrupling by 2060. The contribution of services to Indonesia's economic output rises from 46% today to 56% in 2050, and within services, professional and other office-based activities and retail are the areas that see the largest growth in output, while tourism and hospitality remain a cornerstone of the economy. The shift to less energy-intensive services means that demands for energy services do not rise in step with value added.

Most Indonesians live in areas in which average daily temperatures exceed 25 °C. Even when and where temperatures are lower, high humidity levels increase perceived temperatures. Space cooling needs in Indonesia are among the highest in the world, with an average of over 1 500 cooling degree days per year. Comfort provided by air conditioners is available to only a fraction of the population today, with one-in-ten households having an air conditioner. Fans are much more common at an average of 1.5 units per household. With increasing income, purchasing an air conditioner is high on the list of priorities for many households and businesses. In the APS, air conditioner ownership increases to an average of 0.4 units per household in 2030 and almost 2 units per household in 2060, at which time there are 210 million additional air conditioners in Indonesia compared to today (Figure 3.28), with around 550 million units sold between today and 2060 as units are replaced.

Figure 3.28 ▷ Household appliances and equipment in Indonesia in the Announced Pledges Scenario, 2000 – 2060



Households add 210 million air conditioners between 2021 and 2060

Other types of appliances and equipment used in buildings also see rapid uptake, with the number of refrigerators increasing by 75 million, washing machines by over 30 million, and the total number of televisions and computers rising by 210 million to 2060. Maximising energy efficiency of the appliances and equipment sold in the coming decades plays a decisive role in reaching net zero emissions by 2060 and constraining increases in consumer electricity bills.

3.6.2 Energy efficiency and avoided demand

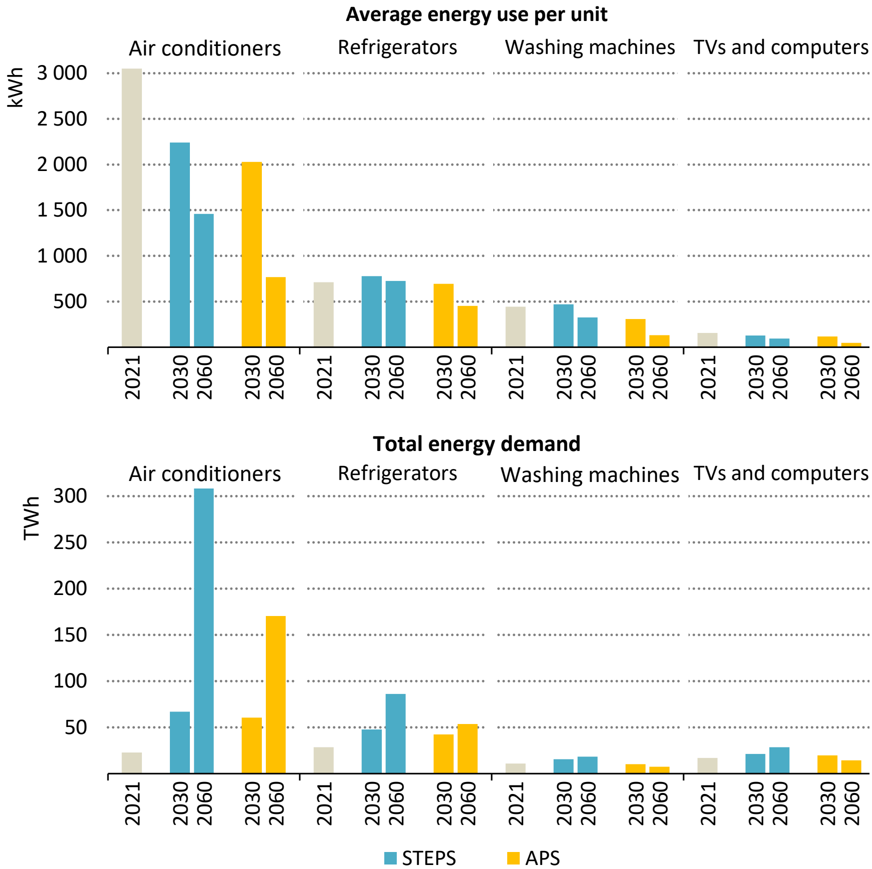
Appliances and equipment sold in Indonesia today are on average 30 -50% less efficient than the most efficient technologies available on its domestic market. The best available air conditioner in Indonesia is more than twice as efficient as the market average, and the best available technologies globally are around three-times more efficient. In the APS, Indonesia's existing framework of minimum energy performance standards (MEPS) is expanded, timelines accelerated and minimum efficiency levels tightened, such that by 2035 all but the most efficient classes of appliances and equipment are banned from sale. In the APS, by 2050 appliances consume 35 -75% less electricity than current models. Improvements in the STEPS are limited, as only current and planned MEPS are in place. For example, in the APS, the average efficiency of an air conditioner increases from a cooling seasonal performance factor (CSPF) of less than 3 today to around 8 by 2060. The combined impact of MEPS and improvements in building envelopes results in the average annual electricity consumption per air conditioner falling from 3 000 kWh today to under 800 kWh in the APS, compared to around 1 500 kWh in the STEPS in 2060 (Figure 3.29).

MEPS for appliances and cooling equipment in the APS apply to the services sector as well. Thanks to MEPS and more stringent building energy codes, electricity demand for cooling and appliances in services increases by only 160% to 2050, while its value added increases by 350%.

Improvements to building envelopes with better insulation and passive design features such as natural ventilation and shading, reduce demand for space cooling and cut thermal losses from conditioned spaces. Other measures such as white roofs, shutters and the use of ceiling fans, assist in achieving thermal comfort while minimising air conditioner use. All such measures can be encouraged or required via their inclusion in building energy codes.

The IEA recommends that countries implement location specific zero carbon-ready building energy codes. They can require or encourage buildings codes to leverage passive design principles, maximise the energy performance of the building envelope, give preference to building materials with low embodied carbon, and employ energy systems based on renewables or low emissions sources or that will be decarbonised in the transition, such as electricity (IEA, 2021c). Additional measures in urban areas can encourage the use of trees to provide natural shading and to reduce concrete surfaces that trap and radiate heat, compounding urban heat island effects.

Figure 3.29 ⊳ Electricity consumption by appliance/equipment in Indonesia in the Stated Policies and Announced Pledges scenarios, 2021 – 2060

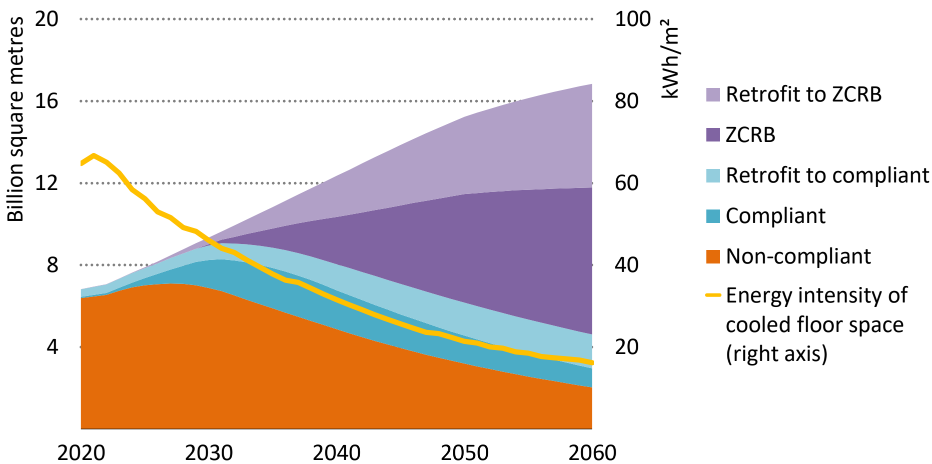


Energy efficiency gains in the APS cut the average electricity consumption of air conditioners by 75%, and 35 -70% for other major appliances, reducing demand by more than 200 TWh relative to the STEPS

Note: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

In Indonesia, a pathway for the implementation of zero carbon-ready building (ZCRB) energy codes is established in the mid-2020s in the APS. Building energy codes ramp up in stringency from 2030 and reach ZCRB levels by the mid-2030s. This means that all buildings constructed after 2035 meet stringent energy efficiency requirements, which dampens growth in electricity demand and increases comfort for building occupants. Buildings constructed between today and 2060 represent over two-thirds of residential floor area in 2060 (Figure 3.30). Policy action is also required to ensure that existing buildings are renovated to improve comfort and energy efficiency. Retrofitting in the APS is driven by the extension of ZCRB codes to existing buildings that require compliance when buildings are sold or rented, complemented with financial assistance and other supporting measures to facilitate action. Support is especially needed for poor households to ensure they can benefit from lower energy bills; such support can also reduce government expenditure on energy consumption subsidies.

Figure 3.30 ⊳ Residential building floor area by envelope type and energy intensity of cooled floor area in Indonesia in the Announced Pledges Scenario



By 2030 all new buildings are built to ZCRB standards and existing buildings are gradually retired or retrofitted; 75% of the housing stock is zero carbon-ready by 2060

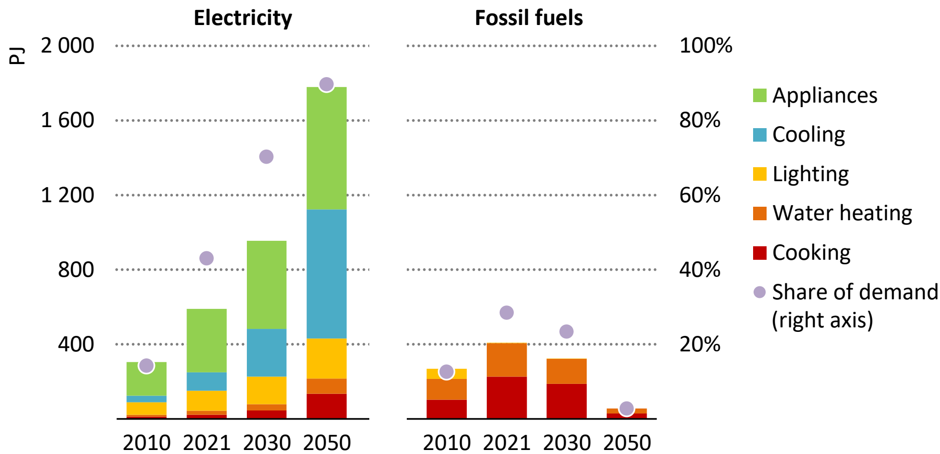
Notes: ZCRB = building meeting country specific zero carbon-ready building standards. Compliant = building meeting the requirements of a building energy code, but not as stringent as ZCRB requirements. Non-compliant = buildings constructed without regard to any building energy code.

Implementation of stringent building energy codes and the retrofit of existing buildings drastically changes the composition of the building stock in Indonesia. Almost all buildings now standing were constructed without compliance to any building energy code or guidance, except buildings constructed to meet green building codes in Jakarta, Bandung and Semarang. In the APS, buildings constructed in the period to 2030 are complaint with the announced national building energy code (which is only mandatory for certain large buildings). The imperative to further improve efficiency and curb electricity demand growth requires a full shift of the buildings construction to ZCRB standards. By 2060 in the APS, 75% of the total residential building stock is either built to or retrofitted to ZCRB standards. This contributes to a decrease of the average energy intensity of air conditioned floorspace from 65 kWh/m^2 in 2021 to 16 kWh/m^2 in 2060.

3.6.3 Transitions in the energy demand mix

Step changes in the energy efficiency of key appliances and equipment as well as in buildings bring multiple benefits to occupants and facilitates the decarbonisation of the electricity sector. Still the sector needs to reduce demand for fossil fuels and ensure increasing demand for modern energy, notably from clean cooking access, does not compromise emissions reduction objectives. Today 99% of fossil fuel demand in the buildings sector is in the form of LPG for cooking and water heating, and a very small amount of kerosene for lighting. In the APS, fossil fuel demand in the buildings sector starts an immediate decline and by 2030 falls to 24% of total energy demand in the sector (340 PJ), and to 2% by 2050 with all use of fossil fuels well on the way to full phase out by 2060 (Figure 3.31).

Figure 3.31 ▹ Buildings sector electricity and fossil fuel demand by end-use in Indonesia in the Announced Pledges Scenario, 2010 – 2050



Electricity rises from a 43% share of energy demand in 2021 to 90% in 2050 as the traditional use of biomass fades and appliances and equipment are added

Reducing fossil fuel use, particularly LPG demand, is both motivated by and complicated by LPG subsidies. Over a decade ago the government carried out a vast conversion from the use of kerosene for cooking to LPG for most of the population in order to reduce the strain of kerosene subsidies on the national budget. The programme provided LPG stoves and bottles free of charge to over 57 million households and businesses, with heavily subsidised canister refills available. The programme was also instrumental in reducing reliance on the traditional use of biomass for cooking thereby improving indoor air quality and public health. However, with no purchase volume or income restrictions on subsidies, the LPG programme became a victim of its own success; the cost of subsidies has become a significant burden on public budgets. Moreover, domestic production accounts for only one-quarter of LPG demand with imports accounting for the remainder to the detriment of the national trade balance.

The government prioritises the use of domestic energy resources, desires to improve energy security and to reduce the LPG subsidy burden on public finances. This frames its efforts to reduce the use of LPG. However, LPG remains the most cost-effective cooking and heating option for households in light of recent scaling back of electricity subsidies and the higher relative cost of natural gas where network connections are available. Subsidy reform is required to reduce the attractiveness of LPG. To date, reform efforts have stalled in the face of public opposition, the impacts of the Covid-19 pandemic, and currently the desire to avoid further inflationary pressure.

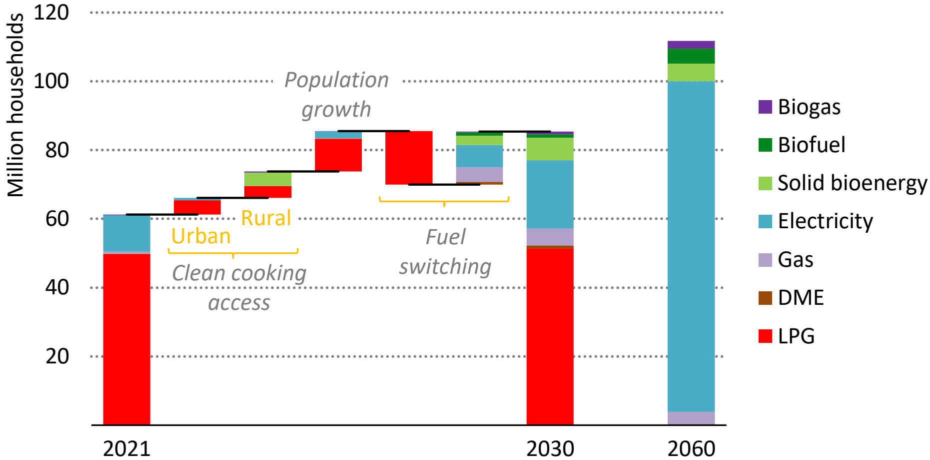
Electric cooking and water heating emerge in the APS as the optimal long-term solution to meet decarbonisation objectives, secure energy affordability without subsidies, and reduce indoor air pollution. A combination of measures are implemented to overcome barriers to the uptake of electric cooking and water heating. These include providing free and subsidised upgrades to building electricity connections and wiring where they are insufficient to handle the load, government procurement of electric cooking and water heating equipment and subsidised access to this equipment for poor households. It could also be designed to facilitate use of electric water heaters for load management of the electricity system with suitable tariff provisions. In parallel, LPG subsidies need to be eliminated for wealthy households and shifted to a needs-based subsidy access system.

Of the 50 million people in Indonesia who lack access to clean cooking solutions today, the majority gain access via LPG in the APS, as despite being a fossil fuel, it is the most readily available and affordable option, especially for those living in informal settlements and rural areas. Improved biomass cookstoves and bioethanol stoves also play an important role, especially in rural areas.

In 2021, almost 50 million Indonesian households relied on LPG for cooking while 11 million households were cooking with electricity (Figure 3.32). Population growth further increases the number of households cooking with LPG, however, policy efforts to reduce the attractiveness of LPG and to encourage alternatives bear fruit, 15 million households transition away from LPG in the period to 2030 in the APS. Reform efforts in the APS need to be put in place in the 2020s to avoid additional LPG demand growth in the coming years and to put the buildings sector on track to a full phase out of LPG by mid-century

Alternatives to LPG in the short term include natural gas. The government aims to rapidly scale up access to gas networks. However, in the APS, the increasing economic attractiveness of electricity, its declining CO_2 intensity and the emissions associated with natural gas use, mean that expansion of gas connections is limited to areas in close proximity to industrial clusters where gas has higher value. Additional plans include the downstream processing of domestic coal resources into dimethyl ether (DME) a liquid that can be used in a similar manner to LPG for cooking. While such plans may allow Indonesia to displace LPG, in the APS the cost and emissions intensity of DME render electricity and renewables a preferred energy solution for cooking and water heating. By 2060 in the APS, almost 100 million households, 85% of the total, use electricity for cooking, 4 million tap into urban gas networks and the remainder use bioenergy-based options for cooking and water heating.

Figure 3.32 ▹ Households with access to clean cooking solutions by type in Indonesia in the Announced Pledges Scenario, 2021 – 2030 and 2060



LPG use expands among those gaining clean cooking access, while urban areas transition to electric cooking, fuel switching accelerates after 2030

Notes: LPG = liquid petroleum gas. DME = dimethyl ether, a liquid fuel produced from coal in the case of Indonesia.

Accelerating to net zero emissions by 2050

Exploring the implications

SUMMARY

- Indonesia's target of achieving net zero emissions by 2060 also states an ambition of possibly reaching the goal sooner. The "sooner" is the focus of the Net Zero Emissions by 2050 Scenario (NZE) discussed in this chapter.
- Cumulative capacity additions of renewables to 2030 in the NZE are nearly three-times the level projected in the Announced Pledges Scenario (APS). To make way for renewables, several planned coal-fired power plants are shelved and the last unabated coal plant is completed by 2024. This cuts the coal fleet by 10% by 2030 relative to the APS, and remaining plants operate less, generating 70% less electricity in 2030 in the NZE than in the APS, requiring new commercial arrangements.
- Implementation of stringent energy efficiency measures is brought forward in the NZE relative to the APS, including performance standards for air conditioners, industrial equipment and vehicles. New building codes are implemented by 2030 and retrofits accelerated, to align buildings with the earlier net zero emissions goal. Essentially all motorbikes and passenger cars sold are electric by 2035. Accelerating efficiency gains, such as through electrification, underpin Indonesia's ability to meet its economic growth ambitions with energy consumption that is nearly a fifth lower in the NZE than in the APS.
- The transition to low emitting technologies for end-uses is pushed fast and far in the NZE path. Demand for electricity and low emissions fuels increases by more than 7% annually in the period to 2030. By 2050, almost 85% of end-use energy demand is met by electricity and low emissions fuels in the NZE, compared with 65% in the APS. Electricity demand exceeds 4 600 kWh per capita in 2050.
- Additional annual investments of around USD 30 billion by 2030 are needed to decarbonise the electricity sector. Two-thirds of this is for low emissions generation capacity, largely renewables, and one-third is for networks. This level of investment necessitates additional public financial support, including from international sources.
- The cost of the energy system, including total investment and fuel expenditure, is about 2% of GDP higher in 2030 in the NZE relative to the APS. But, investment needs fall in the NZE in the long term while consumer savings mount; by 2050 the energy system in the NZE is cheaper than in both the Stated Policies Scenario and the APS.
- In the period to 2050, lower domestic fossil fuel consumption and lower international prices in the NZE reduce oil imports by more than half compared to the APS. Indonesia profits from the global clean energy transition as total revenues from critical minerals in 2030 are nearly three-times higher than today. By 2050, total annual revenue from critical minerals is around USD 50 billion in the NZE.

4.1 Introduction

Indonesia's target to achieve net zero emissions by 2060 is ambitious. It is consistent with the upper temperature limit of the Paris Agreement: to limit global warming to well below 2 degrees Celsius (°C), preferably to 1.5 °C, compared to pre-industrial levels. The Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5 °C highlighted the importance of reaching net zero CO_2 emissions globally by mid-century or sooner to limit the average global temperature increase to 1.5 °C and to avoid the worst impacts of climate change (IPCC, 2018).

The door to achieving global net zero CO_2 emissions by mid-century remains open, yet is rapidly closing, as demonstrated in the IEA's *Net Zero by 2050: A Roadmap for the Global Energy Sector* (IEA, 2021)). Its Net Zero Emissions by 2050 Scenario (NZE) has been updated and is the basis of this chapter's exploration of what an accelerated path to achieve net zero emissions by 2050 for Indonesia may encompass.

The NZE assumes a significant degree of international collaboration to demonstrate, commercialise and diffuse key low emissions technologies on an accelerated timeframe, and to provide financial support to Indonesia. The NZE is based on rapid action from all countries, which transforms global fuel and energy technology markets and drives down the costs of clean energy technologies much faster than in the IEA's Stated Policies Scenario (STEPS), which considers where the global energy system might go without additional policy implementation, and the Announced Pledges Scenario (APS), which takes account of all the climate commitments made by governments around the world and assumes they will be met in full and on time. Today's very high energy prices help to catalyse the kind of rapid transition to clean energy as projected in the NZE. The analysis of the NZE in this chapter focusses on the actions required in the current decade to align with a 2050 net zero emissions pathway and how they differ from the APS pathway.

In the few years to 2030, Indonesia's GDP is set to increase by 60%, industrial output to increase by 50% and the number of household appliances and cooling equipment to expand by 45%. Many of the power plants, factories and buildings constructed to 2030, and some of the vehicles and equipment purchased, will still be in use by 2050. Rapid policy action can ensure that the expansion of Indonesia's capital stock accelerates rather than hinders its clean energy transition and preserves the possibility of net zero emissions by 2050.

Delivering the NZE pathway would bring multiple benefits to Indonesia's economy. For instance, a complete shift to domestic renewables and low emission technologies to generate electricity for use in cooking, transport and industrial production, would allow Indonesia to cut energy import dependency and to relieve trade deficits; is compatible with improved energy affordability for households and businesses; and could accelerate the development of the domestic clean energy manufacturing and critical minerals value chains. A more rapid transition both domestically and globally would reduce the human and economic costs of climate change on Indonesia.

The NZE pathway requires both rapid transformation of policies and regulation in all sectors, i.e. electricity generation, industry, transport and buildings, as well as a major changes in investment. This chapter examines what such a transform may look like.

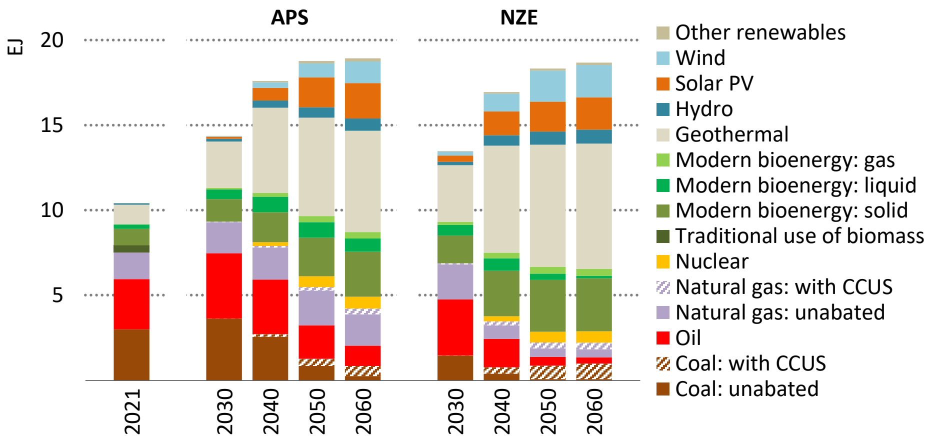
4.2 Energy and emissions pathways

4.2.1 Primary energy

The energy supply mix transition is similar in broad outlines in the NZE relative to the APS. But over time with the even stronger push for energy efficiency and electrification in the NZE, total energy supply peaks and then plateaus after 2050, even as the economy continues to grow. Total energy supply is around 2% lower in 2060 in the NZE compared with the APS.

The electricity sector transition is faster in the NZE with unabated coal-fired generation 70% lower in 2030 and 60% lower in 2040, relative to the APS (see section 4.3). On the other hand, by 2060 the APS uses less coal with carbon capture, utilisation and storage (CCUS) than in the NZE. Oil demand is reduced much faster in the NZE than the APS, due to the accelerated roll-out of electric vehicles (EVs) and other low emissions technologies in transport. While demand grows in the short term, by 2040, oil demand in the NZE is nearly half the level of 2021 and half the level projected in the APS (Figure 4.1). By 2050, the majority of remaining oil use in the NZE is used as a feedstock for chemical processes and in other non-emitting uses.

Figure 4.1 ▷ Total energy supply in Indonesia in the Announced Policies and Net Zero Emissions by 2050 scenarios, 2021 and 2030 – 2060



Faster transition of the electricity sector in the NZE pushes unabated coal use 60% lower in 2030 compared to the APS. By 2050 unabated fossil fuels fall to 6% of the mix in the NZE

Notes: EJ = exajoules. Representation of geothermal in total energy supply is influenced by the accounting standards used to convert geothermal electricity generation into primary inputs (See Chapter 1, Box 1.2).

The contribution of bioenergy in the near term differs between the two scenarios. The NZE path makes stronger use of modern solid bioenergy in electricity generation and industry, while accelerated electrification in transport curbs demand for liquid and gaseous biofuels, compared to the APS. The net effect is that demand for modern bioenergy in the NZE is only around 460 petajoules (PJ) more in 2030 and around 300 PJ more in 2050 compared to the APS.

Renewables in power generation – hydro, geothermal, wind, solar and bioenergy – are deployed much faster in the NZE, with the electricity sector reaching net zero emissions by 2040. Total energy supply from renewables is more than 1 500 PJ higher in the NZE than the APS in 2030, rising to over 3 700 PJ higher in 2040. Most of this increase, in primary energy terms, is from geothermal resources used to generate electricity. Although the picture is somewhat distorted by accounting conventions for estimating primary inputs into geothermal electricity generation.[1] By 2060, the difference between the two scenarios narrows, as the electricity sector in the APS is also largely decarbonised based on renewables.

The main differences in terms of primary energy between the two scenarios relate to the timing and speed of the transition, rather than the nature and scale of the transition that needs to be achieved.

4.2.2 Emissions

Energy-related CO_2 emissions peak in the current decade reflecting an accelerated transition to decarbonise the electricity sector in the NZE pathway, which is faster than in the APS or in current policy plans. Net zero emissions in the electricity sector are reached around 2040. This is far faster than implied by the typical technical and financial lifetimes of the existing fossil fuel generation fleet, and thus would require renegotiation of existing long-term contracts and early retirement of some plants (see section 4.3).

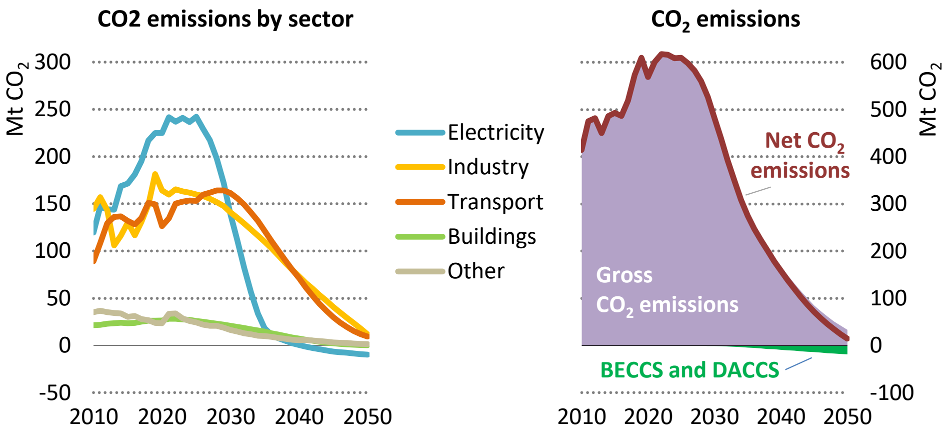
Peak energy-related CO_2 emissions in industry are brought forward by almost a decade in the NZE compared to the APS, and are reduced to close to zero by 2050 thanks to the widespread adoption of electricity, solid bioenergy and CCUS. Transport emissions are more than 15% lower in the NZE compared to the APS in 2030, through the speedier uptake of EVs, more robust fuel economy standards, and measures to increase use of public transport as an alternative to private passenger vehicle use. By 2050, CO_2 emissions from transport are about 10 million tonnes (Mt) in the NZE, compared to around 80 Mt in the APS.

Indonesia gets close to, but does not achieve, net zero emissions from the energy sector in 2050 in the NZE. This implies that the residual emissions are offset by carbon removal in other countries, such that the global energy sector reaches net zero emissions by 2050. On a global basis the NZE projects increased and widespread deployment of carbon removal

[1] The IEA follows a primary energy content approach for geothermal, which accounts for losses in converting the primary heat input into electrical energy, based on available data, or when data is not available on an assumed conversion efficiency. More details are in Chapter 1, Box 1.2.

technologies relative to the APS. These include bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS). These remove almost 20 Mt CO_2 from the atmosphere per year by 2050 in Indonesia, partially offsetting gross emissions of around 30 Mt and resulting in net emissions of just over 10 Mt in 2050 (Figure 4.2).

Figure 4.2 ▹ Energy-related CO_2 emissions by sector, gross and net emissions and CO_2 removals in Indonesia in the Net Zero Emissions by 2050 Scenario, 2010 – 2050



Emissions are close to net zero by 2050, with around 30 Mt of gross emissions offset by almost 20 Mt of carbon dioxide removals

Note: BECCS = bioenergy equipped with CCUS; DACCS = direct air carbon capture and storage.

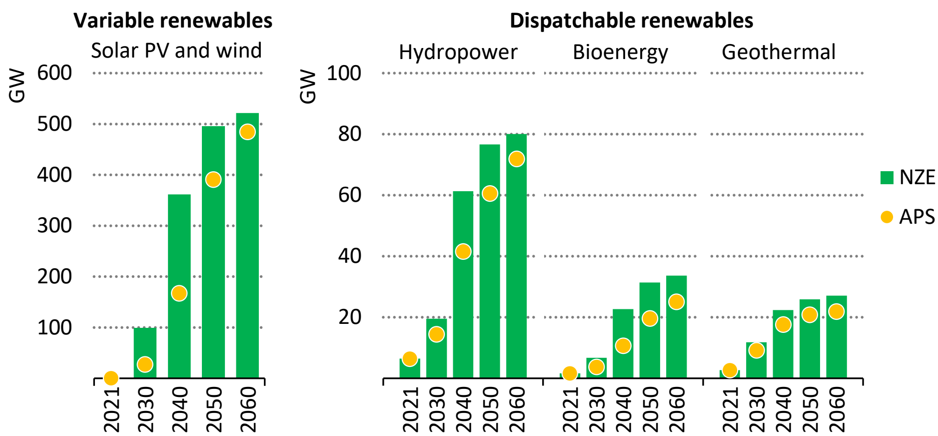
4.3 Focus on the electricity sector

Electricity demand increases by almost 7% per year in the period to 2030 in the NZE, compared with 6% per year in the APS. By 2030, electricity demand is nearly 10% higher in the NZE, due to stronger advances in electrification which is partially counterbalanced by more stringent energy efficiency and demand reduction policies. Beyond 2030, hydrogen production by electrolysis expands significantly to meet domestic hydrogen demand in various sectors, further boosting electricity demand in the NZE. By 2050, electricity demand is about 30% higher in the NZE than in the APS, also driven by widespread electrification in end-use sectors. Electricity demand is over 1 500 terawatt-hours (TWh) by 2050 in the NZE, six-times the 2021 level and nearly 30% more than in the APS.

The NZE pathway calls for changing the profile of the electricity sector over the next decade, starting with scaling up contributions from renewables faster than in current plans. The share of renewables in electricity supply rises from 19% in 2021 to about 60% in 2030 in the NZE, more than 25 percentage points higher than in the APS. Solar PV leads the way, with about

65 gigawatts (GW) of new capacity coming online by 2030 in the NZE, compared with around 20 GW in the APS (Figure 4.3). Wind power scales up with new onshore and offshore wind capacity totalling more than 30 GW by 2030 in the NZE. In addition to these variable renewables, a diverse set of dispatchable renewables, including hydropower, bioenergy and geothermal, must also ramp up faster than in the APS. By 2030, renewables capacity is nearly 140 GW in the NZE, about two-and-a-half times more than in the APS. Clearly, investment needs to achieve such deployment are substantial (see section 4.5.1).

Figure 4.3 ▷ Installed capacity by renewable energy technology in Indonesia in the Net Zero Emissions by 2050 and the Announced Pledges scenarios, 2021 – 2060



Accelerating the electricity sector transition to reach net zero emissions by 2050 requires higher capacity additions of renewables, particularly solar PV

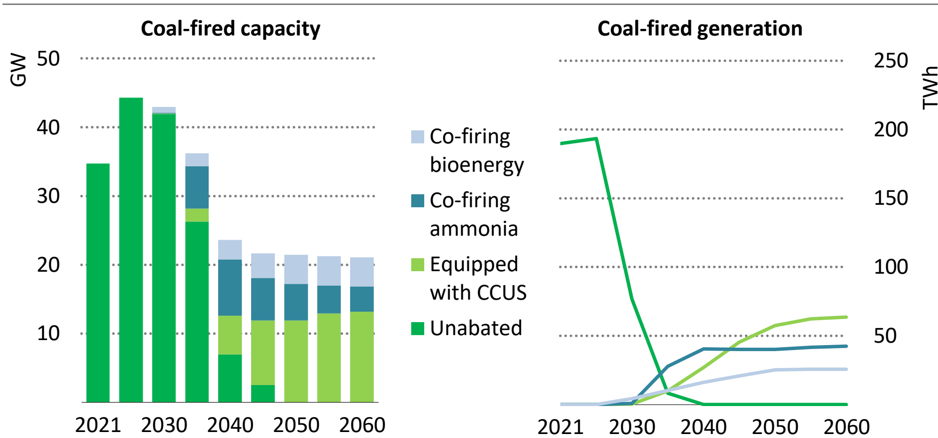
Note: NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario.

Renewables are the central pillar of the NZE path for the electricity sector to reach net zero CO_2 emissions by 2040. Installed capacity additions of renewables increase steadily to account for nearly 90% of electricity supply by 2040 and the bulk of new generation assets through to 2060. Solar PV and wind are the leading sources and provide around 55% of generation by 2040, broadly maintaining this share through to 2060. For solar PV, the majority are utility-scale installations. Operations of the power system are transformed with increased focus on flexibility options to effectively integrate these cheap, variable sources of electricity. Dispatchable renewables such as hydropower, bioenergy and geothermal are relied on heavily, nearing their full potentials in the long run.

The NZE pathway for the existing fleet of coal-fired power plants diverges from current plans over the next decade. Construction of new coal plants is more limited, with the last new unabated coal-fired power plants to be completed in 2024 and development of several plants in the pipeline is halted. By 2030, the coal-fired generation fleet is about 10% smaller in the NZE than in the APS. However, due to the rapidly changing role of coal-fired generation in the NZE and a fleet that operates much less, the difference in generation between NZE and APS becomes even more distinct. Coal-fired generation is 70% lower in 2030 in the NZE, compared to the APS. This reduction means that the capacity factor for coal plants falls significantly, calling for new financial arrangements, innovative financing tools and international support to overcome the barriers of current contracts, as well as to minimise negative impacts on plant owners and workers, and the risk of stranded assets (see Chapter 5, section 5.3).

Beyond 2030, the fleet of coal-fired power plants is made compatible with a net zero emissions pathway in several ways. The oldest, least efficient and challenging to retrofit unabated coal plants are progressively phased out by 2040, focusing first on flexibility before permanently closing. The youngest and most efficient coal plants are retrofitted with CCUS. Despite fewer new plants constructed, the amount of coal capacity with CCUS reaches 13 GW in 2060 in the NZE (Figure 4.4), several GW higher than in the APS. Capturing nearly all emissions (97% is assumed) enables these plants to continue operating for decades without putting the wider net zero emissions by 2050 out of reach. The remaining coal plants, up to 8 GW, are converted to use low emissions ammonia. Due to the higher cost of ammonia compared with coal, these plants shifts from baseload operations to focus on the flexibility and higher value market segments. In 2050, ammonia-fired power plants contribute only 2% of total generation, roughly the same as in the APS.

Figure 4.4 ▷ Coal-fired power capacity and electricity generation by type in Indonesia in the Net Zero Emissions by 2050 Scenario, 2021 – 2060



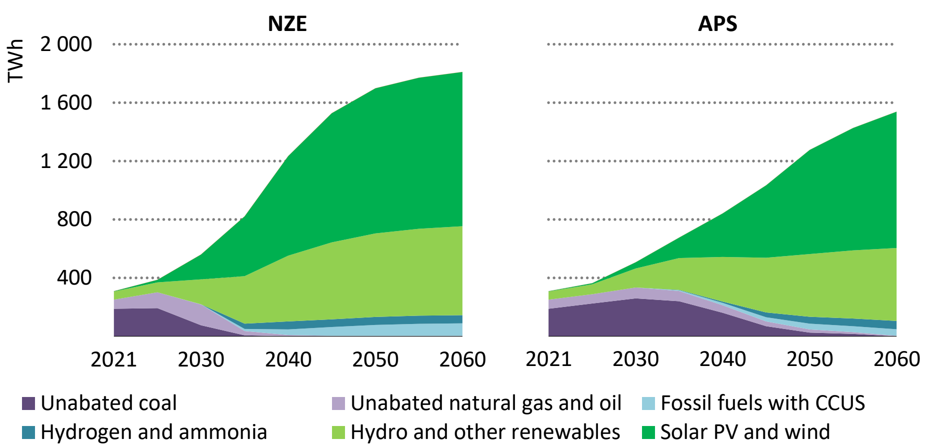
There is no unabated coal-fired generation by 2040, as coal plants are equipped with CCUS, co-fired with ammonia or bioenergy or are retired early

Note: in 2040 some unabated coal capacity remains online as it is being retrofitted with CCUS.

Natural gas-fired power plants follow a similar path as coal plants in the NZE. While unabated capacity expands in the near term, it soon peaks, with capacity factors declining by 2030. Unabated gas-fired generation is mostly phased out by 2040. Yet, many gas-fired power plants are retrofitted with CCUS and remain online, enabling the system to benefit from these young assets and their operational flexibility. In addition, co-firing with increasingly high shares of hydrogen is made possible at many gas plants after retrofits, allowing yet another pathway of continued use without negatively impacting emissions. However, hydrogen-based generation is small in absolute terms, contributing less than 2% to total generation in the NZE in 2050.

The power generation mix is completely re-shaped in the NZE, with low emissions sources completely taking over by 2040 (Figure 4.5). Unabated fossil fuels fall from 80% of the mix in 2021 to under 1% in 2040. Whereas in the APS, this level of decarbonisation of the generation mix takes an additional 20 years, only reaching a similar share from low emissions sources in 2060, leading to 3.7 Gt of additional CO_2 emissions from 2022 to 2060. CCUS technologies are deployed earlier in the NZE as well, capturing almost 2 Gt CO_2 emissions to 2060, double the amount in the APS. Similarly, hydrogen and ammonia also scale up earlier in the NZE, although levels in the APS catch up in the long term.

Figure 4.5 ▻ Electricity generation by source in Indonesia the Net Zero Emissions by 2050 and Announced Pledges scenarios, 2021 – 2060



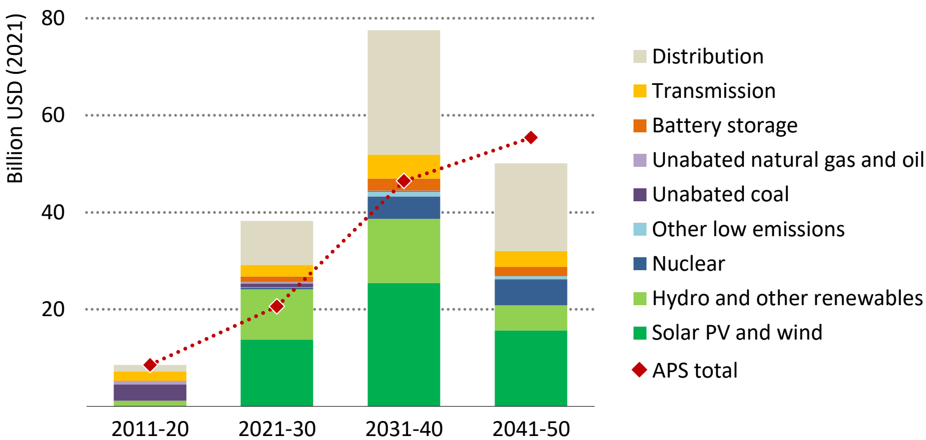
Higher electricity demand is met by scaling up renewables in the NZE, which account for nearly 90% of total generation by 2040 while unabated coal is phased out

Note: NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario.

In order to support the rapid transition in electricity sector in the NZE, transmission and distribution networks also need to be strengthened and expanded at a rapid pace.

Investment in electricity grids increase eightfold in the period to 2030 and maintains a high level in the years that follow (Figure 4.6). In order to enable and accommodate the fundamental shift in electricity generation sources in the NZE, the power grid must adapt to become a stronger, more interconnected network across the whole of Indonesia, and to be able to tap renewables resources and to deliver generated electricity to demand centres. For example, rising electricity demand of the population in Java-Bali surpasses the estimated renewables potential in that region, making it attractive to tap the renewable resources of other islands and transmit the electricity to demand centres (see Chapter 5, section 5.3).

Figure 4.6 ▷ Average annual investment in the electricity sector by type in Indonesia in the Net Zero Emissions by 2050 Scenario



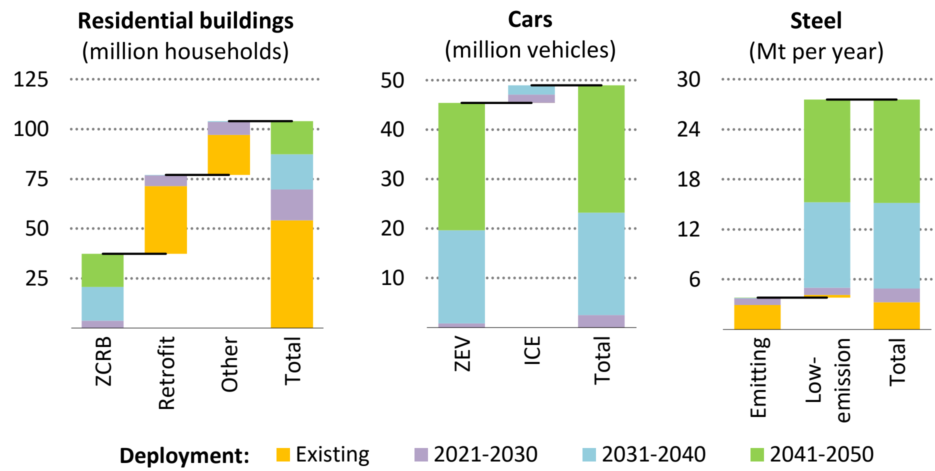
Significant boosts to investment for low emissions generation and networks enables accelerated decarbonisation of the electricity sector in the NZE relative to the APS

Note: NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario.

4.4 Focus on energy end-use

Many industrial plants and buildings have lifetimes up to several decades, so achieving net zero emissions by 2050 in a smooth and cost-efficient manner requires early and concerted action to shift to low emissions and efficient energy technologies across all end-uses. Buildings existing today make up half of the residential building stock in Indonesia in 2050. So achieving the efficiency levels needed in the buildings sector to achieve net zero emissions by 2050 requires retrofitting the existing stock. In parallel, over 40 million residences will be constructed in the period to 2050, underscoring the need to increase the stringency of energy-related building codes. In the NZE almost 85% of these new buildings are all electric zero carbon-ready buildings (Figure 4.7).

Figure 4.7 ⊳ Equipment stock in 2050 by deployment period and technology in Indonesia in the Net Zero Emissions by 2050 Scenario



Rapid action ensures that stock added in the coming decades is compatible with net zero emissions and also improves the existing stock via retrofits and retirements

Notes: Buildings: ZCRB = zero carbon-ready building; other includes buildings that are not ZCRB aligned. Cars: ZEV = zero emissions vehicles; ICE = internal combustion engine vehicles. Steel plants: emitting = conventional CO_2 emitting steel plants, low emission = plants with CCUS, hydrogen-based direct reduced iron, electric arc furnaces, or other non-emitting plants. When emitting plants are retrofitted with CCUS they are considered as new capacity.

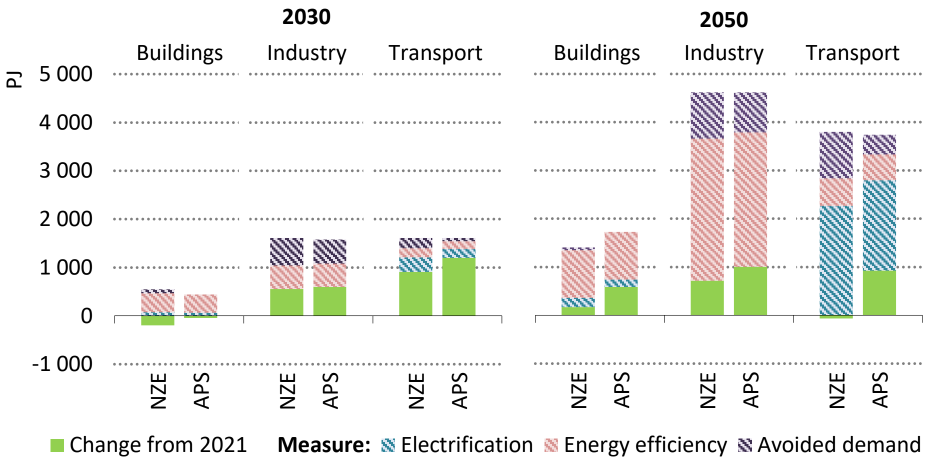
In the industry sector, capacity existing today or built before 2030 is largely traditional CO_2-intensive processes. After 2030 and especially in the 2040s, many existing energy-intensive industrial processes are retrofitted with CCUS while low emissions technology approaches are deployed in new additions.

Road vehicles have shorter expected lifetimes than factories and buildings. Thus there will be more stock turn-over in the period to 2050. Banning sales of internal combustion engine (ICE) cars in the 2030s and the uptake of electric vehicles, including two/three-wheelers, means that more than 90% of the passenger car stock in 2050 is zero emissions, and the remaining ICE vehicles run mostly on biofuels.

4.4.1 Measures to improve energy efficiency

Rapid improvements in energy efficiency, including through electrification and avoided demand, are fundamental in the clean energy transition (Figure 4.8). Efficiency gains reduce both consumer bills and import dependency further in the NZE than the APS. The rate of increase in total final energy consumption is curtailed from 1.2% per year in the APS to 0.4% per year in the NZE in the period to 2050. This means that final energy consumption over the period rises by 13% in the NZE versus 40% in the APS. Electrification of end-uses is faster in the NZE, which delivers the efficiency gains associated with the use of electricity and the benefits of reduced air pollution. The NZE path also includes measures that rein in energy demand growth through improved materials use and some limited behavioural changes (Figure 4.8).

Figure 4.8 ▷ Changes in energy demand by sector and savings from electrification, efficiency and avoided demand in Indonesia in the Net Zero Emissions by 2050 and Announced Pledges scenarios, 2030 and 2050

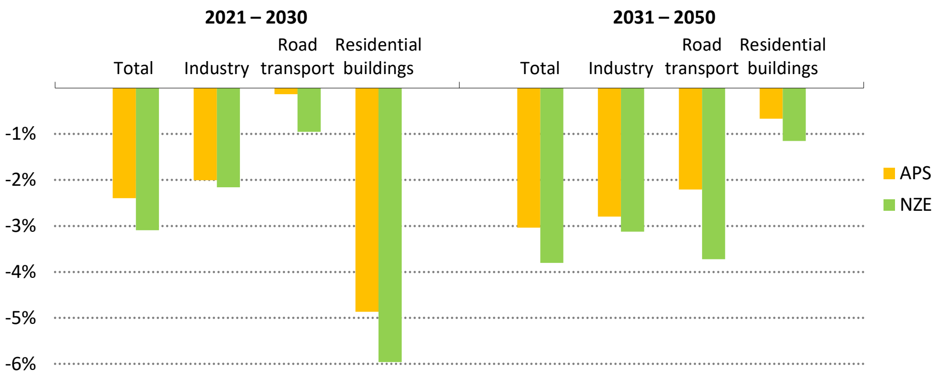


Electrification, energy efficiency and avoided demand reduce energy demand growth in both scenarios

Notes: NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario. Avoided demand includes materials efficiency, structural and economic effects (such as the response of consumers to higher prices) and behavioural changes.

Measures to reduce energy demand growth in the NZE do not adversely impact economic or wellbeing outcomes for Indonesian citizens. They are implemented in the context of the population expanding by 55 million people, a 20% increase, and an economy that triples in value over the period to 2050. The final energy intensity of the economy improves nearly 3% per year on average in the APS and around 3.5% in the NZE (Figure 4.9).

Figure 4.9 ⊳ Average annual change in energy intensity of final energy consumption in Indonesia in the Net Zero Emissions by 2050 and Announced Pledges scenarios, 2021 – 2030 and 2031 – 2050



Energy intensity of the economy and in key sectors improves significantly

Notes: NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario. Total = unit of energy per unit of GDP. Industry = unit of energy per unit of value added. Road transport = unit of energy per vehicle-kilometre. Residential buildings = unit of energy per unit of floor area, including the traditional use of biomass which is phased out by 2030.

Buildings

Final energy consumption in the buildings sector in 2050 is around 11% higher (170 PJ) than in 2021 in the NZE, and 40% higher in the APS. This modest increase in the NZE happens in the context of a more than twofold increase in the total floor area in residential buildings by 2050. Demand growth is mitigated by the phase-out of the inefficient traditional use of biomass and the shift to zero carbon-ready standards for new buildings. As a result, the energy intensity of residential buildings improves by an annual average of almost 5% to 2030 in the APS, and by 6% per year in the NZE.

Energy efficiency plays the largest role in suppressing growth in energy demand in the buildings sector. In addition to stringent standards for new buildings, the rate of energy-related renovations of existing buildings rises to almost 3% in 2030 in the NZE and around 2% in the APS, compared to around 0.5% today. Retrofitting existing buildings to the performance standards of new constructions is a key measure to curb energy demand growth as ownership of air conditioners and appliances surges with rising incomes in Indonesia. The combination of efficiency measures for buildings reduces the average energy demand per square metre of cooled floor space from over 60 kWh/m^2 today to around 40 kWh/m^2 in 2030 and less than 20 kWh/m^2 in 2050 in the NZE.

Minimum energy performance standards help to reduce energy demand growth to power appliances and equipment as ownership rates grow rapidly from a current low base. For example, around one-in-ten households in Indonesia today owns an air conditioning unit, but in 2050 there are 1.7 air conditioning units per household on average. Yet, due to technical efficiency improvements of air conditioning units, as well as better thermal insulation in existing and new buildings, this twenty-fold increase in demand for cooling is met by only a sixfold increase in energy demand for cooling in the NZE (and almost eight-fold in the APS).

There is also a role for avoided demand and electrification measures in the buildings sector. Together these types of measures reduce demand growth by an amount equivalent to around 10% of 2030 demand in the NZE, although their impact declines by 2050. Some of this impact comes from reducing wasteful energy use, such as reducing boiler temperatures for water heating (which predominantly reduces oil use in 2030, but electricity demand by 2050) and reducing the temperature at which clothes are washed.

Industry

Energy efficiency improvements in industry reduce demand growth to 2030 by around 350 PJ in the NZE. This trend continues to 2050, due to the combined effects of retiring less energy efficient assets and technological efficiency gains in new assets: by 2050 energy efficiency avoids around 1 200 PJ of energy demand in NZE. Gains in material efficiency, which is a set of measures to make the most of materials by improving the design or extending the lifetime of goods and buildings, also contributes strongly to the reduction in energy demand. Steel and cement production is around 10% lower in 2050 in the NZE compared to the APS due to material efficiency, and related energy use is more than 30 PJ lower, or 1% of total industry demand. The energy intensity of industry decreases by almost 2.2% per year in the NZE (2% in the APS) between 2021 and 2030, due to a combination of improving existing installations, the replacement of old plants by best available technologies, deployment of best-in-class electric motors and heat pumps in other industries, increased reliance on secondary production[2] for steel or aluminium, and on alternatives to clinker for cement production.

Transport

Final energy consumption in the transport sector in 2050 is around 40% higher (900 PJ) than in 2021 in the APS, but is 3% (65 PJ) lower than in 2021 in the NZE. In the APS, improvements in energy efficiency save over 500 PJ in transport energy demand to 2050, with the remaining energy savings coming from electrification, mainly of cars. In the NZE, however, while energy efficiency gains happen more quickly than in the APS, there is also a huge push to electrify across road transport modes, including buses and light trucks. For example, EVs make up 45% of car sales in the NZE by 2030, whereas they account for around 20% in the APS. For other modes the difference is starker: over one-in-three heavy-duty trucks sold in 2035 is electric in the NZE, relative to fewer than one-in-twenty in the APS.

This means that electrification provides over half of the avoided growth in transport sector energy demand in the NZE to 2050, and one-quarter comes from avoided demand due to

[2] Secondary production is based on recycled material such as scrap material.

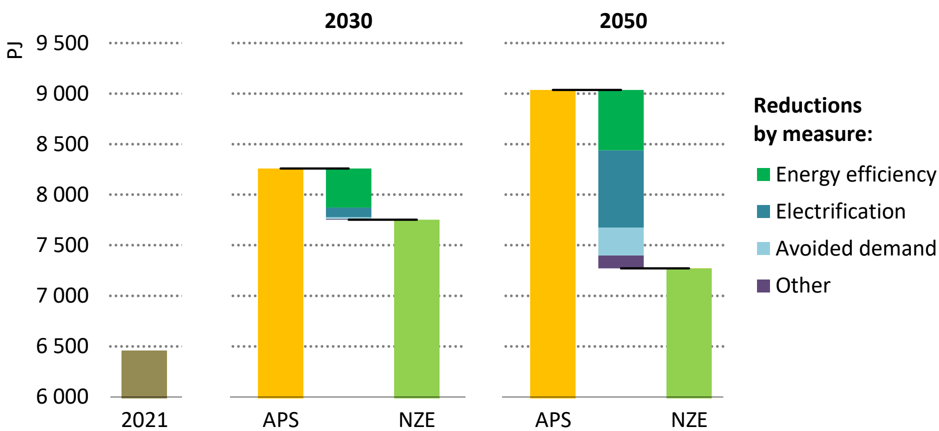
behavioural changes. These include more use of public transport, the reduction of ICE car use in city centres, increased teleworking to reduce commuting by car and less flying for business purposes.

There is significant activity growth in all modes of road transport over the period to 2050. For example, in the APS there is a fivefold increase in car travel and a fourfold increase in bus travel. However, the energy intensity of road transport in vehicle-kilometre terms falls by 0.1% per year on average between 2021 and 2030, and 2.2% per year on average between 2031 and 2050, as electrification accelerates. In the NZE, energy intensity falls at seven-times this rate to 2030, and almost twice this rate between 2031 and 2050. The result is that by 2050 driving one kilometre (km) by car requires about two-and-a-half times less energy than today in the APS, and almost three-and-a-half times less energy in the NZE.

Bridging the gap from the APS to the NZE

Across the energy system as a whole, energy efficiency is a common denominator to reduce energy demand growth in the NZE. This is particularly true in the near term: differences in the speed of energy efficiency improvements between today and 2030 account for over three-quarters of the gap between the APS and the NZE in final energy consumption (Figure 4.10). By 2050, faster electrification in the NZE takes over as the main path to curb energy demand, chiefly due to the electrification of road transport.

Figure 4.10 ▷ Total final energy demand in both scenarios and reduction measures in the Net Zero Emissions by 2050 Scenario in Indonesia, 2030 and 2050



By 2030, energy efficiency provides the bulk of energy demand reductions and by 2050 electrification and avoided demand are also important contributors

Notes: NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario. Other includes CCUS and non-electrical fuel switching.

Energy efficiency is key to close the gap in the near term because it relies mainly on technologies and economic options that, for the most part, are available on the market today. Highly energy efficient cars, light bulbs and air conditioners are sold today, the challenge is getting people to buy them. By contrast, the electrification of many end-uses depends on technologies which are not commercially viable at scale today (such as electric trucks), and which can require supportive infrastructure (such as charging networks). The rewards of a concerted and immediate push to electrify in the NZE therefore only become manifest in reducing final energy demand after 2030. In a similar vein, avoided demand from material efficiency gains and behavioural changes often depends on changes in long-established industrial practices or socio-cultural habits, often facilitated by infrastructure (such as public transport networks) or technologies currently far from the mainstream in their use.

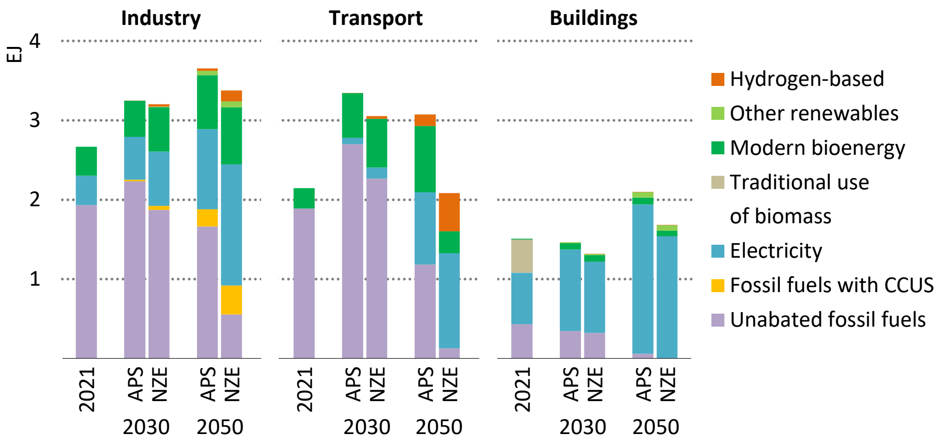
4.4.2 End-use fuel switching to electricity and low emissions fuels

The NZE requires a much more rapid uptake of electric technologies and low emissions fuels such as modern bioenergy, hydrogen and hydrogen-based fuels, compared to the APS. Demand for electricity and low emissions fuels increases by more than 7% annually between 2021 and 2030 in the NZE. By 2030, the share of these energy sources in end-use sector energy demand rises to 40%, up from 25% today and six percentage points higher than in the APS in 2030. The rapid pace of fuel switching across end-uses is maintained in the 2030s and 2040s, a result of ambitious policies to drive the uptake of clean energy technologies and, in certain cases, restrictions on sales of fossil fuel using technologies. By 2050, almost 85% of end-use energy demand is met by electricity and low emissions fuels in the NZE, and an additional 5% is met by fossil fuels with CCUS.[3] This compares to an electricity and low emissions fuel share of around 65% in the APS by 2050. Electricity is the dominant source of energy for end-use sectors in the NZE by 2050, meeting almost 60% of demand, up from 22% in 2030 and 16% today.

The pace of fuel switching is fastest in the transport sector, with use of low emissions fuels increasing by more than 10% annually from 2021 to 2030, led by increasing demand for biofuels and electricity. By 2030, 26% of energy demand in the transport sector is met by low emissions fuels and electricity, compared to 12% today and 19% in the APS in 2030. Electricity accounts for only 5% of this total, but due to higher efficiency of EVs, they represent over 20% of the total road vehicle stock in 2030. Industry sees the biggest gap between the APS and NZE in 2030, with low emission fuels increasing by 7% annually and meeting 40% of demand by 2030 compared to 31% in the APS. The traditional use of biomass is phased out completely by 2030 in both scenarios, while faster improvements in energy efficiency in the NZE reduce electricity demand growth from air conditioners and appliances relative to the APS. As a result, the share of low emissions fuels in the buildings sector is broadly similar at three-quarters in both the NZE and APS in 2030 (Figure 4.11).

[3] When excluding fossil fuels used for plastics and other feedstocks, the share of electricity and low emissions fuels is 95%.

Figure 4.11 ▹ **Energy demand by sector in Indonesia in the Net Zero Emissions by 2050 and Announced Pledges scenarios, 2030 and 2050**



Effective policy frameworks and regulations in the NZE drive rapid shifts to low emissions energy in all sectors, and by 2050, almost 60%of final demand is met by electricity

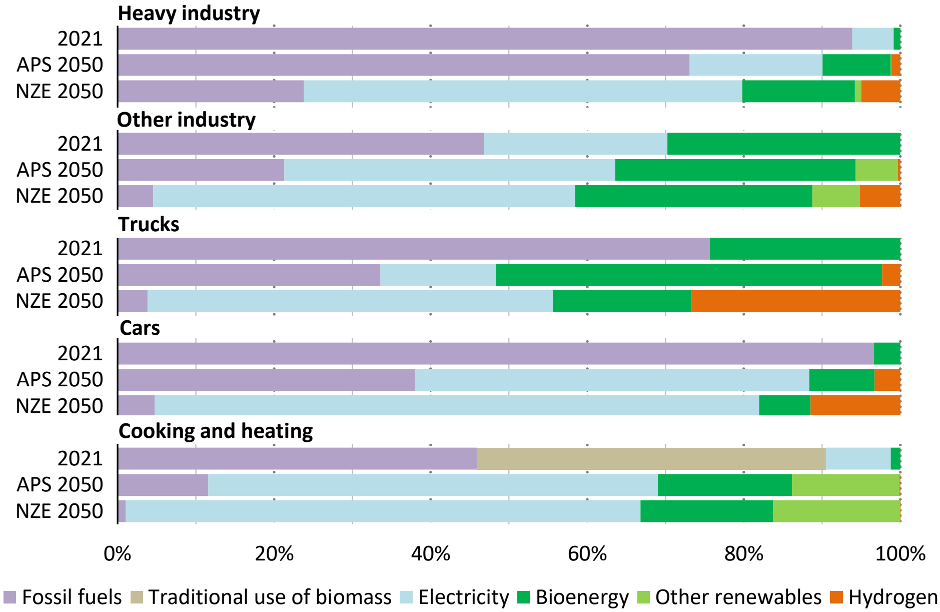
Note: NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario.

As 2050 approaches, the NZE sees an almost full phase out of fossil fuels in the *buildings sector*, and efficiency pushes electricity demand lower than in the APS. Almost 100% of cooking and heating energy demand is met by low emissions energy sources, including two-thirds by electricity (Figure 4.12).

In the *transport sector*, the imperative to reduce oil demand by 2050 results in more rapid electrification of all road transport; the share of oil in passenger vehicle energy demand drops to around 5% by 2050 in the NZE compared to 38% in 2050 in the APS. Progress in reducing oil demand in trucks is achieved thanks both to rapid scaling up of biofuels use in the short term (reaching 40% of demand by 2040), and subsequently shifting sales to electric models as they become increasingly market mature. By 2050 less than 5% of energy demand for trucks is met by oil.

In *industry*, reducing fossil fuel use is more complicated, especially for heavy industry where high-temperature needs often limit the potential for heat pumps. Nonetheless, use of electric resistance heaters and significant technology improvements for heat pumps, and an increasing share of electric arc furnaces in the steel subsector, result in electricity meeting over half of heavy industry energy demand by 2050 in the NZE, with bioenergy and hydrogen accounting for a further 20%. Bioenergy plays a bigger role in other industry, notably in food processing where waste organic material, such as empty palm oil kernels, is used directly to provide onsite heat.

Figure 4.12 ⊳ Energy mix for selected end-uses in Indonesia in the Net Zero Emissions by 2050 and Announced Pledges scenarios, 2050



Much more rapid switching to electricity and low emission energy sources is required in the NZE, especially in hard to abate sectors such as heavy industry and freight

Notes: NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario. Fossil fuels include both unabated and abated use of coal, oil and natural gas. Other renewables refers to solar thermal and geothermal. Hydrogen includes direct use of low emission hydrogen, as well as low emission hydrogen-based products such as ammonia.

Major policy and regulatory milestones are required in order to drive the transformation of the energy mix across end-uses in the NZE. For the *transport sector*, the economic and environmental advantages of electrifying the two/three-wheeler fleet in Indonesia allow for sales of ICE models to be phased out fully by the early 2030s in the NZE, with support policies for poorer families to stimulate this shift. For cars, their long operational lifetime means that to achieve the 2050 emissions objective the sale of conventional ICE cars is banned by 2035, taking advantage of the massive emergence of electric models with increasingly more attractive payback periods. Despite few models available on the market today, electric trucks begin to enter the market by 2025 in Indonesia (compared to the 2030s in the APS) and are rapidly scaled up, with sales of conventional ICE trucks phased out by 2045.

Battery electric models become increasingly cost competitive for shorter distances, while hydrogen and biofuels are the most cost-effective options for heavy-duty trucks travelling distances of 800 km or more. Emissions standards for trucks as well as later bans on ICE truck sales are the key levers to increase the use of low emissions fuels in freight trucking. While liquid biofuel use is increasingly phased out for short distances as ICE trucks leave the market, biofuels nonetheless have a critical role to play in decarbonising aviation and shipping in the NZE, with blending mandates leading to over 10% of aviation energy demand met by sustainable aviation fuels by 2030 and 75% by 2050. This includes synthetic kerosene, which meets 45% of aviation demand in 2050, driven by blending mandates.

In the *industry sector*, the long lifetimes of industrial equipment require accelerated implementation of efficiency and emissions standards for key processes, as well as CO_2 pricing, in order to encourage rapid adoption of low emissions technologies for plants developed in the 2020s and 2030s. The limited availability of electric technologies for many industrial processes due to high-temperature needs, and the limited maturity of hydrogen-based technologies, means that CCUS is the most cost-effective option for many cement, chemical and steel plants, with CCUS also allowing for the capture of industrial process emissions. By 2030, CO_2 emissions captured increase to 10 Mt in the NZE compared to 4 Mt in the APS across the industry sector. Addition of CCUS capacity accelerates in the 2030s and 2040s, as well as retrofitting existing plants with CCUS: by 2050 more than 30 Mt CO_2 are captured annually. 90% of cement production is covered by CCUS, as well as more than 60% of ammonia production and more than 90% of iron production.

The industry sector also increasingly shifts towards low emissions hydrogen use in the NZE as 2050 approaches. Almost 2 Mt are produced from fossil fuels today and used onsite, mainly for ammonia production and less so for iron production. By 2030, hydrogen consumption across the energy sector increases by 1 Mt (almost all of this additional use is low emissions hydrogen). After 2030, electrolytic and CCUS based low emissions hydrogen production steps up to meet rising hydrogen demand. In 2050, almost 10 Mt of low emissions hydrogen are used in Indonesia's energy system in the NZE, of which 1.5 Mt are from natural gas with CCUS and the remainder is renewables-based electrolytic hydrogen. To cope with this massive uptake, Indonesian industry deploys almost 6.5 GW of electrolyser capacity in the NZE, 20-times today's installed capacity.

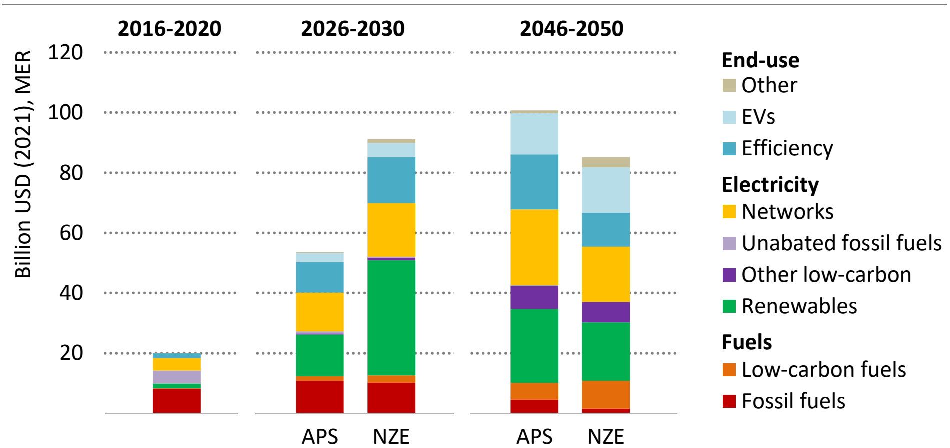
In the *buildings sector*, major difference between the APS and the NZE relate more to the efficiency of the equipment and appliances sold and the buildings constructed, than to the fuels used. Even in the APS, 90% of demand in 2050 is met by electricity and 97% by non-emitting energy sources. Nonetheless, more rapid fuel switching in the NZE is critical to bring emissions from the buildings sector to zero, and to reduce emissions on the pathway to 2050. While the NZE and APS follow similar paths to 2030 for cooking and water heating, delivering universal access to clean cooking with a mix of electricity, liquefied petroleum gas (LPG) and modern bioenergy, the scenarios diverge post-2030, and by 2050 an extra 15 million households are cooking with electricity in the NZE compared to the APS. The number of high efficiency heat pump water heaters is also considerably larger in the NZE, approaching 50 million by 2050 compared to 35 million in the APS. Bioenergy (in gaseous, liquid and solid forms) contributes to meeting almost 20% of cooking and heating energy demand, and solar thermal over 15%, almost exclusively for water heating.

4.5 Investment and affordability

4.5.1 Investment

The huge ramp up in low emissions sources of electricity, in particular renewables, projected in the NZE necessitates large increases in investment in both generation capacity and networks (Figure 4.13). Electricity sector investments drive the massive increase in total investment in the NZE. Total investment in the energy sector increases by more than four-and-a-half-times by 2030, relative to the average level over the 2016 to 2020 period. To put this in perspective, in the same period, Indonesia's GDP increases by 60% and electricity generation increases by almost 80%. This implies a substantial increase in the capital intensity of the energy sector.

Figure 4.13 ▷ Average annual investment in Indonesia in the Net Zero Emissions by 2050 and Announced Pledges scenarios, 2016 – 2050



Energy sector investment needs to increase by more than four- and-a-half-times by 2030 in the NZE, a pathway that is 70% more capital intensive than the APS pathway

Note: MER = market exchange rate; NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario. Networks also includes battery storage.

In recent years, energy sector investment amounted to around 2% of GDP each year in Indonesia. In the NZE, this increases to around 5.2% by 2030, nearly tripling the energy sector's call on macroeconomic resources. However, over the last twenty-five years, Indonesia has seen large variations in the amount of annual GDP dedicated to investment across all sectors. As Indonesia recovered from the Asian financial crisis, the investment share of GDP doubled in the span of just six years, with the average annual increase of 0.34 percentage points per year matching the increase seen in the NZE in the coming decade. In other words, from a purely macroeconomic perspective, sustaining the increase in investment levels seen in the NZE is not unprecedented by any means.

Total energy sector investment increases from an annual average of around USD 20 billion in recent years to around USD 90 billion by 2030 in the NZE. This is 70% higher than in the APS in the same year; the largest driver is renewables in the electricity sector, which accounts for nearly two-thirds of the investment increase between the APS and NZE in 2030 (in absolute terms, an increase of about USD 25 billion). Investment in networks also increases by close to USD 5 billion in the NZE compared to the APS. Achieving the rate of electricity sector decarbonisation seen in the NZE, with both electricity sector emissions and unabated coal reaching net zero by 2040, therefore requires additional electricity sector investment of around USD 30 billion by 2030.

This near-term investment is essential to deploy renewables fast enough to supplement and then replace coal-fired generation and to meet electricity demand growth. This massive rise of renewables lays the foundation for coal to start being retired in the 2030s while ensuring sufficient quantities of alternative generation.

In the longer term, the level of investment in the NZE decreases both in absolute terms and expressed as a share of a growing GDP. By 2050, total annual energy investment in the NZE is around USD 10 billion lower than in 2030. The investment in the NZE declines to around 2% of GDP in 2050, as once the low emissions power plants and networks, factories, vehicles and appliances have been established, the rate of investment is no longer determined by the accelerated replacement of existing high-emitting energy infrastructure.

In 2050, end-uses make up one-third of total energy sector investment, up from around a quarter in 2030. As the electricity sector is the first to reach net zero emissions around 2040, end-uses then come to be the dominant drivers of energy sector investment. In 2050, around USD 30 billion is spent on energy efficient equipment and processes, low emissions vehicles and other end-use decarbonisation options such CCUS in industry. This is on the same order of magnitude as the peak of investment spending on electricity sector renewables, highlighting the importance of policy frameworks to unlock investment by energy end-users such as households, businesses, industries and municipalities.

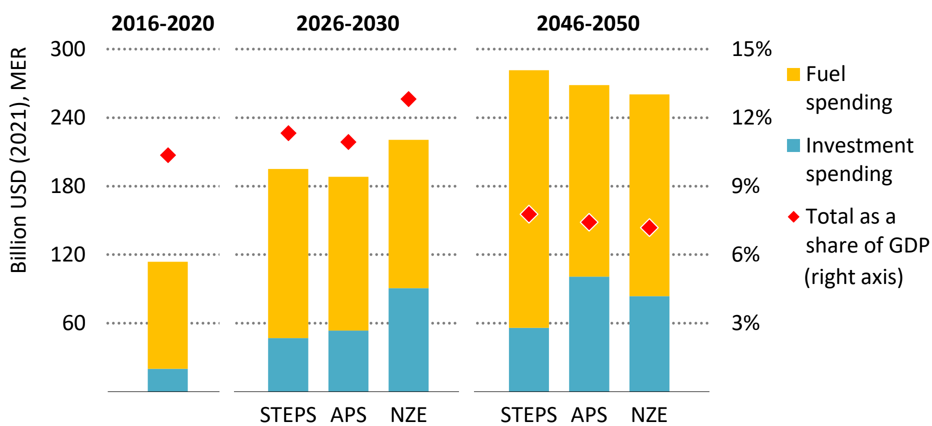
4.5.2 Aggregate energy system costs

A low emissions energy system is more capital intensive than an energy system based on the combustion of fossil fuels, because most low emissions sources tend to have low fuel costs, but high capital costs. Thus, even though investment needs may be higher in the NZE, this will be at least partially offset by lower fuel spending by households and businesses. Total energy sector costs represent the sum of investment spending and spending on energy bills.

Financing costs – capitalised interest on debt and returns on equity – are a major component of investment spending, and they also rise in capital intensive energy transitions. Managing financing costs and diversifying the sources of finance become increasingly important to make these transitions affordable.

Before the current high energy price environment, global average energy prices in the preceding years were relatively low, reflecting low oil prices in 2017 and 2018, and the collapse in energy prices in 2020 as the Covid-19 pandemic took hold. Those effects, combined with the slow unwinding of today's high price environment, result in total energy costs expressed as a share of GDP increasing to 2030 in a scenario where no additional policy action is taken to reduce emissions, represented by the IEA's Stated Policies Scenario (STEPS). In recent years, energy system costs in Indonesia were equivalent to around 10% of its GDP per year, including both investment and fuel costs. In the STEPS, this increases to around 11% per year by 2030, as fuel prices rise compared to historical levels (Figure 4.14).

Figure 4.14 ▷ Average annual energy system costs in Indonesia in the three scenarios, 2016 – 2050



Higher investment drives up energy system costs in the near term, but this pays dividends in the long term to reach net zero emissions

Note: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario.

In the APS, total energy system costs are very comparable to the STEPS by 2030, as the increased investment needed to move Indonesia's energy sector onto the pathway to net zero emissions by 2060 are offset by lower fuel bills. These lower fuel bills are driven both by more efficient consumption and by lower world prices for key energy commodities as countries implement their net zero emissions pledges. In the NZE, total energy costs in Indonesia by 2030 are higher than both the STEPS and APS by almost 2% of GDP. This reflects that the high energy sector investments in the NZE are not yet fully compensated by lower fuel bills.

The picture changes by 2050. Energy costs are higher in absolute terms in 2050, but lower as a share of GDP compared to today's level in each of the three scenarios. In the STEPS, total energy costs are lower than today as a share of GDP, as higher incomes are spread across a range of goods and services, not just energy, and energy efficiency has also improved. In the

APS, however, total energy costs are about 0.5% lower as a share of GDP, compared to the STEPS. Although annual energy sector investment continues to be higher in the APS compared to the STEPS in 2050, these investments are compensated by lower fuel bills.

This trend is even more pronounced in the NZE. Higher near-term investments leave less to be done in the long term in the NZE, and so investments are smaller than the level seen in the APS in 2050, but the NZE delivers lower emission levels. As the energy system in the NZE is predominantly based on efficient, low emissions technologies by 2050, lower fuel bills lead to a total energy cost that is the lowest in any of the three scenarios.

In other words, the surge in investment projected in the NZE raises energy system costs in the near term, but in the longer term, they are compensated in the form of lower fuel bills.

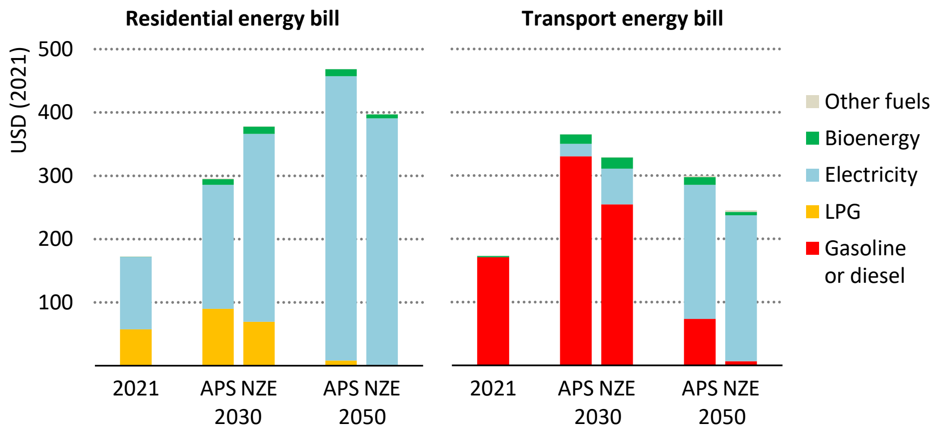
4.5.3 Affordability

The accelerated pace of the energy transition in the NZE paints a different picture for household energy bills and purchases of appliances and vehicles. Overall, households face increased energy bills in the near term, as both consumption and electricity prices rise, though over the longer term, household spending on energy in the NZE drops below APS levels, largely thanks to the impacts of efficiency and electrification. While the NZE offers lower bills in the longer term, financial and regulatory support nonetheless is crucial to enable low income households to switch to cleaner technologies faster, and to assist them in managing short-term bill increases.

Oil products make up the largest share of household spending on energy today in Indonesia, due to their dominant role in transport and the widespread use of LPG for cooking. By the late 2020s, electricity takes the largest share of household energy expenditure, a result of the rapid electrification of cooking, two/three-wheeler transport, and increasingly, electric cars. Prices also play a significant role in pushing up household spending on electricity, as the major short-term scale up of renewables deployment in the NZE relative to the APS requires an increase in consumer electricity prices to 2030. Beyond 2030, electricity prices begin to decline in the NZE and the improvements in the energy efficiency of appliances and buildings further moderate electricity bills. By 2050 in the NZE, consumers spend less on electricity for the home than in the APS. Spending on electricity for transportation remains higher in the NZE than the APS in the longer term, yet this is a function of the faster and more widespread electrification of transport. The efficiency gains associated with the electrification of transport more than offset the higher price of electricity relative to oil, leaving total household spending on transport lower in the NZE than the APS. The gains are especially strong in the short term, largely due to rapid electrification of two/three-wheelers (Figure 4.15).

Households gradually move away from LPG to electric cooking solutions, such as induction plates and electric resistance rice cookers in both the NZE and APS cases. The transition is incentivised in both the APS and the NZE by policies to assist households to purchase efficient electric equipment, and concurrent phase out of non-targeted LPG subsidies. By 2030, the resultant increase in LPG prices drives up total household expenditure on LPG, but also renders electricity a cheaper cooking option for most households. Particular care will be required during this transition to ensure that the affordability of energy is not compromised for the poorest households. By 2050, the economics of LPG and support for households to access electric equipment brings household LPG use to a negligible level.

Figure 4.15 ▷ Annual household energy bills in Indonesia in the Net Zero Emissions by 2050 and Announced Pledges scenarios, 2030 and 2050



Household bills are higher in the NZE to 2030, but greater efficiency puts bills below the APS in the long term, compounding the savings from electrifying passenger transport.

Note: NZE = Net Zero Emissions by 2050 Scenario; APS = Announced Pledges Scenario. Transport energy bill includes expenditure used in personal transportation, in passenger light-duty vehicles and two/three-wheelers.

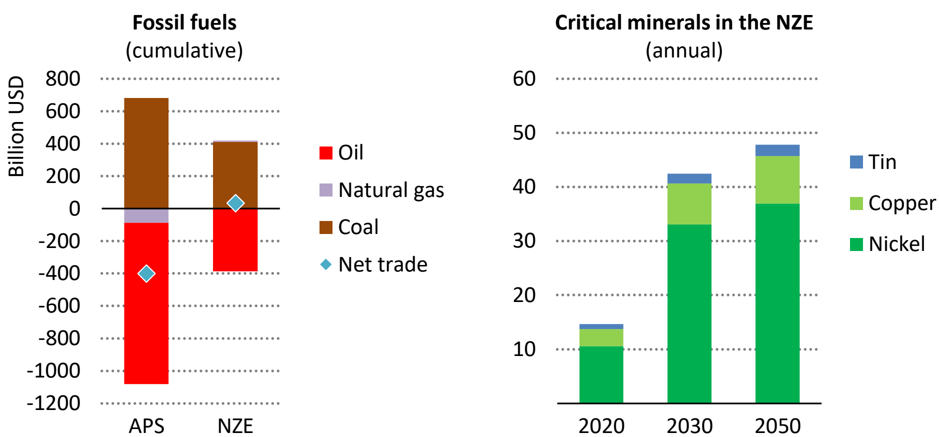
For transport energy bills, the speed of electrification is significantly faster in the NZE than in the APS. Electric two/three-wheelers bring the biggest affordability improvements over the NZE pathway as their total cost of ownership, i. e. purchase and operating costs, is close to parity with conventional motorcycles in Indonesia already as battery costs have come down quickly (Afraah, 2021). Unlocking the affordability and other benefits of electromobility requires overcoming upfront cost barriers, buying an electric two/three-wheeler today would take around one-third of the annual income for households in the median income decile in Indonesia. Subsidies to support fossil fuels can be gradually redirected, in a targeted manner, to support purchases of efficient appliances and electric vehicles.

4.5.4 Implications for trade

Indonesia's trade in fossil fuels changes significantly in the NZE compared with the APS, as global markets are transformed in the drive to reach net zero emissions from the energy sector by 2050. The value of Indonesia's coal exports are around USD 270 billion lower between 2021 and 2050 in the NZE relative to the APS, as the coal market, particularly in its main markets in the Pacific Basin, declines much faster in the NZE. Total cumulative net trade of natural gas is higher in the NZE compared to the APS, as the faster transformation of Indonesia's energy sector frees up more natural gas for exports.

But the real difference is in oil imports. In the APS, despite the rapid restructuring of its energy sector, total oil imports still amount to nearly USD 1 trillion between 2021 and 2050. In the NZE, this value is more than halved, due to lower domestic oil consumption and lower global prices.

Figure 4.16 ⊳ Fossil fuel trade and annual revenues for critical minerals in Indonesia in the Announced Pledges and Net Zero Emissions by 2050 scenarios, 2021 to 2050



Reduced oil imports lower the cumulative energy trade deficit by USD120 billion in the NZE

Regarding critical minerals needed for the energy transition, the outlook changes substantially between the two scenarios. In the APS, total annual revenues from the production of nickel, copper and tin are around USD 33 billion in 2030 and nearly USD 40 billion in 2050, assuming Indonesia maintains its current 9% share of the global market for these three critical minerals. In the NZE, the size of the global market is larger due to stronger decarbonisation efforts. Indonesia's total annual revenues from critical minerals production reaches more than USD 40 billion in 2030 in the NZE, 50% higher than the highest ever value of Indonesia's coal exports. By 2050, total annual revenues from critical minerals production reach almost USD 50 billion in the NZE, with a 9% market share. If Indonesia increases its market share to around 20% of the global market, total revenues would be around USD 80 billion annually by 2050.

Key implications

Opportunities and challenges on the road to net zero emissions

SUMMARY

- About 1.3 million people, 1% of Indonesia's workforce, are currently employed in the energy sector, of which over one-third of the jobs are related to coal. Indonesia has some of the most coal mining dependent regions in the world. For example, coal accounts for up to a third of GDP, three-quarters of exports and 4-9% of total employment in some provinces in Kalimantan. We estimate that a pathway to net zero emissions by 2060 could entail a net gain in employment by 2030, but forward-looking and integrated policies are essential to ensure a just transition for exposed workers and communities.
- With the recent surge in world energy prices, the cost of energy subsidies in Indonesia is set to climb to about 3% of GDP for 2022, which equates to nearly one-fifth of government revenue. An orderly energy transition can provide a degree of protection for consumers even as subsidies are phased out. In the Announced Pledges Scenario (APS), average household energy bills rise to around USD 660 in 2030, yet are below current unsubsidised levels as a share of household disposable income.
- The costs of net imports of oil and gas increase from about USD 17 billion in 2021 to nearly USD 100 billion in 2050 in the Stated Policies Scenario (STEPS), increasing pressure on Indonesia's balance of payments. In the APS, however, net imports of oil and gas peak by 2035 and decline thereafter, driven by lower global prices and reduced domestic demand.
- Coal is critical to Indonesia's economy. It is also exposed to global policies to mitigate climate change. An estimated 85% of Indonesia's coal exports are bound for countries that have a net zero emissions pledge. Exports from Indonesia's low cost coal reserves are more resilient than those of other exporters in the APS projections, yet they contract from about 340 million tonnes of coal equivalent (Mtce) in 2021 to 175 Mtce by 2050.
- Notably, Indonesia is a crucial producer of critical minerals needed for the global energy transition. By 2030, the production value its critical minerals more than doubles to around USD 33 billion in the APS, higher than the peak historical value of coal exports of USD 28 billion in 2011. Indonesia, however, needs to improve its environmental performance and governance systems in relation to critical minerals production.
- Total annual energy sector investment is about USD 8 billion higher in 2030 in the APS relative to the STEPS. The APS outlook necessitates increased spending to expand renewables capacity for electricity generation and networks, as well as to boost energy efficiency. To promote the needed investment, current regulatory and market barriers that inflate the cost and inhibit the deployment of otherwise cost-effective

renewables need to removed. Higher levels of investment are offset by lower fuel bills. Energy imports are reduced in the APS to the degree that the difference in import bills between the STEPS and APS to 2050 is larger than the difference in cumulative energy sector investment between the two scenarios.

- Improving the flexibility of the existing electricity system, developing new sources of flexibility, and extending inter-regional electricity networks are essential to integrate the high share of renewables projected in the APS. Coal supplies around half of firm electricity capacity in 2030, but by 2050 this is overtaken by dispatchable renewables, storage and demand-side management. Enhancing the operational flexibility of the electricity system can provide substantial near-term savings, on the order of 5% of annual production costs in 2030.
- In the APS, CCUS applications pick up after 2025, with the amount of CO_2 captured rising to 6 Mt annually in 2030 and reaching around 190 Mt annually in 2060. Indonesia can benefit from its large and well-understood storage potential in depleted oil and gas fields: 45% of emissions sources are located within 50 km of depleted fields.
- Around seven-in-ten people in Indonesia breathe polluted air, which contributed to 150 000 premature deaths in 2021 and cost over 6% of GDP in recent years. There are large reductions in all major air pollutants as the energy sector shifts to cleaner fuels. The APS pathway reduces air pollution-related premature deaths by around 1 million in the 2021-50 period relative to the STEPS.

5.1 Just transition

Transitioning Indonesia's energy sector to net zero emissions will require "just transition" policies to cushion disruption due to structural changes in the economy. But structural change is nothing new for the Indonesian economy. The contribution of oil and gas production to GDP declined from about 10% of GDP in 2000 to 2.4% in 2021 while the wider economy almost tripled in size. And as Indonesia continues to develop, it must address numerous challenges related to the structural transition of its economy and workforce.

A just transition driven by climate policy needs to be seen in the broad context of Indonesia's development pathway, as it does face some particular challenges. Case in point, on some metrics, it is the world's most coal-dependent economy (Box 5.1). Supporting a just transition requires a combination of sound multi-sectoral macroeconomic and social policies going beyond the realm of climate policy per se, as well as targeted, energy-related transition policies, particularly in the coal mining sector.

Box 5.1 ▷ Indonesia's economic and energy sector dependence on coal

To put Indonesia's economic and energy sector dependence on coal in a cross-country perspective, the IEA's multi-component Coal Transition Exposure Index (CTEI) is useful. This index includes four categories of dependence, each with two quantifiable indicators.

- *Energy system dependence*: This category reflects the share of the national energy mix supplied by coal. Its indicators are the share of coal in total energy supply and its share in electricity generation.
- *Development gap*: This category captures the economic development gap a country faces. Less developed countries generally will have higher energy demand growth as they advance, and weaker technological and financial capacities. Its indicators are GDP per capita at purchasing power parity and total final consumption per capita.
- *Economic dependence*: This category looks at the importance of coal to the national economy. The first indicator is the share of coal in national goods exports. The second is the degree of coal self-sufficiency. A country with ample coal to supply domestic consumption has less incentive to consider alternatives to coal.
- *Physical lock-in*: This category looks at the degree of asset lock-in of coal infrastructure. Power plants and industrial facilities that have considerable remaining operating lives may make it more challenging and costly for economies to transition. The indicators are the capacity weighted average age of the coal power plant fleet and the capacity weighted age of the crude steel production capacity.

The CTEI covers 21 countries and combines the largest producers and consumers of coal, representing more than 90% of global coal production and consumption (Table 5.1). In order to provide an aggregate score across different indicators, we normalise the raw data for each indicator. The combined normalised scores for each category are put into quintiles, with each assigned a qualitative score: low, medium low, medium high, high, very high.

Table 5.1 ▻ Coal Transition Exposure Index

	Energy dependence	Development gap	Economic dependence	Lock-in	Aggregate numerical normalised score
Indonesia	Medium high	High	Very high	Very high	5.76
Mongolia	Very high	Medium high	Very high	Low	5.58
China	Very high	Medium high	Medium high	Very high	5.52
Viet Nam	High	High	Medium low	Very high	5.43
India	High	Very high	Medium high	Very high	5.33
South Africa	Very high	Medium high	High	Medium high	5.15
Botswana	Very high	High	Low	Medium high	3.97
Zimbabwe	Medium low	Very high	High	Medium low	3.95
Colombia	Low	High	Very high	Medium low	3.72
Pakistan	Low	Very high	Low	High	3.63
Kazakhstan	High	Medium low	High	Low	3.62
Türkiye	Medium high	Medium high	Medium low	High	3.57
Poland	High	Medium low	Medium high	Low	3.41
Australia	Medium high	Low	Very high	Medium low	3.27
Bangladesh	Low	Very high	Low	High	3.16
Korea	Medium high	Low	Low	High	2.71
Russia	Low	Medium low	Medium high	Low	2.47
Germany	Medium low	Low	Medium low	Medium high	2.28
Japan	Medium low	Medium low	Low	Medium high	2.21
United States	Medium low	Low	High	Low	1.52
Canada	Low	Low	Medium low	Medium low	1.09

Sources: Based on data from Harvard Kennedy School (2022); World Bank (2022); S&P Global (2021); GID (2022).

Indonesia scores the highest of the 21 countries on the aggregate CTEI. Its energy sector dependence on coal is ranked medium high. Coal in Indonesia accounts for almost one-third of total energy supply and 60% of electricity generation. This is lower than China, where coal accounts for around 60% of total energy supply and around 65% of electricity generation. Indonesia scores high in the development gap category due to its relatively low GDP and energy consumption per capita. But, Indonesia scores very high on economic dependence, with only Australia and Mongolia having higher shares of coal exports in total goods exports. Similarly, Indonesia scores very high in the lock-in category due to the very young age of its capital stock. The average age of its coal-fired power plants is just 12 years, just under China at 13 years, but higher than Viet Nam at 8 years.

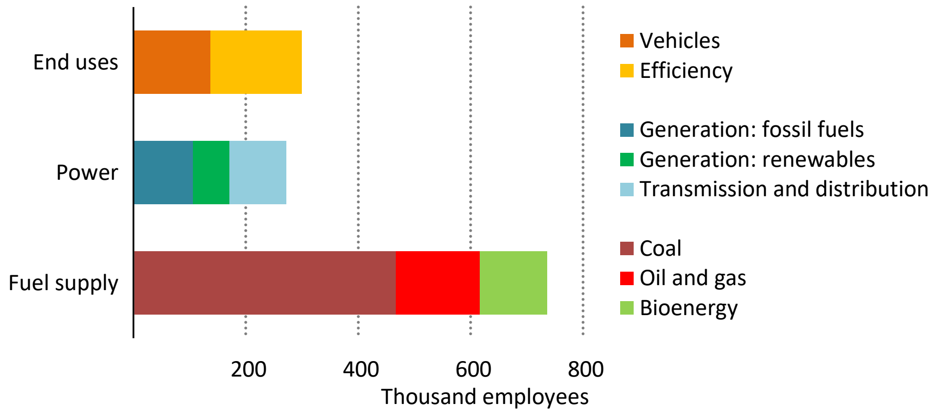
5.1.1 Employment

National energy sector employment

Overall, the labour force in Indonesia has seen steady increases in employment in the last two decades, and totalled 131 million workers in 2019. Employment prospects have been positive, with the unemployment rate at just over 4% in recent years. However, Indonesia's labour force has high needs for training and skills development. Around 10% are high-skilled workers, 70% are medium-skilled and 20% are low-skilled (ILO, 2022). Employment is an important pathway out of poverty. Indonesia's working poverty rate[1] is 3%, well below the regional average among the Association of Southeast Asian Nations (ASEAN).

About 1.3 million people, 1% of Indonesia's workforce, are currently employed in the energy sector (Figure 5.1). This includes jobs in fuel supply, the electricity sector, and end-uses such as vehicle manufacturing and energy efficiency for buildings and industry. The majority of workers in the energy sector have jobs directly associated with the construction or the operation of energy infrastructure. Another 230 000 workers are indirectly employed in the energy sector, manufacturing inputs for the deployment of new technologies. Millions more induced jobs, i.e. jobs generated as a result of spending incomes earned from direct employment, are affiliated with the energy sector, particularly in regions where mining and electricity generation are concentrated.

Figure 5.1 ▷ Energy-related employment by sector in Indonesia, 2019



About 1.3 million – 1% of the employed population – are employed in energy production, generation or end-use electrification and efficiency

Notes: Employment is measured as full-time equivalents. This includes direct jobs in constructing and operating energy assets and indirect jobs for manufacturing of immediate inputs to the energy sector. Induced jobs are not included. Informal employment is included based on best available estimates. Vehicles includes the manufacturing of both conventional and alternative drivetrain vehicles.

Around 735 000 workers are employed in fuel supply. This includes around 465 000 working in the production and transportation of coal and 150 000 employed in the production, refining and transportation of oil and gas. It also includes bioenergy-related employment, which is the most difficult to measure due to the largely informal nature of biomass cultivation, collection and retailing, but is estimated at approximately 120 000 workers.

[1] Working poverty rate conveys the percentage of employed persons living in poverty in spite of being employed.

The electricity sector is staffed by about 270 000 employees, of which around 170 000 are employed in electricity generation and the rest in transmission and distribution. Coal-fired electricity generation dominates with 70 000 employees. Another 65 000 employees work in electricity generation from renewables and 35 000 employees in generation from oil and natural gas.

Employment related to major energy end-uses is about 300 000, of which 135 000 are employed in manufacturing conventional road vehicles. The other workers, in a variety of ways, provide services for energy efficiency improvements in industries, businesses and households, such as installation of more efficient heating, ventilation and air conditioning equipment.

Regional energy sector employment and economic dependence on coal

From the overall national employment picture, this section takes a disaggregated look at employment within Indonesia's regions. Coal is particularly important to this discussion for a number of reasons. First, the coal sector is a large employer. Second, coal production and employment are spatially concentrated. Third, addressing the continued use of unabated coal to meet energy demand is critical to global strategies to address climate change, and in scenarios with strong climate action, such as the Announced Pledges Scenario, coal sees the fastest declines in global demand.

Table 5.2 ▷ Key economic indicators for Indonesia's main coal-producing provinces

	South Kalimantan	Central Kalimantan	East Kalimantan	North Kalimantan	South Sumatra
Coal mining share in provincial GDP	17.2%	7.3%	35.1%	17.8%	6.1%
Coal share in provincial goods exports	78.1%	58.0%	75.6%	74.2%	18.9%
Mining and quarrying share in provincial employment	3.9%	6.0%	8.6%	3.6%	1.6%
Credit to mining and quarrying as share total non-financial bank credit	5.0%	0.1%	3.4%	n.a.	0.4%
Estimated mining and quarrying share in total provincial labour income	3.5%	7.0%	7.5%	3.8%	1.5%

Notes: Labour income share is calculated as average wages in each sector weighted by its share in total employment. It includes informal employment and in-kind incomes.

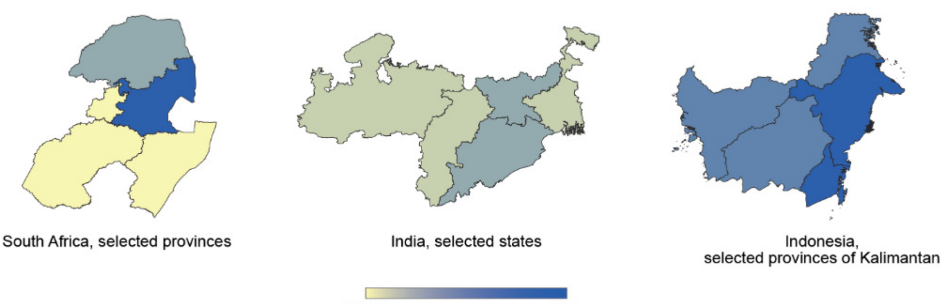
Sources: IEA analysis based on data from BPS (2021a); BPS (2021b); BPS (2021c); BPS (2019); OJK (2021).

Indonesia's coal production is heavily centred in Kalimantan, mostly in East Kalimantan and South Kalimantan provinces. About 10% of its coal production is in Sumatra, mostly in South Sumatra. Reflecting this concentration, this section focusses on the four coal-producing provinces of Kalimantan and the province of South Sumatra.

Coal mining accounted for as much as 35% of East Kalimantan's provincial GDP, and almost 20% in South and North Kalimantan in 2019 (Table 5.2). Goods exports from these provinces were overwhelmingly dominated by coal, which accounted for around three-quarters their total goods exports in 2019. However, these two metrics attribute the entire value of production and export to the territory of origin. In reality not all of this value will accrue to the territory of production: some will flow out in the form of revenues to the central government or profits to the – not necessarily local – owners of capital.

The mining and quarrying sector[2] accounts for as much as 8.6% of total employment in East Kalimantan, and around 4-6% in other provinces on Kalimantan. Although not a perfect metric for investment, the flow of commercial bank credit to the mining and quarrying sector can give a sense of its share in total investment spending within coal mining provinces. In 2021, the mining and quarrying sector received around 3-5% of total commercial bank credit to the non-financial corporate sector within the coal-dependent provinces of Kalimantan, although Central Kalimantan saw a lower value. We estimate the share of the mining and quarrying sector in total labour income for each province. Because workers are likely to spend their income locally, this provides a proxy for the value that is captured within the territory of production. Consistent with the sector's share in total employment, we estimate that mining and quarrying accounted for around 4-8% of total labour income within the most coal-dependent provinces in 2021.

Figure 5.2 ▷ Coal mining share in total employment at provincial/state level in South Africa, India, and Kalimantan, Indonesia



Coal mining share of total employment in Kalimantan provinces in Indonesia are among the highest in the world

Notes: Selected provinces of Indonesia are: Kalimantan Barat, Kalimantan Tengah, Kalimantan Selatan, Kalimantan Timur and Kalimantan Utara. Selected provinces of South Africa are: Free State, KwaZulu-Natal, Gauteng, Mpumalanga and Limpopo. Selected states of India are: Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha and West Bengal. Data for Indonesia are for the whole mining and quarrying sector.

Sources: IEA analysis based on data from BPS (2021c); NSSO (2022); Statistics South Africa (2020).

[2] Indonesia does not provide separate employment estimates for coal mining within the mining and quarrying category, but it is safe to assume that in provinces where coal mining is significant the vast majority of employment in the mining and quarrying sector can be attribute to coal mining, given its relatively high labour intensity.

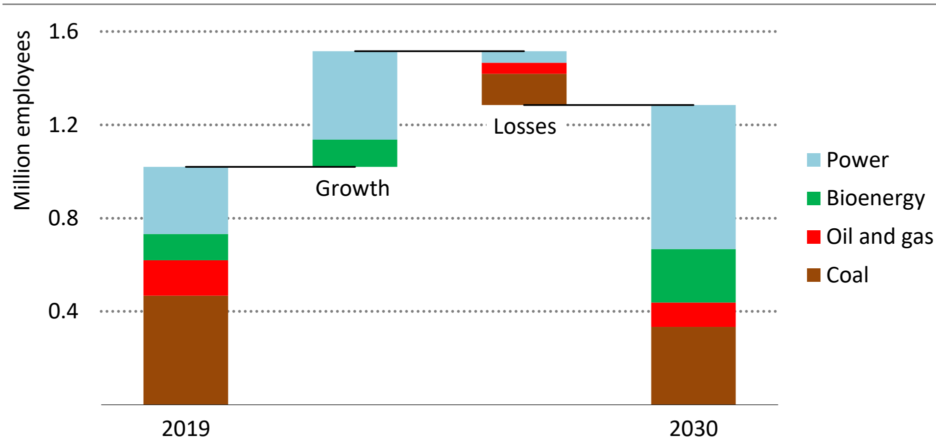
How does Indonesia's level of subnational dependence on coal mining compare in the international context? Figure 5.2 compares the provincial or state share of coal mining in total employment in South Africa, India and the four Kalimantan provinces. Compared to employment shares of 4-8% in the most coal-dependent provinces of Kalimantan, the most coal-dependent province in South Africa, Mpumalanga, has a coal mining employment share of around 5% (and further coal-related employment in the downstream sector), whereas the most coal-dependent states of India, Jharkhand and Chhattisgarh, have a coal mining share of total employment on the order of 1-2%. It is safe to say that Indonesia's provinces in Kalimantan are among the most coal-dependent subnational regions in the world.

Outlook for energy sector employment

Indonesia's energy sector employment depends not just on the transition pathway it follows, but also global energy transitions, given its role in coal exports. In the APS, countries implement their net zero emissions pledges, and there is a relatively rapid transition in the global energy sector, albeit not as swift or profound as in the IEA's global Net Zero Emissions by 2050 Scenario (IEA, 2021a). We estimate that a pathway to net zero emissions by 2060 in Indonesia could entail a net gain in employment by 2030, but forward-looking and integrated policies are essential to ensure a just transition for exposed workers and communities.

Indonesia's total employment in energy supply expands in the outlook of the APS, in gross terms, by around 500 000 jobs, largely in the electricity sector but also in bioenergy supply (Figure 5.3). These are partially offset by job losses of around 230 000, largely in coal mining. Net gains amount to around 265 000 jobs, although these are unlikely to be located in the same places as the job losses because of the spatial concentration of coal mining.

Figure 5.3 ▷ Changes in energy-related employment in Indonesia in the Announced Pledges Scenario, 2019 – 2030



Employment in the energy sector increases by 265 000 by 2030 with more jobs in the electricity sector and fewer in coal

Just transition policies

Just transition policies are essential to help ensure that energy transition policies are socially inclusive and provide decent employment opportunities. In Indonesia's case, just transition policies can provide a safety net and active support to the 720 000 currently employed in fossil fuels value chains (including fossil fuel use in the electricity sector), whose jobs would be at risk in the transition to net zero emissions, as well as their communities.

To achieve energy transitions in an equitable manner, best practice involves governments communicating a long-term vision for the energy system and engaging in comprehensive stakeholder consultations to help achieve buy-in for policy changes. Several countries undergoing transitions from coal have established a "coal commission" to engage stakeholders to determine the pathway for transitioning the coal mining sector, as well as to foster broad societal consensus. For instances, coal commissions have been established in Canada, Chile, Czech Republic, Germany, and recently in Spain and South Africa. These commissions include members from private and public bodies focused on energy, environment, employment and economic development. They aim to foster social dialogue and generate policy measures based on inclusive deliberation. Colombia, in its Pledge for Green Jobs and Just Transition, included a commitment to strengthen tripartite dialogue among the government, employers and workers, as well as to establish new models of dialogue between national and regional governments.

Human capital development is a government priority identified in Indonesia's National Medium-Term Development Plan for 2020-2024. Several existing programmes, started in response to the Covid-19 pandemic, can offer support to workers affected by the energy transition. For example, the pre-employment card programme (*kartu prakerja*) connects job-seekers with approved training institutions and offers a stipend and temporary monthly benefits contingent on course completion (Government of Indonesia, 2022a). Vocational training in schools is supplemented with training centres via the *Balai Latihan Kerja* programme (Government of Indonesia, 2022b). There are also national programmes in place to promote gender equality in the energy labour force, including in support of clean energy deployment.

In addition to training and career services, further support for affected workers often also needs to include monetary support in the form of unemployment benefits, temporary salary guarantees or adjusted pension packages to allow for early retirement. Commissions across countries facing coal transitions have reached the common conclusion that compensation payments for affected workers, regions and companies may be necessary as a means to create new economic opportunities and alleviate hardships related to the transition (CINTRAN, 2022). Just transition measures need to reach the 70-80% of Indonesia's workforce that are informal workers, typically receiving lower wages and fewer benefits and facing job insecurity.

Moreover, macroeconomic and growth policies, industrial and sectoral policies, as well as enterprise policies are among key areas that need to be addressed simultaneously to deliver coherent policy packages (ILO, 2015). Macroeconomic policies can be designed to invest in alternative industries particularly in the affected localities where coal mines and coal power plants are closing. Aside from shifting to the production of clean fuels and electricity as an alternative, governments can consider how best to take advantage of local infrastructure assets and the human capital skill base.

On an international scale, just transitions also refer to advanced economies or international development banks supporting emerging market and developing economies to achieve energy transitions with financial means and technical knowledge. Indonesia has partnered with the Asian Development Bank via the Energy Transition Mechanism (ETM) programme (ADB, 2021). ETM includes two funds of several billion dollars each: one devoted to the early retirement or the accelerated repurposing of coal-fired power plants, and the other intended for the upgrade of power plants and electricity networks. The ETM objective in the pilot phase is to raise the financial resources required to accelerate the retirement of five to seven coal-fired power plants in Indonesia and the Philippines. International financing platforms like the ETM could potentially provide funding for just transitions costs related to support for affected workers and communities.

5.1.2 Affordability

Current situation

Ensuring affordable energy for end-users in Indonesia is a critical goal for policy makers. Current high prices on global fuel markets, and commodity price inflation more broadly, have put substantial pressure on households and firms around the world. Many governments are responding through various support packages. However, it is important to consider how these support packages impact on public finances and incentives to invest in the clean energy transition. In addition, for importing countries subsidies are not only a fiscal drain but also, to the extent they increase consumption of imported goods, put additional pressure on the balance of payments. For instance, in Indonesia liquefied petroleum gas (LPG) imports have increased more than fourfold since 2010.

Indonesian households, industries and other end-use consumers spent USD 80 billion on energy (about 7% of GDP) in 2021. Around half of this spending was for oil products, electricity accounted for nearly 30%, and bioenergy and natural gas the rest. Energy subsidies to consumers in Indonesia in 2021 amounted to around USD 19 billion, or about 1.6% of GDP or 12% of general government revenue. Around half of this was for electricity and LPG use in households, and the remainder for diesel and gasoline in transport. In 2022, subsidies are expected to almost double to USD 32 billion if the price levels of oil products in the first-half of the year, due to the Russian invasion of Ukraine, are sustained (Figure 5.5). This would increase subsidies to nearly 3% of projected GDP, or nearly one-fifth of projected general government revenues. To compensate operating losses of public energy companies from maintaining end-use prices of fossil fuels lower than supply costs, the parliament has approved the provision of USD 28 billion in support for 2022.

Energy subsidies in Indonesia have put strain on government spending and, in general, have been poorly targeted, although this has improved over time. From 2005 to 2014 electricity subsidies were provided to all consumers, which amounted to 5-8% of total governmental spending. As electricity access increased from around 60% in 2008 to 98% in 2018, the government continuously narrowed subsidy eligibility to consumers with lower level power connections. Today, 85% of total electricity subsidies are provided to households of below 900 volt-ampere power connection.

LPG subsidies have been in place since 2007 as the government aimed to replace the use of kerosene and wood for cooking. LPG is sold in 3 kg cylinders at a fixed price and is available to all consumers. This leads to excessive consumption by higher income groups, while only 30% of total LPG subsidies serve low income households. Oil used in transport is subsidised for premium gasoline (RON 88) and pertalite gasoline (RON 90). Diesel prices are lowered by a fixed amount relative to international prices.

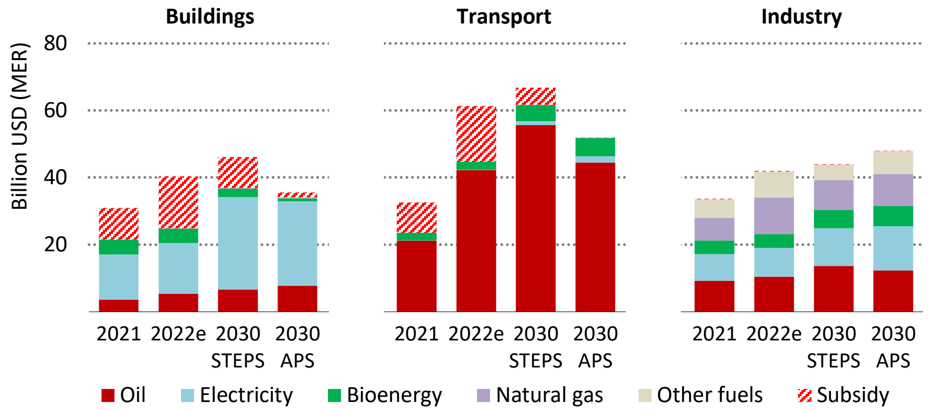
In the near term, it is important to balance the urgency of pricing reforms with a need to preserve economic stability and to shield low income households from energy poverty. However, in the longer term, clean energy transitions can provide consumers with a degree of protection from volatile global market prices. Governments should balance near-term protection for consumers with incentives to promote the clean energy transition.

Outlook for energy affordability

In the outlook to 2030, energy expenditure before subsidies increases in all sectors in both the Stated Policies Scenario (STEPS) and the APS, as incomes and economic activity increase (Figure 5.4). In the STEPS, total energy expenditure increases from 8.2% share of GDP today to 8.3% in 2030. In the APS, however, stronger action on energy efficiency, lower global prices due to lower energy demand, and switching to more efficient technologies such as electric vehicles (EVs), sees energy expenditure at 7.2% of GDP in 2030. This lower expenditure by consumers nonetheless requires investment in clean energy technologies by both consumers and energy producers (see section 5.4).

Rapid growth in vehicle and appliance ownership is set to drive up household energy bills in absolute terms in both scenarios. Average household energy bills in Indonesia increase from USD 350 per household in 2021 to over USD 750 in 2030 in the STEPS. This represents an increase in the share of household disposable income spent on energy from the around 3% in 2021 to around 5.4%. Without subsidies the share of income spent on energy in 2021 would have been 5.6%. While prices do increase in the STEPS as subsidies are somewhat reduced, the main driver of rising household bills is the choice of many households to disproportionally spend additional disposable income on energy. This needs to be kept in mind when comparing household energy spending today versus 2030. In the APS, subsidies are mostly removed by 2030, with only electricity consumption support subsidies remaining for the poorest households. Nonetheless, with average bills of USD 660 in 2030, or 4.7% of household disposable income, household bills are almost USD 100 lower in 2030 than in the STEPS, thanks to investments in clean energy technologies such as more energy efficient appliances and air conditioners, electric motorbikes and increasingly, electric cars. The higher levels of investment in the APS are more than offset by the energy bill savings relative to the STEPS (Figure 5.5).

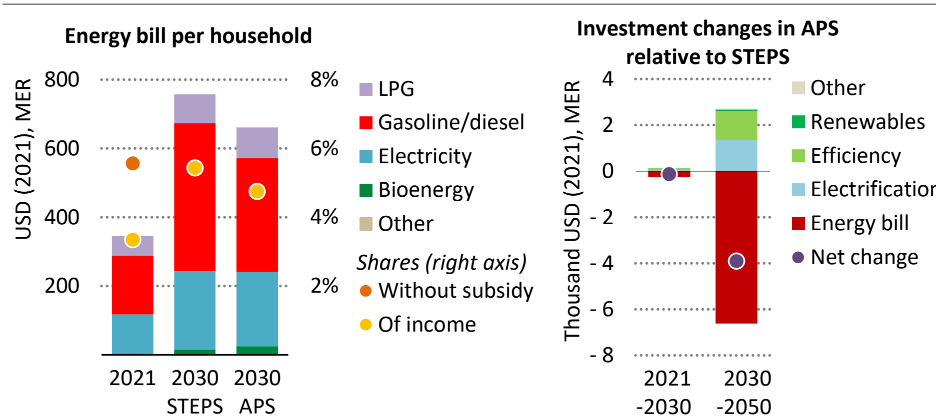
Figure 5.4 ⊳ **Energy expenditure in Indonesia in the Stated Policies and Announced Pledges scenarios, 2021 – 2030**



Energy subsidies to consumers totalled USD19 billion in 2021, and look to double in 2022 if subsidies for residential LPG and transport fuels are maintained with current high prices

Notes: MER = market exchange rate; e = estimated; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario. Values for 2022 are estimates that assume prices for transport fuels and LPG remain at the elevated first-quarter levels over the whole year.

Figure 5.5 ⊳ **Household energy bills and energy spending in Indonesia in the Stated Policies and Announced Pledges scenarios**



Spending on additional efficiency, renewables and electrification lowers energy bills in the APS relative to the STEPS and increases access to energy services without major bill increases

Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario. In the left graph, household energy bills are based on the subsidised energy prices. In the right graph, change in costs in the APS are compared to the STEPS over the two periods and include spending on EVs in terms of additional costs compared to conventional cars, energy efficiency and renewables, and household energy bills.

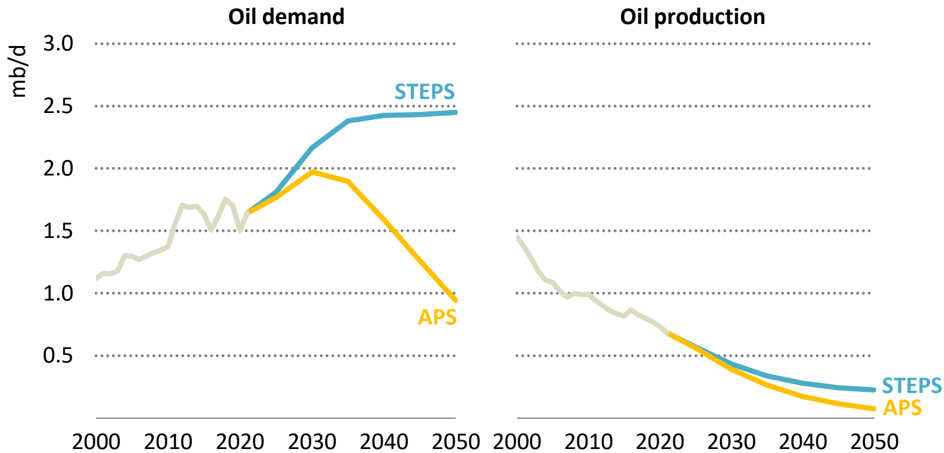
5.2 Energy security

5.2.1 Conventional fuels

Oil demand and supply

Oil demand in Indonesia increased by around 50% between 2000 and 2021 (Figure 5.6), driven by a 150% increase in the number of passenger cars and trucks on the road. Indonesia has a long history of oil production, with exploration and production activities first occurring in the 19th century. Production rose to its peak of 1.6 million barrels per day (mb/d) in the late 1970s and averaged more than 1.5 mb/d between 1980 and 2000. Its two largest fields, the Duri and Minas fields, were approved for development in the 1940s and accounted for around one-quarter of total Indonesian oil production in the 1990s. Since 2000, as the resource base has matured, production has fallen by an average of 4% each year. Exploration and development activity has been ongoing since 2000 and a number of new projects have come online, but these have been unable to compensate for declines in the larger fields.

Figure 5.6 ▷ Oil demand and production in Indonesia in the Stated Policies and Announced Pledges scenarios, 2000 – 2050



Oil production has fallen by about 4% per year since 2000 and the decline is projected to continue in both scenarios

Note: mb/d = million barrels per day; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

A number of international companies (IOCs) have chosen to sell or reduce their oil and gas project portfolios in Indonesia, including TotalEnergies in 2018, Chevron in 2021 and ConocoPhillips in 2022. Pertamina, Indonesia's national oil company, took over most of the assets sold by these companies and is responsible for just over half of domestic oil production today. In 2022, as a result of the global increase in oil and gas prices, Pertamina announced plans to drill 29 new exploration wells and more than 800 new development wells in an effort to boost its oil and gas production to 1 million barrels of oil equivalent per day in 2022 (a 10% increase from recent levels). Pertamina has been commissioned by the government to develop several new projects, which will double its refining capacity to 2 mb/d.

Oil demand increases by 20% between 2021 and 2030 in the APS. Thereafter, increases in fuel efficiency standards, electrification and use of biofuels result in demand halving between 2030 and 2050. In the STEPS, oil use rises by 30% between 2021 and 2030, given continued growth in passenger transport demand, limited penetration of EVs and slow progress on fuel economy standards.

On the supply side, despite increases in development activity, declines in mature large fields mean that overall oil production drops by 40% to 2030 in the APS. Around USD 2 billion is spent each year on average in oil production in Indonesia around 2030, less than half the levels spent in the 2010s. There is continued use of enhanced oil recovery (EOR) technologies to stem declines in mature fields. The Duri oil field has been using thermal EOR for more than 30 years and is the world's largest project using this technology. In the STEPS, oil prices are slightly higher than in the APS, due to higher global demand in this scenario, but this is not enough to stimulate a major new wave of investment and production in Indonesia. Production falls faster in the APS, with the drop in oil demand, increasing CO_2 prices and capital needs in other areas of the energy sector reducing the incentive to invest in oil production.

Natural gas demand and supply

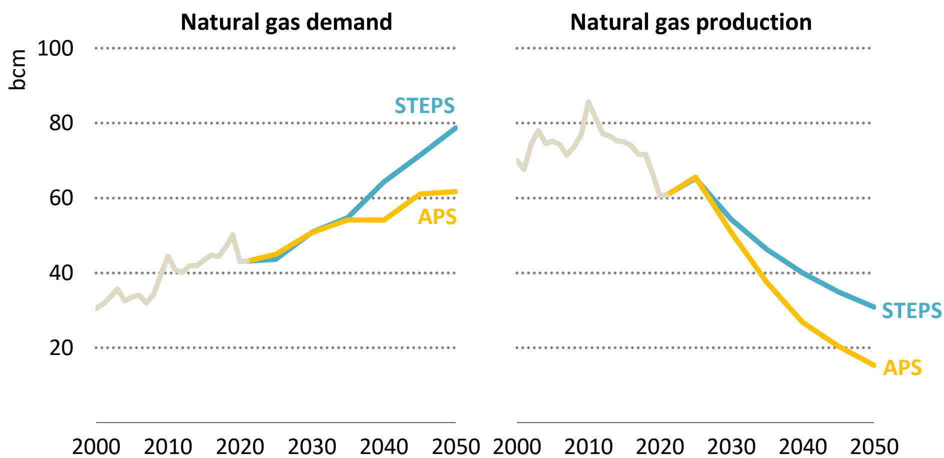
Natural gas demand in Indonesia increased by around 50% between 2000 and 2010 to 45 billion cubic metres (bcm), and has since remained around this level (Figure 5.7). The plateau in demand in the 2010s stemmed mainly from trends in domestic gas production: Indonesian production rose by 20% in the 2000s, but fell by around 30% in the following decade. New gas developments in Indonesia have faced a number of challenges related to domestic market obligations, the decisions by IOCs to reduce their presence in the country, the geographic spread between demand centres in Java and the location of existing and new gas fields in central and eastern areas, and project delays and cost overruns. Recent technical troubles at the Natuna pipeline have hampered Indonesia's ability to export gas to Singapore.

Certain industry sectors, such as fertiliser and cement, as well as electricity generators, pay a regulated natural gas price of about USD 3-6 per million British thermal units (MBtu), much lower than international prices. This low cost gas is supplied through a domestic market obligation, implemented in 2018, that requires oil and gas companies to provide around one-quarter of production from new projects to the domestic market. The new Tangguh LNG Train 3 project is required to sell around three-quarters of production to domestic buyers. Such requirements significantly weaken the investment case for new gas developments.

The decision by a number of IOCs to reduce their presence in Indonesia has also hampered prospects for new project developments. Partnerships with IOCs are important to provide finance and technical expertise, especially for natural gas projects that naturally contain a high level of CO_2 as these fields can be expensive and technically challenging to exploit. For example, the East Natuna field discovered in the 1970s is estimated to contain more than

6 000 bcm of natural gas in place, but the gas is also around 70% CO_2. The field was to be developed by Pertamina, TotalEnergies, ExxonMobil and PTT Exploration and Production, but development has stalled as parties withdrew from this consortium given the cost and complexity of developing the field. The emissions intensity of oil and gas production in Indonesia is also relatively high and the emissions reductions targets of a number of IOCs were likely a factor in their decision to leave.

Figure 5.7 ▷ Natural gas demand and production in Indonesia in the Stated Policies and Announced Pledges scenarios, 2000 – 2050



Natural gas production has fallen over the last decade, but is set to increase slightly in the mid-2020s and then decline over the longer term in both scenarios

Note: bcm = billion cubic metres; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

In the APS, recent high and volatile natural gas prices cast a shadow of uncertainty over demand. Demand increases gradually to the early 2030s as electricity demand increases and natural gas use in industry grows by some 4 bcm to 2030. Thereafter, gas use in the electricity sector falls rapidly as renewables capacity expands.

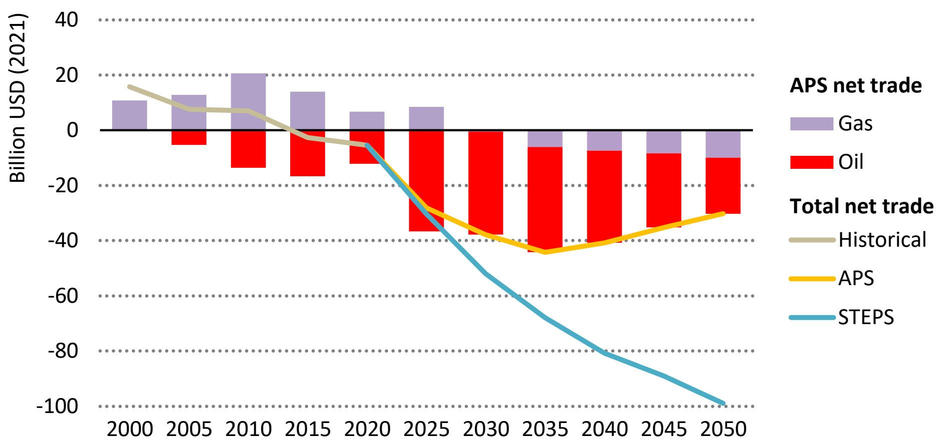
Natural gas production recovers marginally to 2025, driven by new production from Tangguh LNG Train 3. After 2025, while there is continued investment in exploration and development, including to supply the offshore Abadi LNG facility, aggregate production declines, dropping to less than half of 2025 levels by 2040 and one-quarter by 2050.

In the STEPS, natural gas demand trends parallel the APS to 2030, but post-2030 demand continues to increase in the STEPS, driven by growth in both the electricity and industry sectors, and demand rises to around 80 bcm in 2050. On the supply side, trends to 2025 are similar to the APS, but higher domestic demand and prices encourage a new wave of projects that partially offset declines from mature fields, helping to limit, but not eliminate the need for natural gas imports.

Net trade and security implications

Indonesia has been a net oil importer since the early 2000s and imported around 600 000 barrels per day of oil in 2020. Refineries in Indonesia are mainly geared towards light and sweet crude oil, as this is the crude oil produced in Indonesia. Crude oil of a similar quality produced in West Africa and the Middle East is preferred for imports. The Middle East provided 60% of total imports to Indonesia in 2020 and Africa provided 15%. Indonesia is an exporter of natural gas today and provided around 4% of the global LNG market in 2020. It also has some LNG regasification terminals, which can import around 10 bcm annually.

Figure 5.8 ▷ Value of oil and gas trade in Indonesia in the Stated Policies and Announced Pledges scenarios, 2000 – 2050



The clean energy transition in the APS significantly lowers Indonesia's energy import bill

Note: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

In the APS, net oil imports expand to a maximum of around 1.7 mb/d in the early 2030s and Indonesia's net oil import bill increases from about USD 24 billion in 2021, to almost USD 40 billion in 2035 (Figure 5.8). However, after 2035, as oil demand falls, so too does its oil import bill, which drops to USD 20 billion in 2050. Indonesia becomes a net natural gas importing country around 2030 due to rising demand and declining domestic production, by 2050 annual natural gas imports cost around USD 10 billion. The STEPS highlights the consequences for import bills if Indonesia does not achieve its net zero emissions targets: net oil imports rise to around 2.3 mb/d in 2050 and the volume of net gas imports is 40% larger than in the APS. Indonesia's net imports bill in total rises to USD 100 billion. The difference in import bills between the STEPS and APS to 2050 is larger than the difference in cumulative energy sector investment between these two scenarios. In other words, the energy transition in the APS in Indonesia would be paid for just by the lower import fossil fuel imports it sees in this scenario.

Russia's invasion of Ukraine has highlighted the importance of energy security and the negative impacts of volatile and surging commodity prices. Some of the current oil imported by sea to Indonesia passes through choke points such as the Strait of Hormuz and Bab-el-Mandeb. The expansion of imports in the APS to 2030 highlights that energy security cannot be ignored even during a transition towards net zero emissions. Pertamina is mandated by the government to retain oil stockpiles as an operational reserve, which are currently equivalent to 23 days of crude oil consumption and 14 days of oil product consumption (IEEJ, 2020). These oil stocks can be an important factor to protect consumers and the economy from supply disruptions, although current stocks are lower than the 90 days of consumption that the IEA requires of its member countries.

Although Indonesia is a net natural gas exporter today, supply is unable to match demand and, in the APS and STEPS, it becomes a net gas importer around 2030. Indonesia could face tough competition in the LNG market to satisfy this demand. The European Union has announced plans to phase out energy imports from Russia as quickly as possible and countries in northeast Asia are traditionally willing to pay a premium and lock in imports with long-term contracts.

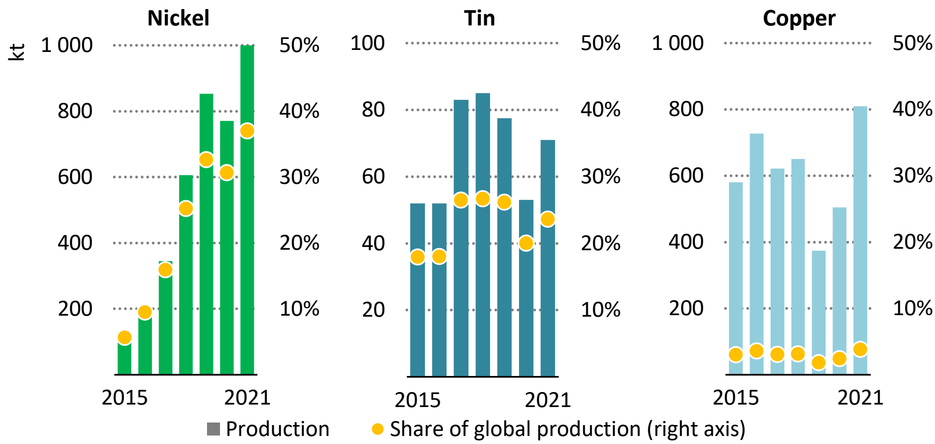
Targeted investment in natural gas infrastructure including in regasification capacity and transmission and distribution networks will be critical to enhance gas supply security in the APS. Investors and government will need to work together to overcome investment hurdles and to adapt to changing asset utilisation profiles. One option is to use floating storage and regasification units (FSRU), which are less costly and quicker to build than land-based terminals, as well as the ability to flexibly redirect to other areas depending on the regional demand profiles. Indonesia is already home to Southeast Asia's largest gas-fired power plant, the Jawa 1 LNG-to-power FSRU project, which successfully fired the first unit in early 2022 (Pertamina, 2022).

5.2.2 Critical minerals

Indonesia is poised to play a major role in clean energy supply chains, both as a consumer of clean energy technologies and as a key supplier of critical minerals. Indonesia is already a leading source of energy transition minerals, particularly nickel and tin (Figure 5.9). The strong growth in clean energy technologies worldwide provides further opportunities for Indonesia to position itself as a reliable supplier of critical minerals while also capturing additional value along supply chains such as EVs and batteries.

Indonesia is the by far the world's largest nickel producer, accounting for around 37% of global production in 2021, followed by the Philippines (14%) (USGS, 2022). This share is set to expand in the coming years, with the country accounting for nearly 70% of global nickel supply growth to 2026. Following the government's ban on nickel ore exports in January 2020, some USD 30 billion has been invested in the Indonesian nickel supply chain, mostly from Chinese companies. High-pressure acid leaching projects to produce battery-grade nickel from Indonesia's vast laterite resources – the world's largest reserves (22%) – could have a major impact on the near-term global supplies of nickel.

Figure 5.9 ▷ Nickel, tin and copper production in Indonesia, 2015 – 2021



Indonesia is the world's largest producer of nickel and second-largest producer of tin

Note: kt = kilotonnes.

Indonesia is also a leading producer of tin (24%), second only to China (30%), and holds the world's second-largest reserves (16%) (USGS, 2022). Tin is used for soldering in a wide range of electronic components including those in clean energy technologies. Tin demand is expected to continue to grow, but the limited number of new planned projects globally is raising concerns of a potential market tightening in the years ahead. Following bauxite and copper ore, Indonesia is considering stopping raw material exports of tin in 2024 in order to promote investment in the downstream value chain, posing additional supply challenges.

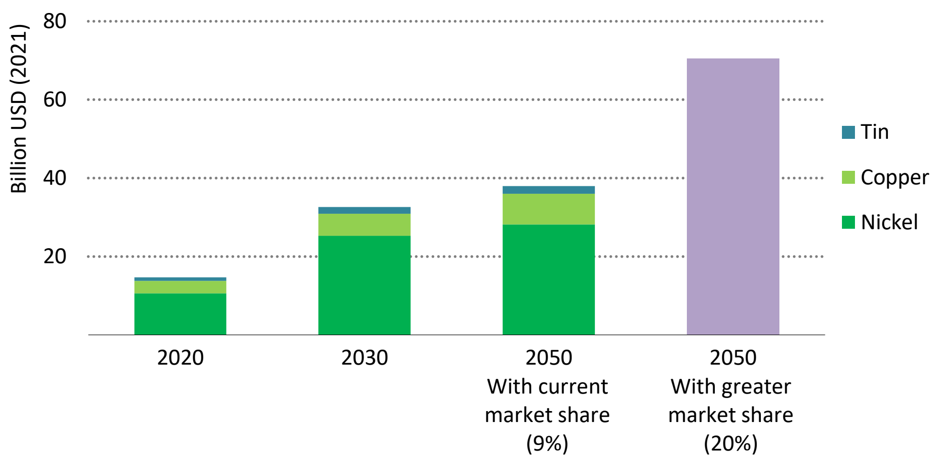
Copper and aluminium are also widely used in clean energy technologies, including solar PV modules, wind turbines, EVs and electricity networks. Indonesia is the world's ninth-largest copper producer, accounting for around 4% of mined production and 3% of reserves (USGS, 2022). Aluminium metal is most commonly produced from alumina, which is in turn produced from bauxite. Indonesia is the sixth-largest bauxite producer (5%) and holds the fifth-largest reserves (4%) (USGS, 2022) .

To maximise benefits from its vast nickel resources, Indonesia is also aiming to develop integrated battery and EV supply chains. In September 2021, construction began on its first EV battery plant worth USD 1.1 billion, with expected annual production capacity of 10 gigawatt-hours (GWh). In late 2021 and early 2022, the Indonesian government signed memoranda of understanding (MoU) with several companies to support domestic EV battery manufacturing, including a USD 10 billion MoU with LG Energy Solution. In May 2022, the Indonesian Minister of Investment said that Tesla had agreed in principle to build a battery and EV factory in the country following a meeting between the Indonesian president and the Tesla CEO (Antara, 2022).

The mining sector (including coal mining) has historically been an important contributor to Indonesia's economic development, accounting for around 5% of GDP (EITI, 2021; ASEAN, 2021).[3] However, mineral exploration budgets in Indonesia have fallen by around two-thirds since the early 2010s (S&P Global, 2022). A lack of exploration investment could threaten the long-term future of minerals production in the country. Foreign direct investment (FDI) in the mining sector in Indonesia also declined over the past several years before rebounding strongly in 2021, up 90% from 2020 levels to USD 3.8 billion. The sector's share of total FDI (excluding upstream oil and gas and financial sectors) fell from nearly 14% in 2017 to 7% in 2020 before rising to 12% in 2021 (Ministry of Investment/BKPM, 2022).

Thus, Indonesia is already a key player in supplying several of the critical minerals needed for clean energy transitions. For example, revenues from nickel, copper and tin production in Indonesia are estimated to have totalled around USD 15 billion in 2020 – 9% of the global market. With rising global demand for these minerals, revenues would grow by two-and-a-half-times to nearly USD 40 billion by 2050 in the APS, assuming no increase in its market share. This compares to the peak historical value of coal exports of USD 28 billion in 2011. If the country were able to raise its market share to 20%, revenue could increase by five-times through to 2050 (Figure 5.10).

Figure 5.10 ▷ Potential revenue from selected minerals in Indonesia in the Announced Pledges Scenario, 2020 – 2050



Global demand for critical minerals in clean energy technologies is set to grow rapidly, providing a big opportunity for Indonesia to make the most of its large mineral resources

Note: Assumes average 2021 prices for long-term mineral prices in 2030 and 2050.

[3] Total mining and quarrying, including oil and gas extraction, accounts for about 8% of GDP, of which the mining sector, excluding oil and gas extraction, accounts for slightly more than 5%.

There are a wide range of environmental issues associated with mining in Indonesia, including greenhouse gas emissions, impacts on local air quality, water use, water quality, biodiversity and land use, as well as handling of mining waste. Nickel deposits in Indonesia are typically mined using open-cut methods, since laterite ores are formed near the surface and located horizontally in the soil. These deposits cover vast areas, and are often located beneath rainforests with rich biodiversity and carbon stocks. These mining methods also generate substantial volumes of tailings waste which need to be managed and disposed of responsibly. Tailings dewatering techniques such as pressure filtering and thickening agents are being adopted as they reduce land use and lower risk of dam failure and acid drainage. In 2022, PT Huafei Nickel Cobalt's laterite nickel ore project decided to use filtration technology to dewater its tailings.

Social and governance concerns stemming from mining also need to be addressed. As consumers and investors increasingly demand that manufacturers source minerals that are sustainably and responsibly produced, Indonesia needs to improve its environmental performance and governance systems to position itself as a reliable supplier. Mitigating the wide range of environmental and social impacts from mining requires a comprehensive approach and concerted action from government and industry. Policies are needed to encourage the displacement of unabated coal-fired power with low-carbon sources to help reduce the emissions intensity of mineral production and processing. Recycling and other circular economy practices relieves pressure on primary supply and significantly reduces the adverse environmental and social impacts associated with minerals extraction and processing. Enhancing capacity building efforts is central to ensure the sustainable production and governance of mining activities. This includes technical capacity building, e.g. geological surveys, reserve estimation, sustainable mining practices, as well as institutional capacity building for sound governance and transparent regulations.

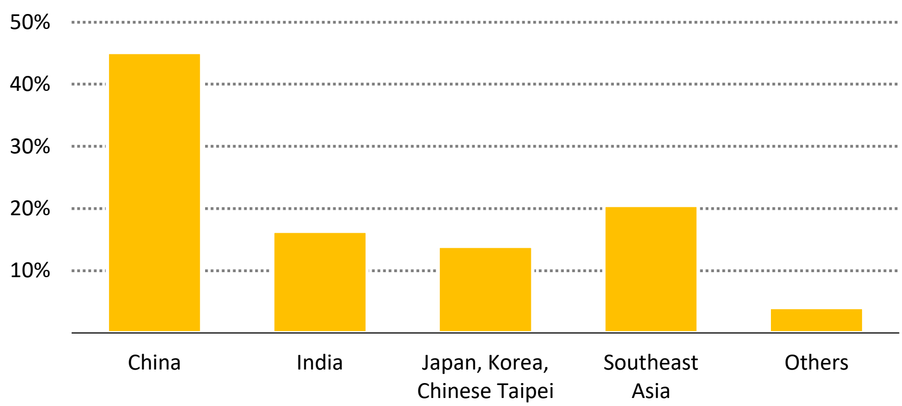
5.2.3 Outlook for coal

Current situation

Indonesia is currently the world's third-largest coal producer, behind China and India, and ahead of United States, Australia and Russia. In 2021, Indonesia produced 585 million tonnes (Mt) of coal. For 2022, the government has set a production target of 663 Mt in order to meet increasing domestic demand and profit from high prices in international markets. The bulk of production is bituminous coal, sub-bituminous coal and lignite used for thermal purposes, while less than 1% of the output is coking coal. At the regional level, around 90% of coal is produced in Kalimantan, mostly in East Kalimantan and South Kalimantan provinces and small production in Central Kalimantan, and around 10% is produced in Sumatra, mostly in South Sumatra. Mines are open pit mines with low strip ratios, generally in the range of 3-8 bcm per tonne, which underpins competitive coal production costs.

In the 1980s, Indonesia started to export small volumes of coal. Based on a large coal reserve base, availability of low cost transportation by barge and low cost mining, exports grew rapidly, reaching 5 Mt in 1990 and 57 Mt in 2000. International coal trade, and in particular exports from Indonesia, received a big push in 2009, when China turned from being a large coal exporter to net importer. China became the largest coal importer worldwide in 2011, surpassing Japan, while Indonesia became the largest coal exporter, surpassing Australia. Since then, with the exception of 2015 and 2016, Indonesia has maintained its position as the world's largest exporter of coal, ahead of Australia.[4] Indonesia is by far the largest exporter of thermal coal, more than doubling the second- and third-largest exporters, Australia and Russia. Accounting for around 40% of the seaborne thermal coal trade, Indonesia is the key player in this market. Around 60% of Indonesia's coal exports are destined for China and India, with the remainder to markets in Southeast Asia or East Asia (Figure 5.11).

Figure 5.11 ▷ Indonesian coal exports by destination, 2021



Indonesian coal exports are dominated by the Pacific Basin trade, with China and India accounting for around 60%

Coal production plays an important role in terms of economic development and jobs, especially in East and South Kalimantan provinces (see section 5.1). Revenues and royalties are calculated as a percentage of price, and have therefore been volatile in recent years. According to the Commodities Research Unit, in 2020 amid Covid-19 restrictions and collapsing demand, a combination of low production and low prices pushed royalties below USD 2 billion. The surge of export volumes and prices in 2021 pushed royalties up to over USD 5 billion. Coal royalties therefore accounted for about 3% of general government revenue in 2021.

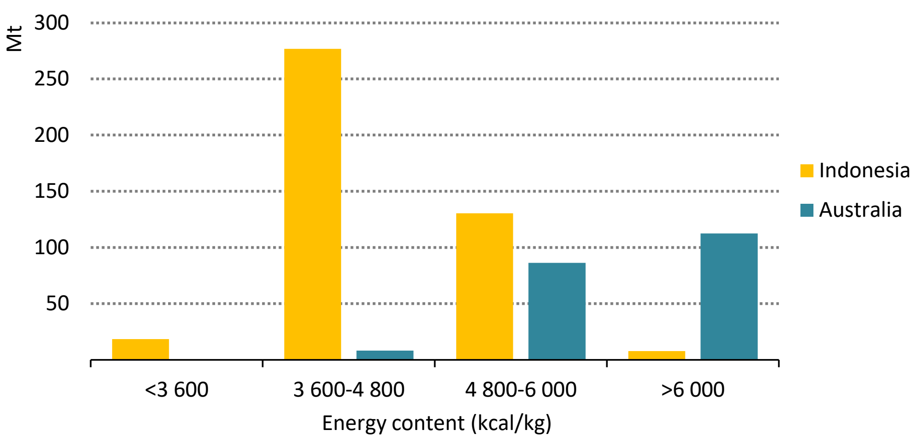
Coal is not a homogeneous commodity. There are different price indices based on energy content levels. In general, higher energy content equates to a higher price, but the

[4] Half of Australian exports are metallurgical coal, with higher energy content and higher economic value than thermal coal, which makes Australia the largest coal exporter by energy and value.

relationship is not linear. Coal with high energy content is priced at a premium (or lower energy coal has a penalty) due to lower logistics costs per unit of energy and better thermodynamic performance when burned.

In the case of Indonesia, price indices used to trade coal include specifications of 6 200, 5 500, 4 600, 3 800 and 3 000 kilocalories per kilogramme (kcal/kg) net as received (NAR).[5] The most liquid market is the one corresponding to 3 800 kcal/kg coal. In Australia, however, 6 000 kcal/kg is the main benchmark, although 5 800 kcal/kg and 5 500 kcal/kg are increasingly used. Figure 5.12 shows the distribution by energy content of Australian and Indonesian coal exports. Most of the coal exported by Indonesia is in the range of 3 600 - 4 800 kcal/kg, whereas around half of Australian thermal coal exports are 6 000 kcal/kg and the other half in the range of 4 800-6 000 kcal/kg. Among the main markets, some are more willing to pay a premium for higher quality – typically Japanese utilities – whereas many others are more price sensitive. Consumers such as cement producers can generally accept a wider range of qualities.

Figure 5.12 ▻ Coal exports by energy content from Indonesia and Australia



Indonesia's thermal coal exports are mostly in the lower quality, lower energy content segments of the market

Note: Mt = million tonnes; kcal/kg = kilocalories per kilogramme.

Another important parameter related to coal quality is sulphur content. As in the case of the energy content, some countries, some sectors and some buyers are more flexible in terms of quality, whereas others work within a narrower range. Indonesia and Russia are the most important exporters of low sulphur coal. Russian coal is mostly low sulphur (between 0.2 and 0.5%), while around 30% of Indonesian coal is very low sulphur (<0.2%). Indonesia is the only major exporter of very low sulphur coal.

[5] Gross as received is more commonly used in Indonesia than NAR.

Outlook for coal activity

Looking ahead, coal mining activity in Indonesia will have to adapt its output to domestic demand plus demand from exports. In order to preserve jobs and revenues, it is important that Indonesia's coal industry remains competitive and profitable, for which supply-related policies are pivotal, as investment in sustaining production will be required even in the APS. However, external factors impacting global coal demand will very much determine the outlook for coal mining in Indonesia.

The evolution of its coal exports will depend on three main factors:

- Climate and other policies impacting coal demand in major importing countries.
- Coal supply-related policies in China and India, as they will play an important role in the domestic supply balance and therefore import needs.
- Evolution in the output and competitiveness of other major exporting countries.

Future trends in domestic demand will very much depend on climate policies implemented by the government, related in particular to the decarbonisation of the electricity sector, the development of coal downstream activities and the deployment of carbon capture, utilisation and storage (CCUS) (Box 5.4). In the APS, coal demand in Indonesia increases from today's level of around 100 million tonnes of coal equivalent (Mtce) in the near term, peaks in the early 2030s, and falls to around 90 Mtce by 2040, and around 25 Mtce by 2060.

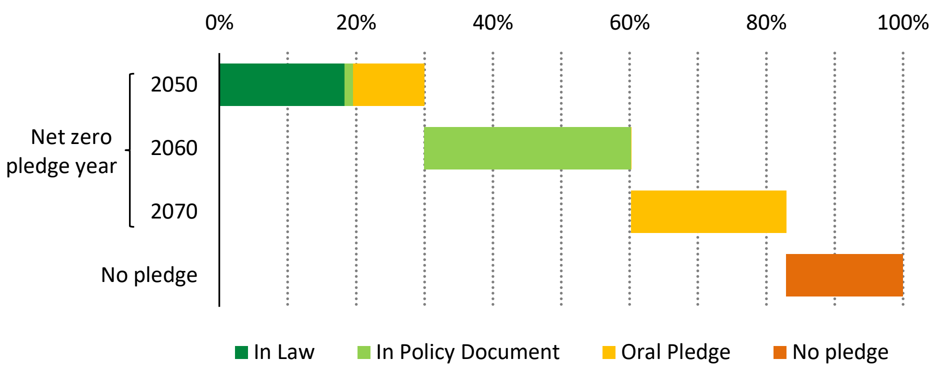
By far the most important impact, however, will be in terms of the energy transition targets and policies of Indonesia's major export markets. Countries accounting for nearly 85% of its coal exports by value have a pledge to reach net zero emissions, although with various target dates and legal status affiliated with the pledges (Figure 5.13).

In *Japan and Korea*, domestic coal production is negligible, so coal imports and coal consumption are almost equivalent. Both Japan and Korea have net zero emissions by 2050 targets. In the APS, Japan and Korea's combined coal demand of around 250 Mtce today declines sharply in the 2020s, and reaches around 80 Mtce in 2040, as they pursue their targets. Japan, Korea and Chinese Taipei currently account for around 15% of Indonesia's coal exports.

In *Southeast Asia*, the main importers of Indonesian coal are Philippines, Malaysia, Viet Nam and Thailand. Of these, Thailand, Viet Nam and Malaysia have made a net zero emissions by 2050 pledge, although these pledges are not yet anchored in legal documents, and in the case of Thailand are conditioned on international support. Overall, demand in the other ASEAN region declines from about 165 Mtce in 2021 to around than 110 Mtce in 2050 in the APS.

India is the second-largest importer of Indonesian coal. India is a bit more complex, as uncertainties exist both on the demand side and supply sides. India's government has pledged to reach net zero emissions by 2070, and driven spectacular growth in renewables capacities, with installed solar PV increasing ten-fold in the last six years. In addition, the Indian government aims to reduce coal imports as much as possible, especially thermal coal imports. Coal India, the government-owned coal mining corporation and the world's largest coal producer, has a production target of 1 billion tonnes of coal, and captive blocks are ramping up production. At the same time, the government has issued successive rounds of auctions for merchant miners, i.e. producers that can sell coal in the market at prices outside the monopoly of Coal India. The first rounds have been awarded and it is too soon to see how fast production will ramp up. In any case, thermal coal imports will be restricted by domestic production. Therefore, a double risk exists for Indonesian exports to India, one from declining demand as India implements its net zero emissions pledge and the second from its increasing domestic production.

Figure 5.13 ▷ Share of Indonesian coal exports by value covered by net zero emissions pledges by target date and legal status



Countries representing about 85% of Indonesia's coal exports by value have announced targets to reach net zero emissions, although with different target dates and legal status

Notes: Data are for 2019 and are by monetary value, not volume or energy content

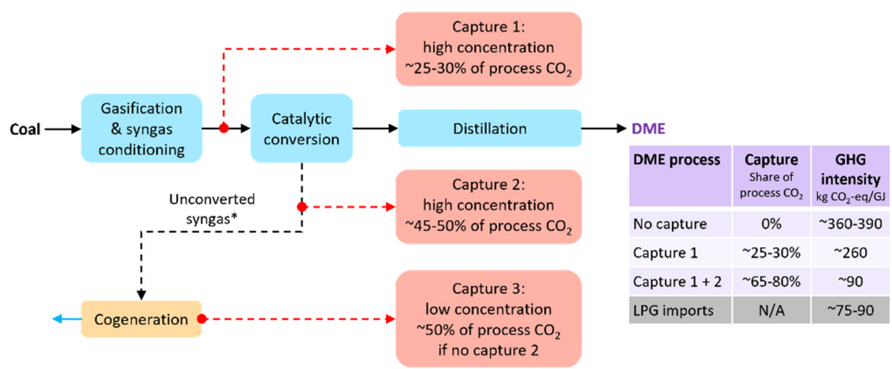
China is the largest importer of Indonesian coal. China has committed to peak CO_2 emissions before 2030 and achieve carbon neutrality by 2060. This implies a significant reduction in coal demand and consequently in coal imports. Coal imports in China account for less than 10% of coal demand, but this does not mean that a 10% cut in demand will end imports. First, imports of low ash, low sulphur Indonesian coal are an excellent option for blending with some of China's domestic high ash, high sulphur coal. In addition, imported coal plays an important role as a means of arbitrage with domestic coal. In China, the main producing regions, such as Shanxi, Inner Mongolia and Shaanxi, send coal mostly by rail to the northern ports, where it is shipped to the coastal regions of Shandong, Jiangsu, Shanghai, Zhejiang, Fujian and Guangdong. So, Indonesian coal imports compete with domestic coal in China which must be transported by rail and ship to demand centres. Indonesian coal can be transported very economically by barge before being loaded onto a ship. On the demand side, consumption of coal in China falls in the APS from more than 3 000 Mtce in 2021 to around 1 600 Mtce by 2040, and to around 750 Mtce by 2050.

Indonesian coal exports compete with other suppliers in the international market. Competition is based on cost, quality and location. Indonesia has advantages relative to other major exporters, notably regarding location, as its exports are almost entirely to the Asia Pacific region. Coal demand in the Atlantic market is expected to decline under any scenario much faster than in Asia Pacific markets. The markets that will maintain higher coal demand for longer, i.e. China, India and Southeast Asia, are the main importers of Indonesian coal today, accounting for around 80% of its exports. This is why exports from Indonesia are more resilient than for other coal exporters in the APS, although Indonesian exports still fall from around 340 Mtce in 2021 to 175 Mtce by 2050.

Box 5.2 ▹ Can the coal downstream be compatible with net zero emissions?

Indonesia is expanding its coal-to-chemicals industry to decrease reliance on imported fuels such as LPG. Today about 90% of energy for cooking is from LPG, of which 80% is imported. There currently are six coal-to-methanol or dimethyl ether (DME) plants at various stages of development, with the capacity to produce close to 7 Mt of methanol/DME before 2030.

Figure 5.14 ▹ Life cycle emissions of coal to DME production with CCUS compared with LPG imports



DME process	Capture Share of process CO_2	GHG intensity kg CO_2-eq/GJ
No capture	0%	~360-390
Capture 1	~25-30%	~260
Capture 1 + 2	~65-80%	~90
LPG imports	N/A	~75-90

Even with the highest capture rates achievable, the life cycle emissions of coal to DME production would be above those of LPG

Note: Unconverted syngas can be recycled to improve the process energy efficiency and increase the amount of CO_2 available for capture at point 1.

Sources: Celik, Larson and Williams (2004); Clausen, Elmegaard and Houbak (2010); Larson, Jin and Celik (2005).

CCUS is being explored to mitigate CO_2 emissions from this expanding industry. Given the high-carbon intensity of coal and low efficiency of the process (~25% in a typical once-through process configuration), coal gasification to chemicals is a highly carbon-intensive process. The overall unabated life cycle emissions for DME are between 360-390 kilogrammes of carbon-dioxide equivalent per gigajoule (kg CO_2-eq/GJ). Project stakeholders have indicated that equipping the Muara Enim DME plant with CCUS could reduce CO_2 emissions by 45% compared with plant without CCUS, though the plant would still have significant emissions. Even in a configuration where all the point sources are captured (up to ~80% of the overall process), DME production from coal with CCUS is unlikely to deliver significant emissions reduction relative to current LPG imports, which have a life cycle carbon intensity of around 75-90 kg CO_2-eq/GJ (Figure 5.14).

5.3 Renewables integration and electricity security

Renewable energy resources and centres of electricity demand are not conveniently co-located in Indonesia (Box 5.3). Indonesia's economy and energy demand is expected to diversify in geographical terms in the coming decades, yet Java will continue to play a predominant role. In the long term, the mismatch between energy demand and low emissions energy supply may create challenges for Indonesia's clean energy transition.

In the near term, Indonesia's transition faces the challenge of a large and relatively young coal fleet. The capacity weighted age is around 12 years, one of the youngest in the world. Indonesia also has a significant overcapacity of coal, due to the burst of coal capacity additions over the last decade and overly optimistic electricity demand projections. The current capacity margin in the interconnected Java-Bali system is around 50-60%, way above international benchmarks. This creates hurdles in the near term for the transition, as capacity additions of renewables face an oversupplied and inflexible electricity market.

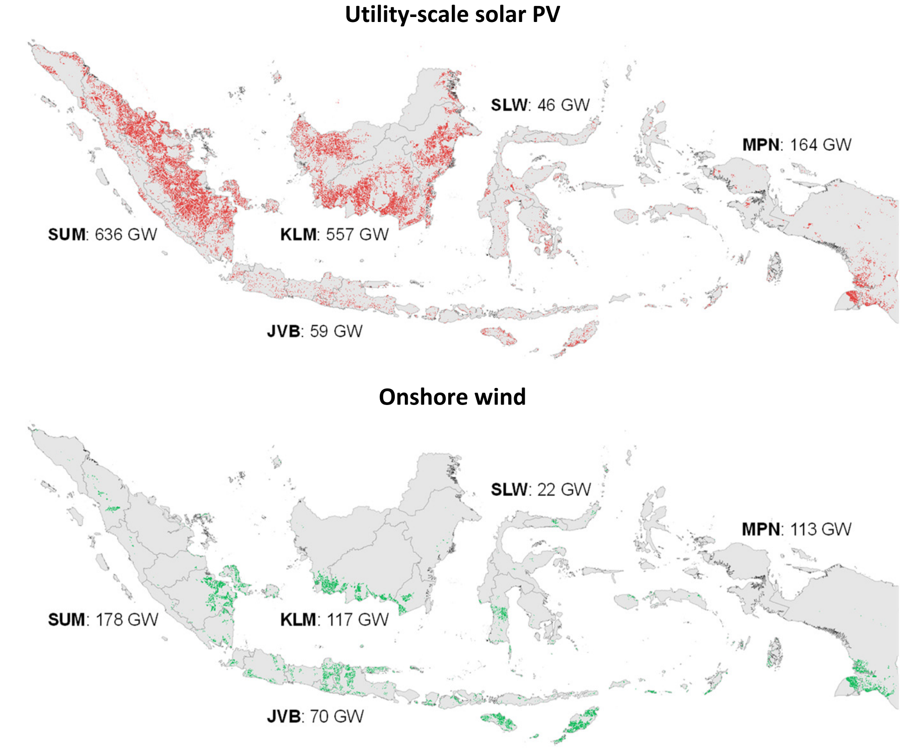
Absent resolution, there is a real risk of Indonesia falling behind in its net zero emissions pathway, and missing out on the benefits of developing a domestic renewables industry. This section explores these issues and uses a new model developed specially for this analysis.

Box 5.3 ▹ Technical potential for wind and solar PV in Indonesia

Published studies of Indonesia's wind and solar resource potential are few, and come to widely diverging conclusions. For this reason, the IEA performed specific analysis for this report. It takes into account historical weather data from both the Global Wind Atlas and Global Solar Atlas, and 2020 land-use data from the European Space Agency, Climate Change Initiative. In addition, protected areas were taken from the World Database on Protected Areas. Areas in the immediate vicinity of roads, airports and railways are excluded. For wind, the model uses an average wind speed cut off of 4.5 metres per second (m/s). The model assumes that mixed land use is possible for onshore wind, given the low land footprint of the turbine base. A land-use factor of 9 megawatts per square kilometre (MW/km^2) and 30 MW/km^2 was assumed for wind and solar respectively (Denholm et al., 2009; Ong et al., 2013). To take account of non-technical barriers to land use, the model assumes that only 50% of the technically available land can actually be exploited for solar and wind projects.

Using this model, the analysis finds a total technical potential of 1 500 GW for utility-scale solar PV and 500 GW for onshore wind, though most of the potential is concentrated outside the load centres of Java (Figure 5.15). It also identifies large technical potential for offshore wind. Indonesia's technical potential for wind and solar is substantial, and is in addition to estimates for the total technical potential of 24-40 GW for geothermal and more than 70 GW for hydropower.

Figure 5.15 ▷ Technical potential for utility-scale solar PV and onshore wind by region in Indonesia



Indonesia's solar PV and wind technical potential is concentrated on Sumatra and Kalimantan, far from the load centres on the island of Java

Note: JVB = Java-Bali; SUM = Sumatra; KLM = Kalimantan; SLW = Sulawesi; MPN = Maluku-Papua-Nusa Tenggara.

Sources: IEA analysis based on data from DTU, World Bank Group, Vortex, ESMAP (2021); Solargis, World Bank Group, ESMAP (2021); ESA Climate Change Initiative (2021); UNEP-WCMC (2021).

5.3.1 *Electricity system operation in the near term*

There are a number of electricity generation companies in Indonesia, but only one buyer – the state-owned electricity corporation, Perusahaan Listrik Negara (PLN). The electricity generators are both independent power producers and PLN subsidiaries. The power purchase agreements (PPAs) with the generation companies often contain minimum "take-or-pay" clauses. These constrain plants from being operated flexibly and restrict the opportunities for new renewables capacity to be deployed. For renewables that are deployed, these contracts displace generation from renewable sources and force curtailment. Such PPAs are often long-term contracts covering the lifetime of the plants. Not only do they create inflexibility, these contracts also add costs to the system, if the off-taker pays for energy that is not needed or could be provided at a lower cost by other generators, such as solar PV or wind.

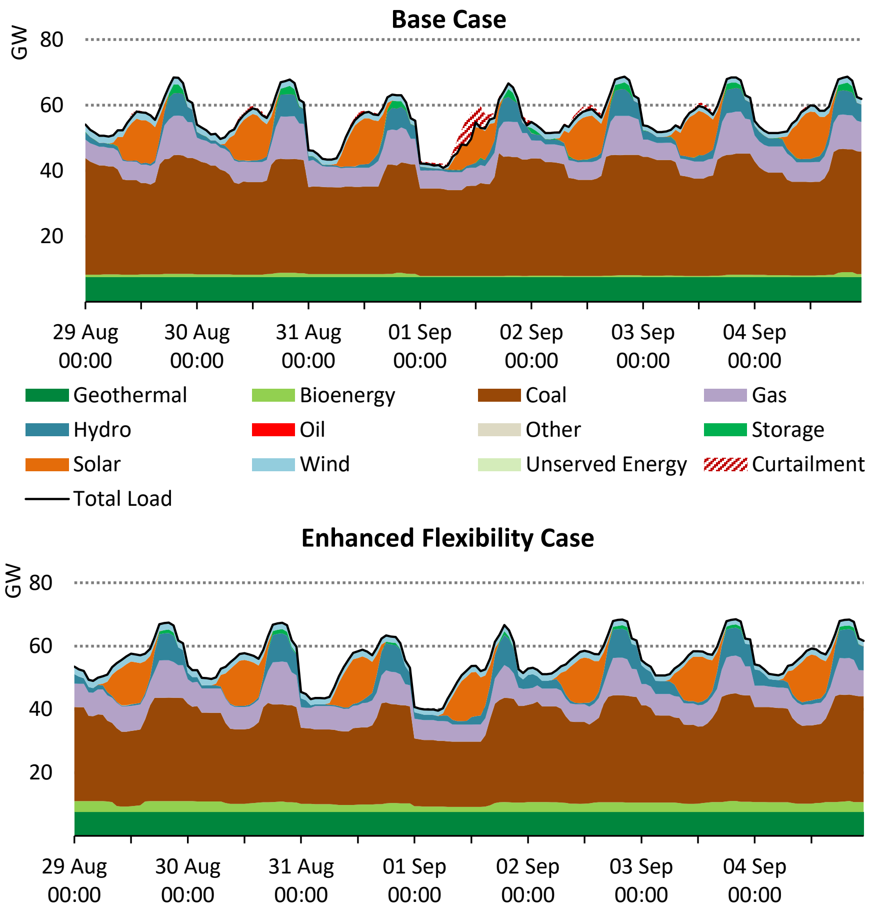
Fuel supply contracts are also a source of contractual inflexibility in Indonesia's electricity system. These are especially prevalent with fuel suppliers that were perceived to need revenue certainty to support investment in related infrastructure, such as gas pipelines, LNG terminals and storage. In Indonesia, take-or-pay clauses in natural gas supply contracts are common and often set daily minimum values, which further limits flexibility in electricity system operations. Such contracts lead to sunk fuel supply costs, constrain the flexibility offered by gas-fired generation and limit options for renewables in electricity system operation.

The near-term task of increasing the share of variable renewables in the generation mix is further hindered by the technical inflexibility of the current generation fleet. Today, coal and natural gas plants in Indonesia are not positioned to rapidly adapt their output to respond to variations in wind and solar output. While other countries have shown that coal plants can provide substantial flexibility services, this remains a challenge in Indonesia.

By 2030, if not addressed, this technical and contractual inflexibility could have unwanted consequence for the transition of the Indonesian electricity system. We explored the impact of increased technical and contractual flexibility by 2030 in the APS in two sensitivity cases: the Base Case assumes the existing technical and contractual constraints; the Enhanced Flexibility Case assumes enhanced operational and contractual flexibility of the existing generation fleet.

In both cases, the Indonesian electricity system is able to integrate the level of variable renewables projected in the APS by 2030. Aggregate annual curtailment of variable renewables in the Base Case is around 10%, while it falls to less than 1% in the Enhanced Flexibility Case. Most of the curtailment is driven by the inability to ramp down coal and gas generation in order to integrate larger shares of wind and solar during their midday generation peak (Figure 5.16).

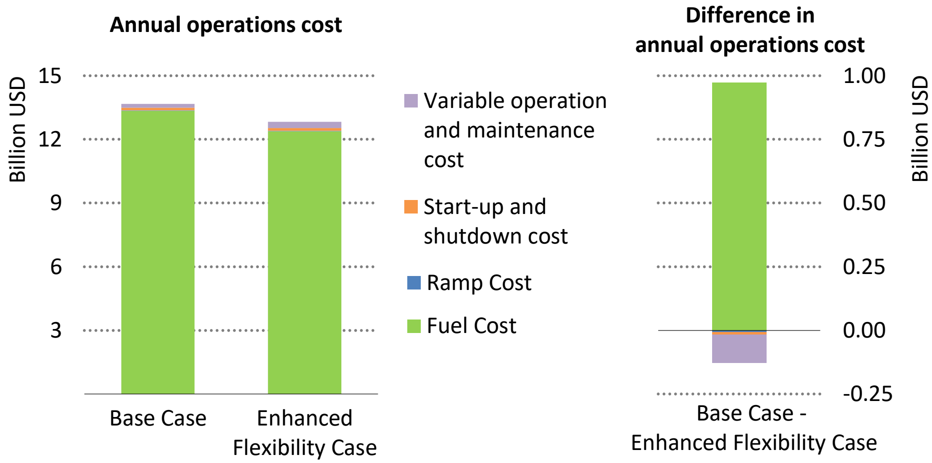
Figure 5.16 ⊳ Electricity generation during a period of minimum net demand with and without contractual inflexibility in the Announced Pledges Scenario, 2030



Technical and contractual inflexibility can lead to increased curtailment of variable renewables and increased costs of operating the electricity system

The lower flexibility of the Base Case also leads to higher operating costs compared to the Enhanced Flexibility Case, in which the dispatch of the electricity system is better optimised to integrate renewables and lower operational costs (Figure 5.17). Annual operating costs are around USD 0.8 billion higher in the Base Case relative to the Enhanced Flexibility Case by 2030, representing savings both from a more optimal dispatch of the existing coal and gas fleet and from the substantially reduced curtailment of renewables. This equates to slightly more than 5% of the annual production cost.

Figure 5.17 ▷ Annual operations cost by component in the Base and Enhanced Flexibility cases, 2030



Contractual flexibility can lead to large savings as it provides opportunities for renewables generation and avoids unnecessary curtailment

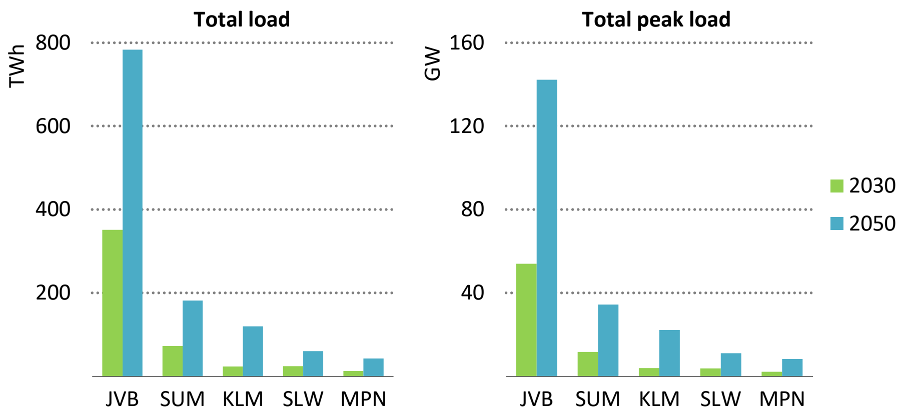
S P O T L I G H T

Modelling Indonesia's regional electricity system

In order to understand how the electricity system of Indonesia may operate in the coming years on the pathway to net zero emissions by 2060, a new hourly model has been developed. Indonesia is modelled as five separate regions as defined in the *Electricity Supply Business Plan* (Rencana Umum Penyediaan Tenaga Listrik [RUPTL]). The regions are Java-Bali (JVB), Sumatra (SUM), Kalimantan (KLM), Sulawesi (SLW), and the rest of Indonesia represented by the combined regions of Maluku-Papua-Nusa Tenggara (MPN). Model runs are performed for 2030 and 2050 in order to analyse the near-term and long-term challenges of Indonesia's transition to net zero emissions.

Annual national electricity demand and peak loads were broken down using regional data for household disposable income per capita, industrial and service sector value added and vehicle stocks (Figure 5.18). Hourly profiles of electricity demand were developed using Indonesian data on regional load profiles, and IEA models of load profiles by end-use. In 2030, more than 70% of total national electricity demand is projected to be located in Java-Bali, while this level is about two-thirds in 2050.

Figure 5.18 ▷ Annual total electricity load and peak load by region in the Announced Pledges Scenario, 2030 and 2050



In 2030, more than 70% of total national electricity demand is projected to be located in Java-Bali, while this level is about two-thirds in 2050

Note: JVB = Java-Bali; SUM = Sumatra; KLM = Kalimantan; SLW = Sulawesi; MPN = Maluku-Papua-Nusa Tenggara.

The model allocates the electricity generation capacities deployed in the APS to the regions based on historical data of existing capacities, the planned project pipeline, data from the analysis of Indonesia's technical potential for renewables, and the projections of regional demand and peak load. In 2050, almost 40% of the utility-scale solar PV capacity is located in Java-Bali, 27% in Sumatra, 29% in Kalimantan, 3% in Sulawesi and the remainder in the rest of Indonesia.

Within each region, various generation technologies are represented, taking account of both their technical and economic properties. These include:

- Outage rates, ramp rates, minimum stable generation levels and minimum up and down times.
- Plant efficiencies.
- Fuel types and costs.
- Variable operation and maintenance costs.
- Start-up and shutdown costs.

Various flexibility measures have also been modelled, including several kinds of storage, demand-side response and regional transmission interconnections. In order to determine the optimal mix of regional interconnectors and storage, a capacity expansion model was employed for both 2030 and 2050 to determine how much storage and transmission capacity should be built in these years.

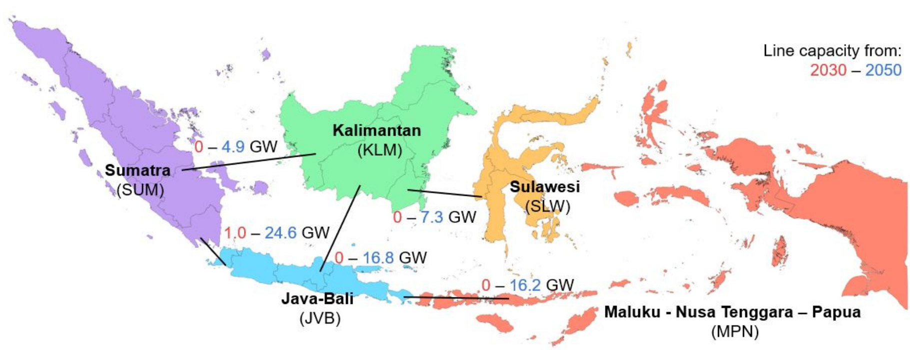
5.3.2 Electricity system operation in the longer term

In the period to 2050 and beyond, the key challenge shifts from the integration of a growing share of variable renewables with the existing generation fleet to the integration of renewables across the islands of Indonesia. This arises as the renewables potentials on Java are exhausted, while its demand for low emissions electricity continues to rise.

A number of strategies are deployed to address the mismatch of renewable energy resources and demand centres. First, low emissions sources of generation that can be deployed on Java continue to be developed. These include nuclear, bioenergy, co-firing of hydrogen and ammonia in the existing gas and coal fleet, and equipping fossil fuel plants with CCUS.

In addition, it is both necessary and cost effective to develop the inter-regional electricity system to allow the transfer of low emissions electricity from outside Java to load centres on the island. By 2050, transfer capacities of around 25 GW are required between Sumatra and Java, while around 17 GW are built between Kalimantan and Java, and around 16 GW between Java and Nusa Tenggara (Figure 5.20). These interconnections assist with balancing variable renewables, as well as with the transfer of bulk electricity between sources of low emissions supply and demand centres. They can build upon the very significant progress that has been made on the costs and performance of high-voltage direct current (HVDC) transmission projects.

Figure 5.19 ▷ Expansion of inter-regional electricity grids in Indonesia, 2030 – 2050

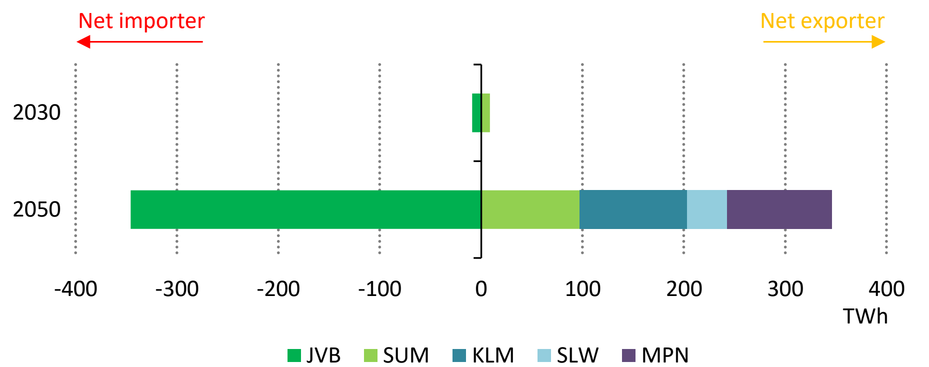


Inter-regional grids can connect sources of renewables generation with demand centres as well as boosting access to sources of flexibility

Notes: The model used represents the Indonesian electricity system in five regions. So this illustration of inter-regional lines should be considered as indicative of transmission lines between broad regions rather than precise locations of the lines.

By 2050, annual flows on these interconnectors are on the order of 100-350 terawatt-hours (TWh) (Figure 5.20). Java is importing around nearly half of its annual electricity demand by 2050, while net exports from Sumatra and Kalimantan amount to 50-85% of their own demand. This need for electricity transfers from outside Java creates a large challenge around the integrated planning of the electricity system in the long term, encompassing supply, transmission and demand across regions.

Figure 5.20 ⊳ Net electricity trade by region in Indonesia in the Announced Pledges Scenario, 2030 and 2050



Inter-regional grids link sources of clean supply to demand centres, as well as interconnecting sources of flexibility

Note: JVB = Java-Bali; SUM = Sumatra; KLM = Kalimantan; SLW = Sulawesi; MPN = Maluku-Papua-Nusa Tenggara.

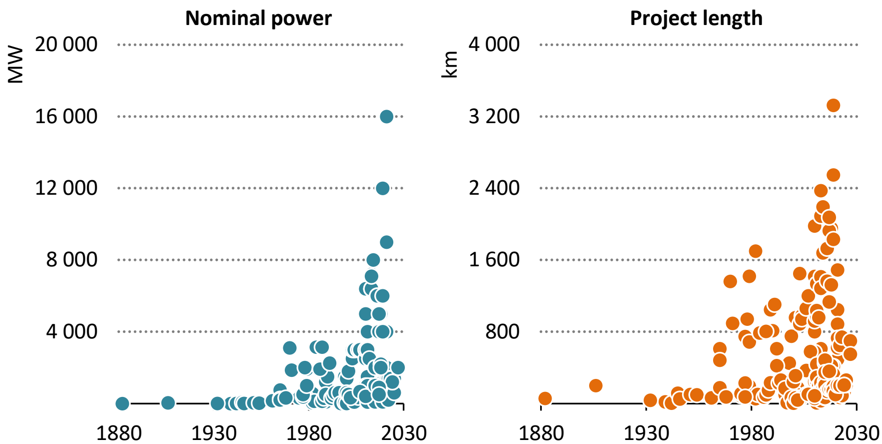
Box 5.4 ⊳ HDVC technology for inter-regional electricity transfers

A high-voltage direct current (HVDC) electric transmission system uses direct current for the transmission of electrical power instead of the more common alternating current. Starting at low voltages and transmission capacities, a technology known as mercury-arc valves became available for power transmission in the 1930s. Voltage up to 463 kilovolts (kV) and transmission capacity up to 1 850 MW were achieved. This technology was superseded by high-power semiconductors in the 1970s that replace the large and expensive tubes. The new technology advanced rapidly.

The development of higher rated insulated-gate bipolar transistors was the next technology milestone. Recent developments have made this technology even more economical. Losses are decreasing and key components are getting cheaper.

Figure 5.21 shows the evolution of HVDC projects over time by nominal power and transmission line length. As technologies have improved and the manufacture of HVDC lines has shifted from a specialised to a commodified industry, costs have come down significantly. Projects with larger and larger nominal power ratings, higher voltages and longer distances have become viable. This widens the option for Indonesia to cost effectively develop an integrated regional power system.

Figure 5.21 ▹ HVDC projects by nominal power and transmission line length, 1880 – 2030



IEA. All rights reserved.

Technology advances are driving down the costs of long-distance HVDC projects, which expands options for regional electricity systems with high levels of renewables

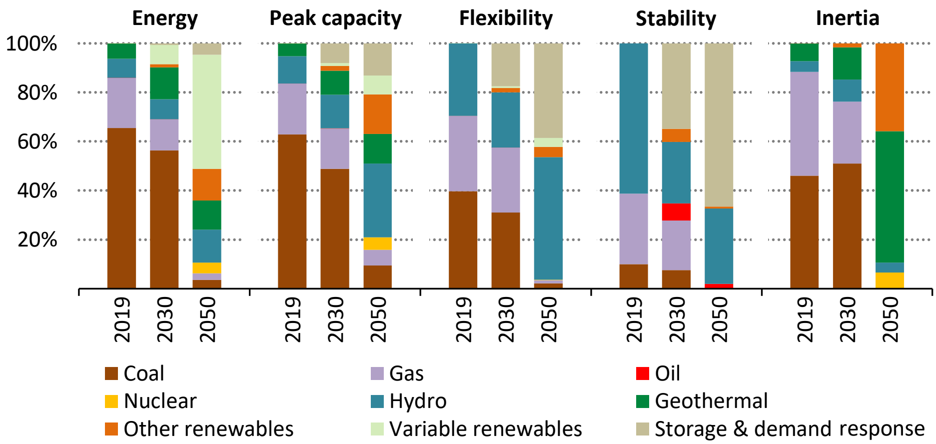
5.3.3 Balancing the electricity system with a high share of renewables

The flexibility needs of the current electricity system in Indonesia are relatively limited. The load profile is relatively flat and without pronounced seasonality, and the generation capacity is dominated by dispatchable sources of coal, gas, geothermal and hydropower (although most of its hydro capacity is run-of-river). Limited flexibility needs are currently met by conventional generators varying their output up and down and providing capacity adequacy and ancillary services to the system.

By 2030, the need for flexibility services increases to accommodate incorporation of variable renewables in the generation mix, as well as increasing electrification of more dynamic loads, notably for air conditioning and EVs. In the near term to 2030, coal, as the largest available source of dispatchable capacity, provides one-third of these flexibility needs, highlighting the importance of measures to enhance the operational flexibility of the existing coal fleet. Coal also provides 50% of the capacity adequacy in the system in 2030.

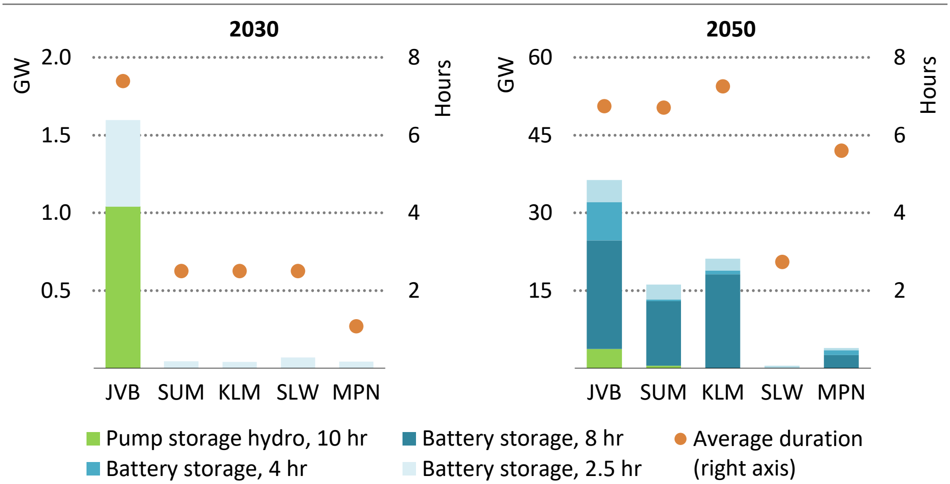
In the longer term, the nature of the electricity system changes fundamentally, as the share of renewables reaches over 90%, and that of wind and solar over two-thirds. With the retirement of a significant share of dispatchable thermal capacity, geothermal plays a critical role in providing ancillary services. Demand response and storage provide around 40% and 15% of ramping flexibility and capacity adequacy respectively (Figure 5.22).

Figure 5.22 ▷ Key services provided to the electricity system in Indonesia in the Announced Pledges Scenario, 2019 – 2050



As the share of variable renewables in the energy mix rises, the role of storage and demand response evolves to provide key services, supported by geothermal and biomass

Figure 5.23 ▷ Deployment of storage by region in Indonesia in the Announced Pledges Scenario, 2030 and 2050



As more wind and solar PV capacity is deployed, the average duration of storage options also increases

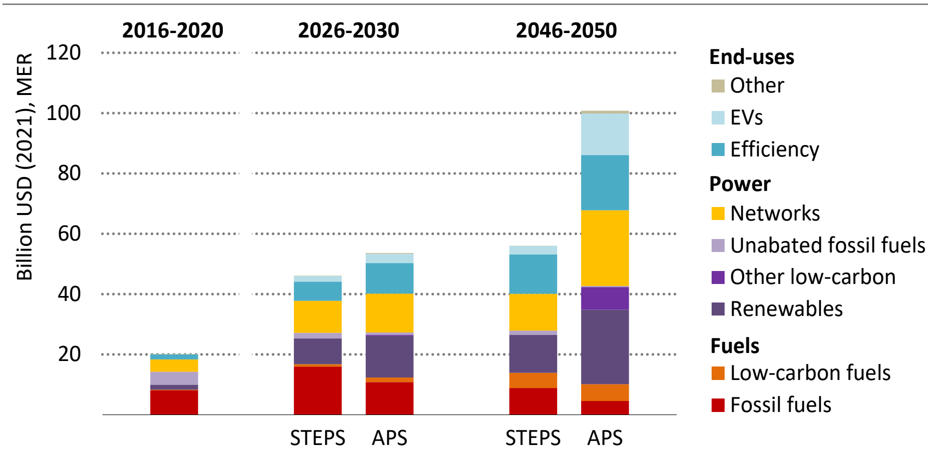
Note: JVB = Java-Bali; SUM = Sumatra; KLM = Kalimantan; SLW = Sulawesi; MPN = Maluku-Papua-Nusa Tenggara.

As the share of variable renewables expands in the APS, storage becomes more and more important as part of the portfolio of flexibility options. In 2030, total storage is about 1.8 GW across of Indonesia, dominated by pumped storage capacity in Java. The rest is battery storage capacity, with typical storage duration of 2.5 hours. Storage options assist with meeting peak demand and minimising curtailment at the time of peak renewables generation (typically midday). By 2050, the picture changes substantially, with storage capacity of 80 GW and the average battery storage duration of more than six hours in most regions (Figure 5.23). Storage options help to provide both capacity adequacy and ramping services, as well as bulk energy transfer between periods of excess generation and deficit demand.

5.4 Financing and investment

Annual average capital investment in Indonesia's energy sector was USD 20 billion between 2016 and 2020, with fossil fuel supply and electricity generation accounting for well over two-thirds of this amount. This level would need to more than double by the end of this decade driven by increasing GDP in the STEPS. The increased capital intensity of the net zero emissions pathway sees total average annual energy sector investment increasing to almost USD 55 billion over the same period in the APS (Figure 5.24).

Figure 5.24 ▷ Average annual energy investment in the Stated Policies and Announced Pledges scenarios, 2016 – 2050



Energy investment is higher in scenarios that meet emissions reduction goals, although higher upfront expenditure delivers much lower fuel costs over time

Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario, Networks includes battery storage. Unabated fossil fuels = fossil fuels without carbon capture, utilisation and storage. Other low-carbon includes nuclear, bioenergy, CCUS and hydrogen/ammonia.

The way that capital is allocated also shifts considerably, especially to meet the more stringent sustainable development goals embedded in the APS. In recent years, renewables in electricity have accounted for 10% of investment and networks for 20%; these shares need to rise rapidly in the APS: by mid-century they each represent almost a quarter of annual investment. Similarly, end-use investment represents around a quarter of capital investment in the APS compared to less than 10% in recent years. This is driven largely by much more investment in efficiency in the buildings sector as urbanisation increases, alongside fast growth in electromobility. EV sales account for around 15% of total energy spending in the APS by the late 2040s, from less than 1% over the 2016-20 period.

Investment at these levels requires the mobilisation of additional capital, which means in practice more private sources of capital, debt and off-balance sheet financing over the coming decade. More than 50% of total energy investment is financed by private funds by the late 2020s in the APS, or almost USD 30 billion, compared to 40% and around USD 8 billion in recent years. Debt and off-balance sheet financing also increases by around three-times compared with recent levels (to above 40% and 15% respectively). This accompanies and facilitates the increase in solar PV and wind generation investments – average annual investments increase by more than thirty-times compared to the late 2010s, reaching almost USD 6 billion. The APS also assumes more ambitious policies as well as improved regulation which reduce risk perceptions and help improve the investment case for clean energy investments, leading to increased levels of private and international investment and a more effective use of public sources. Average annual investment from international sources, both public and private, almost doubles over the next decade in the APS, to around USD 10 billion.

Key factors influencing clean energy investment decisions

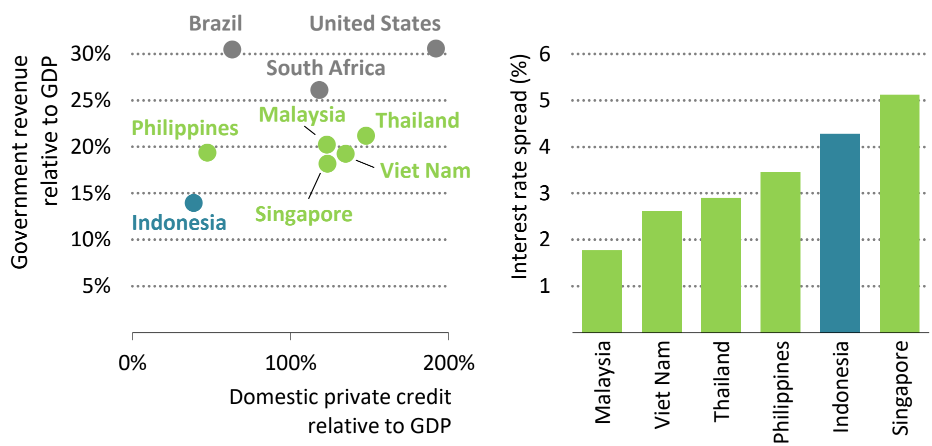
Investments across the Indonesian economy are shaped by the broad macroeconomic context. The prospects for spending on capital-intensive clean energy projects are particularly sensitive to the cost of capital, which is affected by a range of economy-wide and sector-specific factors. Medium-term prospects will also depend on how global macroeconomic tensions evolve and how the domestic currency responds to changing financial conditions worldwide.

Improvements around transparency, the quality of institutions and the general business environment have been notable, but the government's approach to FDI remains "restrictive, with many primary and services sectors still partly off limits to foreign investors" (OECD, 2020). Restrictions include higher minimum capital requirements for foreign-invested companies and local content requirements across different areas (including renewable electricity projects). However, in 2021 the government introduced the Omnibus Law on Job Creation to ease some of these factors and to spur economic growth. The law aims to loosen labour market conditions, reduce red tape and bring in private and foreign capital.

Despite being quite a large economy, Indonesia's financial sector is relatively shallow and access to finance, especially long-term capital, can still be challenging (Figure 5.25).

Government revenues and private credit as a share of GDP are low compared to peer economies, even before the pandemic. Bank assets as a share of GDP are below 55% in Indonesia, compared to levels above 150% in Viet Nam, Malaysia and Singapore, or around 70% in India and 115% in Brazil. The system is also quite costly, as average net interest margins (the difference between earnings on loans and deposits) of Indonesian banks are higher than its regional peers. All in all, this contributes to weak intermediation efficiency and holds back financial development and economic growth (World Bank, 2022).

Figure 5.25 ▷ Government revenue and private credit as share of GDP and interest rate spread, 2016 – 2020



Access to finance in Indonesia can be challenging compared with other emerging market economies, holding back private sector investment and economic growth

Notes: Annual averages for 2016-2020 are shown. Revenue consists of taxes, social contributions, grants receivable and other revenue. Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations. Interest rate spread equals lending rates minus deposit rates.

Sources: IMF (2022); World Bank (2022).

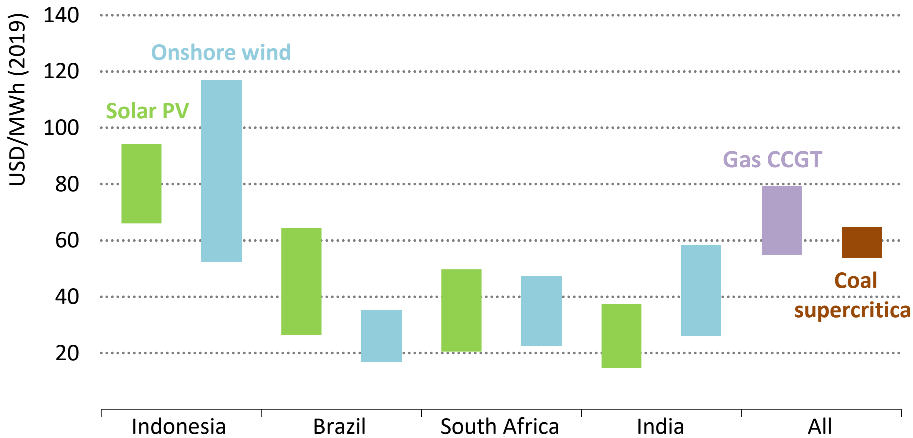
Mobilising high levels of investment in clean energy sectors in Indonesia will require further public support with regards to both cross-cutting and sector-specific factors. A credible long-term vision for the country's transition is critical to create confidence among investors.

Clean electricity

Clean electricity investment depends on various factors, notably project costs, policies and regulation, the ease to obtain permits and buy land, the underlying contracts offered to investors, and transmission constraints. Despite progress in some of these areas, persistent risk factors push up the costs of renewable electricity projects in Indonesia compared with other emerging market economies. Capital costs for utility-scale solar PV and wind electricity generation in Indonesia are higher than in South Africa or Brazil, and much higher than in

China or India (IEA, 2021b). IEA analysis shows that if financing conditions for utility-scale solar PV in Indonesia fall to the average level in advanced economies, the levelised cost of electricity (LCOE) of this technology could be around 40% lower (IEA, 2021b).

Figure 5.26 ▷ LCOE for utility-scale solar PV and onshore wind in selected countries



Higher policy and regulatory risks are a major reason why the costs of solar and wind in Indonesia are above the levels seen in other emerging market economies

Notes: LCOE = levelised cost of electricity; CCGT = combined-cycle gas turbine. LCOEs are based on projects with final investment decisions in 2020.

Source: IEA (2021b).

The attractiveness of an investment depends critically on sector policies and regulations. For example, persistent uncertainty around the tariff for renewables in Indonesia has been a key impediment for investment. Local continent requirements raise the cost of renewables projects. In 2020, the government passed Ministerial Regulation 4/2020 which introduced priority dispatch for generation from renewables and removed the need to develop renewable projects on a build–own-operate-transfer basis for a build-own-operate scheme. (The transfer requirement created difficulties for developers to own land and access financing). Yet, the regulation did not change the tariff mechanism, which currently is a feed-in tariff that is not easy to calculate and is set restrictively low. The regulation is unclear about the role of auctions. More recently, the government announced a combination of updated measures to increase solar PV development by 2025: developing 2.3 GW of solar PV capacity at former mining sites, replacing diesel generators with solar (almost 900 MW) and a USD 1 billion plan to boost rooftop solar (IESR, 2021). How these ambitions will translate into firm investment remains to be seen.

Issues around land access, permits and the ability of the transmission system to integrate increasing amounts of variable renewables are also important to ensure project bankability. According to a survey prepared by the Institute for Essential Services Reform in Indonesia, over 85% of renewable electricity developers surveyed claim that the permit process is time consuming and increases overall transaction costs (IESR, 2021. Streamlining the permitting and licensing process could help), as could a more independent regulatory body for the electricity sector.

End-use electrification and efficiency

Demand-side investments are an essential component of Indonesia's journey to net zero emissions. These include spending to increase electrification and improve efficiency in the industry and transportation sectors. Efficiency improvements in the buildings sector will also be essential given its contribution to electricity demand and the challenge of decarbonising its emissions-intensive electricity mix.

Lack of access to affordable financing, and the ability to pay for higher upfront costs (especially when efficiency services or appliances are paid by households or small- and medium-size enterprises directly), is a key impediment to mobilise larger amounts of capital to end-uses and efficiency in Indonesia. In the case of EVs, the degree and speed at which charging infrastructure is rolled out will be a crucial variable. The lack of energy-related building codes and performance standards also holds back investment; the green building market is still in an early stage of development. Public finance is a constraint: of the three cities – Jakarta, Bandung and Semarang – that have already established green building codes, only Bandung provides incentives.

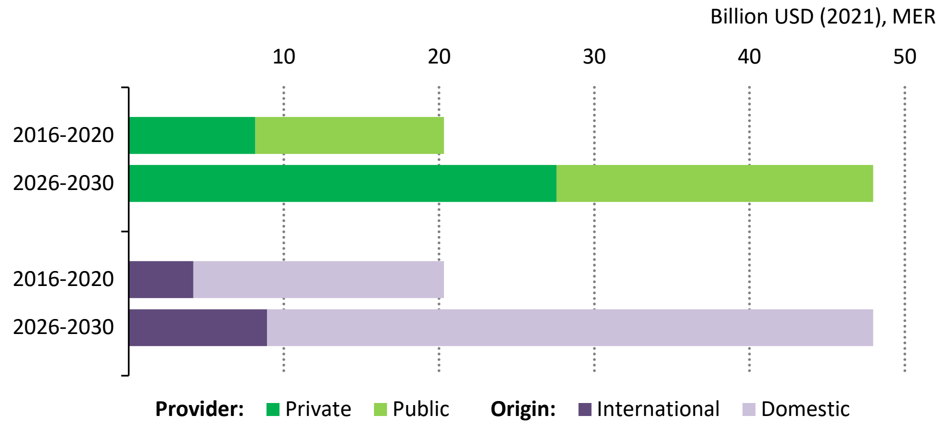
5.4.1 Actions for mobilising finance

Use public finance strategically to mobilise private funds

Public finance will not cover more than a fraction of the investments that are required in Indonesia, so these funds will need to be used prudently and strategically to ensure higher levels of investment in the APS, as well as a different allocation of sources of finance (Figure 5.27). Most transition-related energy investment will need to be carried out by private developers, consumers and financiers responding to market signals and policies set by governments. Alongside the necessary policy and regulatory reforms, public financial institutions – led by international development banks and larger climate finance commitments from advanced economies – play crucial roles to bring forward investment in areas where private players do not yet see the right balance of risk and reward.

Public actors, including state-owned enterprises, often have a key part to play in funding network infrastructure and clean energy transitions in emissions-intensive sectors. This includes the social implications of change, for example in regions that are reducing reliance on coal mining and/or generation. Private capital can play much larger roles in areas where technology risks are lower, as is the case for mature clean technologies such as wind and solar.

Figure 5.27 ▷ Sources of finance for total energy investment in Indonesia by provider and origin in the Announced Pledges Scenario, 2016 – 2030



Investment required to meet Indonesia's climate goals will need to come primarily from private actors, although public finance retains a crucial catalytic role

A larger range of financial products will also be essential. For instance, mechanisms to promote longer term savings could help match deposits with the long-life investment profiles of clean energy assets. Financial products can also be tailored to address specific project risks: Indonesia's experience with the Geothermal Resource Risk Mitigation Facility provides a useful example of some of the opportunities and challenges (World Bank,2020).

Development finance institutions (DFI) can support local banks to allocate green finance and aggregate it into portfolios. This can facilitate investment, for instance, for end-use appliances which are generally financed by households and businesses. These borrowers tend to have lower credit capacity and to request relatively small amounts (with high transactions costs for commercial banks).

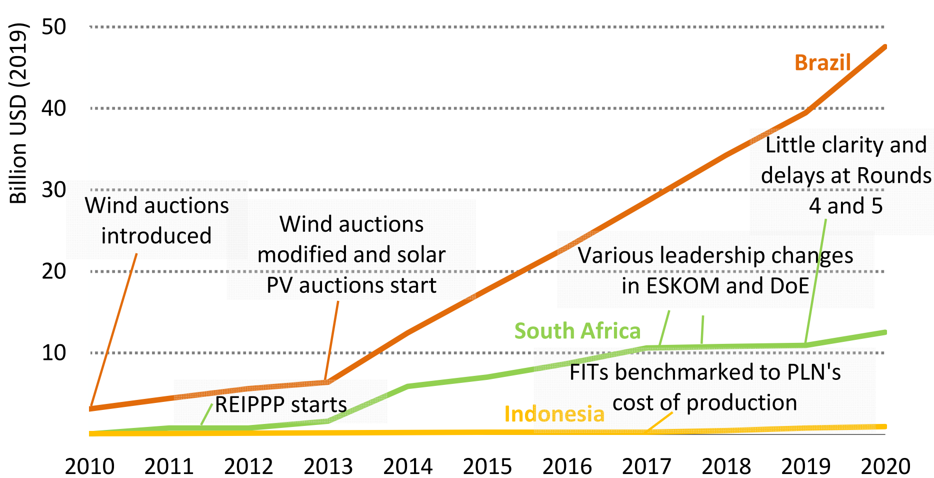
In parallel, public finance, including from DFIs, will be important to improve the financial and operational performance of state-owned enterprises, PLN in particular. PLN is the main investor in the electricity sector in Indonesia and is the main counterparty to independent power producers (IPPs) in generation. However, PLN's existing take-or-pay contracts (mainly with IPPs operating coal-fired electricity generators) and a lack of cost-reflective tariffs has been putting pressure on its balance sheet and government finances. Frozen tariffs since 2018, and a combination of government discounts introduced during the pandemic, lower electricity demand and reduced payment capability of consumers has added stress. DFI support in these areas – alongside necessary policy and regulatory changes – is essential to facilitate the phase-out of coal.

Improve the enabling environment for renewable energy investment

There are various approaches to attract more private capital to renewable electricity projects in Indonesia, but providing clarity on tariffs needs to be a first-order priority. The attractiveness of investments is heavily affected by the level and predictability of revenue streams. Indonesia is a large and expanding untapped renewables market with the scale to attract international players.

Introducing clear multi-stage procurement programmes that provide long-term visibility for investors and financiers has proven effective to boost market development across the world (Figure 5.28). Various emerging market and developing economies have combined such programmes with concessional funds to help mitigate particular risks and with technical assistance from DFIs. Such programmes have generally had two key components: competitive mechanisms to assign generation capacity (auctions) and well-designed underlying contracts, both of which have facilitated price discovery, learning, reduced the costs of capital, and ultimately lower prices (IEA, 2021b). Indonesia does not yet have such a programme.

Figure 5.28 ▷ Cumulative investment in utility-scale solar PV and wind in Brazil, Indonesia and South Africa, 2010 – 2020



Reducing the risks facing private investors will be crucial for Indonesia's spending on clean electricity to take off

Notes: FITs = feed-in tariffs. REIPPP = Renewable Energy Independent Power Producer Programme in South Africa; DoE = Department of Energy in South Africa. ESKOM is the state-owned electric utility in South Africa. PLN is the state-owned electric utility in Indonesia.

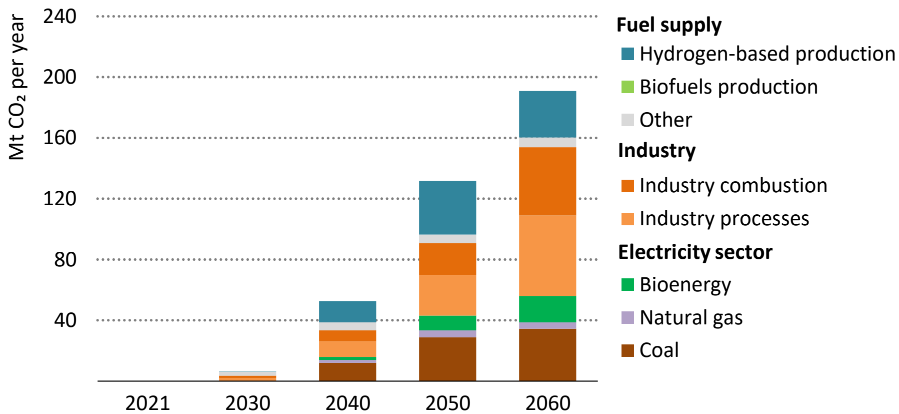
Source: IEA (2021b).

5.5 Role of CCUS

5.5.1 CCUS in net zero emissions pathway

Carbon capture, utilisation and storage (CCUS) is a suite of technologies that involve the capture of carbon dioxide from point sources or from the air, combined with transport to a place of permanent geological sequestration or utilisation. CCUS is set to play important and diverse roles in supporting Indonesia's clean energy transition, in particular in industry, electricity generation and fuel transformation. In the APS, CCUS applications pick up after 2025, with the amount of CO_2 captured rising to over 6 Mt annually in 2030, and reaching around 190 Mt annually in 2060 (Figure 5.29).

Figure 5.29 ▹ CCUS deployment in Indonesia in the Announced Pledges Scenario, 2020 – 2060



CCUS technologies are instrumental to curb CO_2 emissions from the electricity and industry sectors, allowing some existing coal-fired plants to be used as low emissions options

Notes: Hydrogen-based production also includes other hydrogen-based fuels and products such as ammonia. Total CO_2 captured includes the CO_2 captured from CCUS facilities in the energy sector, but excludes CO_2 captured and used for urea production. Other fuel supply includes fossil fuels extraction and transformation (e.g. refining).

Indonesia is the most advanced country in Southeast Asia in terms of planning for CCUS. There are ten proposed CCUS projects at various stages of development: six involve CO_2 capture at natural gas processing plants, and four relate to low-carbon ammonia production for fuel applications, coal-to-liquids, pulp and paper production and refining. If all plans proceed, these projects could be capturing over 14 Mt CO_2 per year by 2030. While encouraging, these projects have yet to reach the final investment decision stage, and supporting policies are required to incentivise investment.

Regulatory frameworks for CO_2 transport and storage infrastructure are crucial enablers of storage development. In a promising step, in February 2022, Indonesia introduced the first draft regulatory framework for CCUS in Southeast Asia. Successful development of the current pipeline of projects, and ramp up of capture in the APS toward 2060, requires that government leadership and policy support is significantly strengthened, particularly for early investment in CO_2 transport and storage infrastructure. Further, regulations and financial support for CCUS should privilege dedicated storage of captured CO_2; most proposed projects plan to use CO_2 for enhanced hydrocarbon recovery (EHR), a process through which CO_2 is injected to increase hydrocarbon production (IEA, 2015).

Cost-competitive decarbonisation of heavy industry

Heavy industry is a key driver of CCUS deployment in the APS. It is deployed to tackle emissions from existing industrial facilities, many of which were only built in the past decade, as well as emissions from the current project pipeline of new industrial capacity. CCUS provides solutions for heavy industry sectors such as cement, and iron and steel that are cost competitive relative to other low emissions technologies, and relatively mature and scalable (see Chapter 3, section 3.4.5). By 2060, CCUS deployment in steel and cement capture 75 Mt CO_2, making up almost 40% of all CO_2 captured in the APS. By 2060, CCUS deployment in the chemicals sub-sector captures more than 20 Mt CO_2.

Owing to its high concentration of CO_2, ammonia production is one of the least-cost capture opportunities for CCUS. About 5 Mt CO_2 is already being captured and utilised in urea production in Indonesia.[6] Japan and Indonesia signed a Memorandum of Co-operation in January 2022 to collaborate on hydrogen, ammonia, "carbon recycling" and CCUS. Panca Amara Utama, a 0.7 Mt ammonia plant in Central Sulawesi, is studying the feasibility of capturing CO_2 from ammonia production, with the export of clean ammonia to Japan.

Contributing to a flexible and low emissions electricity sector

CCUS helps Indonesia to make the best use of existing and planned power plants to meet its growing electricity needs in the APS, by providing dispatchable low-carbon electricity to balance variable renewables. With deployment starting after 2030, more than 50 Mt CO_2 are captured in 2060 from coal, gas and biomass power plants. The share of coal-fired power plants equipped with carbon capture increases from about 6% in 2040 to around 80% in 2060 in the APS.

Supercritical and ultra-supercritical coal-fired power plants are better candidates for CCUS retrofitting than subcritical coal-fired plants as they have a higher design efficiency and are less likely to require any boiler or turbine upgrades to meet steam conditions for CO_2 capture. Only 20% of Indonesia's coal plants today are supercritical or ultra-supercritical, though capacity additions under construction will increase that share to around 30% in the next few

[6] CO_2 captured and used in urea production is outside of the energy sector boundary and is therefore not included in the total amount of CO_2 captured in the energy sector presented in this report.

years. Equipping today's supercritical and ultra-supercritical coal plants with CCUS could deliver over 30 Mt CO_2 abatement annually, increasing to around 80 Mt CO_2 annually when including the plants in the construction pipeline to 2030. The APS taps a portion of this potential, with over 30 Mt CO_2 captured from coal-fired electricity generators in 2060, while other plants are either retired or converted to burn low emissions fuels. Bioenergy equipped with CCUS (BECCS) and biomass fuel switching or co-firing in coal or gas plants can also mitigate emissions from electricity generation. Carbon dioxide removal (CDR) can be employed to mitigate residual emissions in other sectors. By 2060, almost 20 Mt CO_2 is removed in the electricity sector through BECCS in the APS.

Role of CCUS in the fuel transformation sector

Given the important role of natural gas, both in Indonesia's domestic energy mix and in exports, CCUS plays a major role in reducing emissions from the natural gas value chain in the APS. CO_2 concentrations vary across gas fields and can be as high as 70% as in the case of the East Natuna gas field. This CO_2 needs to be separated from methane to meet natural gas or LNG standards. This process results in a highly concentrated (>98%) CO_2 stream, which makes natural gas processing one of the least-cost applications of CCUS.

In oil production, refineries vary in scale and configuration, with some high concentration emissions from chemical processes. Around half of refinery emissions originate from a number of small process heating sources, and these lower concentration emissions are more costly to capture. Around the world, over 4 Mt CO_2 per year are captured from hydrogen production in refineries. In May 2022, Pertamina and Air Liquide announced a joint study to implement CCUS at the hydrogen production unit at the Balikpapan refinery in East Kalimantan.

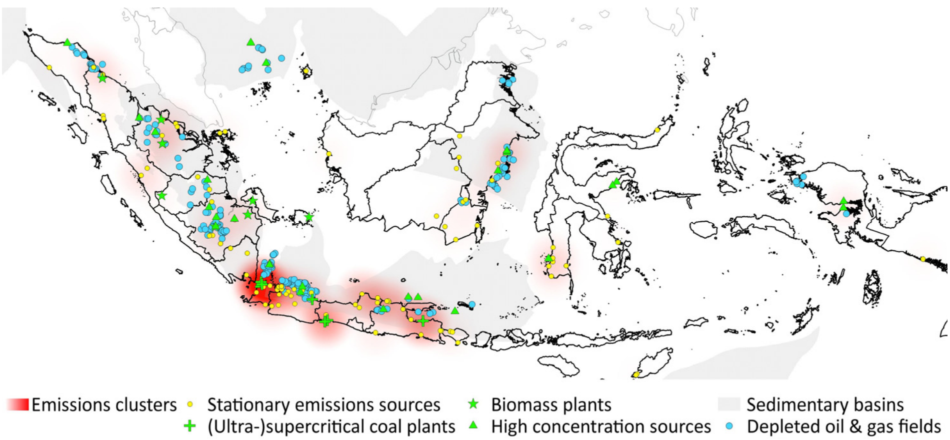
Capturing CO_2 from existing biorefineries constitutes opportunities for CDR deployment with limited land-use impact. Biodiesel plants which rely on biomass gasification with the Fisher-Tropsch process produce a high concentration CO_2 stream which can be captured at low cost. However, biodiesel in Indonesia is mainly produced as a co-product of palm oil refineries, through the transesterification process, which presents little opportunity for CCUS retrofits.

5.5.2 Aligning capture opportunities with CO_2 storage

Around 15 900 Mt CO_2 of storage capacity has been identified in sedimentary basins and depleted oil and gas fields in Indonesia, although detailed storage assessments and site-level characterisations are still needed (OGCI, 2022). Theoretical capacity in oil and gas fields has been assessed at 1 800 Mt CO_2, equivalent to three years of Indonesia's total current emissions. Potential CO_2 storage capacity is not evenly distributed in Indonesia. Over 50% of storage capacity is located in South Sumatra and around 15% in West Java, which hosts around 35% of the country's stationary emissions sources, with Java as a whole concentrating around 70% of Indonesia's stationary emissions sources.

Half of CO_2 emissions sources are located within nine highly concentrated emissions clusters that emit at least 5 Mt CO_2 per year.[7] Two of these clusters are located in East Kalimantan and Central Sumatra and the rest are in Java (Figure 5.30). Targeting clusters with low cost CO_2 abatement opportunities such as ammonia, methanol and natural gas processing, e.g. the East Kalimantan cluster, and high efficiency coal plants, e.g. the West and Central Java clusters, could represent an early opportunity to deploy CO_2 transport and storage infrastructure.

Figure 5.30 ⊳ CO_2 emissions clusters and potential for source-sink matches in Indonesia



Around 50% of Indonesia's CO_2 emissions sources are located within nine highly concentrated clusters

Notes: High concentration sources include ammonia, methanol and ethylene, oil and gas extraction, and LNG trains. All the sources represented are facilities less than 30-years old and emit more than 100 000 kilotonnes CO_2 per year.

Sources: IEA analysis based on S&P Global(2021); GID (2022); Rystad (2022).

Indonesia's well distributed oil and gas activity could offer important opportunities for matching storage opportunities in depleted oil and gas fields to clusters of emissions sources. The average distance from emissions sources to potential depleted fields is around 90 km, with 45% of emissions sources located within 50 km of depleted fields, 70% within 100 km and 93% within 200 km. Most identified industrial clusters are within 100 km of potential depleted fields, but currently assessed capacity in these fields falls short of capture needs for all identified clusters on Java.

The largest cluster in Cilegon, West Java, is within 50 km of the closest fields, but the combined capacity of depleted offshore and onshore fields in West Java is currently assessed

[7] Classified as having a minimum of 5 Mt CO_2 per year distance between emissions sources of less than 10 km.

at around 400 Mt, just enough to store ten years' worth of the cluster's suitable emissions sources at current emissions levels. However, over 2 000 Mt of storage capacity in saline aquifers would be accessible within 200-300 km. Detailed assessments and characterisation of CCUS opportunities should prioritise depleted fields located close to large emissions centres, while a whole suite of emissions reduction measures should be pursued in addition to CCUS, to allow capture and storage opportunities to be utilised for emissions sources with limited economic alternatives for emissions reduction.

Emissions sources are smaller scale and more diffuse in Sumatra and Kalimantan, which explains the lower number of large clusters on these islands. However, a high distribution of oil and gas fields might reduce the need to aggregate sources to leverage cost reductions in CO_2 transport, with over 20% and close to 30% of emissions sources within 15 km of potential storage in Sumatra and Kalimantan respectively, which increases to over 50% in North Sumatra. The ratio of assessed capacity to emissions sources is also larger in Kalimantan and Sumatra. The two identified clusters are both within 50 km of potential depleted oil and gas fields with enough assessed capacity to store 20-30 years' worth of emissions of the respective clusters.

5.6 Air pollution

Today around seven-in-ten people in Indonesia breathe polluted air, with major consequences for human life expectancy and economic productivity. Around 150 000 people died prematurely in 2021 from exposure to ambient air pollution, and 100 000 from breathing polluted indoor air, mainly due to the lack of access to clean cooking. Air pollution is particularly marked in Jakarta, with 136 registered industrial facilities and power plants in highly emitting sectors within a 100 km radius of the city border (CREA, 2020). It is estimated that on average, Indonesians live two-and-a-half years less than they would do in the absence of polluted air and that the overall costs of exposure to ambient particulate matter[8] air pollution was 6.6% of GDP in 2019 (World Bank Group, 2022).

In the STEPS, the outlook for air pollution depends heavily on the pollutant in question (Figure 5.31). Emissions of nitrogen oxides (NO_X) are relatively steady between 2021 and 2050, with increases in industry balanced by decreases in transport and power. Sulphur dioxide (SO_2) emissions decrease by 16% over this period, with electricity generation accounting for more than half of this reduction. Total emissions of fine particulate matter ($PM_{2.5}$) are almost 10% lower in 2050 compared to 2021, with sharp reductions in emissions from the buildings sector, mainly from less use of fuelwood for cooking - more than offsetting increases in road transport and industry.[9]

There are large reductions of all major pollutants between 2021 and 2050 in the APS. NO_X emissions decline by almost 40%, of which 65% is from road transport, underpinned by

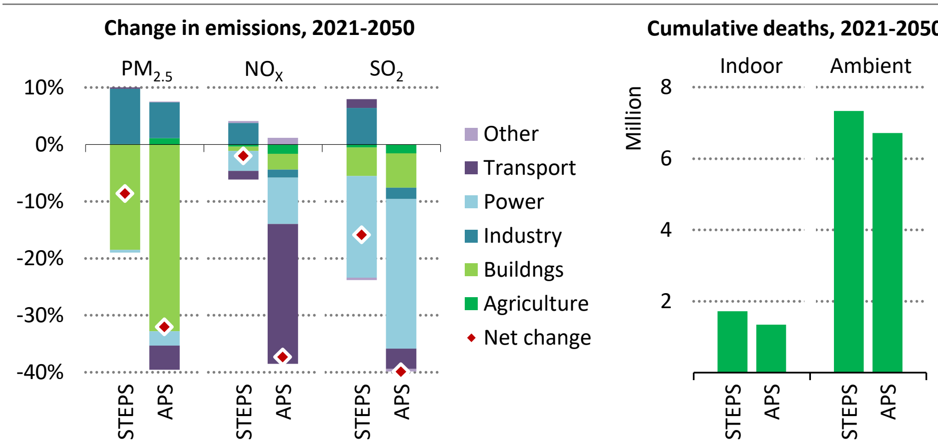
[8] Ambient air pollution is polluted air from outdoor sources.

[9] Fine particulate matter of less than 2.5 micrometres in diameter is known as $PM_{2.5}$.

electrification. Some of the biggest emitters today undergo the steepest declines. For example, pollution from trucks, which make up three-quarters of road transport NO_X emissions today, declines by around 95% by 2050. SO_2 emissions decline by 40% in 2050 compared to 2021 levels. In 2050, $PM_{2.5}$ pollution is down one-third on 2021 levels, with almost all of the additional reductions in APS compared to STEPS from the buildings, power and transport sectors.

The differences in air pollution levels between the two scenarios have stark consequences. In the STEPS, around 7.3 million people are projected to die prematurely due to ambient air pollution between 2021 to 2050, whereas the APS projection is for 6.7 million premature deaths over the same period, saving more than half a million lives. A chief cause of premature deaths related to indoor air pollution is $PM_{2.5}$ pollution from the traditional use of biomass in homes. The APS also projects fewer deaths than the STEPS, as households gain access to clean cooking faster and with a great share of zero emissions electric cooking options. To 2050, the APS pathway would result in around almost 400 000 fewer premature deaths compared to the STEPS.

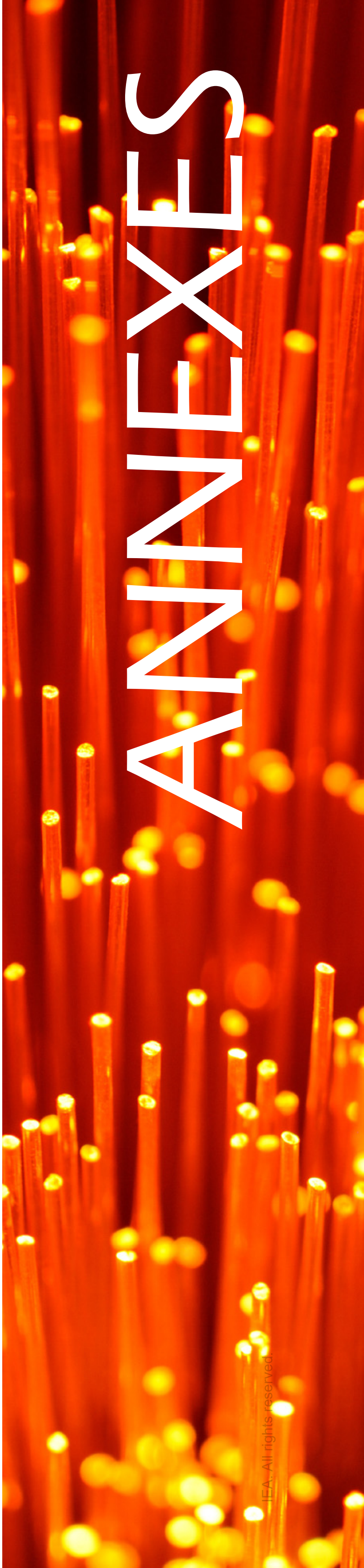
Figure 5.31 ▹ Change in air pollution by pollutant and source, and total number of premature deaths in the Stated Policies and Announced Pledges scenarios, 2021 – 2050



A 30-40% cut in all major air pollutants in the APS may reduce premature deaths by 1 million between 2021-2050

Note: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

Source: IEA analysis based on IIASA modelling.


ANNEXES

Definitions

This annex provides general information on terminology used throughout this report including: units and general conversion factors; definitions of fuels, processes and sectors; regional and country groupings; and abbreviations and acronyms.

Units

Area	km^2	square kilometre
	ha	hectare
Coal	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)
Distance	km	kilometre
Emissions	ppm	parts per million (by volume)
	t CO_2	tonnes of carbon dioxide
	Gt CO_2-eq	gigatonnes of carbon-dioxide equivalent (using 100-year global warming potentials for different greenhouse gases)
	kg CO_2-eq	kilogrammes of carbon-dioxide equivalent
	g CO_2/km	grammes of carbon dioxide per kilometre
	kg CO_2/kWh	kilogrammes of carbon dioxide per kilowatt-hour
Energy	EJ	exajoule (1 joule x 10^{18})
	PJ	petajoule (1 joule x 10^{15})
	TJ	terajoule (1 joule x 10^{12})
	GJ	gigajoule (1 joule x 10^{9})
	MJ	megajoule (1 joule x 10^{6})
	boe	barrel of oil equivalent
	toe	tonne of oil equivalent
	ktoe	thousand tonnes of oil equivalent
	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal units
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
	kcal	kilocalorie
Gas	bcm	billion cubic metres
Mass	kg	kilogramme (1 000 kg = 1 tonne)
	kt	kilotonnes (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonnes (1 tonne x 10^9)

Monetary	IDR	Indonesian Rupiah (USD 1 = ~IDR 15 000)
	USD million	1 US dollar x 10^6
	USD billion	1 US dollar x 10^9
	USD trillion	1 US dollar x 10^{12}
	USD/t CO_2	US dollars per tonne of carbon dioxide
Oil	kb/d	thousand barrels per day
	mb/d	million barrels per day
	mboe/d	million barrels of oil equivalent per day
Power	W	watt (1 joule per second)
	kW	kilowatt (1 watt x 10^3)
	MW	megawatt (1 watt x 10^6)
	GW	gigawatt (1 watt x 10^9)
	TW	terawatt (1 watt x 10^{12})

General conversion factors for energy

		Multiplier to convert to:				
		PJ	Gcal	Mtoe	MBtu	GWh
Convert from:	PJ	1	2.388 x 10^5	2.388 x 10^{-2}	9.478 x 10^5	277.8
	Gcal	4.1868 x 10^{-6}	1	10^{-7}	3.968	1.163 x 10^{-3}
	Mtoe	41.868	10^7	1	3.968 x 10^7	11 630
	MBtu	1.0551 x 10^{-6}	0.252	2.52 x 10^{-8}	1	2.931 x 10^{-4}
	GWh	3.6 x 10^{-3}	860	8.6 x 10^{-5}	3 412	1

Note: There is no generally accepted definition of boe; typically the conversion factors used vary from 7.15 to 7.40 boe per toe.

Definitions

Advanced bioenergy: Sustainable fuels produced from non-food crop feedstocks, which are capable of delivering significant life cycle greenhouse gas emissions savings compared with fossil fuel alternatives, and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts. This definition differs from the one used for "advanced biofuels" in US legislation, which is based on a minimum 50% life cycle greenhouse gas reduction and which, therefore, includes sugar cane ethanol.

Agriculture: Includes all energy used on farms, in forestry and for fishing.

Agriculture, forestry and other land use (AFOLU) emissions: Includes greenhouse gas emissions from agriculture, forestry and other land use.

Ammonia (NH_3): Is a compound of nitrogen and hydrogen. It can be used directly as a fuel in direct combustion processes, as well as in fuel cells or as a hydrogen carrier. To be a low emissions fuel, ammonia must be produced from low-carbon hydrogen, the nitrogen separated via the Haber process with electricity generated from low-carbon sources.

Aviation: This transport mode includes both domestic and international flights and their use of aviation fuels. Domestic aviation covers flights that depart and land in the same country; flights for military purposes are included. International aviation includes flights that land in a country other than the departure location.

Balance sheet finance: Involves the explicit financing of assets on the balance sheet of a company using retained earnings from business activities, including those with regulated revenues, as well as corporate debt and equity issuance in capital markets. To some extent, it measures the degree to which a company self-finances its assets, though balance sheets also serve as intermediaries for raising capital from external sources. This report also refers to "corporate finance" when describing balance sheet financing.

Battery storage: Energy storage technology that uses reversible chemical reactions to absorb and release electricity on demand.

Biodiesel: Diesel-equivalent, processed fuel made from the transesterification (a chemical process that converts triglycerides in oils) of vegetable oils and animal fats.

Bioenergy: Energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. It includes solid bioenergy, liquid biofuels and biogases.

Biogas: A mixture of methane, carbon dioxide and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment.

Biogases: Include both biogas and biomethane.

Biomethane: Biomethane is a near-pure source of methane produced either by "upgrading" biogas (a process that removes any carbon dioxide and other contaminants present in the biogas) or through the gasification of solid biomass followed by methanation. It is also known as renewable natural gas.

Blended finance: A broad category of development finance arrangements that blend relatively small amounts of concessional donor funds into investments in order to mitigate specific investment risks. This can catalyse important investments that would otherwise be unable to proceed under conventional commercial terms. These arrangements can be structured as debt, equity, risk-sharing or guarantee products. Specific terms of these arrangements, such as interest rates, tenor, security or rank, can vary across scenarios.

Buildings: The buildings sector includes energy used in residential and services buildings. Services buildings include commercial and institutional buildings and non-specified other. Building energy use includes space heating and cooling, water heating, lighting, appliances and cooking equipment.

Bunkers: Includes both international marine bunker fuels and international aviation bunker fuels.

Carbon capture, utilisation and storage (CCUS): The process of capturing carbon dioxide (CO_2) emissions from fuel combustion, industrial processes or directly from the atmosphere. Captured CO_2 emissions can be stored in underground geological formations, onshore or offshore or used as an input or feedstock in manufacturing.

Carbon dioxide (CO_2): Is a gas consisting of one part carbon and two parts oxygen. It is an important greenhouse (heat-tapping) gas.

Clean energy: In *electricity*, clean energy includes: generation from renewable sources, nuclear and fossil fuels fitted with CCUS; battery storage; and electricity grids. In *efficiency*, clean energy includes energy efficiency in buildings, industry and transport, excluding aviation bunkers and domestic navigation. In *end-use* applications, clean energy includes: direct use of renewables; electric vehicles; electrification in buildings, industry and international marine transport; use of hydrogen and hydrogen-based fuels; CCUS in industry and direct air capture. In *fuel supply*, clean energy includes low emissions fuels, liquid biofuels and biogases, low-carbon hydrogen and hydrogen-based fuels.

Clean cooking systems: Cooking solutions that release less harmful pollutants, are more efficient and environmentally sustainable than traditional cooking options that make use of solid biomass (such as a three-stone fire), coal or kerosene. This refers primarily to improved solid biomass cookstoves, biogas/biodigester systems, electric stoves, liquefied petroleum gas, natural gas or ethanol stoves.

Coal: Includes both primary coal (i.e. lignite, coking and steam coal) and derived fuels (e.g. patent fuel, brown-coal briquettes, coke-oven coke, gas coke, gas works gas, coke-oven gas, blast furnace gas and oxygen steel furnace gas). Peat is also included.

Coal-to-gas: Process in which mined coal is first turned into syngas (a mixture of hydrogen and carbon monoxide) and then into synthetic methane.

Coal-to-liquids (CTL): Transformation of coal into liquid hydrocarbons. It can be achieved through either coal gasification into syngas (a mixture of hydrogen and carbon monoxide), combined using the Fischer-Tropsch or methanol-to-gasoline synthesis process to produce liquid fuels, or through the less developed direct-coal liquefaction technologies in which coal is directly reacted with hydrogen.

Coking coal: Type of coal that can be used for steel making (as a chemical reductant and a source of heat), where it produces coke capable of supporting a blast furnace charge. Coal of this quality is also commonly known as metallurgical coal.

Concentrating solar power (CSP): Solar thermal power generation technology that collects and concentrates sunlight to produce high temperature heat to generate electricity.

Concessional financing: Resources extended at terms more favourable than those available in the market. This can be achieved through one or a combination of the following factors: interest rates below those available on the market; maturity, grace period, security, rank or back weighted repayment profile that would not be accepted/extended by a commercial financial institution; and/or by providing financing to the recipient otherwise not served by commercial financing.

Conventional liquid biofuels: Fuels produced from food crop feedstocks. Commonly referred to as first generation biofuels and include sugar cane ethanol, starch-based ethanol, fatty acid methyl ester (FAME), straight vegetable oil (SVO) and hydrotreated vegetable oil (HVO) produced from palm, rapeseed or soybean oil.

Critical minerals: A wide range of minerals and metals used in clean energy technologies. They include chromium, copper, battery metals (lithium, nickel, cobalt, manganese and graphite), molybdenum, platinum group metals, zinc, rare earth elements and other commodities, as listed in the Annex of the IEA special report on the Role of Critical Minerals in Clean Energy Transitions (https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions).

Demand-side integration (DSI)**:** Consists of two types of measures: actions that influence load shape such as energy efficiency and electrification; and actions that manage load such as demand-side response.

Demand-side response (DSR)**:** Describes actions which can influence the load profile such as shifting the load curve in time without affecting total electricity demand, or load shedding such as interrupting demand for a short duration or adjusting the intensity of demand for a certain amount of time.

Direct air capture (DAC): Technology to capture CO_2 from the atmosphere and permanently store it in deep geological formations or for use in the production of fuels, chemicals, building materials or other products that use CO_2. When the CO_2 is geologically stored it is permanently removed from the atmosphere resulting in negative emissions.

Dispatchable generation: Refers to technologies for which power output can be readily controlled, i.e. increased to maximum rated capacity or decreased to zero, in order to match supply with demand.

Economic activities: Include industry groupings such as mining and quarrying, manufacturing and construction, which are categorised in accordance with revision 4 of the International Standard Industrial Classification of All Economic Activities (ISIC) – the international reference classification of productive activities. It provides a set of activity categories that can be used for the collection and reporting of statistics based on similarity of production inputs, process and technology.

Electricity demand: Defined as total gross electricity generation less own use generation, plus net trade (imports less exports), less transmission and distribution losses.

Electricity generation: Defined as the total amount of electricity generated by power only or combined heat and power plants including generation required for own use. This is also referred to as gross generation.

End-use sectors: Include industry (i.e. manufacturing, mining, chemical production, blast furnaces and coke ovens), transport, buildings (i.e. residential and services) and other (i.e. agriculture and other non-energy use).

Energy-related and industrial process CO_2 emissions: Carbon dioxide emissions from fuel combustion and from industrial processes. Note that this does not include fugitive emissions from fuels, flaring or CO_2 from transport and storage. Unless otherwise stated, CO_2 emissions in *An Energy Sector Roadmap to Net Zero Emissions in Indonesia* refer to energy-related and industrial process CO_2 emissions.

Energy sector greenhouse gas (GHG) emissions: Energy-related and industrial process CO_2 emissions plus fugitive and vented methane (CH_4) and nitrous oxide (N_2O) emissions from the energy and industry sectors.

Energy services: See useful energy.

Ethanol: Refers to bio-ethanol only. Ethanol is produced from fermenting any biomass high in carbohydrates. Currently, ethanol is made from starches and sugars, but second generation technologies will allow it to be made from cellulose and hemicellulose, the fibrous material that makes up the bulk of most plant matter.

Fischer-Tropsch synthesis: Catalytic production process for the production of synthetic fuels. Natural gas, coal and biomass feedstocks can be used.

Fossil fuels: Include coal, natural gas, oil and peat.

Gases: Include natural gas, biogases, synthetic methane and hydrogen.

Gaseous fuels: Include natural gas, biogas, biomethane, hydrogen and synthetic methane.

Gas-to-liquids (GTL): Process featuring reaction of methane with oxygen or steam to produce syngas (a mixture of hydrogen and carbon monoxide) followed by synthesis of liquid products (such as diesel and naphtha) from the syngas using Fischer-Tropsch catalytic synthesis. The process is similar to that used in coal-to-liquids.

Geothermal: Geothermal energy is heat derived from the sub-surface of the earth. Water and/or steam carry the geothermal energy to the surface. Depending on its characteristics, geothermal energy can be used for heating and cooling purposes or can be harnessed to generate clean electricity if the temperature is adequate.

Green bond: A green bond is a type of fixed-income instrument created to fund projects that have positive environmental and/or climate benefits.

Heat (end-use): Can be obtained from the combustion of fossil or renewable fuels, direct geothermal or solar heat systems, exothermic chemical processes and electricity (through resistance heating or heat pumps which can extract it from ambient air and liquids). This category refers to the wide range of end-uses, including space and water heating and cooking in buildings, desalination and process applications in industry. It does not include cooling applications.

Hydrogen: In this report, hydrogen refers to low-carbon hydrogen unless otherwise stated. To be low-carbon hydrogen, either the emissions associated with fossil fuel-based hydrogen production must be prevented, e.g. by CCUS, or the electricity for hydrogen production from water must be low-carbon electricity. In this report, total hydrogen demand includes gaseous hydrogen for all uses, including transformation into hydrogen-based fuels and biofuels, power generation, oil refining, and onsite production and consumption. Final consumption of hydrogen includes gaseous hydrogen in end-use applications, excluding transformation into hydrogen-based fuels and biofuels, power generation, oil refining and onsite production and consumption.

Hydrogen-based fuels: Include ammonia and synthetic hydrocarbons, such as synthetic methane and synthetic oil products.

Hydropower: The energy content of the electricity produced in hydropower plants, assuming 100% efficiency. It excludes output from pumped storage and marine (tide and wave) plants.

Improved cook stoves : Intermediate and advanced improved biomass cook stoves (ISO tier ≥ 1). It excludes basic improved stoves (ISO tier 0-1).

Industry: The sector includes fuel used within the manufacturing and construction industries. Key industry branches include iron and steel, chemical and petrochemical, cement, aluminium, and pulp and paper. Use by industries for the transformation of energy into another form or for the production of fuels is excluded and reported separately under other energy sector. There is an exception for fuel transformation in blast furnaces and coke ovens, which are reported within iron and steel. Consumption of fuels for the transport of goods is reported as part of the transport sector, while consumption by off-road vehicles is reported under industry.

Informal employment: Comprises workers whose main or secondary jobs are associated with informal sector enterprises, workers whose production is exclusively for final use by their own household, and workers whose employment relationship is not subject to national labour legislation, social protection, income taxation and/or employment benefits.

International aviation bunkers: Includes the deliveries of aviation fuels to aircraft for international aviation. Fuels used by airlines for their road vehicles are excluded. The domestic/international split is determined on the basis of departure and landing locations and not by the nationality of the airline. For many countries this incorrectly excludes fuels used by domestically owned carriers for their international departures.

International marine bunkers: Covers those quantities delivered to ships of all flags that are engaged in international navigation. The international navigation may take place at sea, in coastal waters and on inland lakes and waterways. Consumption by ships engaged in domestic navigation is excluded. The domestic/international split is determined on the basis of port of departure and port of arrival, and not by the flag or nationality of the ship. Consumption by fishing vessels and by military forces is excluded and instead is included in the residential, services and agriculture category.

Investment: Investment is measured as the ongoing capital spending in energy supply capacity, energy infrastructure and energy end-use and efficiency. All investment data and projections reflect spending across the life cycle of a project, i.e. the capital spent is assigned to the year when it is incurred. Fuel supply investments include production, transformation and transportation for oil, gas, coal and low emissions fuels. Power sector investments include new builds and refurbishments of generation, electricity grids (transmission, distribution and public electric vehicle chargers) and battery storage. Energy efficiency investments include those made in buildings, industry and transport. Other end-use investments include direct use of renewables; electric vehicles; electrification in buildings, industry and international marine transport; use of hydrogen and hydrogen-based fuels; fossil fuel-based industrial facilities; CCUS in industry and direct air capture. Investment data are presented in real terms in year-2021 US dollars (USD) unless otherwise stated.

Light-duty vehicles (LDVs)**:** Includes passenger cars and light commercial vehicles (gross vehicle weight <3.5 tonnes).

Light industries: Includes less energy-intensive industries such as food processing, machinery, mining and construction.

Liquid biofuels: Liquid fuels derived from biomass or waste feedstock and include ethanol, biodiesel and biojet fuels. They can be classified as conventional and advanced biofuels according to the combination of feedstock and technologies used to produce them and their respective maturity. Unless otherwise stated, biofuels are expressed in energy-equivalent volumes of gasoline, diesel and kerosene.

Liquid fuels: Includes oil, liquid biofuels (expressed in energy-equivalent volumes of gasoline and diesel), synthetic oil and ammonia.

Lignite: Type of coal that is used in the power sector mostly in regions near lignite mines due to its low energy content and typically high moisture levels, which generally makes long distance transport uneconomic. Data on lignite in this report includes peat, a solid formed from the partial decomposition of dead vegetation under conditions of high humidity and limited air access.

Low-carbon electricity: Includes renewable energy technologies, hydrogen-based generation, nuclear power and fossil fuel power plants equipped with carbon capture, utilisation and storage.

Lower heating value: Heat liberated by the complete combustion of a unit of fuel when the water produced is assumed to remain as a vapour and the heat is not recovered.

Low emissions fuels: Include liquid biofuels, biogas and biomethane, hydrogen and hydrogen-based fuels that do not emit any CO_2 from fossil fuels directly when used and also emit very little when being produced.

Mini-grids: Small electric grid systems comprised of generation unit(s) and distribution lines, not connected to main electricity networks that link a number of households and/or other consumers. Mini-grids can be eventually connected to a main grid.

Modern energy access: Includes household access to a minimum level of electricity (initially equivalent to 250 kWh annual demand for a rural household and 500 kWh for an urban household); household access to less harmful and more sustainable cooking and heating fuels, and improved/advanced stoves; access that enables productive economic activity; and access for public services.

Modern liquid bioenergy: Includes bio-gasoline, biodiesel, biojet kerosene and other liquid biofuels.

Modern renewables: Include all uses of renewable energy with the exception of traditional use of solid biomass.

Modern solid bioenergy: Refers to the use of solid bioenergy in intermediate and advanced improved biomass cook stoves (ISO tier ≥ 1), bioenergy is often processed into products such as pellets to facilitate handling and combustion.

Natural gas: Comprises gases occurring in deposits, whether liquefied or gaseous, consisting mainly of methane. It includes both non-associated gas originating from fields producing hydrocarbons only in gaseous form, and associated gas produced in association with crude oil as well as methane recovered from coal mines (colliery gas). Natural gas liquids, manufactured gas (produced from municipal or industrial waste, or sewage) and quantities vented or flared are not included. Gas data in cubic metres are expressed on a gross calorific value basis and are measured at 15 °C and at 760 mm Hg (Standard Conditions). Gas data expressed in tonnes of oil equivalent, mainly for comparison reasons with other fuels, are on a net calorific basis. The difference between the net and the gross calorific value is the latent heat of vapourisation of the water vapour produced during combustion of the fuel (for gas the net calorific value is 10% lower than the gross calorific value).

Natural gas liquids (NGLs)**:** Liquid or liquefied hydrocarbons produced in the manufacture, purification and stabilisation of natural gas. NGLs are portions of natural gas recovered as liquids in separators, field facilities or gas processing plants. NGLs include, but are not limited to, ethane (when it is removed from the natural gas stream), propane, butane, pentane, natural gasoline and condensates.

Nominal: Nominal (value or terms) is a financial and economic term that indicates the statistic in question is measured in actual prices that exist at the time.

Non-energy use: Fuels used for chemical feedstocks and non-energy products. Examples of non-energy products include lubricants, paraffin waxes, asphalt, bitumen, coal tars and oils as timber preservatives.

Nuclear: Refers to the primary energy equivalent of the electricity produced by a nuclear power plant, assuming an average conversion efficiency of 33%.

Off-grid systems: Mini-grids and stand-alone systems for individual households or groups of consumers not connected to a main grid.

Offshore wind: Refers to electricity produced by wind turbines that are installed in open water, usually in the ocean.

Oil: Includes both conventional and unconventional oil production. Petroleum products include refinery gas, ethane, liquid petroleum gas, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirits, lubricants, bitumen, paraffin, waxes and petroleum coke.

Other energy sector: Covers the use of energy by transformation industries and the energy losses in converting primary energy into a form that can be used in the final consuming sectors. It includes losses in hydrogen production, bioenergy processing, gas works, petroleum refineries, coal and gas transformation and liquefaction. It also includes energy own use in coal mines, in oil and gas extraction and in electricity and heat production. Transfers and statistical differences are also included in this category. Fuel transformation in blast furnaces and coke ovens are not accounted in other energy sector.

Other industry: A category of industry sub-sectors that includes construction, food processing, machinery, mining, textiles, transport equipment and wood processing and industries otherwise not categorised. Other industry does not include non-ferrous metals and pulp and paper sub-sectors.

Passenger cars: A road motor vehicle, other than a moped or a motorcycle, intended to transport passengers. It includes vans designed and used primarily to transport passengers. Excluded are light commercial vehicles, motor coaches, urban buses, and mini-buses/mini-coaches.

Payback period: Refers to the period of time required to recover the amount invested in a project from its benefits (cash inflows).

Power generation: Refers to fuel use in electricity plants, heat plants and combined heat and power plants. Both main activity producer plants and small plants that produce fuel for their own use (auto-producers) are included.

Project finance: Involves external lenders, i.e. commercial banks, development banks and infrastructure funds, sharing risks with the sponsor of the project. It can also involve fundraising from the debt capital markets with asset-backed project bonds. They often involve non-recourse or limited-recourse loans where lenders provide funding on a project's future cash flow and have no or limited recourse to liability of the project parent companies.

Process emissions: CO_2 emissions produced from industrial processes which chemically or physically transform materials. A notable example is cement production, in which CO_2 is emitted when calcium carbonate is transformed into lime, which in turn is used to produce clinker.

Productive uses: Energy used towards an economic purpose: agriculture, industry, services and non-energy use. Some energy demand from the transport sector, e.g. freight, could be considered as productive, but is treated separately.

Renewables: Includes bioenergy, geothermal, hydropower, solar photovoltaics (PV), concentrating solar power (CSP), wind and marine (tide and wave) energy for electricity and heat generation.

Residential: Energy used by households including space heating and cooling, water heating, lighting, appliances, electronic devices and cooking.

Road transport: Includes all road vehicle types (passenger cars, two/three-wheelers, light commercial vehicles, buses and medium and heavy freight trucks).

Self-sufficiency: Corresponds to indigenous production divided by total primary energy demand.

Services: Energy used in commercial facilities, e.g. offices, shops, hotels, restaurants and in institutional buildings, e.g. schools, hospitals, public offices. Energy use in services includes space heating and cooling, water heating, lighting, appliances, cooking and desalination.

Shipping/navigation: This transport sub-sector includes both domestic and international navigation and their use of marine fuels. Domestic navigation covers the transport of goods or people on inland waterways and for national sea voyages (starts and ends in the same country without any intermediate foreign port). International navigation includes quantities of fuels delivered to merchant ships (including passenger ships) of any nationality for consumption during international voyages transporting goods or passengers.

Skill level: Indicates whether a high, medium or low level of education and training is required for carrying out a job, as classified by the International Standard Classification of Occupations 08 (ISCO-08).

Solar: Includes solar photovoltaics and concentrating solar power.

Solar photovoltaics (PV): Electricity produced from solar photovoltaic cells.

Solid bioenergy: Includes charcoal, fuelwood, dung, agricultural residues, wood waste and other solid wastes.

Solid fuels: Include coal, modern solid bioenergy, traditional use of biomass and industrial and municipal wastes.

Steam coal: Type of coal that is mainly used for heat production or steam-raising in power plants and, to a lesser extent, in industry. Typically, steam coal is not of sufficient quality for steel making. Coal of this quality is also commonly known as thermal coal. Synthetic methane: Low-carbon synthetic methane is produced through the methanation

Synthetic methane: Low-carbon synthetic methane is produced through the methanation of low-carbon hydrogen and carbon dioxide from a biogenic or atmospheric source.

Synthetic oil: Low-carbon synthetic oil produced through Fischer-Tropsch conversion or methanol synthesis from syngas, a mixture of hydrogen (H_2) and carbon monoxide (CO).

Total energy supply (TES)**:** Represents domestic demand only and is broken down into electricity and heat generation, other energy sector and total final consumption.

Total final consumption (TFC)**:** Is the sum of consumption by the various end-use sectors. TFC is broken down into energy demand in the following sectors: industry (including manufacturing, mining, chemicals production, blast furnaces and coke ovens), transport, buildings (including residential and services) and other (including agriculture and other non-energy use). It excludes international marine and aviation bunkers, except at world level where it is included in the transport sector.

Total primary energy demand (TPED)**:** See total energy supply.

Traditional use of biomass: Refers to the use of solid biomass with basic technologies, such as a three-stone fire or basic improved cook stoves (ISO tier 0-1), often with no or poorly operating chimneys.

Transport: Fuels and electricity used in the transport of goods or people within the national territory irrespective of the economic sector within which the activity occurs. This includes fuel and electricity delivered to vehicles using public roads or for use in rail vehicles; fuel delivered to vessels for domestic navigation; fuel delivered to aircraft for domestic aviation; and energy consumed in the delivery of fuels through pipelines. Fuel delivered to international marine and aviation bunkers is presented only at the world level and is excluded from the transport sector at a domestic level.

Trucks: Includes all size categories of commercial vehicles: light trucks (gross vehicle weight less than 3.5 tonnes); medium freight trucks (gross vehicle weight 3.5-15 tonnes); and heavy freight trucks (>15 tonnes).

Unabated coal: Consumption of coal in facilities without CCUS.

Unabated fossil fuels: Consumption of fossil fuels in facilities without CCUS.

Unabated gas: Consumption of natural gas in facilities without CCUS.

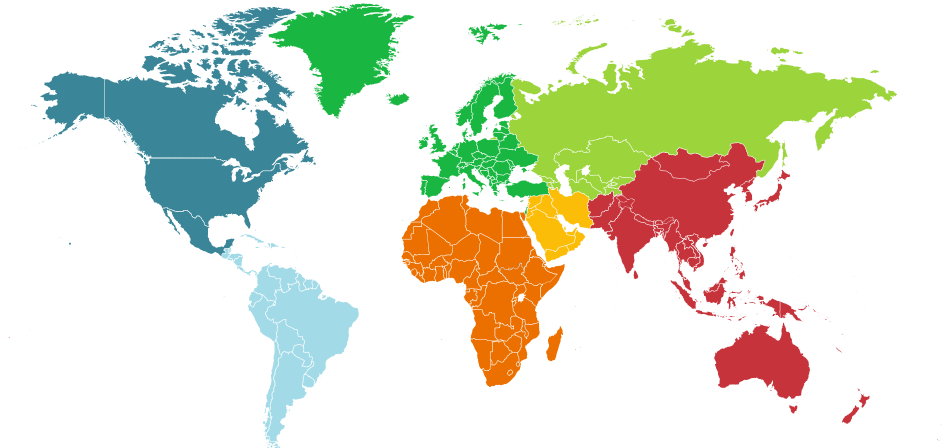
Useful energy: Refers to the energy that is available to end-users to satisfy their needs. This is also referred to as energy services demand. As result of transformation losses at the point of use, the amount of useful energy is lower than the corresponding final energy demand for most technologies. Equipment using electricity often has higher conversion efficiency than equipment using other fuels, meaning that for a unit of energy consumed, electricity can provide more energy services.

Variable renewable energy (VRE)**:** Refers to technologies whose maximum output at any time depends on the availability of fluctuating renewable energy resources. VRE includes a broad array of technologies such as wind power, solar PV, run-of-river hydro, concentrating solar power (where no thermal storage is included) and marine (tidal and wave).

Weighted average cost of capital: The weighted average cost of capital is expressed in nominal terms and measures the company's required return on equity and the after-tax cost of debt issuance, weighted according to its capital structure.

Regional and country groupings

Figure A.1 ▷ Main country groupings



Note: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Advanced economies: OECD regional grouping and Bulgaria, Croatia, Cyprus[1,2], Malta and Romania.

Africa: North Africa and sub-Saharan Africa regional groupings.

Asia Pacific: Southeast Asia regional grouping and Australia, Bangladesh, Democratic People's Republic of Korea (North Korea), India, Japan, Korea, Mongolia, Nepal, New Zealand, Pakistan, People's Republic of China (China), Sri Lanka, Chinese Taipei, and other Asia Pacific countries and territories.[3]

Caspian: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

Central and South America: Argentina, Plurinational State of Bolivia (Bolivia), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Bolivarian Republic of Venezuela (Venezuela), and other Central and South American countries and territories.[4]

China: Includes the (People's Republic of) China and Hong Kong, China.

Developing Asia: Asia Pacific regional grouping excluding Australia, Japan, Korea and New Zealand.

Emerging market and developing economies: All other countries not included in the advanced economies regional grouping.

Eurasia: Caspian regional grouping and the Russian Federation (Russia).

Europe: European Union regional grouping and Albania, Belarus, Bosnia and Herzegovina, North Macedonia, Gibraltar, Iceland, Israel[5], Kosovo, Montenegro, Norway, Serbia, Switzerland, Republic of Moldova, Türkiye, Ukraine and United Kingdom.

European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus[1,2], Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden.

IEA (International Energy Agency)**:** OECD regional grouping excluding Chile, Iceland, Israel, Latvia, Lithuania and Slovenia.

Latin America: Central and South America regional grouping and Mexico.

Middle East: Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen.

Non-OECD: All other countries not included in the OECD regional grouping.

North America: Canada, Mexico and United States.

OECD (Organisation for Economic Co-operation and Development)**:** Australia, Austria, Belgium, Canada, Chile, Costa Rica, Czech Republic, Colombia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, United Kingdom and United States.

OPEC (Organisation of the Petroleum Exporting Countries)**:** Algeria, Angola, Republic of the Congo (Congo), Equatorial Guinea, Gabon, the Islamic Republic of Iran (Iran), Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, United Arab Emirates and Bolivarian Republic of Venezuela (Venezuela).

Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. These countries are all members of the Association of Southeast Asian Nations (ASEAN).

Country notes

[1] Note by Türkiye: The information in this document with reference to "Cyprus" relates to the southern part of the island. There is no single authority representing both Turkish and Greek Cypriot people on the island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus issue".

[2] Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

[3] Individual data are not available and are estimated in aggregate for: Afghanistan, Bhutan, Cook Islands, Fiji, French Polynesia, Kiribati, Macau (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste and Tonga and Vanuatu.

[4] Individual data are not available and are estimated in aggregate for: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Bonaire, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), French Guiana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, Saba, Saint Eustatius, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and Grenadines, Saint Maarten, Turks and Caicos Islands.

[5] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

[6] Individual data are not available and are estimated in aggregate for: Burkina Faso, Burundi, Cabo Verde, Central African Republic, Chad, Comoros, Djibouti, Kingdom of Eswatini, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Réunion, Rwanda, Sao Tome and Principe, Seychelles, Sierra Leone, Somalia and Uganda.

Abbreviations and Acronyms

AFOLU	agriculture, forestry and other land use
APS	Announced Pledges Scenario
ASEAN	Association of Southeast Asian Nations
CAAGR	compound average annual growth rate
CCUS	carbon capture, utilisation and storage
CO_2	carbon dioxide
CO_2-eq	carbon-dioxide equivalent
COP	Conference of Parties (UNFCCC)
EU	European Union
EV	electric vehicle
FDI	foreign direct investment
GDP	gross domestic product
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
LCOE	levelised cost of electricity
LDV	light-duty vehicle
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MEMR	Ministry of Energy and Mineral Resources of the Republic of Indonesia (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia)
MEPS	minimum energy performance standards
NDCs	Nationally Determined Contributions
NZE	Net Zero Emissions by 2050 Scenario
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
$PM_{2.5}$	fine particulate matter
PPA	power purchase agreement
PPP	purchasing power parity

PV	photovoltaics
SDG	Sustainable Development Goals (United Nations)
STEPS	Stated Policies Scenario
TFC	total final consumption
TFEC	total final energy consumption
TPED	total primary energy demand
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USGS	United States Geological Survey
VRE	variable renewable energy
WACC	weighted average cost of capital
WHO	World Health Organization

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Typeset in France by IEA - September 2022
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An Energy Sector Roadmap to Net Zero Emissions in Indonesia

International Energy Agency Special Report

Indonesia is the world's fourth-most populous country and is set to become the world's fourth-largest economy by mid-century. The choices that Indonesia makes now and in the decades to come will have a significant bearing on the world's energy markets and on international efforts to reach collective climate goals.

Indonesia, a member of the IEA family since 2015, has committed to reach net zero emissions by 2060 or before – an ambitious task given the country's growth objectives and status as a globally important consumer and producer of coal. However, with a transition to net zero offering extensive and varied economic opportunities, Indonesia is beginning to put in place the policies and frameworks that can help reach this target while moving towards advanced economy status.

To assist in this critical task, the IEA – at the request of the Government of Indonesia and to coincide with Indonesia's Presidency of the G20 – has developed a comprehensive roadmap to net zero by 2060 for the country, which charts a path for the country's energy transition over the coming decades. The analysis in the *Energy Sector Roadmap to Net Zero Emissions in Indonesia* spans key areas such as people-centred transitions, the phasing down of coal use, investment and financing needs, and critical minerals. It also sets out a high-ambition pathway in which Indonesia reaches net zero by 2050. The project has been conducted in close collaboration with the Ministry of Energy and Mineral Resources of the Republic of Indonesia.