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INDONESIA
ENERGY TRANSITION OUTLOOK

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The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. www.irena.org

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DISCLAIMER

International Renewable Energy Agency

INDONESIA

ENERGY TRANSITION OUTLOOK

FOREWORD

Indonesia is key to the global energy transition. It has the highest energy consumption among the Member States of the Association of Southeast Asian Nations (ASEAN), and its energy use is set to rise significantly as its economy and population grow in the coming decades.

Indonesia has set out near-term targets to increase renewable energy to help meet rising demand. What is needed now is a longer-term view, as the country has also committed to an ambitious climate target to reach net zero emissions by 2060 or sooner.

Endowed with ample geothermal and hydropower potential, as well as an abundance of renewable resources including solar, wind, ocean and bioenergy, Indonesia is uniquely positioned to develop a sustainable energy system based on renewable energy that can support socio-economic development, address climate change, and achieve energy security, universalisation and affordability goals.

This report provides a comprehensive, renewables-focused, long-term energy pathway for the transition to a cleaner and more sustainable energy system in Indonesia. It explores end-use sector electrification, the rapid expansion of renewable generation, energy efficiency solutions, the role of emerging technologies such as clean hydrogen and batteries, as well as the importance of expanding regional power sector integration, both within the country and with neighbouring countries. It also presents sector-specific technological pathways and investment opportunities that will help Indonesia to accelerate its energy transition.

The engagement of the Ministry of Mineral Resources Indonesia and PT PLN was crucial to the development of this report. We are also grateful for the assistance of regional organisations such as the ASEAN Centre for Energy (ACE) as well as to the Danish Energy Agency, the Danish Ministry of Climate, Energy and Utilities, and the Danish Embassy in Indonesia, who supported this project.

IRENA stands ready to work with Indonesia to help make the vision presented in this report a reality, and to assist national stakeholders in utilising the country's ample, affordable, indigenous renewable energy resources to lower energy costs, reduce emissions, drive economic development and meet the country's long-term energy and climate goals.

Francesco La Camera
Director-General, IRENA

FOREWORD

The energy transition is vital in the context of the current global climate situation, in which the 1.5°C target remains barely within reach. It is also important for Indonesia, given that the country's primary energy mix remains dominated by fossil energy, which accounts for approximately 90% of energy production. Indonesia has abundant renewable energy resources of more than 3 000 GW, mostly comprising solar, but also wind, hydro, bioenergy, ocean and geothermal.

Indonesia is committed to a 29% reduction in our greenhouse gas (GHG) emissions by 2030 through our own efforts – or to 41% with international support. We have also pledged to reach net-zero emissions (NZE) in 2060 or sooner. Renewable energy potentials play an important role in achieving these targets, and in meeting energy demand with a high share of renewables in the national energy mix.

There are multiple decarbonisation pathways specific to each country that consider potentials, technology and financing availability. In the case of Indonesia, in addition to the potential for renewable energy, the country also has a very large nuclear energy potential, and the possibility of implementing CCS, which can support Indonesia's decarbonisation path towards net zero emissions.

It is a great pleasure to publish the *Indonesia energy transition outlook*, which captures all possible options for Indonesia to accelerate the energy transition to achieve the net-zero emissions target. We are grateful to IRENA for supporting us in producing this outlook, and it has been an honour to collaborate with IRENA, PT PLN, and all other stakeholders to produce such a comprehensive document.

Finally, on behalf of the Government of Republic of Indonesia, I would like to thank IRENA for the cooperation that was strengthened during this project, and for the Agency's global role in advancing renewable energy solutions to achieve Agenda 2030 and the Sustainable Development Goals (SDGs), as well as preparing for a net-zero emissions future.

Arifin Tasrif
Minister of Energy and Mineral Resources
Republic of Indonesia

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ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
BECCS	bioenergy with carbon capture and storage
BES	Baseline Energy Scenario
BOE	barrels of oil
BOOT	build, own, operate and transfer
BOO	build, own and operate
BPP	Biaya Pokok Produksi
CCGT	combined-cycle gas turbine
CCS	carbon capture and storage
CCUS	carbon capture, utilisation and storage
CO_2	carbon dioxide
COVID-19	Coronavirus disease
DEN	Dewan Energi Nasional
EJ	exajoule
ESG	environmental, social and governance
ETO	energy transition outlook
EV	electric vehicle
FiT	feed-in tariff
G20	Group of Twenty
GDP	gross domestic product
GHG	greenhouse gas
GIS	geographic information system
GJ	gigajoule
Gt	gigatonne
GW	gigawatt
GWh	gigawatt hour
IDR	Indonesian rupiah
IESR	Institute for Essential Service Reform
IFC	International Finance Corporation
IIF	PT Indonesia Infrastructure Finance
IPP	independent power producer
IRENA	International Renewable Energy Agency
IUJPTL	electricity support services business licence (Izin Usaha Jasa Penunjang Tenaga Listrik)
IUPTL	electricity supply business license (Izin Usaha Penyediaan Tenaga Listrik)
KEN	national energy policy (Kebijakan Energi Nasional)
km	kilometre
kV	kilovolt
kVA	kilovolt ampere
kW	kilowatt
kWh	kilowatt hour
LCOE	levelised cost of electricity
LKPP	National Public Procurement Agency (Lembaga Kebijakan Pengadaan Barang dan Jasa Pemerintah)

LME	London Metal Exchange
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LULUCF	land use, land use change and forestry
MJ	megajoule
MEMR	Ministry of Energy and Mineral Resources
MEPS	minimum energy performance standard
MMSCF	million standard cubic feet
Mt	million tonne
$MtCO_2eq$	million tonnes of carbon dioxide equivalent
MVA	Megavolt ampere
MW	megawatt
NDC	Nationally Determined Contribution
NPI	nickel pig iron
OCGT	open-cycle gas turbine
PEN	National Economic Recovery programme
PES	Planned Energy Scenario
PJ	petajoule
PLN	PT Perusahaan Listrik Negara
PPA	power purchase agreement
PPU	private power utilities
PV	photovoltaic
REmap	renewable energy roadmap
RPJMN	National Medium-Term Development Planning (Rencana Pembangunan Jangka Menengah Nasional)
RRA	Renewables Readiness Assessment
RUED	Regional Energy Plan (Rencana Umum Energi Daerah)
RUEN	General Plan for National Energy (Rencana Umum Energi Nasional)
RUKN	General Plan for National Electricity (Rencana Umum Kelistrikan Nasional)
RUPTL	National Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik)
SMI	PT Sarana Multi Infrastruktur (Persero)
TES	Transforming Energy Scenario
TFEC	total final energy consumption
TSCF	trillion standard cubic feet of gas
TWh	terawatt hour
USD	United States dollar
WETO	*World energy transitions outlook*
VA	volt ampere
VRE	variable renewable energy
yr	year
1.5-S	1.5 Degree Scenario

EXECUTIVE SUMMARY

KEY MESSAGES

The Republic of Indonesia (Indonesia) is the largest country in the Association of Southeast Asian Nations (ASEAN) by geographical area, population and gross domestic product (GDP). Over the coming three decades, its population is expected to rise to **335 million people**, the economy to more than triple in size, and primary energy supply to triple.

To meet this rising energy demand, the country stands at a crossroads: utilise more of its domestic coal resources, while also turning to international oil and gas markets to import energy from oversees; or pursue the huge untapped potential of **renewable sources** that can provide local and affordable solutions to fossil fuels. The report shows that it is cheaper to do the latter, with the share of renewable energy reaching two-thirds of the country's energy mix in 2050, up from just 14% today.

The country's energy mix can change from one dominated by fossil fuels, which currently meet around 84% of energy demand, to one that sees rapid uptake of electricity that will meet half of final energy consumption, with a further quarter of final energy coming from renewable direct-use. This entails scaling up electricity generation fivefold, to over 1700 terawatt hours (TWh), while also scaling up key renewable power resources such as solar, bioenergy, geothermal and green hydrogen.

In the near-term, the findings suggest a need for 66 gigawatts (GW) of additional solar photovoltaic (PV) by 2030, together with a rapid expansion of hydropower (+11 GW) and geothermal (+4 GW). Additional growth is needed in associated infrastructure, such as transmission, distribution and storage. Also, biofuel supply and electric vehicle (EV) chargers will need to grow rapidly. The level of investment needed in these important energy transition technologies up to 2030 in the 1.5°C Scenario will amount to around USD 332 billion.

Longer-term to 2050, the power sector sees a radical transformation with over 1 000 GW of renewable capacity or more required. Three possible highly decarbonised pathways are explored in this report: a renewables and nuclear-enabled pathway, a renewables and carbon capture and storage (CCS)-enabled pathway, and a 100% renewable pathway. These scenarios show how availability of key technologies can influence the decarbonisation pathway to allow for a balanced perspective of the impacts of relying on different technologies. All these scenarios entail an 85% or higher renewable share in generation, and between 798 GW and 840 GW of solar PV capacity, with up to 225 GW of other renewables. Regardless of scenario, renewables will become the backbone of the power system, this also applies to lower-ambition scenarios.

Investing in energy flexibility in the power sector will be crucial to enable the transition, with significant expansion of capacity for domestic and international transmission, storage and demand response. In the short-term alone to 2030, over USD 80 billion will need to be invested in grids, storage and related power system infrastructure.

Over the longer-term, significant scale-up in energy investment is required, with up to USD 2 420 billion in cumulative investment to 2050 needed across the energy system, from generation, to efficiency and enabling infrastructure. This is double what would otherwise be invested in the reference scenario (PES).

Indonesia's energy-related carbon dioxide (CO_2) emissions increase by at least 80% over today's levels by 2050 in the Planned Energy Scenario (PES), this report's reference case. IRENA's energy transition scenarios see Indonesia's emissions peaking by 2030 and reducing to around one-third of today's level in the most aggressive scenario. Additional CO_2 removal measures will be needed to reach net zero, as well as measures related to CO_2 emissions outside the energy sector.

The 1.5-S is lower cost overall, resulting in savings of USD 0.4-0.6 trillion cumulatively to 2050. In addition, there are significant costs savings in the 1.5-S due to lower fossil fuel use and associated external costs resulting from damages to human health and the environment , as well as climate change. These savings range from USD 0.2 to 0.6 trillion cumulatively to 2050.

INTRODUCTION

Since 2009 Indonesia's total primary energy supply has increased on average by 3.5% annually – excluding a dip in 2020 due to COVID-19. By 2050 demand is expected to more than triple, to over 23 exajoules (EJ). Indonesia is one of the largest coal producers worldwide and around 70% of all its production is exported. In 2009 Indonesia was a net oil exporter, exporting around one-third of its oil output. Today this share is less than 10%. Oil imports were three times that of oil exports in 2019. Commercially proven gas reserves in Indonesia are significantly higher than its crude oil reserves. However, its gas exports are declining rapidly. Already a net importer of oil, Indonesia may become a net importer of natural gas by the end of this decade. The country's energy mix is dominated by fossil fuels – their share in total primary energy supply remained around 86% between 2009 and 2020.

By the end of 2020, Indonesia had a total installed electricity generation capacity of 70 gigawatts (GW) connected to the grid. Coal-fired power plants accounted for half of the total installed capacity. Coal-fired power capacity has seen immense growth of nearly three times in the same period. These investments have resulted in a relatively young coal fleet, with an average age of less than 10 years. Most of these plants are sub-critical, implying lower efficiency in electricity generation. Three-quarters of the total financing for the coal-fired power plants built between 2016 and 2019 came from international sources, including from other Asian countries and China. Renewables accounted for 12% of the total installed capacity in 2020. This comprises one-half hydropower (including large power plants) and one-half other renewables. Renewable power capacity grew modestly in 2020, with a total of 165 megawatts (MW) added. Many of these additions were in the form of hydropower. Solar capacity additions were next, with a total of 30 MW (IESR, 2021a).

Indonesia has huge untapped renewable resource potential that can provide local and affordable solutions to fossil fuels. However, so far it has utilised only a few percent of this potential. Indonesia is now at a crossroads with the option to diversify its energy mix with renewables. Traditionally a fossil fuel producer and exporter, Indonesia has met growing demand primarily with coal in the electricity sector and other fossil fuels in transport and heating. But its trade balance is changing. Long-term economic and population growth projections indicate that energy demand will increase further. Indonesia is taking timely steps by giving more emphasis to increasing the use of local renewable energy resources to accelerate economic growth, gain further energy independence and meet increasingly ambitious energy and climate targets.

Indonesia's nationally determined contribution (NDC) under the Paris Climate Agreement has pledged to reduce its carbon emissions by between 29% (unconditional) and 41% (conditional) by 2030, relative to Business as Usual. More recently the country announced its intention to reach net zero emissions by 2060, and as early as 2050 with international support. It is important to note that more than half of all Indonesia's total GHG emissions are related to land use, land use change and forestry. Therefore, while this report only focuses on energy-related CO_2 emissions, efforts are needed across all GHGs and, importantly, in these other emitting sources.

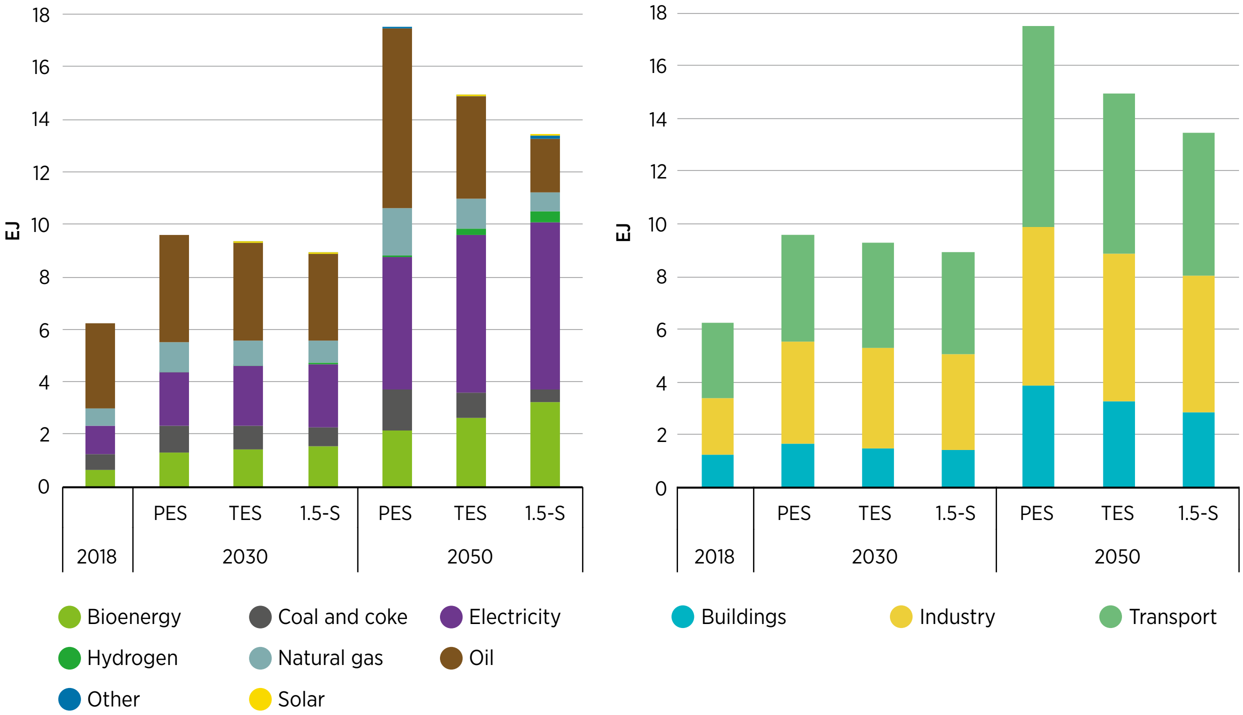
A SUSTAINABLE FUTURE

IRENA's energy transition outlooks detail long-term perspectives for the world (*World energy transitions outlook*), regions (such as ASEAN) and countries (this study). This outlook combines IRENA's Renewable Readiness Assessment with the Renewable Energy Roadmaps toolkit (REmap) and Power System Flexibility Assessment to chart possible energy pathways to 2050. The Planned Energy Scenario is based on current and planned policies, is this report's reference case, and is the most likely energy pathway. Two accelerated energy transition scenarios are also presented: the Transforming Energy Scenario (TES), and the 1.5°C Scenario (1.5-S), which is aligned with IRENA's WETO 1.5-S targeting net zero emissions globally by 2050.

Indonesia's total final energy consumption (TFEC) increases almost threefold by 2050 in the Planned Energy Scenario (PES). Driven by population and economic growth, Indonesia's energy demand grows by 3.3% annually. Fuel switching to renewables and electricity, and energy efficiency efforts, slow Indonesia's demand growth in the Transforming Energy Scenario (TES) and the 1.5°C Scenario (1.5-S) to 2.7% and 2.4%, respectively, saving 14% and 22% of the TFEC seen in the PES. More than a quarter of Indonesia's demand for fuels (non-electricity) by 2050 in the 1.5-S is renewables-based, almost double the renewable energy demand in the same year seen in the PES. Electricity, which is largely renewables-based in the 1.5-S by 2050, makes up 47% of final energy demand.

Renewable energy demand in the 1.5-S will double that of the PES by 2050

Figure 1 Indonesia's total final energy consumption, by scenario, 2018-2050



Recommendation:

Utilise long-term opportunities of the energy transition through acceleration of renewable based energy to drive local economic development and jobs

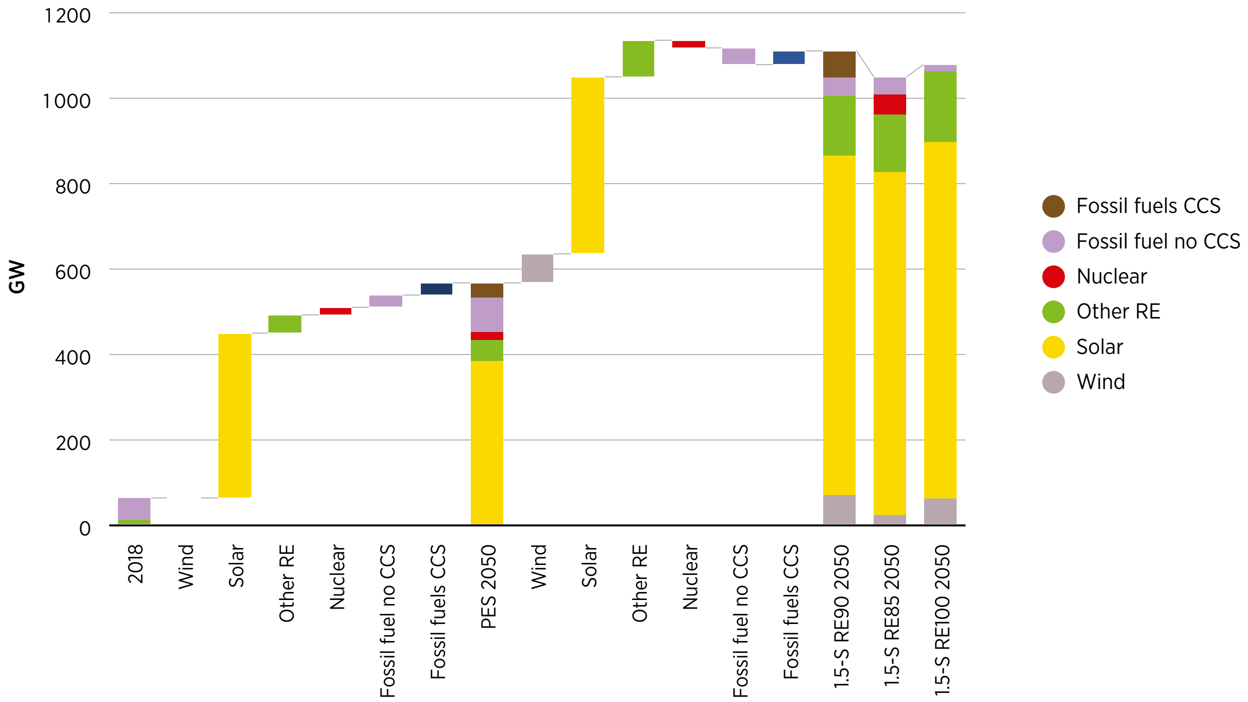
Indonesia should accelerate the transition by building the country's energy policies based on renewable energy development to drive economic growth and job creation, supported by a predictable long-term energy plan that prioritises clean energy investments consistent with national and regional (renewable) energy policies. In the short-term to 2030 there is an investment need of over USD 200 billion to expand solar PV, electric vehicles and biofuel supply alone.

Electricity becomes the dominant energy carrier in both the TES and 1.5-S, and the second most important carrier in the PES. Electricity demand is expected to grow at least fivefold from today's levels out to 2050; how power generation capacity is expanded to meet this will be instrumental to national CO_2 emissions. If no action is taken, power sector emissions could rise from 200 million tonnes (Mt) to nearly 1 000 Mt by 2050.

To chart possible alternatives to a continued reliance on fossil fuels in power generation, this report presents three possible highly decarbonised routes forward for the Indonesian power system: a 100% renewables system (1.5-S RE100), one that utilises carbon capture and storage (CCS) and renewables (1.5-S RE90), and another that relies on some nuclear power and renewables (1.5-S RE85), on the understanding that clean dispatchable power will be key to decarbonising the Indonesian power system. These scenarios, as shown in Figure 2 do not seek to present a singular 1.5-S, but rather show how such a system could be achieved based on the technology choices available. Solar photovoltaic (PV) is key across all scenarios due to Indonesia's abundant solar resources, and the role of CCS and nuclear appear to be largely interchangeable in terms of overall capacity. However, while the 100% renewables scenario has slightly lower installed capacity than the 90% case, this difference results from it having no fossil or nuclear capacity and it has more renewable capacity and electricity imports overall. This scenario calls for a very significant renewable expansion beyond these 85% and 90% scenarios and a similarly large expansion of battery storage of approximately 350 GW.

Solar PV will play a key role regardless of scenario

Figure 2 Indonesia's power capacity expansion from 2018 to 2050 for the PES and 1.5-S variants



Note: RE = renewable energy; VRE = variable renewable energy.

Recommendations:

Create a level playing field for renewable energy resources

Continuation of the government's fossil fuel subsidy reform and improvements in the regulatory framework will lift important barriers to renewable energy and enhance investment signals for the private sector and consumers. Eliminating coal subsidies and including pollution induced costs for fossil fuel use would help create a level playing field for renewables, and also contribute to enhancing PLN's operational efficiency. Electricity purchase tariffs that award the full cost of renewable energy generation at the utility scale under the feed-in tariff (FiT) and for rooftop solar PV systems under net energy metering would create benefits for investors and consumers alike, while accelerating market development.

Continue streamlining procurement processes and develop a clear regulatory framework including auctions and feed-in tariffs

Further streamlining procurement processes and negotiations, complemented with standardised power purchase agreement (PPA) contracts, can ensure a well-functioning and transparent procurement process and contribute to reducing risky investment conditions and increasing competition in the market. Utilising renewable energy auctions and feed-in tariffs will provide quality planning and reliable contractual schemes. Over 90 GW of additional renewable capacity will be required by 2030, with two-thirds of that solar PV. This can only be achieved through wide-scale private participation in providing generation.

Develop solutions to create a distributed renewable energy market

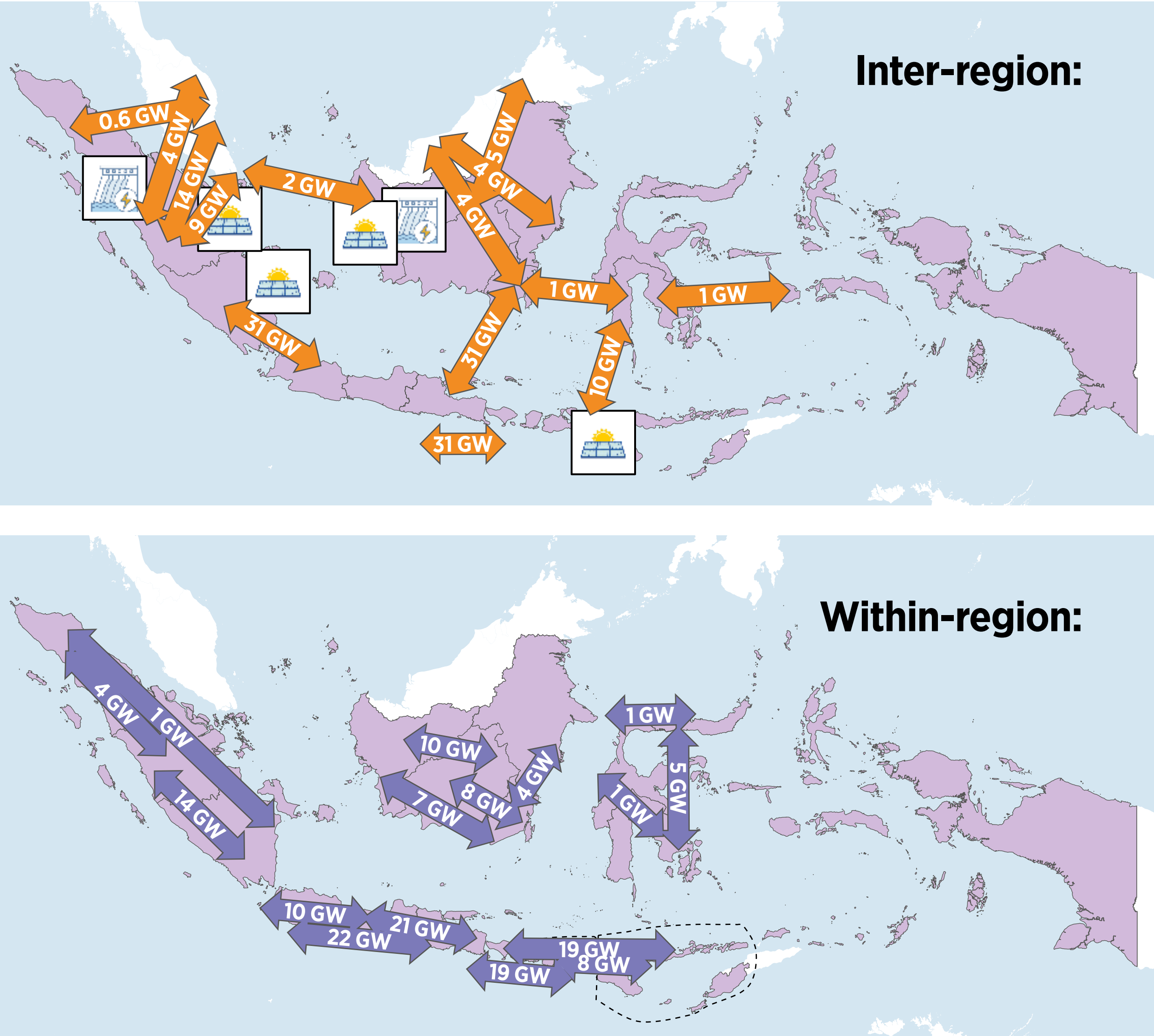
Making the remuneration mechanism more attractive for consumers and developing new finance and business models would significantly accelerate the deployment of distributed renewable energy systems by closing the gap between the generation costs and retail electricity tariffs. Revising the regulatory framework to enable the participation of private investors in the mini- and off-grid markets is essential to achieve Indonesia's electrification targets and replace dirty and expensive diesel generators. Overcoming regulatory and market barriers in PPAs and corporate sourcing would help create new markets for renewables investment. A review of the regulations for power wheeling and renewable energy certificates, and new processes for corporates to procure renewable power are required.

Indonesia has the highest electricity consumption in the ASEAN region, and the three largest cities in the country are on the island of Java, which represents 69% of national demand. This percentage is expected to remain stable despite the move of the national capital to Kalimantan. Therefore, the planning of the country's power sector entails finding effective ways to meet the island's needs, a challenging task given that most renewable resources are located elsewhere (*e.g.* Sumatra and Nusa Tenggara). That requires power system flexibility, particularly in transmission (Figure 3) and storage assets. Batteries will have a key role to play from the 2030s onwards. They will have applications in this decade too, but are likely to be more focused on solving local structural issues such as critical local network congestion, or on experimentation, than large-scale energy demand displacement.

Available batteries and hydropower are also sufficient to provide the system with frequency response reserves. Nevertheless, the need for sizeable power assets requires caution in the planning and operation of the system by 2050. For instance, opting for more circuits of a lower capacity in the case of transmission lines instead of a few larger ones can help reduce operational issues in case of an asset failure. The system should be planned to cope with a steady decrease in synchronous machines in the future, with grid-forming inverters likely to assume the leading role. Importantly, realising the full potential of renewables requires open markets and the alignment of regulations between national system operators across the ASEAN region.

Significant internal and international transmission expansion will be needed by 2050

Figure 3 Transmission lines deployment by 2050, 1.5-S RE90



Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Recommendations:

Advance electricity market design

Advancing the design of the electricity market requires time. A reform plan is needed to enable a more transparent electricity market and allow for private-sector participation, which can strengthen the financial situation of PLN, reduce financing costs for investors and make electricity more affordable to consumers. The 1.5-S results in a lower overall cost energy system; and investments need to be prioritised into renewable capacity, grids, storage and other enabling infrastructure totalling an investment need of USD 160 billion alone by 2030.

Improve system flexibility for cost-effective integration of renewables

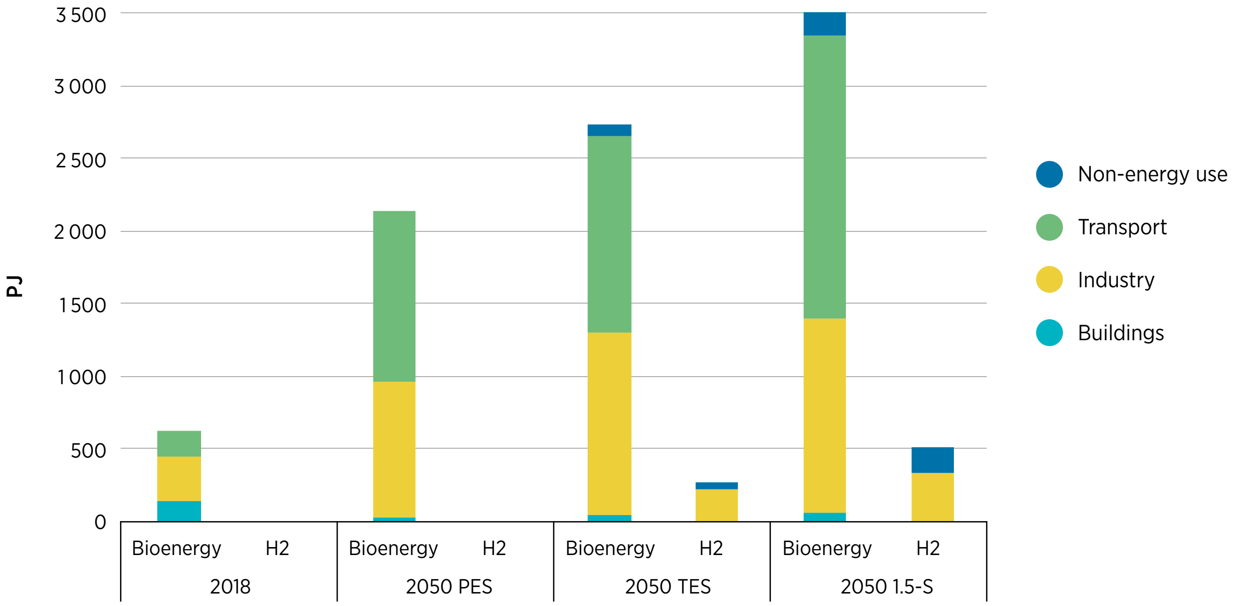
Studies show large potential for the grid integration of renewables beyond what is currently planned by PLN. There is a need for a national plan with emphasis on specific regions, showing the extent renewables can be integrated into the transmission grid and the flexibility solutions needed to enable this. Flexibility must be harnessed in all sectors of the energy system, from power generation to transmission and distribution systems, storage (electrical and thermal) and flexible demand (demand-side management and sector coupling). In the short-term alone to 2030, investment totalling USD 43 billion in domestic transmission, USD 32 billion in distribution, and USD 5.5 billion in energy storage is required.

Bioenergy is set to play an important role in Indonesia's decarbonising effort. Modern bioenergy demand in the 1.5-S grows from just over 0.6 EJ to 3.5 EJ, contributing over one-fifth of Indonesia's TFEC by 2050, as the fuel is versatile and able to be used for heating, fuels, feedstocks and other uses. This coincides with the phase-out of traditional uses of bioenergy, the use of which is generally difficult to quantify as it is largely informal. It is important to tackle barriers to bioenergy development in order to ensure its role in Indonesia's decarbonisation. Low policy incentives, the higher cost of converting biomass to energy carriers, and sustainability assurance for oil palm biomass are among the identified barriers that need intervention by all the related actors in Indonesia's energy transition.

Hydrogen provides a complementary solution in meeting the country's ambitious climate objectives. Green hydrogen plays role in Indonesia's industrial sector, such as in the manufacture of iron and steel, aluminium and chemicals, and also in international bunkering transport.

Bioenergy has wide application in end uses, but hydrogen also begins to play a role

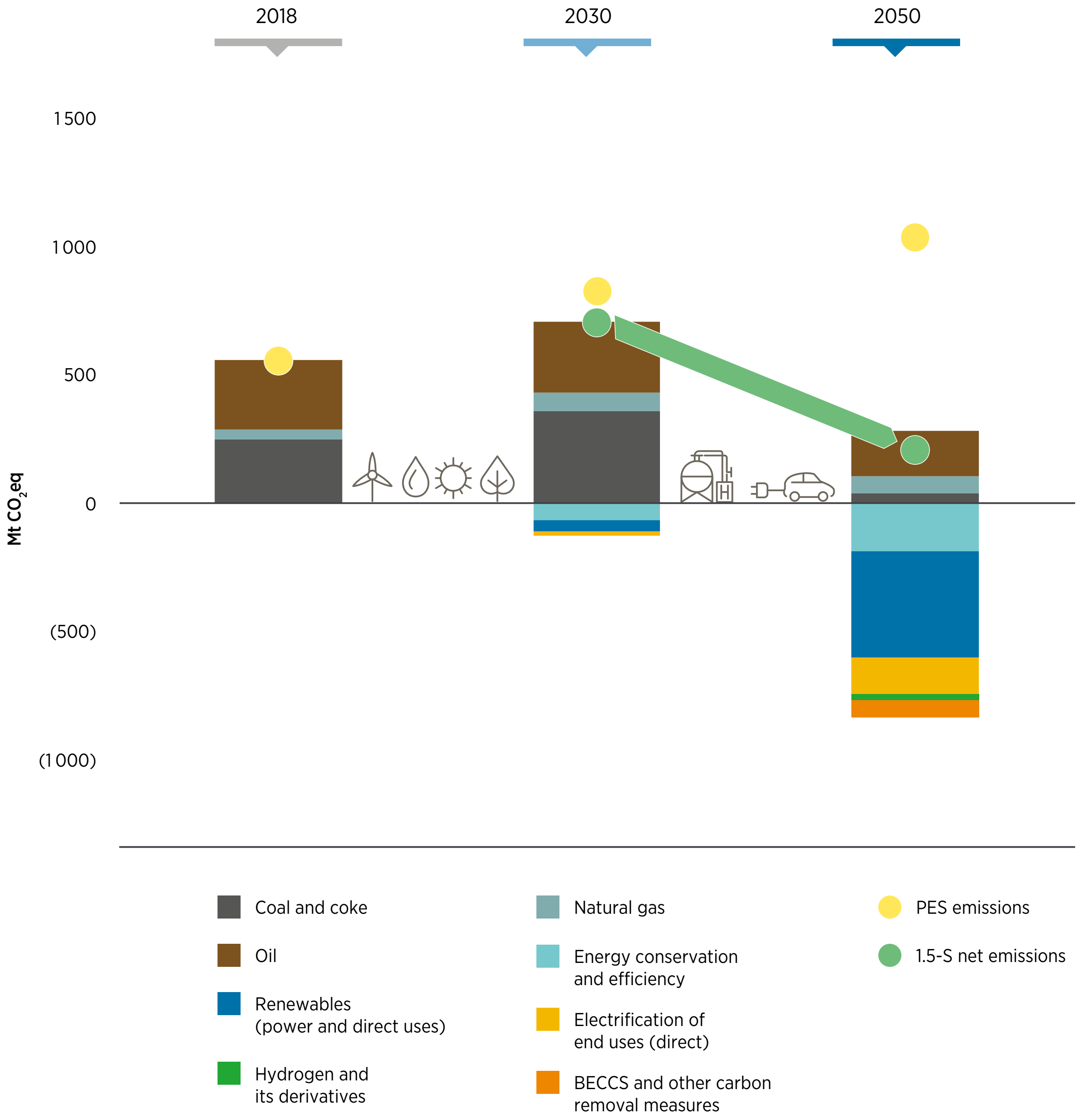
Figure 4 Bioenergy and hydrogen use by end-use sector, by scenario, 2050



In the PES, Indonesia's energy-related CO_2 emissions continue to increase, reaching 80% higher than the 2018 level by 2050, with fossil fuels consumed in the transport, industrial and power sectors responsible for 89% of the total energy-related CO_2 emissions. Both energy transition scenarios, the TES and 1.5-S, see Indonesia's emissions peaking in the mid-2030s. Under the TES emissions are 10% below today's level by 2050, whilst the more aggressive 1.5-S reduces energy-related emissions to about one-half of today's level.

The majority of emission reductions in the 1.5-S result from renewables electrification, or energy efficiency

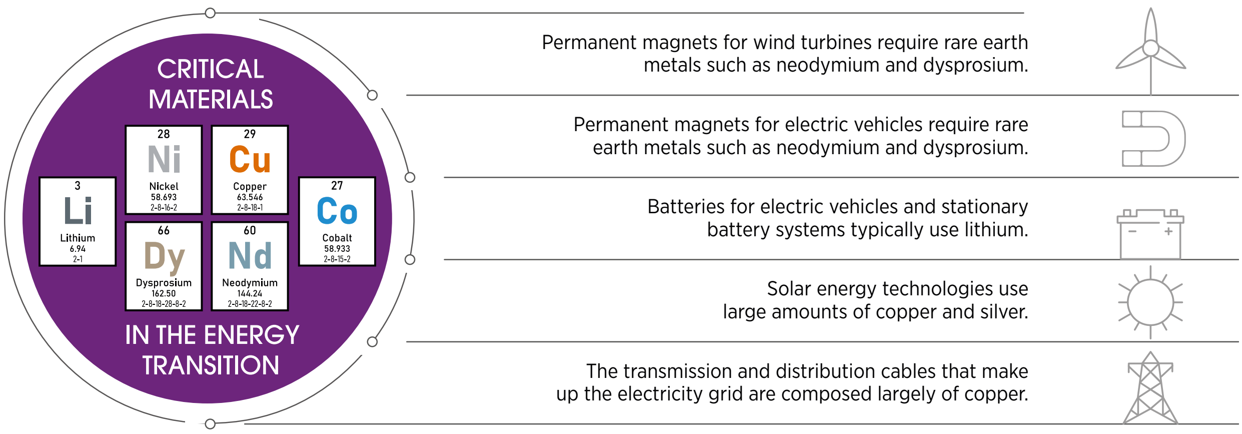
Figure 5 Energy-related CO_2 emissions (positive y-axis) and reductions due to technology by category compared to the PES (negative y-axis), 1.5-S, 2030 and 2050



Plans for the energy transition must take critical materials into account to avoid unforeseen delays in progress. Critical materials are used in many energy transition technologies. Indonesia is the world's largest producer of nickel and accelerating its production locally would enable the country to develop local industry and expertise in critical energy transition technologies, such as batteries for electric vehicles (EVs). An integrated upstream and downstream solar PV industry is needed to accelerate the sector's growth in Indonesia. The potential of the industry is apparent, as many solar PV projects are envisaged in the country's energy transition future. Suitable policies related to renewable energy production and a clear framework for local production and demand-side incentives for attracting more investment are required.

Indonesia can benefit from developing a local industry in critical energy transition technologies such as batteries and solar panels

Figure 6 Critical materials needed for the energy transition



Source: (IRENA, 2022a).

In the near term to 2030, significant investment needs are focused on key technologies, including over 66 GW of solar PV requiring investment of USD 44 billion, and an additional USD 39 billion in other renewable power generation technologies, grid investment of USD 75 billion, and USD 5.5 billion for battery storage. There is also a need for 1.3 million EV chargers to be installed, requiring an investment of USD 22 billion.

Investment in the near-term includes substantial sums in solar PV, grids and storage, and EVs

Table 1 Selected technology scale-up and investment needs to 2030 under the 1.5-S

			TECHNOLOGY	TOTAL		INVESTMENT NEED (billion USD)
				2018	1.5-S in 2030	From 2018 to 2030 for 1.5-S
SHORT-TERM INVESTMENT REQUIREMENT (2018-2030)	POWER	**Solar PV**	Installed capacity (GW)	0.02	66	44
		Other renewables (non-hydro)	Installed capacity (GW)	6	11	17
		Hydro	Installed capacity (GW)	5	16	22
	GRID AND FLEXIBILITY	**Transmission** (national)	km ('000)	67	181	43
		Distribution	km ('000)	738	2 009	32
		Storage	GW	<1	12	5.5
	ELECTRIFI-CATION	**EV chargers**	million units	<0.1	1.3	22
		EV sales	million units	<0.1	6.4	129

Recommendation:

Accelerate renewable energy finance

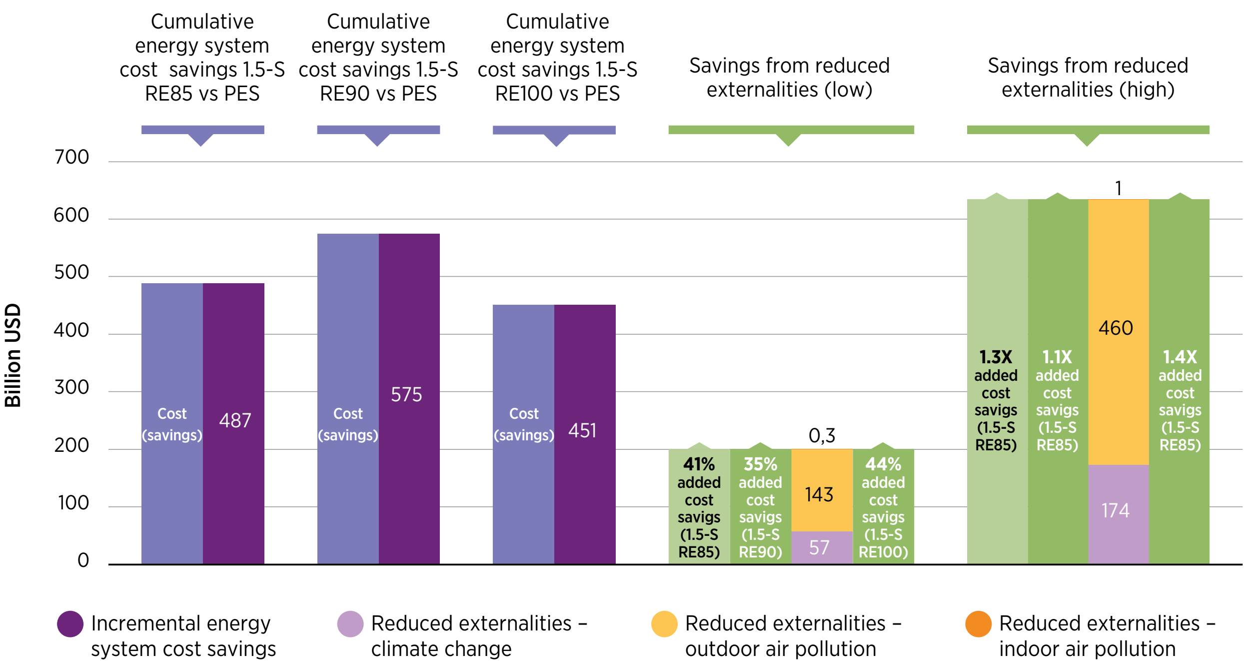
Securing finance for renewable energy investments represents an important barrier to accelerating Indonesia's energy transition. Financing sources need to be expanded and local financing needs to grow. New financing models need to be developed and the capacity of national financing institutions needs to be strengthened to enable their participation. To give an idea of scale, as much as USD 2.4 trillion in investment is needed across the energy system in Indonesia in the 1.5-S by 2050. Finance schemes need to consider the diverse nature of the investment need, ranging from financing large renewable energy power projects to grids and infrastructure; and from energy efficiency in homes and business to biofuel supply and EV chargers.

Overall, investment in the 1.5-S over the period to 2050 totals between USD 2.3 trillion and USD 2.4 trillion, about twice that in the PES. Much of the additional investment is needed in the power sector, which makes up about 40% of the investment need, while end uses such as transport (for EV and related infrastructure) and energy efficiency also require significant investment.

Energy system costs provide a useful perspective, including fuel costs, operation and maintenance, and investment annuities, to give a wider picture of the affordability of each scenario. Over the period to 2050 in the PES, Indonesia spends USD 10.7 trillion on the energy system, whereas the country only spends USD 10.1 trillion to USD 10.3 trillion under the 1.5-S, depending on the 1.5-S scenario variant. Therefore, the 1.5-S is lower cost overall, resulting in savings of USD 0.4-0.6 trillion cumulatively to 2050. In addition, there are significant costs savings in the 1.5-S due to lower fossil fuel use and the associated external costs resulting from damages to human health and the environment, as well as climate change. These savings range from USD 0.2 to 0.6 trillion cumulatively to 2050.

The 1.5-S is more cost-effective than the PES and also reduces external costs related to health and the environment

Figure 7 Total energy system cost of transitioning towards 1.5-S over the PES, 2018-2050



1 INTRODUCTION

1.1 COUNTRY BACKGROUND

Indonesia is in the Southeast Asia region. It is the largest country of the Association of Southeast Asian Nations (ASEAN). Three countries share a land border with Indonesia, namely East Timor, Malaysia and Papua New Guinea. The country's surface area exceeds 1.9 million square kilometres, spread out over more than 17 000 islands.

At the end of 2019 Indonesia's gross domestic product (GDP) reached USD 1.12 trillion, recording an annual growth rate of 7.4% compared with 2018, continuing a steep growth trend since 2015. In 2020, due to the COVID-19 pandemic, GDP declined by 5.5% to USD 1.06 trillion; however, in 2021 GDP rebounded by 12%, increasing to USD 1.19 trillion (World Bank, 2021a). Therefore, on average the growth rate is similar to levels seen pre-pandemic.

Besides being the largest ASEAN economy, Indonesia is also a member of the Group of Twenty (G20)[1] and is categorised as a lower-middle income country with a per-capita GDP of USD 12 335.[2] Services value added represent the largest share of Indonesia's GDP, with a share that reached 44.2% in 2019. Industry (including construction) value added reached 39%, and agriculture, forestry and fishing value added continued its decline to 12.7%.

At the start of 2020, before the COVID-19 pandemic hit the world economy, the average annual GDP growth target to 2024 was set at between 5.7% and 6.0% according to Indonesia's National Medium-Term Development Planning (*Rencana Pembangunan Jangka Menengah Nasional*, RPJMN) (BAPPENAS, 2020). The country's five-year medium-term plans are part of Indonesia's long-term plans that cover a period of 20 years. The latest five-year plan within the 2005-2025 development plan has been running since 2000. The aim is to strengthen the Indonesian economy through competitiveness in the global markets and by advancing human capital. Indonesia's "Vision of Indonesia 2045" aims to for the country to rank among the world's top five largest economies by 2045.

A large share of Indonesia's total population is below just 40 years old, which drives the need for a strong and resilient Indonesian economy to offer opportunities to its people. About 55% of Indonesia's 270 million population lives in urban areas. The country has 8 of the 20 largest cities of the ASEAN and its population has been growing on average by 3 million people each year since the last decade, making Indonesia one of the most populous countries in the world (ADB, 2021). Economic growth is crucial for the young population of the country, as just below 10% of the population lives below the poverty line. Meanwhile, the country's unemployment levels remained below 5% at the end of 2020 (World Bank, 2021c).

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[1] *Indonesia holds the G20 Presidency in 2022, starting on 1 December 2021.*

[2] *This move followed the World Bank's change in country classifications by income level (World Bank, 2021b).*

Box 1 COVID-19 pandemic's impact on the Indonesia economy

The COVID-19 pandemic affected the lives of Indonesian people. The first cases were observed at the beginning of March 2020. Total cases approached 4.2 million by October 2021, with more than 142 000 infected people losing their lives according to the country's statistics. Although COVID-19 measures were relaxed during mid-2020, restrictions were tightened once again at the start of September and their implementation was extended several times until the start of 2021. In January 2021 the country began its vaccination programme.

COVID-19 resulted in the worst economic crisis in Indonesia in the past two decades, the economy contracting by 2.07% in 2020 and recording a recession (Bank of Indonesia, 2021). The economy started rebounding in 2021, with a growth rate exceeding 7% in the second quarter (Reuters, 2021). During 2020 several fiscal relief and recovery packages were released. The national recovery programme (PEN) stands at IDR 579.8 trillion[3] (equivalent to about 3.8% of the GDP) in 2020. In 2021 the government budgeted a total of IDR 699.4 trillion (USD 49.6 billion) for the PEN (IMF, 2021). During the COVID-19 pandemic, 2.5% of the working age population lost their jobs, equivalent to 5.1 million people.

Indonesia is an energy independent country where its exports of coal and gas are much higher than its imports. Exports represented 64% and 10% of production in 2018, respectively (MEMR, 2019). Indonesia also produces crude oil and in 2018 exported around a quarter of its total production, although this has fallen to less than 10%. In 2009 Indonesia was a net oil exporter, exporting around one third of its oil output. Oil imports were three times oil exports in 2019. Commercially proven gas reserves in Indonesia are significantly higher than its crude oil reserves. However, its gas exports are declining rapidly. Already a net importer of oil, Indonesia may become a net importer of natural gas by around 2030 (McKinsey, 2020).

Indonesia has huge untapped renewable energy potential that can provide local and affordable solutions to fossil fuels. However, so far it has utilised only few percent of this potential. Indonesia is now at a crossroads and can choose to diversify its energy mix with renewables. Traditionally a fossil fuel producer and exporter, Indonesia aims to meet its growing energy demand primarily with coal in the electricity sector and other fossil fuels in transport and heating. But its trade balance is changing. Long-term economic and population growth projections indicate that energy demand will increase further, continuing the 3.5% per year growth trend of the past decade. Indonesia is taking timely steps by placing more emphasis on increasing the use of local renewable energy resources to accelerate economic growth and gain further energy independency.

1.2 RENEWABLE READINESS ASSESSMENT

The International Renewable Energy Agency (IRENA) developed the Renewables Readiness Assessment (RRA) as a tool for carrying out comprehensive evaluations of the conditions for renewable energy deployment in particular countries. The RRA is a country-led, consultative process. It provides a venue for multi-stakeholder dialogue to identify challenges to renewable energy deployment and to devise solutions to existing barriers. Short- and medium-term recommendations are presented to governments to guide the formation of new policies or the reform of existing policies to achieve a more enabling environment for renewable energy.

For Indonesia, the RRA process has been led by the government of Indonesia, with technical support from IRENA, and has greatly benefited from stakeholder input. These stakeholders include the Ministry of Energy and Mineral Resources (MEMR), transmission and distribution utilities, power project developers, development partners, financial institutions, civil society and academia. The consultative process was initiated at an expert consultation workshop held online on 28 July 2021. The workshop was based on a background paper describing the challenges and opportunities for renewable energy development.

[3] *The Indonesian rupiah (IDR) exchange rate is around IDR 14 000 per USD (February 2021) and for conversion from IDR to the USD for other years, average annual exchange rates have been used throughout this report.*

During this online event, experts discussed the state of renewable energy in Indonesia, as well as various challenges and possible solutions. Their insights informed a draft report presented in the follow-up validation workshop held on 26 April 2022, which was jointly organised by MEMR and IRENA. In addition, the analysis benefited from bilateral interviews with key stakeholders.

The RRA process in Indonesia has produced the following outputs:

- An analysis of the existing policy environment and renewable energy market.
- Identification of the critical and emerging issues associated with renewable energy development.
- A set of recommendations for taking advantage of the opportunities revealed by the policy analysis and extensive consultations with numerous stakeholders.

The co-ordinated approach employed to produce this RRA helps in setting priorities, in consultation with bilateral and multilateral co-operation agencies, financial institutions and the private sector, for implementing the recommended actions.

1.3 REMAP AND POWER SECTOR ASSESSMENT

REmap is IRENA's Renewable Energy Roadmap and constitutes a key pillar of IRENA's work on assessing the energy transition. REmap focuses on energy system analysis out to the year 2050 and assesses all energy transition technologies, albeit emphasising renewable energy and energy efficiency solutions. REmap consists of three levels of analysis: country (this report), regional (such as the 2nd *Renewable energy outlook for ASEAN*), and global (the *World energy transitions outlook*).

REmap utilises a toolkit that allows for the development of full energy balances covering the whole energy system, including energy demand, energy transformation and losses, and primary energy supply. The toolkit is based on modules that can be used according to the specific requirements and data availability of each project. The toolkit is a parametric model where future energy demand and supply are fully assessed based on input parameters, such as activity levels, energy service penetration, technology shares and fuel mixes. It is a bottom-up approach. These are all exogenous inputs to the model, and energy demand is fully determined from those inputs through deterministic model equations. The toolkit does not rely on cost optimisation or multi-criteria methods.

For the power sector, this study uses the commercial software PLEXOS for both the long-term capacity expansion and operational flexibility analysis. Additionally, IRENA's FlexTool (which is free and open-source) performs power system flexibility assessments based on the resulting capacity expansion in key milestone years. The FlexTool assessments reflect full power system dispatch and offer a detailed view of flexible generation options, demand flexibility and energy storage, along with sector-coupling technologies such as power-to-heat, electric vehicles (EVs) and hydrogen production through electrolysis. More information on the models used can be found in Chapter 4.

Developing the scenarios is a collaborative process that involves close consultation with the government of Indonesia and other stakeholders in the country. Focal points were appointed and IRENA engaged stakeholders through a series of meetings and consultations, to define the scope and ambition and discuss scenario results. For the production of this analysis, meetings were held to define the scope and discuss data in October 2020, then to present the demand analysis in July 2021, later to discuss power sector results in February and April 2022, and finally to review the report in summer 2022. IRENA also engaged Indonesia through the ASEAN Renewable Energy Sub-Sector Network in May 2021 and 2022. IRENA's analysis was also presented and discussed during the modelling workshop in Bogor, March 2022, to give input to Indonesia's Net Zero Energy Sector Roadmap.

2 ENERGY CONTEXT

2.1 ENERGY SECTOR

The "Handbook of Energy & Economic Statistics of Indonesia" is the authoritative source on Indonesia's energy data. The edition from July 2021 provides the key energy data for the year of 2020 (MEMR, 2021a).

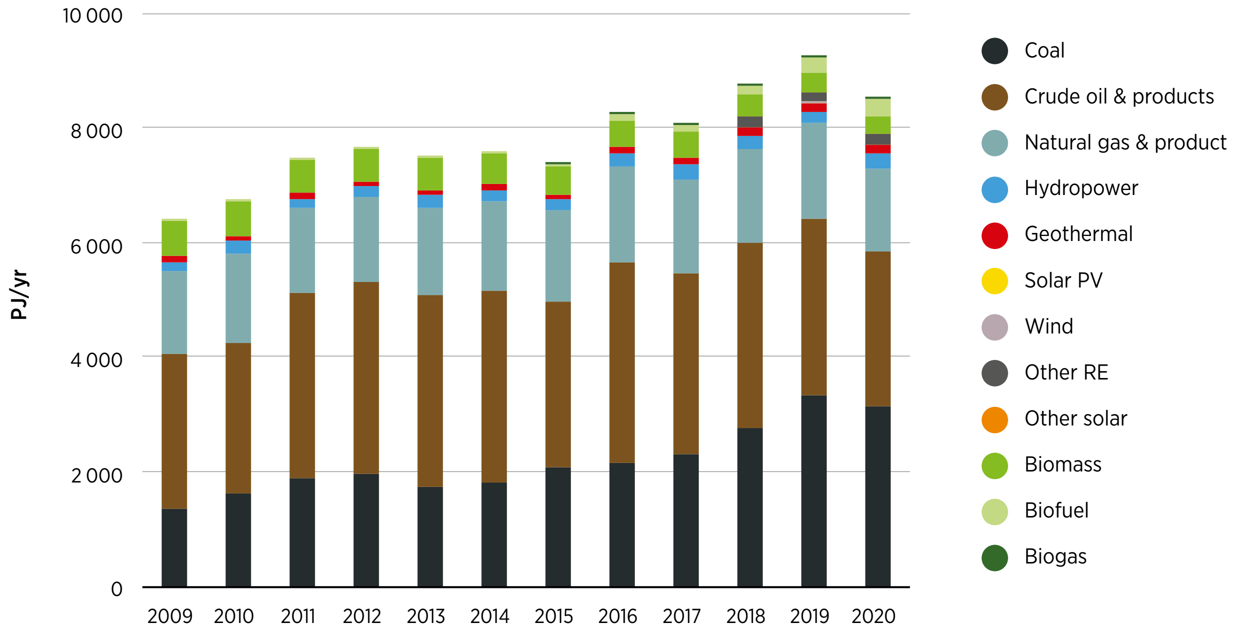
In 2020 Indonesia's total primary energy supply reached 1.493 billion barrels of oil equivalent (BOE), equivalent to 8.5 exajoules (EJ). In 2020 Indonesia's total primary energy supply reached 1.493 billion barrels of oil equivalent (BOE), equivalent to 8.5 exajoules (EJ). Indonesia is both a producer and user of fossil fuels, where the country's energy mix is dominated by fossil fuels where their share in the total primary energy supply has remained around 86% between 2009 and 2020 (see Figure 8). Coal's share of the total primary energy supply has increased from around 21% to 37% in the same period at the expense of oil's share, which declined from 43% to 32%. The gas share fluctuated between 17% and 23%. Renewables accounted for the remaining share of 14.4% of the total primary energy supply. The hydropower share has been around 2-3% in the 2009-2020 period, whereas the total share of biomass energy has declined from 10% to 7%. Biomass has experienced a shift from its traditional use to modern applications such as sustainable biofuels and biogas: the share of traditional biomass in 2020 was 3.6% as opposed to 9.7% in 2009. Sustainable biomass has a potential role in Indonesia's decarbonisation future when implemented in a proper manner. Wind and solar accounted for 0.13% of Indonesia's total primary energy supply in 2020, increasing from zero use in 2017. As a comparison, Indonesia's energy intensity stood at approximately 10.3 megajoules (MJ) per USD at the end of 2020, around half of the level of India, Malaysia and Thailand but relatively higher than the Philippines and the United States (MEMR, 2021a)

Indonesia has traditionally been a producer of fossil fuels. Its coal production target for 2020 was set at 550 million tonnes (Mt) or 13.5 EJ, somewhat lower than the actual output of 616.2 Mt in 2019.[4] In 2020 Indonesia surpassed its production target with a total output of 564 Mt. Compared to 2009, coal production had increased by a factor of 2.4 by the end of 2020. Indonesia exported more than 70% of its coal output, where its exports have doubled in the same period from around 200 Mt to 405 Mt per year. In 2020 China and India were the largest buyers of Indonesian coal, accounting for about 56% of total exports. They are followed by Japan, Korea and the Philippines. COVID-19 affected coal sector exports, which decreased by more than 40% in the first two months of 2020 compared to previous year(IISD, 2020a). By the end of 2020, the decline in coal exports was 11% compared to the year before.

[4] *On average the net calorific value of all coal produced in Indonesia is equivalent to 23.9 GJ per tonne.*

Indonesia's energy supply is still heavily dominated by fossil fuels

Figure 8 Breakdown of Indonesia's total primary energy supply, 2009-2020



Note: PJ = petajoule; RE = renewable energy.
Source: (MEMR, 2021a).

In 2020 Indonesia consumed 132 Mt of coal, a slight decline compared to 2019, the year when the country recorded its historical maximum coal consumption of 138 Mt. Nearly 80% of the total consumption (105 Mt) was for power plants in 2020. Coal demand for electricity generation is increasing rapidly, by around 5-8 Mt per year since 2010, equivalent to the average annual demand of a 1 GW-size coal-fired power plant. Industry is the second largest user of coal, to generate process heat across different industry sectors. Pulp and paper industry consumption was around 2 Mt/yr by the end of 2020, declining from a peak in 2015 of 4.3 Mt. Coal demand from cement, textile and fertiliser plants grew to reach more than 22 Mt/yr in 2019, but this declined to 6.5 Mt in 2020. The iron and steel and the metallurgy sectors are also large users, where their total demand in 2020 was the highest recorded at 13 Mt.

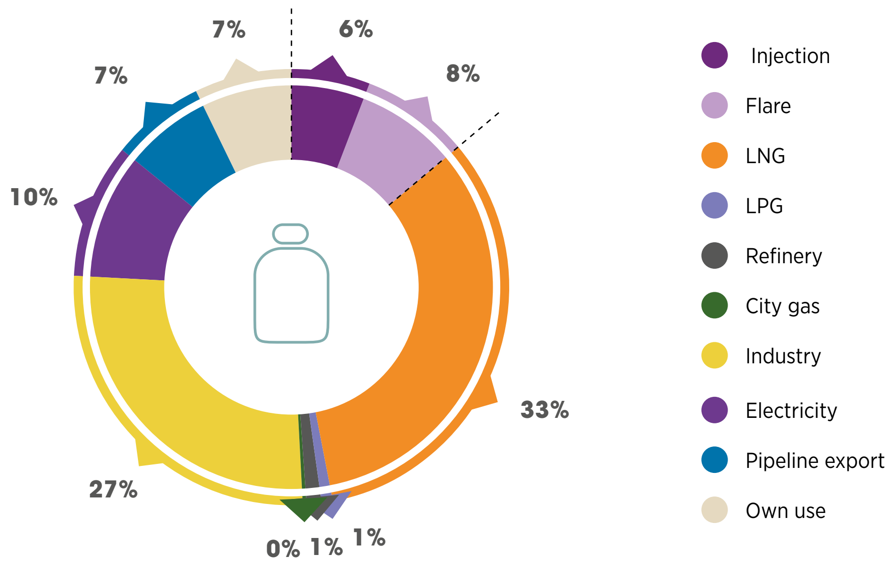
As of July 2021, Indonesia reported a total of 143.7 billion tonnes of verified coal resources, of which 38.8 billion tonnes are verified reserves. Nearly 90% of these reserves are concentrated in the Kalimantan and Sumatra regions. As a large producer (accounting for 7.5% of total global output in 2020), Indonesia has been contributing to the growth of the global coal market (IEA, 2021a). IRENA's Planned Energy Scenario (see Chapter 4) projects that coal's role in total primary energy supply will peak sometime around 2035 and decline towards the mid-century.

Commercially proven crude oil reserves in Indonesia amounted to 2.44 billion barrels by the end of December 2020 (or approximately 13.9 EJ). The potential reserves were estimated at 1.73 billion barrels. Estimated crude oil reserves globally are at around 1.5 trillion barrels (OPEC, 2022). Crude oil production has been declining in Indonesia, from around 0.35 billion barrels per year in 2009 to 0.26 billion barrels in 2020. In 2009 Indonesia was a net exporter and was exporting around one-third of its output (0.13 billion barrels). This share is now around 12% (0.031 billion barrels). Its imports were 2.5 times higher than its exports in 2020 at around 0.080 billion barrels per year. In 2019 0.302 billion barrels of crude oil were input to oil refineries. Indonesia's oil refineries' total output was 0.334 billion barrels in 2020, comprising 0.122 billion barrels of gasoil CN48, 0.042 billion barrels of gasoline RON 88, 0.038 billion barrels of secondary fuels, 0.048 billion barrels of gasoline RON 92. Liquefied petroleum gas (LPG), fuel oil and other transport fuels represent the remainder. Oil is projected to continue being a large element of Indonesia's total primary energy supply under a current policies future.

Commercially proven gas reserves in Indonesia amounted to 49.74 trillion standard cubic feet of gas (TSCF) in January 2020 (or approximately 54 EJ), significantly higher than its crude oil reserves. This value was revised at 43.57 TSCF in January 2021. Indonesia produced 2.4 million million standard cubic feet (MMSCF) of gas (approximately 2.64 EJ) in 2020. Of this total about 84% was non-associated gas produced from wells. Indonesia has been producing gas in similar orders of magnitude in the past decade, with the years 2012 and 2014 peaking at a total output of 3.17 million MMSCF. Compared to total gas output, net gas production was 2.1 million MMSCF (after accounting for gas lift, reinjection and flaring which represent 14% of the total output). About 39% of the net output was utilised for LNG production. Industry and power plants utilised 32% and 12% of the net output, respectively. About 9% was exported through pipelines (see natural gas is heavily used in industry sector and for LNG Figure 9). Pipeline exports have been declining since 2012, when Indonesia exported a total of 0.358 million MMSCF. In 2020 exports were at 0.184 million MMSCF. The decline in LNG exports was sharper. Within a decade the total volume of exports had halved from more than 1 million MMSCF to 0.5 million MMSCF.

Natural gas is heavily used in industry sector and for LNG

Figure 9 Breakdown of gas use in Indonesia, 2020

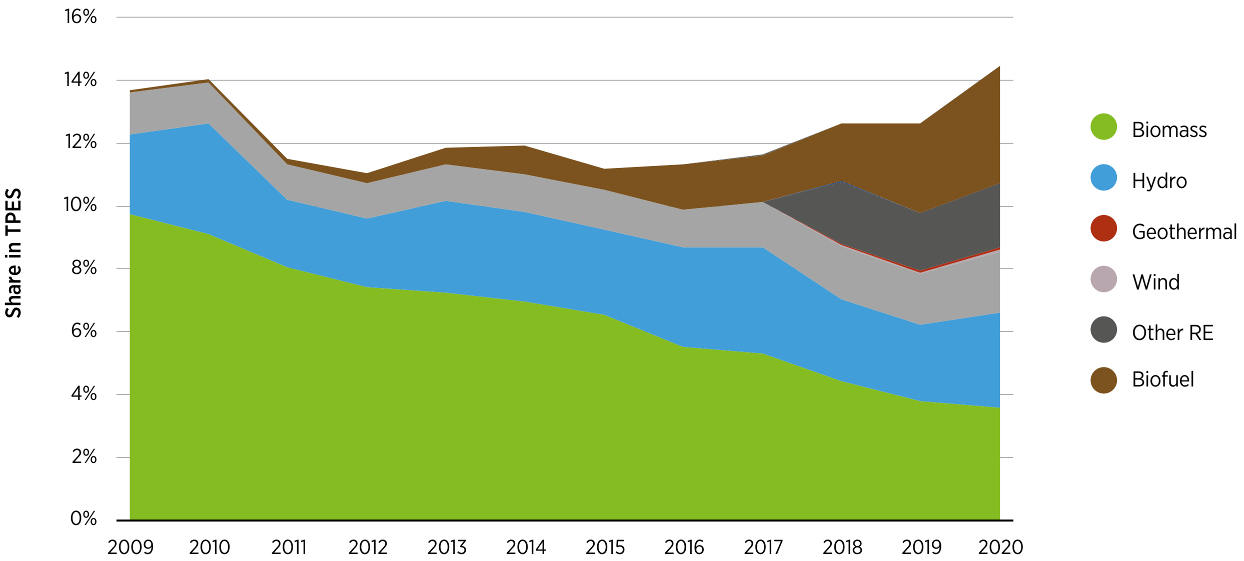


Source: (MEMR, 2021a).

The renewable energy share in Indonesia's total primary energy supply has been fluctuating at around 11-12% since 2011. Before 2011 the share of renewables was higher at around 14%. One reason for the constant share of renewables is the declining trend of solid biomass (mainly the use of biomass in traditional forms) from around 10% in 2009 to 3.6% in 2020. At the same time, the share of biofuels and "other renewables" (solid biofuels, biogas, waste for power plants and hybrid power plants) has increased significantly to 5.7% by 2020. Wind is also gaining a small share in the total energy mix. Indonesia's energy statistics now report solar PV and solar-powered public street lighting as well, but their share of the total energy mix is marginal.

Bioenergy is a large part of Indonesia's primary energy supply

Figure 10 Share of renewable energy in total primary energy supply, 2009-2020



Note: RE = renewable energy.
Source: (MEMR, 2021a)

Indonesia is the third largest biodiesel producer globally, following production in the European Union and the United States (IEA, 2020a). From a total installed biodiesel production capacity of 13.4 billion litres, its production has reached 8.6 billion litres. More than one-third of the total capacity is located in Riau (5.1 billion litres). By comparison, bioethanol production is marginal, with a total production capacity of 40 million litres in eastern Java. Around 16% of the total production in 2019 was exported and the rest was consumed locally. Biogas production amounted to 27.9 million cubic metre. The share of this important form of renewable energy is projected to continue increasing under both current policies and also in IRENA's decarbonising scenarios. This is discussed in more detail in Chapter 4.

Energy consumption

Indonesia is the largest consumer of energy in the ASEAN region with a share of 36% of the region's total final consumption. Across more than 17 000 islands, Indonesia's total final consumption (TFC) had reached 5.3 EJ per year (equivalent to 923 million BOE) by the end of 2020 (including 140 PJ of non-energy use). Transport and industry's consumption were about the same, each sector consuming in total 2.05 EJ per year; in other words, their combined final consumption was 78% of Indonesia's total. Household consumption was 0.88 EJ and the commercial sector consumed in total 0.24 EJ, thereby equalling buildings' share of TFC at 21%. Demand from other sectors such as forestry, fishing and agriculture was less than 1% of TFC at 0.06 EJ.

Oil products (nearly all consumed for transport), biodiesel and LPG represented about 52% of TFC in 2020. This included 1.27 EJ of oil products, 0.4 EJ of LPG and 1 EJ of biogas oil (a blended product of biodiesel; in its pure form 0.31 EJ was supplied). Coal's share of TFC was 12% from a total of 0.65 EJ, down from 16% in 2019. This share is much lower than coal's share of the total primary energy supply as most coal is used for electricity generation. IRENA's long-term projection sees coal consumption continuing to grow if current policies are implemented into the future, although its share of TFC falls. The share of gas in TFC was 13% from a total of 0.7 EJ. Gas use included 0.14 EJ of non-energy use for chemical production, such as fertilisers. Electricity's share of TFC was 18%, slightly below the global average of about 19%, but up from its 15% share in 2019.

Industry is the largest consumer of solid fuels (0.87 EJ). It accounted for all coal and briquette use and 70% of the total solid biomass use in 2020. It also consumed nearly all gas demand in the country (0.68 EJ), with about four-fifths of the total used for process heat generation and one-fifth for non-energy use. Fossil fuels comprised 71% of the sector's TFC, the remaining 29% being split between biomass at 12% and electricity at 17%.

The household sector is the second largest user of solid biomass, accounting for 8% of the sector's total demand (0.07 EJ). It is the only user of biogas with a total demand of 1 PJ and the largest user of LPG (0.38 EJ). LPG and electricity represented 43% and 47% of the household sector's total energy demand. Another 2% of the total demand was from natural gas and other oil products. Electricity met more than 85% of the commercial sector's energy demand, the sector with the highest share of demand met by electricity in Indonesia. Transport's total energy demand is split between 56% oil products (1.2 EJ) and 44% biogas oil (0.9 EJ).

Box 2 Energy subsidies

Coal supply is regulated by the Ministry of Energy and Mineral Resources (MEMR). It has applied a coal price cap of USD 70 per tonne to the coal used by PLN since 2018 (ADB, 2020). The price cap was expected to result in savings of around USD 1.3 billion for PLN provided that the 2018 coal benchmark price stayed above USD 100 per tonne. Since fuel accounts for more than half of the operational costs of an average coal-fired power plant, a reduction in energy costs through a price cap has considerable impact over PLN's profitability (IISD, 2019).

For the year 2019 total energy consumption subsidies amounted to more than USD 30 billion, split between electricity (USD 12 billion) and oil (USD 20 billion) (IEA, 2020b). In the same year, another analysis suggested that fuel and LPG subsidies amounted to USD 2.15 billion (IDR 30 trillion) and USD 3.9 billion (IDR 54 trillion), respectively (IISD, 2021). Peaking in 2019 at USD 25.6 billion (IDR 356 trillion), when they represented about 3% of total GDP, fossil fuel subsidies have steadily decreased since. In 2013 electricity subsidies peaked at USD 8.34 billion (IDR 101.2 trillion), representing about 8.8% of national government spending. In 2017 the total electricity subsidy declined to USD 3.4 billion (IDR 45.7 trillion). Since then it has started to increase again to reach USD 3.8 billion (IDR 52.7 trillion) in 2019 (IISD, 2021).

In recent years, Indonesia has made efforts to reduce its electricity and oil subsidy-related expenditures and has developed tools to better target subsidies, in the form of the united poverty database and a planned smart card system for both electricity and LPG subsidies. This has helped the government to increase funding for social assistance projects, infrastructure and spending for health and education services (IISD, 2021; OECD/IEA, 2021)

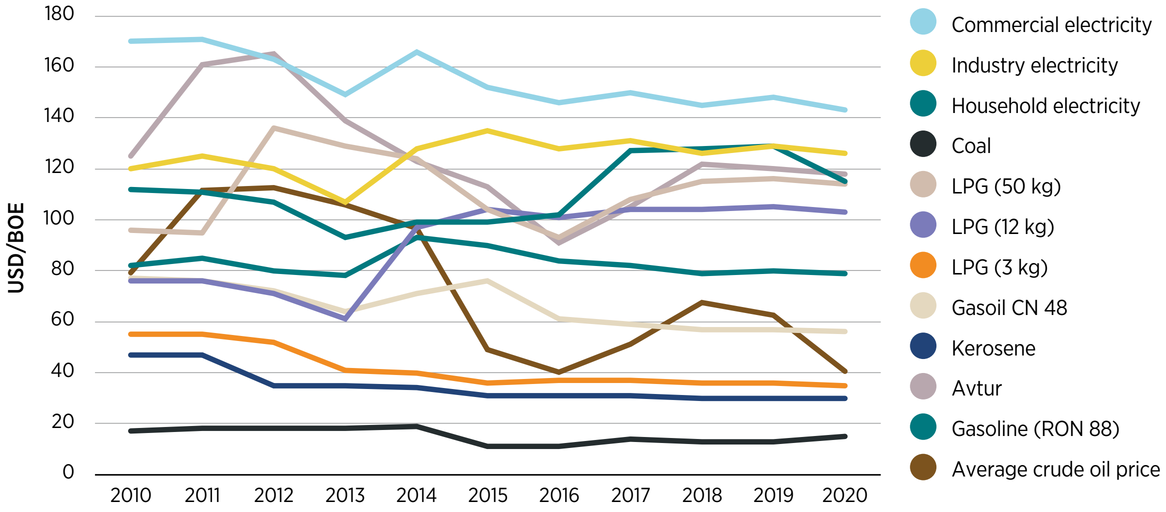
As part of the COVID-19 economic recovery packages, Indonesia has introduced several support measures for its fossil fuel sector. These included a USD 3.12 billion cash compensation bailout for its state-owned oil and gas company, PT Pertamina, USD 2.51 billion cash compensation and state capital injection for the state-owned power utility company, PLN, and a USD 6.54 billion PLN free electricity incentive (bill waiver from April – July 2020 for 450 volt ampere (VA) residential customers and a 50% discount for 900 VA subsidised residential customers). Additionally, USD 983 million was provided to companies that engage in the coal derivatives industry (OECD/IEA, 2021).

An overview of the development in energy prices in Indonesia between 2010 and 2020 is shown in Figure 11. Gasoline prices rated at RON 88, RON 90, RON 92 and RON 98 were at USD 0.46 (IDR 6 450), USD 0.54 (IDR 7 650), USD 0.64 (IDR 9 000) and USD 0.7 (IDR 9 850), respectively (April 2020). The subsidised biosolar (diesel, CN 48) price was USD 0.37 (IDR 5,150). CN 51 and CN 53 rated diesel prices were as high as USD 0.71 (IDR 10 000) per litre. As the price gap between biodiesel and petrol diesel widened, the government revised the biodiesel reference price formula from USD 100 to USD 80 per tonne. In March 2022, a domestic shortage of affordable cooking oil led to a temporary export ban of palm oil in Indonesia. Since then, the government has issued multiple adjustments on palm oil export taxes and levy rates throughout 2020-2022 to ensure a balance between domestic obligations and global demand (Global Compliance, 2022).

Box 2 Energy subsidies (continued)

Energy prices in the last decade fluctuated considerably

Figure 11 Overview of energy prices in Indonesia, 2010-2020



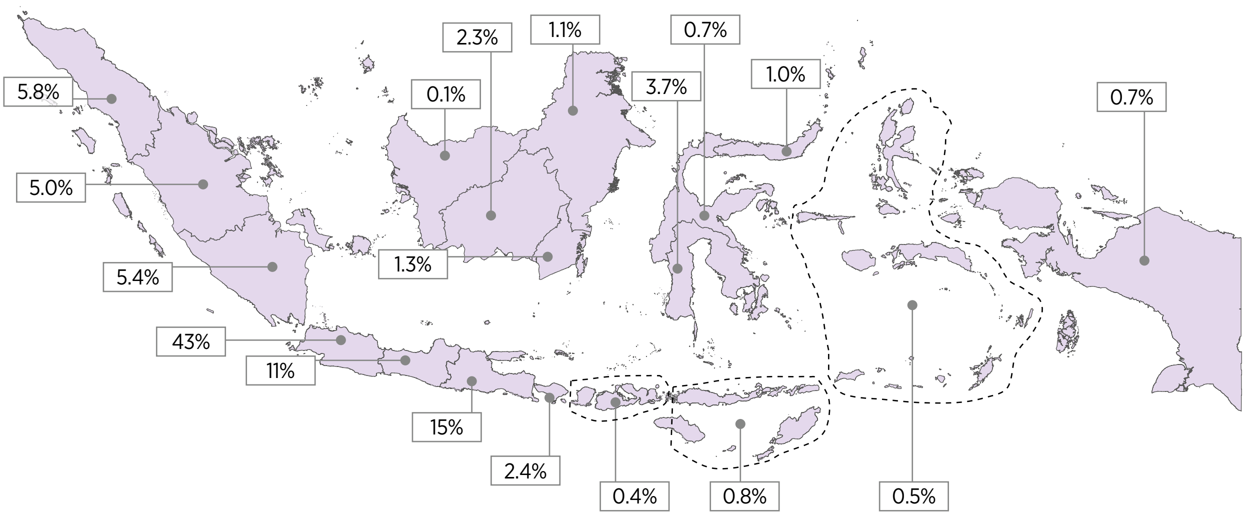
Source: MEMR (2021).

2.2 ELECTRICITY SECTOR

The country is seeing rapid growth in its total electricity demand and therefor the total installed generation capacity is increasing. How this demand and its distribution are spread across Indonesia will be crucial in the future planning of the power sector. In 2020, based on historic electricity demand profiles, well over 60% of electricity demand was concentrated on the island of Java, as shown in Figure 12.

Java, Bali and Sumatera comprise of almost 90% of the country's electricity load in 2020

Figure 12 Approximate distribution of national electricity load in 2020

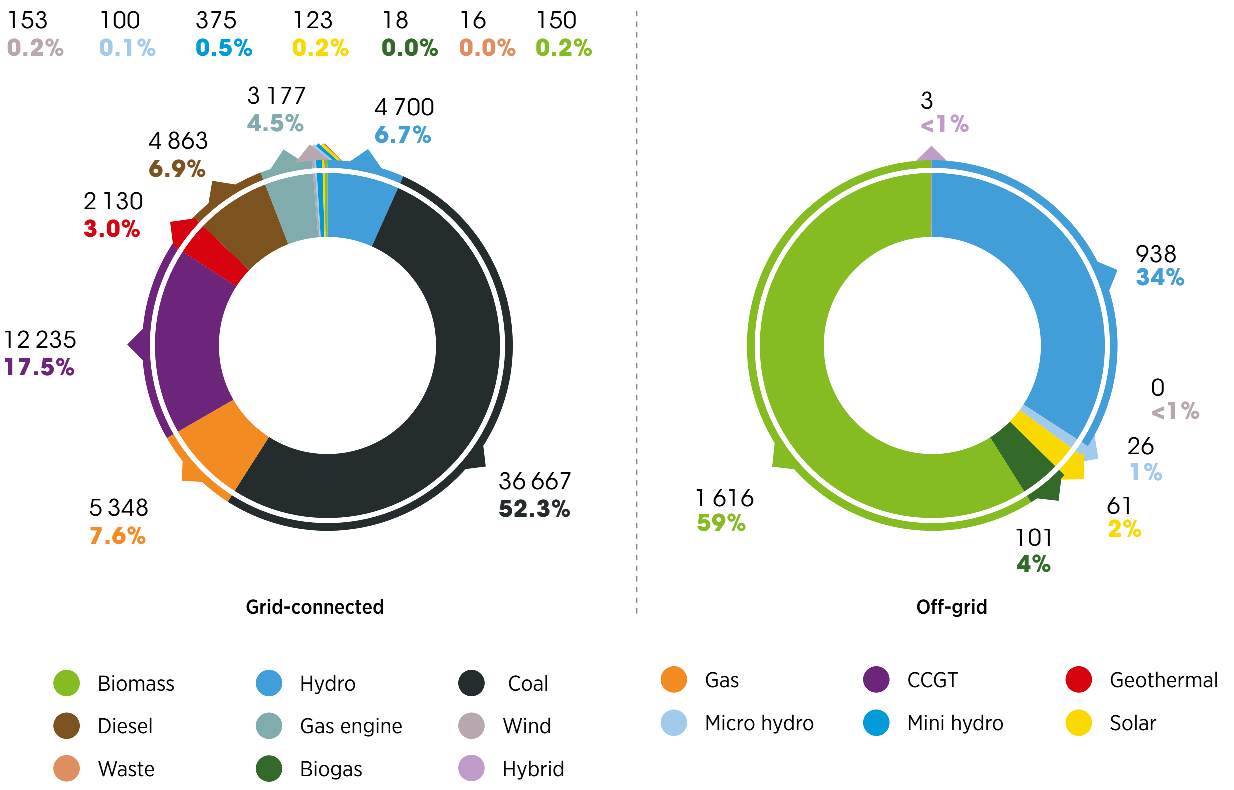


Note: Please see figure 41 for more information on the nodal sub-region representation.
Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

By the end of 2020 Indonesia had a total installed electricity generation capacity of 70 GW connected to the grid. Net capacity additions in 2020 amounted to 3 GW compared to 4.7 GW in 2019. Total installed off-grid system capacity reached 2.75 GW, raising the total installed capacity in Indonesia to 72.8 GW by the end of 2020. More than 60% of this is installed on the Java-Bali electricity system (> 40 GW), while the rest is distributed within several other electricity systems in Indonesia (Sumatra, Sulawesi, Kalimantan, Nusa Tenggara and Papua). The next most extensive system is on the island of Sumatra, with 8.6 GW, followed by Kalimantan and Sulawesi.

Renewables accounted only for 12% of Indonesia's total installed capacity in 2020

Figure 13 Total installed grid-connected (left) and off-grid (right) installed electricity generation capacity, 2020 (MW)



Note: CCGT = combined-cycle gas turbine.
Source: MEMR (2021).

Coal-fired power plants accounted for half of the total installed capacity in 2020, up from 38% in 2010 when combined-cycle and open-cycle gas turbines and diesel and gas engines that represented around half of the total installed capacity. Total installed coal-fired power plant capacity has seen immense growth of nearly three times in the same period. These investments resulted in a relatively young coal fleet with an average age of less than 10 years. Most of these plants are sub-critical, implying lower efficiency in electricity generation. Three-quarters of the total financing for the coal-fired power plants built between 2016 and 2019 came from international sources, including from other Southeast Asia countries and China. The other quarter of the total financing was of Indonesian origin (IEA, 2020b). Gas-fired capacity has also increased, but much less than the growth of the overall fleet. By the end of 2020 its share had declined to 28%.

Renewables accounted for 12% of total installed capacity in 2020. This is split into half hydropower (including large power plants) and half other renewables. Renewable power capacity grew modestly in 2020, with 165 MW added. Many of these additions were in the form of hydropower. Solar capacity additions came after with a total of 30 MW, mainly rooftop solar PV and 2017's independent power producer (IPP) projects that came online (IESR, 2021b). The COVID-19 pandemic resulted in construction delays for some renewables projects, notably for geothermal (virtually no additions during 2020) and hydropower. A total of 561 MW of hydropower projects were planned to come online in both 2019 and 2020 but were delayed.

At the end of 2020 Indonesia had 6.1 GW of installed hydropower capacity and 2.1 GW of geothermal power. Indonesia is targeting 17.9 GW of additional large hydropower energy projects by 2025 and an additional 3 GW of small hydro projects. According to the RPJMN 2020–2024, developments are targeted in the Papua, Sulawesi and North Kalimantan regions as key areas where hydropower can provide support for electrification (ADB, 2020).

Geothermal is regarded as a crucial resource to provide baseload capacity in the long term in realising Indonesia's 23% renewable energy target by 2025. Most geothermal resources are in the regions where demand also exists, namely Sumatra and Java. The Geothermal Law was enacted in 2003 and the geothermal target is 7.2 GW capacity by 2025 (ADB, 2020). The government set up a roadmap for geothermal power development with the aim of increasing geothermal capacity from 2.13 GW in 2019 to 7.87 GW in 2030 and 9.3 GW in 2035. The geothermal target was moved earlier by five years to 2030 from the original plan in the General Plan for National Energy (*Rencana Umum Energi Nasional,* RUEN) (IESR, 2021b).

The various forms of biomass (including waste) have a total capacity of 1.9 GW. The majority of this total comprises off-grid systems with a total capacity of more than 1.7 GW.

Wind and solar energy are growing rapidly from a very low base. Their total installed capacity was more than 340 MW by the end of 2020 (see Figure 14). For the first time in 2020, installed solar energy capacity (including off-grid systems) surpassed the wind power capacity (185 MW vs. 154 MW).

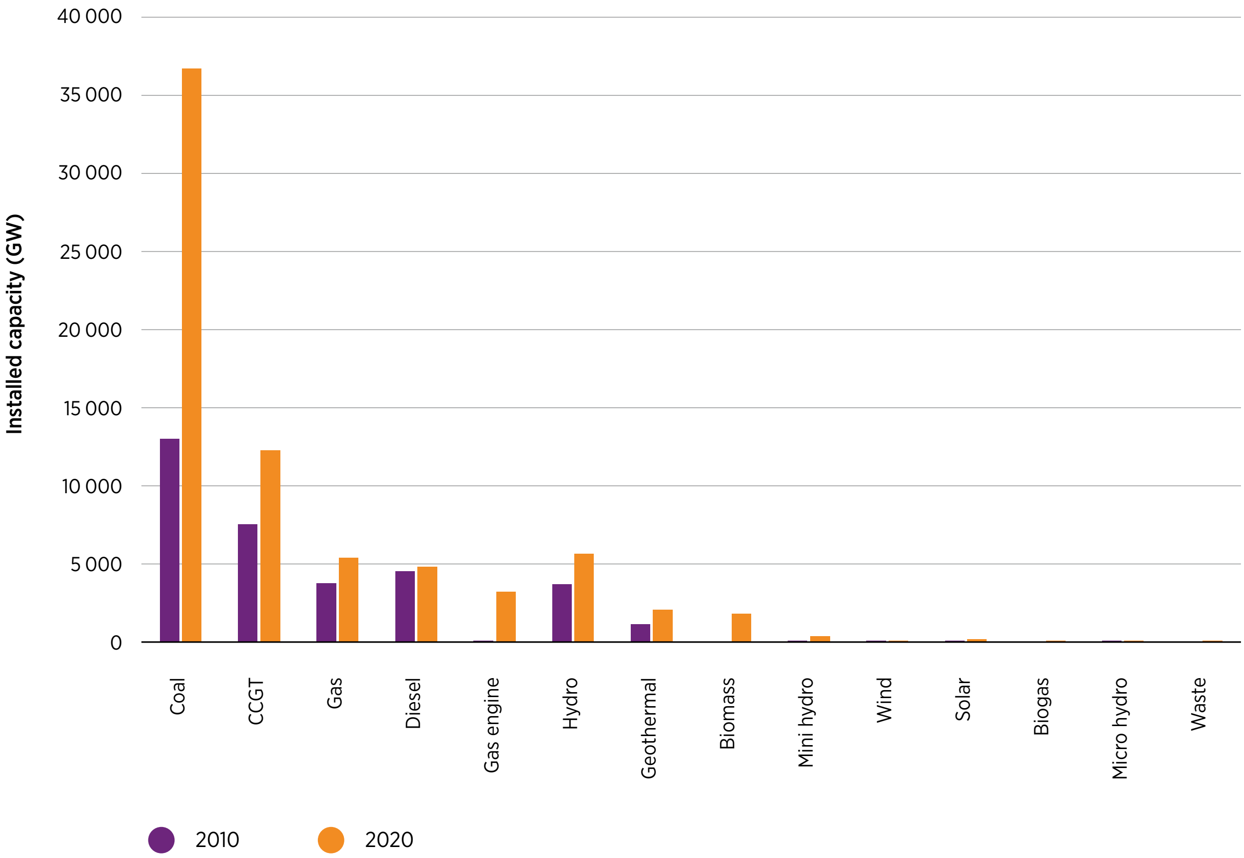
There are two utility-scale wind power plants in Indonesia, namely Tolo 1 (72 MW) operational since 2019 and Sidrap (75 MW) operational since 2018, both connected to Sulawesi's energy grid. Additionally, several small-scale and non-commercial supplies also exist (ADB, 2020). According to the previous version of the Electricity Supply Business Plan (*Rencana Usaha Penyediaan Tenaga Listrik*, RUPTL) 2019–2028, the target for wind power was 850 MW to be reached by 2025. In RUPTL 2021-2030, a total of 597 MW capacity additions are targeted until 2030.

Solar additions made the highlights in 2019, raising the total installed capacity to 145.81 MW (105.03 MW grid connected and 40.78 MW off-grid systems). The achievement of 85.6 MW capacity additions in 2019 was mainly from utility-scale solar power plants. The 15 MW size PLTS Likupang solar PV plant in Minahasa, commissioned in September 2019, is the biggest solar PV plant in Indonesia. The power purchase agreement (PPA) for the project, signed in 2017, is for USD 0.10 per kilowatt hour (kWh) (IESR, 2020). In the first nine months of 2020, a total of 28.8 MW of new capacity was installed. This included 15 MW capacity for two utility-scale projects subject to PPAs in 2017, and 13.7 MW of rooftop solar PV.

At the end of 2021 total installed solar power generation capacity reached 190 MW (MEMR, 2021a). Around 85% of this is ground mounted and 15% is rooftop. Of the ground mounted, one-third is off-grid (mostly used for rural electrification) (61 MW), and the other two-thirds are on-grid utility-scale (123 MW) (MEMR, 2021a). In the two years following the issuance of MEMR Regulation 50/2017, PLN conducted the first tender for two solar power projects with a 25 MW capacity, both located in Bali. The projects have received bids at around USD 0.06/kWh (IESR, 2020). Developments in the solar energy sector are still far from the RUEN target of 5.5 GW by 2025. RUPTL 2021-2030 targets 4.7 GW of capacity by 2030. IRENA's Planned Energy Scenario projected share of installed renewable energy capacity reaches 28% and 55% in 2030 and 2050, respectively (see Chapter 4.3).

Growth in coal power capacity was strong in the last decade

Figure 14 Total installed capacity, 2010 and 2020



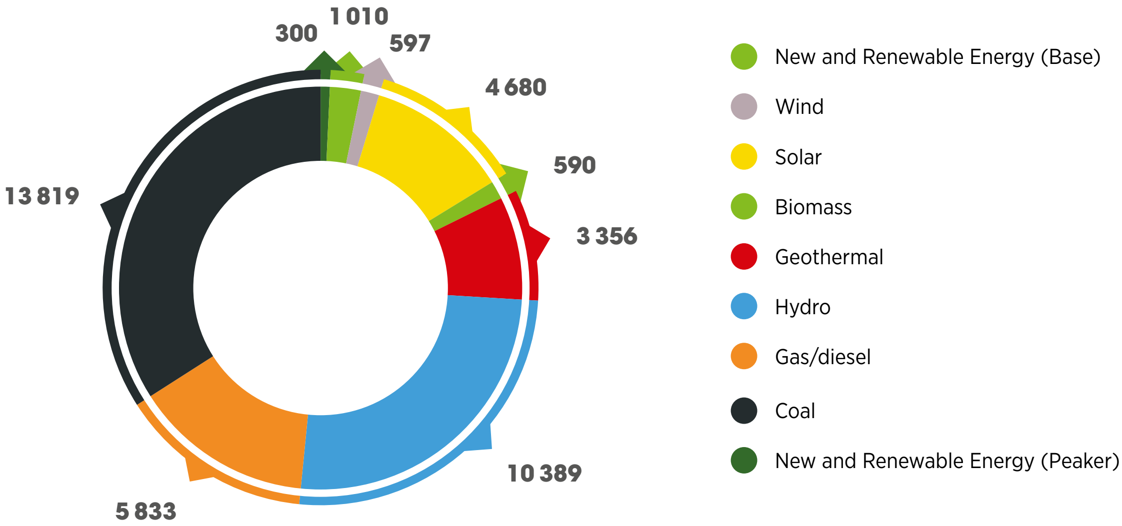
Source: (MEMR, 2021a).

According to RUPTL 2021-2030, released in October 2021, a total of 20.9 GW of renewable energy capacity additions are planned for between 2021 and 2030, which would represent about 51.6% of the total planned capacity additions in the same period (PLN, 2021a). This is a considerable increase compared to RUPTL 2019-2028, which planned for only 16.7 GW of renewable power capacity additions, representing 29.6% of the total additions.

According to RUPTL 2021-2030, about half of the total renewable energy additions are to come from hydropower (10.4 GW), followed by solar PV (4.68 GW) and geothermal (3.36 GW) (see Figure 15). Coal expansion in RUPTL 2021-2030 is less than half of that initially planned in the earlier RUPTL 2019-2028. No further coal-fired plants are to be added to the system beyond what is already agreed, according to the latest plan. This means PLN is only continuing the ongoing projects that have PPAs, although around 13.8 GW of new coal power plants are currently in the pipeline. The share of installed coal power plants is set to fall from 50% in 2020, to 45% by end of 2030. The share of renewable energy in the latest RUPTL is 51.6% by 2030.

About half of total planned additional installed capacity between 2021 to 2030 will be renewables.

Figure 15 Breakdown of capacity additions (MW) between 2021 and 2030 according to RUPTL



Source: (PLN, 2021a).

Electricity generation

Total on-grid power generation in Indonesia was 275 TWh per year in 2020, a decline of more than 1% compared to 2019. About 65% of this was generated by assets belonging to the national utility, PLN, with the remainder from private power utilities (PPUs) and IPPs. PLN's share was about 75-80% until few years ago. The monopoly position of PLN in power generation has been reduced since 2000, when it accounted for 92% of total on-grid power generated in Indonesia. In recent years, however, PLN has expanded generation at a similar pace as PPUs and IPPs, explaining the rather small change in its share in total generation since 2010.

Coal provided the majority of Indonesia's on-grid power generation in 2020 at about 62%, or 181 TWh per year. In the previous six years, its share increased by 9 percentage points. In 2010 the share was at just 40%. Natural gas accounts for a further 18% of electricity generation, with modest changes in its use since 2010. Diesel has a share of 2% in electricity generation. While the share of petroleum products has been stable in recent years, in the longer term it has been shrinking. Renewable energy accounted for 13% of Indonesia's total on-grid power generation in 2020, down from 16% in 2019. Including renewable energy generation from off-grid systems, renewable's share was about 18%. Hydropower and geothermal generated 24.4 TWh and 15.6 TWh, respectively, representing much of Indonesia's renewable power output. Other grid-connected renewables played a small role; for instance, wind energy's share was 0.16% and solar's share was 0.05%. The combined share of various biomass resources was 4.24% (mainly from residues and waste in the palm and paper industries). Nearly all this output was from off-grid capacity.

Hydropower output from PLN-owned power plants has been declining since 2016, falling to under 10 TWh for the first time in more than a decade in 2019. In 2020 output increased slightly above 11 TWh. By comparison, IPP and PPU hydropower output increased sixfold to reach 7.5 TWh in the same period. Output from off-grid hydropower systems was at 5 TWh in 2020. Total geothermal output increased to 15.6 TWh in 2020 from 9 Wh in 2009.

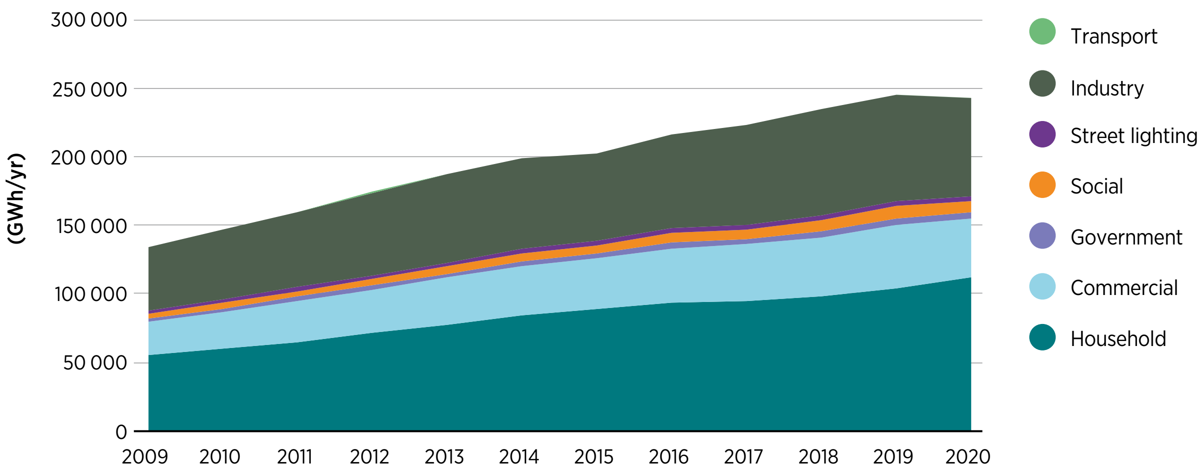
According to RUPTL 2021-2030, total electricity generation should grow on average by about 4.9% per year between 2021 and 2030, increasing from 291 TWh to 445 TWh. Coal would still account for the largest share of Indonesia's total electricity output, albeit declining from about 67% in 2021 to 59.4% by 2030. The gas-fired share would remain around 16%, but LNG would overtake it. Renewable energy would account for 23% and 24.8% of Indonesia's total electricity output by 2025 and 2030, respectively, with about 70% of the total renewable electricity output coming from hydropower and geothermal and the remaining 30% from solar, wind and biomass (PLN, 2021a).

Electricity consumption

A total of 242 TWh of electricity was consumed in Indonesia during 2020. Indonesia's largest consumers of electricity are households and the industrial sector. Household consumption represented around 46% of total demand, whereas industry's demand was around 29%. The commercial sector is the third largest consumer with a share of 17%. The remaining 8% is split between public buildings, social services and street lighting and transport. Demand has grown on average by 6% per annum between 2009 and 2019. In 2020 demand dropped by more than 1%. The large majority of the electricity generated (89%) is consumed in Java-Bali and Sumatra. Provinces that have achieved 99% electrification are expected to experience slowing demand growth. RUPTL 2021-2030 reports that five out of the six provinces on the island of Sulawesi, in addition to the provinces of East and West Nusa Tenggara, East Kalimantan, West Sumatra and Yogyakarta, are expected to have growing electricity demand (ADB, 2020). During the COVID-19 period an increase in household electricity consumption was offset by a larger decline in consumption in the commercial and industrial sectors. The short-term decline in country's energy demand is likely to recover by 2022. Under the current policies implemented, long-term electricity demand is projected to grow almost fivefold between 2018 and 2050.

The building sector makes up the largest share Indonesia's electricity consumption

Figure 16 Total electricity sales by sector, 2009-2020



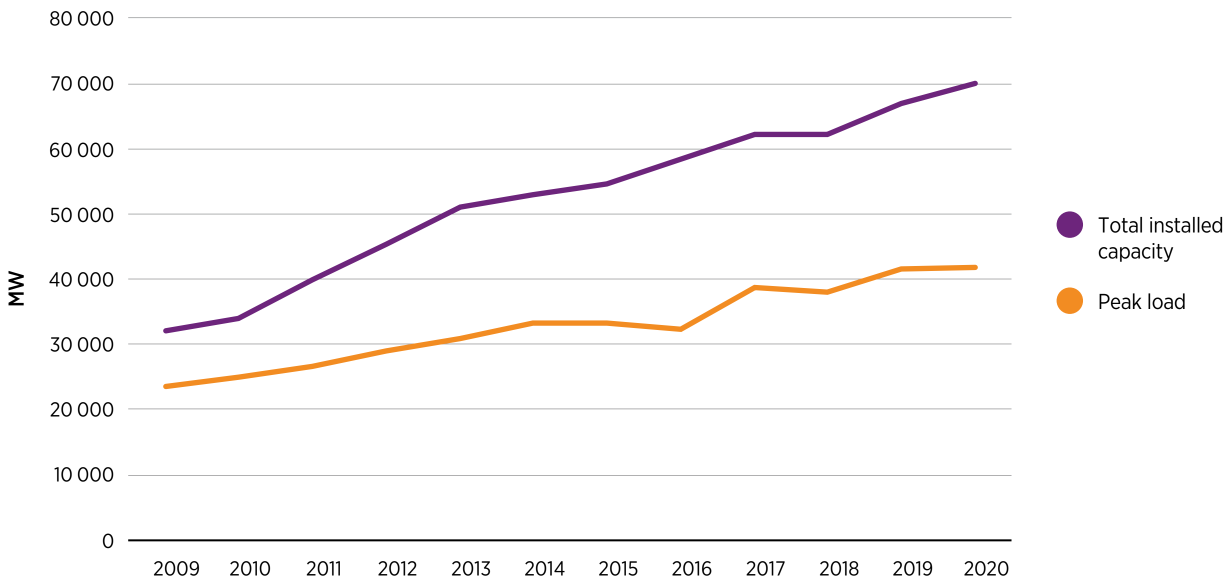
Source: (MEMR, 2021a).

Indonesia's peak load had reached 41.8 GW by the end of 2020 (see Figure 17). Total installed capacity has been growing at a faster pace, in particular because of the investment in coal-fired power plants, indicating some overcapacity in Indonesia's power fleet (Reuters, 2020).This is also marked by the fleet's lower capacity factors, which are now at around 45% compared to 55% about a decade ago. Especially on the Java-Bali grid, electricity oversupply is an issue.

RUPTL 2021-2030 aims to reduce overcapacity by electrifying end-use sectors, including electric vehicles, and planning the construction of new power plants outside Java and Sumatera. The moderate electricity demand projections of RUPTL 2021-2030 show an increase of 4.91% per year on average between 2021 and 2030, from 253 TWh to 390 TWh per year, with the growth rates ranging from 8% per year in Kalimantan and Maluku-Papua-Nusra to 4.1% in Java-Bali. Java-Bali would still account for the majority of demand in 2030, with a share of two-thirds, but slightly less than today's level of about 70% (PLN, 2021a).

Indonesia's over capacity of installed generation has increased over the years

Figure 17 Comparison of the growth in total installed capacity with the peak load



Data source: (MEMR, 2021a).

Transmission and distribution grid

Transmission and distribution plans are captured in PLN's annually updated RUPTL, of which the 2021-2030 edition is the latest version. The 10-year RUPTL plan is the basis for implementing the electricity supply business in the public interest and it is prepared according to the RUEN and the General Plan for National Electricity (*Rencana Umum Kelistrikan Nasional*, RUKN).

According to RUPTL 2021-2030, the length of Indonesia's transmission network increased from 36 550 kilometres (km) in 2011 to 61 234 km by 2020. In addition, a total of 2 201 substations serve the country with a total capacity of 150 008 megavolt amperes (MVA). At the end of 2020 Indonesia's total medium- and low-voltage distribution networks totalled 414 800 km and 591 465 km, respectively. By 2020 electricity had reached 99.2% of Indonesian households, industry and businesses, with the target of reaching 100% in 2022. This was a significant increase from about 67% in 2010. But there are still challenges that remain to ensure reliable operation of Indonesia's electricity grids, as the 2019 blackout in Jakarta and West Java showed, affecting about 22 million customers (McKinsey, 2020),

For several years PLN was not able to fulfil its capacity expansion plans, the reasons being excessive capacity addition plans due to unrealistic load growth forecasts and unforeseen delays in grid capacity investment. There have been notable downward amendments to the targets in the latest RUPTL compared to the previous version (2019-2028 period). Total transmission plans in the latest version were revised down by 17% to 47 723 km, with a 38% reduction for substations to 76 662 MVA. Alongside these changes, the electricity demand projection was revised from annual growth of 6.42% to 4.91%. The majority of additions in transmission capacity are planned to take place in the Sumatra, Java-Bali and the Kalimantan regions, in similar volumes. This is an important insight given that Sumatra and Kalimantan account for only 20% of the total electricity demand in the country. Actually, Kalimantan is the only region where the planned transmission grid and substation capacities were revised upwards in RUPTL 2021-2030 compared with the earlier version. Additionally, RUPTL 2021-2030 announced a forthcoming smart grid plan that will be released later. The government will provide regulatory support for smart grid development through MEMR No. 143/K/20/MEM/2019, MEMR No. 39 K/20/MEM/2019 and the Presidential Regulation No. 18/2020.

Annual investment in Indonesia's power system had increased to more than USD 12 billion during 2019. In recent years investment in fossil fuel capacity (mainly coal-fired) has doubled, currently representing around one-third of all investment in the country's power system. For approximately each dollar spent on renewables in 2019, three times more was spent on fossil fuels. Another area where investment has increased is electricity grids. Around 60% of all grid investment was in the transmission grid and the remaining 40% in distribution. The level of investment in transmission and distribution grids has been impressive in recent years. A shift from investment in generation capacity to infrastructure will be important given the oversupply conditions, and it is expected that further investment will be needed to connect Indonesia's different islands, ensure system reliability for the grid integration of renewables, and close the gap of a few percentage points in realising full electrification, especially in the country's less-developed regions. At the start of 2020 PLN committed to reserve USD 6.3 billion of capital expenditure for new electricity infrastructure (Jakarta Post, 2021). In addition, it has pledged additional investment of around USD 14 billion for future construction of new substations and transmission and distribution networks in the 2021-2024 period (ADB, 2020).

Indonesia's grid is centralised, and the majority of generation, transmission and distribution capacity is owned and operated by the state-owned electricity company, PLN. PLN acts as a single buyer and owns more than two-thirds of generation and virtually all network infrastructure. Java-Madura-Bali, Sumatra and East Indonesia are three main areas of PLN's operations in Indonesia.

Electricity trading

Indonesia imports a small share of electricity from Malaysia, mainly through the West Kalimantan area connected to Sarawak, Malaysia. The are planned additional interconnections as part of ASEAN projects. In recent years total electricity imports have increased from a few gigawatt hours to 1.55 TWh annually by the end of 2020 (MEMR, 2021a). This makes up less than 0.1% of Indonesia's total electricity demand.

Box 3 COVID-19's impact on Indonesia's energy outlook

To avoid economic shock from the impact of COVID-19 restrictions, the Indonesian government allocated at least USD 6.76 billion for different energy projects as part of its commitment to the national economic recovery, including subsidies and incentives. However, the government failed to envision a green recovery in its economic stimulus. Support for clean energy development only accounted for 3.5% of the total budget, according to the Energy Policy Tracker (IESR, 2021b). These public money commitments include an unconditional USD 6.54 billion for fossil fuels through five policies, whereas no public money was committed to fossil fuels on a conditional basis. Some USD 240 million was committed to clean energy technologies through one policy on a conditional basis. Finally, some public money has been committed unconditionally for clean energy through four policies, as well as for other types of energy through five policies; however, the actual value of the public money committed was unquantified. By energy type, a total of USD 3.18 billion was committed unconditionally to oil and gas and USD 3.12 billion unconditionally to other types of fossil fuels. No public money commitment was identified for coal. It should be noted that these public money commitments are additional to any earlier policies in place before the COVID-19 pandemic started.

Box 3 COVID-19's impact on Indonesia's energy outlook (continued)

Indonesia's main vision for green recovery is "Build Back Better with Low Carbon Development", to be realised by 2030. Based on global benchmarks, the overall Low Carbon Development budget should be allocated as 2% of GDP, equivalent to IDR 306 trillion, and 3-5% of the state budget, equivalent to IDR 72.22-120.37 trillion. Currently Indonesia fulfils only 11% of the 2% benchmark, indicating a large gap in investment.

During the COVID-19 period, because of the reallocation of the country's economic resources in 2020, the government had to postpone its green economy programme. The COVID-19 pandemic has delayed the planned investments in the power sector, including those with renewable energy resources. In 2020 negligible capacity was added to the PLN system (much less than the previous five years, during which around 400-500 MW were added). Moreover, PLN produced no further renewables in 2020.

In 2015 Indonesia established a plan for 35 GW of total electricity generation capacity to be realised by 2019, based on a high economic growth assumption. Overall, the programme had completed 19% of its goal by 2019 (ADB, 2020). The completion rate increased to 24% by August 2020, with a total of 8.4 GW capacity installed, and by the end of 2020 the completion rate reached 27.8% (IISD, 2021; OECD, 2021). By the end of 2020 about half of the total target capacity was either completed or under construction and 34.2 GW of PPAs were secured (MEMR and Indonesia, 2019). The ongoing construction of megaprojects has been found unnecessary, and the government's 35 GW target of new capacity by early 2020 have been pushed to 2028, having been revised in 2018 and postponed to 2024. The plan also included an infrastructure development plan. The profitability of power system assets is also being affected. The decrease in electricity demand due to the COVID-19 crisis has stressed the financial situation of PLN, which resulted in the renegotiation of the IPP contracts. Some of the government's measures also focus on reducing the financial burden on PLN and increasing support for poor households through electricity subsidies.

During the COVID-19 period the government reviewed plans to retire around 13 GW of fossil fuel power plants and replace them with renewables to meet the target of 23% new and renewable energy in the national energy mix by 2025. Instead, recent developments indicate that a part of diesel power plant fleet could be converted to gas or coal gasification, and other new regulations support coal power generation in Indonesia. MEMR's plan to take out at least 5.6 GW of coal power plants (including 23 plants older than 20 years) somewhat conflicts with MEMR Regulation No. 7/2020, which provides incentives for the coal industry, including for increasing domestic consumption (IISD, 2020a).

2.3 INSTITUTIONAL STRUCTURE

Key institutions

The Indonesian energy sector is governed by MEMR, under which oil and gas, minerals and coal, electricity, and new and renewable energy and energy conservation are under individual directorates. MEMR has the primary responsibility within the public sector for making policies and decisions concerning Indonesia's energy and mining assets, including implementation of technical programmes and projects. Both the RUEN and RUKN are prepared by MEMR through the National Energy Council (*Dewan Energi Nasional*, DEN). MEMR regulates the power sector via the Directorate General of Electricity and the Directorate General of New and Renewable Energy and Energy Conservation. MEMR also approves the RUPTL for the PLN. Collection and publication of national energy data is under the responsibility of MEMR.

In preparation of the National Energy Policy (*Kebijakan Energi Nasional*, KEN), the DEN assembles seven ministries and energy sector stakeholders. In addition, DEN approves the RUEN and establishes the framework for dealing with crisis conditions and energy emergencies. The Ministry for Maritime and Investment Affairs acts as the co-ordinating body for energy across ministries.

Another relevant ministry in energy matters is BAPPENAS (Ministry of National Development Planning). It also prepares Indonesia's RPJMN, the plan that guides government programmes and budgeting, and manages national development activities relating to energy supply and demand. A further role of the BAPPENAS is the co-ordination, monitoring and evaluation of the national action plan on greenhouse gas emission reductions. The Ministry of Finance determines and administers the budget allocation for MEMR's state expenditure, including energy subsidy allocation, government guarantees and tax regimes for energy products, infrastructure and operations. It also approves government guarantees for PLN's obligations, for instance regarding PPAs. The Ministry of Public Works and Public Housing regulates water use rights, including water use taxes that are part of the operating costs absorbed by hydropower plants. The Ministry of Environment and Forestry approves access to forest land for geothermal projects, hydropower projects, and transmission and distribution lines. Additionally, this ministry establishes and enforces environmental standards and regulations for resource extraction and energy production. The Ministry of State-Owned Enterprises is responsible for the governance of state-owned enterprises, for instance PLN, for which it sets and reviews performance targets and the annual budget (ADB, 2020).

Structure of the power sector

Electricity Law No. 30, in force since 2009, governs Indonesia's power sector (GoI, 2009). According to this law, PLN remains a vertically integrated company and controls the national transmission network. Thus, PLN is responsible for the generation, transmission, distribution and supply of electricity. Although PLN can receive electricity from IPPs through a PPA regulated by MEMR Regulation No. 10/2017 (later amended by MEMR Regulations No. 49/2017 and No. 10/2018), it has the sole responsibility for supplying consumers, either itself or through its subsidiaries, for instance the Java-Bali Generation Company (GoI, 2017a, 2018).

In recent years private-sector participation has been increasing. This is possible in areas that are not governed by PLN. Increasing private-sector participation in Indonesia's energy system is seen as a crucial way to create economies of scale and bring private investment, which are both important for reducing the costs of renewable energy. Private companies accounted for more than 35% of the financing for Indonesia's power sector projects between 2016 and 2019 (IEA, 2020b). While the private sector is involved on the generation side, it can also contribute to some extent to transmission and distribution. IPPs and PPUs generated 27% of all electricity in 2019, up from 25% in 2014. Efforts are also underway to promote private-sector participation through public–private partnership mechanisms (ADB, 2020).

Private-sector participation is allowed through IPP or PPU arrangements. IPP appointments are typically granted through competitive tenders. There are also certain circumstances under Government Regulation No. 14/2012 on Electricity Business Provision (amended by Government Regulation No. 23/2014) where IPPs can be directly selected or appointed. A similar situation applies to public–private partnerships under Presidential Regulation No. 38/2015 and its implementing National Public Procurement Agency (*Lembaga Kebijakan Pengadaan Barang dan Jasa Pemerintah*, LKPP) Regulation No. 19/2015 (PWC, 2018). PLN is the counterpart of any PPA with the IPPs.

Investors who generate electricity for own use are known as PPUs. PPUs with a capacity greater than 200 kilovolt amperes (kVA) must hold an operating licence. This is required to generate, transmit and distribute electricity for their own use or to their own customer base. PPUs with a capacity of 25-200 kVA must obtain approval from the relevant minister, governor or mayor. PPUs with a capacity lower than 25 kVA are only required to report to the relevant minister, governor or mayor. The PPU may sell excess capacity to PLN or directly to end customers subject to the approval of the relevant minister, governor or mayor. In cases where PPUs are producing power for their own use and selling directly to other users, PPUs additionally need an operating area (*Wilayah Usaha*) permit and an electricity supply business licence (*Izin Usaha Penyediaan Tenaga Listrik*, IUPTL) in addition to the operating licence (PWC, 2018).

PLN is required to purchase electricity produced from renewable energy generators, provided that the electricity generated does not disturb PLN's demand–supply balance, a feasibility and connectivity study is verified by the PLN, financing for the project is available and the pricing of the electricity is consistent with MEMR Regulation No. 50/2017 (this was later amended by MEMR Regulation No. 4/2020) (GoI, 2020a).

In November 2020 the government passed the Omnibus Law that amends parts of the Electricity Law, notably those that relate to licensing of actors in the power sector (GoI, 2020b). As a result, IUPTL, the operating licence and the electricity support services business licence (*Izin Usaha Jasa Penunjang Tenaga Listrik*, IUJPTL) have been replaced with a business licence (Perizinan Berusaha) issued by the central or regional government. Licensing is governed by two new regulations that were released in 2021, namely the Government Regulation No. 5/2021 on Administration of Risk-Based Business Licensing and Government Regulation No. 25/2021 on Administration of Power and Mineral Resources Sectors. All IUPTL, operating and IUJPTL licences that were issued before the Omnibus Law remain valid until they expire.

Another important aspect of the Omnibus Law concerns the reintroduction of the requirement to unbundle PLN's services which reverses the Constitutional Court decision issued as Court Decision No. 111/PUU-XIII/2015, which decreed that no unbundling of electricity services could occur if the state would have less control over the electricity sector as a result (Thomson Reuters, 2022).

Grid connection of electricity generators that hold an IUPTL requires that a proposal is submitted to PLN that includes an electricity supply business plan (*e.g.* PPA). Additionally, the generators must meet safety standards. Electricity transmission is considered a high-risk business and is subject to fulfilling administrative and technical requirements as well as the acquisition of an IUPTL (either for transmission only or together with generation). Similarly, an IUPTL is also needed to construct and operate distribution grids; either it is used only for distribution, or its scope can cover generation and transmission. Charges for the transmission and distribution of electricity are determined by the government either through the ministry or the governor, and charges are location-dependent.

2.4 STRATEGIC FRAMEWORK

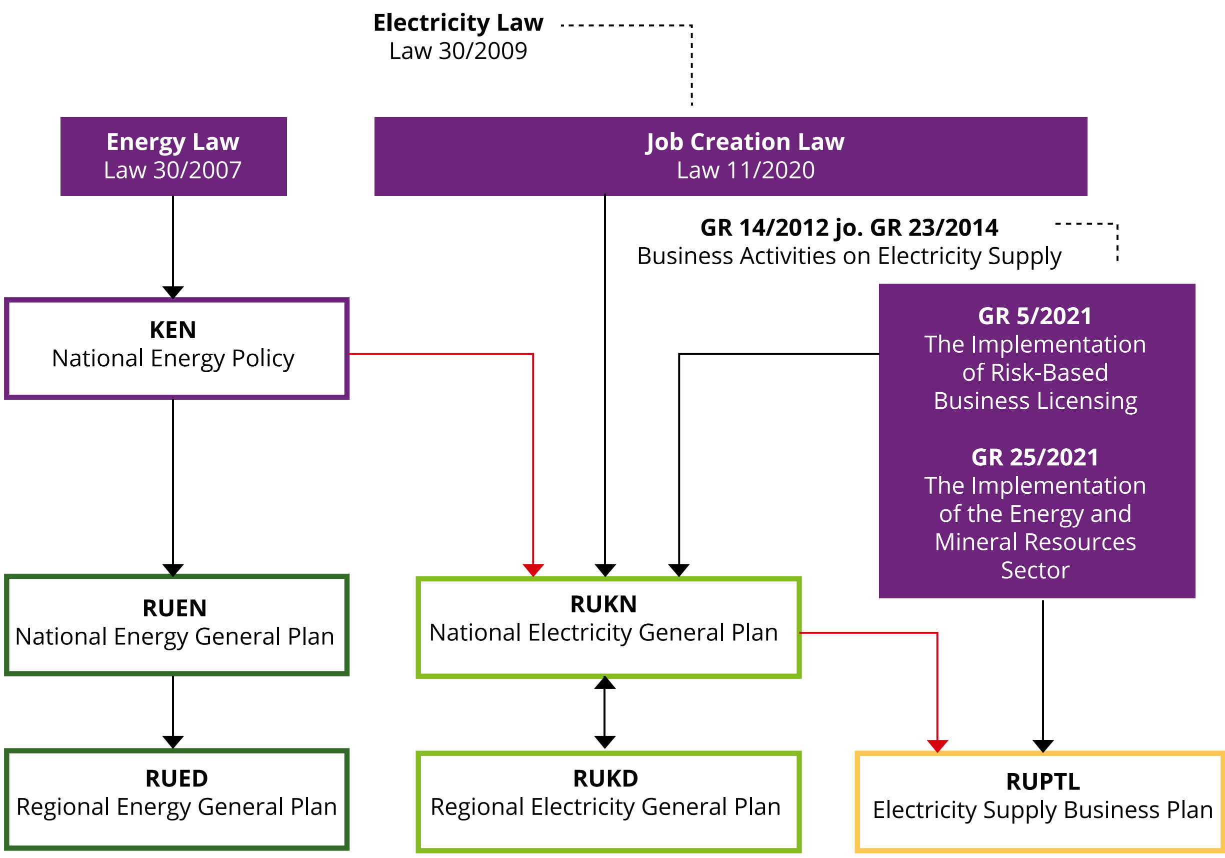
Indonesia's broad development goals are outlined in its long-term national development plan for 2005-2025 (BAPPENAS, 2005). This plan is divided into four five-year phases. Indonesia's priority is ensuring energy security by reducing import dependency and increasing the production of alternative local energy sources, notably renewables.

The government is mandated to establish the KEN and RUEN according to Energy Law No. 30 of 2007 (GoI, 2014). Long-term goals for the energy sector are outlined in the KEN, to be implemented in the RUEN, which emphasises resource diversification, environmental sustainability and maximised use of domestic resources. The policy sets a minimum 23% share of renewable energy in the energy mix by 2025 and a minimum share of 31% by 2050. An electrification goal of 100% was set to be realised by 2020 (shifted to 2022) where the actual rate reached was 99.2% by the end of that year, enabled by rooftop solar PV lamps, Indonesia's rural electrification programme and several other national fast-track programmes for power infrastructure (see Box 4).

Long-term goals for the electricity sub-sector are in the government's RUKN, with specific investment plans outlined in PLN's rolling RUPTL, updated annually and detailing the long-term plans for generation, distribution and transmission growth. In many cases the document includes specific projects, especially for generation projects above 10 MW and transmission projects. Distribution planning and generation projects below 10 MW are generally done by regional PLN offices and fall fully under their authority. While the plan is detailed and includes specific figures for geothermal and hydropower capacity by location, it does not provide this level of detail for the other renewable energy technologies (IRENA, 2017). Regional energy and electricity plans are prepared according to the RUEN and RUKN.

Electricity sector planning in Indonesia is governed by key energy plans

Figure 18 Electricity sector planning in Indonesia



Source: (IESR, 2021a).

RUPTL 2021-2030 aims for total installed capacity of 99.2 GW, of which about 29 GW should be renewable energy (PLN, 2021a). It also aims to maintain a power balance for each electric power system to ensure adequate supply of electricity, and states that new and renewable energy plants should constitute 51.6% of the total new capacity of 40.6 GW, although the current share of renewable energy is far behind the target levels for 2025. The target for renewable energy capacity by 2025 differs under RUKN 2018-2038, at 28 GW (out of 118 GW total installed capacity).[5] The RUEN 2015-2050 target is for a total of 45 GW. The diesel power plant to renewable energy programme aims to reduce the diesel fuel share in the total primary energy mix to 2.91% by 2020. A total of 3 712 MW of diesel plants, 5,200 units, would be replaced under this target.

[5] *The RUPTL renewable energy target includes 1310 MW of capacity to be introduced from PLT EBT Peaker and Base plants, which are assumed as new and renewable energy. However, it is not entirely clear how these are defined as such. "New" resources are not necessarily renewable (e.g. nuclear) and may include new technologies such as battery energy storage.*

With Indonesia's announced target to reach net zero emissions by 2060 or sooner with international assistance, it has also prepared a Long-Term Strategy for Low Carbon and Climate Resilience 2050 as part of its NDC submission (GoI, 2021a). Additionally, Indonesia passed a law in October 2021 to introduce a USD 2.10 carbon tax (IDR 30 000) per tonne of CO_2-equivalent for coal-fired power plants. The carbon tax was planned for introduction in April 2022, but its implementation is currently delayed and planned to be operational by the time the G20 Summit takes place, which will be hosted by Indonesia in November 2022 (Argus Media, 2022). Indonesia ran a voluntary emissions trading trial in the power sector from March to August 2021. The results of the pilot will be used to inform a mandatory emissions trading system. In May 2021 PLN announced its pledge for carbon neutrality by 2060, where it now plans to stop building new fossil fuel-fired capacity once the 35 GW and the 7 GW fast-track programmes are finalised at the latest by 2024 (includes 16 GW coal-fired power plant capacity to come online between 2021 and 2030). The aim is to utilise mainly renewable energy sources to meet more than 1 500 TWh by 2060 to meet Indonesia's growing electricity needs. The plan includes the retirement of conventional power plants from 2030, with ultra-supercritical plants to be retired by 2056 (IEEFA, 2021). This is a major change in view on Indonesia's relatively young coal fleet, with its average age of less than 10 years, and where coal represents a majority of Indonesia's on-grid power generation at about 59%, or 175 TWh per year. Indonesia has implemented a coal moratorium for new plants starting in 2022 and is planning for a massive increase in low-carbon power generation to 2060. In total, this transition away from coal will require an enormous USD 1.165 trillion (Jakarta Post, 2021). The transition away from coal is also reflected in RUPTL 2021-2030, where no new coal power plant additions are planned except for those that have achieved financial close or begun construction. This transition will require financial and technical support.

Box 4 Indonesia's climate policies and net-zero target

More than half of all Indonesia's greenhouse gas (GHG) emissions are related to land use, land use change and forestry (LULUCF) (including peat fires). By comparison, the energy sector's share is around one-third of the total GHG emissions (Climate Action Tracker, 2022).

Indonesia's energy sector in 2020 is responsible for 581 $MtCO_2$ emissions, with 37% of that from industry. Transport and power each contribute another 27%. The carbon intensity of the energy sector had reached 51.6 tonnes of CO_2 per terajoule of primary energy by the end of 2019. This is lower than the G20 average of about 60 tonnes of CO_2 per terajoule. The emissions intensity of the power sector is much higher than the G20 by comparison: 804 grams of CO_2 per kWh compared to 449 grams CO_2 per kWh (Climate Transparency, 2020).

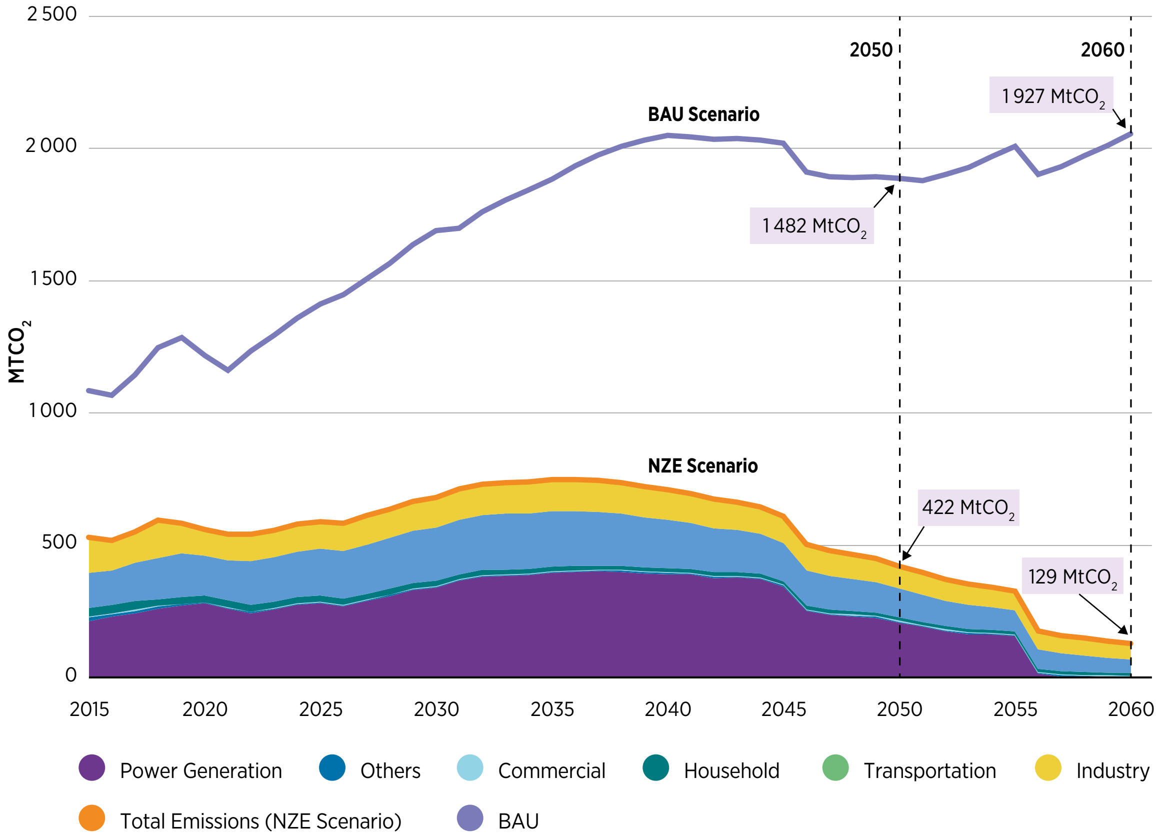
Indonesia's nationally determined contribution (NDC) was submitted in in 2016, where under the Paris Climate Agreement, the country has pledged to reduce its carbon emissions by between 29% (unconditional) and 41% (conditional) by 2030. It's most recent submission called the Enhanced NDC, released in September 2022, further increases its ambition with a reduction target of 31.89% (unconditional) and 43.2% (conditional) by 2030 to align with its Long-Term Low Carbon and Climate Resilience Strategy (LTS-LCCR) 2050 with a target to achieve net-zero emission by 2060 or sooner (GoI, 2022).

Indonesia, led by MEMR, is developing a Net Zero Emission Roadmap for the Energy Sector with a target of 422 $MtCO_2eq$ by 2050, and 129 $MtCO_2eq$ of total energy sector emissions by 2060, focusing on intensifying renewable energy electrification in end-use sectors. In the Net Zero Emissions scenario, energy sector emissions are projected to peak in 2030 at 680 $MtCO_2eq$. The roadmap envisions a zero-emission in the power sector by 2060, while the remaining emissions are from end-used sectors, namely industry and transport.

Box 4 Indonesia's climate policies and net-zero target (continued)

There is a significant reduction between BAU and the net-zero pathway

Figure 19 Total energy sector emissions projection under the Net-Zero Emission Roadmap for the Energy Sector



Source: Presentation by MEMR, January 2022.

2.5 LEGAL, REGULATORY AND POLICY FRAMEWORK

MEMR Regulation No. 50/2017 regulates PLN's purchase of electricity from various renewable energy technologies under the business-to-business scheme (GoI, 2017b). Additionally, in 2019 and early 2020 the government issued the following regulations in the energy sector (IISD, 2020b).

- Government Regulation No. 78/2019, concerning income tax facilities for capital investment in certain business sectors or certain regions, including geothermal energy.
- MEMR Regulation No. 49/2018, setting out the procedure for the use of rooftop solar PV systems by PLN customers, amended by MEMR Regulation No. 26/2021 to set the buyback price at one to one (GoI, 2021b).
- MEMR Regulation No. 4/2020, which sets out the general governance of the use of renewable energy for the public supply of electricity (GoI, 2020a)

In this section, the renewable energy regulatory framework is explained.

Competitive auctions

The first auction for solar PV took place in 2013 where the programme covered a total capacity of 140 MW over 80 projects in 11 locations (Heffron *et al.*, 2021). In 2015 the Indonesian Supreme Court issued a decision requiring MEMR to revoke a previous auction regulation for solar PV, based on a case by the Indonesian Solar Module Association. Following this, seven tenders were conducted for the purchase of solar power and contracts totalling 15 MW were awarded in the provinces of East Nusa Tenggara (five locations), Gorantalo (one location) and South Kalimantan (one location). The bids were won with tariffs ranging from USD 0.18/kWh to USD 0.25/kWh. By the end of 2016 only two of the seven awarded projects were installed, with a total capacity of 8 MW. As of 2021 only five projects had reached commercial operation (MEMR, 2019). The limited success was for several reasons, including strict local content requirement, limited ability for international companies to participate, limited time provided for developers to comply with stringent auction requirements, and the requirement for the use of local currency. Additionally, due to the overcapacity on the Java-Bali grid from thermal power plants built in previous years, the ability to integrate additional solar PV capacity onto the grid is perceived to be limited.

In May 2017 as the first implementation of MEMR Regulation No. 12/2017, a second auction took place where 116 bids competed to contract 168 MW solar power in the Sumatra region (IRENA, 2019). This auction round was not a full bidding process unlike that in 2013; instead, it followed the direct selection principle (see next section). However, implementation was later cancelled as the grid was deemed insufficient. In August 2017 six eastern Indonesia solar PPAs were signed (104 MW in total) and these plants are operating commercially (IESR, 2021a). Subsequently, in Bali another auction took place for 50 MW of solar PV capacity, with favourable bids selected and now under negotiation. In this case, the auction was implemented first and the feasibility study came later, the reverse order than is typical in auctions.

According to the latest draft of RUPTL 2021-2030, six new solar PV auctions are planned in Indonesia between 2021 and 2023 for a total capacity of 320 MW. Of this, 165 MW capacity is to be ground-mounded solar PV capacity to be developed by IPPs in Java and West Nusa Tenggara. The remainder is capacity with battery storage spread across 200 locations to replace diesel generators without a target completion date (IESR, 2021a).

Feed-in tariff

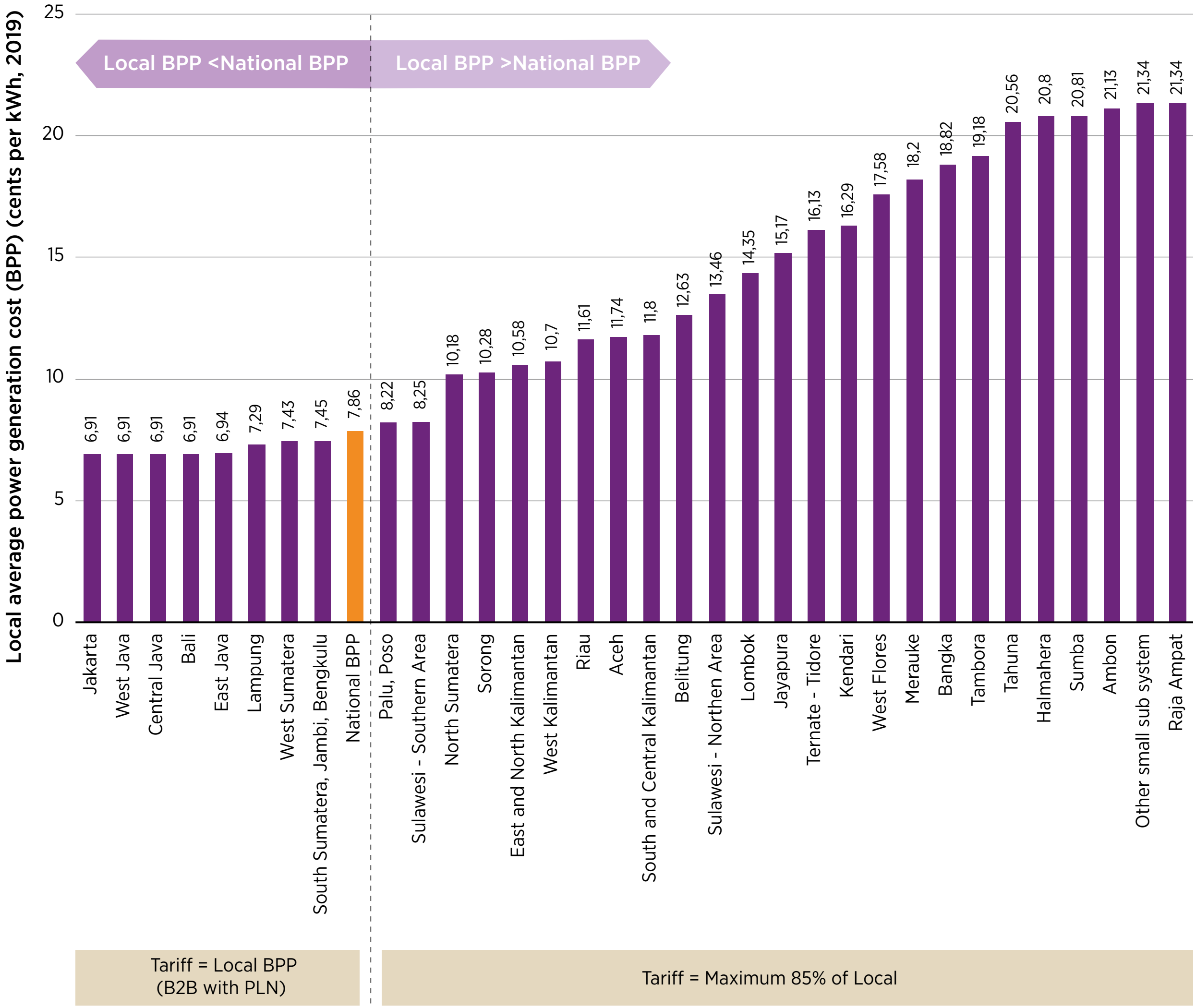
The feed-in tariff (FiT) in Indonesia was introduced in 2016, and in 2017 the tariff was redesigned. The electricity tariff for renewable energy projects follows the general pricing guidelines under MEMR Regulation No. 4/2020 (GoI, 2020a). Projects are benchmarked against PLN's average electricity generation cost for the preceding year in the area where that project is to be located. Grid-connected projects benefit from procurement guarantees set at a maximum of 85% or 100% of the prevailing electricity tariff set by the PLN in the same region. In Indonesia, tariffs for renewables are based on the region (PLN Wilayah) and reflect the current cost of production of electricity in the given Wilayah, referred to as Biaya Pokok Produksi (BPP). BPP represents the cost to PLN of obtaining power from the various systems and sub-systems listed in the applicable BPP, both from its own power generation plants and from third-party suppliers such as IPPs and power rental companies. In principle, through this mechanism, renewable energy competes with various coal-fired power plants that use cheap local coal.

Typically, the agreements underpinning the financing of these assets' generation sources are rather inflexible and structured in such a way that the system operator has little incentive to move to new generation sources because they are already effectively committed to paying for the cost of the existing sources regardless of the quantity of power produced. More specifically, contract structures are a potential limitation on the renewable energy transition in the power sector given the wide-spread use of PPAs and fuel supply contracts with very restrictive "take or pay" obligations. Many of these have the effect of locking in generation for CO_2-intensive generation sources such as coal and offer little incentive for them to vary output to allow for the integration of variable renewable power or provide other ancillary services that would be required.

RUPTL 2021-2030 aims to limit the impacts of BPP by prioritising the cheapest new and renewable energy generators (least cost), while encouraging the uptake of more low-cost solar PV plants and co-firing. Additionally, geothermal and hydropower plants are granted a more realistic delivery schedule (Ruang Energi, 2021). In total, 19 GW coal-fired power plants would be converted to co-firing with biomass. If all coal power plants were to commercially convert to co-firing with biomass, this would translate into a total of 2.7 GW renewable energy capacity, which would require 14 million tonnes of biomass each year. Already several pilot projects have been conducted in more than 20 power plants using various biomass sources, such as wood pellet, wood chip, palm kernel shell, saw dust and rice husk.

Electricity feed-in tariffs vary across Indonesia

Figure 20 Electricity FiTs capped per region, 2018



Source: (MEMR and Indonesia, 2019).

Under applicable regulations, MEMR is required to publish the BPP annually. The national average BPP increased to USD 0.0766/kWh or IDR 1 025/kwh in 2017, approximately a 4% increase compared to the previous year, caused by the increase in the primary energy price for coal, gas, and oil-based fuel between 2016 and 2017, as well as the weakening exchange rate of the IDR to the USD (Glendale Partners, 2019). The national average generating BPP for the 2020 period was USD 0.0705/kWh (MEMR, 2021b).

Since late 2019 the government has been working on a presidential regulation on renewable energy tariffs, including solar energy. FiTs are to be used for small utility-scale solar (≤ 5 MW) and ceiling price-based competitive bidding is designated for medium to large utility-scale solar (> 5 MW) (IESR, 2021b). The new presidential regulation that was planned for release in 2021 is expected to provide further insights into the FiT mechanism, where a higher FiT for renewable projects below 20 MW would be set and competitive auctions for larger solar PV, wind, hydropower, biomass and biogas projects would be in place (IEA, 2020b).

Presidential Regulation on the Acceleration of Renewable Energy Development for Electricity Provision

In September 2022, President Joko Widodo officially issued the long-awaited regulation on the "Acceleration of Renewable Energy Development for Electricity Supply", known as regulation 112/2022. The regulation sets out the provisions to push the establishment of large-scale renewable energy plants by both the state electricity company (PT. PLN) and the private sector. It prohibits construction of new coal-fired power plants, with the exception for national strategic projects, and provides fiscal and non-fiscal incentives to encourage investment in new and renewable energy projects. Prior to the regulation, many renewable energy project developers in Indonesia needed clarity on the renewable electricity purchase tariff to develop their projects.

The new regulation has set a renewable electricity ceiling tariff based on the renewable sources and where they are located. The renewable electricity tariff will be negotiated between the IPP and PLN and cannot be more than the listed ceiling tariff in the annex of the presidential regulation, multiplied by different location factor based on where the power plant is built. This electricity tariff is then considered as the base tariff, and not subject to escalation during the electricity purchase agreement (*Perjanjian Jual Beli Listrik* – PJBL) period, except for geothermal power plants. Although it looks similar to the electricity generation basic cost scheme (*Biaya Pokok Penyediaan* – BPP), the difference is that the new scheme does not benchmark the electricity generation tariff to the non-renewable BPP. The minister will evaluate the stated ceiling prices on the annual basis, and changes in the prices will be regulated under the ministerial decree. In addition, the electricity transmission tariff and the battery storage charge are also regulated and capped at 30% and 60% of the base purchasing tariff respectively. The exception to these caps is subjected to the Minister's approval. Peaking hydro power, tidal and biofuel power plants may also have exemptions from following the ceiling tariff.

PLN is allowed a more streamlined renewable energy electricity purchase through direct appointment and direct selection. Government constructed dam/water reservoirs or multipurpose irrigation channels, geothermal power plants, capacity expansion of various renewable sources, as well as the excess power from geothermal, hydro, biomass and biogas are within the category of direct appointment process. Direct appointment electricity purchase is conducted within 90 days. The base tariff is negotiated but must not exceed the ceiling tariff. PLN may conduct direct selection process for hydropower peaker plants, solar PV, wind, biomass, biogas, tidal and biofuel power plants based on capacity quota stipulated by minister and processed within 180 days.

The presidential regulation mandates a broad non-fiscal support from central and/or regional government in accordance with their authorities to facilitate renewable development in the country. Various fiscal incentives can be considered ranging from changes to income tax, import duties, land and building tax, as well as support for geothermal development and financing facilities and guarantees through appointed state-owned enterprises. Specifically for geothermal power plants, the new regulation also has provisions that incentivize private investment *i.e.*, assignment of additional geothermal data and information, assignment of preliminary and exploratory surveys, risk bearing, and financing facilities

Regarding the planned retirement of coal power plants, the Presidential Regulation officially bans the development of new coal power plants with several exceptions such as if the coal power plants are included in the RUPTL, for industry integrated national strategic projects, power plants that are committed to reduce their greenhouse gas emission by minimum 35% in 10 years after operating. It also mandates the minister to develop an early coal power plant retirement roadmap. The government of Indonesia can offer fiscal support in the form of blended finance from the national budget or other sources to an IPP for accelerating coal power plant early retirement. The implementing regulation on this financial support is mandated to ministry of finance.

Direct appointment and direct selection

Besides the competitive auctions and tenders, renewable power is procured in two other ways: direct appointment and direct selection following the RUPTL capacity plan. The direct appointment process involves the appointment of a specific IPP, whereas direct selection involves the selection of more than one potential IPP.

Direct appointment can be a public tender, which is the easiest method since an IPP is directly appointed by PLN without reviewing or competitively selecting other projects. With this method, unsolicited proposals (which must be listed in the next RUPTL) are collected as a first step after being accepted, before proceeding to PLN's assessment (review, approve and list approved proposals in the RUPTL). According to MEMR Regulation No. 04/2020, all renewables can be procured through direct appointment under specific conditions such as if there is only one bidding IPP. Additionally, the regulation has simplified procurement procedures under direct appointment. However, IPPs that submit unsolicited project proposals under direct appointment have sometimes faced challenges in getting their projects listed in the RUPTL.

Under direct selection, PLN invites tenders from a limited number of eligible investors based on capacity quotas as defined in the RUPTL. PLN can invite eligible developers to bid for projects, while any others not invited are specifically excluded. To be eligible, investors participate in a prequalification process against a set of predefined criteria. PLN conducts due diligence following MEMR Regulation No. 10/2017 on the technical and financial capabilities of the IPPs. IPPs that sign PPAs through the direct selection process have not always reached financial closure, though this can be due to low quality of feasibility study documents. The prequalification processes have been conducted on an irregular basis over the years and their criteria have varied from year to year. Despite prequalification rounds, projects were not subsequently procured in the case of hydropower in 2018. In 2017 around 27 clean energy PPAs did not reach financial closure, partly due to the winning IPPs lacking creditworthiness or the capacity to develop credible feasibility studies.

Since 2020 the procurement process has become clearer for renewable energy projects: a direct selection process must be concluded within 180 days, whereas a direct appointment process must be concluded within 90 days (IISD, 2020b). As an example of these mechanisms, the local utility PT Indonesia Power invited several bidders to tender in 2020 for two floating solar PV projects with a capacity of 60 MW and 90 MW, respectively. The final prices came in at USD 0.0374/kWh and USD 0.0368/kWh, respectively.

New renewable energy markets

In 2019 and early 2020 the government issued the following regulations in the energy sector:

- Government Regulation No. 78/2019, concerning income tax facilities for capital investment in certain business sectors or certain regions, including geothermal energy.
- MEMR Regulation No. 13/2019 and MEMR Regulation No. 16/2019, amending MEMR Regulation No. 49/2018, setting out the procedure for the use of rooftop solar panel power systems by PLN customers.
- MEMR Regulation No. 4/2020, which sets out the general governance on the use of renewable energy for the public supply of electricity.

MEMR Regulation No. 4/2020 includes changes such as removing the requirement for project developers to operate on a build, own, operate and transfer (BOOT) basis. The BOOT basis has caused difficulties because of land ownership and ability to obtain financing. The new regulation allows projects (including those that are under development) to follow a build, own and operate (BOO) basis where a PPA is signed with PLN so that at the end of the project the plant does not need to be transferred to PLN.[6] The decree also requires PLN to take renewable generation on a "must-run" basis. This can be seen as a positive development, since may IPPs now own all project assets and do not have to transfer their project to PLN at the end of the term, helping the bankability concern surrounding most renewable energy projects.

Currently, consumers cannot sign PPAs directly with IPPs. This needs to be done through PLN. Given that there are many emerging business entities who are looking for renewable energy sources to meet their emission reductions, corporate sourcing of renewables is expected to become an important business model in Indonesia. For this, the power wheeling scheme (MEMR Regulation No. 01/2015), rooftop solar PV (MEMR Regulation No. 49/2018) and the renewable energy certificate and premium tariff (to be implemented) are available (EBTKE, 2020). There are already around 70 companies in Indonesia that have pledged to commit to renewable energy under initiatives like the global RE100 campaign. The power wheeling scheme, net metering scheme for rooftop solar PV systems and the renewable energy certificate have been available since the end of 2020, with the premium tariff to be implemented once the regulation has not been enacted. Access to both distribution and transmission with reasonable tariffs will be crucial in integrating meaningful shares of renewables by facilitating their transit to load centres; this extends far beyond rooftop PV in creating bankable projects. This is a major barrier to the deployment of a corporate sourcing mechanism. In addition, the rules for corporate sourcing need to be set clearly to ensure the renewable energy generated and sold is certified. In the current PLN structure, it is not entirely clear whether IPPs can have their energy certified. Additionally, green certificates are not yet recognised internationally. These would be prerequisites for the new system to attract investment in renewable energy development.

Another growing renewable energy segment in Indonesia is distributed renewable energy systems. To achieve the government's commitment to a 23% share of renewable energy in the energy mix, MEMR encourages domestic households to adopt rooftop solar PV power systems – where up to 3.6 GW of solar PV rooftop is targeted by 2025 (MEMR, 2022). Another method of promoting distributed renewable energy systems can be to encourage corporate sourcing of renewables. Corporations can procure renewable energy through third parties via long-term PPAs, or they can themselves develop on-site or off-site generation facilities to meet all or part of their electricity load. Additionally, corporations can locate facilities in regions with ample renewable energy supply, and take advantage of low-cost, local renewables. IRENA's report *Corporate Sourcing of Renewables: Markets and Industry Trends* provides more detail on this important and growing approach to supporting renewable deployment (IRENA, 2018).

In January 2022 a total of 51.20 MW of solar PV capacity was installed on almost 5 000 users' rooftops, including 48 industrial customers with total of 17 Megawatt peak (MWp), according to MEMR. This compares with 16.16 MW at the end of 2019. Almost two-thirds of the currently installed capacity is with PLN customers from different sectors. Several projects at industrial plants in 2020 included Coca-Cola Amatil's Cikarang plant (7.13 MW), Danone-AQUA's Klaten plant (2.91 MW), Softex (0.63 MW) and Fonterra (0.38 MW). Solar capacity installed on residential buildings had reached 34.2 MW by the end of January 2022.

PLN customers that are interested in investing in such systems follow these procedures (set out under MEMR Regulation No. 49/2018): 1) make an application for the installation of a solar panel system to the general manager of PLN, with copies to the Directorate General of Electricity and the Directorate General of New

[6] *Aside from the PPA, the key project documents in renewable energy projects typically include: engineering, procurement and construction (EPC) contracts; operation and maintenance (O&M) contracts; service agreements; government support agreements (if provided); sponsors' agreements; bank guarantees; and performance guarantees. The financing documents include: facility agreements; sponsor support agreements; inter-creditor agreements; direct agreements; hedging agreements; and security documents.*

and Renewable Energy; 2) PLN then assesses the application; and 3) after approval is granted by PLN, the customer may commence installation of the solar panel system. Rooftop solar PV systems are installed by certified companies that fulfil the technical requirements set out by MEMR and which have obtained: 1) a business certificate from the Business Entity Certification Agency, and 2) an IUJPTL from the Directorate General of Electricity of MEMR (GoI, 2018).

MEMR Regulation No. 49/2018 is based on a net metering scheme and the self-procurement of electricity. Exported electricity was offset by electricity imported from PLN and the exported electricity was valued at 65% of remuneration until August 2021. If exports are higher, the excess can be banked and deducted from the customer's electricity bill for the following month. The balance was accumulated for up to three months, after which it expired. This has now changed with the introduction of MEMR Regulation No. 26/2021 (IEEFA, 2019). The offset is carried out on a one-to-one basis, with any surplus power sold back to PLN. Additionally, the balance is calculated on time limits of six months, namely from January to June and from July to December. The period for receiving an approval for construction has been reduced from 15 working days to 5. Additionally, holders of an IUPTLU can trade carbon credits obtained from rooftop solar PV systems. However, despite these improvements, it still has some limitations of the business models which can be deployed such as the size of the installations to the applicable grid connection of the relevant customers and prohibition on the sale of electricity from rooftop solar systems that limit the structures and potential business models. The choice of solar PV equipment is also subject to the local content requirement under the Electricity Law, which requires IPPs to select locally produced equipment with a minimum share, or otherwise face administrative and financial sanctions. Local content has been one of the barriers to solar PV deployment (IEEFA, 2019).

Recent progress was made by the Indonesian government to support solar energy with new policies for rooftop solar systems and by allowing reservoir surfaces to be used for floating solar energy systems. To accelerate the growth of rooftop solar PV systems on commercial and industrial buildings, MEMR revised two regulations in 2019 with the aim of simplifying procedures and reducing additional costs. The first (MEMR Regulation No. 13/2019) simplifies the permitting procedures for all systems with a capacity less than 500 kilowatts (kW). The second (MEMR Regulation No. 16/2019) reduces by a factor of eight the system charge for industrial customers, increasing the bill savings from solar PV and hence making these investments more attractive (Darghouth *et al.*, 2020). Local governments are also pushing the deployment of solar PV capacity. Jakarta's Governor Instruction No. 66/2019 mandates the use of rooftop solar PV on public buildings. Bali's Governor Regulation No. 45/2019 on Clean Energy and Central Java's Solar Revolution initiative promote the use of solar PV in their provinces (IESR, 2020).

PLN's distribution system is an important bottleneck, meaning it is unlikely to be able to accommodate large amounts of distributed solar PV power without additional investment. This could pose challenges for rooftop PV systems, as connecting to the transmission substation is unusual at present and might come with significant additional cost.

Box 5 Renewable power for modern electricity access

Reaching 100% electrification among the population is a key goal for the government, due to be reached by the end of 2022 (PLN, 2021a). There are around 600 grids in Indonesia, most of which are operated by the PLN. Smaller grids are fuelled by diesel but some others, often larger, are fuelled by coal. A study estimates that the country has around 900 isolated grids. By mid 2022, countrywide electrification rate had reached 99.56%, where regions in the eastern part of Indonesia, namely Papua, Maluku, Sultra and East Nusa Tenggara are still left to be fully electrified.

Box 5 Renewable power for modern electricity access (continued)

Electrifying the remaining households could be rather more expensive as most are in remote locations. In addition, these populations are typically too poor to afford the connection. Difficulties in acquiring upfront capital has constrained the public sector. There have been frameworks introduced to reduce the financial burden on PLN. Additionally, non-governmental players could provide an important opportunity for economies of scale and other lower-cost alternatives. Solar PV and storage-based mini-grid projects are being explored for full electrification (ADB, 2020).

One study investigating different renewable energy options in the remote grids of Indonesia shows a significant economic benefit from using palm oil effluent biogas. In Lamandau District it could reduce electricity generation costs from USD 0.031 with diesel generators to USD 0.011/kWh. In Sabu Island, solar PV with battery storage is also cheaper than diesel, but the reductions are smaller (USD 0.038 versus USD 0.035/kWh) (Reber *et al.*, 2016). Another study for East Nusa Tenggara shows a business case for hybrid systems that consist of 95 kW solar PV, 78 kW wind turbine and 200 kW diesel generator, equipped with battery storage that can provide productivity to a cocoa processing plant with increased income for farmers (Salsabila *et al.*, 2019).

Several hundred solar PV- and micro-hydro-based micro-grids have been installed in Indonesia in recent years. This has been the result of several programmes, including innovative uses of public–private partnerships, which have been supported by international organisations, foreign governments and various Indonesian ministries and agencies. This has led to an active market for micro-hydro where communities, local private fabricators and equipment suppliers have formed an ecosystem for sustaining a market. Some systems experienced failures within a short time of commissioning. Despite efforts by the German Agency for International Cooperation to train many of the villages in the basic operation and maintenance of the systems, there is still a lack of capacity in being able to troubleshoot and fix more complicated failures (IRENA, 2017).

2.6 ENERGY TARIFFS

Electricity tariffs are regulated by the government. Until the end of 2019 household tariffs were the lowest while commercial tariffs were the highest. Industry tariffs ranged between these two. PLN's operating revenues depend directly on electricity tariffs. Household tariffs are set below cost and PLN's revenues are insufficient for full cost recovery. This deficit is covered by the government's payments from the national budget. The payment covers all PLN's costs and an additional margin of 7% (ADB, 2020). 2019 tariffs covered around 86% of production costs, and government subsidised in total USD 4 billion to fill the gap. This provides little incentive for PLN to increase its operational efficiency. To make the power sector financially viable, a shift from a cost-plus system to a performance-based system could increase efficiency. In addition, a transparent and predictable plan and fair remuneration for PLN's investments are also important (McKinsey, 2020).

Electricity tariffs include all costs relating to the use of electricity, comprising load cost (IDR/kVA) and usage cost (IDR/kWh). The load element is charged as a subscription (IDR/month) according to the limit of the power used in kVA, or volt amperes (VA) for smaller customers. Under the latest promulgated subsidy regulation, subsidised electricity rates are applied to customers whose electricity bill is lower than the average. These are mostly within the 0-450 VA or 451-900 VA ranges, and are charged IDR 169/kWh and IDR 274/kWh, respectively (World Bank, 2020).

Indonesia's non-subsidised electricity tariff is separated into 13 categories, which are adjusted every three months. These tariffs include five categories for residential, ranging from 900 VA to 6 600 VA and above, two for commercial, above 6 600VA and above 200 kVA, two for industry, above 200 kVA and above 30 000 kVA, three for government buildings and one for special services (PLN, 2022).

3 RENEWABLE ENERGY DEVELOPMENT

3.1 DRIVERS OF RENEWABLE ENERGY DEPLOYMENT

Diversifying the resource base to supply increasing energy demand and maintain energy security is emerging as a priority area for Indonesia. Over the past decade, the country's total primary energy supply has increased on average by 3.5% annually and the energy mix predominantly relies on fossil fuels. Traditionally a producer and net exporter of fossil fuels, Indonesia's trade balance is changing towards the country becoming more dependent on fossil fuel imports. Indonesia's energy strategy so far prioritised local coal use to supply its growing energy demand, but the new electricity sector plans put significantly more emphasis on renewable energy for the coming decade and a transition away from coal in the longer term.

Although the energy sector's structure is largely state-owned and vertically integrated, the private sector's participation in all different areas of the energy sector will become more important for Indonesia's energy transition. Private-sector participation in electricity generation has been typically allowed through power purchase agreements (PPAs) signed with independent power producers (IPPs), gaining a share that reached 27% of total electricity generation by the end of 2019. It also takes place in the non-PLN business concession area (Wilayah usaha) where more than 50 private businesses have a license for electricity provision to the public (IUPTLU) and can build integrated power infrastructure. The private-sector contribution to expansion of grid infrastructure has been limited, but further involvement could be an important pillar to create sustainable financing for energy investment. Private companies accounted for 30% of Indonesia's power sector funding between 2016 and 2019.

IPP appointments are typically granted through competitive tenders. There are also cases in certain circumstances where IPPs can be directly selected or appointed. While implementation of direct selection and appointment procedures have advanced significantly in the past years, there is more room for Indonesia to capitalise on the untapped opportunities of a competitive auction system for the procurement of renewables. This can also help to move away from the feed-in tariff (FiT) scheme that Indonesia has been using with mixed success since 2016 due to low tariff payments. Similarly, Indonesia's large rooftop solar PV potential could benefit from more effective remuneration of the power exported to the grid under a net metering scheme. Successful deployment of distributed renewable energy systems, including off-grid solar PV and storage-based mini-grid projects, will be crucial to reach 100% electricity access in 2022.

Although the level of unemployment in Indonesia is relatively low at under 5%, identifying new areas of economic activity and employment through the creation of a local renewable energy sector remains important. As one of the largest global suppliers of biofuels, Indonesia has already established a biofuel industry. Nearly half a million people work in this value chain, accounting for about 20% of total biofuel jobs globally. The government is expanding efforts to increase employment around other renewable energy technologies. For instance, the Solar Archipelago (Surya Nusantara) plans to install 1 GW of solar PV each year until 2025.

The focus is to create new jobs for up to 22 000 people in installation. The overarching policy to ensure job creation and create new economic activity is the local content share requirements placed on investors.

The huge mineral resource availability of the country presents an unprecedented opportunity for Indonesia to transform its industrial sector. Indonesia owns about a quarter of the total known nickel resources worldwide. At the end of March 2021 the establishment of the Indonesia Battery Corporation was announced, owned equally by four state-controlled companies, namely Mind ID, Antam, Pertamina and PLN. The company aims to become a global leader in the supply of EV batteries, creating value added for Indonesia's economy and contributing to the creation of new jobs along the battery storage supply chain. The target is to produce 140 GWh of battery storage by 2030, of which 50 GWh is to be exported. The investment need is estimated at USD 17 billion.

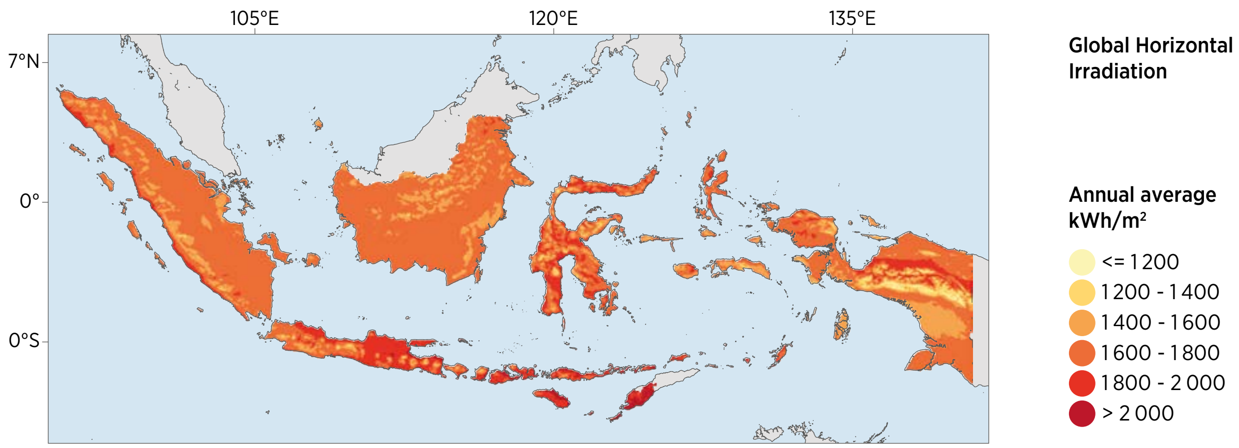
3.2 CURRENT STATUS AND POTENTIAL

The solar energy potential of Indonesia could be as high as nearly 3 000 GW according to IRENA analysis using a geographic information system (GIS), particularly concentrated in East Java, Sumatra, Nusa Tenggara and Sulawesi. Average daily irradiation ranges from 4 kWh to 5.8 kWh per square metre (PWC, 2018). Hydropower is Indonesia's largest source of renewable energy today and has potential for 75 GW of capacity. Other estimates indicate up to 94.3 GW (DEN). Additional large- and small-scale plants are possible. For wind, the country has an estimate potential of 61 GW. The best locations with high wind speeds are Nusa Tenggara, Timur and South Sulawesi provinces, as well as parts of Java island. Central, East Java and Bali have a combined wind potential amounting to 15.2 GW. This compares with the potential in East Nusa Tenggara alone of 12.8 GW (PWC, 2018).

Estimates for biomass-generated electricity are approximately 32.6 GW. The biomass supply chain remains undeveloped despite a large agricultural industry, resulting in extensive wastage of biomass (McKinsey, 2020). Much of this potential could come from palm oil (12.6 GW) and rice husks (9.8 GW). Municipal solid waste, corn and wood could provide another 5 GW. About half of the potential is in Sumatra (15.6 GW), with another one-third in the Java-Bali-Madura region. The municipal waste-to-energy potential is about 535 MW (PWC, 2018).

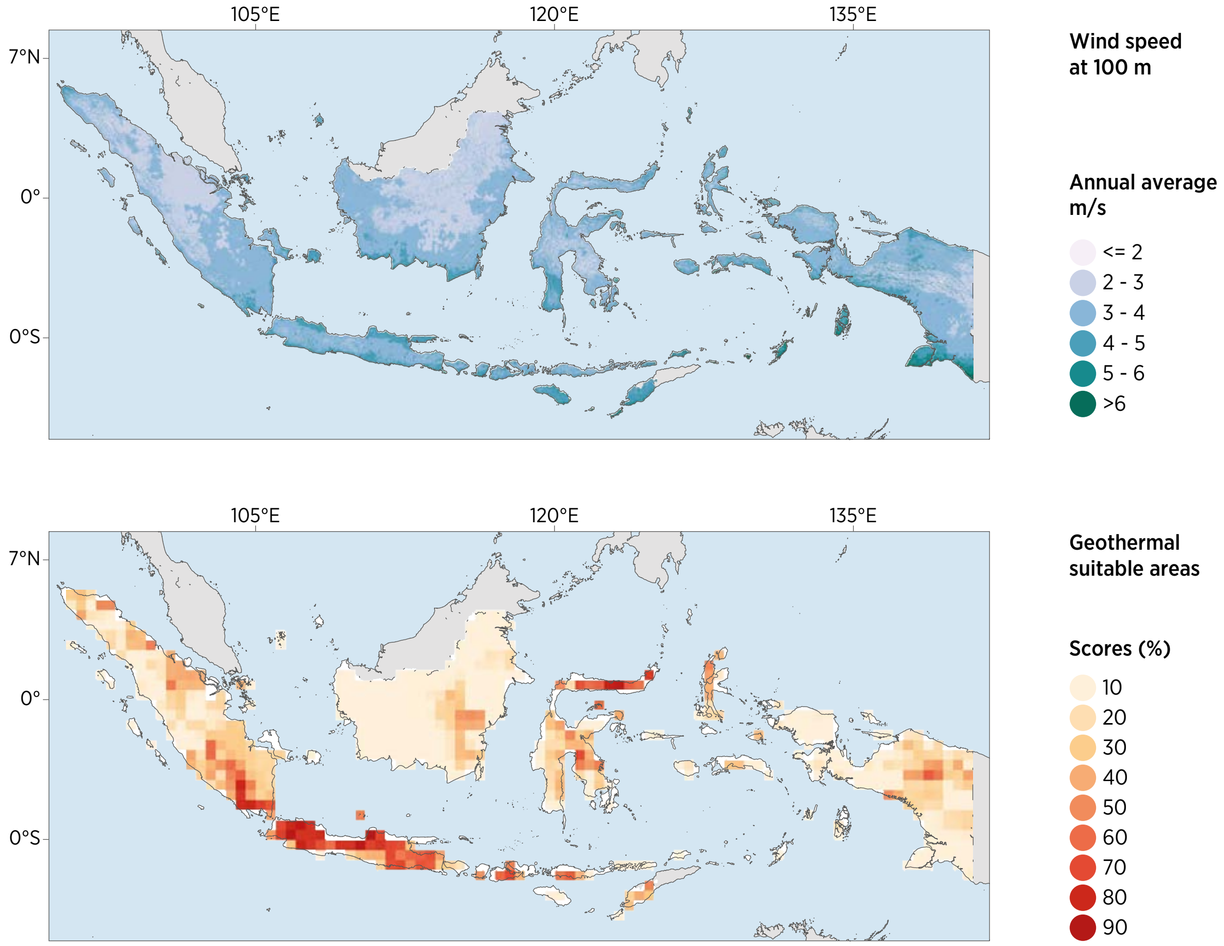
Renewable energy resource potential in Indonesia is massive

Figure 21 Indonesia's renewable energy resource potential



Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Figure 21 Indonesia's renewable energy resource potential (continued)



Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.
Source: (ESMAP, 2019), (DTU, 2015), (Coro and Trumpy, 2020). Also available on the IRENA Global Atlas for Renewable Energy web platform.

The country's geothermal resource potential is estimated at 28.5 GW. More than 2 GW of geothermal generation is already in operation today, amounting to approximately 10% of the country's resource potential. In addition, 17.9 GW of ocean energy potential exists.

The implementation of renewables is currently behind target and one way to accelerate this would be to phase out coal plants. In parallel, cost reductions are feasible in solar and wind energy and the introduction of investment de-risking could facilitate further cost reductions. The country lags in the development of renewable energy against its various energy and capacity expansion plans. Despite a rich variety of regulatory options and support mechanisms, the lack of consistent and supportive policy to develop renewable energy plants has been one of the greatest barriers to solar energy deployment. With only a small share of its electricity supplied from renewables, Indonesia has tapped into just 2% of its total renewable energy potential to date (McKinsey, 2020). Fossil fuels are expected to continue to dominate the power system in Java-Bali, but the draft RUPTL 2021-2030 and the strategy for a transition away from coal in the longer term could reverse this trend in favour of renewables.

This potential and its geographic distribution will be crucial in shaping the expansion of the power sector out to 2050. How they can do so across the Indonesian archipelago is further elaborated in Chapter 4.

Box 6 Planned renewable energy projects

Indonesia's renewable energy share in 2021 is recorded as 11.5%. The commitment by PLN to reach a 23% renewable energy mix in 2025 is made in RUPTL 2021-2030 (PLN, 2021a). PLN recently materialised power purchase agreement on consolidated geothermal assets owned by PLN, PT Indonesia Power and PT Pertamina Geothermal Energy. The list of the geothermal facilities is in Table 2:

Table 2 Geothermal projects in the consolidation programme

	GEOTHERMAL POWER PLANT	CAPACITY	LOCATION
1	Kamojang 1-3	1 x 30 MW and 2 x 55 MW	West Java
2	Mt. Salak 1-3	3 x 60 MW	West Java
3	Darajat 1	1 x 55 MW	West Java
4	Lahendong 1-4	4 x 20 MW	North Sulawesi
5	Ulubelu 1-2	2 x 55 MW	Lampung

The feasibility study on potential hydropower plant projects concluded that about 8 GW can be developed, based on the level of difficulty resulting from land forest status and other social and technical aspects. PLN also continues to develop utility-scale solar PV, utilising their hydropower dam reservoirs for floating solar PV. PLN estimates 612 MW of floating PV potential, among which are 100 MW in Wonogiri, Central Java, 122 MW each in Karangkates and Tulung Agung, East Java, and 100 MW in Jatiluhur, West Java. One of the projects that is currently under development is the floating PV at Cirata cistern, with a rating of 145 MWp. In 2019 a solar PV farm in Likupang, North Sulawesi, claimed to be the largest in Indonesia with 21 MWp capacity. The city of Batam is the location of the world's largest planned floating PV plant, with a rating at 2.2 GWp over 650 hectares on the Duriangkang cistern. The project is a collaboration between BP Batam and SunSeap Group Corp. of Singapore.

Table 3 List of planned floating PV projects by PLN

	FLOATING PV PROJECTS	CAPACITY	LOCATION
1	Wonogiri	100 MW	Central Java
2	Sutami Karangkates	122 MW	East Java
3	Jatiluhur	100 MW	West Java
4	Mrica Banjarnegara	60 MW	Central Java
5	Saguling	60 MW	West Java
6	Wonorejo Tulung Agung	122 MW	East Java
7	Lake Singkarak	48 MW	West Sumatera

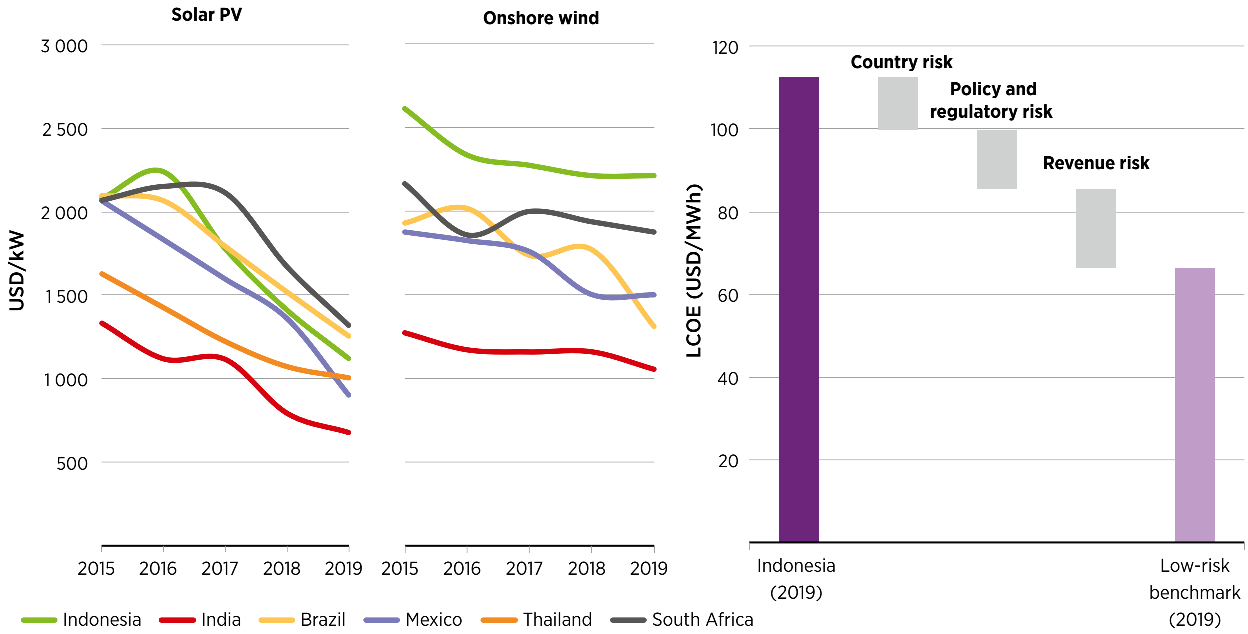
3.3 ECONOMICS OF RENEWABLE ENERGY

In 2019, the capital costs of solar PV projects in Indonesia are much higher than in India or Thailand, averaging above USD 1 000/kW. However, the capex for utility scale solar based on recent projects has rapidly reduced reaching on average at USD 800/kWp, with the Cirata FPV project stands at about USD 650/kWp. Wind project costs are much higher than in many other countries, close to USD 2 500/kW. Wind's potential in Indonesia is less than solar's, which partly explains the relatively higher wind energy capital costs.

During the COVID-19 period, solar PV additions continued, although the 2020 target in the General Plan for National Energy (RUEN) of 900 MW was missed. Despite solar PV's slow progress in recent years, a USD 0.0581/kWh PPA tariff agreement for a 145 MW floating PV plant under construction on a 225 hectare section of the Cirata reservoir in West Java was a promising step forward. Furthermore, the local utility, PT Indonesia Power, invited tenders for two floating PV projects with a capacity of 60 MW and 90 MW, respectively. The final bids for the two projects were at USD 0.0374/kWh and USD 0.0368/kWh, respectively (PV Magazine, 2021).

Renewable electricity costs continue to decline across all markets, including in Indonesia

Figure 22 Renewable power costs in Indonesia and comparison with other emerging economies

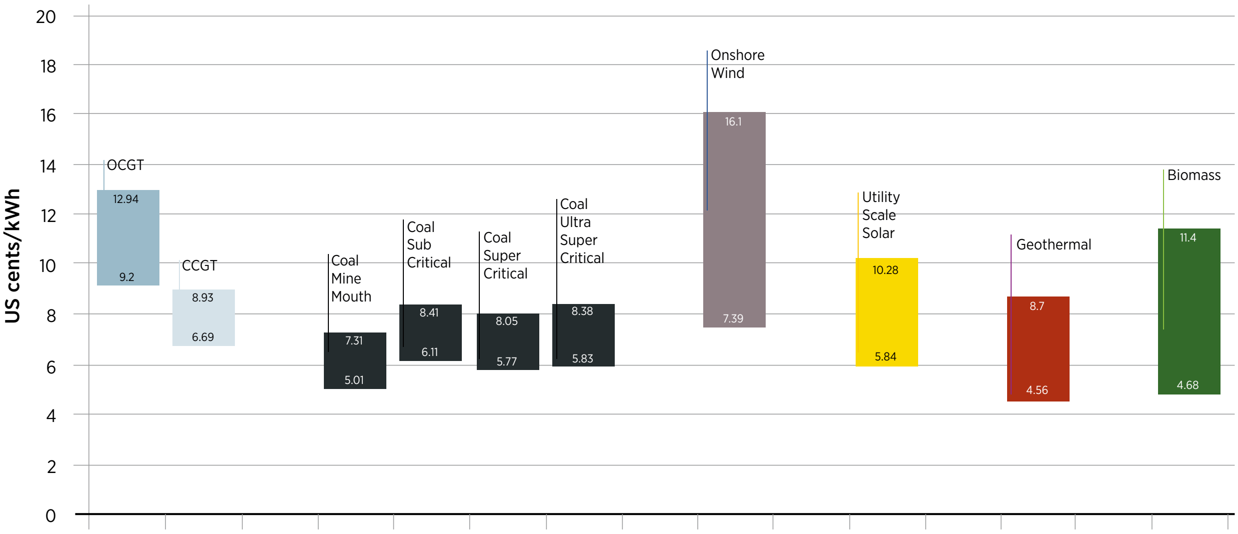


Note: MWh = megawatt hour.
Source: (IEA, 2020b).

As shown in Figure 23, the cost range of large-scale solar PV (> 10 MW) is already on a par with those of new coal power plants. Electricity generation from large-scale solar PV plants may also fall further, from USD 0.06-0.10/kWh (IDR 845-1 400/kWh) to USD 03.5-0.08/kWh (IDR 493-1 125/kWh).

Renewable electricity costs continue to fall and are now generally cost competitive with coal generation

Figure 23 Levelised cost of electricity generation in Indonesia, 2019



Notes: CCGT = closed-cycle gas turbine; OCGT = open-cycle gas turbine.
Source: (IESR, 2019).

IRENA analysis shows the cost of renewables for the entire Southeast Asia region. Electricity generation from solar PV is on average USD 0.09/kWh, where Indonesia's range is much lower than the region's average. Likewise for geothermal, the average cost in the region is around USD 0.07/kWh as opposed to a much lower cost in Indonesia (IRENA, 2020). The weighted average cost of capital for utility-scale solar PV projects in Indonesia in 2020 was about 6% (benchmark value) (IRENA, 2021a). In rural areas, solar PV is already competitive with diesel generators. The levelised cost of electricity from a diesel generator is USD 0.20/kWh compared with a solar PV and battery storage system that has a range from as low as USD 0.113 to USD 0.251 per kWh.

The cost trends of power generation technologies out to 2050 will be crucial in the development of the power sector, regardless of the level of ambition. For low-carbon pathways, however, those of renewable energy technologies will be the most important, including how they correspond with the renewable energy potential and its distribution across Indonesia. These considerations and others are discussed in more depth in Chapter 4.

3.4 GRID INTEGRATION OF RENEWABLES

If Indonesia follows the business-as-usual pathway, the share of wind and solar energy in its electricity mix is expected to remain low in the coming years and the grid integration of variable renewable sources is unlikely to pose an obstacle. However, further technology cost reductions or increasing climate policy pressure may accelerate the uptake of renewable energy in the country, especially solar PV given its large potential. This will make system flexibility an important issue for power system planning and operation.

Indonesia's power generation is dominated by inflexible coal-fired power plants. They have low ramp rates and provide constant output. Currently, the share of gas-fired generators is much less than in earlier years. In addition, the regional grids have specific characteristics that need to be considered for the grid integration of renewables. For instance, in the Java-Bali power system oversupply from coal-fired power plants is an issue given that there is a potential increase in the penetration of grid-connected solar PV systems.

A comprehensive grid code is needed to manage the penetration of variable renewable energy resources. All grid codes in Indonesia have the same structural pattern with almost the same content. The differences are in the PLN organisational structure, generation capacity and voltage levels that vary in each network. There is no grid code that explicitly aims to regulate solar and wind penetration. There are also no terms for the parameters of fault ride-through, low-voltage ride-through or high-voltage ride-through in the grid code. MEMR Regulations No. 03/2007, No. 37/2008, No. 02/2015 and No. 18/2016 set the grid codes for Java-Bali, Sumatra, Sulawesi and Kalimantan system networks, respectively (Barus and Dalimi, 2020).

Many of the large cities located on the same island still operate on independent and isolated grids. The relatively small size of the grids, even when they serve cities with a significant population, limits how much solar, wind and marine energy can be installed. Currently, a penetration limit of 10% variable renewable energy from the daytime peak load is imposed by PLN to ensure grid stability. Under this requirement, the potential for solar and wind energy is limited, both in terms of plant size and the number of suitable locations. Because of the number of isolated grid systems as well as the variable grid sizes, it is difficult to generalise the grid condition and to create a policy or a plan that works well across all regions. In addition, generation forecasting or requirements for centralised monitoring and access to power plants are limited now. This means that it will be difficult to increase the penetration of variable renewables in the grid in the short term.

At the same time, the fact that solar power is available when the demand for air conditioning is high might reduce pressure on the grid at times of high demand. For wind power, preliminary results from a grid impact study for Sulawesi suggest that there might be less capacity to interconnect than initially thought. South Sulawesi was selected by many project developers due to its relatively inexpensive land cost, fairly sizeable grid and expected growth in power consumption, and because it has one of the highest wind resources in Indonesia.

3.5 INVESTMENT AND FINANCING

The capital costs of renewables remain somewhat more expensive relative to other countries, but new investments show a clear business case for renewables, especially for solar PV where the levelised cost of electricity generation is now comparable with that of coal-fired power plants.

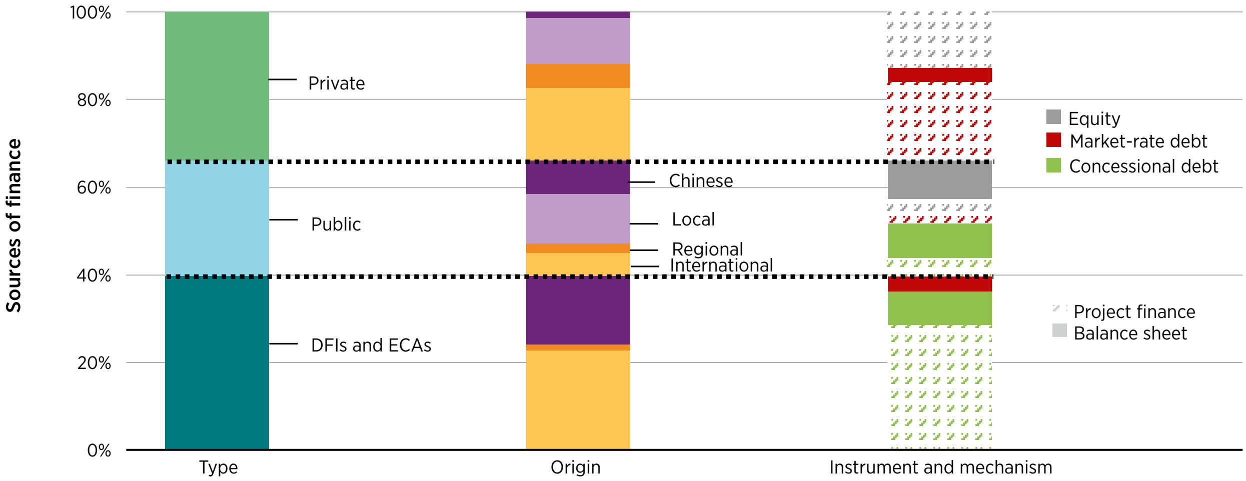
Tax incentives, including land and building tax relief, import duty relief and tax allowances, and various funding models provide for various financial incentives to accelerate renewable energy investment. There are four categories of incentives for renewable energy in Indonesia, namely tax allowances, import duty exemptions, tax holidays and new incentives due to COVID-19 impacts.

A number of issues that warrant attention with respect to financing renewable energy investments in Indonesia. In many cases, Indonesian banks have not implemented project finance for renewable energy. If developers needed project finance, it was necessary to approach other investors or attract international finance. Geothermal projects, for instance, have many sources of private equity. Many own-consumption biogas plants have been built using private sources of finance.

Project finance is typically provided by international commercial banks, multilateral development agencies and export credit agencies. Local banks face challenges because of their limited liquidity for long-term debt and the lack of a derivatives market. Over the past decade, PT Sarana Multi Infrastruktur (Persero) (SMI) (a state-owned infrastructure financing company), and PT Indonesia Infrastructure Finance (IIF), a joint venture between the government (through SMI), the Asian Development Bank, International Finance Corporation, Deutsche Investitions-und-Entwicklungsgesellschaft and Sumitomo-Mitsubishi Banking Corporation, have also provided project financing for infrastructure projects, including renewables. SMI and IIF were established by the government as part of the efforts to accelerate infrastructure developments by providing domestic finance in the form of debt and equity (IEA, 2020b). Direct lending, subsidiary loans and guarantees are among the typical financial instruments used in Indonesia.

Power generation projects are funded from a wide variety of sources

Figure 24 Sources of finance in power generation for projects commissioned in 2016-2019



Notes: DFIs = development finance institutions; ECAs = export credit agencies.
Source: (IEA, 2020b).

An important aspect of Indonesia's financing market is its role in the global green bond market. Indonesia issued a sovereign green sukuk in 2018.[7] It also completed the world's first retail green sukuk in 2019 for a total of USD 150 million. The second retail green sukuk issued in December 2020 was more than three times larger in volume than the first. A green sukuk offers an attractive financing vehicle for developers to raise long-term debt finance. So far Indonesia has issued a total of USD 3.2 billion in green sukuk, of which USD 2.75 billion is from global issuances and USD 0.49 billion from domestic.

According to a study by the Asian Development Bank released in November 2019 (ADB, 2019), the main challenges to financing renewable energy investments were: 1) low feed-in tariffs; 2) high costs of financing; 3) limited project finance; 4) BOOT structure in PPAs, instead of BOO (which has now changed); 5) project scale and related risks; 6) technical and financial capacity of project developers and the technical capacity of financiers; 7) local content requirements making it challenging to design projects in a cost-efficient way; and 8) uncertainties related to project development, such as issues related to licensing, contracting and timelines. Financial institutions have typically lacked experience and knowledge of financing renewables. While developers and investors found all these as investment barriers, financial institutions did not regard local content and licensing and permits as barriers. According to PLN, loan interest and collateral were not barriers (ADB, 2019). Indonesia has made significant progress in overcoming these barriers, although some issues remain.

Indonesia has made important progress in sustainable finance activities. In May 2018 the Indonesia Sustainable Finance Initiative (ISFI) was launched, which aims to promote and implement inclusive sustainable finance practices. It is led by the financial services industry to support the Indonesian Financial Services Authority's relevant regulations on sustainable finance principles and green bonds (WWF, 2018). Indonesia has also joined the International Platform on Sustainable Finance (IPSF), launched in 2019 to scale up the mobilisation of private capital towards environmentally sustainable investments (European Commission, 2022).

[7] *Sukuk is a sharia-compliant bond.*

4 ENERGY TRANSITION OUTLOOK

4.1 METHODOLOGY AND KEY ASSUMPTIONS

The *World energy transitions outlook* (WETO), the latest edition of which was released by IRENA in 2022, shows that a drastic reduction in greenhouse gas (GHG) emissions is needed in order to meet the Paris Agreement goal of keeping the rise in the average global temperature well below 2°C and outlines measures that would keep the rise to 1.5°C (IRENA, 2022a). Key to this emission reduction over the coming decades will be increased investment in the energy transition, including greater deployment of renewable energy and changes to energy infrastructure.

IRENA's renewable energy roadmaps programme, REmap, provides strategies for the energy transition at the country and regional levels, with perspectives for 2030 and 2050. The aim of developing regional studies is to understand how a region can promote an energy transition pathway, respecting countries' unique energy resources and socio-economic status, as well as institutional and regulatory endowments. Simultaneously, the regional pathway contributes to the global emission reduction objective and shows how in the longer term the Association of Southeast Asian Nations (ASEAN) region can contribute to a global energy system consistent with the aims of the Paris Agreement, guided by the energy transition pathway set out in IRENA's WETO.

REmap takes a bottom-up approach. The analysis utilises an internally developed REmap toolkit that incorporates detailed energy demand and supply data by sector, a substitution analysis of technology options for renewables, and an assessment of associated costs, investments and benefits. The analytical process is carried out by IRENA teams in close collaboration with the energy experts in the relevant country through a series of multi-stakeholder consultative workshops and expert meetings. In addition, detailed power sector modelling was performed using PLEXOS to analyse the supply sector for power generation capacity expansion and operational flexibility. A supplementary analysis was also performed using the IRENA FlexTool for operational flexibility.

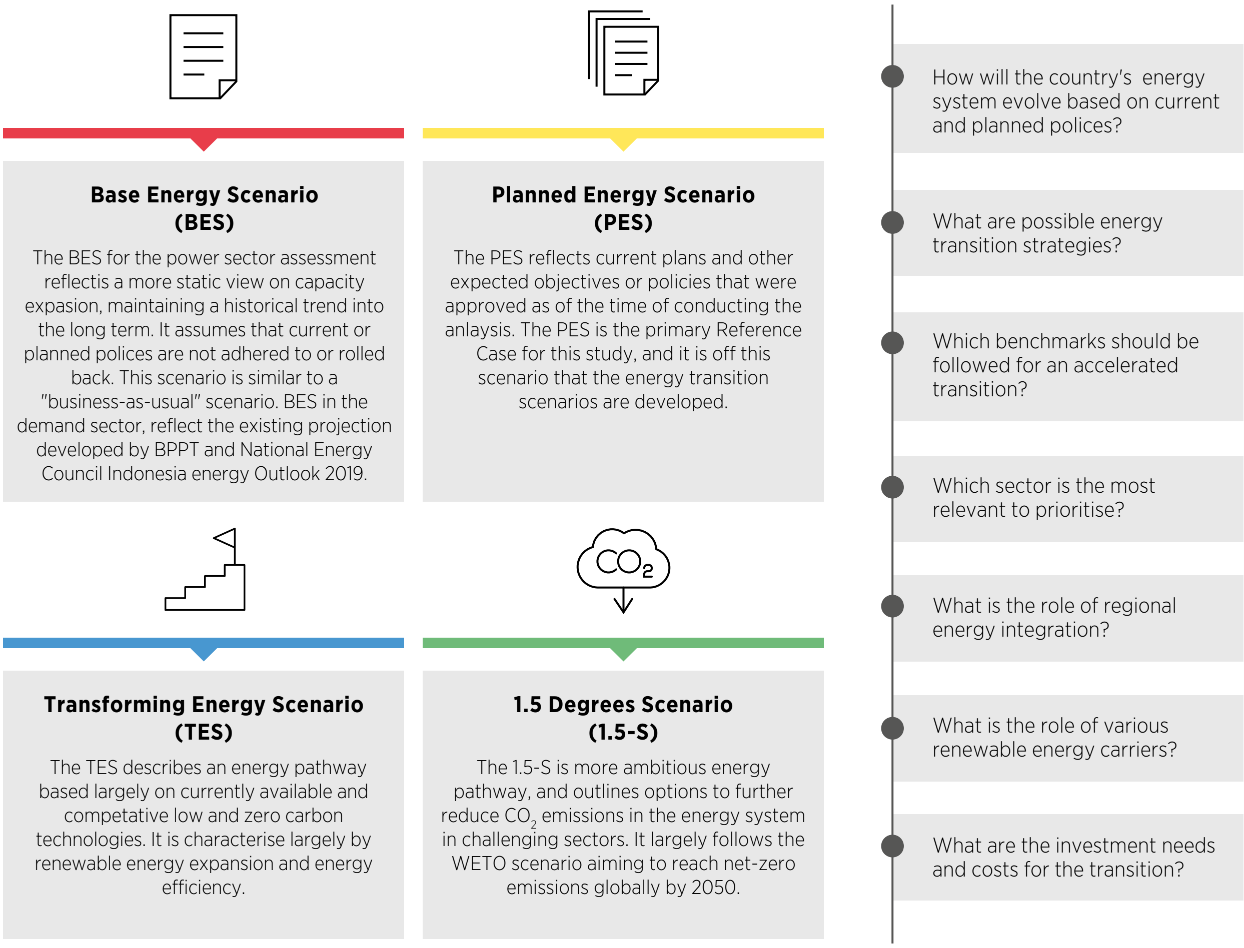
Methodology

The IRENA REmap approach was used to design and elaborate this Energy Transition Outlook for Indonesia, creating technical pathways focused on three scenarios. A bottom-up analysis was carried out to detail the energy demand by end-use sector, conducting a substitution analysis of technology options for renewables, and an assessment of associated costs, investment and reduced externalities. This was all done in close collaboration with country's energy experts through a series of multi-stakeholder consultative workshops and expert meetings. The power sector was modelled using PLEXOS for capacity expansion and operational flexibility, with a supplementary operational flexibility assessment performed using IRENA's FlexTool product.

It is important to note that long-term scenarios are inherently uncertain given the multi-decadal timeframes. There will be varying perspectives on scenario pathways depending on variables such as GDP growth, industrial policy decisions, technological development and diffusion constraints, energy prices, wider geopolitical considerations, and many other factors. The scenarios developed for this report draw on IRENA's expertise in assessing low-carbon energy pathways, led by IRENA's WETO report. The work also draws on expertise across the agency in areas such as costing, innovation, power system transformation and technology assessment. The description of each scenario is described in Figure 25.

This report looks at various scenarios for possible future energy pathways in Indonesia

Figure 25 REmap scenarios description



The energy assessment is then complemented with an analysis of the costs, investment and avoided externalities of the scenarios described above. This assessment provides an estimate of the overall costs involved in implementing each of the scenarios. It includes investment in equipment and new installations, fuel costs, operation and maintenance costs and externalities. This allows an initial assessment of the total costs and benefits.

At its core, the power sector analysis aims to provide a robust yet concise set of scenarios that can show the challenges and opportunities that exist under current plans and under plans with greater ambition for renewables and regional integration. To this end, it aims to analyse how a climate-compatible scenario can be achieved in **three different cases** for Indonesia rather than a single case, while being operationally resilient across all scenarios: 85% renewables and nuclear power (**1.5-S RE85**), 90% renewables and carbon capture and storage (CCS) (**1.5-S RE90**) and using 100% renewables (**1.5-S RE100**). For ease of results aggregation and presentation of the study as a whole for Indonesia (*i.e.* total energy sector emissions, national primary and final energy needs etc.), only the 1.5-S RE90 case was used. However, all cases are detailed and discussed in depth in the dedicated power system capacity expansion section, in addition to each of their respective implications for investment needs.

Box 7 REmap Toolkit

The REmap Toolkit is a software environment that allows for the development of full energy balances covering the whole energy system, including energy demand, energy transformation and losses, and primary energy supply. The Toolkit is based on modules that can be used depending on the specific requirements and data availability of each project.

The toolkit is a parametric model where future energy demand and supply are assessed based on input parameters, such as activity levels, energy service penetration, technology shares and fuel mixes. These are all exogenous inputs to the model, and energy demand is fully determined from those inputs through deterministic model equations. The toolkit's demand analysis does not rely on cost-optimisation or multi-criteria decision algorithms to assess energy demand. Those are determined from expert judgement in consultation with literature and country experts.

The main group of modules of the REmap Toolkit is called the REmap Activity Tool and covers the assessment of energy demand for end-use sectors. The Activity Tool is flexible and can accommodate a detailed bottom-up analysis based on granular activity and technical parameters or a top-down analysis based on aggregated socio-economic information. The choice of the method and level of detail depends on the availability of information and was decided as the analysis developed. For this report, the analysis was based largely on a bottom-up assessment.

Energy demand is broken down into four main sectors: buildings, transport, industry and other consumption. Each in turn can be further divided into sub-sectors such as residential and commercial buildings, passenger and freight transport, and different types of industry. In the bottom-up approach each sector/sub-sector is analysed based on detailed activity and technology characterisation of energy demand. This is a data-intensive approach that depends on the availability of an extensive set of information such as population, households, floor area, transport demand in passenger-kilometres (km) and tonne-km, energy service penetration rates, technology penetration rates, fuel mixes, specific energy consumption by technology type, etc. The top-down approach is based on aggregated socioeconomic data such as population, GDP, number of households and aggregated energy intensity indices.

Energy demand was estimated on a yearly basis, year-by-year, throughout the timeframe of the analysis, with special attention paid to the base year (2018) and two future years (2030 and 2050). Yearly data for electricity demand are then used in the supply-side models. For other, non-electricity carriers, the REmap Toolkit offers a simplified supply-side assessment for different carriers, including bioenergy, hydrogen, e-fuels and fossil fuels. The REmap Toolkit also includes the estimation of CO_2 emissions and an assessment of costs, investments and benefits in terms of avoided externalities.

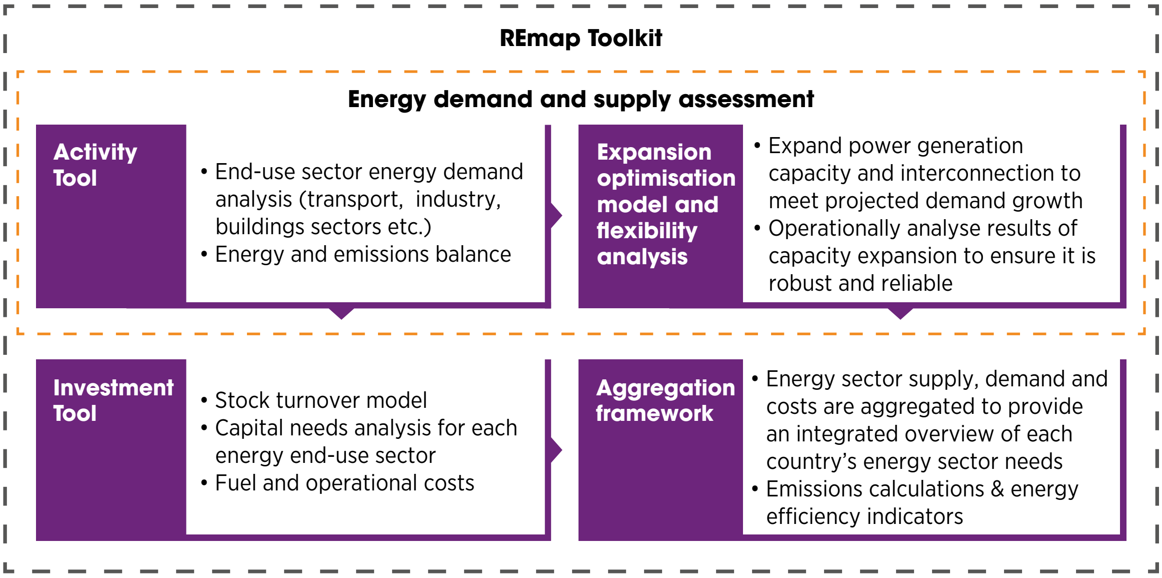
For the power sector, this study uses the commercial software PLEXOS for both the long-term capacity expansion and operational analysis. Additionally, IRENA's FlexTool (which is free and open-source) performs power system flexibility assessments based on the resulting capacity expansion in key milestone years. The FlexTool assessments reflect full power system dispatch and offer a detailed view of flexible generation options, demand flexibility and energy storage, along with sector-coupling technologies such as power-to-heat, electric vehicles (EVs) and hydrogen production through electrolysis.

The figure shows the interaction of the different tools to perform energy analyses of the end-use and power sectors, as well as estimations of investment, for the regional assessment.

Box 7 REmap Toolkit (continued)

The analysis uses a number of toolkits to develop the scenarios

Figure 26 REmap tools for analysis of the end-use and power sectors



References and key assumptions

References

The Handbook of Energy and Economic Statistics of Indonesia was used as the energy statistic reference source when building the base year (2018) analysis. The country's energy consumption was broken down to the sectoral (buildings, transport, industry) and sub-sector level (MEMR, 2021a). Supplementary studies and data sets were used to complement the main data source and build a more detailed picture at the sub-sector level. The End-User Survey and Refrigeration and Air Conditioning Study conducted by Ministry of Energy and Mineral Resources Indonesia were the main resources for activity-level data for the buildings sector, and for developing base year and projection year energy consumption for the buildings sector (BPS, 2021; CLASP, 2020; GIZ, 2017). Historical vehicle stock data were sourced from the Central Statistical Bureau, whereas other transport mode statistics were obtained from the Ministry of Transport Indonesia (BPS, 2021). Statistics data from Pusdatin and the Ministry of Industry were used to build industrial sector energy profiles (MoI, 2019, 2012; Pusdatin, 2019). Historical power sector data were taken from PLN statistics, while National Electricity Supply Business Plans (RUPTL 2021-2030) were used as the base references for the PES power projection (PLN, 2021a). In addition, IRENA studies, such as the WETO, were used to inform the development of the TES and 1.5-S.

Key assumptions

Indonesia has the highest population among the ten ASEAN member states, and is the fourth most populous country in the world. The country's population grew on average by 1.3% annually between 2010 and 2018. Population growth has increased the number of households by 11% over the same period, with the number of persons per household rising to four. Indonesia's population is projected to grow from around 265 million in 2018 to 335 million in 2050, with an average growth rate of 0.74%. The Central Statistical Bureau of Indonesia projected in 2018 that the population would grow at 0.98% annually to reach 296.4 million by 2030, slowing to 0.65% in the last 20 years towards the middle of the century.

The Central Statistical Bureau of Indonesia recorded that the country's GDP has averaged an annual growth rate of 5% during the past decade. Following a plunge to 1% in 2020 during the COVID-19 pandemic, Indonesia's growth rate is projected to increase gradually, reaching 6% in 2025. In the long term, Indonesia's GDP is projected to grow at a rate of 5% annually between 2025 to 2040, and slow modestly to 4.5% in the decade to 2050. This results in an over threefold increase in Indonesia's GDP per capita, reaching more than USD 11 000 by 2050.

Population and GDP growth are substantial during the period to 2050

Table 4 Population and GDP projections

	2018	2030	2050
Population (million persons)	265	296	335
GDP (million USD, 2015 constant)	958 671	1 486 911	3 761 325
GDP per Capita (USD/capita, 2015 constant)	3 617	5 016	11 228

Indonesia's energy use is dominated by fossil fuels, accounting 73% of its total final energy consumption (TFEC) in 2018. Statistical data from the Handbook of Energy and Economic Statistics of Indonesia record that oil products met well over half of Indonesia's TFEC in 2018, with 26.7% and 15.4% being gasoline and diesel respectively, consumed mostly in the transport and industrial sectors. Kerosene makes up the remaining oil demand in Indonesia. Electricity demand in 2018 comprised 16.5% of TFEC, as it is the dominant energy carrier in the buildings sector. The share of natural gas, coal and coke consumed in industrial sectors for their process heat is 29%, and 10% is from other petroleum products. Biomass, liquid biofuels and other petroleum products make up the rest of Indonesia's TFEC. The country reached an electrification rate of 99.2% at end of 2020. The buildings sector dominates electricity consumption, accounting for 57% of the country's total electricity consumption in 2018, with industry consuming the remainder. Indonesia's government has a target to reach 100% electrification in 2022 (MEMR, 2021c).

For more information on the current energy system, make-up and status, please see Chapter 2: Energy Context.

4.2 ENERGY TRANSITION IN INDONESIA

Summary of findings

KEY HIGHLIGHTS

Indonesia's TFEC increases almost threefold by 2050 in the PES. Driven by population and economic growth, Indonesia's energy demand grows by 3.3% annually

Fuel switching to renewables and electricity and energy efficiency efforts slow this growth rate in the TES and 1.5-S to 2.7% and 2.4% respectively, saving 14% and 22% of the total consumption seen in the PES. More than a quarter of Indonesia's demand for fuels by 2050 in 1.5-S is met by renewables, with almost double the renewable energy demand in the same year than in the PES. Additionally electricity, which is largely renewable in the 1.5-S by 2050, makes up 47% of TFEC.

The renewable energy's share of supply in the 1.5-S is more than double that in the PES in 2050. The supply of renewable energy in the 1.5-S grows over eleven times from today's value.

Electricity becomes the dominant energy carrier in both the TES and 1.5-S, and the second most important carrier in PES. This is supported by the role of renewables in the power sector, which will be more vital in all the scenarios.

In the PES, Indonesia's energy-related CO_2 emissions continue to increase, reaching 80% more than today's level. Fossil fuels consumed in the transport, industrial and power sectors are responsible for 89% of Indonesia's total emissions. Both energy transition scenarios see Indonesia's emissions peaking in the mid-2030s. Indonesia's emissions in the TES are 18% below today's level by 2050, whilst the more aggressive transition of the 1.5-S reduces Indonesia's emissions to one-third of today's levels.

Indonesia is expected to see significant and sustained energy demand growth over the coming decades. The country is already the largest energy consumer in ASEAN, and will continue to be the main consumer and largest economy in the period to 2050. Table 5 presents the high-level findings for the PES, TES and 1.5-S in the form of a group of key indicators. Total primary energy supply increases more than threefold over the period to 2050. Largest differences are seen between the scenarios, which are elaborated on later in this chapter.

Renewable energy, with solar photovoltaic (PV) as the key technology, leads Indonesia's energy transition regardless of the scenario

Table 5 Summary table for Indonesia

		2018	2030			2050				
			PES	TES	1.5-S	PES	TES	1.5-S RE85	1.5-S RE90	1.5-S RE100
SUPPLY	**Total primary supply** (EJ)	8.0	12.6	12.2	11.9	23.1	20.0		17.8	
	Renewables share (%)	14	16	21	23	24	45		70	
POWER	**Renewables installed capacity** (%)	18	28	49	51	80	83	96	91	100
	Renewables installed generation (%)	19	26	36	34	57	74	85	90	100
	Total installed solar PV (GW)	0	5	48	66	385	618	805	798	840
DEMAND	**TFEC** (PJ)	6 250	9 592	9 300	8 914	17 471	14 936		13 463	
	Renewables share (%), fuels	10.0	13.3	15.7	18.5	12.4	19.9		28.4	
	Renewables share (%), fuels and electricity	27.8	34.9	39.9	45.3	41.3	60.4		75.8	
	Electricity consumption share (%)	17.6	21.5	24.2	26.8	28.9	40.4		47.5	
INDICATORS	**Total primary supply of energy per capita** (GJ/capita)	30.6	42.6	41.1	40.0	69.0	60.0		53.0	
	TFEC energy per capita (GJ/capita)	23.6	32.4	31.4	30.0	52.2	44.6		40.2	
	Energy intensity (MJ/USD)	8.4	8.5	8.2	8.0	6.1	5.3		4.7	
	Electricity consumption per capita (kWh/capita)	1 155	1 937	2 106	2 239	4 187	5 008		5 302	
EMISSIONS	**MtCO_2 energy-related**	559	827	770	706	1 040	508		210	

Total final energy consumption

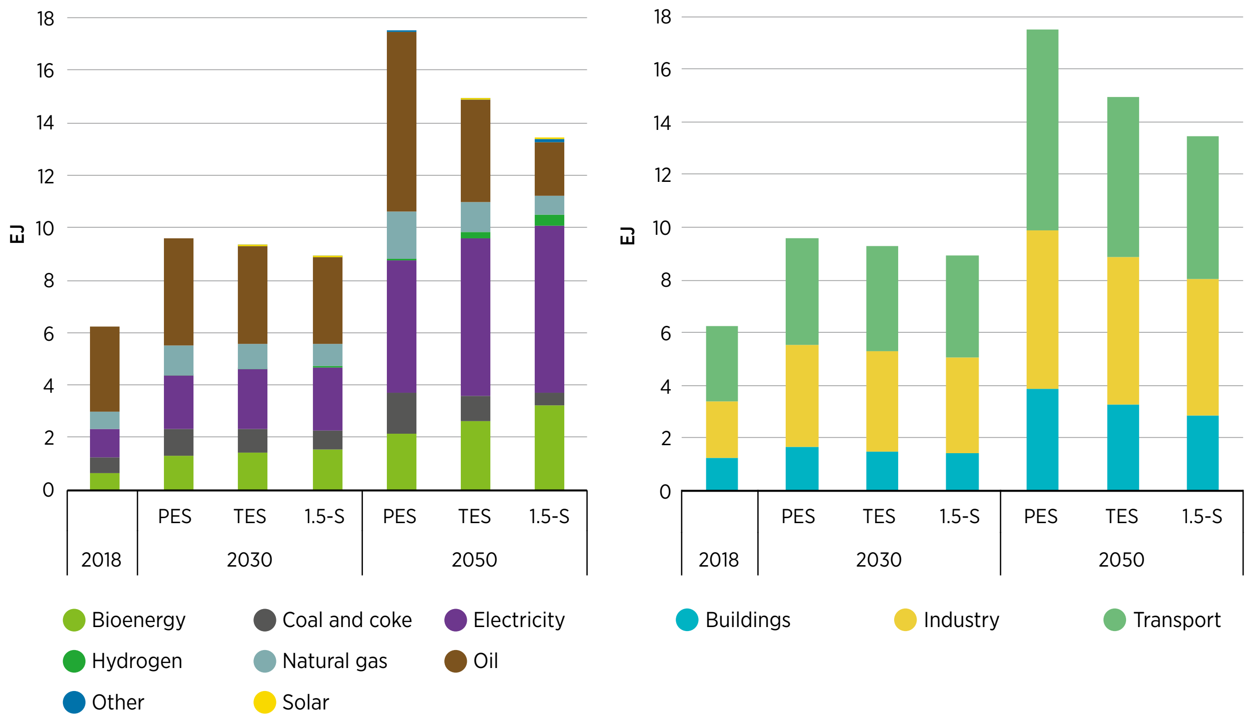
Indonesia's TFEC in the PES is projected to grow nearly threefold by 2050 at a 3.3% annual growth rate, dominated by oil consumption. In 2018 the transport and industrial sectors account for over 83% of the country's TFEC, with the remainder coming from buildings sector. Despite still dominating overall energy demand, the transport sector's share of energy consumption decreases to 43% in 2050. The industrial sector increases its energy consumption by 2050, driven by further development of industrial sectors, especially manufacturing. Energy consumption in the buildings sector also increases it share, driven by increasing population and personal wealth creating more households and commercial buildings. Despite seeing its share fall, demand for oil products in 2050 is still the highest among all carriers in the PES, driven by a rapid increase in road vehicles in the country. Gasoline and diesel consumption more than double, growing 2.3% and 2.7% annually, respectively. The two carriers are responsible for more than 30% of Indonesia's TFEC in 2050.

Electricity consumption grows the most by 2050, reaching over three and half times today's level on a per-capita basis. Rapid electricity demand is driven by many policies implemented by Indonesia's government for energy solutions that require electrification. One of the most apparent is the electric vehicle target set by the Ministry of Energy, as well as the biomass phase-out and LPG subsidy reduction. Electricity consumption grows on average 4.8% annually, accounting for 29% of Indonesia's TFEC by 2050 in the PES. Electricity consumption per capita reaches 4 187 kWh/person by the middle of the century.

Natural gas is consumed mainly by industry and grows on average by 3.4% to meet 10.4% of the country's energy demand by 2050 in the PES. Despite growing 3% annually, the coal and coke's share reduces from 9.6% in 2018 to 9.2% in 2050. The consumption of modern biomass is expected to triple by 2050, growing on average by 3.8% every year.

Indonesia's TFEC grows almost threefold by 2050, dominated by fossil fuel, whilst a transition under the 1.5-S reduces that demand by 23%

Figure 27 TFEC by source and end use, Indonesia, 2018-2050



TFEC in the TES and 1.5-S grows more slowly than in the PES due to high levels of energy efficiency and a carrier transition towards electrification. The TES and 1.5-S see annual growth in TFEC of 2.7% and 2.4% respectively. The transport sector continues to account for the majority of the country's energy consumption, despite growing at the slowest rate of 2% annually in 1.5-S, partly driven by electrification reducing overall energy demand growth in the sector. The buildings sector account for more than one-fifth of Indonesia's TFEC in 2050. The industrial sector grows by over 2.8% every year in 1.5-S, comprising 38% of energy demand in 2050. Energy demand in the TES is 11% above the 1.5-S by mid-century, as the latter deploys high levels of energy and material efficiency, and greater electrification of end uses.

The share of electricity in TFEC stands at around 17.6% today and expands to 40.4% by 2050 in the TES. In the 1.5-S more aggressive electrification drives the share of electricity demand to nearly half of TFEC in 2050. This is driven not only by increased electrification of energy services, such as electric vehicles, cooking and some industrial processes, but also by general trends towards high levels of space cooling and appliance use. Electrification of the transport sector also reduces gasoline consumption in the TES and 1.5-S. The demand for diesel in the TES slightly increases, whilst a higher electrification rate and greater biodiesel consumption in the 1.5-S result in a decreasing trend in diesel consumption by mid-century. The consumption of coal and coke in the 1.5-S reduces drastically, whilst demand for natural gas still increases, albeit more slowly than in the PES or TES.

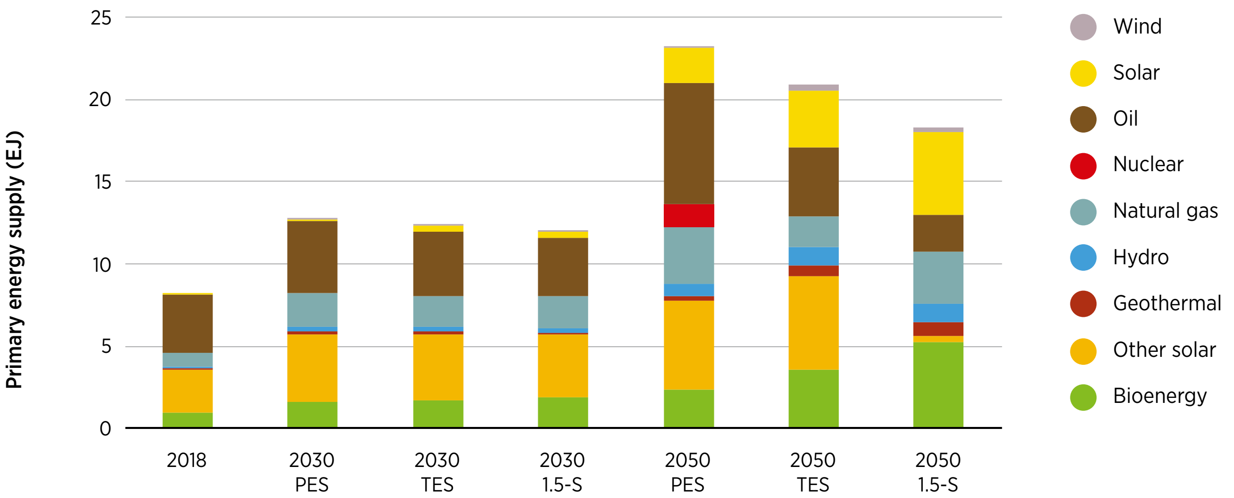
Indonesia's installed electricity generating capacity in 2018 was 62.3 GW, with renewables accounting for 15%. Indonesia's power system generated 283.8 TWh, with 17% of that being renewable.

Total primary energy supply

The share of renewable energy in Indonesia's total primary energy supply grows from 14% in 2018 to 70% in 2050 under the 1.5-S. This translates into more than elevenfold increase in absolute values, growing by 7.9% annually. Despite seeing a reducing share, coal and oil still account for over half of Indonesia's total primary energy supply in 2050 in the PES. Their share in the 1.5-S significantly decreases from 76% in 2018 to 15% in 2050. The share of natural gas grows from 10% in 2018 to 14.8% in 2050 in the PES. The growth seen in the PES is aligned with the aims of Indonesia's current energy policy, which is open to expand the use of natural gas but reduces oil's role in the country's primary energy supply.

The share of renewables in Indonesia's primary energy supply grows from 13% in 2018 to 23% in the PES and 70% in the 1.5-S by 2050

Figure 28 Indonesia's total primary energy supply, 2018-2050

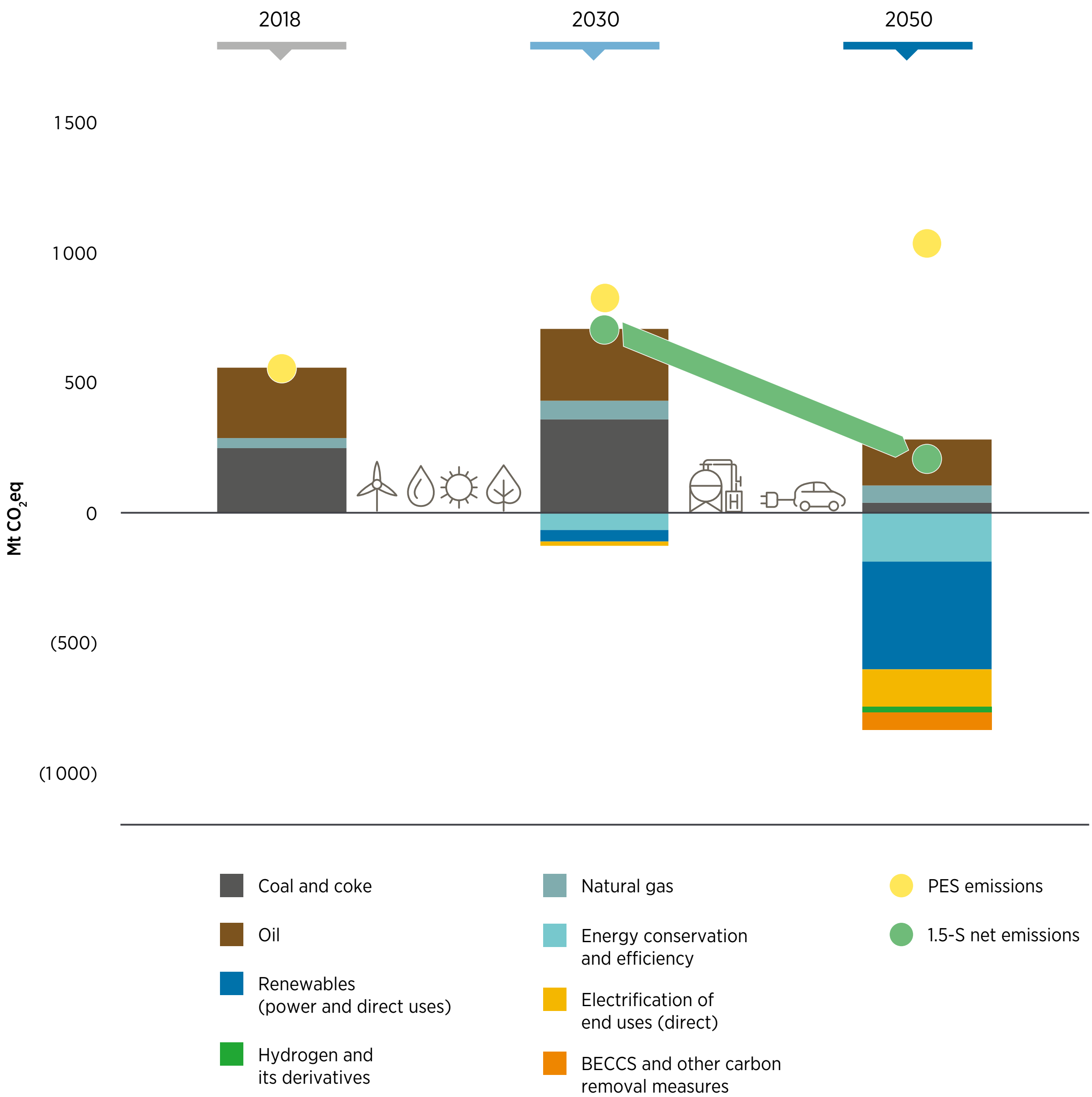


Energy-related emissions

Indonesia's total GHG emissions in 2019 was at 1 845 $MtCO_2eq$ (when considering CO_2 and GHG equivalent from outside the energy sector). Fossil fuel energy-related CO_2 emissions totalled around 550 $MtCO_2$ in 2018 (MOEF, 2021). With its update NDC submitted in 2021, Indonesia has updated its nationally determined contribution (NDC), aiming to reduce (compared to their own baseline energy projections) total emissions in 2030 to 1 953 $MtCO_2eq$ unconditionally or 1 632 $MtCO_2eq$ conditionally with international support (GoI, 2022). This outlook only focuses on energy-related CO_2 emissions.

Indonesia's emissions double under the PES, whilst reducing below today's level in the TES and the 1.5-S by 2050

Figure 29 Energy-related CO_2 emissions (positive y-axis) and reductions due to technology (negative y-axis), 1.5-S compared with PES, 2018-2050



Notes: Includes energy-related fossil fuel CO_2 emissions. Excludes non-CO_2 GHG emissions and CO_2 emissions from agriculture, bioenergy, LULUCF and waste.

The transport sector is projected to be the energy sector emitting the most emissions in the long term. This results from the sector's growth while still heavily relying on fossil fuel, despite the government setting aggressive electrification targets. Transport sector emissions almost double today's level in the PES by 2050, growing 2.7% per year. Despite energy efficiency efforts that aim to see the industrial sector's energy intensity reduce by 1% every year, reliance on fossil fuel will see its emissions grow rapidly at 3.2% per year in the PES. Buildings sector emissions, which are minor, increase in the short term, but decrease in the long term to equal today's level by 2050. Electrification and energy efficiency are the main drivers reducing the sector's emissions. LPG remains the building sector's highest emitter despite reduction in consumption. It is important to note that IRENA only assesses CO_2 emissions from energy, and Indonesia has large CO_2 and GHG emissions resulting from agriculture, LULUCF and waste. Bioenergy-related emissions are also not included in the totals presented for the buildings sector and can explain some of the discrepancy in the base year values.

Emissions in the TES and the 1.5-S grow slightly over the 2018 value in the coming decade, but then start to decline and consistently decrease in the late 2030s all the way to 2050. If the 1.5-S energy pathway is met, emissions in 2050 would be reduced by almost 80% compared to the PES.

The transport sector remains the highest CO_2 emitter in both the TES and the 1.5-S, contributing around half of Indonesia's total emissions in 2050. Industry makes up around one-third of the total emissions in both scenarios. These are emitted from the use of the remaining internal combustion engine vehicles, mainly large trucks, and shipping and aviation emissions, and the use of fossil fuel technologies in the industrial sector. Industry and transport emissions grow on average by 1% annually in the TES, whilst the implemented transformation strategies in the 1.5-S allow emissions in both sectors to fall below the 2018 value.

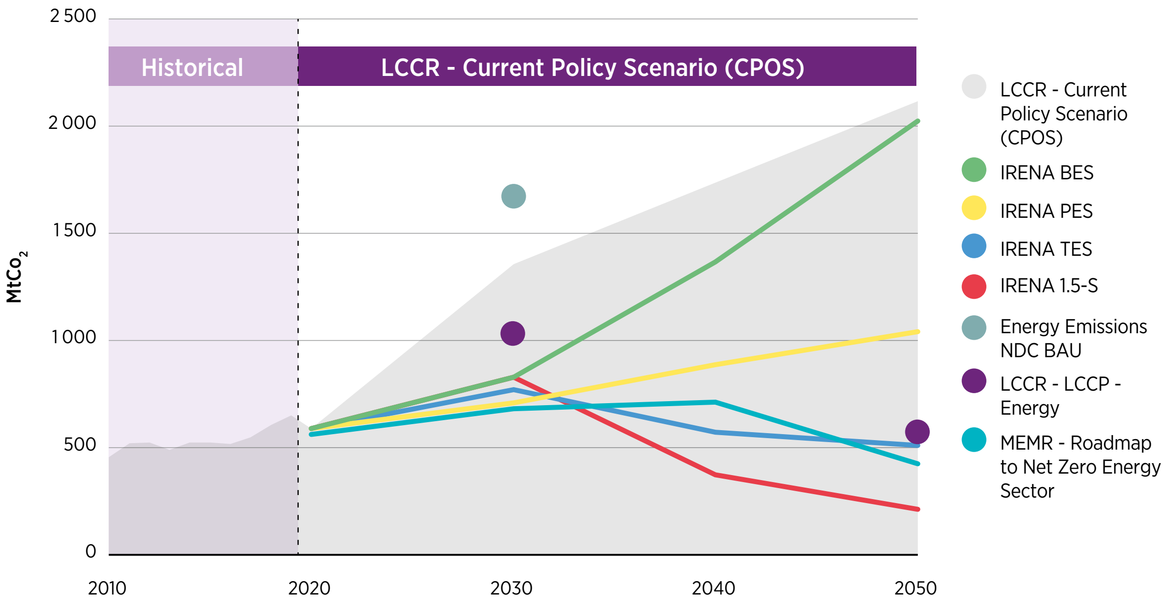
Under current national plans and targets, CO_2 emissions from the power sector are set to increase by 2030 in comparison to 2018 before decreasing slowly out to 2050. This aligns with PLN's plan for the power sector's emissions to peak by 2030 (PLN, 2021a). The near-term 70% increase in emissions by 2030 owes to the large expansion of the coal fleet over this period, which remains operational for the horizon of the study in the PES. However, by 2040 and 2050 emissions from the sector decline to be 33% above and 8% below 2018 levels respectively, which owes to the significant rollout of solar PV, nuclear and CCS, which primarily displace unabated coal in the generation mix. However, due the lingering emissions from coal and coal CCS generation, emissions intensity per kWh remains significant at 150 g CO_2 per kWh, emphasising how challenging it is to reduce emissions when relying on inherently emissive fuels.

Longer term, emissions from the power sector by 2050 at 190 Mt are only marginally below today's levels of about 206 Mt owing to aggressive demand growth and use of unabated coal and coal CCS to meet this growing demand. However, the TES and the 1.5-S pathways show how renewables can be deployed more aggressively to unlock a zero-emission power sector, which can be leveraged to reduce emissions across the whole energy system. However, the TES and the 1.5-S can reach zero emissions intensity by 2050 through the deployment of solar PV and expansion of national and international transmission capacity.

Box 7 Benchmarking IRENA analysis with net zero pledges and commitments

Indonesia's emissions have a wide range of possible future trajectories

Figure 30 Benchmarked emissions projection with net zero pledges and commitments, 2010-2050



Notes: BAU = business as usual; CPOS = current policy scenario; LCCP = Low carbon compatible with Paris; LCCR = Low carbon and climate resilience.
Source: IRENA analysis and from various sources (GoI, 2022, 2021c).

Indonesia's updated NDC, submitted to the UNFCC in July 2021, mentioned that the country has emboldened its climate commitment, targeting reductions of 29% (unconditionally) and 41% (conditionally, with international support) by 2030. The government's BAU projection leads Indonesia's energy sector emissions to reach 1669 Mt CO_2eq (an increase from around 650 Mt today), while the targets dictate that emissions from the energy sector will not exceed 1 355 Mt CO_2eq (unconditional) and 1 271 Mt CO_2eq (conditional) by 2030. Together with the updated NDC submission, Indonesia published its Long-term Strategy for Low Carbon and Climate Resilience (LTS-LCCR) 2050 document, presenting three scenarios, two of which are the current policy scenario (CPOS) that follows the unconditional NDC scenario, and the low-carbon compatible with Paris Agreement target (LCCP) scenario.

Benchmarking these projection values will be beneficial in drawing a picture of Indonesia's envisioned energy transition pathways for reaching net zero by 2060 or sooner. IRENA's 1.5-S aims for Indonesia to reach net zero as early as 2050. In this effort, energy sector emissions will need to constantly follow a downward trend to 199 Mt CO_2eq.

Buildings sector

KEY HIGHLIGHTS

The role of electricity will become more important in the future of the buildings sector, with space cooling dominating electricity consumption. The sector's final energy consumption more than triples by 2050 in the PES. Growth in the population, economy and floor area are the main drivers of buildings sector energy demand growth. Electrification and stringent energy efficiency implementation in the TES and the 1.5-S result in slower energy demand growth at 2.6% and 2.3% respectively.

Traditional biomass use is phased out entirely after 2025. Cooking activity is dominated by LPG in the current policy trajectory to the mid-century, whereas electric stoves dominate the cooking technology in both transformation scenarios

Buildings sector emissions peak in the 2030s in both the PES and the TES. The PES brings down the sector's emissions in 2050 on a par with current levels, whilst a 24% emission reduction is conceivable in the TES. The 1.5-S brings buildings sector emissions down in the short and long term, falling to 70% below today's level.

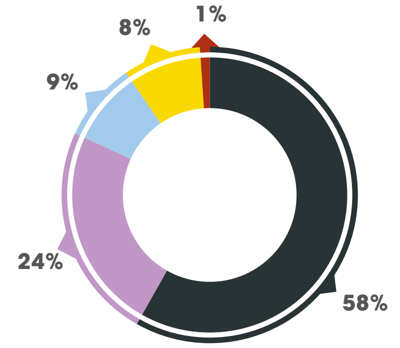
Residential buildings

With an increase in population and the economy, energy demand for residential buildings grow by 2.8% annually, consuming 2 392 PJ in 2050. The sector's energy consumption in 2018 is dominated by electricity at 431.7 PJ, of which space cooling and appliances are the main activity drivers. Space cooling penetration and ownership of electric equipment grows alongside GDP. And despite the government's effort to increase the minimum energy performance standard (MEPS) of residential air conditioners and other household equipment, by 2050 space cooling dominates the energy consuming activities of the residential sub-sector, comprising over 41% of total residential energy demand, whilst appliances make up 35%. Electricity consumption grows almost fivefold at a rate of 5.1% per annum until 2050.

In 2018 cooking dominated the residential sub-sector's energy consumption, with LPG as the most widely used fuel in the country as the result of government's programme of substituting kerosene with LPG stoves, supported with a subsidy programme aimed at low-income families. Overall, LPG meets 38.6% of residential total energy demand. The government has plans to reduce the LPG subsidy and initiate the e-stove programme, targeting the installation of 52 million e-stoves by 2060. This policy anticipates reducing residential LPG consumption to 2050 by 2.3% annually, to almost half of today's consumption. Furthermore, the city gas plan aims to connect 22 000 households by 2060. This effort should increase natural gas consumption from 11 PJ in 2018 to 98 PJ in 2050.

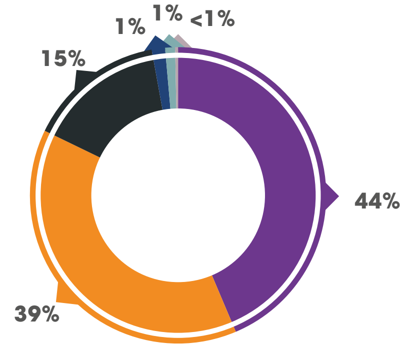
Cooking dominates the residential sub-sector, with LPG meeting almost 40% of its energy demand

Figure 31 Residential buildings energy demand, 2018



Demand by energy service

Cooking, Appliances, Space Cooling, Lighting, Water heating



Demand by energy carrier

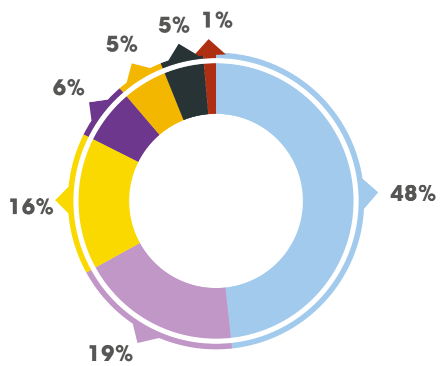
Electricity, LPG, Charcoal, Kerosene, Natural gas, Fuel Wood

Commercial buildings

The commercial sub-sector is expected to grow very rapidly at 5.7% annually in the PES. The sector consumed 253 PJ in 2018, with demand projected to expand almost sixfold over the next 30 years. The sector is heavily dominated by electricity, accounting for 223 PJ in 2018. Space cooling consumes 48% of this electricity. Appliances and lighting consume 34%, while lighting takes the remainder. Cooking activity makes up less than 5% of commercial buildings energy consumption, which is mostly provide by LPG. Diesel is consumed mostly as motive power for back-up generators. Electricity consumption in commercial buildings grows rapidly at 5.7% per annum, driven mainly by the need for space cooling in the future. LPG plays a more important role in commercial sector's cooking activities, growing at over 6.5% annually to reach 53 PJ by 2050.

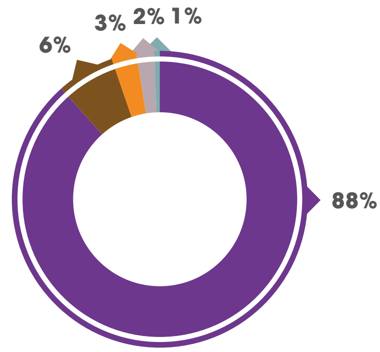
The commercial sub-sector is dominated by electricity, with space cooling accounting for half of the sector's energy demand

Figure 32 Commercial buildings energy demand, 2018



Commercial By Energy Service

Space Cooling, Appliances, Lighting, Motive power, Public lighting, Cooking, Water heating, Water/Wastewater



Commercial By Carrier

Electricity, Diesel, LPG, Fuel Wood, Natural gas

Traditional biomass will be completely phased out before 2025, and the transition towards electrification becomes a trend

Table 6 Summary findings, buildings sector

BUILDINGS SECTOR	2018	2030 PES	2030 TES	2030 1.5-S	2050 PES	2050 TES	2050 1.5-S
TFEC (PJ)	1 242	1 663	1 496	1 402	3 895	3 242	2 863
Renewables share (%) – incl. traditional biomass, fuels, excl. electricity	13	1	1.4	1.8	1	1.9	3.1
Renewables share (%) – incl. traditional biomass, fuels and electricity	23	17	26	26	51	67	87
Solar thermal (PJ)	-	-	1.3	2.5	-	8.7	17.3
Electricity share in buildings (%)	53	67	67	70	80	88	93
Clean cooking (%)	77	86	100	100	91	100	100
Electric stoves (million units)	7	19	29	36	46	56	72
Solar water heaters (million units)	-	-	0.045	0.1	-	0.4	0.9
CO_2 emissions ($MtCO_2eq$)	27	33	29	25	27	21.5	7.9

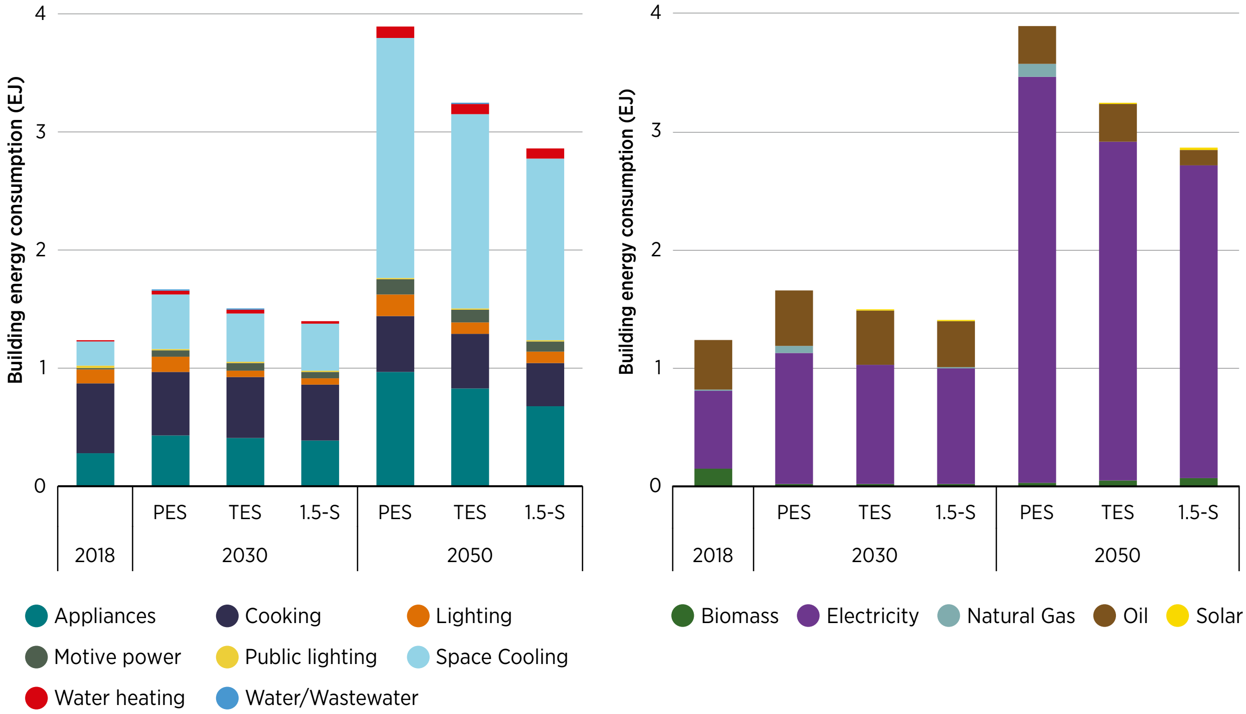
In the PES, building sector energy consumption triples, driven by the total floor area reaching almost double today's value in 2050 and increases in electricity demand due to space cooling and appliances. Electricity dominates the sector, growing from half of the sector's TFEC in 2018, to almost 90%. Demand for space cooling and appliances increases rapidly, whereas that for cooking decreases as the transition to efficient cooking technology is implemented.

Energy efficiency is key to enabling the 1.5-S, reducing the sector's energy intensity (which measures the amount of energy consumed in the sector per unit of floor area) by one-third in 2050. Electricity continues to play a critical role, reaching more than 736 TWh by 2050, over a sixfold increase in the sector, driven not just by the wider adoption of electrical appliances, but also the significant electrification of heat and growth in cooling demand and electric cooking. The role of small-scale solar thermal systems increases particularly in commercial buildings and higher-income households, as the system can be built and backed up by an electric boiler.

Cooking is significantly transformed in the 1.5-S. The electrification of cooking increases, whereby 90% of cooking needs are met through electricity in 2050. The transformation will need to go hand in hand with providing stable electricity access to the entire population. Buildings sector emission in the TES increase slightly in the short term until 2030, and then decrease towards 2050, falling below today's level. Meanwhile, the 1.5-S sees emissions in the sector consistently decrease from the start, reaching less than one third of today's level by 2050.

Trend of energy demand growth by scenarios, broken down by activities and carrier type

Figure 33 Buildings sector energy consumption projection by activity and carrier, 2018-2050



Box 8 Clean cooking

Table 7 Number of villages by type of cooking fuel used by majority of families and availability of agent/seller of fuel, 2014 and 2018

		2014	2018
COOKING FUEL	**City Gas**	88	115
	LPG	41 747	59 106
	Kerosene	4 278	2 979
	Firewood	35 831	21 710
	Others	246	21
	Total	82 190	83 931

Source:(BPS, 2019).

Access to clean cooking is still something Indonesia is working on. In 2010 an estimated 24.5 million households, 40% of Indonesia's total, used firewood as their main source of cooking energy (ASTAE, 2013) A kerosene-to-LPG conversion programme, launched by the government in 2007, has succeeded in making LPG the dominant cooking fuel in the country, replacing kerosene. In 2018 almost 25 000 villages in Indonesia relied on kerosene and fuel wood for cooking, a reduction of almost 40% compared to 2014 (BPS, 2019). Despite a substantial increase in Indonesia's access to clean cooking, the latest The Energy Progress Report tracker statistics show that only 84% of Indonesians had access to clean cooking in 2020 (IEA, IRENA, UNSD, World Bank, WHO, 2020). The use of fuel wood is completely phased out after 2025 in the 1.5-S, where over the long term, electric stoves cover 90% of cooking needs in the country, with LPG covering the remaining 10%.

Box 9 Space cooling

Space cooling is the main driver of the buildings sector's energy consumption into the future. Rapid market growth will increase space cooling penetration in the residential sector from around 8.4% in 2018 (BPS, 2020) to 48.9% by 2050, with the average household owning two air-conditioning units. Space cooling is responsible for 32% of the buildings sector's electricity consumption in 2018. Yet it dominates the sector's total electricity demand in 2050, consuming up to 60% in both the PES and the 1.5-S.

The Decision of the Minister of Energy and Mineral Resources No.113/2021 on Minimum Energy Performance Standards and Energy Efficiency Labels for Air Conditioners was adopted in 2021, regulating across a wide scope that includes the products, exemptions, test methods, design of the energy efficiency label, energy efficiency rating criteria and MEPS.

This regulation covers air-conditioning units with the HS Code 8415.10.10 or amendments thereto: single-split wall-mounted air conditioners of inverter or non-inverter type with a maximum cooling capacity of 27 000 British thermal units per hour. There is no MEPS regulation for large commercial air-conditioning units in Indonesia. One of the main reasons is that testing facilities for large units are currently not available in the country, while commercial space cooling is typically tailor made specifically to meet the building's cooling demand.

The rising demand for space cooling service and thus energy is handled in the TES and the 1.5-S on the assumption that all units sold increasingly adopt the highest efficiency standards, while in concert the electricity powering those units is increasingly from renewable sources or other low-carbon sources.

Transport sector

KEY HIGHLIGHTS:

The road vehicle fleet is projected to double from today's level by 2050, driven mainly by economic growth. The car fleet grows most rapidly as more families move into the middle-income bracket. Road freight transport grows as a result of road infrastructure development by the government. The bus fleet is the third fastest growing as the country encourages greater use of public transport.

Electrification is the most viable transition pathway to decarbonise the transport sector. In the 1.5-S, it is projected that 82% of all road vehicles will run on electricity by 2050. A decarbonised road transport sector sees electric vehicles account for over 90% of light-duty vehicle sales and one-tenth of truck sales by 2050, supported by the provision of over 16 millions charging stations (including private chargers).

Biofuel plays an important role in decarbonising hard-to-electrify heavy-duty transport, mainly long-haul heavy trucks, domestic shipping and aviation. Total liquid biofuel demand grows over 13-fold despite massive electrification in the transport sector.

Electrification of light-duty vehicles and utilisation of biofuel for heavy-duty vehicles are the key to decarbonising Indonesia's transport sector

Table 8 Summary findings, transport sector

				2018	2030 PES	2030 TES	2030 1.5-S	2050 PES	2050 TES	2050 1.5-S
TRANSPORT SECTOR	ENERGY TRANSITION COMPONENTS	ENERGY CONSERVATION AND EFFICIENCY	**TFEC** (PJ)	2 844	4 059	3 999	3 842	7 592	6 040	5 420
			Energy intensity (GJ/USD)	2 966	2 729	2 689	2 583	2 018	1 606	1 441
		ELECTRIFICATION IN END-USE SECTORS (DIRECT)	**Electricity share in transport** (%)	< 1	1	4	6	3	19	28
			Electric cars (million vehicles)	-	0.7	3	5	4.2	51	58
			Electric cars – penetration rate (%)	-	3	11	19	6	70	80
			Electric two- and three-wheelers (million vehicles)	-	13	20	26	47	128	144
			Electric two- and three-wheelers – penetration rate (%)	-	10	16	21	29	80	90
			Charger installations (millions)	-	0.15	0.8	1.3	0.5	13.0	16.4
		RENEWABLES (DIRECT USE)	**Renewables share** (%)	6	17	19	22	15	22	36
			Renewables share (%) incl. electricity	6	17	21	24	18	34	42
			Biodiesel blending rate (%)	20	30	30	40	30	50	80
	EMISSIONS		**CO_2 emissions** ($MtCO_2eq$)	237	234	218	195	433	250	137

The transport sector makes up the largest share of end-use energy demand in Indonesia. Road transport accounts for 90% of the sector's energy consumption. By 2050 most households are projected to own one car and two motorcycles, leading the sector's energy demand to grow at 3.1% annually.

Gasoline and diesel dominate today's fuel demand, and this remains consistent heading towards 2050 in the PES. Road freight activity is expected to grow rapidly as a result of the road infrastructure expansion planned by the government to improve the country's connectivity. As a result, diesel consumption grows by 2.6% annually. The government's B30 mandate will see the biodiesel share reach 9% of the sector's total energy demand in the next 30 years. Despite growing more than doubles by 2050, driven mainly by use in two- and three-wheelers and cars, gasoline share in transport total final energy consumption decreases from 59% in 2018 to about 45% in 2050.

Electricity use grows exponentially (from very low levels today) due to an increasing fleet of electric vehicles (EVs) by mid-century. The government's accelerated EV programme envisions 12 million electric cars being operational by 2050 and 13 million e-motorcycles by 2030. In 2020 the Ministry of Energy and Mineral Resources set a target for the provision of over 2 400 public charging stations and up to 10 000 public battery swap stations to support the EV development of the country(MEMR, 2020). In addition to this, the Ministry of Transport has developed a National E-Mobility Plan, with a target of 100% electrified urban mass public transport for Indonesia's large cities in by 2040.[8] To support this effort, President Joko Widodo inaugurated Indonesia's first EV battery plant in September 2021.

Vehicle growth will be substantial

Table 9 Vehicle stock growth (millions unit) by mode

	2018	2030	2050
Two- and three-wheelers	106.6	124	160
Car	15	27	73
Microbus	1.5	1.8	2.4
Bus	0.7	0.9	1.3
Small truck	4	7	17.6
Large truck	0.7	1.3	3.1
Total (unit)	**128.5**	**162.1**	**257.7**

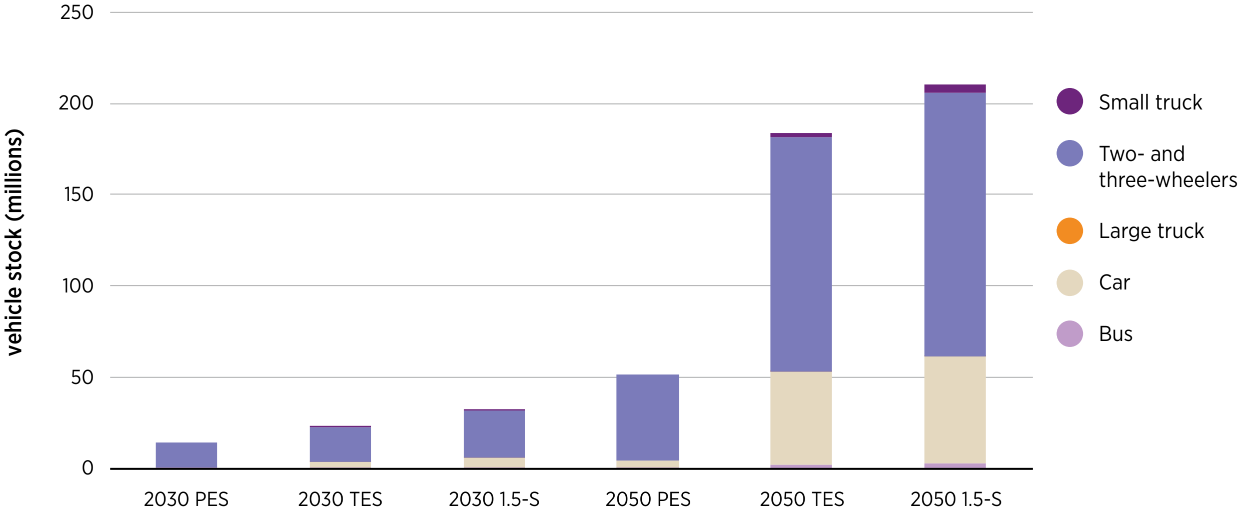
Consuming 2 844 PJ in 2018, transport sector energy demand grows on average by 3.1% annually until 2050 in the PES. Transformation in the sector will see the energy demand reduced by 20% and 29% in the TES and the 1.5-S, respectively, due to rapid growth in EV numbers and improved energy efficiency in road vehicles. Total transport emissions increase slightly in the short term to 2030, and then consistently decrease to 70% below PES levels in 2050 in the 1.5-S.

[8] *Input from Ministry of Transport Indonesia during Transport sector Expert's consultation workshop 30 Sept 2021*

Accelerating the adoption of EVs for road transport, in parallel with decarbonisation of the power supply, is the single most important lever for the decarbonisation of the transport sector. Developing integrated electric charging infrastructure is a key factor in enabling the electrification of the transport sector. The 1.5-S results in two- and three-wheeler sales being 100% electric by 2040, with car sales following suit by 2050. Technological progress – notably, the evolution of batteries supported by development of the EV battery industry – will greatly improve the economic case for EVs in Indonesia's energy transition future.

EV numbers must grow rapidly to achieve a decarbonised future transport sector

Figure 34 EV growth projection



In the 1.5-S EVs dominate, accounting for 82% of total vehicles on the road by mid-century. Electric models account for 90% of the total two- and three-wheeler fleet on the road. In the bus fleet, 70% is electrified in 1.5-S by 2050, while large electric trucks and small electric trucks account for 10% and 30% of total of each vehicle type. The decarbonised road transport sector sees over 90% of light-duty vehicles and one-tenth of truck sales by 2050 being electric. Along with this deployment of EVs, significant growth in charging stations is needed. In 1.5-S by 2050, over 16 million EV charging stations (including private chargers) are found across Indonesia.

The adoption of stringent efficiency standards for these new transport modes, along with behavioural changes, is crucial. Investment in this area, including vehicle scrappage and end-of-life schemes, are among the most important actions needing to be implemented to ensure a smooth transition to a highly efficient future transport sector. The role of biofuel is clear, especially in decarbonising the heavy-duty transport sector such as large trucks, domestic inter-island shipping and aviation. Hydrogen is expected eventually to play a role in transport sector transformation, especially for international shipping and bunkering, albeit with a more limited role for domestic transport.

Box 10 International bunkering for maritime transport

Situated in one of the world's busiest trading routes, Southeast Asia currently serves almost a quarter of the bunkering fuel market for international shipping. Indonesia currently provides about 0.1% (12 PJ) of the ship bunkering market globally, and 0.7% (63 PJ) of the international aviation fuel market(IEA, 2021b). Future energy demand is expected to grow by 40% in both sectors by 2050.

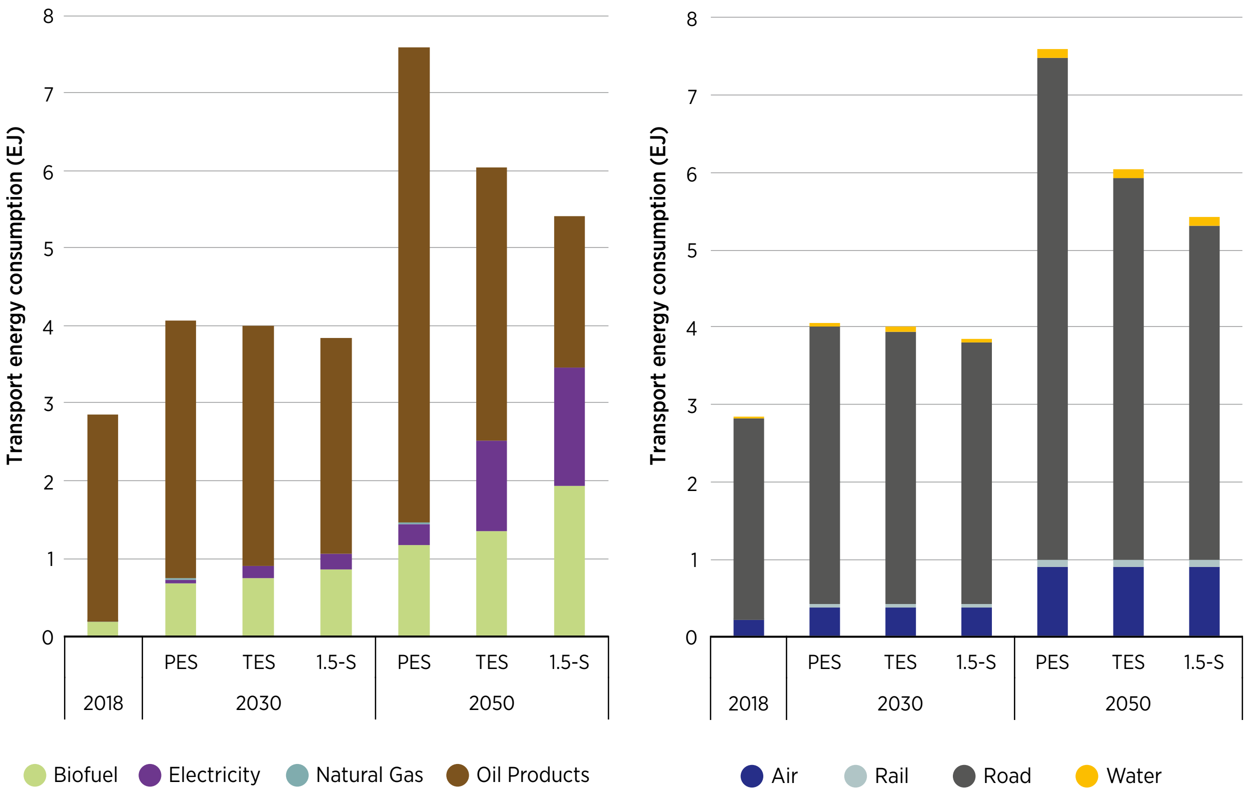
Box 10 International bunkering for maritime transport (continued)

The 1.5-S proposes that by 2050, 60% of all fuel needed for international shipping will be from hydrogen and its derivatives, including ammonia and methanol, with demand in Southeast Asia alone reaching 1 060 PJ by 2050. Therefore, there is an opportunity for Indonesia to capture a larger market share either by providing bunkering fuels or exporting hydrogen from its excess renewable energy-based electricity.

For international aviation, the 1.5-S aims for around 54% of aviation fuel coming from biokerosene and 27% from synthetic kerosene by 2050, for which annual demand combined would reach 1100 billion litres by 2050 in Southeast Asia. Indonesia participates in the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), aimed at reducing emissions in the sector. Cross-country collaboration and partnerships in developing the sustainable aviation fuel (SAF) supply chain for the region are a crucial next step in the coming decade, given Indonesia's vast bioenergy potential.

Oil products still play role in Indonesia's transport sector, mainly for heavy-duty road vehicles, as well as domestic shipping and aviation

Figure 35 Transport sector energy consumption projection by mode and carrier, 2018-2050



Industrial sector

KEY HIGHLIGHTS

Industrial sector energy demand grows by 3.6% annually in the PES despite the government's target of reducing energy intensity by 1% annually. The sector's increasing energy demand is mainly driven by economic growth and activity growth in many industry sectors. Carrier and technology transitions, as well as energy efficiency improvements, see energy demand in the TES and the 1.5-S grow more slowly at 3.3% and 3% respectively.

Electricity and biomass play an important role in the industrial sector. The share of electricity increases to almost half of the sector's energy demand in the 1.5-S. Biomass demand in the PES triples compared to 2018 levels by 2050, while in the 1.5-S biomass demand doubles that the PES, equivalent to four times today's levels.

Industry will require a diverse range of technologies, from bioenergy to electrification, to hydrogen, circular economy and other efficiency measures, and some level of CCS.

Indonesia's government has committed to encouraging the development of the industrial sector to improve the country's economy. The sector's total added value is projected to continue growing at 6.6% annually up to 2030, before slowing to an average of 3.7% to 2050. Indonesia's industrial sector is dominated by eight energy-intensive sub-sectors, which account for 70% of its TFEC. Among these, cement, iron and steel, chemicals, and pulp and paper were responsible for more than 36% of the industrial sector's emissions in 2018.

Driven by rapid modern infrastructure development, iron and steel and cement production are growing on average at 3.7% and 4.8% per year, respectively. Indonesia's utilisatiorate which measures the percentage of potential output levels that is being achieved, remained below 50% in 2019 due to the dominance of imported steel in the market (IISIA, 2021).Many of Indonesia's steel industry players are expecting steel imports to be suppressed through the revision *of Minister of Trade Regulation (Permendag) No. 110/2018, Provisions on the Import of Iron or Steel, Alloy Steel, and its Derivative Products*, otherwise the local steel industry cannot grow and the country will continue to be dominated by imported products. Indonesia's cement industry is classed as emerging, together with the Philippines, and behind the more mature countries of Thailand and Malaysia. Semen Indonesia and PT Indocement Tunggal Prakasa, which is the member of HeidelbergCement, are the leading producers, accounting for a total market share of about 70% (CemNet, 2020). The residential sector continues to be the largest consumer of cement in Indonesia.

The chemical sector is projected to grow almost six-fold by 2050, mainly driven by the methanol and ammonia that are used in the petrochemical and fertiliser industries. Indonesia's pulp industry ranks eighth in the world and third in Asia, whilst its paper industry ranks fourth in Asia, only behind China, Japan and India. Biomass is currently the most dominant energy carrier in the sector, and the 1.5-S sees the pulp and paper sector's energy mix continue to comprise electricity and biomass as the only two carriers used by 2050. Indonesia's pulp and paper industry continues to grow on average by 2.2% to 2050, reaching more than double today's annual production.

Considered as one of the key engineering materials in the future due to its light, durable and functional properties, the aluminium industry has potential to develop in Indonesia. Its application ranges across construction, the power sector, transport and even households due to its non-toxic characteristics. Indonesia's aluminium production is projected to grow threefold by 2050. The country has also announced a complete ban on the export of unprocessed minerals starting 2023, including tin, bauxite and copper, with nickel already banned from January 2020 (Nikkei Asia, 2022). The government's goal is to develop the downstream processing industry in the country and maximise returns and employment outcomes from its resources. Bauxite production in Indonesia is forecast to reach 28.5 Mt by 2030.

Due to this rising level of industrial production, industrial sector energy demand grows by 3.4% annually in the PES, reaching 5 984 PJ in 2050. This occurs despite the government's target of reducing the sector's energy intensity by 1% annually. The industrial sector relies heavily on natural gas and coal to meet the demand for process heat activities. Natural gas accounted for 29% of the sector's TFEC in 2018, while coal and coke accounted for 28%. Biomass is also used to some extent, such as in the pulp and paper industry and in other industries with medium levels of energy intensity. Electricity comprises 21% of industrial sector energy consumption, mainly as the carrier for motors, compressed air and process cooling. Industry is still expected to rely on the fossil fuel to 2050 in the PES. Natural gas is projected to remain the dominant carrier in industry, growing by 3.9% annually. Despite growing by 3.2% annually, the share of coal and coke consumption decreases to 23%, whilst electricity increases its role, growing more than threefold to reach 1 362 PJ and covering 23% of industry's TFEC by 2050.

Electrification, renewable direct use and to some extent hydrogen play a role in decarbonising the industrial sector

Table 10 Summary findings, industrial sector

INDUSTRY SECTOR	ENERGY TRANSITION COMPONENTS		2018	2030 PES	2030 TES	2030 1.5-S	2050 PES	2050 TES	2050 1.5-S
	ENERGY CONSERVATION AND EFFICIENCY	**TFEC** (PJ)	2 163	3 871	3 805	3 670	5 984	5 653	5 179
	ENERGY CONSERVATION AND EFFICIENCY	**Energy Intensity** (GJ/USD)	5 944	5 357	5 224	5 093	4 382	4 062	3 764
	ELECTRIFICATION IN END-USE SECTORS (DIRECT)	**Electricity share** (%)	21	23	29	32	23	36	43

Table 10 Summary findings, industrial sector (continued)

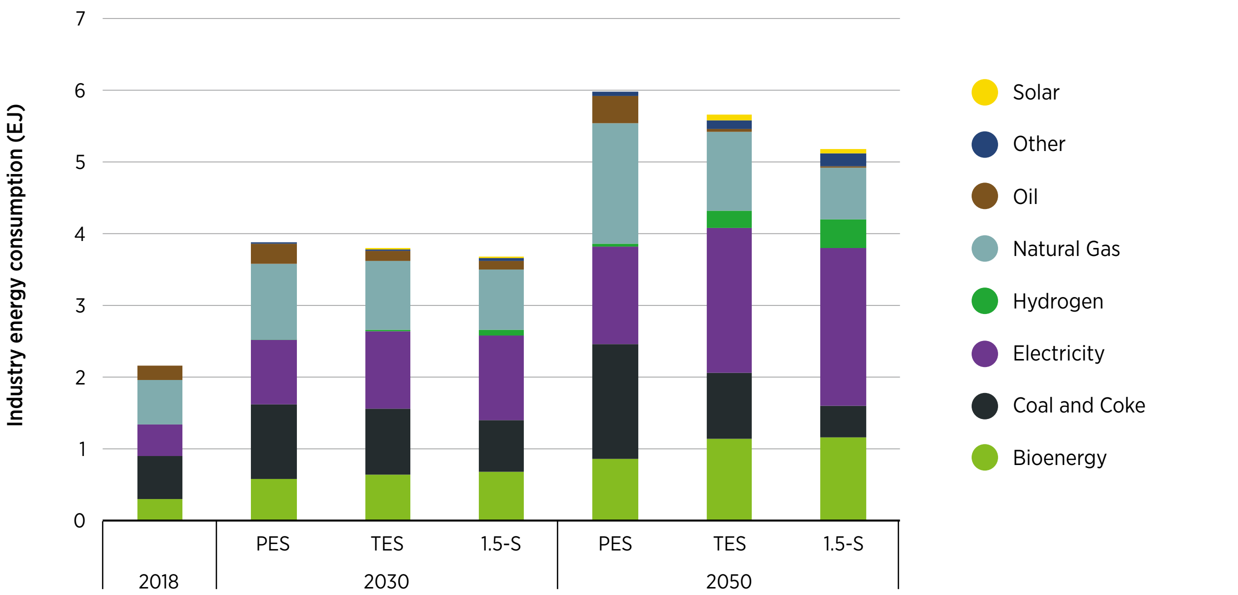
				2018	2030			2050		
					PES	TES	1.5-S	PES	TES	1.5-S
INDUSTRY SECTOR	ENERGY TRANSITION COMPONENTS	RENEWABLES (DIRECT USE)	**Renewables share** (%)	14	15	17	19	14	22	26
			Renewables share incl. electricity (%)	18	21	27	30	27	48	65
			Bioenergy (PJ)	298	573	634	667	862	1140	1155
		NON-ENERGY USE	**Consumption** (PJ)	157	351	351	351	849	849	849
		NATURAL GAS, NEU	**Consumption** (PJ)	157	351	338	317	849	722	510
		BIO-BASED FEEDSTOCKS +HYDROGEN &DERIVATIVES, NEU	**Consumption** (PJ)	-	-	12	34	-	127	341
	EMISSIONS		**CO_2 Emission** (Mt CO_2 eq)	107	180	152	126	276	152	83

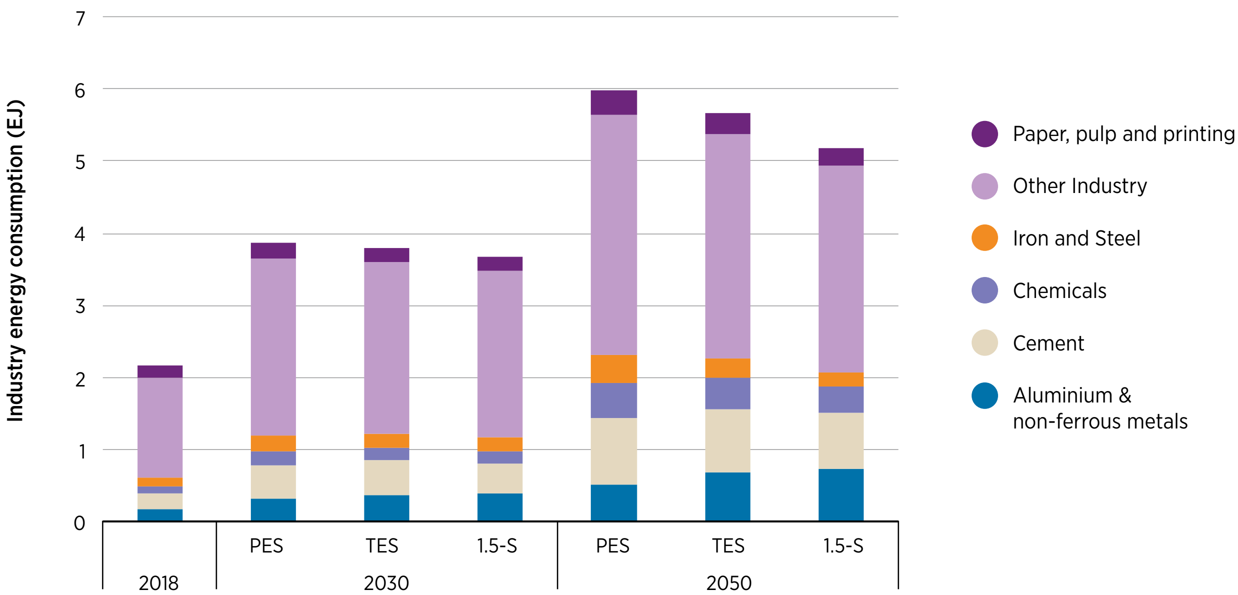
The technologies and measures deployed in the 1.5-S reduce overall emissions by 70% in 2050 compared to the PES. Reduced demand and improved energy and materials efficiency, alongside circular economy practices and structural changes, lead to substantial reductions in energy consumption by 2050 compared to the PES. Overall energy intensity in the 1.5-S and the TES decrease by 37% and 32% compared to today's level, respectively. Direct use of clean electricity (predominantly produced from renewable sources), as well as direct use of renewable heat and biomass (including solar thermal and biofuels), all increase. The direct electrification share rises from 19% in 2018 to 46% by 2050 in the 1.5-S.

Biomass plays an important role in meeting medium- and high-temperature heat requirements, as well as for chemical feedstocks, covering over one-fifth of industrial sector TFEC in 2050, increasing from 14% in 2018. Hydrogen starts to play a role beyond 2030, mainly in the iron and steel, aluminium and chemical industries, climbing to around 342 PJ by 2050 or 7% of industry TFEC. Total industry emissions increase slightly in the short term to 2030, consistently decreasing to below today's level by 2050 in 1.5-S. The TES sees the industrial sector's emissions continue to grow until 2050, albeit reaching only half of those in the PES by the mid-century.

As one of the hard-to-decarbonise sectors, the industrial sector still uses fossil fuel in the form of coal and natural gas in the 1.5-S by 2050, but at much lower levels

Figure 36 Industrial sector energy consumption projection by carrier and sub-sector, 2018-2050





The successful transformation of industry while maintaining competitiveness will require consideration of the full life cycle of activities, with a range of actions needed to decarbonise the sub-sectors (Figure 37).

Figure 37 Industry sub-sectors, key findings, for 1.5-S

Cement

- Reduce process emissions from conventional cement by enhancing use of additives and fillers, substituting for clinker up to 70% of cement content by 2050.
- Improve energy efficiency so that thermal specific consumption in clinker production declines from 3.5 GJ/tonne of clinker in 2018 to 3 GJ/tonne in 2050.
- Switch to renewable energy and alternative fuels as substitutes for conventional fossil fuels, with overall renewable energy share (incl. electricity) in the sector's TFEC increasing to about 76.5% by 2050 from only about 11% in 2018.

Iron and steel

- Transition the production technology from blast furnace to low-emission green hydrogen-based DRI and electric arc furnace-based steel production, which can be close to carbon neutral.
- Increase the renewable, hydrogen and electricity shares in the process.
- Hydrogen becomes the dominant energy source, providing a quarter of total energy demand in the sector. The share of electricity increases from 17% in 2018 to 23% in 2050.
- Enhanced circular economy practices along with the increased use of recycled scrap in electric arc furnace-based production.

Chemical

- Improve energy efficiency in the production process and substitute the remaining fossil fuel demand for process heat generation with renewables, electrification and other renewables-driven sources.
- Switch to biomass and synthetic feedstocks based on renewable "green" hydrogen and renewable CO_2.
- Shift power supply to carbon-free electricity, notably renewables.

Pulp and paper

- Improve the system's energy efficiency to reduce the sector's energy consumption by 30% and 14% respectively over the PES in 2050.
- Recycling processes will have a greater role in the industry in the future to reduce the energy demand of the sector.

Aluminium

- Introduce the use of hydrogen in production projecs.
- 100% carbon-free electricity is viable for a decarbonised aluminium sector, reaching zero emissions in 2050.

Box 11 Aluminium manufacturing

Indonesia produced 245 kt of aluminium in 2020 (around 0.4% of world production) (USGS, 2022a). The country's production of alumina feedstock amounted to 1.5 Mt in 2021 (1%), while bauxite mineral mining amounted to 18 Mt (5%) in the same year (USGS, 2022b). The Indonesian president has declared the importance of downstream mineral processing for Indonesia. In the past Indonesia supplied about 60% of China's bauxite imports, but new legislation has halted bauxite exports in a drive to increase national value added.

The production of aluminium is a highly energy intensive process. Modern smelters use around 13 500 kWh/t of aluminium (International Aluminium, 2022). Historically many smelters were placed next to hydropower plants to benefit from reliable low-cost renewable electricity. Around 1.5 GW of baseload power generation capacity is needed per Mt of annual aluminium production capacity.

Whereas Indonesia's aluminium production is not very significant at present, ambitious plans exist to develop new smelters, notably in North Kalimantan and Irian Jaya, as well as expanding the Guaradanjung North Sumatra smelter from 250 kt to 300 kt per year. A feasibility study with Emirates Global Aluminium is set to explore further expansion to 400 kt per year (The National, 2022). Inalum is planning a new 500 kt smelter in North Kalimantan. In addition, PT Adaro Aluminium Indonesia signed a letter of intent to invest USD 728 million in a smelter project to be built in the Green Industrial Park Indonesia in North Kalimantan province (which translates into 300 kt of aluminium per year) (Adaro, 2021; Wood Mackenzie, 2018). The goal is to supply a new solar panel industry and electric car manufacturing. PT Adaro's aluminium smelter will utilise renewable energy from a hydroelectric power plant with modern environmentally friendly construction standards, and a solar power plant.

Tsingshan Holding Group is planning to enter the field by building the new aluminium smelter in conjunction with Huafon Group. The firm operates an industrial park in Sulawesi, which is the smelter's planned location. Tsingshan would initially produce at a rate of 500 kt per annum by 2023 (Aluminium Insider, 2021). The preparation of feedstock is also slated for expansion. Antam intends to open a new alumina refinery in West Kalimantan with a 1 Mt/yr capacity in 2023. This would double national alumina production capacity (China Daily, 2021).

In conclusion, as aluminium production expands from 250 kt to around 1.5 Mt in the coming years, this will require around 2.5 GW of baseload power. More growth can be expected in the following years and decades. The ongoing investment in alumina production and smelting is in the order of USD 10 billion.

Box 12 Tackling hard-to-decarbonise sectors with CCS

Indonesia's end-use sector emissions in the PES grow almost twofold, growing by 1.9% annually to 2050. Despite a decreasing trend in the 1.5-S, whereby these emissions fall to 80% below those in the PES, Indonesia will still have residual emissions in 2050. The transport and industrial sectors are responsible the majority of Indonesia's total end-use sector emissions in 2050.

Carbon sequestration units could help capture process emissions in hard-to-abate sectors such as cement, iron and steel. Pilot projects could be deployed at scale with selective use of CCS in order to prove and test the technology and make it commercially available. Existing plants need to be retrofitted, whereas new plants must include CCS. As of early 2021, 24 commercial fossil fuel-based CCS facilities were in operation globally, with an installed capacity able to capture about 0.04 Gt/yr of energy- and process-related CO_2 emissions (IRENA, 2021b). Indonesia will need to learn from the successes and failures of CCS projects across the globe. Planning resources adequately and enhancing institutional skills are crucial steps in the process, as well as co-ordination to avoid bottlenecks along the value chain. The following will be crucial for CCS and bioenergy with CCS (BECCS) in Indonesia.

Box 12 Tackling hard-to-decarbonise sectors with CCS (continued)

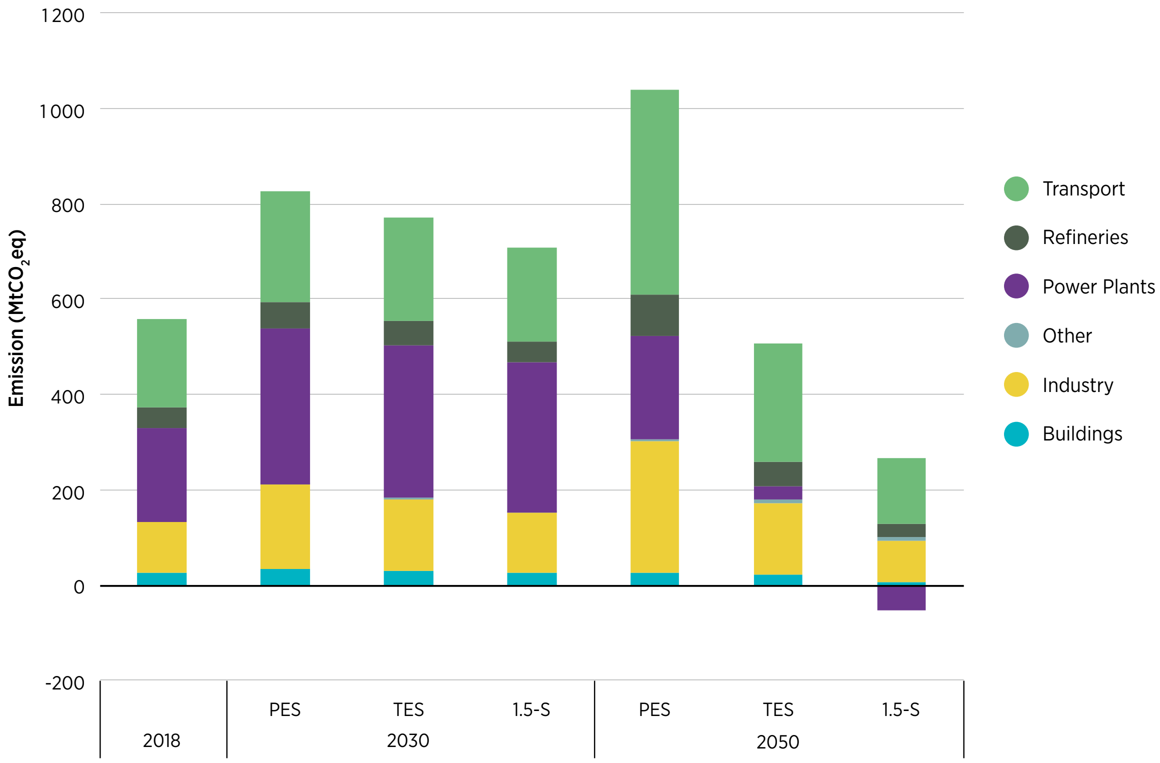
A legal and regulatory framework for storage facilities must be set in place before planning a CCS facility. Overall project execution for CCS usually takes up to four to five years with several steps, such as pre-feasibility and feasibility studies (one to two years), licensing approvals (*e.g.* technical and environmental) and construction (three to four years). An example is the Greensand project in Denmark, which consists of three phases: appraisal, pilot (proof of concept) and full project execution. The appraisal phase took place in 2021 and the CCS facility is expected to be fully operational by 2025 (Ineos, 2021).

Global pipeline infrastructure to support long-term CCS deployment in the coming 30-40 years will need to be scaled up to 100 times what is currently available (Global CCS Institute, 2020). A shared transport and storage network might improve the economics of CCS facilities by reducing operational costs through economies of scale while addressing cross-chain risks

Alternative options to CCS and carbon capture, utilisation and storage (CCUS) include other carbon dioxide removal technologies and measures. These include direct air capture, afforestation and reforestation, enhanced weathering, and other measures. Whereas CCS and CCUS can be applied at the source of emissions, these other measures would need to be part of a larger carbon market allowing for carbon offsets and trading.

Fossil fuel consumption cannot be phased out entirely within the time horizon to 2050; CCS technology may be adopted to further decarbonise the sector

Figure 38 Energy-related CO_2 emissions, by scenario, 2030 and 2050



4.3 POWER SECTOR

KEY MESSAGES

As electricity demand could grow at least fivefold from today's levels out to 2050, how power generation capacity is expanded to meet this will be instrumental in national CO_2 emissions. If no action is taken, sector emissions could rise from 200 Mt today to nearly 1 000 Mt by 2050.

The concentration of electricity demand in Java has a key role in shaping the future power system, with well over 60% of electricity demand situated there and limited land availability. Transmitting power from generation sources to demand centres will require considerable expansion of national transmission capacity across the Indonesian archipelago.

Indonesia has a vast wealth of renewable energy resources, key among them being solar PV at an overall potential of about 3 TW. How and where these resources are developed will need integrated planning in distribution, transmission and generation capacity so that they can be effectively and meaningfully unlocked in a high renewables pathway.

To achieve a highly renewable pathway, renewable energy projects need to be identified and prioritised under national expansion planning and be bankable. Existing power purchase agreements (PPAs) for coal units, in particular, have the effect of disincentivising renewables, while "take or pay" contracts for natural gas generation have a similar effect of impeding renewable deployment. These issues hamper renewables expansion planning and are a barrier to renewables expansion and a coal phase-out.

Overview and scope

To be consistent with a climate-compatible world, the electricity sector will have to be thoroughly decarbonised by mid-century across the ASEAN region. Whether or not that happens will depend on accelerating the deployment in power generation of all forms of renewable energy technologies – wind (onshore and offshore), solar PV, hydropower, biomass and geothermal energy, among others. Wind and solar PV lead the transformation, supplying up to 17% of total electricity generation by 2030 and 64% by 2050 (from under 1% today).

Indonesia's power sector is a key source of emissions and spans over 16 000 islands. Its operation is integrated to varying degrees across the archipelago through an electrical interconnection system. The predominance of coal-fired generation means the power sector has high carbon intensity and is responsible for the largest share of national energy sector emissions. The expansion of coal generation over recent and coming years means that the emissions intensity of electricity has been and will continue to be on an increasing trend. As the largest country and power sector in South East Asia, the scale of Indonesia's emissions also mean that it is pivotal player in total regional emissions and will be central to any regional emissions reduction pathway.

Achieving decarbonisation goals in a climate-compatible pathway will require higher levels of electrification across the energy system combined with increased penetration of renewables. However, measures designed to achieve such goals must also have security of supply, affordability and environmental considerations at their heart, as outlined in the three key sustainability pillars developed by PLN, the national vertically integrated utility company responsible for generation, transmission, distribution and retail.

Indonesia has two specific power sector goals. The first, in line with the national net zero by 2060 goal, is a planned peak in power sector emissions of 349 Mt CO_2 by 2030. The second focuses on the share of renewables in primary energy of 23% by 2025, from which a 45 GW renewable energy target was set for power capacity. The target is 45 GW by 2025 as part of Kebijakan Energi Nasional (KEN), a strategy that was adopted in 2014, with targets out to 2050.

Indonesia has significant resources of both fossil fuels and renewables, but the vast majority of the renewable energy potential remains to be developed. Indonesia has very significant reserves of coal, oil and gas, with much of it exported and contributing significantly to GDP. To date, the key renewables in the power sector have been geothermal and hydropower, with very little development of novel renewables such as wind and solar PV, of which there were approximately 150 MW installed nationally in 2020. Additionally, bioenergy plays quite a minor role, with just under 2 GW installed in 2020 of its 43 GW potential, which implies significant scope for growth. The renewable energy potential used in this study can be seen in Table 11.

Indonesia's renewable energy potential massively exceeds current deployment.

Table 11 Renewable energy potential of Indonesia

		TOTAL POTENTIAL	TOTAL INSTALLED CAPACITY 2021	SHARE DEPLOYED IN 2021
RENEWABLE ENERGY	**Total**	**3 692 GW**	**10.5 GW**	**0.3%**
	Biomass	43.3 GW	1.9 GW	4%
	Geothermal	29.5 GW	2.1 GW	7%
	Hydro	94.6 GW	6.1 GW	6%
	Ocean	17.9 GW	0 GW	0%
	Offshore wind	589 GW	0 GW	0%
	Onshore wind	19.6 GW	0.2 GW	1%
	Solar	2 898 GW	0.2 GW	0%

Source: see text.

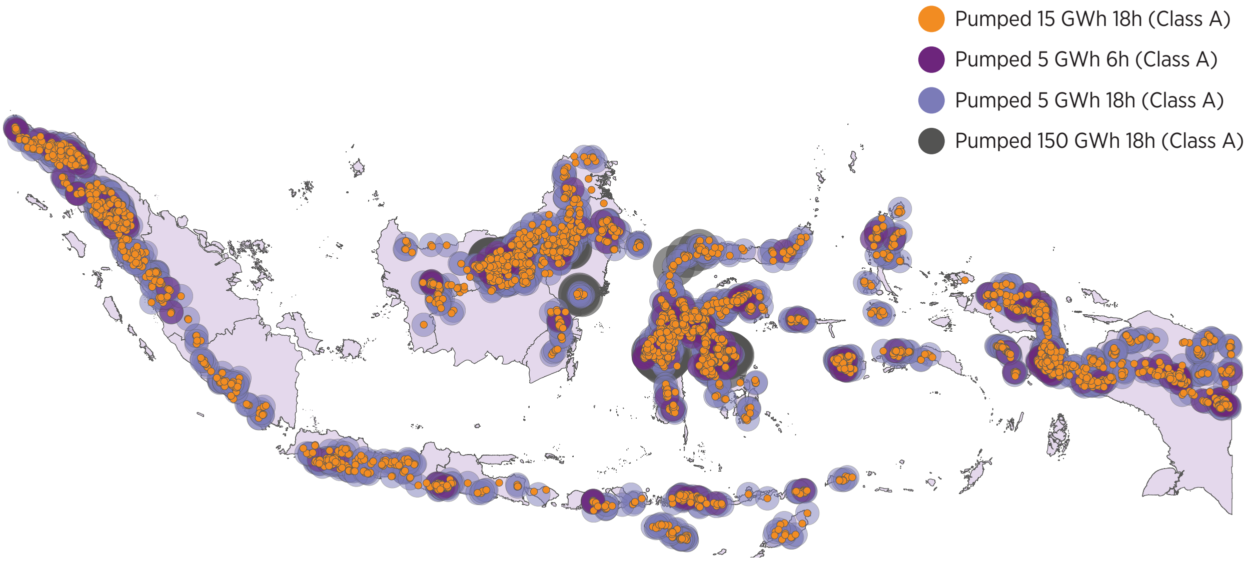
Renewable energy resource potentials used for bioenergy, hydropower and geothermal in this analysis were derived from a range of published reputable national and international studies (DGE *et al.*, 2021; Handayani *et al.*, 2022; IRENA, 2022c). Given the seasonality of hydropower, its generation pattern varies in each country across the year. Thus, the model was calibrated in this regard based on best available data which was either provided by national bodies or extracted from the PLEXOS World model (University College Cork, 2019).

However, to determine the solar and wind energy potentials, an analysis was performed using a geographic information system search engine with extraction layers to determine these potentials and their hourly generation profiles for five different classes each respectively of resource quality using the methodology outlined in (IRENA, 2022d) and using a range data sources (Amante and Eakins, 2009; Amatulli *et al.*, 2018; Friedl *et al.*, 2010; Gao, 2017; IUCN *et al.*, 2022; Maclaurin *et al.*, 2019; Service (C3S), 2017). Given the scale of the resources, in particular solar, such a representation was crucial in understanding the role that they can reasonably play in the long-term expansion of the Indonesian power system by capturing the opportunities and challenges they have in terms of renewable energy integration. It was also important in understand how wind power in Indonesia can be expanded, despite the large national potential in some countries the quality of this resource and its location may make it too costly to effectively harness.

Indonesian islands such as Sumatra and Java have large interior mountains. This topography translates into numerous potentially suitable sites for building non-river-connected pumped storage facilities. Each pair of upper and lower reservoirs was defined based on GIS search criteria, which in turn were placed in order of estimated cost.[9]

Indonesia's pumped storage hydro is well-distributed and could be an invaluable flexibility resource.

Figure 39 Pumped storage potential in Indonesia (Class A resources)



Source: IRENA based on Global Pumped Hydro (ANU, 2022).

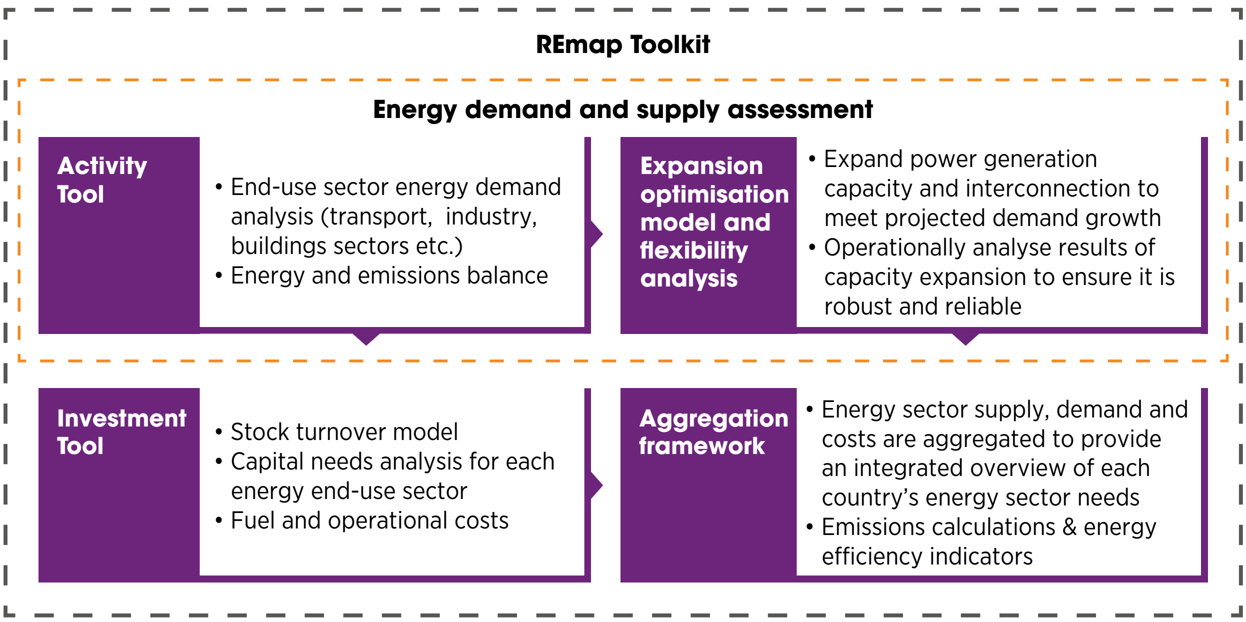
[9] *Class A reservoir pairs would be expected to cost around half that of Class E. Larger systems are generally more cost-effective than smaller systems. Source: Global Pumped Hydro Atlas (ANU, 2022).*

As the single buyer of power in the Indonesian power system, PLN procures power from its own assets, assets it has leased and independent power providers. Typically, the agreements underpinning the financing of these generation assets are rather inflexible and structured in such a way that the system operator has little incentive to move to new generation sources. This is because they are already effectively committed to paying for the cost of the existing sources regardless of the quantity of power procured. More specifically, contract structures are a potential limit on the renewable energy transition in the power sector given the widespread use of PPAs (coal units have a PPA structured in 5 tariffs where capacity quota is paid if availability of the plant [not the capacity factor] exceeds the agreed threshold [*e.g.* 85%]) and fuel supply contracts with very restrictive "take or pay" obligations (take-or-pay fuel contracts are mostly applicable to gas power plants in Indonesia). Many of these have the effect of locking in generation from CO_2-intensive sources and offer little incentive for them to vary their output to integrate variable renewable power or provide other ancillary services that may be required.

The methodological approach applied across this study seeks to deliver an assessment that meets the growing energy demand across the Indonesian archipelago whilst also delivering on several key regional goals in terms of emissions reductions, energy costs, energy security and energy access. To do so requires an integrated approach that spans the whole energy system of the region and captures the evolution of all energy end-use sectors such as transport, industry and buildings out to 2050 with high granularity (*e.g.* passenger transport, industrial process heat, building cooling and miscellaneous appliances etc.). This was achieved was by using the approach outlined in Figure 40, in which the energy supply and demand assessment composed three separate modelling activities 1) Activity-level demand assessment; 2) capacity expansion of the power sector and 3) operational flexibility analysis of the power system. This enabled the power system to be expanded based on the understanding gained of how energy demand will evolve and what levels of electrification of these energy demands can be achieved whilst maintaining reliable operation of the system. This in turn enabled a tailored capacity expansion to be developed to deliver emissions and energy cost reductions whilst bolstering energy security and access, largely through increased deployment of renewables across Indonesia and ASEAN in an operationally robust power system.

IRENA's REmap consists of many intercorrelated analyses

Figure 40 REmap Toolkit overview and power sector models



For the power sector the analysis consists of two key parts: a long-term capacity expansion analysis for all scenarios of energy demand resulting from the activity tool assessment with a view to capturing a broad range of possible power system developments out to 2050; and, an operational assessment of these scenarios for power system flexibility. In the case of this study, both the long-term expansion and short-term operational flexibility analyses were performed using an industry-standard modelling tool, PLEXOS.

The power system's long-term expansion was guided by two key questions:

1) What is the role of national and regional integration in unlocking the potential benefits of a joint energy transition strategy?

2) What is the role of various technologies in achieving a highly renewable and low-carbon power sector?

The answers to these questions depend on the energy demand scenarios considered and wide-ranging assumptions in the power system expansion modelling. Scenarios such as BES and PES were designed to best represent "business-as-usual" and best available national plans, respectively. While TES strives to deliver higher renewable and decarbonisation ambition than BES and PES, and three 1.5-S cases (an 85%, 90% and 100% renewable power generation case) expand on this with a focus on deeper decarbonisation in designing power system technology pathways that can deliver a climate compatible future for Indonesia. The rationale for capacity expansion analysis is shown below in Table 12 which spans five pillars.

Many factors need to be considered for proper long-term power sector modelling

Table 12 Guiding considerations and motivations behind long-term power sector simulations

SCENARIO	BES/PES	TES	1.5-S RE85	1.5-S RE90	1.5-S RE100
Guiding questions and considerations	Existing pipeline of renewable energy projects in each country	What is the implication of not expanding fossil fuel? Is it technically feasible? Is it economical?	Between renewables and nuclear – which is more competitive?	Between renewables and CCS – which is more competitive?	How feasible is it to push further toward 100% renewable generation?
	Fossil fuel expansion based on national plans	Which countries are affected and why?	How challenging is it to deploy additional renewables and to deploy nuclear?	How challenging is it to deploy additional renewables and to deploy CCS?	What are the key factors that affect the technical feasibility and what are the infrastructure needs?
	Limited exchange between market players – countries based on a conservative scenario in the ASEAN Interconnection Master Plan (AIMS)	Which technologies take the role of the fossil expansion?			What are the additional investment needs? Is it economic and is it operationally robust?

Table 12 Guiding considerations and motivations behind long-term power sector simulations (continued)

SCENARIO	BES/PES	TES	1.5-S RE85	1.5-S RE90	1.5-S RE100
Motivation	To demonstrate what can be achieved under current plans with the existing framework, endowment and enabling environment for renewables (PES) or none at all (BES)	To analyse how regional and national systems are affected by an increase in renewable ambition and identify the technical and non-technical barriers that need to be overcome in achieving this	To demonstrate how a climate-compatible and/or highly renewable future can be achieved whilst considering renewable and nuclear technologies	To demonstrate how a climate-compatible and/or highly renewable future (90% renewables in power generation) can be achieved whilst considering renewable and CCS technologies	To explore and analyse what a climate-compatible 100% renewables pathway means means for Indonesia and the ASEAN region and how it can be realised while excluding all fossil and nuclear technologies

Modelling Indonesia within a whole ASEAN regional model shows how it can leverage regional synergies

Figure 41 ASEAN region representation with 35 nodes

Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.
Note: North SM = North Sumatra-Aceh; Northern SW = Gorontalo, North Sulawesi; Central SM = West Sumatra, Jambi, Riau; Central SW = Central, West Sulawesi; South SM = South Sumatra, Lampung-Bengkulu, Bangka Beitung; Southern SW = South, Southeast Sulawesi; West JV = West Java, Jakarta, Banten; Central JV = Central Java-Yogyakarta; East JV = East Java.

These scenarios for the power sector were considered in a 35-node model for ASEAN with 18 nodes in Indonesia (as seen in Figure 41), nine in Malaysia and one node for each of the remaining ASEAN member states. Malaysia and Indonesia are represented in more detail than other ASEAN countries because they are the focus of dedicated national reports. The 18-node representation for Indonesia aimed to properly capture the heterogeneity of the national power system with reasonable representation of key demand centres, the regional distribution of renewable energy resources, and differing generation mixes in regions across the Indonesian archipelago.

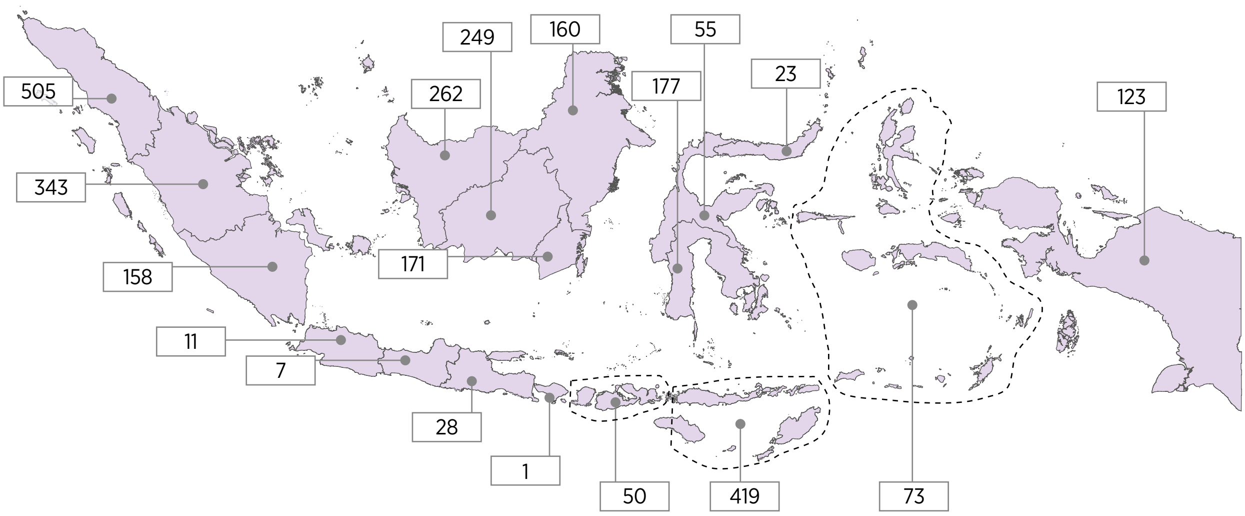
As regards international line expansion, to best represent national and international plans, the BES and PES scenarios take a more conservative approach to international expansion of lines, limited to those envisaged in the most recent AIMS study. However, in the TES and the 1.5-S the long-term model optimally expands these international lines to achieve more ambitious renewable energy integration internationally.

Integrated system operation enabled by close interconnection can facilitate sharing of generation sources and lead to a lower-cost power system due to reduced duplication of effort in energy and non-energy service provision. Additionally, to unlock the national renewables potential it will be crucial to understand the distribution of these renewables across the country in relation to electricity demand distribution out to 2050.

As shown in Figure 12, in 2020 approximately 70% of the power system electrical load was situated in on the island of Java, while only about 2% of the national resource potential of solar PV is located there. This is a powerful illustration of the need for strong system interconnection across the country in any highly renewable future, given the vast majority of the renewables potential is not located on any single island.

Indonesia's solar PV potential is vast but mostly is not collocated with load centres

Figure 42 Utility-scale solar potential for each model node considered (GW)



Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

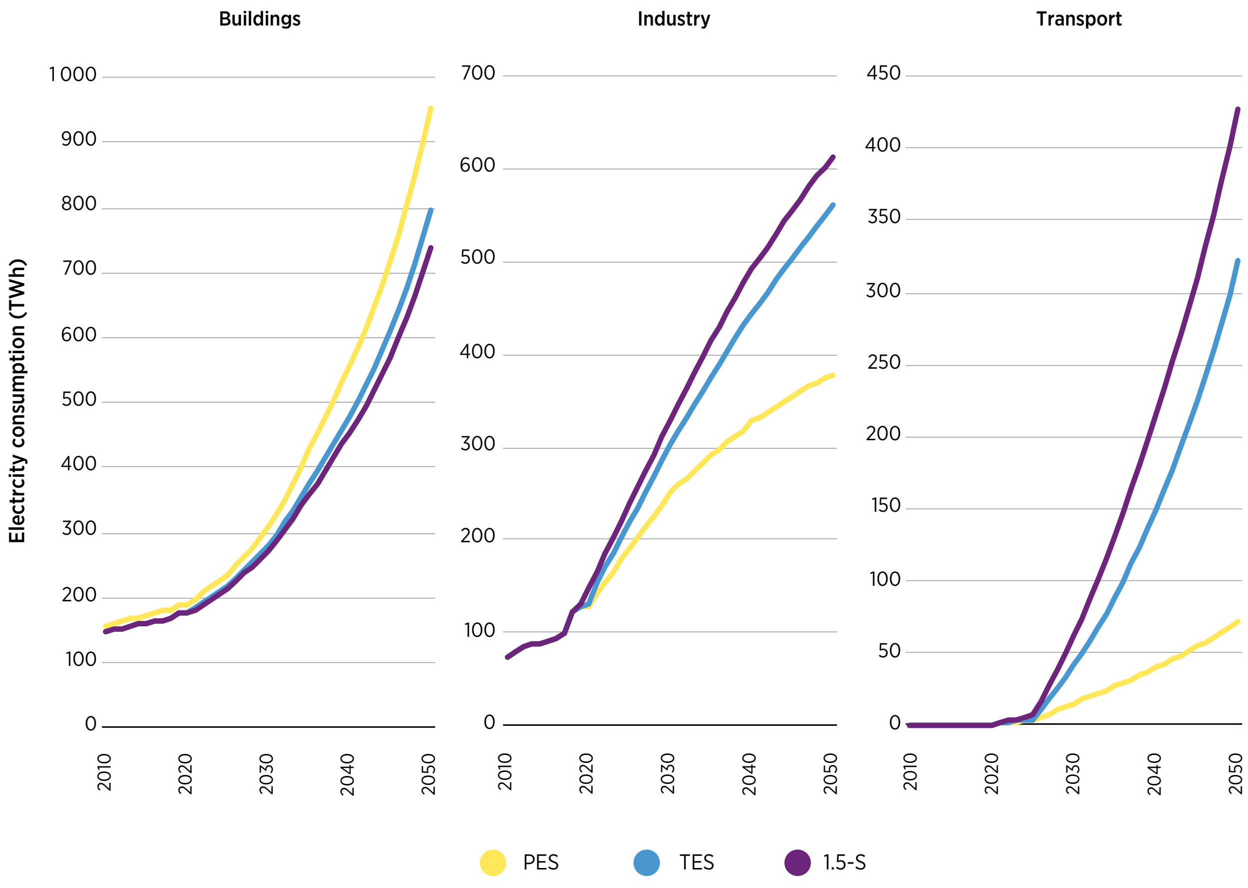
Electricity demand growth

Electricity demand growth is set to be very significant in all scenarios, reaching a range of levels between 1 400 TWh in the PES and 1 760 TWh in the 1.5-S by 2050 where there is robust electrification of end uses. Electrification of end uses harnesses powerful efficiencies and, if done with renewables, can provide both significant reductions in final energy demand and emissions. How capacity needs are expanded along this horizon is instrumental in a climate-compatible future – high levels of electrification alone will not meaningfully reduce emissions unless accompanied by the decarbonisation of power.

Given that 40% of all energy needs by 2050 are met with electricity in the TES and nearly 50% in the 1.5-S, these scenarios have profound implications for the evolution of the power system. The sectoral composition of this demand growth also has consequences for the system and, if harnessed with smart operational practices, can improve the operability of the system with high shares of renewables.

Indonesia's electricity demand growth is set to grow at pace in all scenarios out to 2050

Figure 43 Electricity demand growth by sector and scenario, 2018-2050



Power capacity and generation

KEY MESSAGES

The deployment of solar PV is a common feature across all scenarios considered, given the strength of the resource across Indonesia. By 2050 it could reach a total of over 800 GW, which this would lead to a paradigm shift in system operation and a move towards a more distributed power system.

Clean dispatchable technologies will be key to balancing resource variability; this is analysed in a set of scenarios that explore how this need can be met with batteries, nuclear and fossil fuel with CCS to better understand the roles these technologies can play. The cost and availability of these technologies are pivotal in their cost-effective deployment in any highly ambitious decarbonisation scenario.

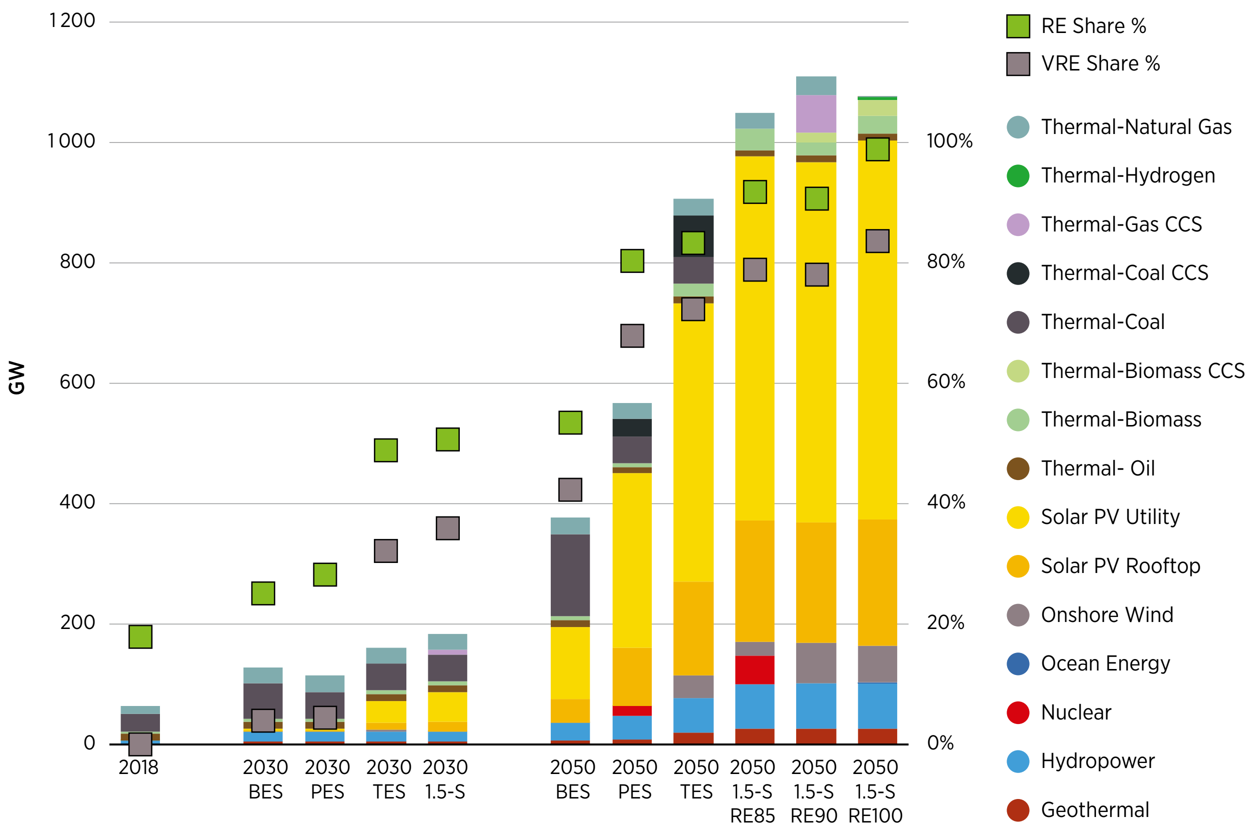
National and regional interconnection within ASEAN more broadly has many benefits in achieving a lower-cost power system for all by allowing integrated energy supply planning and minimising duplication of both energy and non-energy service provision.

Power capacity will need to grow at a pace that ensures Indonesia's electricity needs are met out to 2050. There are many possible trajectories for power system expansion, but action is needed to avoid fossil fuel investments being locked in in the near term, particularly given the prevalence of coal-fired generation across much of the Indonesian archipelago. To give perspective on this evolution of the power system, a central set of scenarios was developed in line with the bottom-up demand-side analysis that was performed using the REmap activity tool, namely the BES, PES, TES and 1.5-S. These scenarios constitute a wide range of development and provide an understanding of the impact of implementing and not implementing measures in the power sector. These scenarios encompass a wide range of ambitions for emission reductions and renewables, reaching renewable capacity shares by 2050 of 54%, 80%, 83% and 91%-100% in the BES, PES, TES and 1.5-S respectively.

National plans imply that coal power generation capacity is set to expand in all scenarios out to 2030, with great implications for sectoral emissions. The BES projects a business-as-usual case where the system is optimised for cost alone with no carbon or technology constraints; the PES meanwhile is on a decarbonisation by 2060 trajectory in line with national plans, while the TES and the 1.5-S explore more ambitious renewable pathways, demonstrating how this coal capacity expansion can be mitigated in the longer term by relying on higher shares of solar PV and clean dispatchable power.

Solar PV will play a key role in Indonesia in all scenarios by 2050

Figure 44 Power capacity growth by scenario, 2018-2050

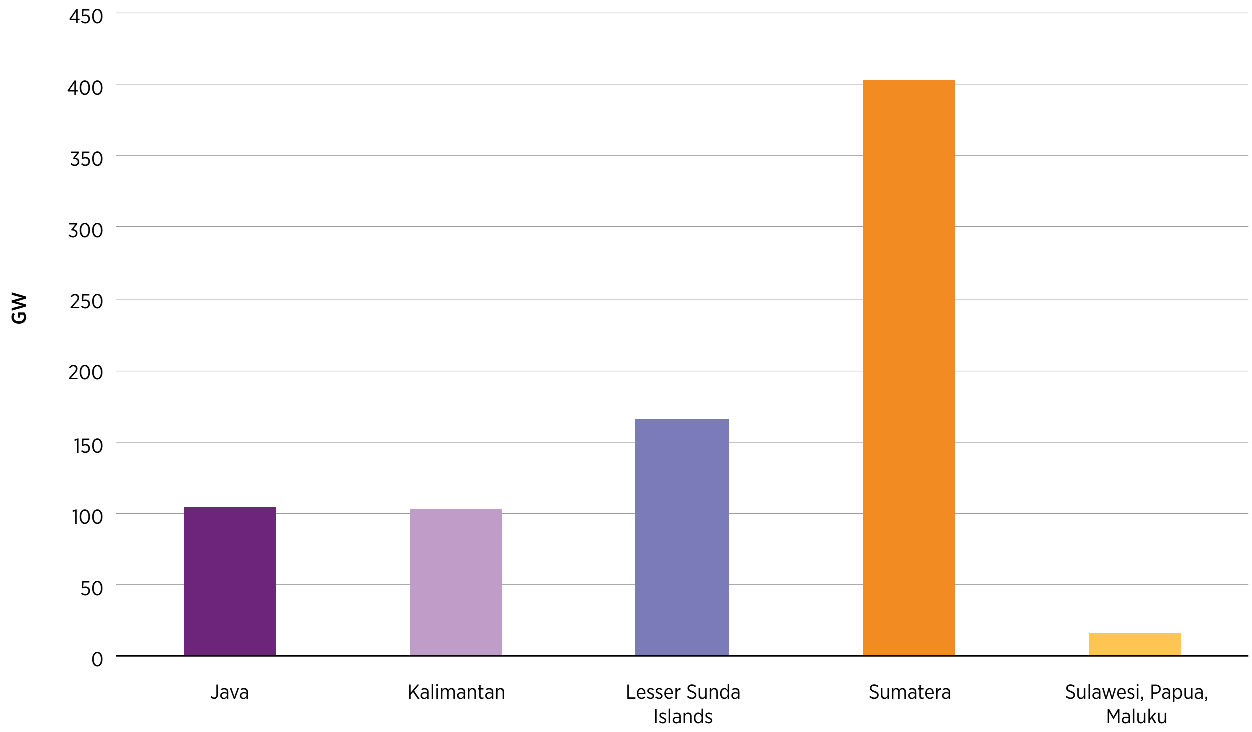


Notes: CSP = concentrating solar power; VRE = variable renewable energy; RE = renewable energy.

Solar PV is a key technology and given its modularity and low costs, and the rich national resource of Indonesia, it plays a key role regardless of ambition level. However, it would require careful operational planning and ancillary service provision to integrate effectively. The BES sees the total capacity of solar PV reach 160 GW, while the PES, TES and 1.5-S see capacity of 385 GW, 618 GW and 798-840 GW, respectively, representing a generation capacity share of 42%, 68%, 72% and 79-84% in the BES, PES, TES and 1.5-S, respectively. The vast potential for solar PV coupled with its well-distributed nature see it become the dominate generation source in most scenarios by 2050, with an average build rate in the 1.5-S out to 2050 of well over 20 GW per year. To integrate such high shares of variable renewable power in all scenarios, although in particular in the 1.5-S as shown below, would implicitly need power system flexibility, transmission expansion and storage. It would also have profound implications for system operation, which itself would require the implementation of a range of innovative operational practices.

Most electricity demand is on the island of Java but solar PV potential there is limited

Figure 45 Solar PV capacity across Indonesia in the 1.5-S RE90, 2050



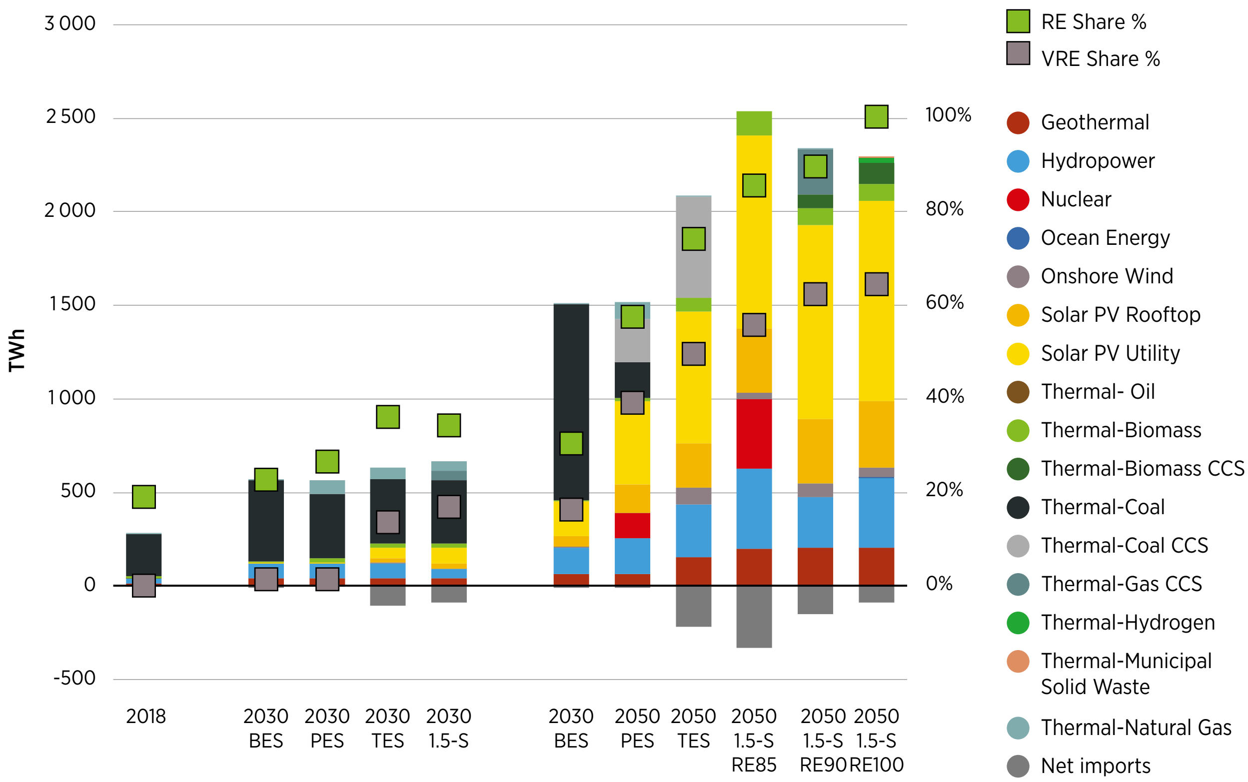
However, it is not only solar PV that key in meeting the capacity needs in these ambitious scenarios. Clear also is the role clean dispatchable power in its various forms – hydropower, geothermal, bioenergy, nuclear, fossil fuel generation with CCS, and battery storage – which help mitigate the diurnal and seasonal variability in the solar resource.

The BES and PES see significant increases in hydropower capacity out to 2050, increasing its installed capacity from about 5.5 GW in 2018 to 29 GW and 40 GW, respectively. Such is the wealth of the national hydropower resource in Indonesia – at about 95 GW, similar to solar PV – that it features in all scenarios. However, to achieve the high-renewables TES and the 1.5-S, these penetrations are dwarfed by the those in the more ambitious scenarios, where they reach 58 GW and 75 GW respectively. Here, hydropower provides an invaluable balancing resource from its ability to balance supply–demand variability. Geothermal power capacity is also envisaged to increase from just under 2 GW in 2018 to a maximum of 27 GW in the 1.5-S, albeit representing a lower share of the generating capacity mix than other key renewables, similar to the envisaged role for bioenergy in power.

Fossil fuel generation with CCS and non-renewable modes of generating capacity also have a role: their combined capacity share of 0%, 8%, 8% and 0-6% in the BES, PES, TES and 1.5-S belie their value in being able to deliver power during periods of low VRE and provide valuable system resilience. Additionally, given the range of uncertainty that exists with these technologies, this role needs to be carefully explored so that their sensitivity to specific uncertainties is well understood.

Each mode of generation plays a role in meeting national power needs across the year

Figure 46 Power generation growth by scenario, 2018-2050



Note: RE = renewable energy; VRE = variable renewable energy.

These scenarios translate into very different power generation profiles, as seen in Figure 46, with renewable shares achieved of 30%, 57%, 74% and 85-100% by 2050 in the BES, PES, TES and 1.5-S, respectively, the majority of which comes from solar PV. In the generation mix the role of individual technologies in meeting demand across the year become clear. This is to say that in power systems with high shares of solar PV and other variable renewables, their very nature implies that the operation of the system and their use across the year rely on the flexibility of the other resources underpinning them. This sees the variability of renewables mitigated in ambitious scenarios with low- or zero-emission technologies that can be readily dispatched, such as battery storage, nuclear and fossil fuel technologies with CCS.

There is one common factor in all scenarios – the decreasing role of coal-fired generation and the rise of solar PV; however, this requires careful policy design and implementation if to be achieved successfully. In 2018 unabated coal represented about 80% of power generation, but by 2050 coal (both abated and unabated) has a penetration of 70%, 28%, 26% and 0% in the generation mix of the BES, PES, TES and the 1.5-S, respectively. Meanwhile, solar PV in 2018 represented 0% of generation, but rises to 16%, 39%, 45% and 54-62% in the respective scenarios. In terms of levelised power generation costs, both modes of generation have some of the lowest costs of any power generation technology today. But while coal has a small land requirements as a technology (albeit with many negative externalities), the same is not true of solar PV, which cannot be as easily placed near demand centres as it needs to be placed where both the land and resource are abundant. This implies a substantial need for expansion of the transmission network to accommodate this solar capacity, which is explored in the following sections.

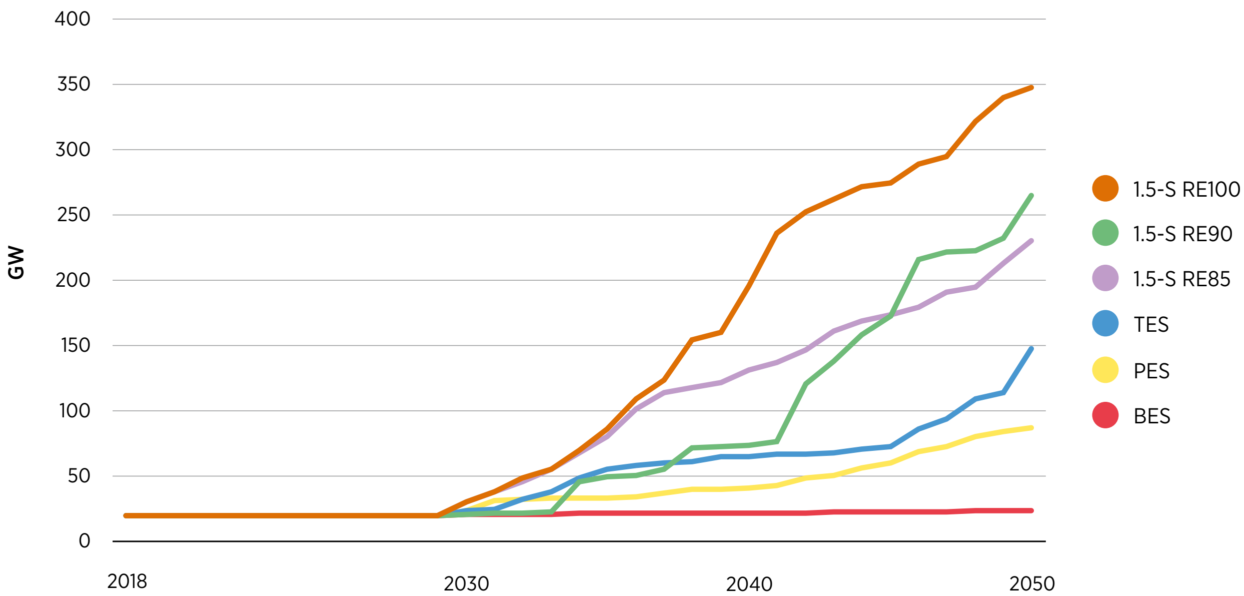
Hydropower, in particular and in addition to geothermal capacity, plays a key role in meeting demand across the year and mitigating supply–demand variability. Combined they provide 10%, 13%, 14% and 11-17% of power needs across the year in 2050 in the BES, PES, TES and 1.5-S. Additionally, similarly to solar PV, these resources are highly location-dependent so the capacity needs to be co-located with the resource. This has implications for transmission capacity and battery storage to meet demand in load centres.

Meanwhile, nuclear and coal with CCS also play a role in the scenarios, reaching a combined generation share of 0%, 24%, 26% and 0-15% in the BES, PES, TES and 1.5-S, respectively, implying a reliance on the dispatchability of these technologies that increases with the share of renewables achieved in the power system. Additionally, given the high levels of renewables achieved, nuclear and coal generation with CCS will need to vary their output to mitigate the increased supply-side variability of the system. Given that both nuclear and coal-fired generation are not traditionally very flexible in ramping and minimum up and down times, these scenarios imply a need for additional flexibility in these modes should they play such a key role in the power system.

National and international interconnections are also pivotal in the expansion of the generation mix in allowing for growing power demand to be met over an increasingly distributed system. Figure 47 below presents the sum of all internal transmission line expansion between Indonesia's regions. While this representation does not show line by line where this expansion occurs, it is a powerful indicator of the transmission needs in achieving a highly renewable future power system, demonstrating the need for reinforcement of the national power system transmission network. Crucial in this expansion is the near fivefold increase in capacity compared to PES levels to achieve the 1.5-S, which is mainly to transmit power generation from solar PV and other renewables to demand centres.

Transmission expansion needs to increase significantly in the energy transition scenarios, especially when RE100 is pursued

Figure 47 Sum total of national line expansion between Indonesian regions for all scenarios, 2018-2050



Building a transmission line, from planning and commissioning to full operation, may take as long as ten years. In addition, building a line across large bodies of water adds a layer of complexity to the entire process. Therefore, planning should start as soon as possible so as not to lag behind the expansion needed under decarbonisation scenarios. In less than a decade, gigawatts of capacity need to operational. Figure 48 identifies key lines that need to be prioritised in the near term for the achievement of the 1.5-S, although reinforcement of these lines is also crucial to varying degrees in the other scenarios. Particularly important, however, is the expansion of transmission between Java and Sumatra, which transits the abundant renewable solar power in Sumatra under these scenarios to the most significant load centres nationally, which are in Java.

Figure 48 Key transmission lines to be expanded in the near term in the 1.5-S RE90

In operation by 2030:

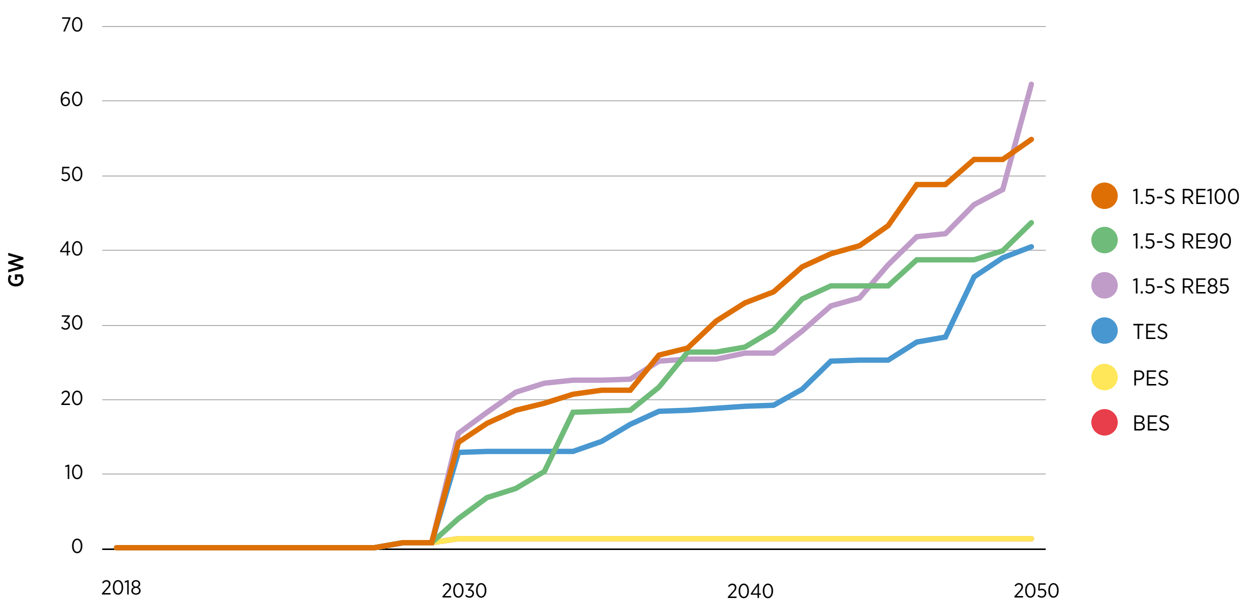
Internal regional transmission reinforcement is pivotal in the short-term across Indonesia, most notably in Java

In operation by 2040 (total, not cumulative):

- **19 GW** between Java and Kalimantan
- **2 GW** between Nussa Tenggara and Java
- **1.3 GW** between Java and Sumatera

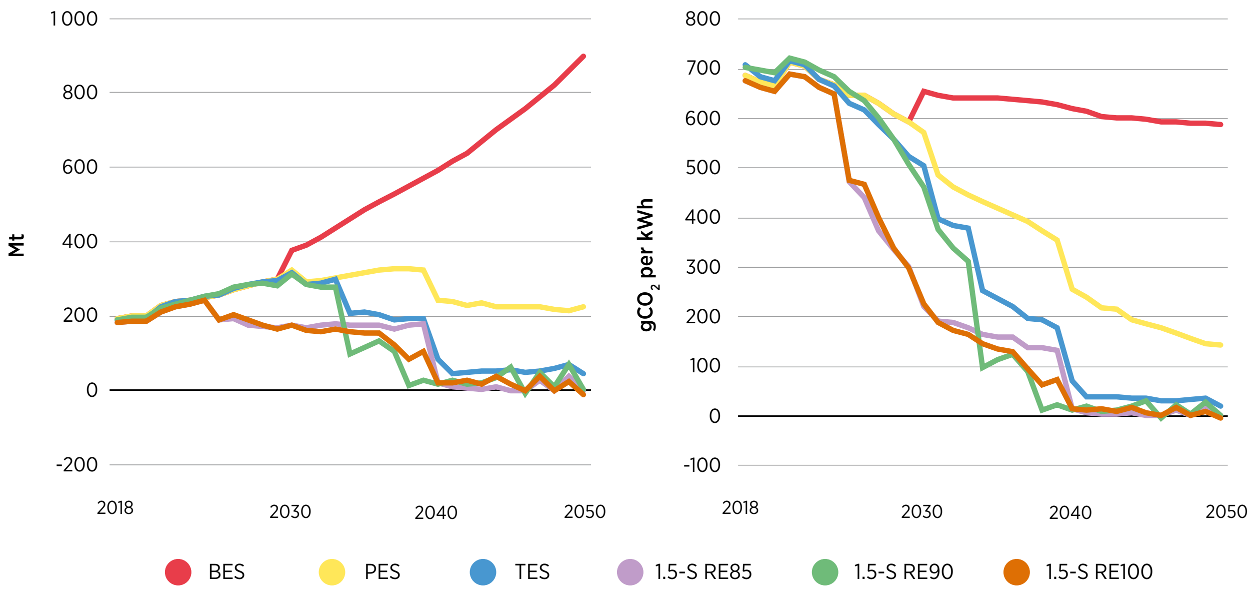
As regards international transmission, expansion is also a significant facilitator of increased renewable shares in both Indonesia and ASEAN as a whole. Not only does this facilitate more renewables, but its implications are also much broader for the sharing of generation resources, demonstrating the clear economic benefit of deeper regional system integration regardless of any level of renewables or decarbonisation ambition. This is a powerful insight gained from modelling all scenarios for ASEAN. The key lines that are expanded internationally for Indonesia in the 1.5-S are those to Malaysia and Singapore. Key among them are a 12 GW line between Sumatra and Singapore, a 9 GW line between Sarawak and Java, and two 5 GW lines to peninsular Malaysia from Kalimantan and Sumatra, all of which should be prioritised for near-term expansion.

Figure 49 Sum total of Indonesian international line expansion for all scenarios, 2018-2050



In terms of the emissions intensity of power generation, in line with the differences in generation mix, there are vast differences in the emission reductions that can be achieved. Analysis of overall power sector emissions can mask this difference between scenarios due to their vastly different levels of electrification. As would be expected, the BES broadly remains at today's level of emissions intensity due to the expansion of coal-fired generation, but this leads to a very significant increase in overall emissions. Meanwhile, the PES, which relies on greater amounts of solar PV, nuclear and coal with CCS, reduces emissions but cannot achieve zero emissions because of the 90% capture rate of emissions in CCS and the remaining unabated coal units. However, the TES and the 1.5-S can reach zero emissions intensity by 2050 through the deployment of solar PV and expansion of national and international transmission capacity.

Figure 50 CO_2 emissions from the power sector and carbon intensity of power generation, all scenarios, 2018-2050



In light of a growing power demand in all scenarios out to 2050, careful investment planning in the power sector will be crucial to facilitate an effective energy transition. In terms of generation capacity investment, as shown in Table 13, solar PV is largest component of investment for all scenarios aside from PES, reaching up to USD 434 billion. The 1.5-S variants differ largely as a result of how dispatchable power needs are met. In the 1.5-S RE85 nesessitates a total of USD 232 billion invesment in nuclear, while the 1.5-S RE90 sees nearly USD 150 billion investment into CCS; finally the 1.5-S RE100 sees higher investment needs in renewables, storage and hydrogen providing long-duration storage capability to bolster system reliablity. Integrated planning is needed to identify the role of different generation sources and that of transmission, distribution and storage to meet electricity needs at the lowest cost. Total power system investment needs in 1.5-S cases (USD 1154 - 1436 billion) are about double what is needed in PES (USD 679 billion). The scale and composition of these investment needs in the 1.5-S indicate that achieving these future scenarios will need stable long-term policy to deliver the range of bankable projects needed across the power system of the Indonesian archipelago.

Table 13 Power sector expansion and investment needs, by scenario, 2050

EXPANSION AND INVESTMENT		PES	TES	1.5-S RE85	1.5-S RE90	1.5-S RE100
VRE share of generation		39%	49%	56%	62%	64%
Renewable investment (billion USD)	**Solar PV**	195	314	405	415	434
	Hydro	71	109	146	145	147
	Wind	1	43	25	75	67
	Geothermal	23	63	87	85	89
	Biomass	3	27	50	28	45
	Hydrogen	-	-	-	-	51
	Ocean	-	-	-	-	8
Nuclear investment (billion USD)	**Nuclear**	90	-	232	-	-
CCS investment (billion USD)	**Coal w/CCS**	132	307	-	-	-
	Biomass w/CCS	-	-	-	93	135
	Natural gas w/CCS	-	-	-	56	-
Fossil fuels investment (billion USD)	**Coal**	25	25	25	25	25
	Natural gas	10	10	10	12	10
Transmission, distribution and battery storage investment (billion USD)		219	296	406	394	425
TOTAL POWER SECTOR INVESTMENT (billion USD)		**679**	**1 426**	**1 154**	**1 328**	**1 436**

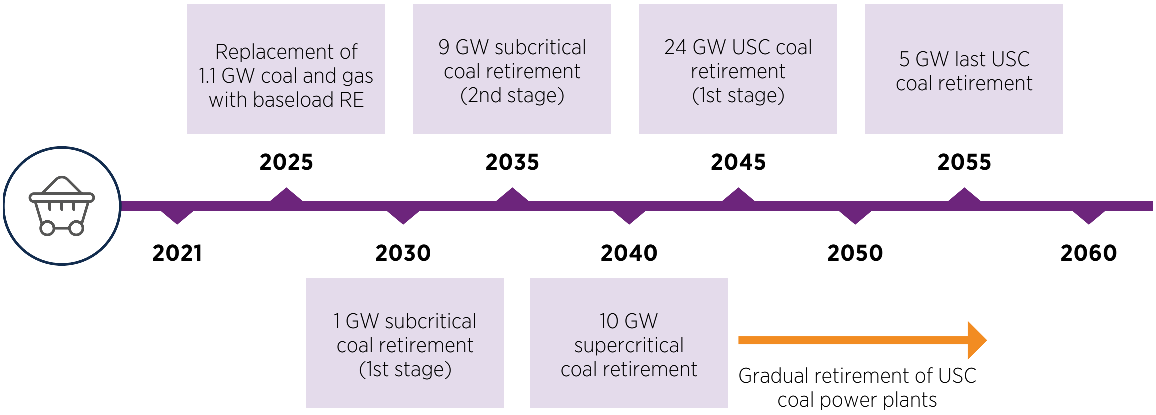
Note: Investment totals for 2050 in the TES and 1.5-S for coal and natural gas are already committed in national plans and do not represent additions within those scenarios. These consist of projects that have been built since 2018 or are in the pipeline that occur by 2030 in the PES. The values thus carried over as cumulative investment are from 2018-2050.

Box 13 Indonesia coal phase-out roadmap

PLN is considered to have released the greenest-ever RUPTL with RUPTL 2021-2030. PLN has pledged to naturally phase out coal power plants, meaning no additional coal-fired plants will be built, and PLN is currently only continuing with ongoing projects that have reached PPAs. It is planning to develop renewable energy aggressively, adding about 16.1 GW during the planned period. However, Indonesia has significant overcapacity of coal-based generation. With nearly 32 GW of coal installed in 2021 and nearly 14 GW of coal capacity pipeline, the total power generation capacity was around 80 GW while peak demand was around 40 GW. This points to significant stranded coal assets that need to be dealt with and complicates the energy transition. The roadmap to phase out coal is depicted in Figure 51.

Box 13 Indonesia coal phase-out roadmap (continued)

Figure 51 PLN timeline for retirement of coal-fired power plants



Note: RE = renewable energy.
Source: (PLN, 2021b).

It is estimated that by 2060 there is the potential for 1 380 TWh of renewably generated electricity to be added to PLN's system. The retirement objectives for fossil power plants should result in a significant reduction in their output by 2040, and they envisaged to be completely phased out by 2056 – to be replaced by renewables. Given the mass retirement of the coal fleet, the sunk costs could be offset by conversion of these units to use other fuels like biomass or their repurposing as synchronous condensers, by which they could provide much-needed flexibility to the system in the form of frequency support. This is of particular importance in a power system with high levels of converter-connected generation. The development of renewables will be immense from around 2028 and increases exponentially in 2040 due to more mature and economically competitive battery technology. Nuclear power plant is also envisaged from around 2040, as it is considered that the technology will become safer.

Shutting down a large proportion of Indonesia's coal-fired generation requires large-scale deployment of renewables to supply the missing energy. It will be crucial to establish enabling policies and a step-by-step phase mechanism that allows a stable grid amid high renewable energy penetration.

PLN predicts the utilisation of large-scale battery technology to enable baseload renewables to compensate for the load served by coal power plants at a competitive cost. It is currently co-operating with various domestic and international stakeholders to accelerate the coal phase-out and is developing low-cost large-scale renewables plus battery systems with long lifetime.

The Institute for Essential Service Reform (IESR) has stated that for a successful phase-out it is imperative to analyse the operational versus retirement cost of coal-fired plants and non-technical aspects such as employment, pollution and human resources capabilities. PLN is risking the possibility of stranded assets of up to USD 15 billion if decides to still commission coal power plants (IESR, 2021b).

Indonesia is currently working with Asian Development Bank to develop an Energy Transition Mechanism (ETM), exploring the acquisition of Indonesian coal-fired plants for early retirement and accelerating the coal phase-out. The ETM covers full regulatory and legal analysis, detailed valuation of the initial plants, and the structure of the country funds. Ultimately this mechanism must ensure an equitable and just energy transition.

The recently enacted Presidential Regulation 112/2022 officially bans the development of new coal power plants with several exceptions such as if the coal power plants are included in the RUPTL, for industry integrated national strategic projects, power plants that are committed to reduce their greenhouse gas emission by minimum 35% in 10 years after operating. It also mandates the minister to develop an early coal power plant retirement roadmap. The government of Indonesia can offer fiscal support in the form of blended finance from the national budget or other sources to an IPP for accelerating coal power plant early retirement. The implementing regulation on this financial support is mandated to ministry of finance.

Box 14 State of nuclear power generation

Nuclear energy is considered by some as part of the solution to meet rising energy demand while also meeting long-term CO_2 emission reduction targets. This is one reason why Indonesia is considering the technology. This report has a power sector development pathway that includes nuclear power, whereby it is used to generate about 15% of annual electricity by 2050, with the remainder from renewables. However, for this to occur in the optimisation model for capacity expansion an optimistic capital cost of 4 200 USD/kW had to be reached by 2050 and it only entered the mix in the late 2040s. The role of nuclear energy is one of the most debated topics relating to the energy transition, and its potential, use and costs need closer examination.

The status of the nuclear industry is well summarised in the World Nuclear Industry status report 2021 (WNISR, 2022):

- Nuclear electricity production accounted for 10.1% of global electricity generation in 2020. This share has been declining steadily from a peak of 17.5% in 1996.
- The mean age of the reactor fleet is 31 years (as of July 2022). 411 reactors are in operation, 29 face long-term outage, and 53 are under construction, whereas for 93 reactors construction has been abandoned.
- The total operating nuclear capacity increased by 1.9% in the year to mid-2021 to reach 369 GW, a new mid-year peak just above the record of 367 GW in 2006.
- At least 31 of the 53 units under construction are behind schedule; 13 have reported increased delays and four have had documented delays for the first time over the past year. In 10 cases (19%), initial construction dates back a decade or more.
- Ten countries completed 63 reactors – with 37 in China – over the past decade, with an average time between construction start and grid connection of 10 years.

In 2020, for the second time in a row, and the fourth time since 2015, the total investment in non-hydro renewable electricity capacity exceeded US 300 billion, almost 17 times the reported global investment that year in the construction of nuclear power of around USD 18 billion for 5 GW of new plant capacity. Investment in nuclear power is one-eighth of the investment in wind (USD 142 billion) and solar (USD 149 billion).

The Fukushima accident is estimated to have cost around USD 223 billion according to the government of Japan. An independent assessment established a range of USD 322–758 billion. Because of these costs it is not possible to insure nuclear accidents.

There are no new signs of a major breakthrough for small modular reactors (SMRs), neither technologically nor commercially. Indications are that unit costs are twice those of large nuclear reactors, due to the lack of economies of scale.

Cost estimates for nuclear power vary widely. Delays and changes in project scope result routinely in massive cost overruns, and therefore ex ante cost estimates should be closely scrutinised.

Two new reactors are being built at the existing Plant Vogtle site in the United States. Originally estimated by the owners to cost slightly more than USD 14 billion and to be in service in April 2016 and April 2017, the total cost has more than doubled, climbing above USD 30 billion. These plants will have a total capacity of 2 234 MW, so the investment cost is likely to amount to USD 13 400/kW. The owners now estimate commercial operation will not begin until 2022 and 2023 – more than six years behind schedule. The state's commission staff estimate the power from the new reactors will cost Georgia Power's customers an average of USD 150/MWh (PSC, 2021).

In Finland a fourth-generation Russian-designed pressurised water reactor type VVER-1200 is being built, with a capacity of 1 200 MW, estimated to supply about 10% of Finland's electricity needs. Cost estimates have climbed significantly, up from EUR 6.5-7 billion to EUR 7-7.5 billion currently (EUR 6 250/kW). Start of operation is scheduled for 2029, but it remains to be seen in the light of the current political situation if this schedule will be realised.

Box 14 State of nuclear power generation (continued)

Another well-known project is Hinkley Point in the United Kingdom. The country's latest nuclear power plant was expected to cost USD 145/MWh. Nine years on, it is two years behind schedule and GBP 10 billion over budget.

Reactors may be cheaper in China or Russia, but it is not clear if they are built to the same safety standards. It is important to note that China has given up its ambitions to develop a nuclear reactor export industry. This leaves Korea and Russia as potential technology suppliers, with France, Japan and the United States as distant contenders.

Solar is typically much cheaper than fossil fuel-fired or nuclear power generation. In 2021 the global weighted-average levelised cost of electricity (LCOE) of utility-scale solar PV fell by 13% to USD 46/MWh. The global weighted-average total installed cost of utility-scale solar PV was USD 857/kW in 2021.

It is a similar story for wind. The global weighted-average LCOE of onshore wind projects commissioned in 2021 amounted to USD 33/MWh. The global weighted-average LCOE of new offshore wind projects amounted to USD 75/MWh. The global weighted-average total installed cost of newly commissioned onshore wind projects was USD 1 325/kW, while offshore wind was USD 2 858/kW in 2021.

Robust data for utility-scale battery cost reductions are not widely available. Yet, at the end of 2019, the United States had an installed, utility-scale battery capacity of 1 022 MW, with 1 688 MWh of electricity storage capacity. Between 2015 and 2019, the cost of utility-scale battery storage in the United States fell by 72%, from USD 2 102/kWh to USD 589/kWh (EIA, 2021). This cost decline predominantly reflected the rate of decline in costs for lithium-ion batteries, given that they represented 93% of total installed battery energy capacity.

Some argue that nuclear power is more reliable than renewables. France produces around 70% of its electricity from nuclear power and has 56 reactors – more than any other EU country. In order to become even more independent, it announced plans to extend the lifetime of existing power plants and build six new reactors. However, of the 56 French nuclear power plants, 29 are idle. Many reactors of the state operator Electricité de France (EDF) were unexpectedly taken off the grid due to suspected corrosion and cracks in the cooling tubes. Some plants have already had to reduce their output because there is no longer enough cooling water due to the lower water levels in rivers and lakes (Merkur, 2022).

French consumers have profited for a long time from artificially low electricity prices based on a combination of nuclear generation with near-zero marginal cost and state dirigisme. That has come to an end now the reactors are reaching the end of their life and it is becoming clear that maintenance and waste management costs have not been covered properly. The French government is aiming for the full nationalisation of the debt-laden utility EDF.

Finally, nuclear is a dual-use technology and does increase the world's capability to produce nuclear weapons. Proliferation, long-term nuclear waste storage, and the low-probability, but high-stakes risk, of nuclear disasters all make nuclear power less attractive than alternatives.

Flexibility

KEY MESSAGES

As the world's fourth largest country by population, Indonesia has the highest electricity consumption in the ASEAN region. With the three largest cities in the country, the island of Java accounts for 69% of national demand. This share is expected to remain stable despite the forthcoming move of the national capital to Kalimantan. Therefore, the planning of the country's power sector essentially involves finding effective ways to meet the island's needs, a challenging task given that most of the renewable resources are located elsewhere (*e.g.* Sumatra and Nusa Tenggara).

Power storage facilities are set to become operational during 2030-2035 and reach large-scale cost-effectiveness from 2040 onwards to become the backbone of the future system. Storage resources see steep growth, primarily batteries, and the respective manufacturers and overall industry must be ready when the time comes. Battery projects coming online before that period are expected to be location-specific, more focused on solving local structural issues like critical network congestion of allowing experimentation than displacing large-scale energy demand.

Available batteries and hydropower are sufficient to provide frequency response reserves at 10% of the load in 2050. Nevertheless, the need for sizeable power assets requires caution in planning and operating the system by 2050. For instance, stability could be threatened by infrastructure failure. Therefore, opting for a larger number of circuits of lower capacity in the case of transmission lines instead of fewer larger ones can help address potential issues, as can the adoption of fast frequency reserves in small and medium-sized grids in the medium term, and large grids in the long term. Furthermore, the system should be planned to cope with fewer and fewer synchronous machines in the future, where grid-forming inverters are likely to assume the leading role.

The full potential of renewables requires open markets and the alignment of regulations, including with system operators from neighbouring ASEAN countries. There should be no privileges for domestic resources, with the ability to book operations through an integrated ASEAN market for generators and transmission rights. Standard regulations secure reliability across the region by setting norms for the provision of services (energy, regulation, reserves), the amount to be procured at each time scale, and the practices followed by system operators.

The following section describes the implications of the 1.5-S RE90 and the 1.5-S RE100, given these are the most challenging in terms of flexibility. The BES, PES, TES and 1.5-S show overall lower requirements for flexibility and fewer potential stability concerns. The share of renewables in generation achieves 54% under the business-as-usual scenario (BES), 91% in the decarbonisation scenario (1.5-S RE90) and 100% in the 1.5-S RE100 by 2050. Most of these renewables comprise utility-scale and distributed solar systems. This means that roughly three-quarters of the generation primarily arises according to daily solar profiles. Seasonally, solar availability does not change much across the year due to the country's equatorial location, unlike higher-latitude regions. Nevertheless, there is a need to 1) adapt the solar generation to the demand (*e.g.* storage solutions), 2) operate the non-VRE generating portion of the system flexibly, ensuring system stability based on the net load, and 3) adjust demand to the availability of energy in the system (*e.g.* smart charging of EVs).

Additionally, power generation from renewables is constrained by the location of resources. For instance, the island of Java, home to 69% of demand, possesses only 4% of the solar potential. That will necessarily mean transporting massive quantities of electricity from the highest-quality renewable spots to where it is most needed, as pointed out in the previous section.

Balancing supply and demand at all times is crucial for a system's reliable operation because even a small mismatch can disturb the system frequency and possibly affect the reliability of system operations.[10] Put simply, power system flexibility refers to a power system's ability to respond to both expected and unexpected changes in demand and supply. Given that supply must equal demand across all timescales, flexibility is generally the ability of system assets to modulate either the production or uptake of electricity according to its availability and price across all timescales.

A series of flexibility options have been considered to help integrate VRE in Indonesia. They assume that there will be a price or time-based signal to consumers, or a call from system operators under a given framework to increase or decrease consumption according to the availability of electricity at a given moment in time. That can be created under wholesale markets that also include the participation of small and medium-sized consumers through aggregators, demand response programmes at industrial facilities, and other means.

Flexibility options considered in this study are:

- The smart charging of EVs (as opposed to charging up when most convenient from the user perspective, *e.g.* when arriving at home).
- Flexible production of green hydrogen.
- Storage assets to support both arbitrage and also the provision of spinning reserves.
- The expansion of the transmission grid across islands.

Impacts on the non-VRE portion of the system: Steeper power ramping

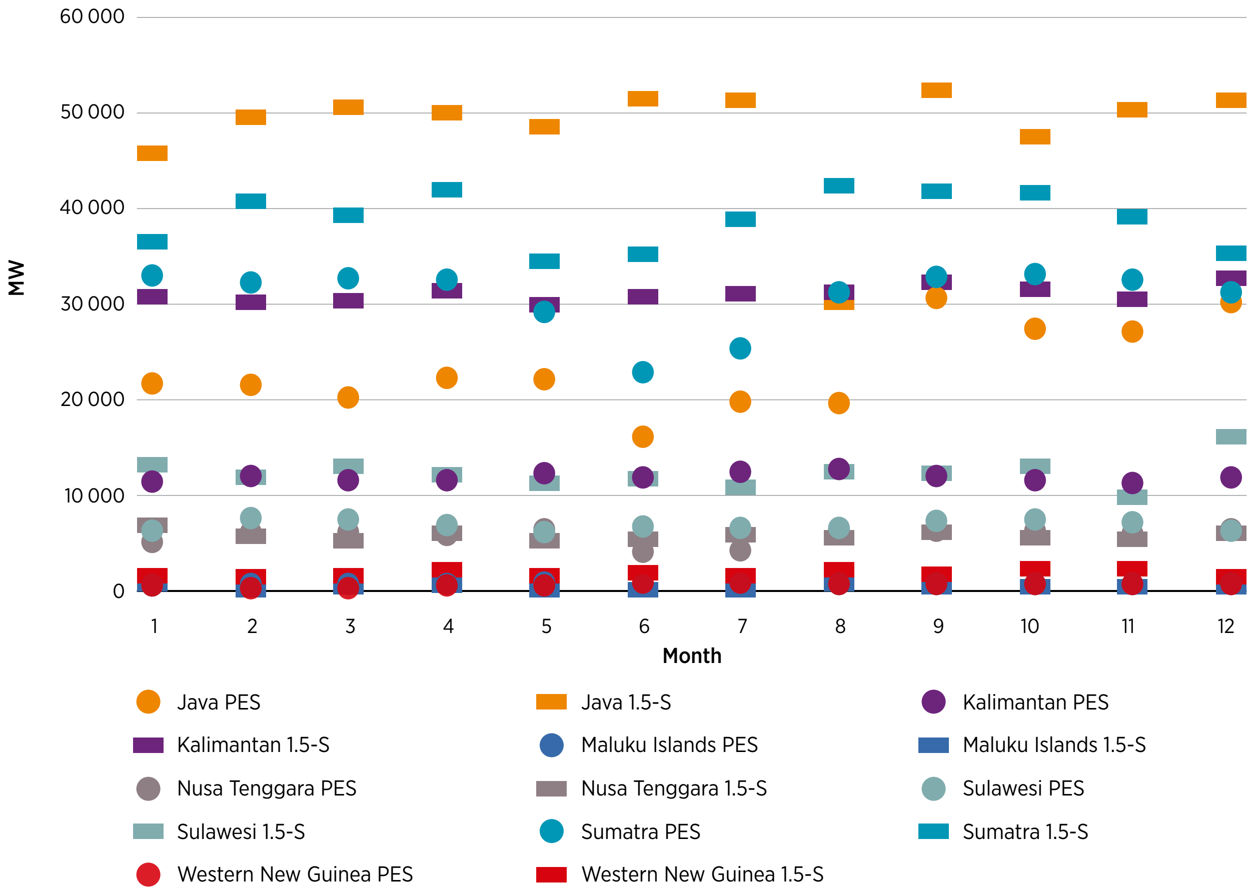
To harness as much VRE as possible (and minimise curtailment), while at the same time ensuring demand is met even under an unexpected decrease in VRE generation, the non-VRE portion of the system needs to adjust to solar and wind profiles to the extent possible or, as commonly referred to, to meet the net load. As more VRE come into the system, the gap between the lowest and highest net load tends to increase (Figure 52). There will be moments in which net load will be close to zero due to high VRE generation (or even negative in the existence of cross-border exchange), and thus non-VRE generators may need to either power down to minimum stable levels or shut down. Conversely, these units need to steeply increase power at the moment of

[10] *Power systems are designed to operate under nearly constant frequency. Frequency deviations beyond acceptable limits and time periods can damage generators and electromechanical equipment and thus create a chain reaction of loss of load and/or generation that can lead to a blackout.*

VRE reduction in generation or when there is no generation. Furthermore, electrification of end uses increases the overall demand, which in turn stretches the peak further. So non-VRE generators will likely need to ramp more steeply and cycle more often than seen nowadays. Going towards a renewables-dominated power system, this role will fall to dispatchable renewables plus batteries.

The increasing generation from solar and wind widens the gap between base generation capacity and that one needed only at moments of the day

Figure 52 Monthly gap between minimum and maximum net load met by the non-VRE portion of the system

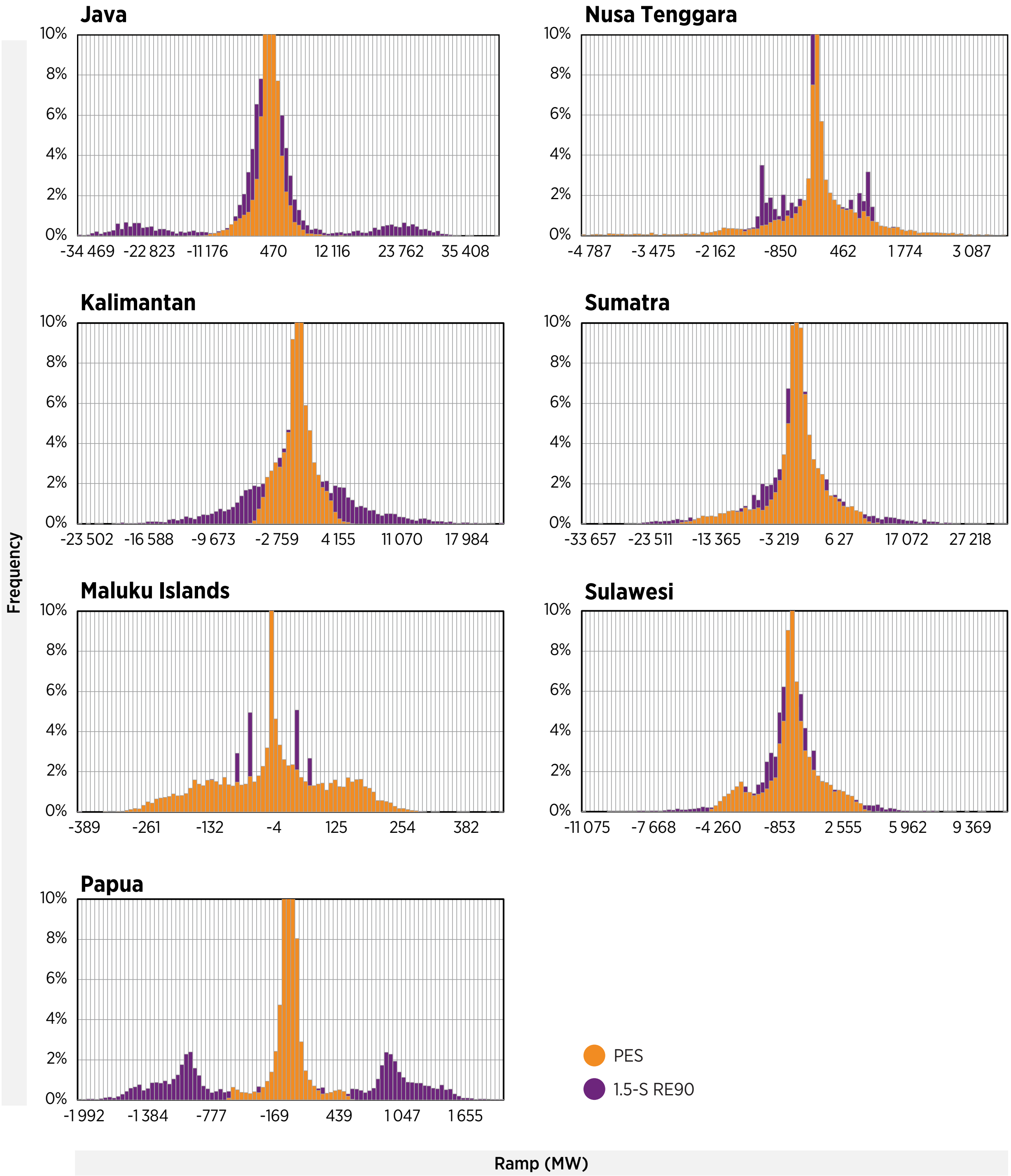


Hourly power ramping of a higher magnitude at the non-VRE portion of the system, including storage assets, becomes more frequent (Figure 53). As a result, average values tend to increase as well. Co-ordination is fundamental between dozens of generators to meet ramping of 30 GW (or 500 MW per minute) in regions like Sumatra and Java. For illustration, the highest ramping in Java by 2050 under the 1.5-S RE90 sees an almost threefold increase from the 16 GW in the PES.

Some of this can be met by pumped storage facilities, which can retain energy in the form of water for days, in addition to hydropower facilities with reservoirs, paving the way for the substantial reduction in fossil-based generation.

Collaboration between non-VRE assets is essential to deal with increasing extreme power ramps in netload at the hourly resolution

Figure 53 1-hour ramping of non-VRE generators for the PES and 1.5-S RE90 in 2050



Managing system needs with from imports from exporting-oriented regions

Solar is the flagship resource for Indonesia's decarbonisation; thus, its potential must be extensively explored. Most high-quality solar resources are located in Sumatra, Eastern Nusa Tenggara and Kalimantan. There will also power exchange with neighbouring countries, although on a relatively smaller scale. On the demand side, consumption is heavily concentrated in Java (69% of total), most of it on the island's western side (43% of total). Such concentration in a relatively small area of land creates a challenging mismatch between supply and demand, which is exacerbated by the island nature of the country.

Due to land limitations, a region like Java sees a relatively low development of solar facilities and is bound to import most of its power needs (Figure 54). The low solar development results in fewer storage needs except for short-term batteries that are likely to play a role in providing reserve response. At the other end of the spectrum, regions like Sumatra and Eastern Nusa Tenggara are centres of solar resource with a significant storage to help balance the system. Not surprisingly, these are the central exporting regions domestically. It should be noted that the combination of high VRE generation and low demand or synchronous generation may limit power exchange at certain moments, not because of the line capacity but because of voltage stability requirements. Furthermore, devices like synchronous compensators may be required to improve the system's strength.

Net importing and exporting regions are complementary and highlight the importance of cross-region flexibility

Figure 54 Typical power dispatch in West Java (upper) and South Sumatra (lower), 2050 in 1.5-S RE90

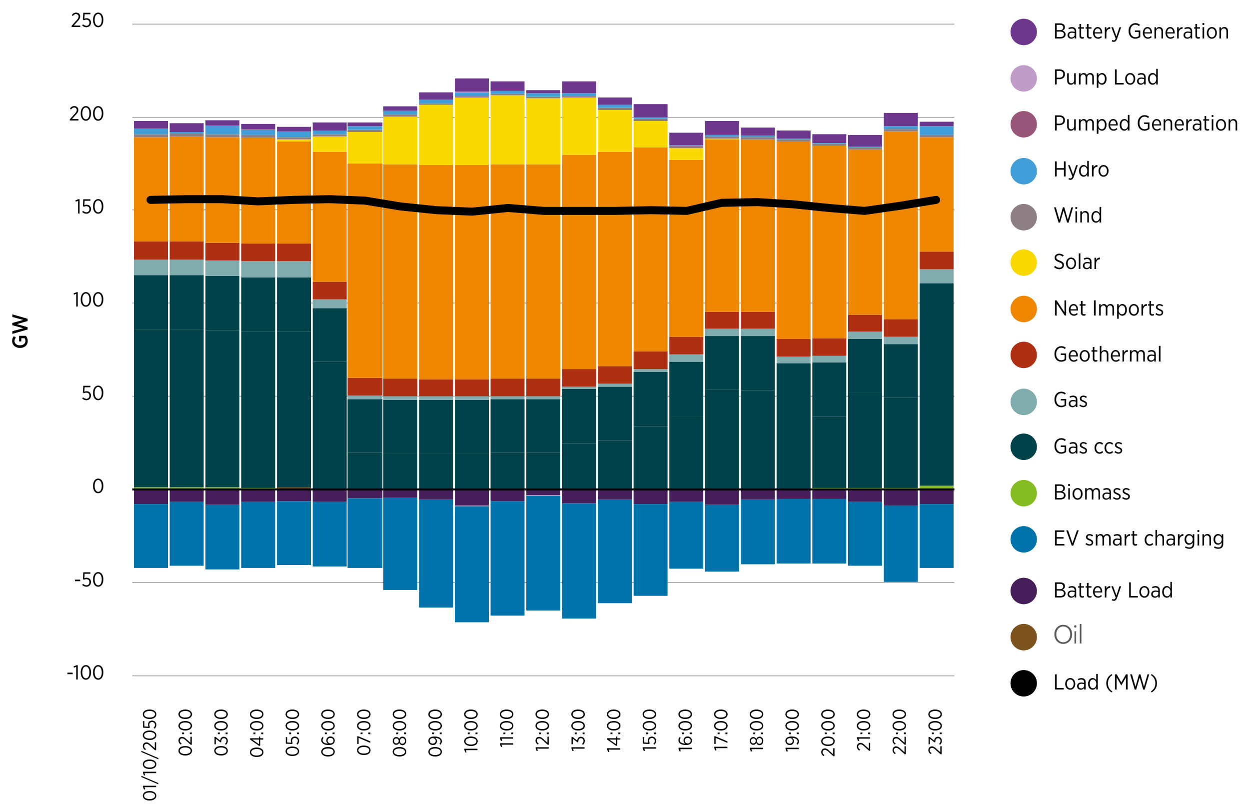
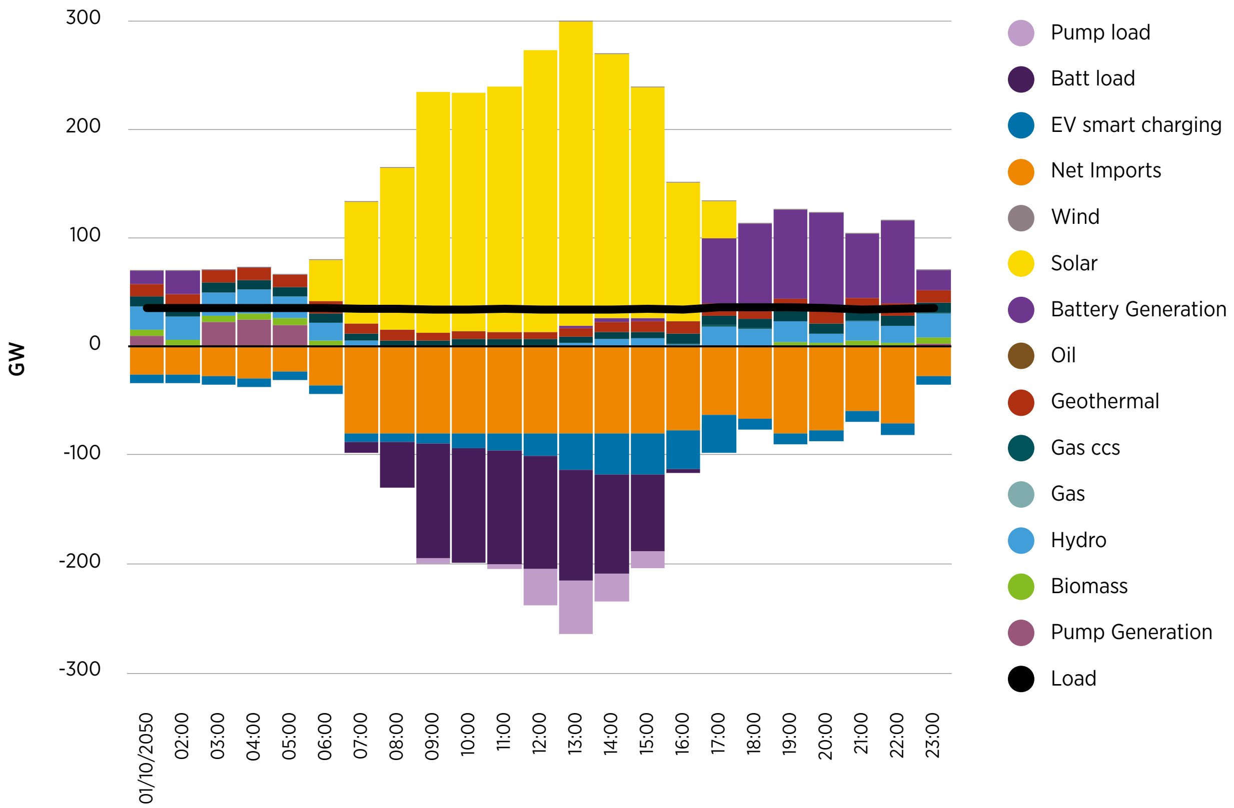


Figure 54 Typical power dispatch in West Java (upper) and South Sumatra (lower), 2050 in 1.5-S RE90 (continued)



Note: Uni-directional smart charging of electric vehicles allows for modifying charging rates and charging time. It gives the user the possibility to charge the vehicle when power prices are lower, and the availability of renewables is on the high.

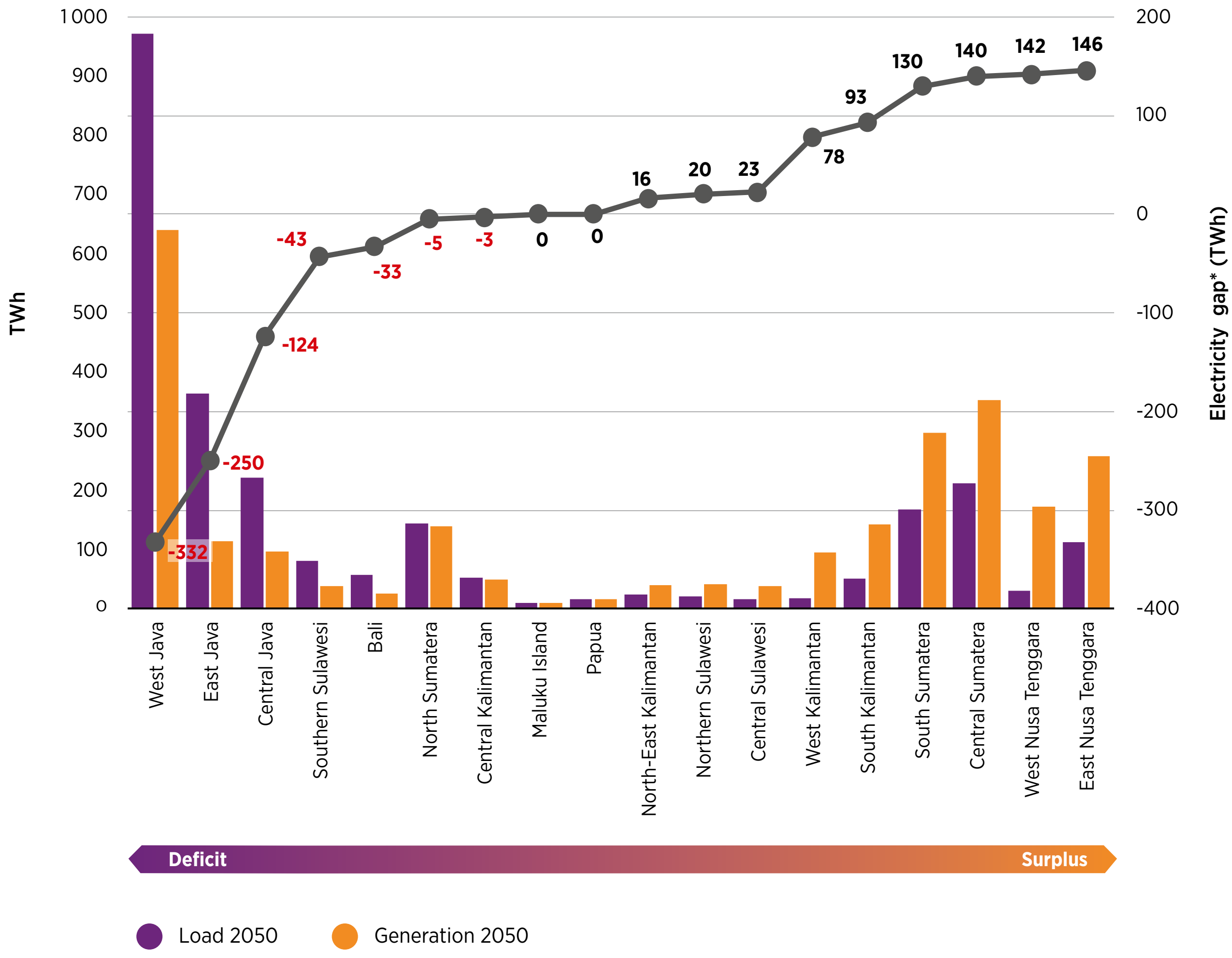
Short- to medium-term storage facilities cycle daily to absorb the extensive generation at major solar spots and, as such, operate in tight co-ordination with power generation and energy excess. At the same time, interconnectors make way for solar towards the destination where it is most needed. The ability of EVs and green hydrogen to support the system balance is higher in regions where EV fleets and green hydrogen demand are higher, respectively, which are the most densely urbanised regions.

Transmission is vital to integrating renewables in an island country like Indonesia

The mismatch between supply and demand, exacerbated by the country's island nature, means that transmission forms the basis of electrification and decarbonisation to a greater extent. Despite the move of Indonesia's capital to Kalimantan, demand distribution is not expected to change by 2050, when there will be a load deficit of 706 TWh on Java, equivalent to 45% of Javanese demand (Figure 55).

Electricity must be taken from the best renewable sites to where it is most needed, requiring holistic planning for importing-oriented, exporting-oriented and self-sufficient regions

Figure 55 Surplus/deficit of electricity by 2050 in the 1.5-S RE90, not considering power exchange between regions

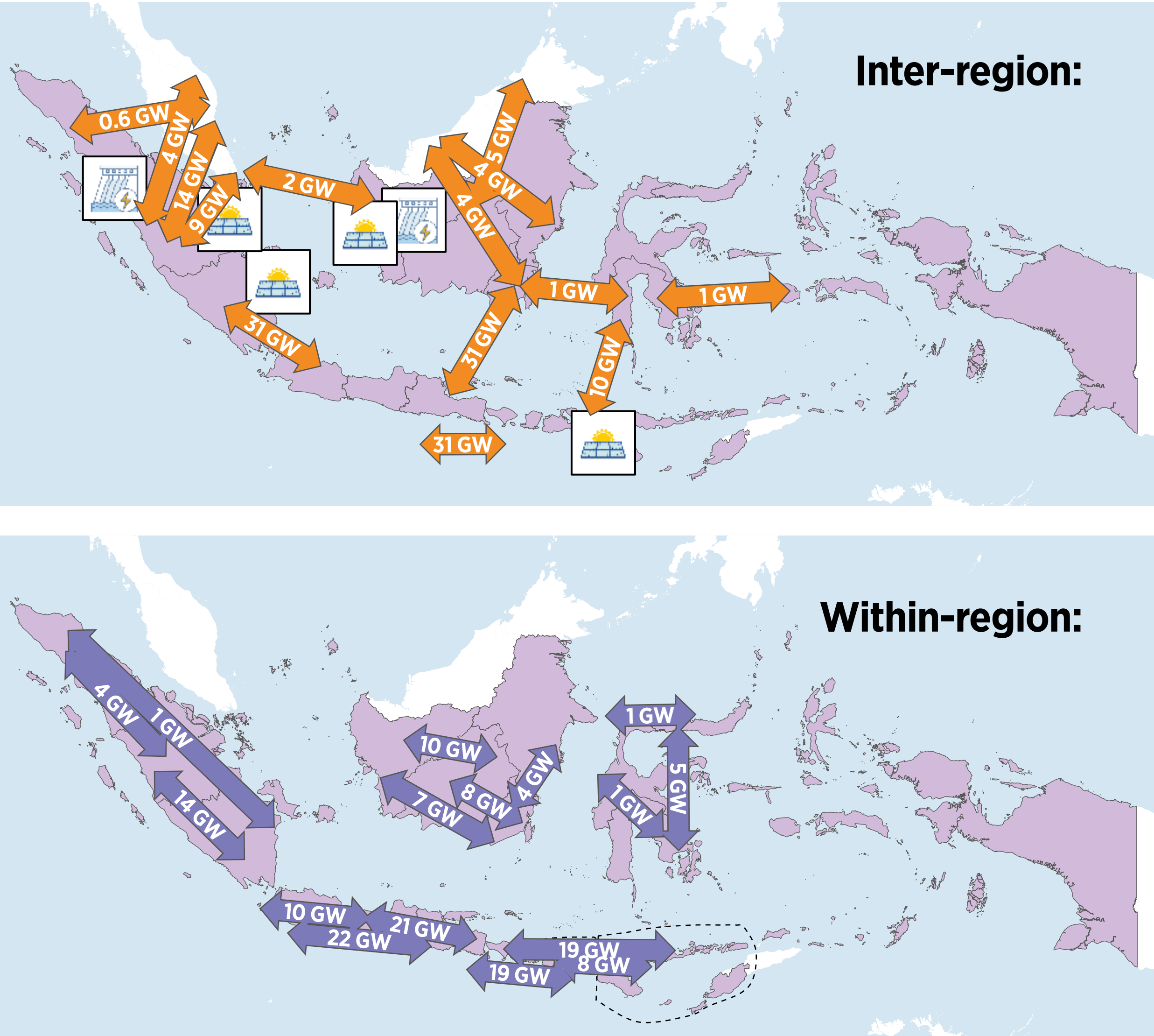


*Electricity gap is the difference between load and generation.
Note: region codes are available in session/figure.

Given that there is a 91% renewable share in the 1.5-S RE90 by 2050, connecting islands is vital to tap and bring renewable resources into main load centres (Figure 56). Transmission lines connecting Sumatra and Java are needed in all scenarios, expanding and extending those from Bali to Eastern Nusa Tenggara. In a second stage, renewables in Kalimantan will require submarine cables crossing the Java Sea (red arrows). Finally, on-island reinforcement and expansion will also be needed (blue arrows). The impact of moving the capital from Java to Kalimantan is uncertain and may increase the share of demand for the latter. The eventual lower than expected demand growth in Java and higher in Kalimantan would make renewables more efficient, and less electricity would need to be transported across long distances.

Transmission is key for the country's decarbonisation. Nonetheless, caution is required in the planning, commissioning and operation of sizeable transmission assets

Figure 56 Transmission lines in 2050 – 1.5-S RE90



Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Storage facilities interplay with transmission assets and shift generation to meet the peak load

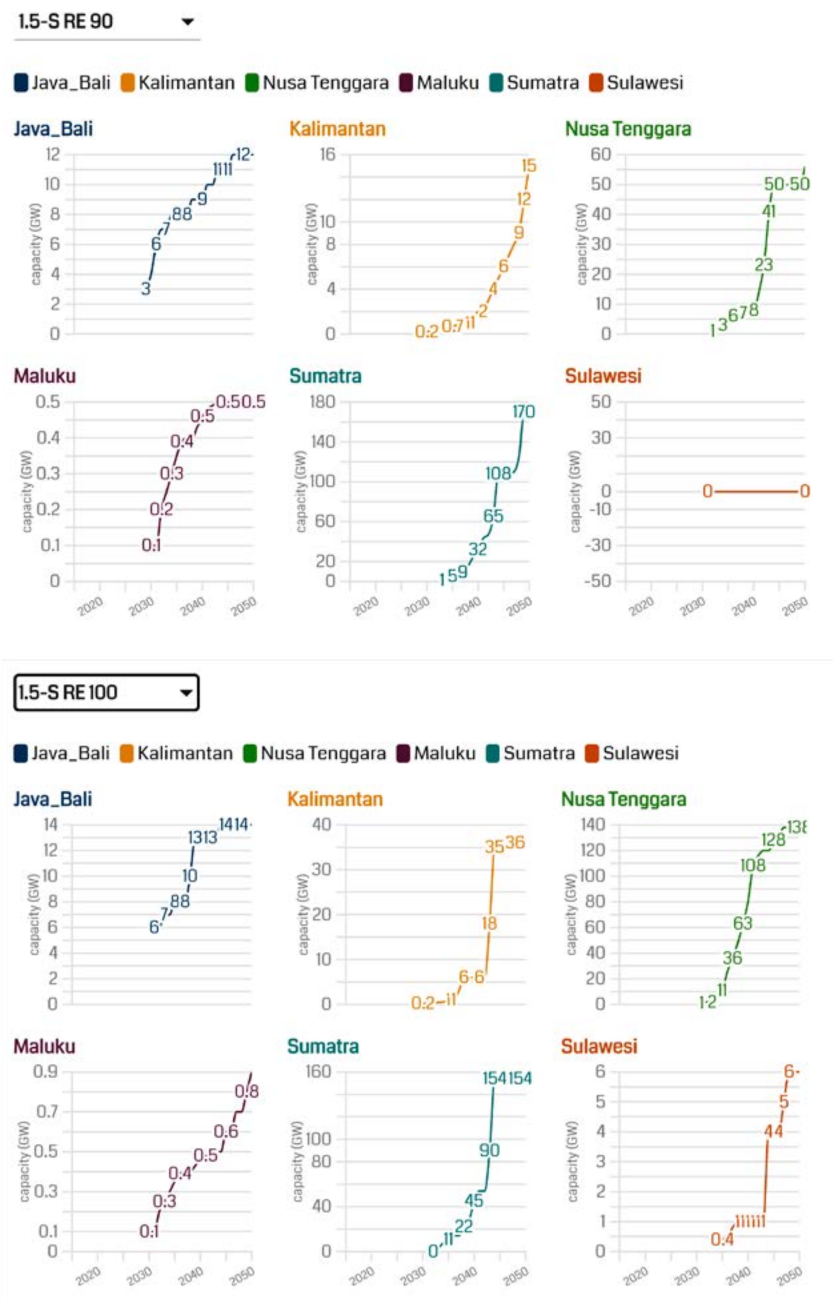
A wide range of commercial storage technologies are available, most of which are likely to have a role in providing the different services needed for the energy transition (IRENA, 2020). However, for the sake of simplicity, this study considers two technologies as flexibility candidates: batteries and pumped storage.

Given that the high shares of solar PV do not provide continuous power over the day, storage is the most powerful tool to meet demand outside daylight hours. Results show a direct correlation between storage and the expansion of renewables in all scenarios. However, this is most pronounced in 1.5-S RE90 and the 1.5-S RE100. By 2050, battery capacity reaches 253 GW and 332 GW under each scenario, resulting from a moderate increase in 2030-2035 before rising more steeply between 2040 and 2045. Battery projects eventually coming online before that are location-specific, more focused on solving local structural issues like local critical network congestion and on experimentation than large-scale energy demand displacement. Pumped storage capacity is 10 GW (150 GWh) and 116 GW (1 760 GWh) under each scenario by 2050.

Generally, there is a correlation between the need for storage and the existing transmission capacity. The higher the transmission capacity across the region, the lower the need for storage and vice versa. However, storage has a role even in an unrealistic case where electricity flow between islands is unconstrained, since solar generation is highly concentrated during one portion of the day. In an indirectly analogous way, storage may postpone or avoid the need for transmission projects. System optimisation inherently finds the right balance between the two flexible resources.

Both batteries and pumped storage are cost-effective, particularly from 2040 onward, and the first large-scale systems come online from 2030-2035.

Figure 57 Battery development capacity in 2050 under the 1.5-S RE90 (above), and RE100 (below)



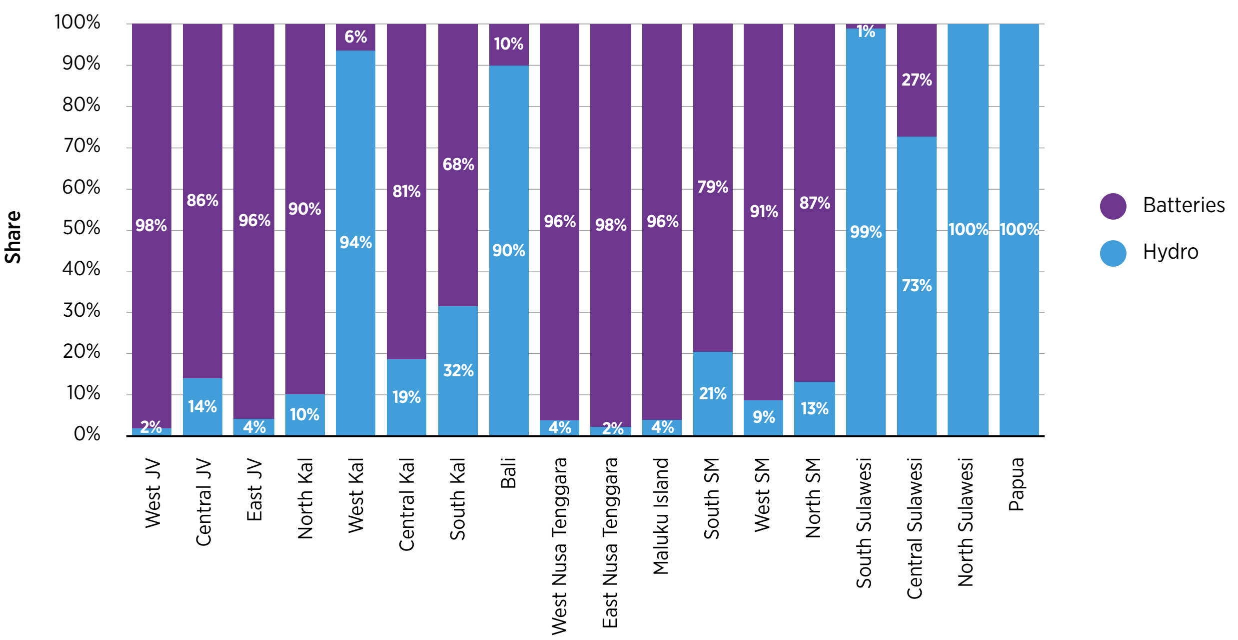
Spinning reserves are the amount of unused generation capacity at online power assets kept on stand-by for the resolution of power shortages or frequency drops. In practice, reserve providers must operate below their rated value to quickly ramp up power when needed. Reserve requirements are typically defined by the largest power asset (usually a generator, but possibly also transmission line and other assets), the so-called n-1 criteria. That is currently the standard approach in Indonesia. In renewables-dominated systems, the installed capacity of generation units tends to decrease with distributed and smaller-scale assets rather than large, centralised power plants. And, therefore, reserve requirements would also reduce. However, transmission capacity tends to increase given the growing need to take power from the best renewable resources to demand centres, which could increase requirements.

In this study, reserves are defined as 5% of the load for all regional grids, except for Java-Bali,[11] where a 10% load risk was considered. Reserves can be shared within a region (*e.g.* Sumatra's southern provinces SM 1 and Sumatra's mid-centre provinces SM2), but not across macro-regions (Sumatra and Java). The exception is the Java-Bali grid, given their existing synchronous grid. Only hydropower and storage assets are allowed to provide assets by 2050 (upward/downward), to avoid having non-renewable assets locked in for this purpose. Where power electronics are designed to do so, battery technologies can deliver a response on a millisecond scale, being faster than any traditional generator. Solar and wind are set to provide downward reserves only (curtailment), though operational adjustments could also allow the technologies to offer an upward response.

The provision of reserves is a function of the resources available in each region. For instance, southern Sumatra is mainly supplied by hydropower, while eastern Nusa Tenggara is mostly supplied by batteries in the wake of the great solar development there.

Hydropower and storage are sufficient to meet operating reserve requirements by 2050

Figure 58 Spinning reserve provision, 1.5-S, 2050



[11] *Grids considered are Java-Bali, Kalimantan, Sumatra, Eastern Nusa Tenggara, Sulawesi, Maluku, and Western New Guinea. Eastern Nusa Tenggara and Maluku are island regions, made up of several small isolated systems, so requirements are a proxy exercise.*

A sensitivity scenario with distinct risk levels (hypothetical infeed loss amounting 5-20% of load) was undertaken for the Java-Bali grid. The provision of reserves is potentially challenging there, given the magnitude of resources and the phase-out of a significant number of thermal units that traditionally contribute to its reliability. Although the 15% of load case presents operating reserve shortages occasionally (1.5% of the time), only the highest risk level (20% of load) is worrying overall (62% of the time).

Table 14 Sensitivity regarding the provision of reserves in the Java-Bali grid

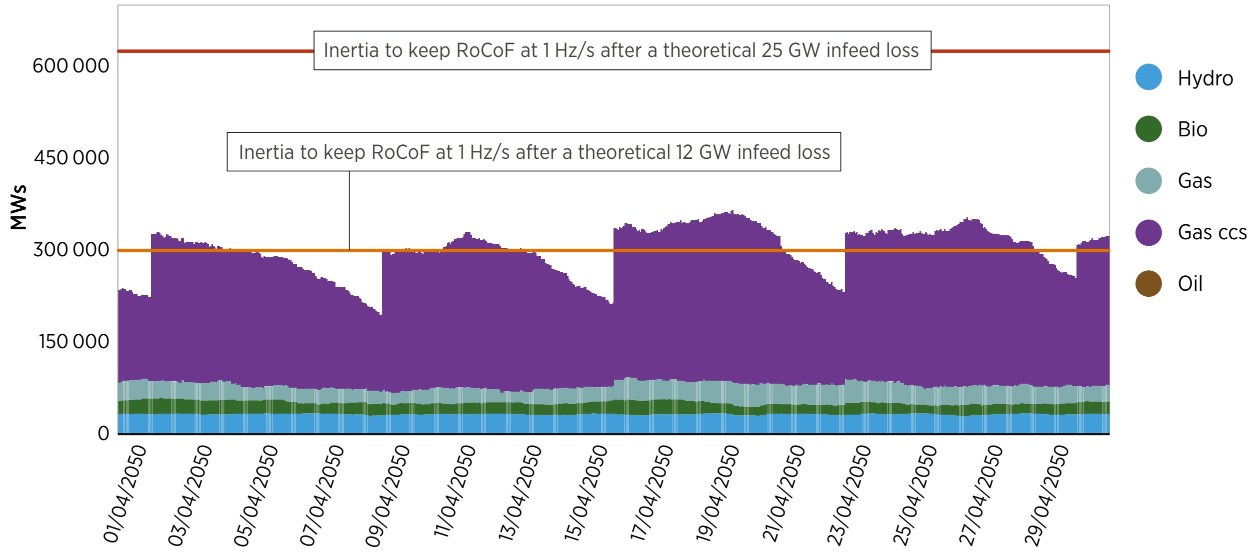
		STATUS		
		SHORTAGE (GWh)	HOURS (hrs)	GWh/hr
LOAD RISK	5%	No	No	-
	10%	No	No	-
	15%	190	138	1.37
	20%	49 390	5 443	9.07

The immense development of solar requires high-capacity transmission lines across islands. The significant transmission assets connecting the Java-Bali grid can result in operational challenges in case of the tripping of a line, namely with Sumatra (36 GW), Kalimantan (33 GW) and Nusa Tenggara (31 GW). These may provide 24%, 22% and 20% of the Java-Bali grid's average load at total capacity, or 70% in case of simultaneous imports. Even though this is not likely to happen, and each line should be comprised of two or more independent smaller circuits, it should be adequately explored in grid integration studies. There will be a need to rethink how imbalances are detected and reserves are activated. Gradually less synchronous inertia will be available, with diminished ability to oppose changes in frequency after a failure, as inertia is inherently provided by synchronous generators like thermal plants and hydropower. The amount of reserves and agility needed in today's power systems is a function of inertia conditions. Figure 59 shows inertia provision in the Java-Bali grid in 2050 at around 300 MW on average. At least twice this value is needed to maintain the rate of change of frequency (RoCoF) at 1 Hz/s, and more than four times to keep it at 0.5 Hz/s,[12] in case of two of the abovementioned lines trip simultaneously, considering each as a single asset. Therefore, the future system is likely to need faster frequency response resources like batteries and a different way to signal imbalances. The good news is that grid-forming inverters are on the verge of addressing this issue, allowing operation at very low or even zero-inertia conditions.

[12] *Considering grid frequency y at 50 Hz.*

Moving from synchronous machines to inverter-dominated systems reduces the system inertia, requiring innovative approaches

Figure 59 Inertia contribution by synchronous machines in the Java-Bali grid in April 2050, 1.5-S RE90



Note: MWs: Megawatt-second.
Source: 2nd *Renewable energy outlook for ASEAN*

4.4 SPECIAL FOCUS: THE ROLE OF BIOENERGY, HYDROGEN, CRITICAL MATERIALS AND LOCAL SOLAR PV INDUSTRY

KEY HIGHLIGHTS

Bioenergy plays an important role in Indonesia's energy transition. Bioenergy demand in the 1.5-S grow fivefold, contributing over 20% of Indonesia's TFEC by 2050. Bioenergy, including solid biomass, biogas and biomethane, and liquid biofuels, represent up to 18.5% of Indonesia's total primary energy supply by 2050 in the 1.5-S.

It is important to remove barriers to bioenergy development in order to secure its role in Indonesia's decarbonising effort. Low policy incentives, the higher cost of converting some biomass into an energy carrier such as biofuel, and the need for sustainability assurance for oil palm biomass are among the identified barriers that needed intervention by all the related actors in Indonesia's energy transition.

Hydrogen provides a complementary solution in the country's ambitious climate objectives. Green hydrogen plays a role in Indonesia's industrial sector, such as in iron and steel, aluminium and chemicals, and also in international bunkering.

Plans for the energy transition must take critical materials into account to avoid unforeseen delays. Critical materials are used in many energy transition technologies. Indonesia is the world's largest producer of nickel and is accelerating its production locally.

An integrated upstream and downstream solar PV industry is needed to accelerate Indonesia's solar roll-out. The potential of the industry is apparent, as many solar PV projects are envisaged in the country's energy transition future. Suitable policies related to renewable energy production, a clear framework for local production and demand-side incentives for attracting more investment are all required

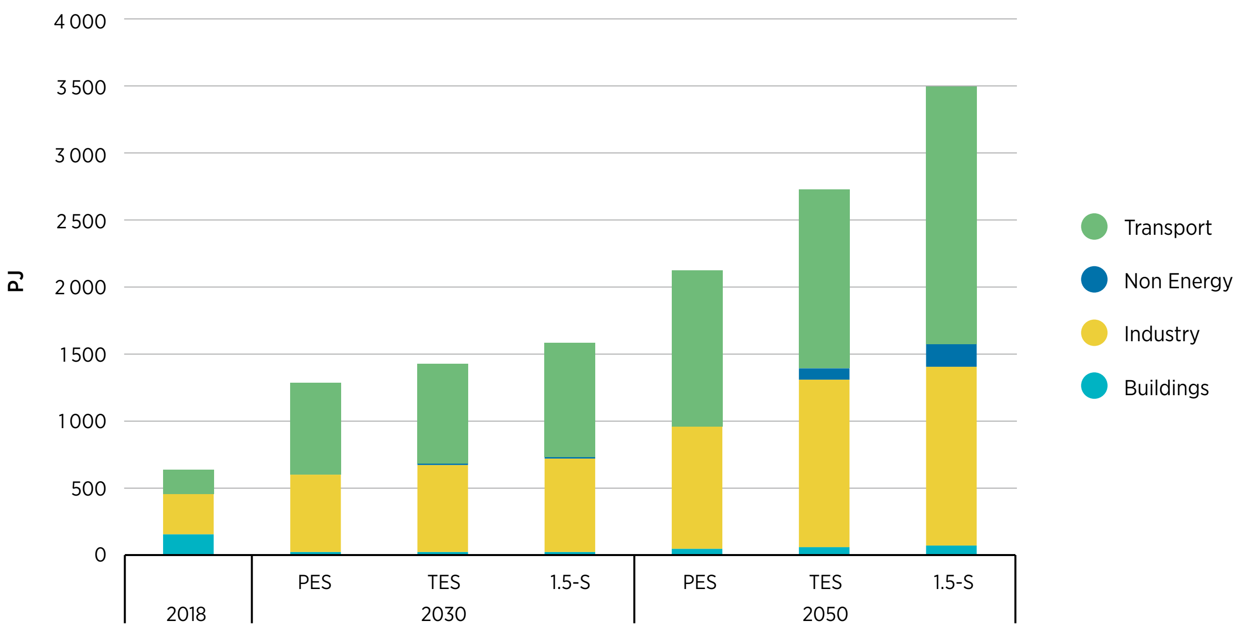
Bioenergy pathways for Indonesia

Achieving the net zero goal will not be possible with renewable electricity and energy efficiency alone. Bioenergy, including solid biomass, biogas and biomethane, and liquid biofuels, represent up to 18.5% of Indonesia's total primary energy supply by 2050 in the 1.5-S. That would require just over 4 567 PJ of primary biomass supply, an increase of over four and half times the 2018 levels. Bioenergy demand grows fivefold, contributing over-20% of Indonesia's TFEC by 2050.

Indonesia's large land mass, coupled with its abundant rain and sunshine throughout the year, facilitates a thriving agricultural sector. This translates into significant potential for biomass feedstock supply, accessibility and sustainability. Biomass is predominantly used in the industrial sector, growing over twofold in the 1.5-S. The industrial sector consumes over 87% of total biomass demand by 2050. The high productivity of Indonesia's agricultural sector generates considerable volumes of underutilised collectible bioenergy feedstock, reaching 2 594.6 PJ potential supply by 2050 (IRENA, 2022c).

Bioenergy will play an important role in decarbonising the transport and industrial sectors

Figure 60 Bioenergy demand by sector, 2018-2050



Key barriers and interventions

Within Indonesia's current bioenergy framework it is possible to identify key barriers to implementing the bioenergy pathways identified above, and the potential intervening actions required to mitigate the barriers and accelerate sustainable bioenergy scale-up.

Key barrier 1 Low policy incentive to decarbonise industrial process heat

A high proportion of Indonesia's GHG emissions stem from the industrial heat generation process through the combustion of coal. To date, policy incentives are still too weak to decarbonise this process. There are several approaches that Indonesia can take to begin building a policy framework that seeks to reduce GHG emissions from the industrial sector.

First, carbon trading regulations are an option for Indonesia – namely the current drafting of the presidential regulations on carbon trading; this offers the opportunity to aid progress towards meeting an enhanced NDC target in line with net zero targets. The regulation sets out plans for carbon trading, carbon offset trading and a commodity market(Climate Transparency, 2020). Second, Indonesia can seek to build a policy framework that provides private and public institutions with incentives to develop decarbonisation measures in the following areas related to bioenergy. Sustainably produced biomass can be used in place of some fuels and feedstocks, with co-firing being a realistic option for accelerating fuel switching. Mobilising palm oil residues and wastes such as empty fruit bunch, palm kernel shell, old trunks and palm oil mill effluent for bioenergy feedstock will not only reduce GHG emissions, but also boost the overall sustainability of the oil palm industry. Indonesia can seek to create more incentives for private institutions to retrofit their facilities with commercially viable technologies that will allow existing plants to use biomass feedstock for the heat generation process.

Key barrier 2 Higher cost of converting biomass into energy carriers compared with traditional fuel sources

The production of commercially viable solid, liquid and gaseous biofuels will facilitate uptake of the bioenergy pathways as outlined in the 1.5-S. To further increase commercial viability and reduce the cost of producing biofuels, the Indonesian government can take three actions (IRENA, 2022c):

1. Introduce a favourable regulatory framework.
2. Redirect fossil fuel subsidies to clean energy.
3. Increase spending on R&D to further reduce the cost of conversion from biomass to energy carrier.

Key barrier 3 Sustainability assurance and confidence for oil palm biomass

Palm oil is a potential biomass feedstock that has negative connotations. It is crucial to ensure any expansion of supply with sustainability criteria. There are several ways to harness the bioenergy potential of the palm oil sector by addressing the following challenges(IRENA, 2022c):

1. As more scientific evidence is accumulated, farming practices must be constantly updated to improve the sustainability standards of plantation management. However, farmers are generally not adaptive to such changes. Bringing oil palm residues such as old palm trucks and empty fruit bunch out of the farm as feedstock for bioenergy requires a breakthrough in cultural barriers and a behavioural change among farmers. Research organisations should play a critical role in not only disseminating scientific knowledge, but also prompting farmers to adapt to up-to-date scientific evidence.

2. Third-party certification schemes such as Malaysian Palm Oil (MSPO) and Indonesian Sustainable Palm Oil (ISPO) will play a central role in providing sustainability assurance. These schemes should also incorporate handling of oil palm residues and by-products in their sustainability standards. All oil palm growers and millers in the country must be checked for compliance with mandatory ISPO certification. This mandatory requirement was implemented to address environmental issues in 2011. The credibility of ISPO should be further raised by implementing its mandatory processes properly, including among smallholders.

Green hydrogen in the energy transition

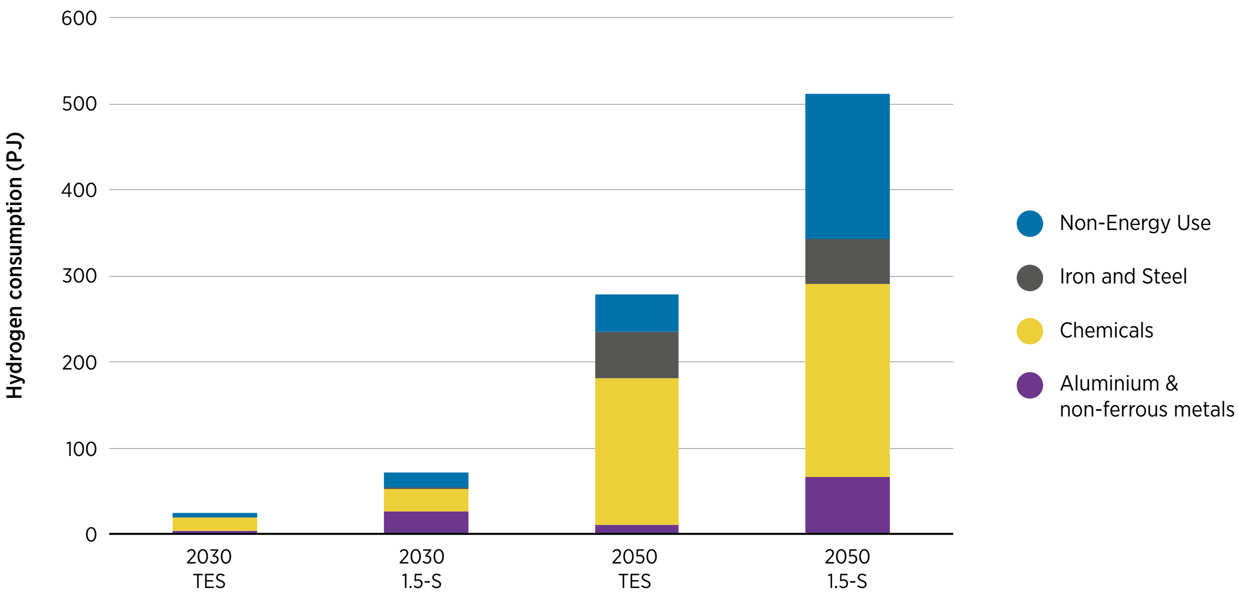
Green hydrogen, produced with renewable electricity, is projected to grow rapidly in the coming years (IRENA, 2019). Globally, hydrogen from renewable power is technically viable today and is rapidly approaching economic competitiveness. Green hydrogen in Indonesia is set to play a role most predominantly in decarbonising hard-to-abate sectors such as the iron and steel, chemical and aluminium industries. Starting early in the next decade, hydrogen demand grows by 10% annually, accounting for 4% of Indonesia's TFEC by 2050 in the 1.5-S, reaching 512 PJ.

Hydrogen also appears in Indonesia's transport sector. Green hydrogen and its derivatives are used for international bunkering for shipping; however, these sums are not included in Indonesia's TFEC, but will constitute another significant source of demand. Its implementation is limited to long-range international bunkering vessels, and largely not in domestic transport activities.

A hydrogen-based energy transition will not happen overnight. Hydrogen is likely to trail other strategies such as electrification of end-use sectors, and its use will target specific applications. The need for a dedicated new supply infrastructure may limit hydrogen use to certain countries that decide to follow this strategy. Therefore, hydrogen efforts should not be considered a panacea. Instead, hydrogen represents a complementary solution that is especially relevant for countries with ambitious climate objectives (IRENA, 2019).

Hydrogen has a role to play in decarbonising the industrial sector

Figure 61 Hydrogen demand projection in the industrial sector by scenario



Hydrogen supply in a global context

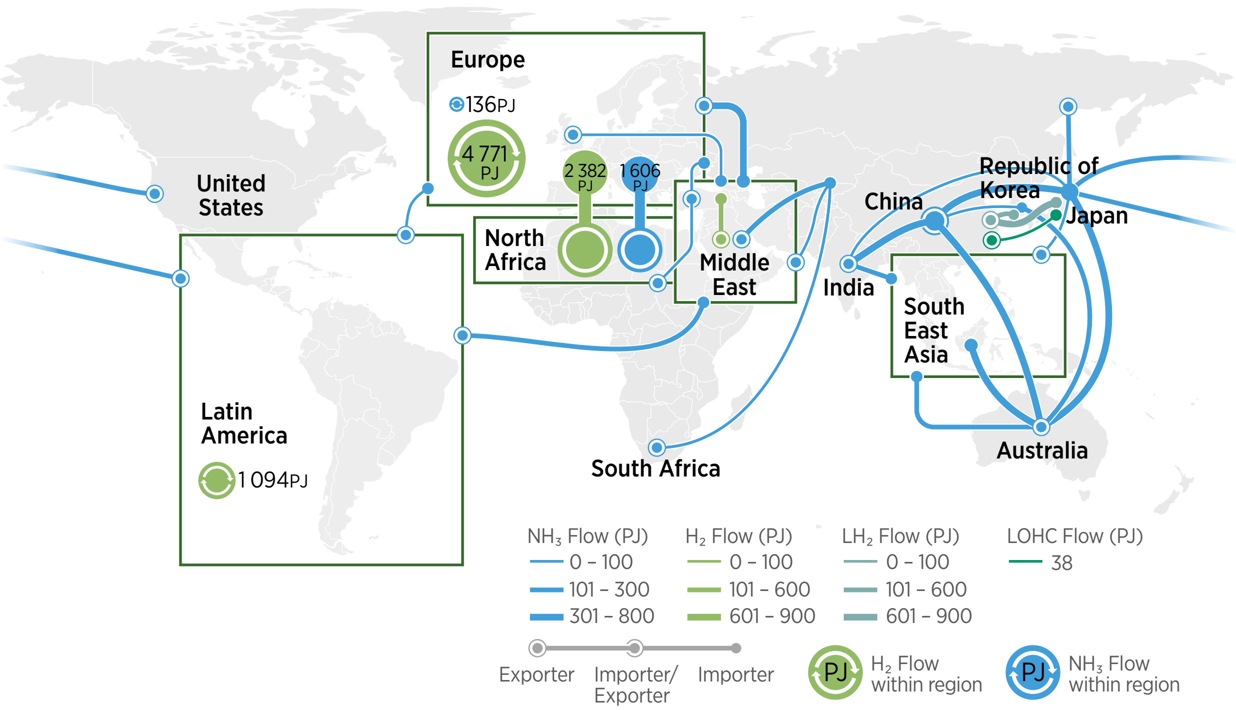
By 2050, the Asia hydrogen demand could increase nearly six times to reach almost 190 MtH_2/yr from today's values. China, India and Japan are expected to be the largest markets in this region. Beyond meeting domestic needs, Indonesia has interesting prospects for becoming a regional supplier of green hydrogen based on its extensive resources, particularly solar energy. However, there might be a need for increasing the availability of low-cost capital in the region for the deployment of utility-scale solar facilities, together with incentives to reduce costs of the technology.

IRENA's recent report *Global hydrogen trade to meet the 1.5°C climate goal – part 1* outlines a perspective of the hydrogen trade by mid-century based on the scenarios from IRENA's WETO report (IRENA, 2022e). The study highlights that meeting the increasing demand for hydrogen worldwide will depend on matching sources of low-cost production with demand centres. Pipelines are prone to be the most cost-effective of transferring hydrogen, particularly for regional trade, such as across ASEAN. Ammonia is the most attractive carrier to cover long-distance transport given the existing infrastructure and an expanding market as fuel for shipping and power generation. Most of the ammonia to be transacted may be consumed as ammonia itself, avoiding the ammonia cracking stage, which is still costly and overall challenging.

The study showed that Australia is currently a step ahead of Indonesia and ASEAN countries in meeting the regional demand. The country has vast land of 7 million square kilometres for renewable production, which, combined with a low cost of capital, enables the production of green hydrogen competitive with fossil fuels-based. Besides, the country has a solid roadmap going forward to develop the sector. So, the Australian case relies on the country's capability of producing renewable electricity at very low costs, which makes the bulk of hydrogen total costs. Compared to ASEAN, that might be enough to compensate for the extra distance from demand centres like China and Japan (Figure 62).

Hydrogen will be increasingly traded globally

Figure 62 Global hydrogen trade flows under the 1.5-S

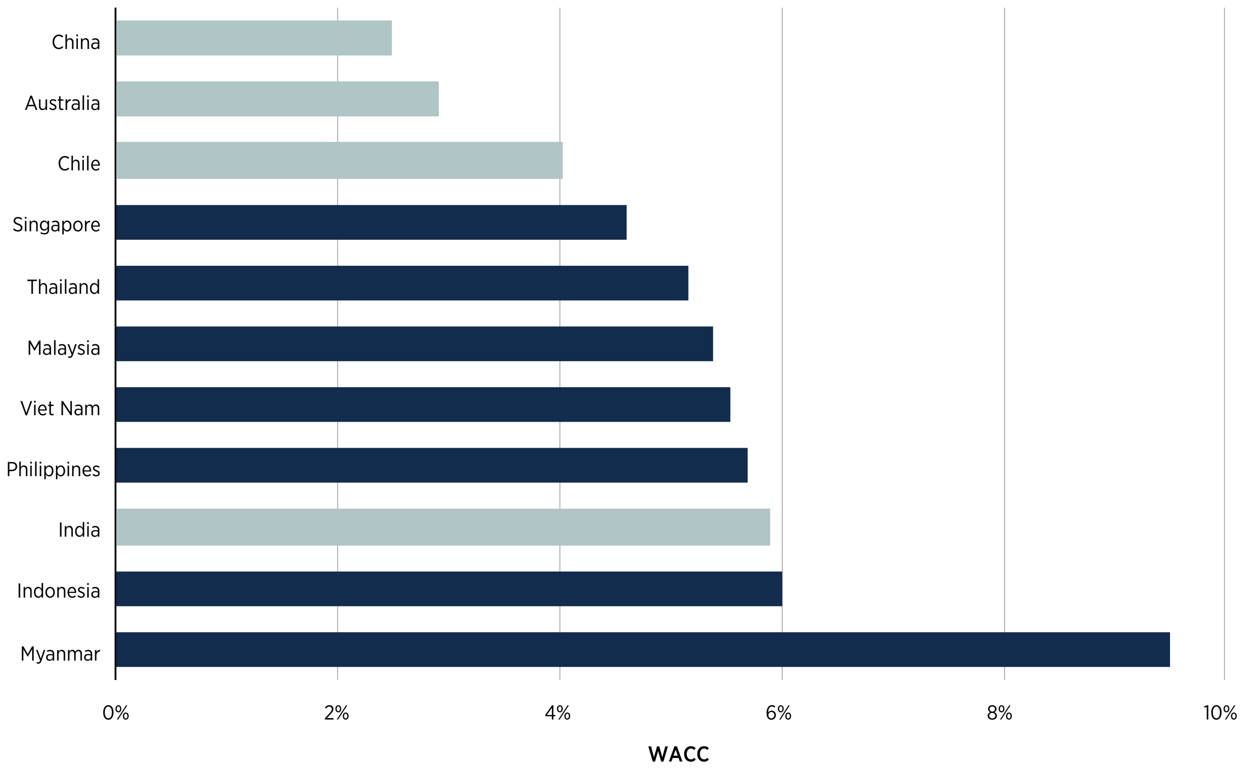


Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA.
Source: (IRENA, 2022e).

The cost of capital for solar and wind projects in Australia ranges from around 2.9-3.7%, which is significantly below that of Indonesia. In combination with relatively low investment costs, Australia has the potential to produce about 378 EJ/yr of green hydrogen below USD 1.5/kg. For illustration, that is higher than Japan and China's primary energy supplies (PES) in 2020 at 16 EJ and 126 EJ, respectively (blue/red vertical lines in Figure 64). Based on current assumptions, Indonesia could supply about 5 EJ per year at around USD 2.0/kg, roughly above USD 0.5/kg of Australia could deliver at production sites for the same supply range. However, costs to produce green hydrogen would significantly increase beyond this value, making fundamental to reduce capital costs, and investment costs of renewables to increase competitiveness.

The cost of capital related to solar and wind new projects is significantly higher in ASEAN countries than in other potential world hydrogen exporters like Australia and Chile

Figure 63 Average cost of capital (WACC) of solar and wind projects in ASEAN and selected countries

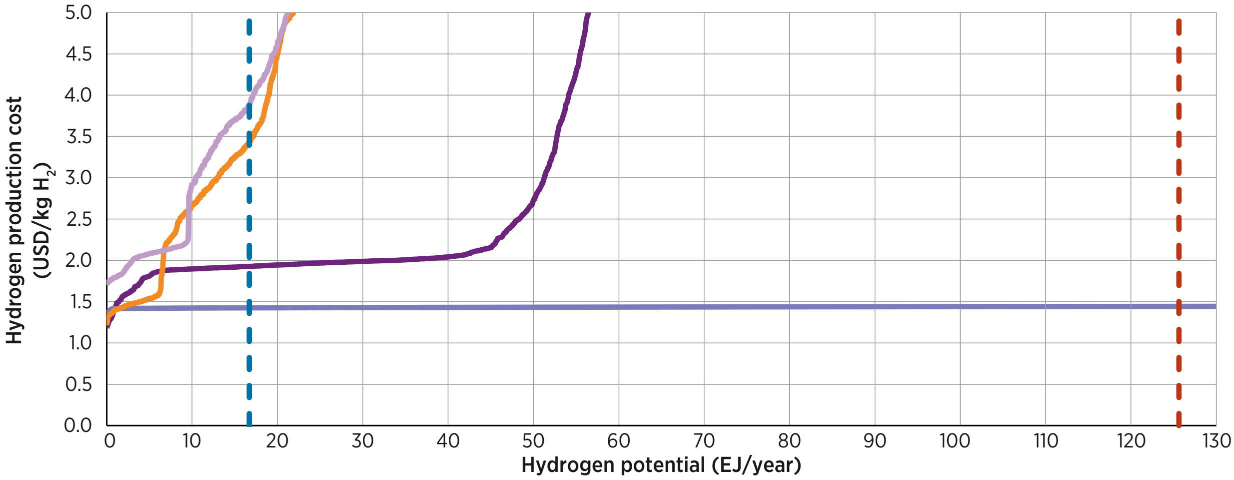


Source: (IRENA, 2022f).

The other cost component mounting to total costs at the destination is naturally the cost to transport hydrogen. High overall costs to ship hydrogen tend to slightly favour Indonesia, compared to Australia, due to the shorter distance to important markets like China, Japan and South Korea. Besides, it would also increase the competitiveness of Indonesia to provide the commodity across the ASEAN. Kalimantan and Sumatra arise as potential hydrogen exporting hubs in Indonesia. Whereas the former might be competitive in providing hydrogen overseas mainly to China, the latter may export through pipelines to ASEAN countries, to Peninsular Malaysia and beyond. A forthcoming report focusing on the ASEAN region will go into more detail on hydrogen supply in the region.

Production costs rise considerably in some countries as volume increases.

Figure 64 Hydrogen cost curve potential based on 2030 values



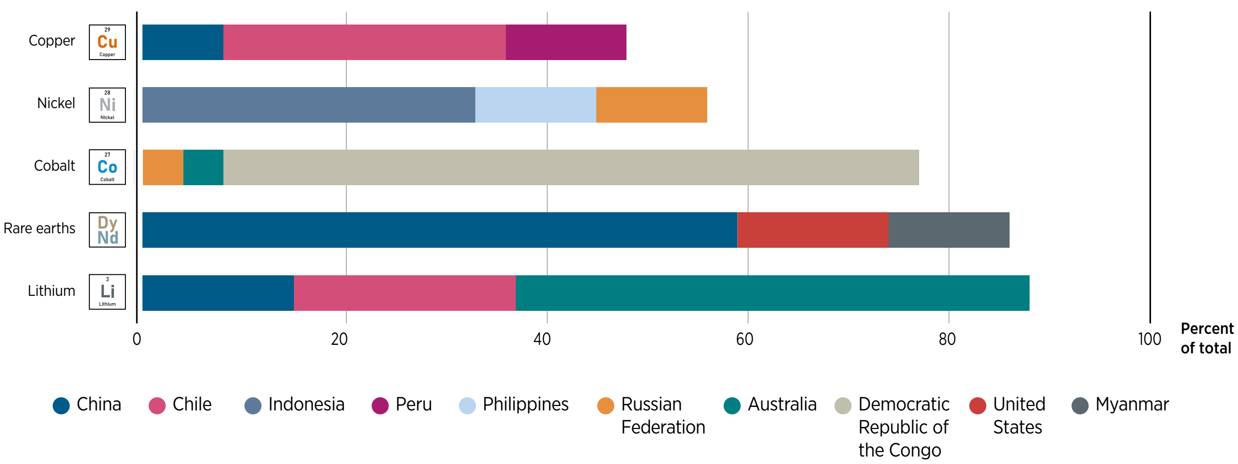
Source: 2nd Renewable energy outlook for ASEAN

Critical materials

A critical material is defined as matter with unique properties that have importance for a product, where the risk associated with the supply of the material is of potential concern, for instance due to political unrest or restricted availability of viable substitutes owing to scarcity or underdevelopment. The energy transition involves three pillars: energy efficiency, renewable energy generation and the mass electrification of end-use sectors. Critical materials are used in the manufacture of key transition technologies, such as copper for electric wiring, nickel for battery cathodes, cobalt and lithium for batteries, and neodymium and dysprosium for permanent magnets used in high-performance electric motors and generators. Plans for the energy transition must take critical materials into account to avoid unforeseen delays to the energy transition.

ASEAN countries of note are Indonesia and the Philippines, accounting for about 45% of global nickel production, and Myanmar, producing 11.5% of global rare earth elements

Figure 65 Top three countries producing nickel, cobalt, rare earth elements and lithium



Source: (IRENA, 2022a).

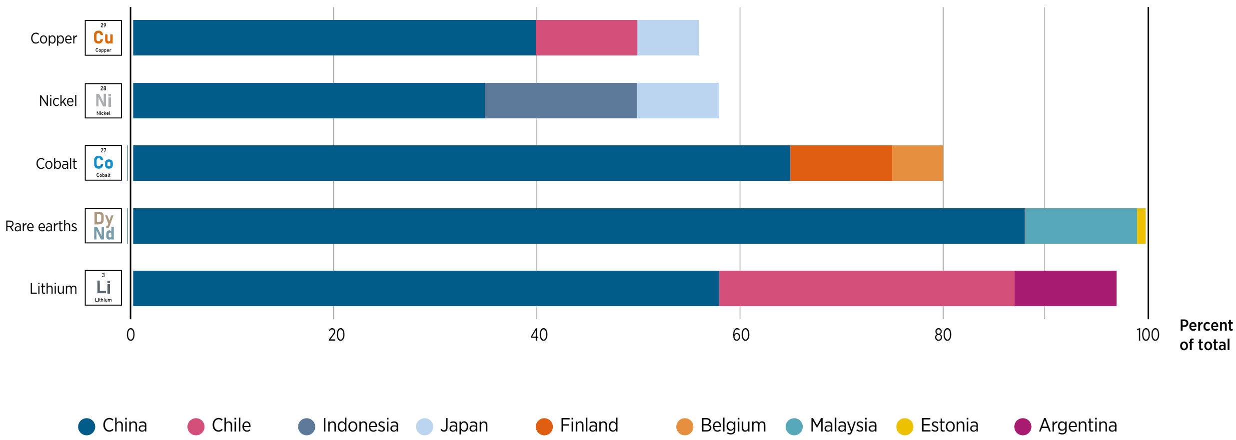
Lithium and nickel are among the critical materials that are used in the production of rechargeable batteries. Nickel demand has increased following Tesla's six-year supply contract for 75 Mt of nickel concentrates from Talon Metals' Tamarack mine (Deaux, 2022). Global nickel consumption reached about 2.4 Mt in 2019, with China and Indonesia as the leading costumers (IRENA, 2022a). The demand for nickel is projected to grow as the transition towards EVs is now considered the preferred decarbonising option for the road transport sector globally.

Indonesia has the world's largest reserves, and is the second largest processor of nickel globally, behind China. Indonesia, the Philippines and the Russian Federation account for 56% of global nickel production (IRENA, 2022a). Indonesia is making large investments in nickel-processing facilities, however, which will shift some processing away from China. Indonesia commissioned the first nickel processing plant in 2021 (Huber, 2021). These investments are supported by Indonesia's policy to ban exports of nickel ore and process it domestically. Nickel demand is projected to exceed supply by 2025 (McKinsey & Company, 2017). Recycling is widely implemented for nickel, with approximately a third of global nickel supply derived from recycled materials (Nickel Institute, 2022).

President Joko Widodo has stated the development of downstream industry as one of the three economic strategies to boost Indonesia's economic growth, and nickel will be the focus for processing commodities into ready-to-use products. The Minister of Industry, Agus Gumiwang Kartasasmita, stated that downstream mining- and mineral-based industries are progressing, with investment in the smelter industry totalling USD 51.43 billion from 2015 to the third quarter of 2021. The annual capacity of operating smelters has reached 12.3 Mt for nickel, 6 Mt for aluminium, 3.2 Mt for copper, and 19 Mt for steel (MoI, 2022).

Indonesia accounts for 15% of nickel processing capacity, and Malaysia for 11% of rare earth element processing

Figure 66 Top three countries for processing copper, nickel, cobalt, rare earth elements and lithium



Source: (IRENA, 2022a).

Nickel production

Indonesia is set to produce over 1.2 Mt of nickel pig iron (NPI) this year, and by 2025 it is expecting to be producing well over 1.5 Mt /year. The country is the world's largest nickel producer.

The world will not run out of nickel any time soon as identified land-based resources with 0.5% nickel or greater contain at least 300 Mt of nickel, with about 60% in laterites and 40% in sulphide deposits.

To extract nickel, laterite ores require extensive and complex treatment, which has been historically more expensive than sulphide ores. So far, markets for NPI and battery-grade nickel have functioned independently, with battery-grade nickel being much more expensive. Tsingshan has developed a revolutionary new technology to process laterite nickel with a substantial reduction in processing cost, pioneering the production of NPI from nickel laterite ores.

Indonesia's nickel production is based on the laterite resource type. Laterite resource vastly exceeds the sulphide resource, a reason why Indonesia is currently expanding its production significantly, with USD 42 billion of planned investments by Fortescue and Tsingshan, while other parties are also investing in the Indonesian nickel mining and processing sector.

Not all mined nickel is used for EV batteries or traded on the London Metal Exchange (LME). It can be split into two broad categories: low- and high-grade primary nickel. High-grade nickel (Class I) accounts for 55% of all nickel mined globally, while low-grade primary nickel (Class II) accounts for the remaining 45%. Class I nickel contains at least 99.8% nickel. Class II nickel, such as NPI or iron-nickel, actually contains a relatively small amount of nickel – 8-16% and 15-55% respectively.

Battery technology exclusively uses Class I nickel for cathode production. Only Class I nickel is traded on the LME due to the high purity standard of the mined metal. Such LME exchange-traded Class I nickel satisfies specific delivery standards (this accounts for less than 25% of total finished nickel supply). Hydrometallurgical processes use Class I nickel sulphides to produce battery-grade sulphate NiSO4.

Tsingshan refines saprolite ore (from laterite soils) and turns it into NPI, which is in turn refined into nickel matte and then further processed to make Class I nickel. High-matte nickel products contain 75% nickel.

Provided that this new process becomes the norm, growing EV battery demand could mean NPI supply being diverted away from stainless steelmaking. Through the new process, the supply bottleneck for nickel sulphate has been broken and the expectation is that Class I and Class II nickel prices will converge, taking into account that conversion of NPI to nickel sulphate adds around USD 5 500-6 500/t of nickel.

This process would increase the carbon footprint substantially, adding 50-70 tCO_2/t of mined nickel to convert NPI to matte and then further into NiSO4. An alternative process uses high-pressure acid leach (HPAL) technology to recover nickel and cobalt separately from each other from low-grade nickel-oxide laterite ores. The nickel that is recovered is Class I, battery-grade nickel sulphate. The technology has been deployed in New Caledonia. However high capital expenditure and environmental costs have caused it to lag behind current methods.

Also, 39% of global nickel reserves are found in locations that are exposed to high or extreme biodiversity risks – and because nickel typically comes in thin ore deposits, these areas are often destroyed. Proactive environmental, social and governance (ESG) safeguards are critical for widespread acceptance of the product.

Vale has conditionally approved the long-awaited Bahodopi nickel project in Indonesia. The project is a joint venture with Chinese firms Tisco and Xinhai, and will produce 73 kt of Ni in NPI for the stainless steel market. It will be Indonesia's most expensive plant, with a capital intensity of USD 31.5k/t Ni, which is 320% higher than other plants in Indonesia.

The Bahodopi project will involve a new gas-fired power plant. This is likely to make this the most expensive operating cost in the Indonesian NPI sector (as well as being the highest CAPEX plant too). Other NPI plants use a combination of coal and solar power. Other NPI producers are also now shifting to build their new plants in Kalimantan, where they will be able to access hydropower in the future, providing a huge cost advantage. The price of NPI in Q2 2022 slipped below USD 18 000/t, indicating how competitive NPI has become. At the same time, NPI production costs in Indonesia have reached USD 14 500/t (based on coal power). The production costs for a gas-fired NPI plant would be even higher.

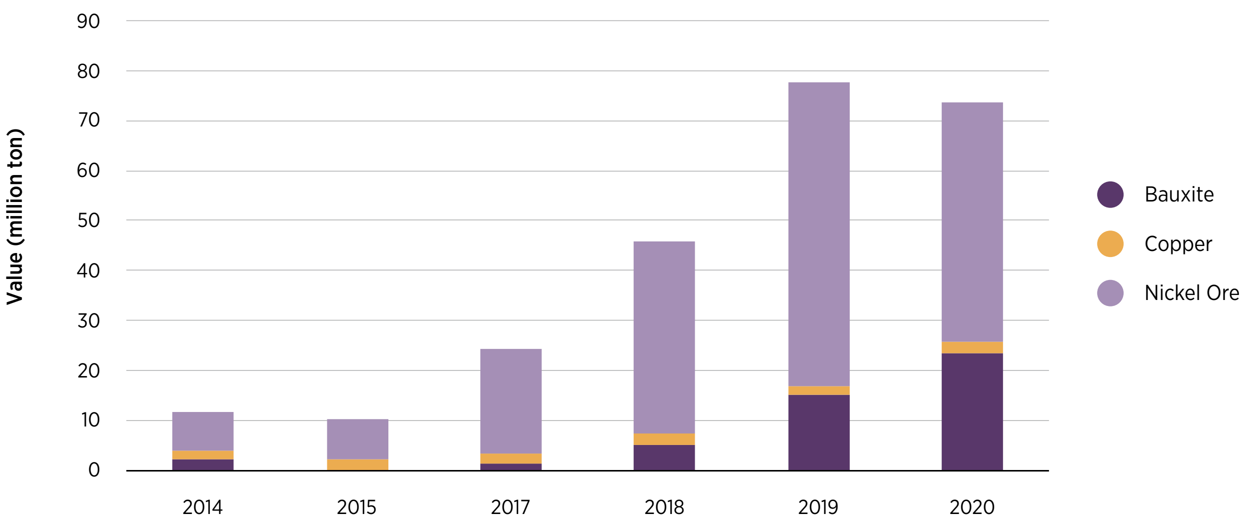
Indonesia battery and EV manufacturing

Global EV sales are on the rise. This year 7 million sales are foreseen, with projected growth to 40 million units by 2030. The battery represents the single most important cost component in an EV. The rapidly growing popularity of EVs is causing demand for lithium-ion batteries to soar. An optimised supply chain with a focus on vertical integration and strategic partnerships is vital to mitigate risks and guarantee a secure supply of essential raw and refined materials.

Indonesia is currently focusing on the nickel-cobalt-manganese, and lithium-cobalt-nickel-aluminium, which are among the most popular EV lithium-ion battery combinations today, as the two nickel-based battery blends for development in the country. Domestic production of nickel ore-related product has been strongly encouraged by the government, as the country aims to become the ASEAN's EV production hub by 2030, mainly in the role as the major producer of lithium-ion batteries, targeting capacity of 140 GWh – as much as global EV battery production in 2020 (CSIS, 2022). The country is blessed with reserves of nickel, cobalt and copper, which are the essential ingredients for EV battery manufacture.

Indonesia's ambitions are wide-ranging. As the world's biggest nickel producer it wants to utilise its mineral resources, but also aims to reduce emissions by creating a domestic EV market. On the upstream side, the country has vast nickel reserves and applies restrictive measures to attract foreign investment in nickel processing. Further down the supply chain, ASEAN's largest car market offers large opportunities for EV battery and vehicle manufacturers.

Figure 67 Indonesia mineral mining production



Source: Production of Minerals Mining, Statistics Indonesia (2020).

President Jokowi inaugurated the ground-breaking of the first EV battery factory in West Java in September 2021, targeted to begin production by 2023 with total investment estimated to reach USD 9.8 billion. Indonesia has also secured a deal with Contemporary Amperex Technology (CATL) and LG Chem as the world's top EV battery producers that supply Tesla's Chinese output, with investment reaching about USD 5.2 billion. Production is targeted to commence in 2024 and is currently aiming to supply Volkswagen's future production of EV battery cathode precursors in Indonesia. Japan's giant car manufacturer, Toyota Motor Corporation, is also committing to invest USD 1.8 billion over the next five years in Indonesia, aiming to tap in to ASEAN's burgeoning EV industry. It began the development of the Toyota xEV Center in May 2022, to provide automotive electrification and digitalisation training to local engineers. Furthermore, Reuters reported that Tesla has also joined the party by signing an estimated USD 5 billion contract for five years with Indonesian nickel processing companies for materials used in their batteries (Electrive, 2022). Tesla is even considering investing in a battery and possibly EV factory in the country following a meeting between its CEO, Elon Musk, and Indonesia's President Joko Widodo, in May this year.

In support of the efforts, the government has introduced several regulations, among which are the introduction of import tariff reductions for EV production machinery and materials, and up to 10 years' tax holiday incentives for EV manufacturers making at least IDR 5 trillion of investment in the country. The government will need to continue addressing the investment challenges to realise their goal of reaching 140 GWh battery production by 2030. With the average EV car battery at around 40 kWh (E.ON, 2022), and around 45 kg of nickel being required for the production of a single lithium-ion battery pack (Mining, 2021), Indonesia will need to allocate about 4 Mt of domestic nickel production to power the EV and motorcycle fleet in the country by 2050 under the 1.5-S. To put this in context, globally around 2.7 Mt of nickel were produced in 2019, with Indonesia as the largest producer at around 0.8 Mt. Therefore, significant scaling up will need to occur, not just in Indonesia but globally. As nickel extraction and processing it very energy intensive, this must go hand in hand with clean energy and sustainable mining practices.

Whether or not Indonesia can reach its goal to produce 140 GWh in 2030 will depend on attracting substantial foreign investment over the next few years. The government will have to address further challenges related to conducting business in Indonesia, as well as ESG concerns related to nickel mining and processing.

In recent years, a combination of rapid technological progress and scaled-up production rates have led to improved performance and – mostly – a fall in production costs for EV batteries. Rising raw material costs and the recent semiconductor shortage have caused prices to temporarily rise again over the last two years. Based on figures from mid-2021, an average NCM811 battery pack (80% nickel cathode) costs around USD 130/kWh. Battery costs are heavily influenced by the cell technology used, the production location and the price of raw materials. Cell costs comprise approximately 75% of the total cost of the battery pack. Materials, such as cathode and anode active materials (CAM and AAM), account for 70% of the cost of each cell, with raw and refined materials like cobalt- and nickel-sulphates and lithium salts accounting for more than 30% of cell costs (Roland Berger, 2022).

Local solar PV industrialisation opportunities

Solar energy is widely seen to dominate the energy transition future. In 2021 around 257 GW of new renewable power generation capacity was added worldwide. More than half was solar PV: About 133-140 GW of newly installed systems were commissioned during 2021 alone at the AC level, with more than 180 GW of modules at DC level. Europe (EU27) added 26 GW in 2021, so about a fifth of the global total market. China dominates today's global PV production: polysilicon (66%), wafers (> 95%), cells (78%) and modules (72%). And by the end of 2022 China is expected to have 500 GW annual module production capacity and 550 GW wafer production capacity (PV Magazine, 2022).

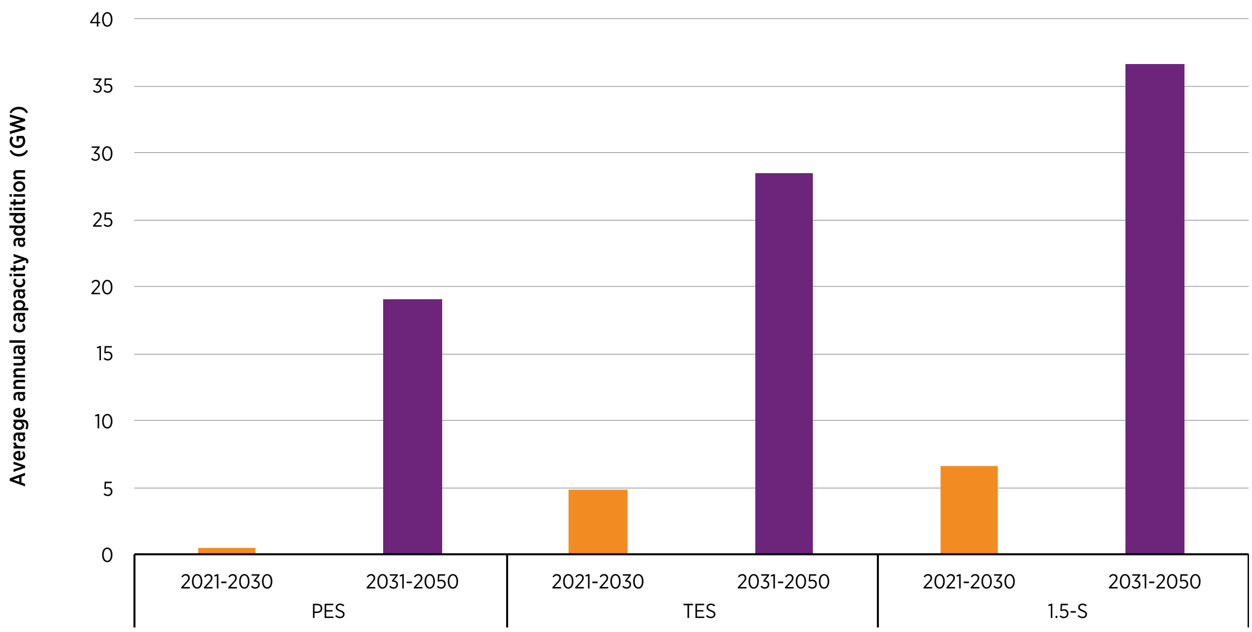
Indonesia also envisages solar PV as the main renewable source to decarbonise the power sector and is one of the renewables with the biggest development quota in RUPTL 2021-2030. The Minister of Energy and Mineral Resources, Arifin Tasrif, stated that Indonesia has market potential to install 30-100 GW every decade (Meilanova, 2021). This decade should be the time for the solar PV industry to fulfil the announcements on renewable energy development in Indonesia.

Despite high potential, Indonesia's solar PV industry has not hit the ground running. One of the barriers is the local content requirement mandated by the government. The policy is seen by many to impede the competitiveness and quality of the projects, and hinder multilateral financing for renewables projects because it does not align with international lender procurement rules. The Association of Solar PV Manufacturers Indonesia (APAMSI) stated that in 2021 Indonesia's PV manufacturing capacity was in the range of 50-100 MW per factory per year. This is only about 2% of China's average plant capacity. One of the reasons is that their production is project driven, and the uncertainty of product and project capacity has held back local PV manufacturers. Furthermore, the rapid decline of PV costs brings another challenge as the local manufacturers need to always keep up with the up-to-date technology. This is certainly costly when the production is never significantly optimised. This has resulted in the cost of a local PV panel being about 40% more expensive than an imported panel.

Between 2015 and 2020 annual solar PV additions were only at about 29 MWp. The Ministry of Energy and Mineral Resources claims that to achieve the installed capacity target of 3.6 GW in 2025, the solar PV industry must be able to meet demand of between 600 MW and 1200 MW annually. This value is projected to be even higher in the 1.5-S, with annual demand for solar PV reaching 27 GW per year until 2050. Indonesia will need to spur its domestic manufacturing rapidly to avoid bottlenecks and ensure the energy transition will benefit local industry to its full potential, so that eventually Indonesia becomes a much larger producer and meets the domestic market need for about 800 GW of installed solar PV capacity in the 1.5-S by 2050.

Solar PV capacity additions will need to expand to as high as 27 GW per year

Figure 68 Solar PV annual capacity additions in IRENA's scenarios



The development of an integrated upstream and downstream solar PV industry in Indonesia needs to be accelerated and supported with the suitable policies on renewable energy production, a clear framework for local production and demand-side incentives for attracting more investment. The Institute for Essential Service Reform (IESR) estimated that commercial, industrial, and residential demand for solar PV will increase in the coming years, especially when the PLN project pipeline begins.

Despite all the challenges, Indonesia is seeking to boost its polysilicon industry for solar panel production. Deputy for mining and investment at the Coordinating Ministry for Maritime Affairs and Investment, Septian Hario Seto, quotes that the first USD 800 million plant is set to open in the third quarter of 2022, one that is estimated as being able to produce 40 kt of polysilicon in the preliminary phase. North Kalimantan will host the second polysilicon plant for an investment worth USD 3.2 billion, with the four times the production capacity of the first plant in Central Java.

The availability of affordable funding is expected to attract more investment, especially in the projects where battery production is included. Indonesia is assembling massive investment in the battery industries, with many global companies showing interest, supported by government's policy of accelerating renewable energy and EVs. All of these planned investments will provide technology transfer and job creation opportunities that eventually offer good prospects for local industry to grow in the future.

4.5 INVESTMENTS, COSTS AND BENEFITS

KEY HIGHLIGHTS

Total energy sector's investment needs in the 1.5-S are up to USD 2.3 to USD 2.4 trillion by 2050, twice those in the PES. The power sector contributes the most of this investment requirement, accounting for 40% of total investment in the 1.5-S.

Transport investment in the 1.5-S is more than nine times higher than in the PES, needed for efficiency improvement and EV charging infrastructure, whereas industry shows almost twice the investment requirement to achieve the 1.5-S compared to the PES.

The total energy system cost in the 1.5-S is lower than the PES. Cumulative incremental energy system cost savings in the 1.5-S range across USD 0.4-0.6 trillion to 2050 compared to the PES. Additionally, avoided **externalities due to health and climate change are USD 0.2-0.6 trillion cumulatively in the 1.5-S over the PES**. Thus, transitioning to the 1.5-S is not only more affordable in energy terms, but also results in significant cost savings from reduced health and environmental externalities.

4.5.1 Investment needs

A substantial increase in investment is required to accelerate the energy transition in Indonesia. Policy support in the energy sector is crucial to enable the reallocation of capital towards sustainable solutions and ensure active participation from private sector actors.

Investment in decarbonising the power sector and EV infrastructure in this decade is key to the energy transition

Table 15 Short-term investment requirement to 2030 in the 1.5-S

1.5-S SHORT-TERM INVESTMENT REQUIREMENT (2018-2030)			PARAMETER		TOTAL INVESTMENT (billion USD)
POWER	Solar PV		Installed capacity (GW)	66	44
POWER	**Other renewables** (non-hydro)		Installed capacity (GW)	12	17
POWER	**Hydro**		Installed capacity (GW)	16	22
GRID AND FLEXIBILITY	**Transmission** (national)		km ('000)	115	43
GRID AND FLEXIBILITY	**Distribution**		km ('000)	1 271	32
GRID AND FLEXIBILITY	**Battery storage**		GW	12	5.5
	Biofuel supply		billion litres	35	19
ELECTRI-FICATION	**EV chargers**		million units	1.3	22
ELECTRI-FICATION	**EV cars sales**		million units	6.4	129

To enable the 1-5.S, on average between USD 73 billion and USD 76 billion would be invested annually over the period 2018-2050, about double the investment requirement projected in the PES. This translates into an additional USD 36 billion to USD 39 billion per year. Indonesia's required investment in the 1.5-S over the period to 2050 is more than double the country's GDP in 2018, and 62% of Indonesia's projected GDP in 2050. It is about 80% the total ASEAN GDP in 2018, but only one-fifth in 2050. However, on an annual basis investment is only around 2-7% of annual Indonesia's GDP.

High upfront investment is critical mainly to enable the accelerated deployment of key renewable energy technologies in the power sector; a massive scaling up of electrification of transport modes, buildings and industries; and large-scale green hydrogen projects. Renewable energy with CCS for the remaining fossil fuels is projected to be the most economical power transformation pathway for Indonesia, costing the country about USD 29 billion annually in total energy system, whereas a renewables and nuclear pathway requires an additional USD 1.4 billion annually. If the country decides to go for 100% renewables, an additional energy system cost of USD 2.4 billion will be entailed.

Higher up-front investment is needed in the transformation scenarios

Table 16 Total investment requirement, by scenario, 2018-2050

				2018-2050 PES	TES	1.5-S RE85	1.5-S RE90	1.5-S RE100
INVESTMENT REQUIREMENT (BILLION USD)	POWER	Renewables	Solar PV	195	314	405	415	434
			Hydro	71	109	146	145	147
			Wind	1	43	25	75	67
			Geothermal	23	63	87	85	89
			Biomass	3	27	50	28	45
			Hydrogen	-	-	-	-	51
			Ocean	-	-	-	-	8
		Nuclear		90	-	232	-	-
		CCS	Coal w/CCS	132	307	-	-	-
			Biomass w/CCS	-	-	-	93	135
			Natural gas w/CCS	-	-	-	56	-
		Fossil fuels	Coal	25	25	25	25	25
			Natural gas	10	10	10	12	10
	GRID AND FLEXIBILITY	Transmission		109	142	190	190	190
		Distribution		82	107	143	143	143
		Battery storage		28	47	73	61	92
	RENEWABLE END USES	Biofuels supply		43	54	69	69	69
	ENERGY EFFICIENCY	Buildings		166	223	270	270	270
		Industry		153	172	247	247	247
		Transport		34	137	178	178	178
	ELECTRIFI-CATION	EV chargers		9	140	218	218	218
TOTAL INVESTMENT REQUIREMENT 2018-2050 (BILLION USD)				**1 174**	**1 920**	**2 367**	**2 310**	**2 418**

Note: Investment totals for 2050 in the TES and 1.5-S for coal and natural gas are already committed in national plans and do not represent additions within those scenarios. These consist of projects that have been built since 2018 or are in the pipeline that occur by 2030 in the PES. The values thus carried over as cumulative investment are from 2018-2050.

Investment in a wide range of renewable and energy efficiency technologies is required in the buildings sector, including LED lamps, more efficient appliances and development of low-energy buildings in the 1.5-S. The average annual investment needed in the buildings sector is USD 8.4 billion. Overall, the buildings sector represents about 11% of the total energy transition investment over the period to 2050.

When considering investment in EV chargers, the transport sector requires investment of USD 12.4 billion annually in the 1.5-S, without considering the incremental cost of EVs. Charging infrastructure provision takes up over half of total transport investment. Investment for charging infrastructure will need to grow 17% annually in the short-term heading to 2030, and then declines in the two decades towards 2050 to 8% annually. Energy efficiency in transport sector requires USD 5.6 billion of investment annually until 2050. A USD 4.5 billion and USD 1.3 billion additional annual investment is required over the PES and the TES, respectively.

Total required investment to decarbonise the industrial sector in the 1.5-S reaches USD 246.6 billion in 2050, equalling USD 2.9 billion additional investment annually over the PES. The industrial investment requirement covers energy efficiency implementation and investment in new energy-efficient plants.

Cumulative power sector investment reaches nearly USD 550 billion in the PES by 2050, with the majority of these investments being in coal with CCS, nuclear and solar PV. Under the energy transition scenarios, however, given the role of electrification in achieving these highly renewable and low-carbon scenarios, this investment is considerably higher at between USD 936 billion and USD 1 011 billion cumulatively over the same period. Solar PV and other renewables represent between 75% and over 80% of the power sector's investment needs.

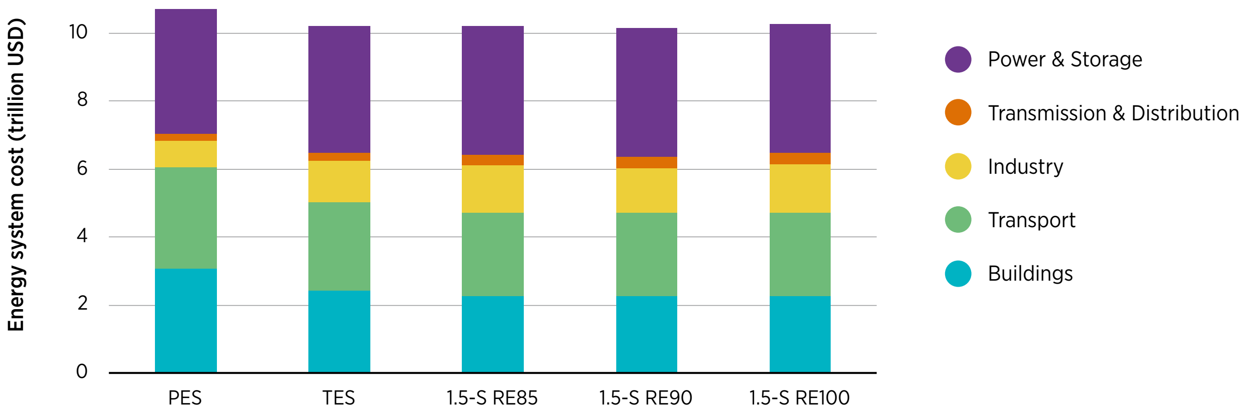
4.5.2 Costs and savings

Energy system costs provide a perspective on variables including fuel costs, operation and maintenance and investment annuities, and give a wider picture of the affordability of each scenario. Over the period to 2050 in the PES Indonesia spends USD 10.7 trillion on the energy system, whereas the country spends only USD 10.1 trillion to USD 10.3 trillion for the 1.5-S, depending on the case. Therefore the 1.5-S is lower cost overall, resulting in savings of between USD 0.4-0.6 trillion cumulatively to 2050 depending on the 1.5-S variant.

The cost of fuel and electricity used in all end-use sectors reaches more than USD 7 trillion in 1.5-S for the period to 2050, a number equal to 69% of total energy system cost. The transport sector is responsible for over 40% of the demand sector's fuel cost. Overall, the energy system cost for the transport sector in the 1.5-S – including fuel, operation and maintenance, vehicle disposal and equivalent annual cost – accounts for more than one-third of total energy system cost of the demand sector. Spending USD 118 billion every year, this is about USD 3.4 billion annually more than the PES. The total energy system cost for the industrial and buildings sectors are expected to reach USD 77 billion and USD 71 billion per year, respectively. These equal savings of USD 16 billion and USD 25 billion annually over the PES, respectively. Power sector total energy system cost in the 1.5-S RE100 is slightly more expensive than the 1.5-S RE85 and RE90 mainly due to a greater investment need for the penetration of wind power, with the RE100 scenario producing the highest total energy system cost among the three decarbonising scenarios. This results in additional cost of about USD 1 billion to USD 4 billion annually needing to be spent over the other decarbonising scenarios. Despite the result, all the three decarbonising scenarios result in lower total energy system cost over the PES, saving USD 14 billion to USD 18 billion annually. This avoided cost equals 47% to 60% of the country's GDP in 2018.

The 1.5-S is the least-cost energy pathway when compared to the PES

Figure 69 Total energy system cost by scenario, 2018-2050



The transition away from fossil fuels also helps to reduce the externality costs associated with air pollution and climate change. A broad view of the balance between the costs and benefits of the energy transition can be obtained by using estimates of externalities related to pollution and climate change and comparing them with transition costs, including investment, operation and maintenance expenditure and subsidies.

The reduced externalities associated the 1.5-S yield an annual avoided cost of between USD 200 billion and USD 635 billion. This implies that the country can potentially save between USD 20 billion and USD 38 billion annually, or about 2%-4% of its current GDP by transitioning to the 1.5-S by mid-century.

The energy transition scenarios result already in cost savings, with additional external cost savings resulting from reduced externalities

Figure 70 Total energy system cost of transitioning towards 1.5-S over the PES, 2018-2050

5 KEY CHALLENGES AND RECOMMENDATIONS

This section presents a set of short- to medium-term recommendations to address the key challenges relating to the renewable energy market in Indonesia and support its development. These recommended actions focus on providing a solid basis to create a more conducive investment environment for renewable energy, recognising that the government is already making progress towards the realisation of these actions.

5.1 ENERGY SYSTEM PLANNING

The government put its National Economic Recovery (PEN) programme into effect in mid-2020. The programme's budget was raised to nearly USD 50 billion by February 2021 (IDR 688.3 trillion), a near doubling of the initial level of IDR 372.3 trillion. The Ministry of Finance reported that by mid 2022, the economy grows by 5.4%, and is expected to grow by 5.0% - 5.3% in 2023. The Indonesian government aims to build a resilient and sustainable economic recovery by reviving the implementation of its Low Carbon Development vision. During the COVID-19 period, because of the reallocation of the country's economic resources in 2020, the transformation of the energy sector has been delayed. The funding for a green recovery is far below the international benchmark. Additionally, there is not sufficient clarity on the support mechanisms available for renewable energy resources or their implementation in Indonesia's recovery-focused energy policies.

A green recovery plan that accelerates the transition to a more renewable energy system would not only allow the country to attain its 2025 targets and beyond, but would also put Indonesia on a climate-neutral pathway in the longer term. PLN's newly announced plans to phase out coal in the long term and supply an increasing share of electricity from renewables are a favourable next step, but more clarity is needed on how this transformation will be enabled from regulatory, technology and financing perspectives. It should also address the issue of overcapacity by reconsidering the commissioning of new coal-fired power plants that will potentially be left unutilised, thereby also reducing unnecessary payments to the private sector under the take-or-pay principle and limiting ineffective coal subsidies. Enhancing regional plans for the deployment of renewables should also play an important role given the large differences in the country's energy consumption (recognising that much of the electricity demand is in the Java-Bali power system) and the varying opportunities across its large geography. As of June 2022 34 provinces have completed a Regional Energy Plan (*Rencana Umum Energi Daerah*, RUED, with nine more provinces that are between early to final stage to completion (NEC, 2022). A more predictable long-term energy transformation plan – that is also consistent with the strategies and targets of Indonesia's different institutions – is also essential.

Action 1 Utilise the long-term opportunities of the energy transition with a clear green recovery programme

Indonesia has taken important steps to transform its energy system into a more secure, clean and affordable one in the future. More attention is needed on utilising the current recovery period as an important opportunity for Indonesia to accelerate its transition by building the country's energy policies on a green recovery programme and predictable long-term energy plans that prioritise clean energy investments and which are consistent nationally and regionally. These can also help to strengthen Indonesia's climate action plans in the long term whilst contributing to aligning the ambition of its nationally determined contribution with the goals of the Paris Agreement.

Insights from this report

Total investment of around USD 2.3 trillion to USD 2.4 trillion until 2050 is needed to realise the 1.5°C Scenario (1.5-S) in Indonesia. This is a huge green recovery opportunity, utilising its wider momentum to accelerate the energy transition in Indonesia. Almost half of the investment is needed to transform the power sector through investments in renewable capacity, grids, storage and other enabling infrastructure. Additionally significant investment is needed in the end-use sectors, from bioenergy and hydrogen, to energy efficiency and electrification. Long-term energy system planning must consider a holistic and interconnected energy system, from supply to demand.

PLN's role as the single electricity buyer and operator of the electricity market as well as the largest generator has impacts on how the electricity market is developing in Indonesia. Although the Omnibus Law mentions the reintroduction of the requirement to unbundle the PLN services, the Constitutional Court's decision remains a barrier to unbundling.

This unbundling has been discussed for many years and there have been attempts to realise it, but the court's decision was to maintain the status quo. The government has subsequently issued decrees to guarantee fair competition and a well-functioning market, but their implementation is challenging given the court ruling.

In recent years PLN has been increasing generation at a rate comparable with the private power utilities and independent power producers (IPPs). IPPs have so far played a minor role, but there is more room for them to participate in the ownership and operation of the electricity sector assets, to create fresh sources of funding for investment and reduce PLN's economic burden.

Some IPPs find the process of project development rather ambiguous, while the process for IPPs to connect to the grid lacks transparency.

PLN's revenues are insufficient for full cost recovery. This deficit is covered by the government's payments from the national budget. This provides little incentive for PLN to increase its operational efficiency. Also, the government is not entirely clear on the timeframe to receive the subsides, which results in a financial burden for PLN. To make the power sector financially viable, a shift from a cost-plus system to a performance-based system would increase efficiency. In addition, a transparent and predictable plan, and fair remuneration for PLN's investments, are also important.

Action 2 Advance the design of Indonesia's electricity market

Advancing the design of Indonesia's electricity market requires time. There is a need for a reform plan that will enable a more transparent electricity market and allow for private-sector participation, which can strengthen PLN's financial situation, reduce financing costs for investors and make electricity more affordable to consumers.

Insights from this report

In the 1.5-S, up to 66 GW of solar PV, 0.4 GW of wind, and 13 GWh of storage are needed in Indonesia between now to 2030. Installed capacity of solar PV will get between 798 GW to 840 GW and wind between 60 GW to 68 GW by 2050, requiring between 0.3 TWh to 3.5 TWh of storage. An advanced electricity market design is crucial to enable enhanced private-sector participation in the development of such a renewables-oriented power sector in just 30 years.

Indonesia has significant resource potential for all types of renewables. Existing regulations related to electricity purchase tariffs and coal price caps adversely affect the creation of a renewable energy market. Eliminating coal subsidies and including pollution induced costs for fossil fuel use would help create a level playing field for renewables, and also contribute to enhance PLN's operational efficiency. Electricity purchase tariffs that award the full cost of renewable energy generation at the utility scale under the feed-in tariff (FiT) (see also *Action 5*) and for rooftop solar PV systems under net energy metering (see also *Action 6*) would create benefits for investors and consumers alike, while accelerating market development. The government reconsidering its minimum local content requirements would send further positive signals to investors, as they currently restrict investment given the small manufacturing base in Indonesia.

Action 3 Create a level playing field for renewable energy resources

Continuation of the government's fossil fuel subsidy reform and improvements to the regulatory framework will lift important barriers to renewable energy and enhance investment signals for the private sector and consumers.

Insights from this report

The development of a solar PV manufacturing industry in Indonesia needs to be accelerated and can be used to spur economic growth in areas where fossil fuel industries are declining. The government needs to support renewable energy production with a framework for enhancing local manufacturing and demand-side incentives for attracting more investment.

5.2 REGULATORY AND LEGAL FRAMEWORK

Indonesia has advanced considerably in its regulatory framework to provides a suite of options for renewable energy investment, including auctions. As renewables become more cost-competitive in Indonesia, ensuring more effective and transparent auctions will be crucial to drive investment, strengthening their design and increasing the participation of private-sector investors by clarifying the procurement processes. Investors need policy certainty and continuity to create an enabling and predictable investment environment.

Indonesia has two procurement processes, namely direct appointment and direct selection. Direct appointment can be done with limited circumstances including emergency situation, purchase of excess electricity, expansion pro. Regulations have simplified the procurement procedures for direct appointment; however, IPPs that submit unsolicited project proposals under direct appointment have sometimes faced challenges in having their projects listed in the RUPTL. Regarding the direct selection process, IPPs have not always reached financial closure, although this can be due to the low quality of feasibility study documents. Prequalification processes have been held on an irregular basis over the years and their criteria have varied from year to year. Despite prequalification rounds, no projects were subsequently procured in the case of hydropower in 2018.

PPAs were instrumental in moving on the renewable energy market of Indonesia. Recent PPAs, for instance for solar PV, are showing favourable results. In 2017 around 27 clean energy PPAs did not reach financial closure, partly due to winning IPPs lacking creditworthiness as well as the capacity to develop credible feasibility studies. More than one-third of the 75 renewable PPAs that were signed between 2017 and 2018 had not reached financial closure by the end of 2019. Additionally, five PPAs were terminated. These included several for small-scale projects with high transaction costs. The main issue around the PPAs is bankability. Typically project financing is hard to obtain and the cost of financing is high. Small-scale hydro PPAs require projects to be built in two years, which is rather a short time, or incur a penalty for exceeding this time limit. PPA negotiations may also take a long time, as in the example of the Bali solar PV auction. While they follow a relatively high international standard, there are still high penalties on the investor if the generation is higher or lower than the agreement price and transparency warrants further attention. The government decree released in early 2020 changed the BOOT (build-own-operate-transfer) principle to BOO (build-own-operate), which was crucial, but there are concerns about the extent to which this is followed in in practice as it is subject to negotiation between the IPP and the PLN.

Action 4 Continue streamlining the procurement processes

Further streamlining renewables procurement processes and negotiations, in tandem with standardising PPA contracts, can ensure a well-functioning and transparent procurement system and contribute to reducing risky investment conditions and increasing competition in the market.

Insights from this report

Minister of State-Owned Enterprises is looking to the possibility to restructure PLN by establishing subsidiaries for retail – focusing on electricity services to PLN's customers, and for power plant – focusing on power generation both fossil and renewables. Given the scale-up in generation capacity seen in the 1.5-S, the large scale deployment of renewables should be consider in any possible restructuring plan.

Renewable energy costs have declined significantly in Indonesia, approaching cost-competitiveness with fossil fuels. But in many cases the BPP-based FiT (based on the current regional cost of electricity production) does not create a business case for project developers and the maximum tariff condition provides a certain degree of freedom for PLN (the only offtaker) to negotiate tariffs with the project developers on a project-specific basis. This makes the overall PPA process less transparent and predictable for the project developers. The regional BPP may include projects that have already depreciated their capital costs, making it hard for renewables to compete with such projects. In addition, PLN has some flexibility to negotiate the final tariff with each project. This makes it difficult for investors to prepare their investment plans. Such negotiations may be viable for specific technologies, but not necessarily for all renewables. The new presidential regulation that is planned to be in place soon is expected to provide further insights into a more effective FiT mechanism.

Competitive renewable energy auctions could have significant potential for Indonesia in realising its renewable energy goals; however, their use has been rather limited to date. A long-term energy transition plan for Indonesia should clarify the role auctions will play to achieve its targets. During a period of redefining and unbundling PLN's roles, the regulatory framework could also better define the future role of auctions as a step forward for Indonesia's energy procurement process. There are several actions that would enhance renewable energy auctions, notably creating a standard for their scope and application. Investors highlight the need to allocate sufficient time to prepare their bids, the importance of transparency in the auction requirements and the need for more information about the auction plan, such as locations. As part of standardising PPA practices in Indonesia, the cost of the interconnection tariff could be embedded in the final decision of the winning bid instead of being subject to negotiation, as this requires more time. In addition, local content requirements could form part of the auction scheme by strategically planning for local equipment supply capacity. Additionally, a semi- or fully independent body could help with monitoring the auction mechanism.

Action 5 Develop a clear regulatory framework with effective renewable energy auctions and a well-functioning FiT mechanism

To ensure success, auctions can be tailored to the country's technical, administrative and political capabilities and deployment and development objectives. The success of auctions builds on clear linkages with the country's renewable energy deployment strategy, which incorporates political commitment, long-term targets, high-quality planning and reliable contractual schemes, such as PPAs.

Insights from this report

According to MEMR Regulation No. 04/2020, all renewables can be procured through direct appointment under specific conditions such as if there is only one bidding IPP. Additionally, the regulation has simplified procurement procedures under direct appointment. Given that in 1.5-S, over 1 000 GW of additional renewable capacity will be needed by 2050, measures such as auction, FITs and other PPAs are necessary to enable this significant growth.

The government has set a target of 3.6 GW of rooftop solar PV by 2025 in which specific deployment plan is still missing.. The MEMR Regulation 26/2021 improves some of the key features on rooftop sola PV including the net metering multiplier increased to 100% (from 65% previously), accumulation period of net metering credits increased from 3 to 6 months and allowing rooftop solar customer to engage in carbon trading schemes. However, despite these improvements, there are still some limitations including the size of the installations to the applicable grid connection and prohibition on the sale of electricity from the system that limit the business model.

Distributed renewable energy resources in mini- and off-grid systems can help Indonesia reach its 100% electricity access goal by 2022. By the end of 2019 more than 1 000 hybrid renewable mini-grid systems were operational in Indonesia, with a total capacity exceeding 37 MW. Many people who do not receive power at all or have limited access throughout the day can benefit from a larger mini-grid market. Additionally, solar PV systems with battery storage could be instrumental in achieving PLN's diesel conversion goal to be realised by 2026, since they are cost-competitive or even cheaper than diesel generator systems in many regions of Indonesia. The project ownership of mini-grids is an area that warrants attention. Mini-grid operators can sell power to customers outside the PLN area at a capacity below 50 MW. To sell to PLN end users, operators need to hold negotiations with PLN and to date no IPP has managed to secure a licence. Opening the electrification market to IPPs could reduce the cost to PLN, which is by definition responsible for electrification projects. If the IPP decides to connect its mini-grid to the main grid at a later stage, the current regulated tariffs limit the business case as the remuneration is too low.

Action 6 Develop solutions to create a distributed renewable energy market

Making the remuneration mechanism more attractive for consumers and developing new finance and business models would significantly accelerate the deployment of rooftop solar PV systems in Indonesia by closing the gap between generation costs and retail electricity tariffs. Revising the regulatory framework to enable participation of private investors in the mini- and off-grid markets will be essential to achieve Indonesia's electricity access targets and replace dirty and expensive diesel generators.

Insights from this report

Tax incentives, including land and building tax relief, import duty relief and tax allowances, and various funding models provide for various financial incentives to accelerate renewable energy investment. The issuance of MEMR Regulation No.26/2021 has set a good precedence but still face some challenges in the implementation.

Given that there are many emerging business entities that are looking for renewable energy sources to meet their emission reduction targets, corporate sourcing of renewables is expected to become an important business model in Indonesia. IPPs can only directly sell power to consumers in limited areas that are outside PLN's responsibility. The power wheeling regulation is in place, but the tariff has not yet been set and the regulation has not been enacted to open PLN's grid for power wheeling. This is a major barrier to the deployment of a corporate sourcing mechanism. In addition, the rules for corporate sourcing need to be set down clearly to ensure the renewable energy generated and sold is new. In the current PLN structure, it is not entirely clear whether IPPs can have their energy certified. This would be a prerequisite for the new system to attract investment in renewable energy development.

Action 7 Utilise the opportunities presented by new renewable energy markets

Overcoming the regulatory and market barriers in PPAs and corporate sourcing would help Indonesia to create new markets for renewable energy investment. Reviewing the current terms and conditions of renewable energy PPAs to address concerns raised by investors, including putting in place standardised project document templates for renewable energy projects, is likely to be needed. In addition, PLN could be required to offer renewable energy options. The regulations for power wheeling and renewable energy certifications should be reviewed, and encouraging processes for corporates to procure renewable power developed. Otherwise, the presence of green electricity programmes depends on the willingness of PLN to implement a programme – and the quality of such offerings can vary.

Insights from this report

Contract structures are a potential limitation on the renewable energy transition in the power sector given the wide-spread use of PPAs and fuel supply contracts with very restrictive "take or pay" obligations. Many of these have the effect of locking in generation for CO_2-intensive generation sources such as coal and offer little incentive for them to vary output to allow for the integration of variable renewable power or provide other ancillary services that would be required.

5.3 TECHNOLOGY AND INFRASTRUCTURE

The focus in Indonesia is traditionally on the most effective operation of baseload capacity, which also guides the country's power system planning process. As PLN now takes renewables on a must-run basis, greater attention is needed on renewables integration from the grid perspective.

PLN's new investments has been regularly scaled down according to the RUPTL with the decline in economic growth, whilst significant capacity investment is still planned at both the distribution and transmission levels. Given the prevalent oversupply conditions, renewables will face grid integration challenges. Particularly in Java-Bali system, the need is to shift from investment in generation capacity to investment in infrastructure – this would advance Indonesia's infrastructure investment plans and limit the critical growth of oversupply. This is especially important as it is expected that more investment will be needed to connect Indonesia's different islands and ensure system reliability for the grid integration of renewables, and to close the 0.8% gap in realising full electricity access, especially in the country's less-developed regions. The distribution grid will also need to be strengthened to ensure more distributed renewable energy resources can be accommodated.

Analysis suggests a significantly higher potential to integrate renewables into grids from a technical and operational perspective than what is planned, but barriers exist to achieving this. There is limited capacity available in many cities that are connected to isolated grids. Limited interconnector capacity with neighbouring countries, inflexible coal-fired power plants and a limited gas share do not help provide a flexible grid. There is also no grid code that explicitly aims to regulate solar and wind penetration.

There is a need to publish the RUPTL in a timely manner to ensure predictability in the market for investors. Regional plans need to be aligned with the RUPTL to ensure that the overarching plan applies to the entire country. It is also necessary to include details and specific locations for other renewables in the plan as done for geothermal and hydropower capacity in line with an enhanced auction scheme. This will allow for investment planning and system-friendly locating planning of wind and solar capacity to minimise grid integration costs. PLN's work to allow private companies to developing grid infrastructure will be important.

Action 8 Improve system flexibility for the cost-effective integration of renewables

Independent studies show great potential for the grid integration of renewables beyond what is currently planned by PLN. A national plan is needed with an emphasis on specific regions that show the extent renewables can be integrated on the transmission grid and the flexibility solutions needed to enable this. Flexibility must be harnessed in all sectors of the energy system, from power generation to transmission and distribution systems, storage (both electrical and thermal) and, increasingly, flexible demand (demand-side management and sector coupling).

Insights from this report

Available batteries and hydropower are sufficient to provide frequency response reserves at 10% of the load in 2050, but the planning is essential to find effective ways to the challenging scattered renewable resources. Storage, primarily batteries, will grow significantly and the respective market manufacturers and overall industry must be ready when the time comes. Furthermore, the full potential of renewables requires open markets and the alignment of regulations, including with system operators from neighbouring ASEAN countries.

5.4 RENEWABLE ENERGY FINANCING

Important progress has been made to improve the bankability of renewable energy projects in Indonesia. New regulations are overcoming past obstacles and with the realisation of the suggested actions on auctions and procurement mechanisms, renewable energy development is likely to make stronger progress in the future. The need remains to increase the share of private sources of financing (see Action 2) and overcome the risks related to financing.

Financial institutions face several challenges due to a lack of familiarity with renewable projects, high perceived risks due to few operating projects, lack of suitable financing instruments and funds, and limited green finance to support the corporate sourcing of renewables. Similar issues exist for bank financing as well. Some financial institutions are actually familiar with financing, but national banking regulation limits their involvement in financing. At the same time, many local financial institutions are not necessarily familiar with these projects. They cannot provide long-term financing as their own resources are short term. These local financial institutions also do not receive long-term financing from institutional capital, such as pension funds. Additionally, uncertainty related to the requirements, timelines and outcomes of licensing and permitting procedures contribute to higher risks for project developers. The uncertainty of the regulatory framework and the local content requirements make private investors reluctant, while project developers experience difficulties in presenting their projects as bankable.

Project scale is among the barriers to financing. Small- and medium-sized projects come with higher project development and transaction costs. Small and medium-size project developers in particular have limited access to capital and therefore rely on debt financing. However, these projects cannot benefit from the same tax advantages as large projects. Subsequently risks in relation to investment costs also increase. Small-scale projects typically rely on local resources as international financiers consider them too small.

In 2019 the bankability of PPAs remained a major issue for renewable projects due to MEMR Regulation No. 10/2017 and No. 50/2017 (IESR, 2020). The way risks are allocated among actors and the low remuneration incentives limit the ability of projects to raise finance. More than one-third of the 85 renewable PPAs signed between 2017 and 2018 did not reach final closure by the end of 2019, where most projects were small scale with high transaction costs (IESR, 2020). High financing costs can be explained by the following risks: country risk (although declining in Indonesia), policy and regulatory risk (permitting and project preparation barriers, local manufacturing capacity conflicting with local content requirements, evolving regulatory landscape, complex tariff design) and revenue risk (or uncertainty of payment, which is the largest risk).

The development of guarantee schemes and new financing structures and the introduction of de-risking mechanisms will be needed. Blended financing mechanisms can help to mobilise private capital from domestic and foreign sources. These can reduce project risks and help the banking sector to gain experience in financing clean energy projects. Further support for clean energy projects using the SMI (which manages two funds relevant to clean energy, the Geothermal Resources Risk Mitigation Fund and SDG Indonesia One) would help with de-risking and financing. The Ministry of Finance is currently working with stakeholders on policy de-risking and ways to finance and incentivise private-sector participation. These discussions should be aligned with the efforts of the Ministry of Energy and Mineral Resources. Additionally supporting the expanded use of green bonds will be important.

In achieving the last mile of Indonesia's electricity access target, the lack of bankable offtakers represents a key barrier to off-grid system development. While some project developers might be willing to accept tariff payments directly from communities, this would come with challenges related to economic viability, given the high number of fragmented unelectrified villages with low levels of demand and where people are unable to pay the electricity price that is required to cover capital expenditure and operational expenses.

Action 9 Accelerate renewable energy finance

Obtaining finance for renewable energy investments is a significant barrier to accelerating Indonesia's energy transition. Financing sources need to be expanded and local financing capacity needs to grow. New financing models should be developed, while strengthening the capacity of national financing institutions to enable their use. Enhanced dialogue between developers and financiers would help increase understanding of how project risks can be mitigated and increase project bankability.

Insights from this report

Total energy sector's investment needs in the 1.5-S are up to USD 2.3 to USD 2.4 trillion by 2050, twice those in the PES. The power sector contributes the most of this investment requirement, accounting for 40% of total investment in the 1.5-S. Within this decade, total power sector investment need to reach at least USD 130 billion, or equal to more than 1.5 times more than PES

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