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MINISTRY OF NATURAL RESOURCES,
ENVIRONMENT & CLIMATE CHANGE

IRENA
International Renewable Energy Agency

# MALAYSIA
# ENERGY TRANSITION OUTLOOK

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## ABOUT IRENA

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.
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# MALAYSIA
## ENERGY TRANSITION OUTLOOK

# FOREWORD

Malaysia is among the most highly developed states of the Southeast Asia region and a founding member of the Association of Southeast Asian Nations (ASEAN). Over the next three decades, the Malaysian economy is expected to triple in size, while its population is projected to rise to over 40 million people; consequently, primary energy supply in Malaysia is set to increase by 60% over the same period.

Today, Malaysia stands at a crossroads. To meet this rising energy demand, the country could utilise its diminishing oil and gas resources and ultimately become reliant on international imports. On the other hand, it can choose to tap its considerable renewable energy resource potential to provide affordable, domestic alternatives to fossil fuels.

Malaysia has wisely begun to focus on the latter, setting near-term targets to increase renewable energy to help meet rising demand. The country has also announced its aim to reach net-zero emissions by as early as 2050 – reflected in its latest National Energy Policy – and continues to refine a long-term low-emission development strategy.

Malaysia is well positioned to develop a sustainable energy system based on higher shares of renewable energy that can support socio-economic development, address climate change and achieve greater energy security.

To support this transition, this report provides a long-term energy pathway to a cleaner and more sustainable energy system in Malaysia. 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 further power sector integration, both within the country and with neighbouring countries.

The engagement of the Ministry of Natural Resources, Environment and Climate Change, Tenaga Nasional Berhad (TNB), Sabah Energy Berhad, Sarawak Energy Berhad and the Sustainable Energy Development Agency (SEDA) were central to the development of this report. We are also grateful to the Government of Denmark for its support for IRENA's work in the ASEAN region.

Malaysia can pursue a path to sustainability, prosperity, energy leadership and connectivity in ASEAN. This report, and the process undertaken to create it, represent an important phase in this journey. We stand ready to help Malaysia pursue an energy system based on the ample renewable energy resources available across the country and beyond, which can serve 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

Malaysia recognises the importance of a future-proof energy system that is modern, reliable and affordable. We also believe that a sustainable and low carbon energy sector is vital contain the impacts of climate change. Malaysia's relative share of cumulative carbon dioxide emissions is nominal – at 0.37% of global emissions – and compared with its peers in emission terms, the country is emissions efficient, with a GNI per capita of USD 10 930 in 2021. Admittedly, however, it is still necessary for us to play our part in ensuring that our cumulative emissions remain low.

Therefore, as a responsible global citizen, Malaysia has pledged, in tandem with the international community, to ramp up our mitigation measures and gradually decarbonise our energy sector. We aspire to be carbon neutral by 2050 and we take this goal seriously. Based on our existing plans and projections, the power sector is expected to increase its renewable energy capacity to 31% by 2025 and 40% in 2035, reducing the carbon intensity to GDP of the sector by 60% by as early as 2030, compared to the year 2000 baseline.

At the same time, Malaysia aspires to remain a dynamic and pre-eminent trading nation. Therefore, in response to heightened global calls for urgent climate action and a systemic shift to more sustainable economic models, our country needs to explore and unleash sustainability-driven economic areas, opportunities and potential to support our future growth, while decarbonising its various economic sectors. Indeed, a just and successful energy transition can emerge as a future source of jobs and business opportunities for our people.

Hence, this *Malaysia energy transition outlook* – which embodies the cumulative efforts of IRENA and the Ministry of Natural Resources, Environment and Climate Change – is a timely document that presents options for the nation to accelerate its energy transition and achieve our carbon-neutral goals. I am confident that it represents a positive contribution to long-term policy planning for the energy sector in Malaysia.

I would also like to take this opportunity to acknowledge the valuable support, inputs and insights provided by all stakeholders during its preparation, which have provided depth and nuance to the energy transition pathway we are exploring. Finally, I would like to express my sincere gratitude to IRENA for its collaboration on this project, in addition to the Agency's continued, vital efforts in advancing renewable energy solutions globally. It is my earnest hope that this report will mark the beginning of a significant partnership, as well as further beneficial co-operation, between IRENA and the Ministry in furthering the global energy transition agenda.

**Nik Nazmi Nik Ahmad**
Minister of Natural Resources,
Environment and Climate Change
Malaysia

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# ABBREVIATIONS

| | |
|---|---|
| °C | degrees Celsius |
| 1.5-S | 1.5°C Scenario |
| 1.5-S RE 100 | 1.5°C Scenario with 100% renewable generation |
| 1.5-S RE90 | 1.5°C Scenario with 90% renewable generation |
| ASEAN | Association of Southeast Asian Nations |
| BES | Baseline Energy Scenario |
| CCS | carbon capture and storage |
| $CO_2$ | carbon dioxide |
| COVID-19 | Coronavirus disease |
| DOSM | Department of Statistics Malaysia |
| EJ | exajoule |
| ETOU | enhanced time of use |
| FIT | feed in-tariff |
| GDP | gross domestic product |
| GITA | Green Investment Tax Allowance |
| GITE | Green Income Tax Exemption |
| GJ | gigajoule |
| Gt | gigatonne |
| GTFS | Green Technology Financing Schemes |
| GW | gigawatt |
| Hz | Hertz |
| IBR | incentive-based regulation |
| ICPT | imbalance cost pass-though |
| IPCC | Intergovernmental Panel on Climate Change |
| IPP | independent power producer |
| IRENA | International Renewable Energy Agency |
| KeTSA | Kementerian Tenaga dan Sumber Asli (Ministry of Energy & Natural Resources) |
| kV | kilovolt |
| kW | kilowatt |
| kWh | kilowatt-hour |
| Lao PDR | Lao People's Democratic Republic |
| LCOE | levelised cost of electricity |
| LPG | liquefied petroleum gas |
| LSS | large scale solar |
| LT-LEDS | long-term low emission development strategy |
| LULUCF | land use, land-use change and forestry |
| $m^2$ | square metre |

**MESI** Malaysia Electricity Supply Industry

**MGATS** Malaysian Green Attribute Tracking System

**MJ** megajoule

**MoF** Ministry of Finance

**MoT** Ministry of Transport

**Mt** million tonne

**MVA** megavolt amper

**MW** megawatt

**MWh** megawatt-hour

**MYR** Malaysian ringgit

**NDC** Nationally Determined Contribution

**NEDA** New Enhanced Dispatch Arrangement

**NEM** net energy metering

**NGV** Natural Gas for Vehicles

**NRECC** Ministry of Natural Resources, Environment and Climate Change (formerly KeTSA)

**PES** Planned Energy Scenario

**PJ** petajoule

**PPA** power purchase agreement

**PPP** purchasing power parity

**PV** photovoltaic

**REmap** Renewable Energy Roadmap

**RRA** Renewables Readiness Assessment

**SEB** Sarawak Energy Berhad

**SEDA** Sustainable Energy Development Authority

**SESB** Sabah Electricity Sdn. Bhd.

**SREP** small renewable energy power

**ST** Energy Commission (Suruhanjaya Tenaga)

**SRI** socially responsible investing

**TES** Transforming Energy Scenario

**TNB** Tenaga Nasional Berhad

**TOU** time of use

**tscf** trillion standard cubic feet of gas

**TWh** terawatt-hour

**WETO** World Energy Transitions Outlook

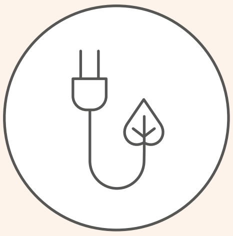
**UNFCCC** United Nations Framework Convention on Climate Change

**USD** United States dollar

# EXECUTIVE SUMMARY

## KEY MESSAGES

**Malaysia is an emerging economy** located in Southeast Asia and a member state of the Association of Southeast Asian Nations (ASEAN). By 2050, Malaysia's population is expected to rise to **40.7 million people** and the economy will nearly triple in size. The country's primary energy supply will increase by 60% to 6.7 exajoules (EJ) from 4.1 EJ in 2018.



**To meet rising energy demand while ensuring energy security and affordability in the future, Malaysia stands at a crossroads**: either continue using its diminishing oil and gas resources while also turning to volatile international oil and gas markets to import energy, or tap the significant potential of **renewable energy sources** that can provide local and affordable alternatives to fossil fuels. The report shows that it is cheaper to do the latter, with the share of renewable energy reaching over half the country's final energy mix by 2050, up from just 5% today.

**Overall, the total cumulative energy system cost in the report's 1.5°C Scenario (1.5-S) is USD 9 billion lower annually** than in the main reference scenario, the Planned Energy Scenario (PES) in 2050. The avoided externalities due to health and climate change are between USD 2 billion and USD 4 billion annually in the 1.5-S compared to the PES. Thus, transitioning towards renewable energy in the 1.5-S will save Malaysia between USD 9 billion and USD 13 billion annually in avoided energy, climate and health costs.

**In this lower-cost and lower-carbon future, the energy landscape in the country would change from one dominated by fossil fuels**, which currently comprise around three-quarters of primary energy demand, to one that sees deep electrification across all end-use sectors, with **electricity making up 40% of final energy**. This entails scaling up annual electricity consumption from around 150 terawatt-hours (TWh) in 2018 to over 348 TWh by 2050, while also scaling up key renewable resources such as bioenergy, geothermal and hydrogen.

**Renewable direct-use is also important**, with 20% of final energy coming from these sources by 2050. The production of **clean hydrogen and its derivative fuels** must ramp up from negligible levels in 2020 to at least 1.5 million tonnes by 2050.

**The power sector would be greatly transformed, with two possible highly decarbonised routes explored in this report**: a 100% renewable energy case (1.5-S RE100), and one with around 90% renewables combined with carbon capture and storage (CCS) (1.5-S RE90). These cases show how the availability of key technologies can influence the decarbonisation pathway to allow for a balanced perspective of the impacts of relying on different technologies. The two cases entail between 103 gigawatts (GW) and 153 GW of installed solar photovoltaics (PV), with 36 GW of other renewables, supported by 20 GW of battery storage. Regardless of the case, renewables would become the backbone of the power system; this also largely applies to lower-ambition scenarios.

**To capitalise on the transition, Malaysia has an opportunity to capture large parts of the transition value chain**, which will require the country to install up to 153 GW of solar PV, a total of 782 gigawatt-hours of storage and 109 million electric cars by 2050.

**The report concludes with a chapter covering key recommendations on how to accelerate the energy transition in Malaysia**. The broad categories include energy system and policy planning, regulatory and legal frameworks, technology and innovation, and financing.

## INTRODUCTION

Between 2010 and 2019, Malaysia's total primary energy supply increased 3% annually on average, driven by strong economic and industrial growth as well as rapid urbanisation. By 2050, primary energy supply is expected to increase 1.5% annually on average, to 6.7 EJ.

Malaysia has traditionally been a producer of oil and natural gas, with large reserves spread across the offshore waters of Peninsular Malaysia and the two states of Sabah and Sarawak on the island of Borneo. However, with limited reserves, the country could soon become a net importer of oil and gas. Malaysia's primary energy mix is dominated by fossil fuels, which have accounted for more than 95% of the total for the past decade. This includes large amounts of imported coal to fuel the country's power plants. Additionally, decades of direct and indirect fuel subsidisation policies in the country have kept energy prices low to spur economic growth, although several reforms made in the last decade have improved the government's fiscal balance.

By the end of 2021, Malaysia had a total installed electricity generation capacity of 33 GW connected to the grid. Power plants fired by coal and natural gas each accounted for around a third of the total installed capacity, with the rest consisting of a mix of large and small hydropower, biomass and solar PV. Based on the current plans for power generation, additional gas-fired plants are slated to be built in the coming decade, replacing old coal and gas units, while the country also seeks to increase solar PV capacity through various programmes. However, with the volatility in coal and gas prices in 2021 and 2022, Malaysia has now reached a crossroads, at which it may choose to either continue its current trajectory or further accelerate its energy transition beyond its renewable energy targets, while also keeping energy affordable.

Malaysia has huge untapped potential renewable energy sources that can provide local and affordable alternatives to fossil fuels. The country's installed capacities of solar PV and other renewables have been growing thanks to the establishment of concrete renewable energy policies and schemes, and a dedicated agency since the 2010s. However, more can be done to further accelerate the uptake of solar PV in order to exceed the target for renewable energy installed capacity of 40% by 2035. Furthermore, renewable energy targets should also be translated across other end-use consumption such as in the transport and industry sectors, which still rely heavily on fossil fuels.

Malaysia's latest Nationally Determined Contribution (NDC) submission towards reducing greenhouse gas emissions under the Paris Agreement aims for an unconditional reduction in emission intensity (tonnes of $CO_2$ emissions per unit of gross domestic product) of 45% by 2030 relative to the 2005 level. The country has also announced a target for net zero emissions by as early as 2050, as echoed in its latest National Energy Policy, and is preparing a Long-Term Low Emission Development Strategy (LT-LEDS). This report is intended to shed light on possible energy pathways for how these targets can be met. This report focuses only on energy-related $CO_2$ emissions and does not account for offsets from carbon sinks, however it is important to note that efforts are needed across all greenhouse gases emitting sources.

## A SUSTAINABLE FUTURE

The International Renewable Energy Agency (IRENA) has prepared Energy Transition Outlooks to detail long-term perspectives for the world (*World Energy Transitions Outlook*, WETO), for regions (such as ASEAN) and for countries (this study). The present outlook combines IRENA's Renewables Readiness Assessment with the Renewable Energy Roadmap (REmap) and Power System Flexibility Assessment to chart possible energy pathways to 2050 for Malaysia. The accelerated energy transition scenarios presented include the Transforming Energy Scenario (TES) and the 1.5°C Scenario (1.5-S), which is aligned with the 1.5-S in IRENA's WETO, targeting net zero emissions globally by 2050.

The analysis shows that there are seven general key actions to achieving the 1.5-S. These are presented in Table 1. They include efforts focused on scaling clean electricity to between 90-100% of generation as well as increasing renewable solutions in end-uses. Electrification will play an important role in important sectors such as transport and certain industry sub-sectors. Energy efficiency is also vital and improvements in energy intensity need to accelerate. Overall investment in energy transition investment needs to scale considerably, with as much as USD 415 billion needed in the 1.5-S. Finally carbon management solutions are also required to go the final mile in certain challenging sectors to reach net-zero emissions.

**Table 1** Selected key actions for achieving the 1.5-S in Malaysia by 2050

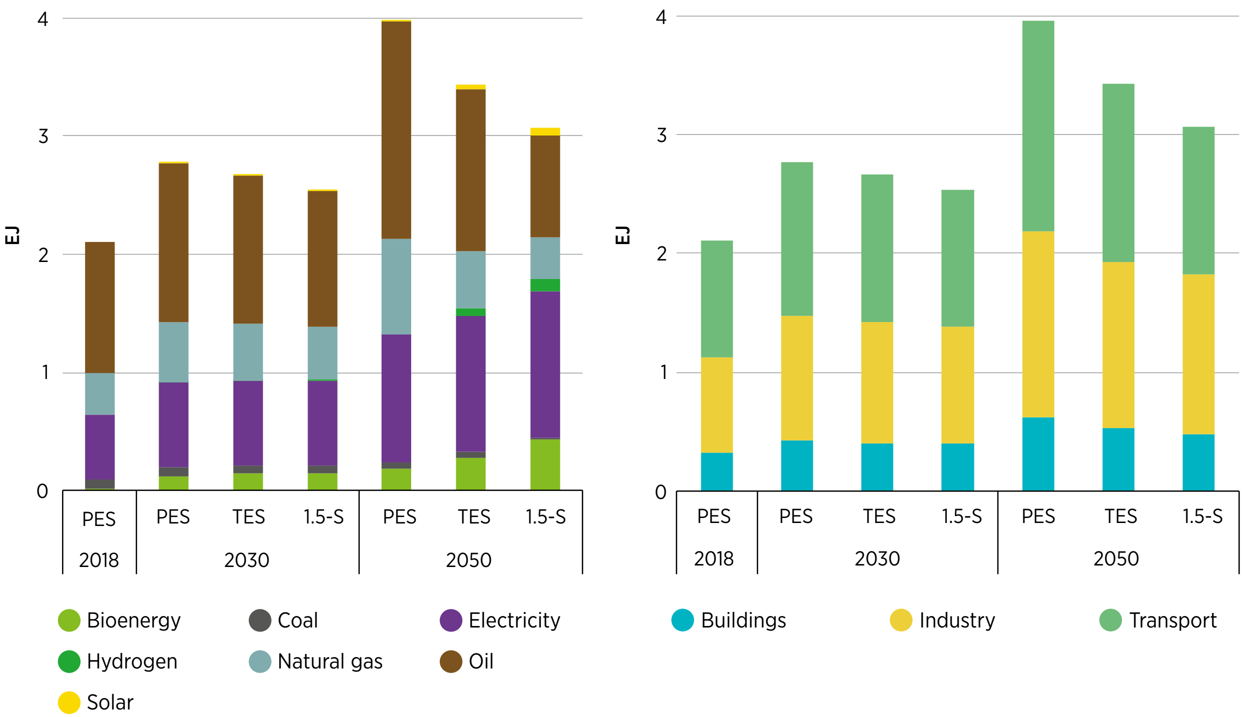
| KEY ACTIONS | | | | REFERENCE TIME FRAME | BASE VALUE | WHERE WE NEED TO BE IN 2050, IN THE 1.5-S |
|---|---|---|---|---|---|---|
| KEY ACTIONS | 1 | **Clean electricity** | With electricity generation doubling by 2050 in the 1.5-S, renewables must provide 90-100% of the total electricity supply by 2050, up from 16% in 2018. | 2018 | 16% | 90-100% |
| | 2 | **Maximise use of local renewables** | The share of renewables in total final energy consumption will need to increase from 5% in 2018 to 59% by 2050. Direct electrification with renewables is the largest contributor, followed by bioenergy. Solar and hydrogen will also play important roles. | 2018 | 5% | 59% |
| | 3 | **Scale investment sustainably** | As much as USD 415 billion will need to be invested in energy transition technologies and related infrastructure in the 1.5-S by 2050, compared to USD 159 billion in the PES. | PES to 2050 | USD 159 billion | USD 375-415 billion |
| | 4 | **Electrify end uses** | The share of electricity in total final energy consumption should increase from 26% in 2018 to 40% by 2050. | 2018 | 26% | 40% |
| | 5 | **Energy efficiency** | Energy efficiency measures and efficient technologies are crucial. The energy intensity improvement rate will need to increase from 1.6% per year in the PES to 2.4% per year in the 1.5-S. | PES to 2050 | 1.6% | 2.4% |
| | 6 | **Invest in disruptive technologies** | The production of clean hydrogen and its derivative fuels must ramp up from negligible levels in 2020 to at least 1.5 million tonnes by 2050. | 2020 | < 0.1 million tonnes | 1.5 million tonnes |
| | 7 | **Carbon management solutions** | While the measures outlined in this report reduce emissions 60% compared to the PES, to reach net zero emissions, $CO_2$ capture will be required via CCS, bioenergy with carbon capture and storage (BECCS), and other carbon removal and storage measures. | PES to 2050 | – | Reductions of 120 million tonnes of $CO_2$ |

Malaysia's total final energy consumption is projected to almost double by 2050 according to the Planned Energy Scenario (PES), which reflects current plans and policies for the energy sector. Driven by an increasing urban population and economic growth, the country's overall energy demand is expected to grow 2.0% annually. However, with deep electrification across all end-use sectors, fuel switching to renewables, and energy efficiency measures – as outlined in the TES and the 1.5-S – the total final energy consumption can be reduced further by 15% to 22% (Figure 1).

Almost one-fifth of Malaysia's demand for fuels by 2050 in the 1.5-S will be renewable-based – coming from bioenergy, renewable direct-use (such as solar thermal) and hydrogen – a large shift from just 1% today. Electricity will comprise up to 40% of final energy consumption, reflecting the additional electricity demand required to power the transport sector and green hydrogen production.

***With higher electrification and energy efficiency in the 1.5-S, the country's total energy consumption will be reduced by almost a quarter in the 1.5-S compared to the PES by 2050.***

**Figure 1** Malaysia's total final energy consumption, by scenario, in 2018, 2030 and 2050

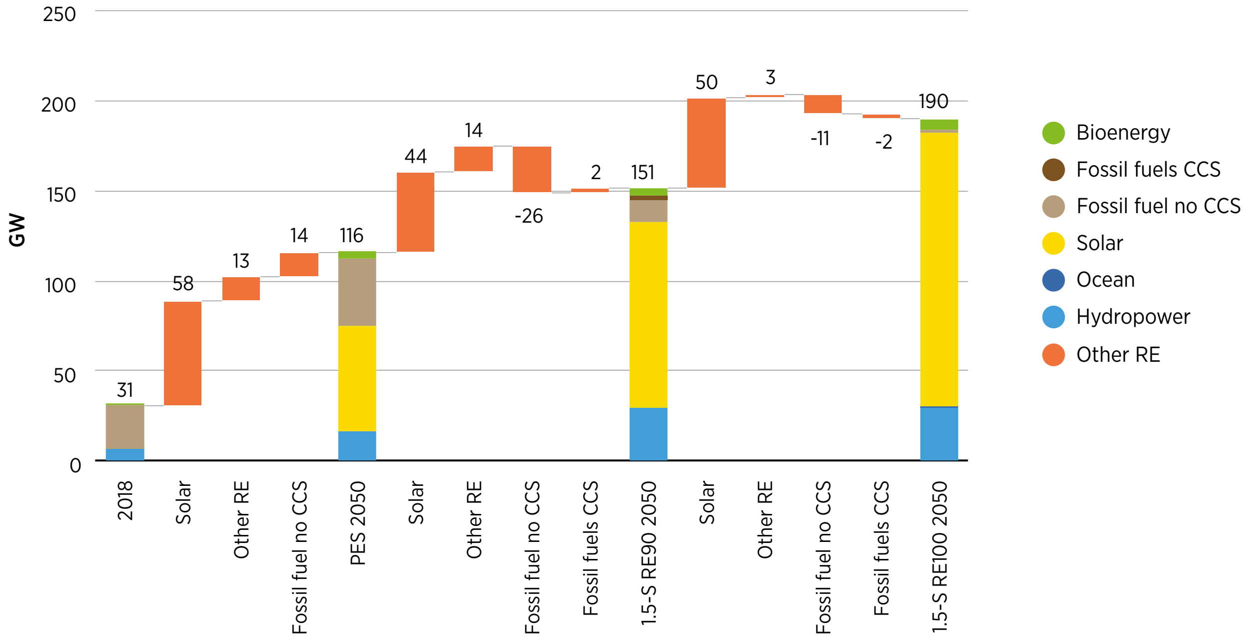



Electricity will become the dominant energy carrier in both the TES and the 1.5-S by 2050, and will become the second most important carrier in the PES. Electricity demand is expected to at least double from today's levels to 2050 regardless of the scenario. Therefore, how the country's power generation capacity is expanded to meet this demand will be instrumental in achieving national targets for emission reduction and net zero emissions.

To chart possible alternatives to a continued reliance on fossil fuels in power generation, this report presents two highly decarbonised routes forward for the Malaysian power system: a 100% renewables system (1.5-S RE100) and one that is around 90% renewable, with the rest relying on carbon capture and storage (1.5-S RE90). These cases 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 PV is key across all scenarios due to Malaysia's abundant solar resources. However, the 100% renewables case calls for very significant expansion of solar and a similarly large expansion of battery storage of around 21 GW by 2050.

***Solar PV will play a key role in power generation regardless of the scenario.***

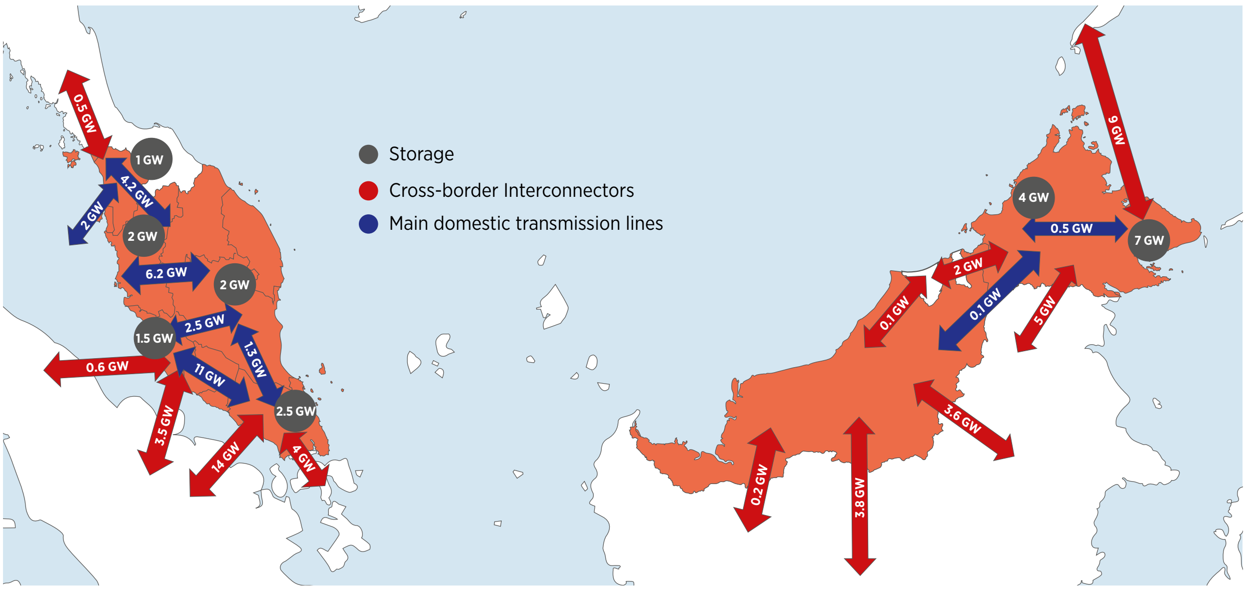
**Figure 2** Malaysia's power capacity expansion, 2018 to 2050, under the PES, 1.5-S RE100 and 1.5-S RE90




From a national perspective, imports of electricity will have a part to play in the future. However, the country has an interesting role in providing renewables and flexibility to neighbouring countries, in particular from Sarawak and Sabah to Kalimantan (Indonesia) and as far away as the Philippines. From an ASEAN regional perspective, an interconnection linking Western and Eastern Malaysia may not be cost effective (for more on regional interconnection, see IRENA, 2022). This means that any power deficit in Peninsular Malaysia could be potentially supplied mostly by electricity from neighbouring countries, namely from Sumatra, Indonesia (Figure 3).

***Domestic transmission as well as regional interconnection will need to be expanded in the 1.5-S.***

**Figure 3** Transmission lines and storage in 2050 under the 1.5-S

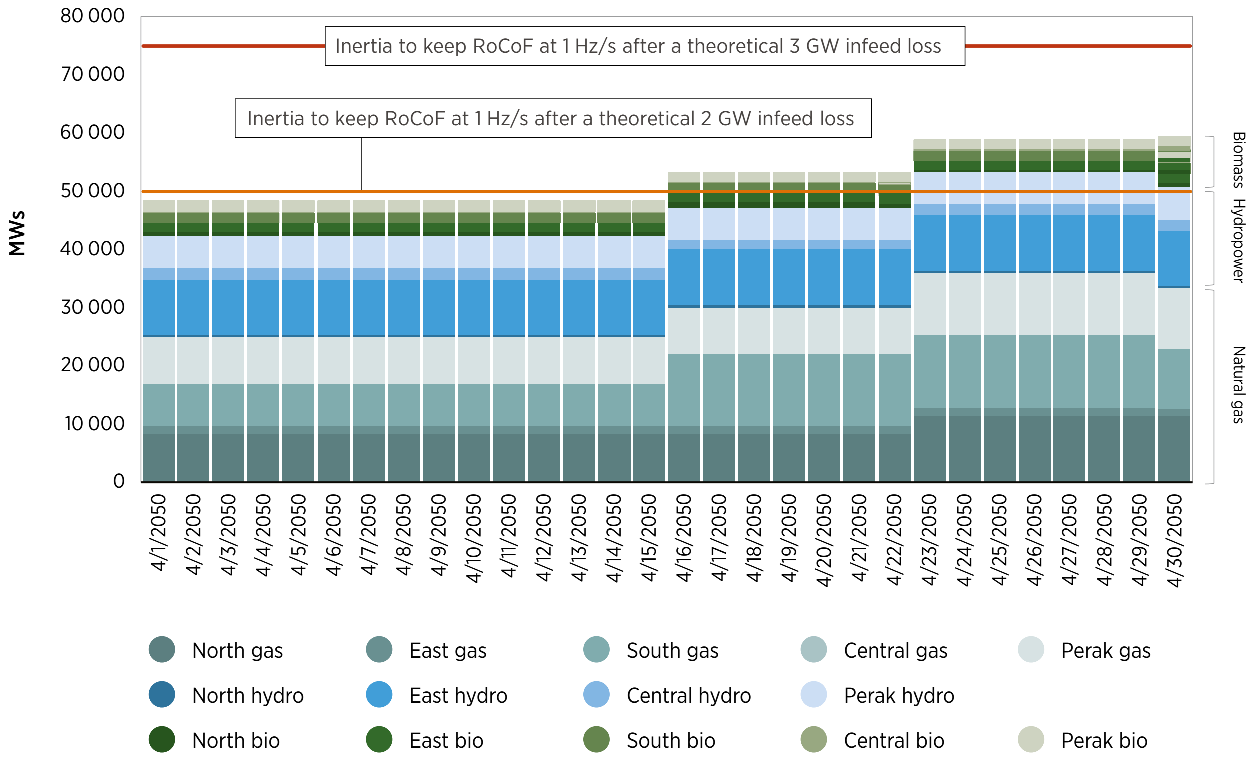



*Disclaimer:* This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers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

Deployment of energy storage would be substantial, in particular in Sabah and Peninsular Malaysia. In the case of Sarawak, hydropower reservoirs act as storage, and therefore other technologies are not needed. This also has implications for the provision of spinning reserves in the country. Spinning reserves equal to 10% of the load can be met at all times by both hydropower and storage without the use of fossil-fuel-based provision. Nonetheless, stability protocols need to be redesigned as power systems move from synchronous machines to inverter-based generation. Results suggest that inertia available in the system by 2050 would not be enough to maintain stability after a hypothetical in-feed loss larger than 2 GW (Figure 4). The system should be planned to reliably operate with fewer and fewer synchronous machines in the future, when grid-forming inverters are likely to assume the leading role.

***Upholding system stability will need to change as operations move from synchronous machines to inverter-dominated generation.***

**Figure 4** Inertia contribution by synchronous machines in the Peninsular grid in April 2050 under the 1.5-S RE90

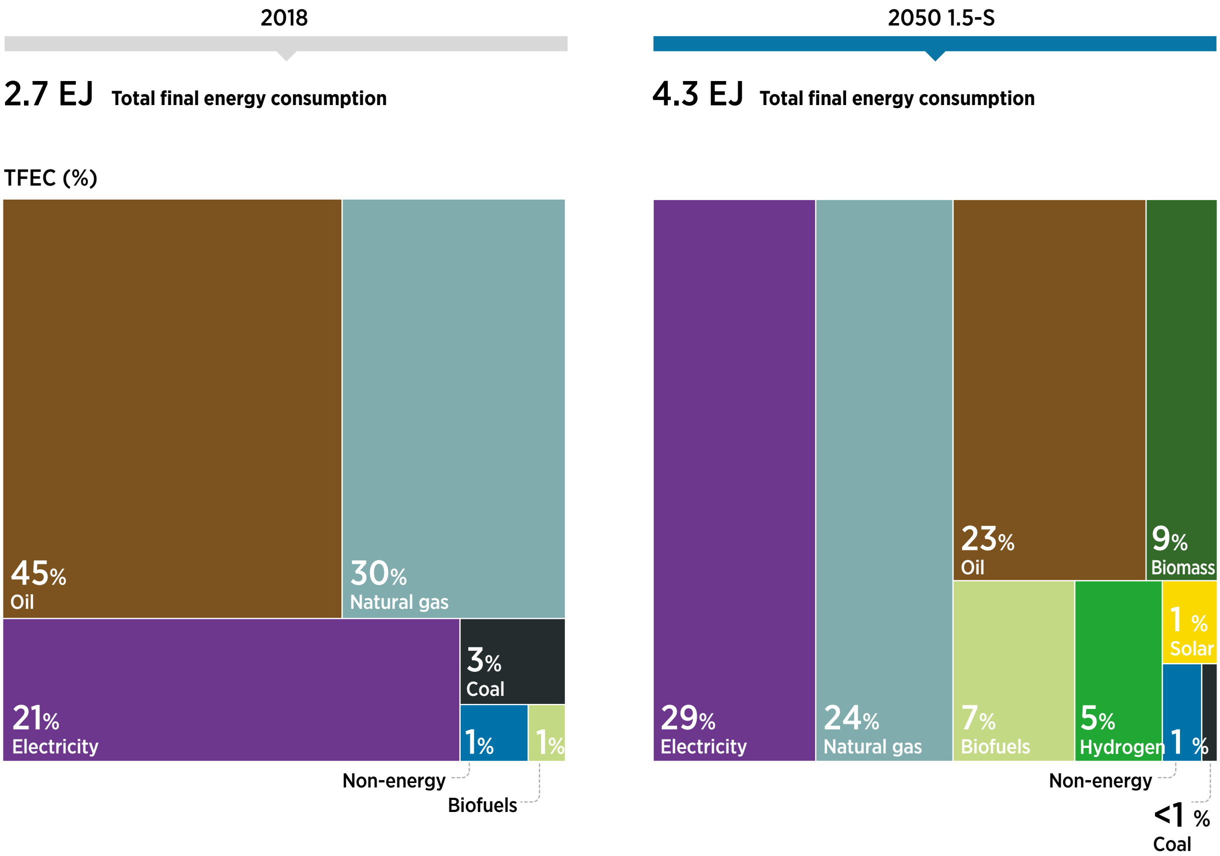



Bioenergy will play a role in Malaysia's energy transition, contributing around 16% of total final consumption by 2050 in the 1.5-S (Figure 5). Its application will be mostly as biofuel, for instance in aviation, as well as substituting fossil fuels in some industrial sub-sectors, such as the iron and steel, and cement industries. To further unlock the potential of bioenergy in Malaysia, it is crucial to have stronger inter-institutional co-ordination and strategy that includes bioenergy as part of the energy transition, while also addressing sustainability and industrial concerns to scale up potential resources.

Hydrogen will provide a complementary solution to meet the country's ambitious climate objectives. Green hydrogen will comprise up to 5% of total final consumption (including non-energy use) in the 1.5-S by 2050, where it will play a role in decarbonising some industrial sub-sectors and meeting a growing export market for green hydrogen in Asia and the Pacific.

***Bioenergy has wide application in end uses, but hydrogen also begins to play a role in the 1.5-S towards 2050.***

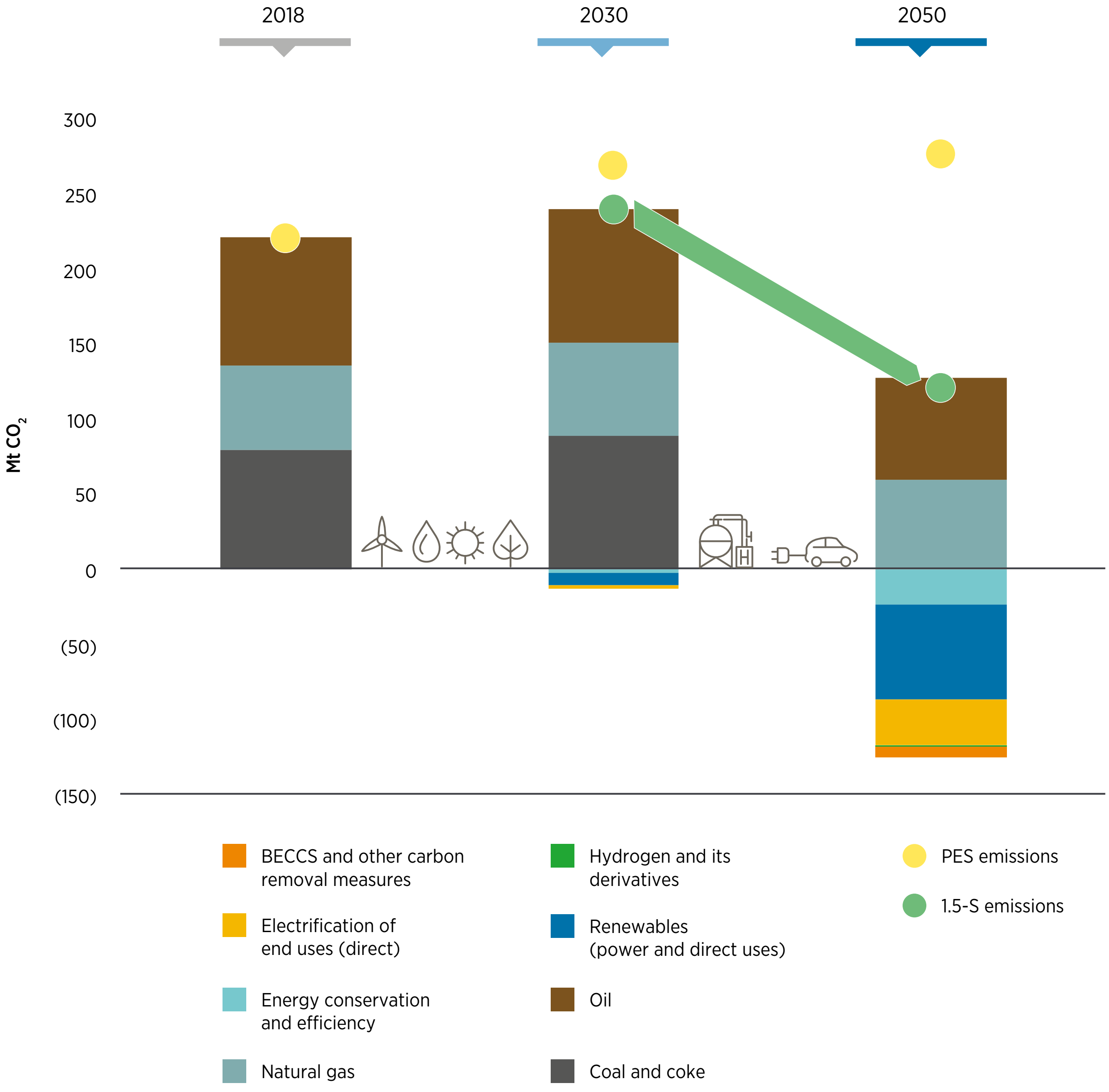
**Figure 5** Energy carrier shares in total final consumption, 2018 and under the 2050 1.5-S




Malaysia aims to reach net zero emissions by as early as 2050. If the established measures in the 1.5-S are met the country can reduce its energy-sector emissions to only 120 million tonnes of $CO_2$ by 2050, a reduction of 58% compared to the current pathway (Figure 6). However, carbon offsetting via land use, land-use change and forestry (LULUCF) will be instrumental for Malaysia to go the final mile and reach net-zero emissions, where other $CO_2$ removal technologies can be considered to further offset remaining emissions.

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

**Figure 6** Energy-related $CO_2$ emissions (positive y-axis) and reductions due to technology by category compared to the PES (negative y-axis), under the 1.5-S for 2030 and 2050




Over the period to 2030, significant investment will need to be directed to renewables, energy efficiency, and enabling technologies and infrastructure. In the nearer term, to 2030, more than 17 GW of solar PV will need to be installed, requiring investment of USD 10.8 billion (Table 2). Grid expansion will require an investment of USD 8 billion to 2030. Electric vehicles will increase to as high as 2.9 million electric cars, with the need for over 150 000 public chargers by 2030.

**Table 2** Selected technology scale-up and investment needs to 2030 under the 1.5-S

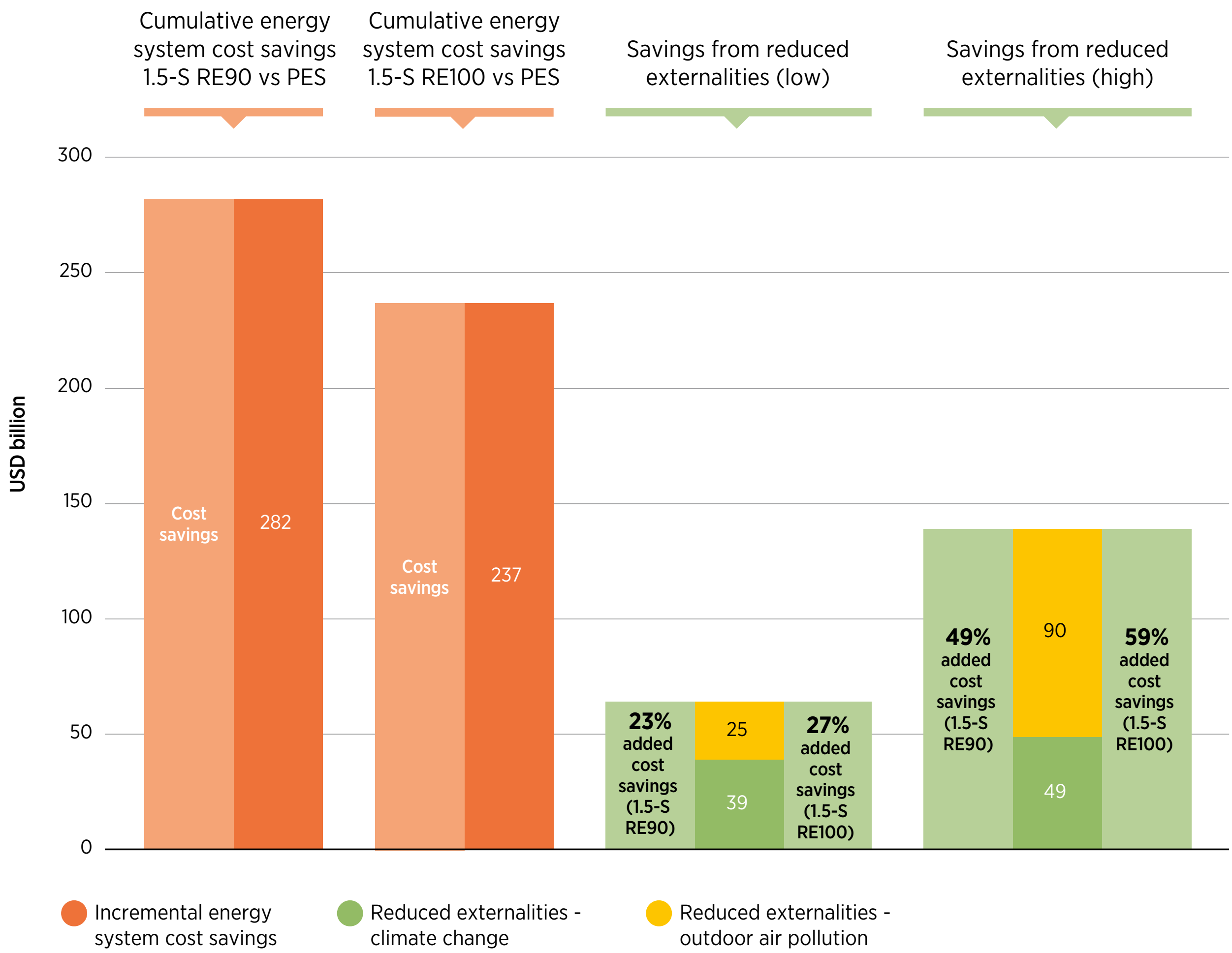
| | | TECHNOLOGY | 2018 | 1.5-S IN 2030 | TOTAL INVESTMENT (USD) |
|---|---|---|---|---|---|
| SHORT-TERM INVESTMENT REQUIREMENT (2018-2030) | POWER | **Solar PV** Installed capacity | 0.4 GW | 17.1 GW | 10.8 billion |
| | | **Bioenergy** Installed capacity | 0.2 GW | 0.4 GW | 0.8 billion |
| | | **Hydropower** Installed capacity | 6.1 GW | 9.4 GW | 7.1 billion |
| | ENERGY EFFICIENCY | **End-use sectors** | - | - | 13.6 billion |
| | GRID AND FLEXIBILITY | **Transmission** (national) | 37 000 km | 50 000 km | 4.8 billion |
| | | **Distribution** | 412 000 km | 555 000 km | 3.6 billion |
| | | **Storage** | 0 MW | 62 MW | 0.03 billion |
| | ELECTRIFICATION | **Public electric vehicle chargers** | < 10 000 | 150 000 units | 3.7 billion |

*Note:* km = kilometres.

Overall, investments totalling up to USD 415 billion will be required until 2050 in IRENA's 1.5-S, more than two-and-a-half times higher than in the PES. Much of the additional investment (up to 40%) will be needed to build renewable power capacity, while one-third will be in grids and flexibility. The remainder will be distributed across end-use sectors to increase energy efficiency, scale up electric vehicle charging infrastructure and support green hydrogen. When considering the total cost of the energy system (fuel costs, operations and maintenance, and financing costs) as well as externalities, the 1.5-S results in lower overall energy system costs and additional reduced external costs (Figure 7).

***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 the 1.5-S over the PES, 2018 to 2050




## Recommendations

Chapter 5 discusses four key recommendation categories for how to accelerate the energy transition in Malaysia. These include energy system and policy planning, regulatory and legal frameworks, technology and innovation, and financing. Selected key takeaways include:

**Utilise the long-term opportunities of the energy transition – through the development of cohesive and integrated long-term energy planning strategies.**

Malaysia has taken important steps to transform its energy system to a more secure, clean and affordable one in the future. However, more attention is needed to integrate various policies for – and beyond – the power sector to achieve a more comprehensive and transparent long-term energy policy and planning strategy, aimed at energy transition and achieving climate targets. In the short term to 2030, investment of more than USD 26 billion is needed to expand solar PV capacity, electric vehicle charging infrastructures and renewable direct-use supply alone.

**Develop a stronger regulatory framework by enhancing the LSS programme and a well-functioning FIT mechanism.**

Malaysia's renewable regulatory framework needs to strengthen the e-bidding system of the FIT with respect to project selection criteria and to overcome financing issues. To ensure the continued success of the LSS programme, regularity and periodicity are needed for a predictable investment environment, and solutions will need to be developed related to land use and grid connection issues.

**Develop new policy mechanisms for increased participation of various consumers and open new renewable energy markets, including using models beyond the traditional PPAs.**

It is necessary to develop new policy mechanisms to increase economic viability and to encourage the participation of various consumers and clarify the next steps in the rooftop solar PV market once the NEM 3.0 has ended. To ensure the success of the NEM programme, new business and financing models should be developed beyond the traditional PPA. These should be tailored to the economic viability of such systems for various consumer groups, including the effective use of voluntary markets such as renewable energy certification and corporate sourcing, complemented by an enhanced time-of-use electricity tariff.

**Improve system flexibility for cost-effective integration of renewables.**

Studies show large potential for the integration of renewables to the grid. Use of Malaysia's significant renewable energy resource potential is limited by grid issues. An ambitious and long-term plan is needed, with an emphasis on specific regions, that shows the extent that renewables can be integrated with the transmission grid – including solutions to overcome the current integration challenges as well as the flexibility solutions needed to enable this. Flexibility must be harnessed in all sectors of the energy system – from power generation, transmission and distribution systems, to storage (both electrical and thermal) and increasingly to flexible demand (*i.e.* demand-side management and sector coupling with smart cooling and electric vehicle charging systems). In the short term alone (to 2030), the required investment needs total USD 4.8 billion in domestic transmission, USD 3.6 billion in distribution and USD 0.02 billion in energy storage.

**Support enabling technologies in the end-use sectors with a focus on hard-to-abate sectors.**

Transforming how end-use sectors consume energy is crucial in enabling a net-zero energy system. Attention needs to be paid to challenging sectors, such as transport and industry. The government needs to consider programmes that support key enabling technologies in these sectors, for instance by focusing on electric vehicles in transport and related charging infrastructure. In industry, clean fuels will be required, including support for green hydrogen. Wider principles of supporting changes to use habits, wider structural change and circular economy should also be considered and supported through government policy.

**Accelerate renewable energy finance.**

Financing renewable energy investments remains an important barrier to accelerating Malaysia's energy transition. There is a need to assess and understand the barriers and needs of the market to develop suitable financing products and models tailored to individual renewable energy technologies and to strengthen the capacity of national financing institutions to enable their use, coupled with a transparent electricity market design.

Total energy sector investment needs in the 1.5-S are up to USD 375 to USD 415 billion by 2050, more than twice those in the PES. The power sector makes up most of this investment requirement, accounting for almost 40% of total investment in the 1.5-S. Within the present decade, total power sector investment needs will reach at least USD 30 billion, or around 1.5 times more than in the PES. Finance schemes must consider the diverse nature of the investment need, ranging from financing large renewable power projects to grids and infrastructure, and from energy efficiency in homes and business to biofuel supply and electric vehicle chargers.

# 1 INTRODUCTION

## 1.1 COUNTRY BACKGROUND

Malaysia is the third largest country in the Association of Southeast Asian Nations (ASEAN). The country is divided into two regions: West Malaysia – also known as Peninsular Malaysia, which is located on the peninsula sharing its northern border with Thailand – and East Malaysia, which shares borders with Indonesia and Brunei. The states of Labuan, Sabah and Sarawak are situated in East Malaysia. Major cities such as Kuala Lumpur and Johor Bahru are located in Peninsular Malaysia, which is also the economic hub of the country. More than 32.4 million people were living in Malaysia at the end of 2018 (DOSM, 2021).

Between 2010 and 2021, Malaysia's gross domestic product (GDP), in current international purchasing power parity (PPP), grew from USD 578 billion to USD 970 billion, reflecting average annual growth of 5.6% (World Bank, 2021a). Malaysia's economy is expected to grow further in the coming years to transition the country to high-income level by 2024.

So far, Malaysia's strategy to grow its economy has been to diversify towards the manufacturing and service sectors. At the end of 2021, exports of goods and services accounted for around 69% of the total gross domestic product (GDP) (World Bank, 2021b), whereas imports represented 61.8% (World Bank, 2021c). Malaysia's economic outlook is based on five-year plans, with the 12th Malaysia Plan 2021-2025 focusing on strengthening security, wellbeing and inclusivity, and advancing sustainability (GoM, 2021a).

### Box 1 The COVID-19 pandemic's impact on the Malaysian economy

The first COVID-19 case in Malaysia appeared in early February 2020, followed by an outbreak in March. Subsequently the Movement Control Order was introduced, helping to reduce the spread of the virus. Although restrictions were eased in May to re-open businesses, a new wave of infections in September resulted in new lockdowns in various states until January 2021. A more stringent Movement Control Order was introduced in most states, international borders remained closed and overseas travel was restricted until March 2021.

The pandemic impacted Malaysia's economy, particularly vulnerable households. The economy contracted 5.8% in 2020 but recovered the following year with 3.1% growth in 2021 (BNM, 2022a).

To respond to the pandemic, at the end of June 2021 the Malaysian government unveiled a USD 36 billion stimulus package (Shukry and Ngui, 2021). Several measures in the package addressed clean energy investments, including: the undertaking of the fourth phase of Malaysia's Large Scale Solar (LSS) auction scheme for a total of 1 GW of capacity; a total of USD 3.1 billion (MYR 13 billion) for the installation of LED streetlighting and the installation of rooftop solar PV systems; and investments in new transmission lines.

Within this package, planned investments in renewable energy capacity totalled USD 3 billion, with the investment size of projects ranging from USD 10 million to USD 50 million. Among the estimated benefits from these investments are the creation of around 6 000 new jobs and a reduction of 1 million tonnes of carbon dioxide ($CO_2$) equivalent emissions (EY, 2021).

Long-term economic and population projections indicate that Malaysia's energy demand will continue to grow. In the past two decades, energy demand has grown by around 3% per year, and growth is estimated to average around 1.4% per year until mid-century. Malaysia is traditionally a fossil fuel producer with large reserves of oil and natural gas. Although it remains a net exporter of gas and oil, its coal imports have been increasing to meet the growing energy demand.

Meanwhile, renewable energy plays a marginal role in the total primary energy supply, representing around 3.4% as of 2019, with much of this supplied from traditional hydropower resources (ST, 2022a). Malaysia has a huge untapped potential of renewable energy resources that can provide local and affordable alternatives to fossil fuels and help to diversify the energy mix.

## 1.2 RENEWABLES 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. The assessment presents governments with short- and medium-term recommendations to guide the formation of new policies or the reform of existing policies to achieve a more enabling environment for renewable energy.

For Malaysia, the RRA process has been led by the Government of Malaysia, with technical support from IRENA, and has greatly benefited from stakeholder input. These stakeholders include the Ministry of Natural Resource, Environment and Climate Change (NRECC, then known as KeTSA), transmission and distribution utilities, power project developers, development partners, financial institutions, civil society and academia. The consultative process was initiated at the Government & Internal Stakeholders Consultation Session workshop held online on 3 September 2021. The workshop was based on a background paper describing the challenges and opportunities for renewable energy development.

During this online event, experts discussed the state of renewable energy in Malaysia as well as various challenges and possible solutions. These insights informed a draft report presented in the follow-up validation Expert Consultation Workshop with all relevant industry players held on 9 September 2021, which was jointly organised by NRECC and IRENA. In addition, the analysis benefited from bilateral interviews with key stakeholders.

The RRA process in Malaysia 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; and
- 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 FLEXTOOL ASSESSMENT

The Renewable Energy Roadmap – or REmap – process is a key pillar of IRENA's work in assessing the energy transition. REmap focuses on energy system analysis to the year 2050 and assesses energy transition technologies with an emphasis on renewable energy and energy efficiency solutions. REmap consists of three levels of analysis: country (*e.g.* this report), regional (such as the second *Renewable Energy Outlook for ASEAN*) and global (the *World Energy Transitions Outlook* or WETO) (IRENA, 2022a, 2022b).

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 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. 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 nor multi-criteria methods.

The IRENA REmap-FlexTool approach for the design and elaboration of the *Malaysia Energy Transition Outlook* aims to create technical pathways focusing on different scenarios and cases. A bottom-up approach analysis was carried out for details on the energy demand by end-use sector. This included a substitution analysis on technology options for renewables and an assessment of associated costs, investments and benefits in close collaboration with country energy experts through a series of multi-stakeholder consultative workshops and expert meetings. The power sector was modelled using PLEXOS for capacity expansion, and a flexibility assessment was performed using IRENA's FlexTool product. More information on these models can be found in section 4.

The process of developing the scenarios is a collaborative one involving close consultation with the government of Malaysia and other stakeholders in the country. Focal points are appointed, and IRENA engages stakeholders through a series of meetings, consultations and discussions to define the scope and ambition and to discuss scenario results. Two expert consultation workshops on preliminary demand outlook results were held with government stakeholders and larger stakeholders in September 2021.

In addition, the analyses of end-use sectors, the power sector and hydrogen benefited from bilateral meetings and inputs with key stakeholders held in 2021 and 2022. These included the Energy Commission (Suruhanjaya Tenaga – ST); the electricity suppliers Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn Bhd (SESB) and Sarawak Energy Berhad (SEB); and the Malaysian Green Technology and Climate Change Corporation (MGTC). A power sector technical discussion was held on 17 March 2022, in which the majority of the stakeholders mentioned above participated.

Additionally, IRENA's Director General, Francesco La Camera, presented early results on the study during a keynote speech at the 5th International Sustainable Energy Summit (ISES 2022) in Kuala Lumpur in August 2022. Preliminary results also were presented at the 27th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 27) held in Sharm El-Sheikh, Egypt in November 2022.

# 2 ENERGY CONTEXT

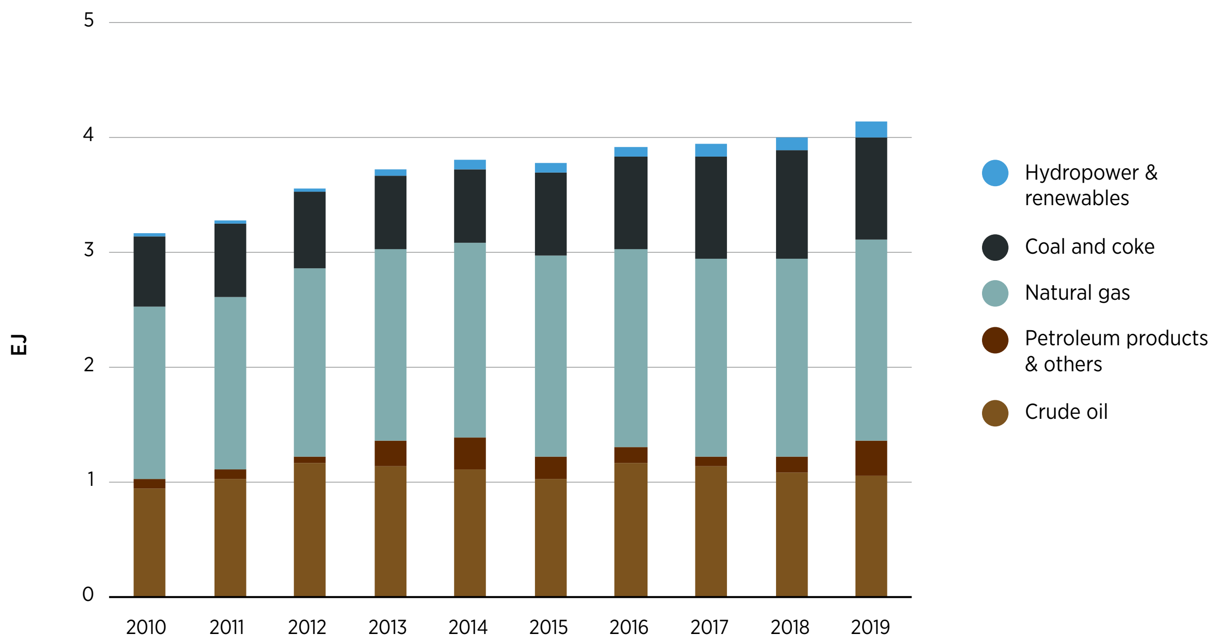
## 2.1 ENERGY SECTOR

Malaysia's total primary energy supply grew by 2.9% in 2019, to reach a total of 4.1 exajoules (EJ) (Figure 8) (ST, 2020a, 2021a). All fuels recorded an increase except for coal, which showed a negative growth of 5.5% due to lower imports of coal. Natural gas accounted for 42% of the total primary energy supply in 2019, followed by crude oil, petroleum and others at 33.3%, coal and coke at 21.4%, and renewables at 3.4%.

By 2019, renewables share in the total primary energy supply comprises mostly hydropower (2.3%) but also small contributions from other renewables (1.1%). Solar energy grew significantly between 2012 and 2020 with the rapid expansion of Solar PV installations in the country during the period. Although the use of biofuels is increasing rapidly, hydropower continues to make the largest contribution to renewables in the country, with a total supply of 93 PJ in 2020.

***Malaysia's energy supply is still heavily dominated by fossil fuels.***

**Figure 8** Malaysia's total primary energy supply, by source, 2010 to 2019




*Source:* ST, 2021a.

Malaysia has traditionally been a producer of fossil fuels, with large reserves of oil and natural gas. As of 2019, a total of 4.7 billion barrels of crude oil and condensate reserves existed in the country, spread evenly across Peninsular Malaysia, Sabah and Sarawak.[1] The country also has large natural gas reserves. As of 2019, estimated natural gas reserves consisted of 9.9 trillion standard cubic feet (tscf) of associated gas and 69.3 tscf of non-associated gas.[2] Reserves in Sarawak accounted for more than half of this total (58% or 45.8 tscf, followed by Peninsular Malaysia (27%) and Sabah (the remaining 15%). For coal, Malaysia has reserves totalling 276 million tonnes of different coal types.[3]

Over the past decade, total natural gas production in Malaysia has ranged between 2.7 EJ and 3.0 EJ per year. Gas is typically exported as liquefied natural gas, with exports reaching 1.2 EJ in 2019; 0.04 PJ of gas was exported through pipelines. Imports reached 0.1 PJ for LNG, and 0.2 PJ for pipelines.

Crude oil production reached around 1.25 EJ in 2019. Malaysia is a net exporter of crude oil, with net export of around 0.1 EJ in 2019. However, the country was a net importer of petroleum products (by 0.2 EJ) in 2019, with total imports of 17.6 million tonnes of oil equivalent. Malaysia's refineries processed nearly 1.0 EJ equivalent of crude oil, of which two-thirds came from local production.

Coal production reached around 3.4 million metric tonnes in 2019. Malaysia's coal imports have been increasing steadily and reached 0.8 EJ in 2019. Coal exports are negligible.

The main sources of energy supply in Malaysia are oil and natural gas – with equal shares – followed by coal. Three-quarters of all oil supply is for the transport sector. Industry, including non-energy uses, is the second largest oil consumer, accounting for 17% of the total oil supply. A small share of oil is also used for electricity generation in both centralised power plants as well as for self-generation.

More than half of all natural gas supply is for industry, followed by electricity generation which uses another 40% of the total. Coal is supplied mainly for electricity generation (more than 90%), with the rest used mainly in industry.

### **Box 2** Energy subsidies in Malaysia

Energy subsidies are a long-standing topic in Malaysia and have undergone several reforms in recent decades in an effort to balance government spending, natural resource use and economic growth while maintaining affordability for consumers. Energy subsidies in the country exist in several forms and have eaten up at least 7% of the annual GDP during the past decade (Figure 9) (UNSTAT, 2022).

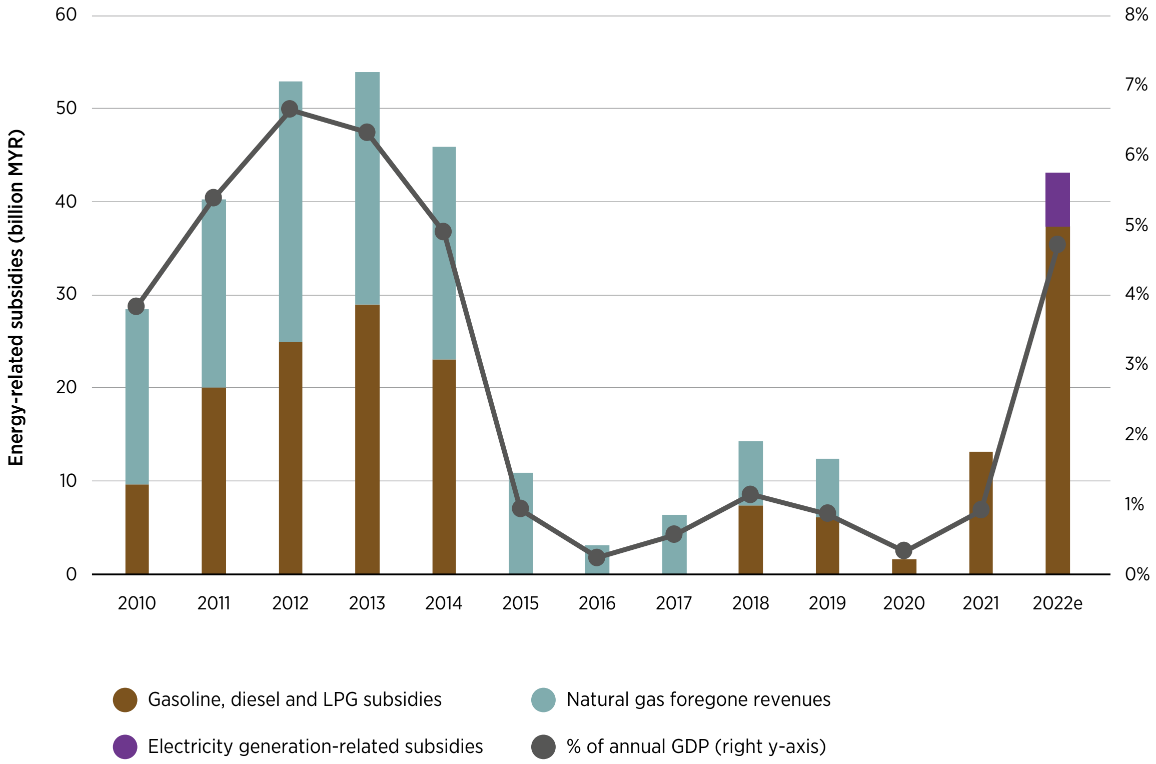
The largest subsidies are in the transport sector, and consumer prices at petrol and diesel stations in Malaysia are among the lowest globally (Murugiah, 2022). Government spending on petroleum subsidies represented between 10% and 26% of the government budget between 2004 and 2010; this continued to balloon due to rising oil prices, a weakening currency, rapid urbanisation and the 7% average annual growth in demand in oil-fuelled transport between 2010 and 2015 (ERIA, 2016; Sulaiman, Harun and Yusuf, 2022; ST, 2021a).

*1 1 barrel of oil equivalent is equivalent to 5.7 gigajoules (GJ) in lower heating value terms.*
*2 Calorific value of natural gas is about 1000 British thermal units (BTU) per standard cubic feet.*
*3 1 tonne of coal steam coal has a lower heating value of around 25 GJ per tonne.*

## Box 2 Energy subsidies in Malaysia (continued)

***These energy-related fossil fuel subsidies can be better directed towards investing in renewables and energy efficiency.***

**Figure 9** Estimated energy subsidies in Malaysia, 2010 to 2022




*Source:* IRENA analysis, estimated from MOF, 2020, 2022; PETRONAS, 2020a.

Fuel subsidies were abolished in late 2014 to take advantage of the decline in global oil prices and were followed by a managed floating price mechanism; however, they were reinstated within a few years (MOF, 2022; Ngui and Raghu, 2014). Apart from petroleum, liquefied petroleum gas (LPG) cylinders used by the majority of the population for cooking are also largely subsidised. Both petroleum and LPG have been subject to fuel smuggling by neighbouring countries (Kojima, 2016)

Energy is also subsidised through low electricity tariffs in Malaysia, which are among the lowest compared to neighbouring countries (Global Petrol Prices, 2022). For example, in the residential sector the first 300 kilowatt-hours (kWh) per month of use is being cross-subsidised at around half of the highest tariff (TNB, 2022a) by the commercial and industrial consumer segments. While this is advantageous to low-consumption consumers, the subsidy is applied for all households regardless of their total electricity use.

Electricity generation was largely reformed through Malaysian Electricity Supply Industry (MESI) plans introduced in 2014 to improve the efficiency, governance and security of the power supply system. Typically, fuel supply costs for power plants are managed under supply agreements by TNB Fuel Services (TNBF) for coal and by Petroliam Nasional Berhad (PETRONAS) Energy & Gas Trading (PEGT) for oil (OIES-UNITEN, 2021). Prior to the liberalisation of the gas market in 2016, natural gas prices supplied from PEGT to power plants were regulated at lower market prices, where the foregone revenues reported also can be seen as a form of energy subsidy (MGA, 2017; PETRONAS, 2020a).

## Box 2 Energy subsidies in Malaysia (continued)

Today, fuel generation costs are largely governed through the Incentive-based Regulation (IBR) mechanism, where any additional costs or savings in power generation relative to the base tariff are revised every six months, then passed through to consumers via the Imbalance Cost Pass-Though (ICPT) mechanism, in the form of either a surcharge or a rebate to different consumer segments. Total energy subsidies were expected to rise sharply again in 2022 due to increases in oil, coal and natural gas prices globally as well as the pressure to maintain a low electricity tariff for consumers to manage the cost of living (The Edge, 2022).

In conclusion, Malaysia has successfully managed to implement several important reforms across the energy industry in the past decade to maintain its energy security and fiscal balance; however, it continues to shield consumers from the real cost of energy, reflecting changes in global market prices. While targeted subsidies can ensure energy affordability to lower- and middle-income households and enable behavioural changes, it is also crucial that incentives and investments are directed towards long-term, productive and sustainable uses. These include investments in renewables and energy efficiency and creating efficient and effective policy mechanisms to solve Malaysia's energy "trilemma" of energy security, accessibility and sustainability.

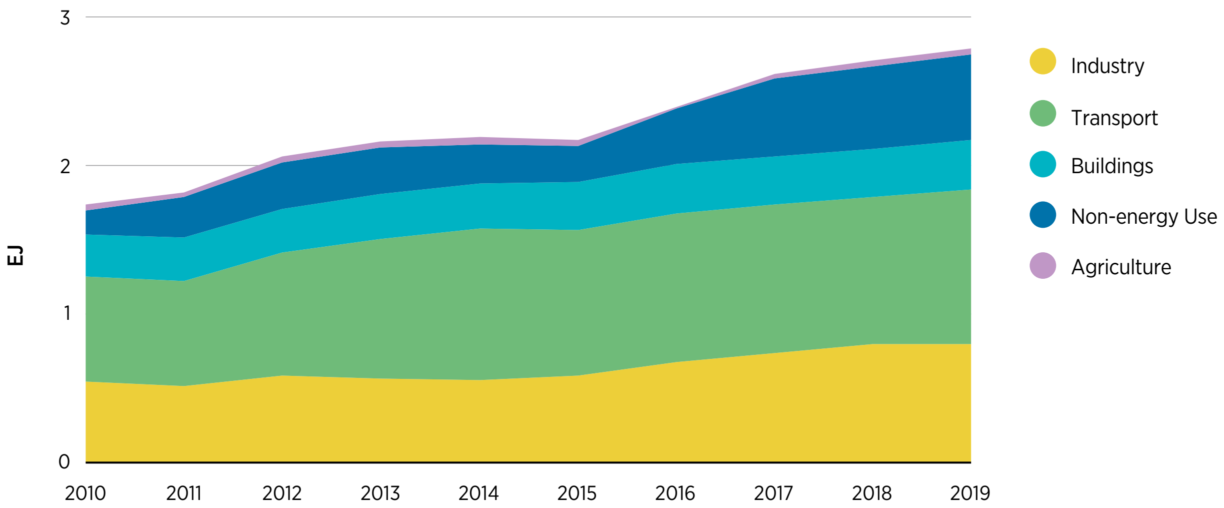
## Energy consumption

Malaysia's total final energy consumption in 2019 reached 2.8 EJ, equivalent to 65% of the total primary energy supply. Transport is the largest final user of energy, accounting for 38% of the total final energy consumption, followed by industry with 28% (Figure 10). When non-energy uses are included, industry becomes the largest final energy user with a total share of 50% (DOSM, 2021).

Given that both the demand for heating and the per capita electricity consumption by households in Malaysia are still at low levels, the share of buildings in total energy demand is only around 12%. However, cooling demand is relatively high with more than 70% of all households owning an air conditioner (DOSM, 2020a).

***The transport sector has dominated Malaysia's final consumption in the last decade.***

**Figure 10** Total final consumption in Malaysia, by sector, 2010 to 2019




*Source:* ST, 2022a.

Oil products represented the largest share in Malaysia's total final energy consumption in 2019, at 66%. Three-quarters of all oil is used by transport, with the rest used in industry. Natural gas follows oil with a 29% share in total final consumption. Meanwhile, coal's share was only 3%, used mainly for the power sector. Industry is the main user of all natural gas and oil for process heat generation.

Direct use of renewables in Malaysia is minimal with only around a 1% share. This mostly reflects the use of biodiesel, which accounts for 1.5% of the total final energy consumption in the transport sector. Electricity's share in total final consumption is 20%. It is the main source of energy in residential and commercial buildings (more than 80% of the total), and their total demand covers half of Malaysia's total electricity demand. The other half is used by the industry sector.

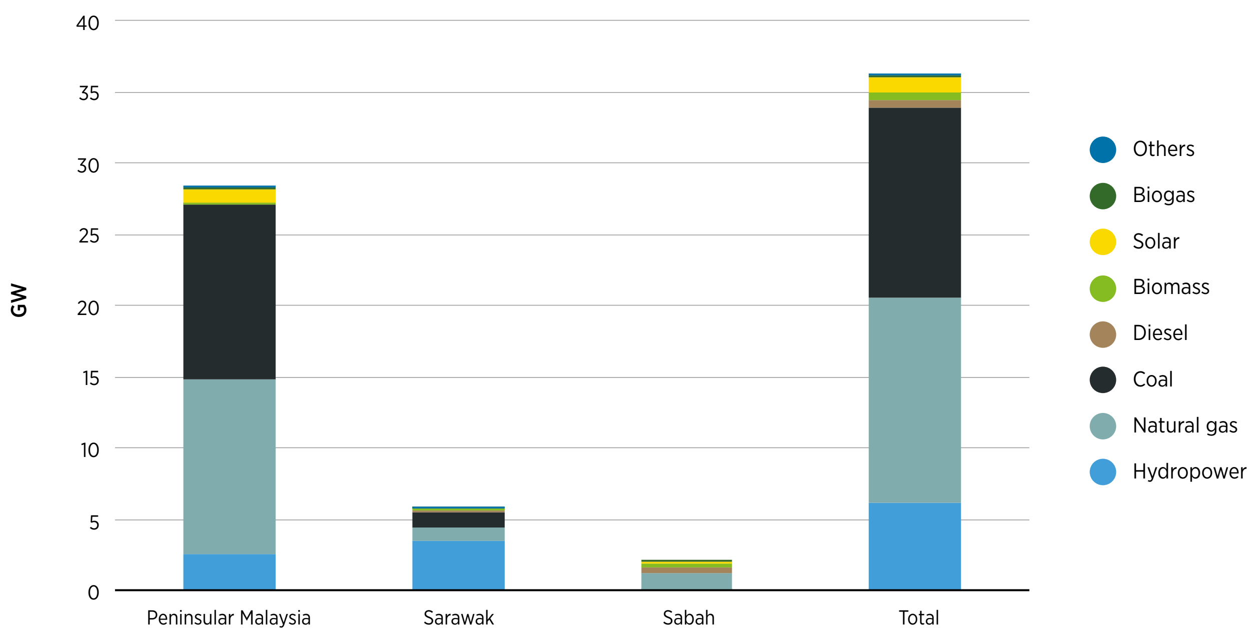
## 2.2 ELECTRICITY SECTOR

### Electricity supply and generation

The installed power generation capacity in Malaysia totalled 36.2 gigawatts (GW) in 2019 (ST, 2021a). This is dominated mainly by coal and natural gas, while renewables represent 22% of the total installed capacity. The regional breakdown of power installed capacity is shown in Figure 11, with Peninsular Malaysia accounting for 78% of the total. In Sarawak, hydropower is the dominant electricity supplier, representing 70% of total capacity. Of the total 7.8 GW of renewable energy capacity installed in Malaysia as of 2019, 1.2 GW was installed through three key schemes: the Feed-In Tariff (FIT), the Large Scale Solar (LSS) programme and the Net Energy Metering (NEM) mechanism.

***Malaysia's installed power generation capacity remains dominated by fossil fuels, with hydropower accounting for most of the renewable capacity.***

**Figure 11** Total installed power capacity by region, 2019



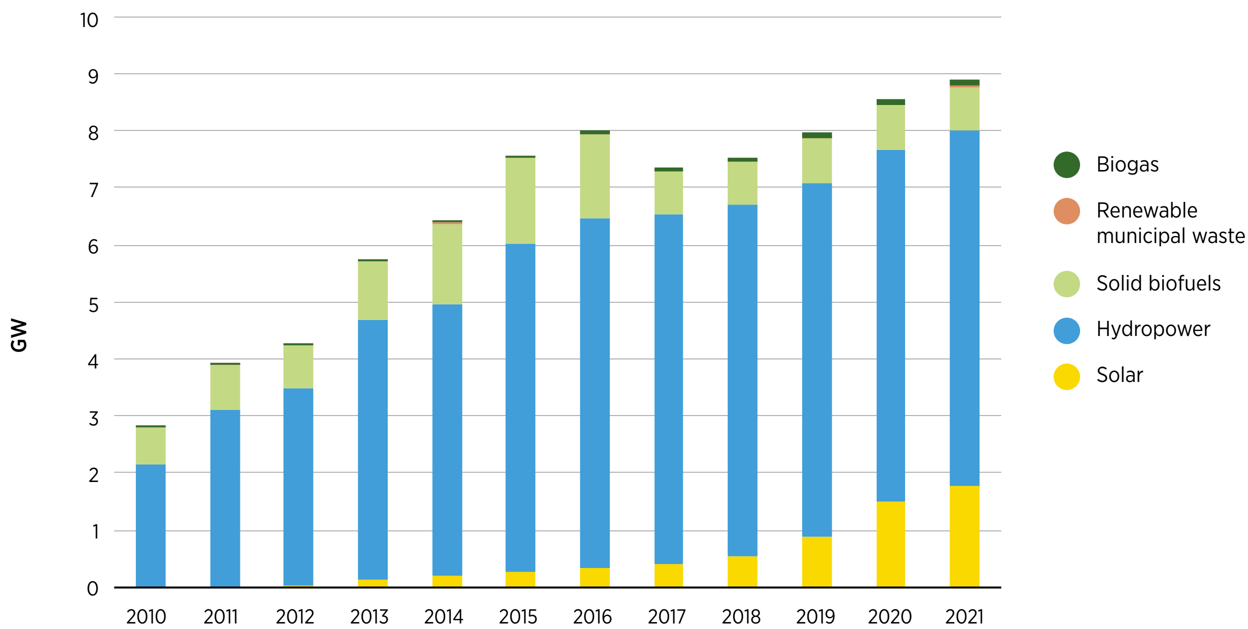

*Source:* ST, 2022a.

In 2021, Malaysia's total installed renewable energy capacity reached around 8.9 gigawatts (GW) according to IRENA statistics (Figure 12) (IRENA, 2021a). Of this, 68% was hydropower capacity connected to the transmission grid. Over the past decade, the country's total installed hydropower capacity has tripled to 6 211 MW, although only 14 MW of capacity was added in 2021. A small capacity of mini hydropower plants also exists in off-grid systems.

Grid-connected solar photovoltaic (PV) capacity reached 1 780 MW in 2021, up from 1 493 MW in 2020. More than 7 MW of this capacity was in off-grid systems in 2021. The installed capacity of solid biofuels was large between 2013 and 2016 but has since been declining, reaching 774 MW by the end of 2021. By comparison, biogas systems are increasing rapidly with a total installed capacity of 120 MW in 2021.

***Hydropower has dominated the renewable installed capacity, but solar has become increasingly promising in the last few years.***

**Figure 12** Malaysia's total installed renewable energy capacity, by source, 2010 to 2021




*Source:* IRENA, 2021a.

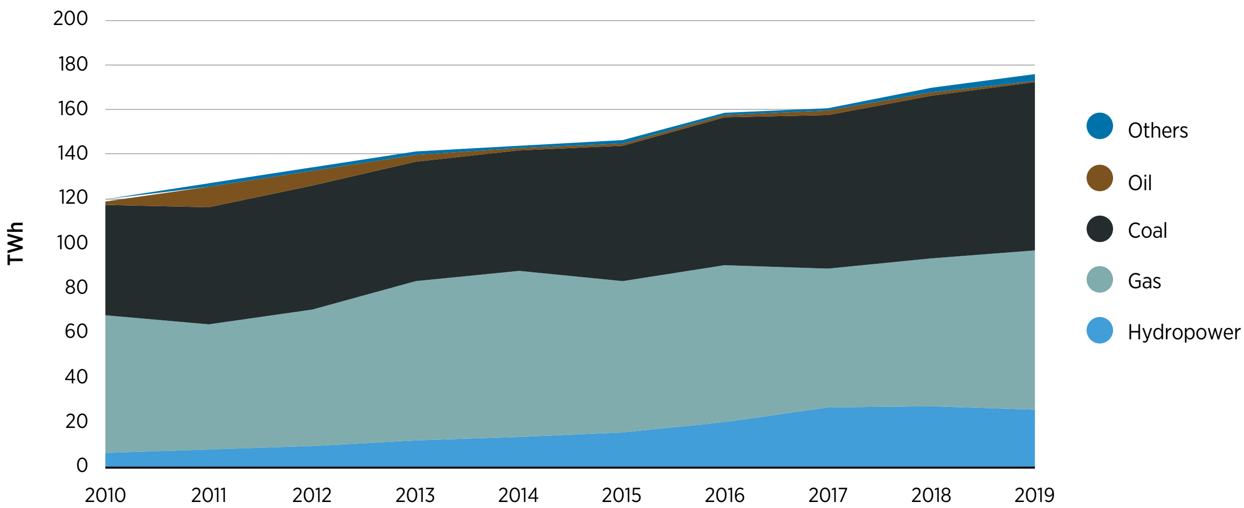
In Malaysia, electricity capacity is shared between independent power producers (IPPs) and the power generation arm of Tenaga Nasional Berhad (TNB), Malaysia's largest electric utility company. Besides generation, TNB is also responsible for the transmission and distribution of electricity. The power is procured via the Single Buyer units of TNB in Peninsular Malaysia, via Sarawak Energy Berhad (SEB) in Sarawak and via Sabah Electricity Sdn. Bhd. (SESB) in Sabah and Labuan (SESB is owned 80% by the TNB and 20% by the Sabah State Government). The IPPs in Peninsular Malaysia are licensed by the government to generate electricity, and they sell the power according to the terms set out in the power purchase agreements (PPAs).

In 2019, IPPs accounted for three-quarters of the total installed electricity generation capacity in Peninsular Malaysia (21.2 GW). All coal generators and a large share of natural gas generators were IPPs, whereas nearly all hydropower plants belonged to TNB. In Sabah, IPPs (1.1 GW) represented nearly 60% of the grid-connected capacity, with the rest split between SESB (0.4 GW) and co-generation, self-generation, FIT and LSS plants. In Sarawak, SEB owned 5.2 GW of the total generation assets, with the remaining 0.5 GW split between co-generation and self-generation plants.

Electricity generation in Malaysia totalled 176 terawatt-hours (TWh) in 2019 (Figure 13). Electricity demand has grown at an average annual rate of 5% over the past decade. While hydropower's share in the electricity supply increased from 6% to 15% between 2010 and 2019, coal's share increased from 34% to 43%, becoming the country's largest source of electricity supply. The total share of renewables was around 17% in 2019; however, this share has likely increased since then as a result of the growth in renewable capacity installations in the 2020-2021 period through various schemes.

***Fossil fuels account for around 80% of Malaysia's total electricity generation, although this share has fallen from around 90% in 2010.***

**Figure 13** Malaysia's total electricity output, by source, 2010 to 2019

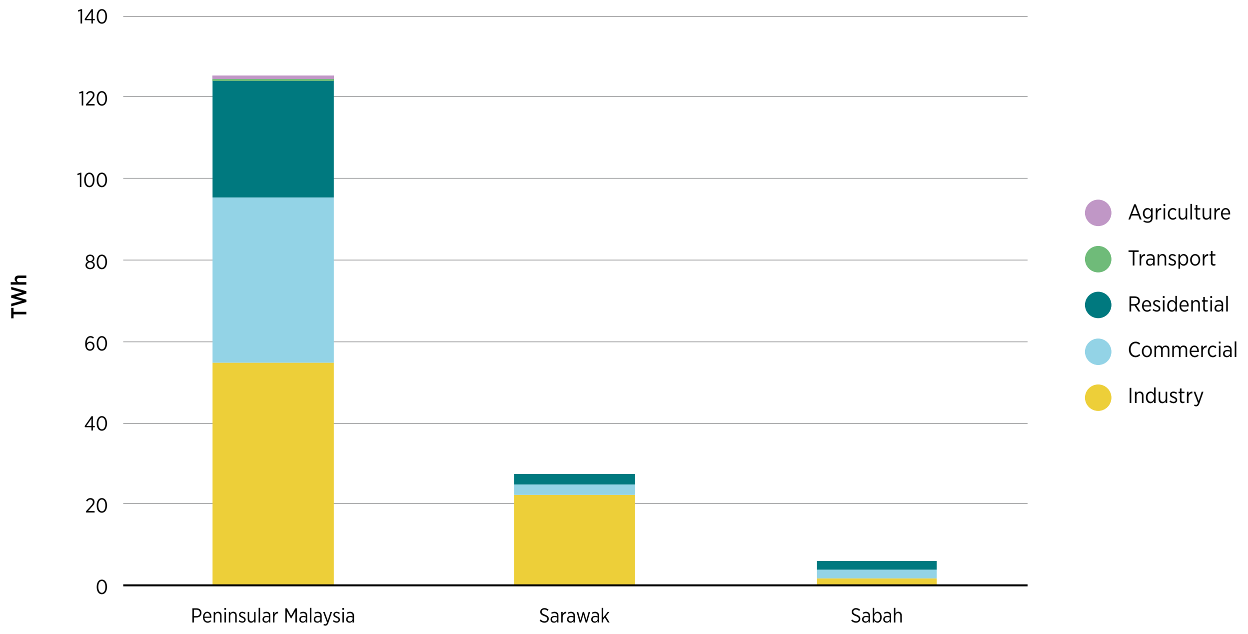



*Source:* ST, 2022a.

The electricity consumption by region is proportionate to the installed capacity and is highest in Peninsular Malaysia (Figure 14). The current reserve margin (percentage of available unused capacity of an electrical power system to meet its peak demand) in Peninsular Malaysia reached 38% in 2019 and 52% in 2021; according to the region's master plan to 2039, the aim is to reduce this to 21% (ST, 2021b). The reserve margin declined in Sabah and Labuan, falling from 29% to 23% between 2018 and 2019 (ST, 2020b).

***Electricity demand in Peninsular Malaysia is proportionally larger than in Sabah and Sarawak.***

**Figure 14** Total electricity consumption by region, 2019



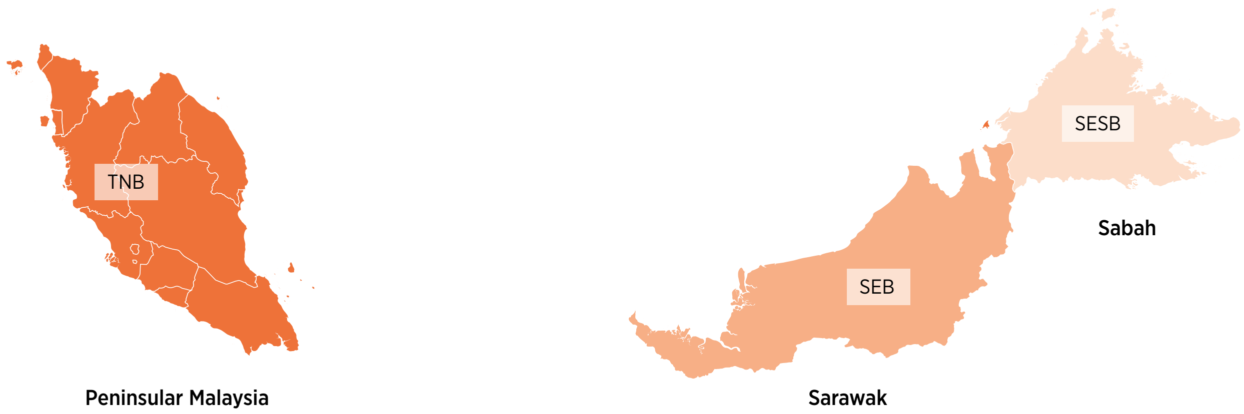

*Source:* ST, 2022a.

## Transmission and distribution grid

Malaysia has three major electricity grids: the national grid on Peninsular Malaysia, the Sabah grid (on Borneo) and the Sarawak grid (also on Borneo). The transmission voltage networks include grids of 500 kilovolts (kV), 275 kV and 132 kV. The supply frequency is 50 hertz (Hz). The utilities and boundaries for each of the three grids is shown in Figure 15, where TNB is responsible for Peninsular Malaysia, SESB for Sabah and SEB for Sarawak.

***The Malaysian electricity grid can be broadly broken down into three major grids.***

**Figure 15** Electricity grids and utility distribution in Malaysia




*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.

The total length of the TNB transmission grid is 23 082 kilometres, with a 132 kV network covering around half of the total grid. The transmission grid has a total of 407 sub-stations, with a combined capacity of 115 120 megavolt amperes (MVA). The TNB distribution grid covers a total 352 565 kilometres of overhead lines and 307 474 kilometres of underground cables. A total of 81 327 sub-stations serve the distribution grid, with a combined capacity of 114 089 MVA.

The SESB transmission grid has 66 kV lines. The total length of the grid is 2 288 kilometres, and a 132 kV grid network represents nearly the entire capacity. A total of 45 sub-stations serve the grid with a combined capacity of 5 049 MVA. The SESB distribution grid uses mainly overhead lines with a total length of 9 465 kilometres. Underground cables cover a total length of 1 109 kilometres, and the grid's 7 957 sub-stations have a total capacity of 5 440 MVA.

The SEB transmission grid has a total length of more than 4 400 kilometres, with 275 kV lines covering more than 2 800 kilometres of this. A total of 37 transmission sub-stations have a combined capacity of 10 246 MVA. The SEB distribution grid has 26 236 kilometres of overhead lines and 8 769 kilometres of underground cables. A total of 13 824 distribution sub-stations have a combined capacity of 9 600 MVA.

The distribution grid voltages of Malaysia comprise 33 kV, 11 kV and 415/240 volts (ST, 2021a).

## Electricity trading

The national grid is connected to Thailand's grid to the north with a total capacity of 380 MW (commissioned in 2002), comprising a 300 kV high-voltage DC line with 300 MW capacity from Gurun to Khlong Ngae and a 132 kV AC line with 80 MW capacity from Bukit Ketri to Sadao. There is also interconnection to Singapore's main grid to the south with a total capacity of 450 MW (commissioned in 1985) that has since been upgraded to two 550 MVA of high-voltage AC. The total interconnection capacity of Malaysia is only around 2% of the total installed capacity.

The ASEAN Interconnection Masterplan Study (AIMS) III covering the period until 2040 updates the previous version and emphasises that around 20 GW of interconnection capacity would be needed by 2025 in the Southeast Asia region (USAID, 2021). In September 2014, the governments of the Lao People's Democratic Republic (Lao PDR), Malaysia, Thailand and Singapore released a joint statement to initiate a pilot project for facilitating cross-border electricity trade. Power would flow from Lao PDR to Singapore via Thailand and Malaysia. The four countries agreed to form a working group to assess the viability of trading up to 100 MW through the existing interconnector capacity.

The commitment to the implementation of the joint statement plan was reaffirmed in November 2020 (MTI, 2020). Phase 1 commenced on 1 January 2018. Malaysia purchased electricity from Lao PDR through Thailand as a wheeling country based on a predefined price and quantity. The second phase expanded Lao PDR's electricity export from 100 MW to a maximum of 300 MW. Commenced on 23 June 2022, Singapore signed power purchase agreement with Lao PDR, that will allow import up to 100 MW of renewable hydropower from Lao PDR to Singapore via Thailand and Malaysia using existing interconnection. As the only multilateral power trade agreement in the Southeast Asia region, the pilot project demonstrated that such trade in the region is possible.

Thailand and Malaysia are conducting a joint study to increase the capacity of interconnection between the two countries. One option they are considering is developing two new interconnections: a 300 kV line with a total power transfer capacity of 300 MW and a 132/115 kV line with a total capacity of 100 MW. In addition, a new 600 MW interconnection line with Indonesia has been proposed and was expected to be commissioned after 2021, although the project was postponed as Indonesia decided to focus on its domestic priorities. The SEB has plans to expand transmission towards the hydro resource rich regions of Baleh and Murum. This expansion would create an opportunity for electricity trade with Indonesia and Brunei Darussalam.

## 2.3 INSTITUTIONAL STRUCTURE

### Key institutions

The Economic Planning Unit of the Prime Minister's Department is responsible for development planning, which builds on the close engagement of various stakeholders from government entities (at both the federal and state levels), businesses, civil society and other relevant actors.

The Ministry of Natural Resources, Environment and Climate Change (NRECC), formerly known as the Ministry of Energy and Natural Resources (KeTSA), manages the supply of electricity, with the objective of optimising renewable energy and energy efficiency to ensure reliable, affordable and sustainable electricity supply services. The ministry develops related policies, strategies and legislation and enforces laws.

The Energy Commission (Suruhanjaya Tenaga, ST) is responsible for regulation of all electricity and gas issues in Peninsular Malaysia and Sabah. The ST reports to NRECC and is responsible for policy matters concerning the supply of energy; the generation, transmission, distribution and the use of electricity and gas; promoting renewable energy use and energy efficiency measures and research in these areas; and safeguarding the operations of competition and fairness and efficiency in the energy markets. The ST also works closely with the Sustainable Energy Development Authority (SEDA), which was formed under the Sustainable Energy Development Authority Act of 2011 to administer and manage the implementation of the FIT under the Renewable Energy Act of 2011 (GoM, 2011).

### Structure of the power sector

Since Malaysia's independence in 1957, the power system has been undergoing continuous change. The following institutions have been established:

- Central Electricity Board (1949)
- National Electricity Board (1965)
- Tenaga Nasional Berhad (1990), the successor to the National Electricity Board
- Suruhanjaya Tenaga (2002), taking over the role of the Department of Electricity and Gas Supply.

Malaysia's market is a managed model in where the generation sector is open for participation, consisting of large independent power producers and state-owned utilities. The upstream market is more competitive, allowing the participation of both local and foreign power producers. For renewable energy generation projections, there is a competitive bidding process through numerous schemes further elaborated in the report.

The Malaysia Electricity Supply Industry (MESI) 1.0 initiative, introduced in 2009, aimed to transform the power sector between 2010 and 2014 through an improved tariff mechanism, fuel supply and security, and governance for the effectiveness of the power sector. As a result of the MESI 1.0 initiative, the Single Buyer model was established in Peninsular Malaysia within the TNB in September 2012 based on the Electricity Supply Act (1990) (OIES-UNITEN, 2021). According to this model, the Single Buyer is responsible for the procurement of electricity from all generators, and it also plans for the dispatch based on a least-cost approach by considering constraints in the generation and transmission capacity in line with the Grid Code.

To supplement the Single Buyer Rules, the ST introduced the New Enhanced Dispatch Arrangement (NEDA) system in 2015, which allowed merchant generators to supply power to the grid without necessarily entering a PPA. NEDA is designed to enhance short-run competition (based on scheduling and dispatch) and cost efficiency as well as to incentivise the power generators to be more efficient; it arranges the scheduling and dispatch of generation used by the Single Buyer (ST, 2020b). According to NEDA, power plant generators bid daily against each other based on their variable costs following the rules set by the ST. In May 2019, NEDA started including solar power plants as a new category.

The competition takes place under PPAs, which IPPs secure with TNB for a contract duration of 21 years for gas-fired power plants and 25 years for coal-fired plants. The contracts require power plants to be always available. The payments by the Single Buyer to generators under the PPA arrangement include an energy payment and a capacity payment.

For renewable energy PPAs that are applicable for the FIT and LSS mechanisms, the take-and-pay principle is applied for a period of 21 years. This means that the off-taker accepts the supplied electricity whenever it is available. In current renewable energy PPAs under the LSS mechanism, capacity payment is not applied since solar is not a dispatchable resource. In PPAs there are no linkages to inflation or currency changes for a fixed period of 21 years.

In September 2019, the Malaysian government approved the 10-year MESI 2.0 master plan with the objective to open the market to diversity and competition to improve its flexibility and cost efficiency and to empower consumers (ST, 2020b). Key reform measures of the MESI 2.0 include: to allow generators to source for their own fuel to optimise cost; move from the PPA regime to capacity and energy markets; establish a third-party access framework and network charges for the grid to allow third parties to use the infrastructure; and, facilitate green energy producers and consumers. A key objective is to have market-based competition, whereas in the current model which sees competition exists only at the generation level. An additional objective is to promote trade across borders with neighbouring ASEAN countries to enhance the efficiency of operations.

In November 2021, a Green Electricity Tariff was launched, where subscribers can opt in to use electricity generated from renewable resources by providing an additional payment per kWh; subscribers also receive a renewable energy certificate (Aziz, 2021).

Additionally, the government announced the Corporate Green Power Programme (CGPP) in late 2022, where the private sector can undertake a corporate PPA with a solar PV producer, further incentivising the uptake of renewables (ST, 2022b). The CGPP also encourages the trading of renewable energy certificates between both parties, fulfilling their environmental, social and corporate governance (ESG) commitments.

## 2.4 STRATEGIC FRAMEWORK

Malaysia has implemented several major energy policies. The Electricity Supply Act was introduced in 1990 and then amended in 2015. The Energy Commission Act was introduced in 2001 and later amended in 2010. The National Renewable Energy Policy and Action Plan was introduced in 2010, the same year as the Malaysia New Energy Policy. The SEDA and Renewable Energy Acts followed in 2011. In 2015, the National Energy Efficiency Action Plan was introduced.

For bioenergy, Malaysia has implemented a biodiesel blending programme in the transport sector under the National Biofuel Policy enforced in 2006. Blending biofuels for road transport started in 2010, and in five years the biodiesel blending rate reached 7%. Malaysia's biodiesel now caters to both the domestic market and the export market, and a blending mandate of B10 (10% biodiesel) is used for the road transport sector and B7 for industrial use (Wahab, 2021). A B20 blending target was planned in 2020 but was delayed due to supply chain issues that were further exacerbated by the COVID-19 pandemic. A wider National Biomass Industry Action Plan was also developed, aiming for energy-intensive industries to increase the share of biomass in their energy use (GoM, 2013).

The Green Technology Master Plan, introduced in 2017, covers the period to 2030. In this plan, Malaysia aims to increase the renewable energy capacity in the total generation mix to 20% by 2020 (2 080 MW, excluding large hydropower), 23% by 2025 and 30% by 2030 (4 000 MW).

The Malaysia Renewable Energy Roadmap (MyRER), launched at the end of 2021, outlines strategies and provides an action plan to reach the target of 40% renewable energy installed capacity or 18 GW by 2035; under its "New Capacity Target" Scenario, 7.3 GW is projected to be solar PV (SEDA, 2021a).

### **Box 3** Malaysia's climate policy and net zero targets

Malaysia's Intended Nationally Determined Contribution (INDC), submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2015, aimed for a 45% reduction in greenhouse gas emission intensity (tonnes of $CO_2$ emissions per unit of GDP) by 2030 relative to 2005. This is split between an unconditional target of 35% and a conditional target of 10% if the country receives climate finance, technology transfer and capacity building from developed countries (GoM, 2015).

In July 2021, the cabinet approved raising the unconditional target to 45%, representing an increase of 10 percentage points from the previous version of the NDC (GoM, 2020a, 2021b). In September 2021, Malaysia's Prime Minister announced a goal for the country to become carbon neutral as early as 2050, alongside a commitment to stop building new coal-fired power plants post 2040 (Salim, 2021).

In 2016, the Malaysian state-owned oil and gas company, PETRONAS, aimed to become a net zero emitter of greenhouse gases by 2050, and the company also announced that it will increase renewable energy investments. In a press release issued on 5 November 2020, PETRONAS stated that it will continue to intensify its efforts towards reducing Scope 1 and Scope 2 emissions from its assets by delivering continuous improvements in operational excellence and by deploying innovative operations and technologies (PETRONAS, 2020b).

Malaysia's second largest lender by assets (CIMB) has committed to phase out coal from its portfolio by 2040 and to end funding for new coal mines and generators as early as 2021 (Reuters, 2020). In August 2021, TNB announced its aspirations to become net zero by 2050, by adopting a sustainable pathway to reduce its emission intensity by 35% and to halve its coal generation capacity by 2035 (TNB, 2021a). Additionally, the national investment arms such as Permodalan Nasional Berhad (PNB) and Khazanah Nasional have committed to net zero targets by 2050, aiming for greener portfolios and investments (Khazanah, 2022; PNB, 2022).

On 9 December 2022, Bursa Malaysia launched the Bursa Carbon Exchange (BCX) as a voluntary carbon market aimed at enabling companies to trade voluntary carbon credits from climate-friendly projects and solutions to offset their emission footprint and meet climate goals. The first auction is expected to start in March 2023; projects permitted to be traded include nature-based and technology-based solutions that help avoid, reduce or remove GHG emissions (Bursa Malaysia, 2022).

Each utility company in Malaysia has developed its own plans for the coming years. TNB in Peninsular Malaysia has set a target for 20% renewable energy capacity by 2025 (ST, 2021b) and has announced its aspirations to become net zero by 2050, by adopting a sustainable pathway to reduce its emission intensity by 35% and halve coal generation capacity by 2035. Other goals from the government include the use of the Incentive-Based Regulation (IBR) mechanism (a tariff price-setting mechanism for affordable and secure energy supply in a deregulated market), an optimal generation expansion plan (to improve service reliability at minimal cost), least-cost dispatch (to promote market liberalisation to reduce transmission and distribution costs) and fuel portfolio diversification (to balance affordable electricity and energy security).

Renewable energy generation in Peninsular Malaysia covers solid waste, small hydropower, biomass, biogas, geothermal and solar. Large hydropower plants (more than 100 MW capacity) are not considered to be renewable energy. TNB's target of 20% renewable energy capacity by 2025 focuses on increasing solar generation capacity while also creating new business opportunities for big companies, small and medium enterprises, microbusinesses and households.

The latest generation development plan of Peninsular Malaysia, covering the 2021-2039 period, aims for a 31% share of renewable energy capacity by 2025, raising the initial target of 20% (excluding large hydropower plants) (ST, 2021b). The renewable share in the capacity mix is projected to increase to 40% by 2035. This will require an additional 1 178 MW of new capacity to be installed in Peninsular Malaysia by 2025 – of which the majority will be solar PV – followed by 2 414 MW between 2026 and 2035. The total installed renewable energy capacity would reach 8 531 MW by 2025 and 10 944 MW by 2035.

Under the plan, the share of coal is estimated to decline from 37% in 2021 to 22% in 2039, while natural gas' share is expected to increase slightly from 45% to 47%. The 31% share of renewables would include a 26% contribution from Peninsular Malaysia (from a total of 8 531 MW of capacity) and 5% from East Malaysia. Although the energy sector has perceived this to be an ambitious target, in view of the country's significant resource potential much more could be done – which will also provide investment opportunities.

Sabah grid goals are slightly different, as the grid faces limitations from a significant reliance on natural gas by an ageing fleet. There are also challenges to renewable energy development and planning. The government highly subsidises the electricity supplied in the grid (further discussion can be found in Box 2 on Energy Subsidies in Malaysia). The Sabah grid aims to develop solutions to overcome these challenges in order to ensure a secure supply of electricity to meet growing demand. The Sabah grid aims to improve the electricity supply with grid expansion and interconnection investments. Additionally, it seeks to increase the share of renewables, notably solar PV plants, which will also help to reduce the greenhouse gas emission intensity.

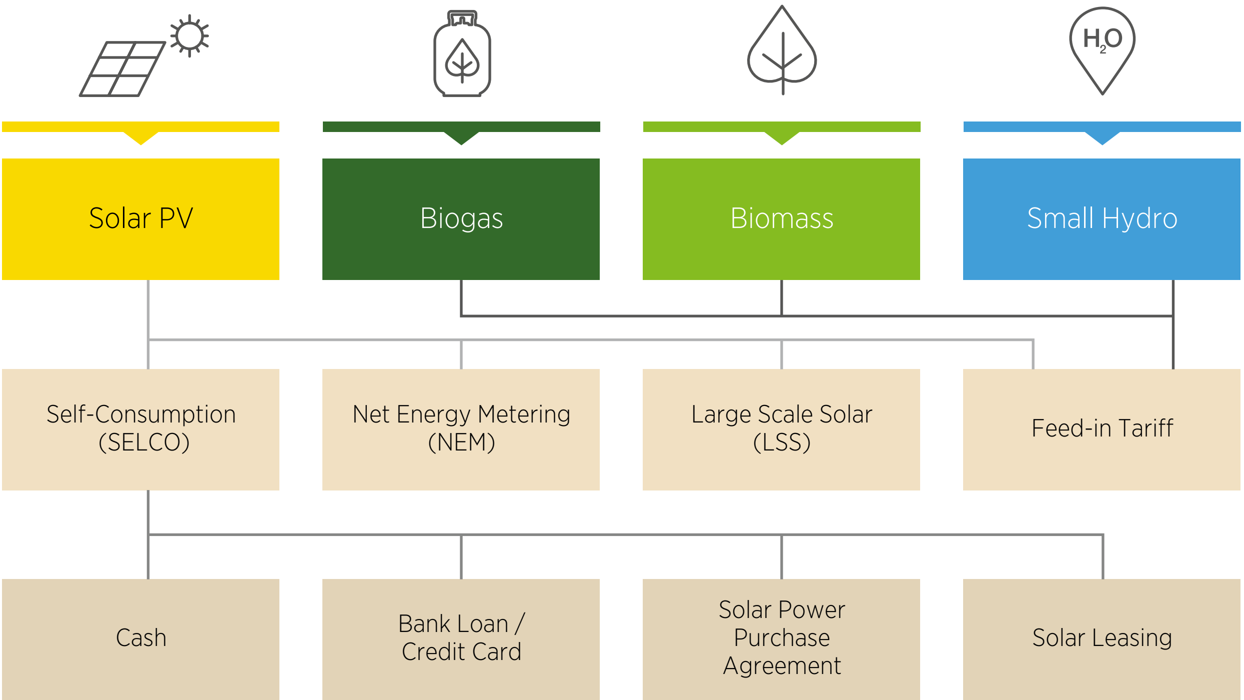
As implemented in Peninsular Malaysia, the Sabah grid aims to introduce the IBR. In addition, in 2019 the energy ministry announced the target of achieving a 20% renewable energy share in the Sabah grid by 2025 as well as savings of 8% through energy efficiency initiatives by the same period. Specific to the Sabah grid, planning for micro-grid frameworks and project monitoring for rural electrification are also part of the initiatives (ST, 2019).

## 2.5 LEGAL, REGULATORY AND POLICY FRAMEWORK

Figure 16 provides an overview of the renewable energy regulatory framework in Malaysia and the available financing instruments to enable their implementation.

***Several renewable energy installation types and financing schemes are available for various renewable energy sources in Malaysia.***

**Figure 16** Overview of the renewable energy regulatory framework and the available financing instruments in Malaysia




*Source:* SEDA, 2021a.

## Feed-in tariff mechanism

Between 2001 and 2008, the impact of the Small Renewable Energy Power (SREP) Programme was limited. As a result, the Ministry of Energy, Green Technology and Water (then KeTTHA, now NRECC) developed a more comprehensive programme that resulted in the National Renewable Energy Policy and Action Plan (NREPAP). Two bills were drafted subsequently in 2011, namely the Renewable Energy Act and the SEDA Act. These acts led to the implementation in 2011 of the feed-in tariff mechanism, which is executed by the SEDA. The FIT was initially established in Peninsular Malaysia, but its scope was subsequently expanded in early 2014 to include Sabah and Labuan.

The FIT is financed by the Renewable Energy Fund established under the Renewable Energy Act. The fund is generated through the collection of a 1.6% surcharge in the electricity bill (consumers in Sarawak are excluded), which is also the current FIT rate. Domestic consumers whose monthly electricity use is below 300 kWh are exempted from contributing to the Renewable Energy Fund; otherwise surcharges are imposed on all residential, commercial and industrial sectors. The contribution is mandatory only during times when the FIT mechanism is in place.

The FITs range over a 21-year period for solar PV plants and mini hydropower plants, and 16 years for biomass and biogas. Existing renewable power plants under the existing SREP under the Renewable Energy Act 2011 were allowed to convert to the current FIT mechanism. FIT rates have changed on the basis of annual degression rates since 2013. The annual degression rate for solar PV is 10% and has been in effect since 2014 for capacity below 24 kW. FIT eligibility criteria limit the total installed capacity of power plants to 30 MW.

Throughout the programme, several improvements have been made:

- Increase in FIT bonus rates for biomass and biogas starting in 2014 based on further analysis and to reflect evolving price dynamics
- Revised degression for solar PV starting in 2014
- Establishment of a FIT for geothermal projects for up to 30 MW, starting in 2015, to support scaled-up development of this largely untapped resource in Malaysia
- Launch of the net metering (NEM) programme in January 2016 to complement Malaysia's solar PV FIT policy (the FIT for solar PV was later replaced entirely with the NEM programme at the end of 2017).

By 2021, SEDA had awarded feed-in tariff (FIT) quotas totalling 174 672 megawatts (MW) for biogas, biomass, and small hydro resources to 34 companies. In 2021 alone, projects under the FIT had generated a total of 1.35 TWh. This included 33% solar PV, 12% biomass, 34% biogas and 21% small hydropower.

## Large Scale Solar (LSS) programme

The LSS programme, based on a bidding process, was introduced in 2016 by the ST with a total quota of 1 250 MW allocated for the 2017-2020 period. Of this, 250 MW was directly awarded under the fast-track programme. The remaining 1 000 MW falls under the bidding mechanism. By the end of 2022, there were four rounds of LSS bidding that had taken place.

During the first 50 MW-size project, several challenges occurred during construction and operation, including changes in requirements during bids and construction, and delays in getting approval from authorities. Additionally, fluctuations in the local currency led to higher project costs (Abdullah *et al.*, 2019), usually as a result of higher material procurement costs. After the second round of the LSS, there were difficulties in obtaining the development order, as the multiple processes within state governments delayed project implementation. The government has taken actions to address issues experienced during the first and second rounds of the LSS.

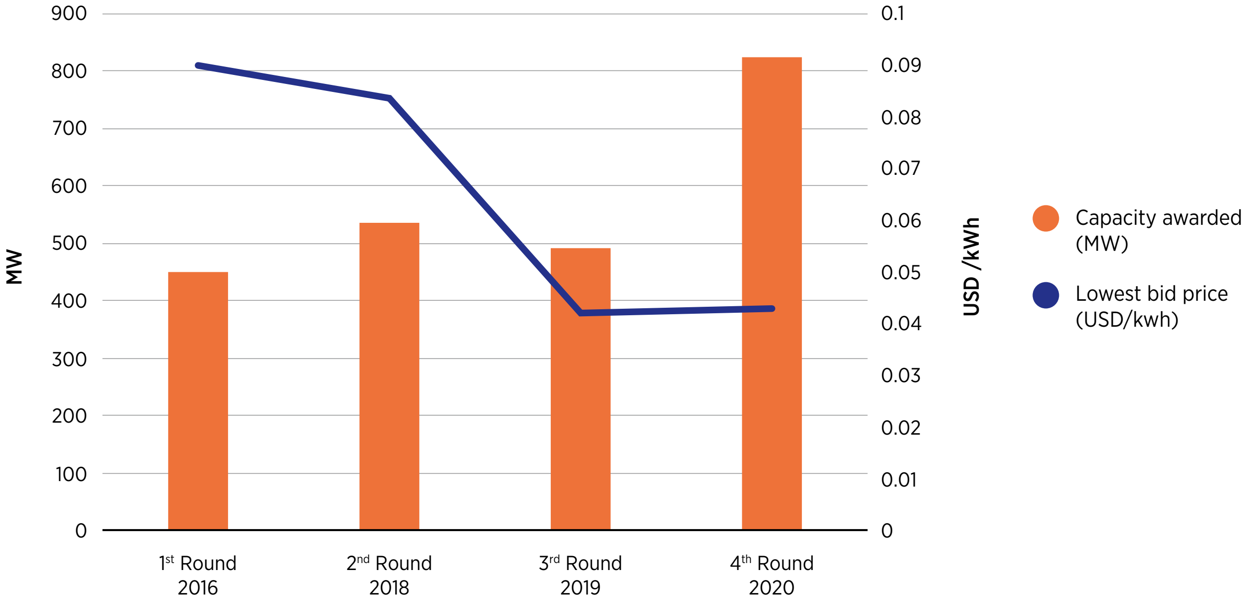
In August 2017, the ST announced the bid open price for LSS solar PV plants for 2019-2020. The results showed that the lowest bid received was in the 10 MW to 30 MW category, with a tariff of USD 0.079 (MYR 0.3398) per kWh (ST, 2021c).The first round of the LSS tender was designed in similar fashion but with the high end of the categories reaching up to 50 MW capacity in Peninsular Malaysia and 10 MW in Sabah/Labuan. Of the total capacity awarded in the first and second rounds of the LSS, most was located in Perlis, which has higher solar irradiation compared to the rest of the country.

The third round of the LSS attracted 112 bids, for more than 6.73 GW of generation capacity (oversubscribed above 500 MW), and with a lowest solar energy price of USD 0.042 (MYR 0.178) per kWh from a 100 MW scale project in 2019. However, the ST shortlisted only five bidders, for a total generation capacity of 490 MW (ST, 2021c).

The fourth round of the LSS took place in March 2021. The bid where plants are planned to be commissioned in 2022 and 2023 attracted projects with bids as low as USD 0.043 (MYR 0.177) per kWh. A total of 30 projects were pre-selected by the government with a combined 823 MW of electricity generation capacity (PV magazine, 2021). A summary of LSS programme outcomes is provided in Figure 17.

***Several rounds of the Large Scale Solar programme have taken place, with increasing capacity awarded.***

**Figure 17** Large Scale Solar (LSS) program and lowest bid prices in Malaysia, 2016 to 2020




*Source:* ST, 2022b.

The continuing decline in prices achieved in the four distinct bidding LSS rounds showed that renewables are gaining a business case in Malaysia. The last two rounds of LSS where oversubscribed by up to 5 and 13 times from the original auction capacity, showing that there is a great interest from project developers and further expansion potential for utility-scale solar (IRENA, 2022c). The tendering guidelines of the LSS have improved greatly, and more criteria are now included to ensure that projects are successfully delivered in time for their commercial operation date.

Details on the auction design and results in Malaysia can be found in IRENA's publication *Renewable energy auctions: Southeast Asia* (IRENA, 2022c).

## Net Energy Metering (NEM) programme

The NEM is executed by the energy ministry and regulated by the ST, with SEDA as the implementing agency. A total of 500 MW of capacity was planned to be reached by the end of 2020 by domestic, commercial and industrial users. The NEM prioritises self-consumption and any surplus to be exported and sold to the utility at a displaced cost. Initially, progress in the NEM was slow. As of late 2018, the NEM scheme had received 520 applications with a total capacity of 27.8 MW, and 223 projects with a total capacity of 9.0 MW had started operation. This left a balance of 472.2 MW of NEM quota available until the end of 2020.

In October 2018, NEM 2.0 was announced, which allowed excess solar electricity to be compensated on a one-on-one basis instead of the displaced cost, effective in early 2019. NEM 2.0 was aimed at TNB customers only, including agricultural consumers (SEDA, 2018). At the start of 2020, a total of 94 MW of new rooftop solar PV capacity was installed until the end of November 2019, far more than the 14 MW installed capacity achieved in the first NEM program that ran between 2016 to 2018. The total installed capacity was split into 75 MW for industrial installations, 25 MW for commercial systems, 7.7 MW for residential systems and 130 kW for agricultural projects (Bellini, 2020).

The NEM 3.0 programme was announced in December 2020 and is effective from the beginning of 2021 until the end of 2023, with a total quota of 500 MW. NEM 3.0 introduced three new initiatives: NEM Rakyat (residential customers), with a total capacity of 100 MW; NEM GoMEn (Government Ministries and Entities), aimed at lowering the electricity bills of government buildings and offices through a 100 MW quota; and NEM NOVA, targeted at commercial and industrial consumers affected by the COVID-19 pandemic, with an allocated quota of 300 MW. As a continuation from the NEM 2.0 period, customers can choose to purchase solar electricity through signing a PPA, through a solar leasing programme or through a hybrid of both, as offered by solar investors.

There are four principal modes for financing rooftop solar PV systems, as seen in Figure 16. Through the NEM programme and a self-consumption business model, electricity consumers have an additional choice of financing solar PV systems either through solar leasing, signing a PPA, or a mix of both known as a hybrid PPA.

In the hybrid PPA, upfront payment is negotiable and is based on agreement between the investor and the consumer. The payment in energy is in MYR per kWh. The system is owned by the investor, the installation is done by the investor's contractor, and at the end of the contract period the system is handed over to the customer. This is different in the leasing model, where the system is owned after the leasing period ends, while the installation model is identical with the PPA model. In the leasing model, the payment is done monthly in MYR. The difference between leasing and a PPA is that leasing is based on a fixed monthly payment, while a PPA entails paying per solar energy produced (typically the solar tariff is fixed).

### New renewable energy markets

Corporate PPAs could be a new option to sell power directly to end users, and there is significant interest in this model from investors. Enabling corporate PPAs will require overcoming the power wheeling charges. In addition, rooftop solar PV and small hydropower plants have shown interest in peer-to-peer electricity trading, where a pilot project was implemented by SEDA. This could be an interesting option in particular following the end of the NEM 3.0 in 2023. The Corporate Green Power Programme (CGPP) which use virtual Power Purchase Agreement Mechanism was introduced in November 2022 with quota of 600MW. The objective of CGPP is to enable corporate companies operating in Malaysia to achieve environmental, social and governance commitment.

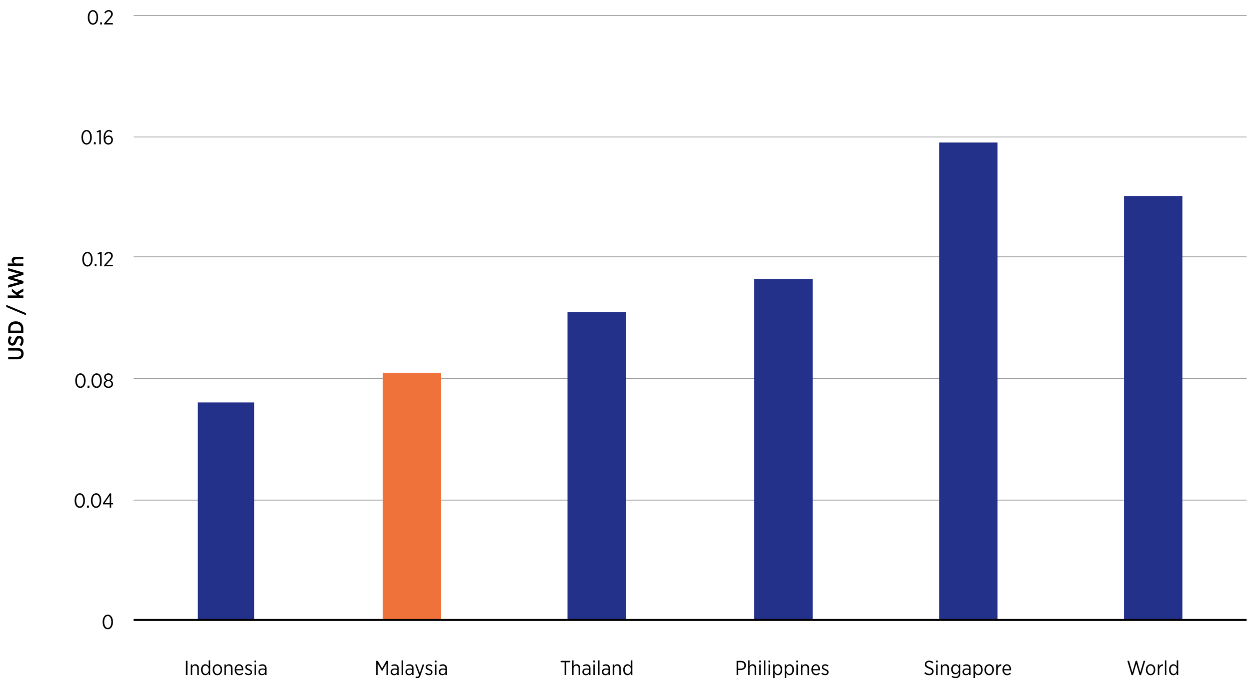
In Malaysia, renewable energy certificates have been offered by TNB through the Green Electricity Tariff since the end of 2022, after the myGreen+ scheme was discontinued (ST, 2021d). Certificates are gaining traction in the country by companies seeking to fulfil their environmental sustainability goals. The mechanism requires subscribers to pay an additional amount for the certificate on top of the regulated tariff. To date, all the available renewable energy generation offered on the scheme (4.5 gigawatt-hours a month) has been subscribed (MGATS, 2022).

## 2.6 ENERGY TARIFFS

Malaysia's electricity tariff is one of the lowest in Southeast Asia, as shown in Figure 18. Electricity is sold to consumers at fixed tariff rates that are approved by the government and regulated by the ST. In general, tariffs are categorised according to the sector (residential, commercial and industrial) and are based on the level of consumption and on the supply voltage level (TNB, 2022b).

***Malaysia's electricity price for the business sector is among the lowest in Southeast Asia.***

**Figure 18** Regional comparison of electricity prices for the business sector



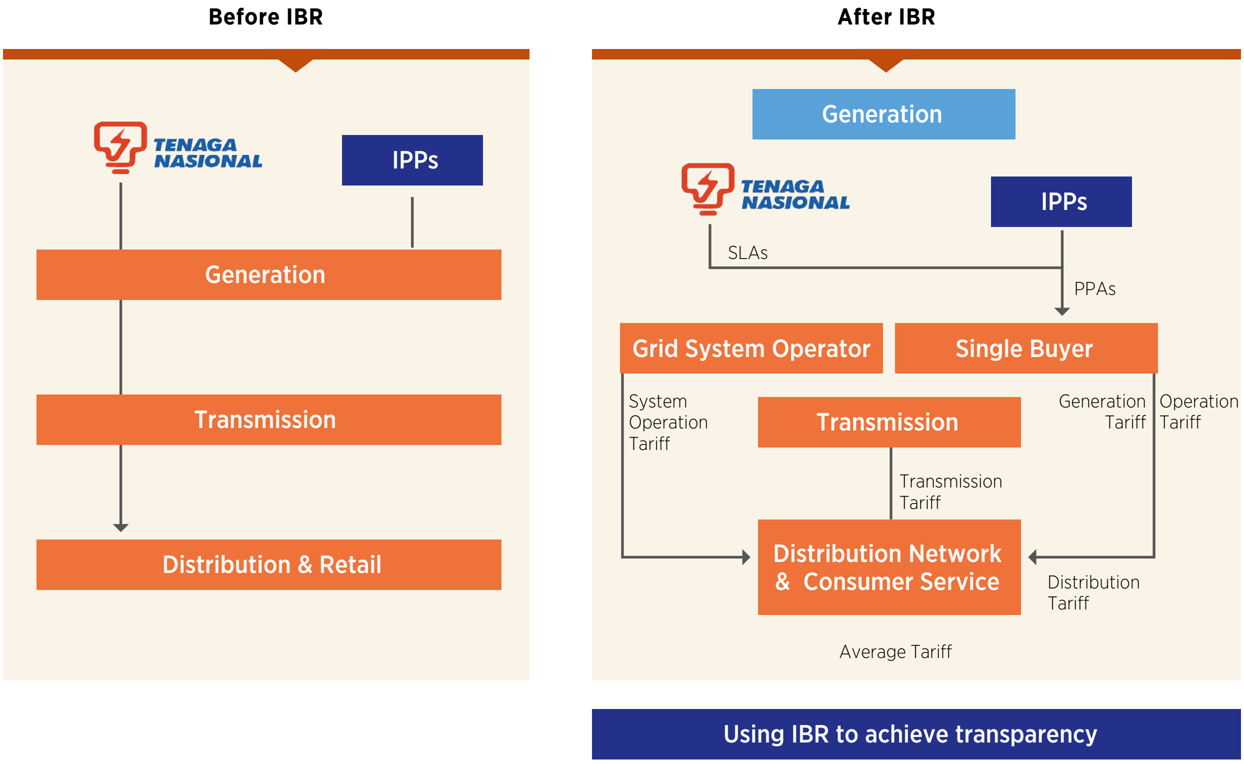

*Source:* Global Petrol Prices, 2022, as of March 2022.

For the residential sector, electricity tariffs are priced according to blocks of 300 kWh, 200 kWh and 100 kWh with increasing prices from USD 0.046 to USD 0.12 per kWh. The commercial and industrial sectors enjoy tariffs between USD 0.07 and USD 0.11 per kWh, with a much lower tariff during off-peak hours (around USD 0.04 per kWh) (TNB, 2022a).

In December 2017, the government introduced the Incentive-Based Regulation (IBR) mechanism to be further implemented in Peninsular Malaysia for Regulatory Period 2 (RP2), in effect from 1 January 2018 to 31 December 2020. The IBR mechanism is a tariff price-setting mechanism for affordable and secure energy supply in a deregulated market. It allows utility companies to earn a reasonable return on power sector investment, through the implementation of an Imbalance Cost Pass-Through (ICPT) mechanism, allowing any increase of costs beyond the base tariff (see Figure 19) to be adjusted as a surcharge or rebate on the consumer's electricity tariff every six months (Energy Watch, 2019).

***The Incentive-Based Regulation (IBR) mechanism allows for affordable and secure energy supply.***

**Figure 19** Overview of tariff structure before and after the Incentive-Based Regulation




In Malaysia, electricity generation costs, including fuel costs, comprise around 70% of the base electricity tariff. Due to the rise in coal and gas prices in 2022, the country's power generation costs are expected to increase four- to five-fold compared to the previous year (TNB, 2022c). This led to additional ICPT surcharges being passed on to commercial and industrial consumers in 2022 (TNB, 2022d).

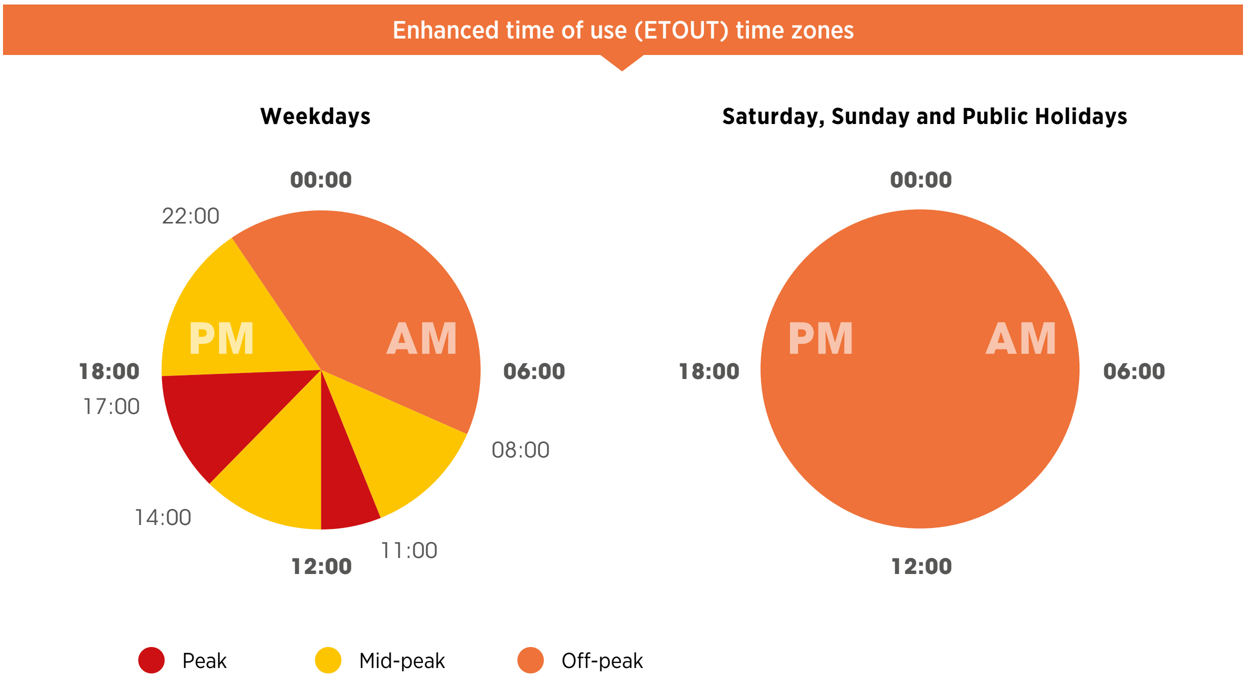
## Enhanced Time of Use (ETOU) scheme

The Enhanced Time of Use (ETOU) tariff scheme was introduced to encourage demand-side management, allowing customers to manage their electric consumption efficiently by using less electricity during peak hours. The ETOU are offered as an option for eligible customers, mainly targeted towards commercial and industrial consumers. (TNB, 2021b).

Under this scheme, there are three time zones for energy charges, with Peak, Mid-Peak and Off-Peak rates. By comparison, the Maximum Demand charge had two time zones, with Peak and Mid-Peak rates. The scheme is also divided as follows: Monday to Friday and Saturday, Sunday and Public Holidays (Enhanced Time of Use, 2021). The peak hours are from 8 a.m. to 10 p.m. according to the TOU tariff. The ETOU tariff has three time zones (Peak, Mid-Peak and Off-Peak) for Monday to Friday, and only one time zone (Off-Peak) applied on Saturday, Sunday and Public Holidays (Figure 20).

***The Enhanced Time of Use scheme allows customers to manage their electric consumption efficiently by using less electricity during peak hours.***

**Figure 20** Enhanced Time of Use time zones



# 3 RENEWABLE ENERGY DEVELOPMENT

## 3.1 DRIVERS OF RENEWABLE ENERGY DEPLOYMENT

Diversifying the resource base to supply increasing energy demand and maintain energy security emerges as a priority area for Malaysia. Over the past decade, the country's total primary energy supply has grown at an average annual rate of 3%, and the energy mix relies predominantly on fossil fuels. While Malaysia has traditionally been a producer and net exporter of fossil fuels, this trade balance could shift towards greater dependence on fossil fuel imports. The country's energy strategy has so far prioritised the use of local fossil fuels to supply the growing energy demand, and coal is currently the largest source of electricity supply. The new net zero plan for the electricity sector puts much greater emphasis on renewable energy for the coming decade, yet the overall energy system still lacks a clear net zero emission transition pathway for the long term.

The energy sector has made crucial advances to enable privatisation of the power sector. Additionally, the role for consumers in the power system will increase as the energy system becomes more distributed, notably through the deployment of rooftop solar PV and as electric vehicles gain more importance, allowing for smart charging and the coupling of end-use sectors with the power system. This is in line with Malaysia's Low Carbon Mobility Blueprint 2021-2030, which targets electric vehicle shares to reach 5% for cars, 15% for motorcycles and 20% for buses by 2030 (KASA, 2021).

A more advanced green recovery plan can accelerate Malaysia's transition to a more renewable energy system to utilise the country's untapped renewable potential and put it on a climate-neutral pathway in the long term, while providing further social and economic benefits. In 2019, Malaysia's labour force participation rate was 68.7% and its unemployment rate was 3.3% (DOSM, 2020b). With regards to the labour market, upskilling and reskilling the local population in high-tech and value-added industries, including in renewable energy is necessary to decrease widening inequality as well contributing to economic value to Malaysia.

While inequality between the more vulnerable "bottom 40" of the population has only widened in the last decade, such household income classifications need to be revised to reflect reality on the ground for a more robust social assistance programme (Jomo and Hawati, 2020). In addition, the high share of young people in the rapidly growing population underscores the importance of identifying new areas of economic activity and employment.

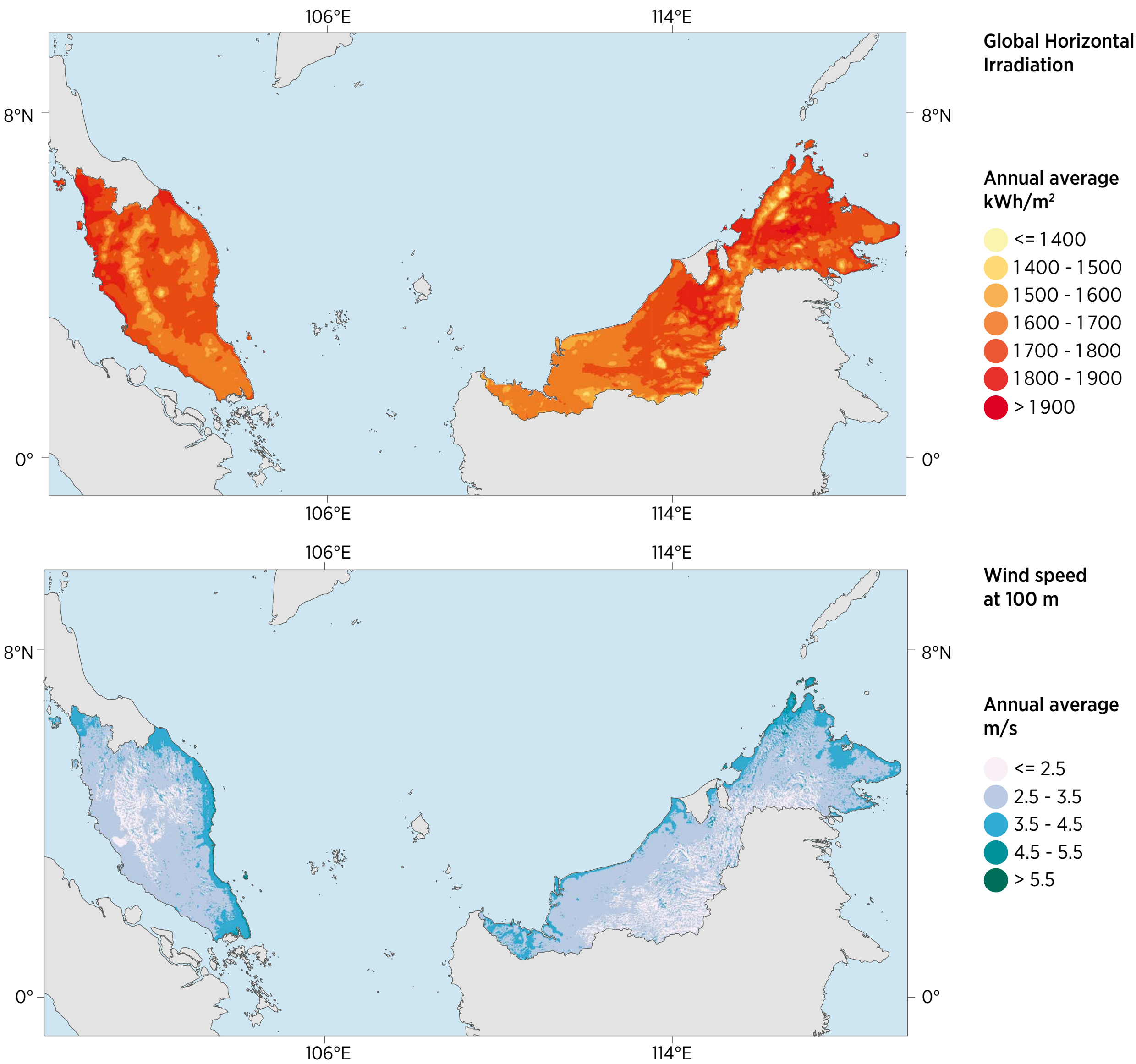
The creation of a local renewable energy sector is therefore of utmost importance. SEDA has estimated that around 54 900 people were working in Malaysia's solar PV sector in 2019, and IRENA calculates a further 100 900 jobs in the agricultural supply chain for biodiesel that year. Altogether, IRENA estimates that Malaysia's renewable energy workforce totalled 187 000 in 2019 (IRENA, 2020). According to these estimates, Malaysia has the second largest workforce in the solar PV sector among ASEAN countries, after Vietnam. It ranks third in jobs in the liquid biofuels sector, following Indonesia and Thailand.

## 3.2 CURRENT STATUS AND POTENTIAL

Malaysia has strong renewable energy potential (Figure 21). Because it is located close to the equator, it has high solar irradiation throughout the year. The highest irradiation is found in Kota Kinabalu, at 1 900 kWh per square metre ($m^2$), followed by Bayan Lepas (1 809 kWh/$m^2$/year) and Georgetown (1 785 kWh/$m^2$/year) (Abdullah *et al.*, 2019). Annual average wind speeds are relatively low, but the Indian Ocean and the South China Sea provide good wind streams. The monthly mean wind speed is between 1.5 and 4.5 metres per second (m/s), although higher-altitude areas can achieve speeds between 9 and 11 m/s. In Peninsular Malaysia, Mersing, Johor and Kuala Terengganu are suitable areas for wind power. In East Malaysia, Kudat and Sabah are the highest wind potential areas. Generally, the southern part of Peninsular Malaysia has more wind potential (Ibrahim *et al.*, 2015; Islam, 2011). Malaysia also has high rainfalls and is rich in hydropower potential, particularly for small hydropower plants with capacities below 30 MW.

***Malaysia possesses considerable solar and wind energy resources.***

**Figure 21** Malaysia's renewable energy resource potential

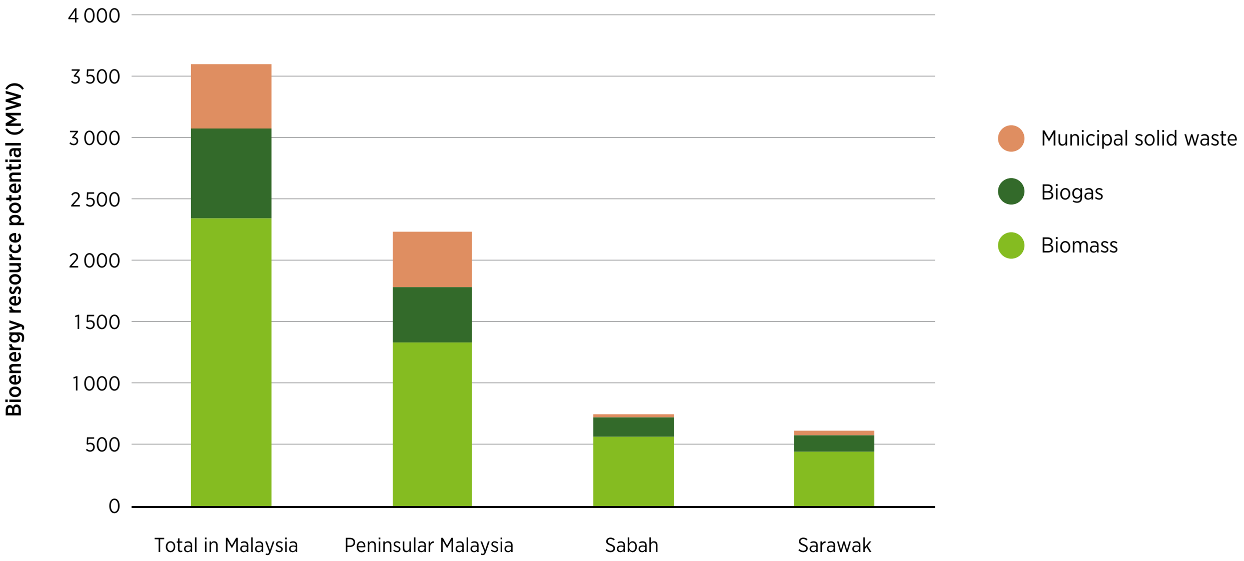



*Disclaimer:* This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers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

As one of the largest biofuel suppliers globally, Malaysia has large areas of oil palm plantations, covering a total of 5.9 million hectares in 2021 (Ahmad Parveez *et al.*, 2022).Over the past six decades, the oil palm plantation area has expanded more than a hundred times. Mills span the entire territory, including 76 large-scale mills that can process 250 000 tonnes of fresh fruit bunches annually. Biomass plays an important role in Malaysia's energy mix but has not achieved its full potential due mainly to the uncertainty of biomass feedstock supply and other technical, financial and policy barriers (Salleh *et al.*, 2020). Biogas could offer large potential, coming mainly from municipal solid waste, food waste, cattle manure, sewage and palm oil mill effluent (POME). With approximately potential of 2.3 GW, biomass constitutes the largest resources in Malaysia. Peninsular Malaysia accounts for 1.3 GW, Sabah with 561 MW and Sarawak with 448 MW. Biogas and municipal solid waste also have promising potential, with total of 736 MW and 516 MW respectively (See Figure 22).

***Malaysia has a diverse mix of bioenergy potential.***

**Figure 22** Overview of bioenergy resources availability in Malaysia




*Source:* (SEDA, 2021a)

## 3.3 ECONOMICS OF RENEWABLE ENERGY

According to the IRENA cost database, Malaysia is among the countries with good solar irradiation, and since 2013 it has benefited from increasingly competitive total installed costs for residential solar PV systems. As a low-cost market, the levelised cost of electricity for solar PV in Malaysia fell more than 50% between 2013 and 2019, from USD 0.187 per kWh to USD 0.089 per kWh. Data for commercial rooftop solar PV systems shows a comparable decline from USD 0.175 to USD 0.078 per kWh. This trend is in line with reductions in the capital costs of solar PV systems, which are now below USD 900 per kW in the commercial sector and just above USD 1 000 per kW in the residential sector (IRENA, 2021b).

A study from 2019 prepared by the ASEAN Center for Energy (ACE) provides several data points to the levelised cost of electricity generation in Malaysia from renewable energy sources. According to the study that covers the TNB area in Malaysia, biomass-fired power plants with capacity factors of around 86% had generation costs slightly above the TNB average at USD 0.11 per kWh. Solar PV plants with capacity factors above 10% are estimated to have levelised cost of electricity ranging from as low as USD 0.10/kWh to as high as USD 0.28/kWh. In the same study, a limited number of data points for Malaysia reveals generation costs of around USD 2.5/kWh for hydropower with capacity factors ranging from 70% to 80%. The low end of the solar PV range is comparable with the household electricity tariffs in Malaysia at USD 9.3/kWh. Capital costs of hydropower plants range from USD 1,350 to USD 3,000 per kW. According to the same study the operation and maintenance costs of hydropower plants are on average 2% of the total capital costs whereas the solar PV plants' costs of operation and maintenance are on average 1.5% of the total capital costs. The capital costs of biomass plants are on average USD 2 200/kW with operation and maintenance costs averaging above 5% of the total capital costs. The fuel costs of biomass plants are between million USD 6.4 and USD 17.8 per tonne (ACE, 2019).

## 3.4 GRID INTEGRATION OF RENEWABLES

Given Malaysia's large renewable energy resource availability, there is a realistic potential for the renewable share in the total generation capacity to go beyond what is already planned. This will be important in light of the country's dispersed population centres and economic activity. Additional measures to ensure system flexibility may be required. There is limited country-wide analysis investigating the extent to which the transmission grid can accommodate renewable energy resources. A study undertaken in 2018 for Peninsular Malaysia shows that by 2025, solar energy penetration of up to 27% (as a share of peak demand) is technically possible in the system with no significant technical impacts to the system operation albeit comes with cost increase, and up to 38% penetration can be accommodated with some frequency stability concerns that possible to mitigate with more costly dispatch (DNV, 2018).

TNB already aims for a more flexible and enhanced grid for Peninsular Malaysia that should allow for the grid integration of renewables and enable the charging of electric vehicles. Grid modernisation with smart meters and a system to optimise voltage flows will be essential to support a smarter, more efficient and more resilient grid, such as the one being planned in Sarawak (Sarawak Energy, 2020). The approved share of the capital investments between 2018 and 2021 that dealt with energy transition was equivalent to 12.3%. In the proposed investment plan to 2024, this share was higher at 19.3%. Sarawak is embarking on the implementation of 50 MW floating solar project at Batang Ai reservoir. The farm will be the first floating solar project under Independence Power Producer (IPP) in Sarawak.

The Energy Commission's Report on Peninsular Malaysia Generation Development Plan 2019 (2020-2030) provides an overview of the transmission grid planning in Peninsular Malaysia. Between 2015 and 2019, demand grew at an annual rate of 2.5%, rising from 16 822 MW to 18 566 MW (ST, 2020c). For the 2020-2030 period, demand growth is projected at 1.8% annually. As demand is expected to be supplied increasingly from renewable power, net demand (the demand that is left over after that supplied by wind and solar power) is projected to grow 0.7% annually, which is a crucial indicator for transmission grid planning.

According to the planning document, to achieve the target of 20% renewables in the energy mix by 2025, 3 758 MW of new renewable energy capacity needs to be developed in Peninsular Malaysia starting by 2020. Of this total 2 172 MW is solar PV and 1 586 MW is other renewables. The 20% renewable capacity target would maintain system stability with solar penetration limited to 24% of the peak demand. Post-2025, the renewable capacity mix is planned to be maintained at 20%. Here, the projected capacity mix for Peninsular Malaysia increases from 9% to 23%, while the share of thermal (gas and coal) generating capacity decreases from 82% to 70%. To meet the demand growth and the additional supply capacity, the projected annual system cost for the Generation Development Plan (2020-2030) ranges from USD 8.4 billion (MYR 35.2 billion) in 2020 to USD 10.8 billion (MYR 45.4 billion) in 2030 (ST, 2020c).

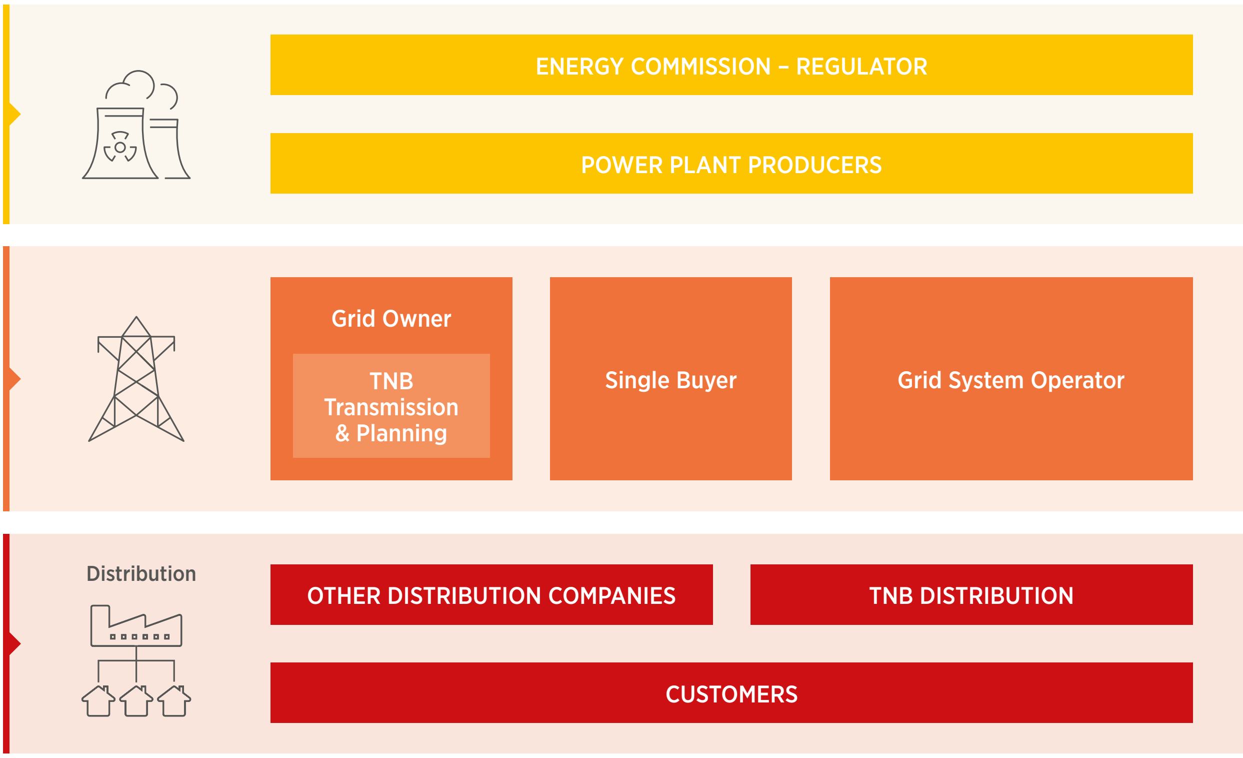
In the newly released Peninsular Malaysia generation development plan to 2039, the penetration limit for grid-connected solar PV is set at 24% of the estimated peak demand by 2025. The penetration limit is derived from the common convention for solar threshold computation, which calculates the total grid-connected solar capacity (at both the distribution and transmission networks) relative to the annual forecasted peak demand.

To support this strategic intent, the grid infrastructure would be further strengthened and enhanced with much-needed technical enablers such as energy storage systems. Solar penetration is expected to reach 30% of the projected peak demand in 2035. To address system stability concerns due to the influx of renewable energy, five units of a battery energy storage system with a capacity of 100 MW were planned for installation annually into the system from 2030 to 2034 (ST, 2021b).

The Grid Code and Distribution Code were launched and published by the ST in December 2010. These codes are regulatory instruments for co-ordinating the various electricity supply activities of the electricity supplier, grid operators, distributors and consumers (TNB, 2022e). The Grid Code is a set of technical regulations used by utility companies such as TNB and the IPPs, and it serves as the main guideline for reliable electricity supply operations (Figure 23). The Distribution Code is a set of technical regulations established to ensure systematic distribution operations. The codes set the regulations and technical requirements for all parties involved in planning, managing and maintaining the grid and distribution systems.

***The Grid Code and Distribution Code are regulatory instruments for co-ordinating the various electricity supply activities of the electricity supplier, grid operators, distributors and consumers.***

**Figure 23** Peninsular Malaysia electricity industry structure by functions as used in the Grid Code




*Source:* TNB, 2022e.

## 3.5 INVESTMENT AND FINANCING

A number of fiscal incentives are in place for renewable energy project developers. In addition to the feed-in tariff, the Large Scale Solar mechanism, and net metering, the other three key financial enablers are the Green Investment Tax Allowance (GITA), the Green Income Tax Exemption (GITE) and the Green Technology Financing Schemes (GTFS).

The GTFS were initiated in 2010. In a first step, USD 0.8 billion (MYR 3.6 billion) in green financing was approved. A performance assessment of the GTFS between 2010 and 2017 found that, in total, 28 financial institutions provided support to 319 projects during this period, with more than 90% of the beneficiaries being small and medium enterprises. This resulted in USD 1.6 billion (MYR 7.05 billion) in green investments, including in renewable energy projects that generate a combined 532.9 megawatt-hours (MWh) of electricity annually. Of the total finance, 53% came from conventional financing and 47% from Islamic financing.

In March 2019, the Ministry of Finance approved an upgraded scheme, GTFS 2.0, for companies that are majority Malaysian-owned, allocating USD 0.47 billion (MYR 2 billion) for the period between January 2019 and the end of 2020 (Koo Boo Hin and Chiah, 2022). This step offered a 2% annual interest subsidy for the first seven years, with the government providing a 60% capital guarantee on the financing.

The GTFS 2.0 performance assessment showed that by the end of 2019, a total of 35 projects had been certified at a combined cost of USD 0.37 billion (MYR 1.6 billion), with 25 of the projects receiving bank loan approvals totalling USD 0.2 billion (MYR 0.9 billion). Around half of the projects are solar (mainly utility scale). The impact is expected to reach USD 0.3 billion (MYR 1.33 billion) in green investments (APEC, 2020).

In addition to the Green Investment Tax Allowance (GITA) and the Green Income Tax Exemption (GITE), further tax incentives have provided support for green financing (APEC, 2020). These include a tax deduction until the assessment year 2020 on issuance costs of socially responsible investing (SRI) sukuk either approved or authorised or lodged with the Securities Commission; the USD 1.43 million (MYR 6 million) Green SRI Sukuk Grant Scheme to defray independent expert review costs incurred by issuers; and a tax exemption for recipients under the Green SRI Sukuk Grant Scheme for the assessment years 2018 to 2020.

According to International Energy Agency analysis, investment risks are low with regard to the financial health of the system, financing and capital costs, and integrated approaches; however, there are potential risks concerning the bankability of projects. According to the Energy Commission, to reach a 50% renewable share in electricity generation, Malaysia would require a total investment of around USD 6-11 billion. Solar PV would play a crucial role in this. Although debt capital market instruments are available to large renewable energy developers through debt, equity or mezzanine financing, additional personal and business loans may be required to help companies and consumers manage the cost of installing solar panels in offices and homes (Ng, 2020). Malaysia's financial markets comprise nearly 90% bank loans, followed by around 7% bonds and 3% equity (Peimani, 2018).

Islamic finance is considered one of the new options for solar financing outside of the conventional loans, bonds and equity schemes. One popular finance technique is "green sukuk", a Shariah-compliant green bond mechanism that recently was used to finance five renewable energy projects in Malaysia. In July 2017, Tadau Energy Sdn Bhd issued the first green sukuk in the world, raising USD 59 million (MYR 250 million) to finance a 50 MW solar PV plant in Sabah. Following this demonstration, a larger-scale project (MYR 1 billion) was issued (World Bank, 2018). In January 2018, Sinar Kamiri Sdn Bhd, an indirect subsidiary of Mudajaya Group Berhad, issued a green sukuk of USD 60 million (MYR 245 million) to finance the construction/development of a 49 MW solar PV plant in Sungai Siput, Perak (DME and ISRA, 2019). In April 2018, UiTM Solar Power Sdn Bhd, an indirect subsidiary of Universiti Teknologi Mara, issued a green sukuk of USD 60 million (MYR 240 million) to finance the development and operation of the 50 MW utility-scale solar PV plant in Gambang, Pahang. It was the first institute of higher learning in the world to issue a Green SRI Sukuk (DME and ISRA, 2019).

The Malaysian Government Credit Guarantee Corporation provides financing for the preparation/early-stage, financing and implementation stages of projects. Bank Pembangunan Malaysia Berhad High Technology Fund provides financing for the preparation/early-stage and financing stages of projects.

# 4 ENERGY TRANSITION OUTLOOK

## 4.1 METHODOLOGY AND KEY ASSUMPTIONS

The *World Energy Transitions Outlook*, released by IRENA in 2021, shows that a drastic reduction in greenhouse gas emissions is needed in order to meet the Paris Agreement goal of keeping the rise in global temperature well below 2 degrees Celsius (°C). Key to this emission reduction over the coming decades will be increased investments in the energy transition, including greater deployment of renewable energy and changes in the energy infrastructure.

IRENA's renewable energy roadmaps programme, REmap, provides strategies for 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, socio-economic status, as well as institutional and regulatory endowments – while at the same time contributing to the global emission reduction objective and leveraging opportunities to meet regional energy and investment goals. For ASEAN, REmap identified a pathway for the region to achieve its renewable energy target of 23% in the energy mix by 2025.

REmap takes a bottom-up approach. The analysis uses an internally developed REmap tool that incorporates detailed energy demand and supply data by sector, a substitution analysis on 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 in-country energy experts through a series of multi-stakeholder consultative workshops and expert meetings.  For the REmap analytical study conducted for Malaysia, a wide range of stakeholders were consulted with coordination from the energy ministry (then known as KETSA, now NRECC) throughout 2020 to 2022. These included the energy regulator (Energy Commission), state utilities (Tenaga Nasional Berhad, Sarawak Energy Berhad, and Sabah Electricity Sdn Bhd), the Ministry of Transport (MOT), and other stakeholders (Single Buyer, Grid System Operator, and Malaysian Green Technology And Climate Change Corporation)

A detailed engagement process for the development of this report is elaborated in Chapter 1.

### Methodology

The IRENA REmap-FlexTool approach for the design and elaboration of the *Malaysia Energy Transition Outlook* aimed to create technical pathways focusing on multiple scenarios. A bottom-up analysis was carried out for details on the energy demand by end-use sector, which included a substitution analysis on technology options for renewables and an assessment of associated costs, investments and benefits in close collaboration with country energy experts through a series of multi-stakeholder consultative workshops and expert meetings. The power sector was modelled using PLEXOS for capacity expansion, and a flexibility assessment was performed using IRENA's FlexTool product.

The description of each REmap scenario is described in Figure 24.

***This report looks at various scenarios for possible future energy pathways in Malaysia.***

**Figure 24** Description of REmap scenarios

**Base Energy Scenario (BES)**

The BES for the power sector assessment reflects a more static view on capacity expansion, maintaining a historical trend into the long term. It assumes that current or planned polices are not adhered to or rolled back. This scenario is similar to a "business-as-usual" scenario. BES in the demand sector reflects the existing projection developed based on the Second Biennial Update Report (BAU).

**Planned Energy Scenario (PES)**

The PES reflects current plans and other expected objectives or policies that were approved as of the time of conducting the analysis. The PES is the primary Reference Case for this study, and it is off this scenario that the energy transition scenarios are developed.

**Transforming Energy Scenario (TES)**

The TES describes an energy pathway based largely on currently available and competitive low and zero carbon technologies. It is characterised largely by renewable energy expansion and energy efficiency.

**1.5°C Scenario (1.5-S)**

The 1.5-S is a more ambitious energy pathway, and outlines options to further reduce $CO_2$ emissions in the energy system in challenging sectors. It is informed by the WETO scenario aiming to reach net zero emissions globally by 2050. For the power sector two cases were analysed: one with 90% renewable electricity generation (RE90) and one with 100% renewable electricity generation (RE100).

- How will the country's energy system evolve based on current and planned polices?
- What are possible energy transition strategies?
- Which benchmarks should be followed for an accelerated transition?
- Which sector is the most relevant to prioritise?
- What is the role of regional energy integration?
- What is the role of various renewable energy carriers?
- What are the investment needs and costs for the transition?

The energy assessment was then complemented with an analysis of the costs, investment and benefits (avoided negative externalities) of the various scenarios. The analysis provides an estimate of the overall costs involved in implementing each of the scenarios. This includes investment in equipment and new installations, fuel costs, operation and maintenance costs, and externalities. It allows for a first assessment of the total costs and benefits necessary to achieve investments in the energy transition and decarbonisation scenarios for the region.

### **Box 4** REmap Toolkit

The REmap Toolkit is a software application that enables 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 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 nor multi-criteria methods.

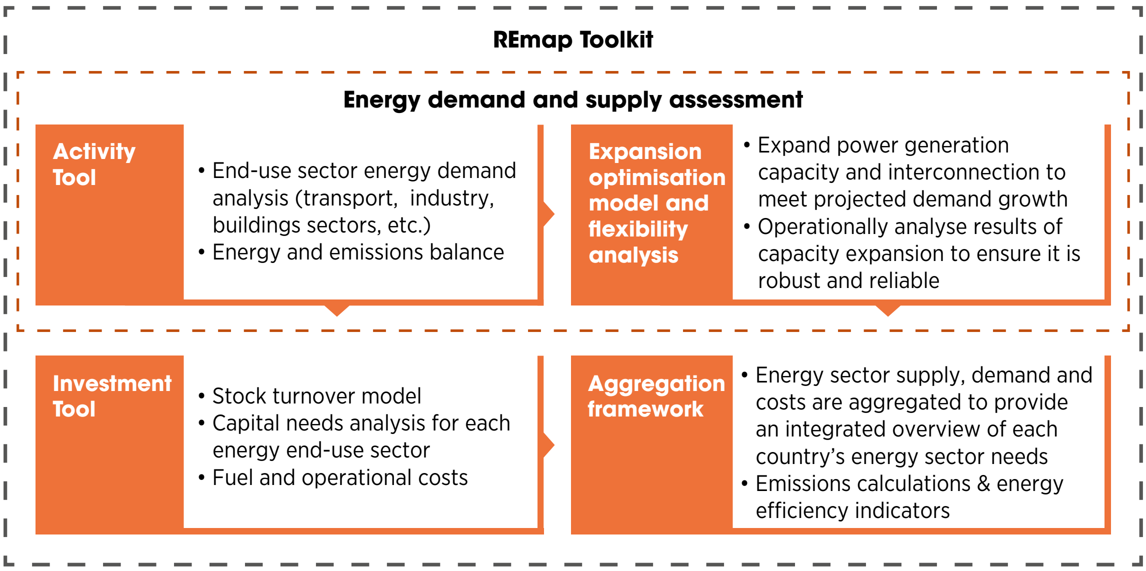
## Box 4 REmap Toolkit (continued)

The IRENA FlexTool, developed with VTT Technical Research Centre of Finland Ltd, performs power system flexibility assessments based on national capacity investment plans and forecasts. The tool 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 and hydrogen production through electrolysis.

Figure 25 shows the interaction of different tools to perform energy analysis of the end-use and power sectors, as well as estimations of investments and $CO_2$ emissions for the study.

***The analysis uses a number of toolkits to develop the scenarios.***

**Figure 25** REmap tools for analysis of the end-use and power sectors




## References

Energy statistics were obtained from the Energy Commission of Malaysia (ST), with the 2018 national energy balance used as the primary reference and base year.

Further breakdowns of energy consumption by sector (transport, industry and buildings) into sub-sectors and end uses were obtained from other studies and datasets. For buildings, Household Expenditure Surveys from the Department of Statistics Malaysia were used together with statistics for the commercial sector from the National Property Information Centre (NAPIC). Transport data, especially vehicle stock, sales and activity-level data, were gathered from the Ministry of Transport, Jabatan Pengangkutan Jalan (JPJ) and from the Malaysian Institute of Road Safety Research (MIROS). The Low Carbon Mobility Blueprint 2021-2030 was referenced for national plans in the transport sector. Industrial energy data were obtained mainly from surveys conducted by the Energy Commission as well as from company and industry reports in the petrochemical, manufacturing, iron and steel, and cement sectors to estimate growth projections and production outputs. Finally, an earlier study on Demand Side Management undertaken by UNDP Malaysia and Economic Planning Unit (EPU) in 2017 was also consulted.

For the power sector, historical data and data on future planning and projections were obtained from KeTSA, the Energy Commission, and SEDA, with close consultation and discussion calls with the state utilities (TNB, SEB, SESB) in 2021 and 2022. National plans such as the Report on Peninsular Malaysia Generation Development Plans (2021-2039) and the Malaysia Renewable Energy Roadmap were also consulted.

For climate targets, Malaysia's submitted and revised National Determined Contribution document in 2021 was used as the primary reference, with actual and projected emissions data supplemented by the Second Biennial Update Report submission (in 2018) to the UNFCCC. While carbon neutrality targets were announced in late 2021, as of the time of this writing emission projection pathways covering the whole energy sector were not available. In late 2022, it was announced that a new agency, the National Energy Council, will be established to steer agendas and strategies set under the National Energy Policy (2022-2040), including a mandate to enhance nationwide emissions reporting. In addition to this, Malaysia is currently also preparing its own Long-term Low Emissions and Development Strategies (LT-LEDS), as referenced in the aforementioned document (EPU, 2022).

## Key assumptions

The population of Malaysia is expected to grow from around 32 million people in 2018 to around 40.7 million people by 2050. While the population growth rate has been higher in the past (1.4% on average during 2010-2020), a slower growth rate is expected in the next three decades (0.8%) due to a decrease in net migration and a slowing birth rate in the country (DOSM, 2016; United Nations, 2020).

The GDP of Malaysia grew at a modest average rate of 4.5% annually between 2010 and 2018, reaching USD 349 billion (in constant 2015 dollars) in 2018. The GDP dropped 5.6% in 2020, during the first year of the COVID-19 pandemic, but then quickly rebounded to 3.1% growth in 2021 (BNM, 2022b). Future growth is expected to occur mainly in the manufacturing sector, with total GDP increasing 3.1% annually on average to reach USD 934 billion by 2050.

For more information on the composition and status of the current energy system, see section 2.

**Table 3** Population and GDP growth assumptions

| | 2018 | 2030 | 2050 |
|---|---|---|---|
| **Population** (million) | 32.4 | 36.1 | 40.7 |
| **GDP** (million USD, 2015 constant) | 348 948 | 506 138 | 934 665 |
| **GDP per capita** (USD/capita) | 10 753 | 14 004 | 22 975 |

## 4.2 ENERGY TRANSITION IN MALAYSIA

### Summary of findings

**KEY MESSAGES**

**Malaysia's final energy consumption will double by 2050** in the Planned Energy Scenario (PES), where energy demand is expected to increase 2.0% annually on average.

**In the two energy transition scenarios – characterised by increased energy efficiency, fuel switching to renewables and electrification of transport** – average annual growth in energy demand will be slower, at 1.5% in the Transforming Energy Scenario (TES) and 1.2% in the 1.5°C Scenario (1.5-S).

**Solar PV will play a key role in the energy transition**, with its total capacity reaching 83 GW in the TES and 153 GW in the 1.5-S by 2050; renewable energy will contribute 89% or more of total electricity generation, up from 16% today.

**Renewable direct-use is also important**, with 20% of final energy consumption coming from these sources by 2050. The production of clean hydrogen and its derivative fuels must ramp up from negligible levels in 2020 to at least 1.5 million tonnes by 2050.

**In the PES, $CO_2$ emissions from the energy sector are expected to increase to 268 million tonnes by 2030**, owing to a substantial increase in energy needs for power generation. The 1.5-S energy scenario will lead to a 60% reduction in emissions in 2050 compared to the PES. Additional efforts in $CO_2$ removal will be needed to close the gap for Malaysia to reach its carbon neutrality target by 2050.

Malaysia is expected to see sustained growth in its energy demand over the coming decades, as it continues to be one of the largest economies in Southeast Asia. The total primary energy supply increases more than three-fold over the period to 2050. The large differences seen among the scenarios are elaborated on later in this chapter.

***Renewable energy, with solar PV as the key technology, leads Malaysia's energy transition regardless of the scenario.***

**Table 4** Summary table for Malaysia

| | | 2018 | 2030 | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | PES | TES | 1.5-S | PES | TES | 1.5-S RE90 | 1.5-S RE100 |
| SUPPLY | **Total primary energy supply** (EJ) | 4.1 | 5.0 | 4.8 | 4.7 | 6.7 | 5.5 | 5.3 | |
| SUPPLY | **Renewables share** (%) | 3% | 7% | 8% | 11% | 14% | 26% | 40% | |
| POWER | **Renewables installed capacity** (%) | 22% | 42% | 41% | 50% | 67% | 81% | 91% | 100% |
| POWER | **Renewables installed generation** (%) | 16% | 24% | 27% | 33% | 54% | 96% | 89% | 100% |
| POWER | **Total installed solar PV capacity** (GW) | 0.4 | 8.6 | 10.6 | 17.1 | 58.9 | 83.5 | 103.2 | 153.1 |
| DEMAND | **Total final energy consumption** (EJ) | 2.1 | 2.8 | 2.7 | 2.5 | 3.9 | 3.4 | 3.1 | |
| DEMAND | **Renewables share** (%), fuels | 0.9% | 4.5% | 5.6% | 6.0% | 4.6% | 10.7% | 19.2% | |
| DEMAND | **Renewables share** (%), fuels and electricity | 5% | 10.7% | 13.0% | 15.2% | 19.4% | 43.0% | 59.6% | |
| DEMAND | **Electricity consumption share** (%) | 26% | 26% | 27% | 28% | 27% | 34% | 40% | |
| INDICATORS | **Total primary energy supply per capita** (GJ/capita) | 127 | 138 | 133 | 130 | 164 | 134 | 130 | |
| INDICATORS | **Total final energy consumption per capita** (GJ/capita) | 65 | 77 | 74 | 70 | 97 | 84 | 75 | |
| INDICATORS | **Energy intensity** (MJ/USD) | 11.8 | 9.9 | 9.5 | 9.3 | 7.1 | 5.8 | 5.7 | |
| INDICATORS | **Electricity consumption per capita** (kWh/capita) | 4 722 | 5 576 | 5 570 | 5 580 | 7 525 | 8 001 | 8 562 | |
| EMISSIONS | **$MtCO_2$, energy-related** | 220 | 268 | 238 | 237 | 280 | 162 | 120 | |

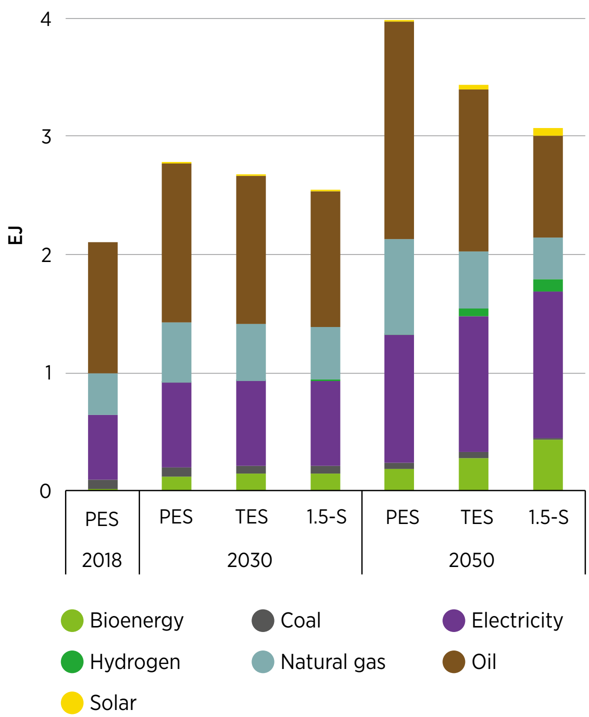
### Total final energy consumption

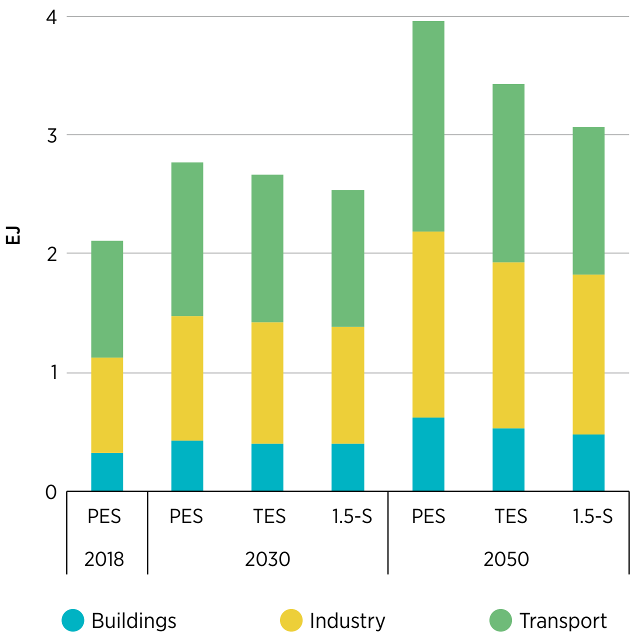
In the PES, Malaysia's total final energy consumption is expected to increase 2.0% annually on average, from 2.1 EJ in 2018 to 4.0 EJ by 2050. Consumption of electricity is expected to increase 2.3% annually on average by 2030, from 152 TWh in 2018 to 200 TWh, after which it will increase 2.1% annually to reach 300 TWh by 2050. However, fossil fuels will still comprise 68% of total final energy consumption, or 77% of total final consumption, by 2050 in the PES, where they will remain crucial for the transport and industry sectors, including for non-energy uses. Sectoral summaries are elaborated in the following sections.

In the 1.5-S – with renewables, aggressive energy efficiency measures and electrification across all sectors – the final energy consumption will grow at an annual average rate of 1.2% to reach 3.1 EJ, with a total reduction of 23% compared to the PES. A larger trend of electrification (29% share) is also present, as well as a higher biomass share (20%) used in the industry and transport sectors, in the form of biofuels. Hydrogen will also begin to play a nominal role in Malaysia, where it will comprise up to 5% (4.3 EJ) of the total final energy consumption by 2050 in the 1.5-S.

***Malaysia's total final energy consumption nearly doubles by 2050 in the PES, dominated by fossil fuels, whereas a transition in the 1.5-S reduces that demand by 23%.***

**Figure 26** Malaysia's total final energy consumption by source and sector, all scenarios, 2018, 2030 and 2050



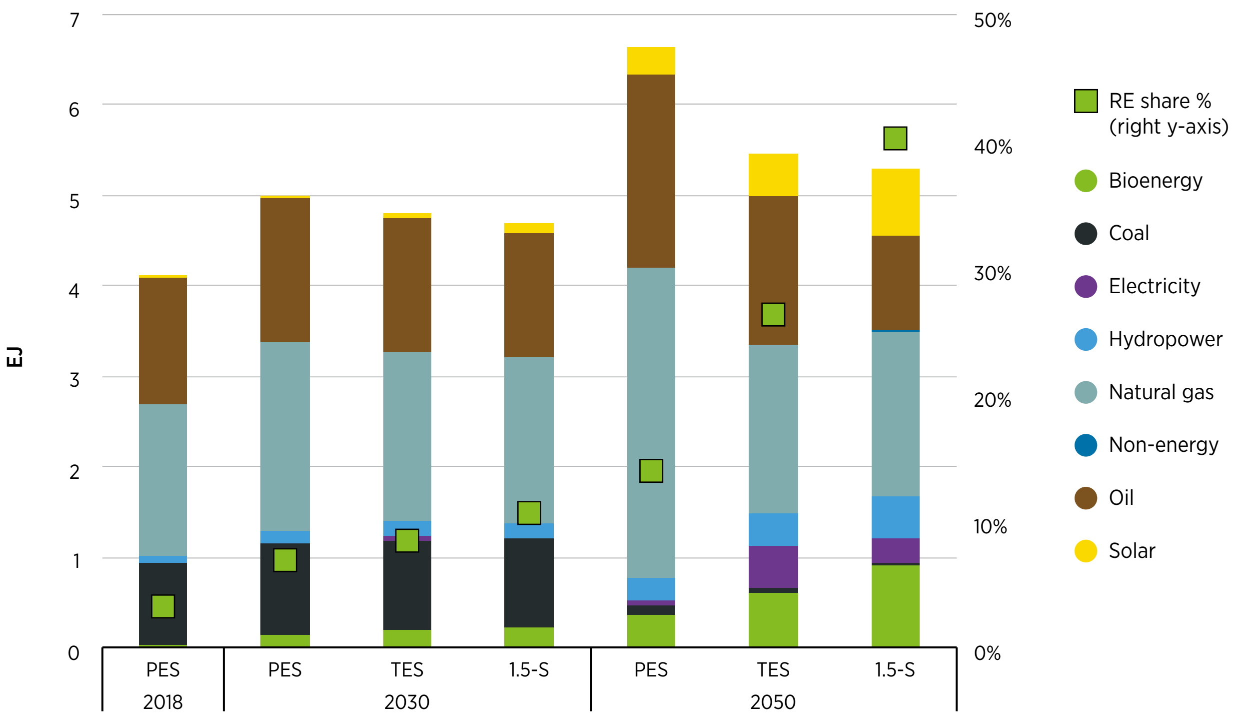

### Total primary energy supply

As of 2018, Malaysia's primary energy supply was around 4.1 EJ, with the share of renewables at only 3%. If all of the measures and actions are undertaken for the two energy transition scenarios, the share of renewables can reach up to 26% in the TES and 40% in the 1.5-S by 2050. This represents a savings in energy use of between 18% and 21% compared to the PES in 2050.

The savings are due primarily to reduced use of fossil fuels (mainly oil products) in the transport sector, to be replaced by electric vehicles, as well as the substitution of coal and natural gas power plants with a significant influx of renewable energy technologies in the power sector (mainly solar PV, hydropower and carbon capture and storage (CCS), where power generation scenarios for 90% renewables (RE90) and 100% renewables (RE100) are modelled). A summary of the power capacity, generation and flexibility analysis is presented in section 4.3.

***The share of renewables in the primary energy supply grows from 3% in 2018 to 14% in the PES and 40% in the 1.5-S by 2050.***

**Figure 27** Malaysia's total primary energy supply by source, all scenarios, 2018, 2030 and 2050




*Note:* RE = renewable energy.

### Energy-related emissions

IRENA's analysis covers only energy sector emissions, using emission factors for energy combustion from the Intergovernmental Panel on Climate Change (IPCC). Based on this analysis, energy sector emissions in 2018 are calculated to be 220 million tonnes of $CO_2$.[4] The power sector accounted for the highest share of emissions, at 47%, followed by the transport sector at 33%.

In the PES, emissions are expected to rise to 280 million tonnes of $CO_2$ by 2050. While there will be reductions from the power sector as renewable electricity generation increases (particularly from solar PV), emissions from the transport and industry sectors will continue to rise.

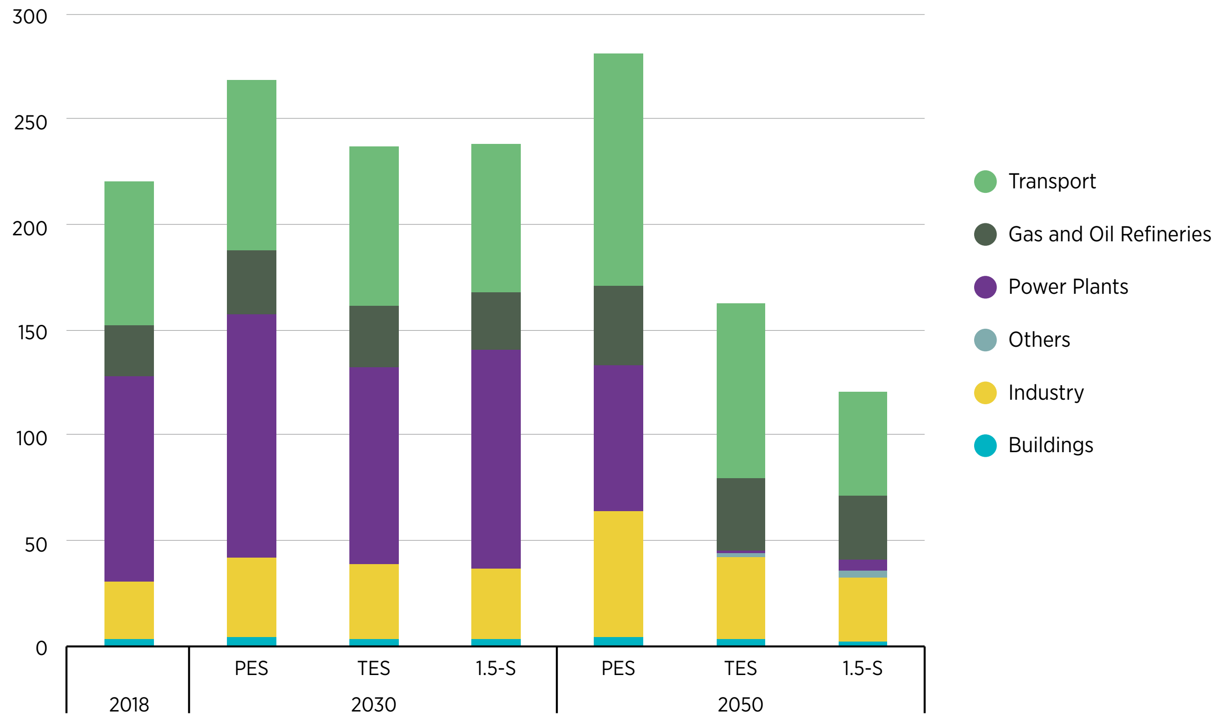
*4 IRENA's methodology for calculating energy sector-related emissions includes emissions from the power and energy transformation sectors and all end-use sectors, excluding non-energy. It is based on fuel input and combustion data obtained from national energy balances (historical) and IRENA analysis for the different scenarios, where emission factors from the IPCC are used. These might differ slightly from Malaysia's national accounting reported to UNFCCC through the Biennial Update Reports (BURs).*

If the established energy targets in the 1.5-S are met and the investment and end-use technology costs are undertaken, a gain in emission reduction can be expected after 2030. Emissions in 2050 can be reduced by 30% in the TES and 58% in the 1.5-S, compared to the PES. The largest emission reductions will be in the power sector, a trend seen almost immediately after 2030 due to increased use of carbon capture technology, solar PV and battery storage to curb the use of fossil fuel power plants.

Although the transport and industry sectors would contribute the bulk of the remaining emissions in the 1.5-S in 2050, emission reductions can also be achieved in the transport sector due to the massive push towards electric vehicles and modal shift. The remaining emissions that come from the remaining internal combustion engine vehicles, mainly large trucks, and the use of fossil fuels in the industrial sector for energy-intensive processes.

***Malaysia's energy sector-related $CO_2$ emissions are expected to rise to 280 Mt$Co_2$ by 2050. IRENA's 1.5-S will see Malaysia's emission reducing by around 60%.***

**Figure 28** Energy-related emissions by sector, all scenarios, 2018, 2030 and 2050




## **Box 5** Benchmarking IRENA analysis with net zero pledges and commitments until 2050

Malaysia's greenhouse gas emissions were last reported in 2020, calculated for the year 2016. After accounting for offsets from land use, land-use change and forestry (LULUCF), the country's net greenhouse gas emissions totalled 76 million tonnes of $CO_2$. Energy-related emissions totalled around 251 million tonnes of $CO_2$-equivalent in 2016, with the power sector representing 39% of these emissions (GoM, 2020b).

At the 26th Conference of the Parties to the UNFCCC (COP 26) in 2021, Malaysia pledged to achieve carbon neutrality by 2050. As of the time of this writing, no official long-term energy planning policy document or pathways had yet been released; however, the development of a Long-Term Low Emission Development Strategy (LT-LEDS) is under way (Yun, 2022).

## Box 5 Benchmarking IRENA analysis with net zero pledges and commitments until 2050 (continued)

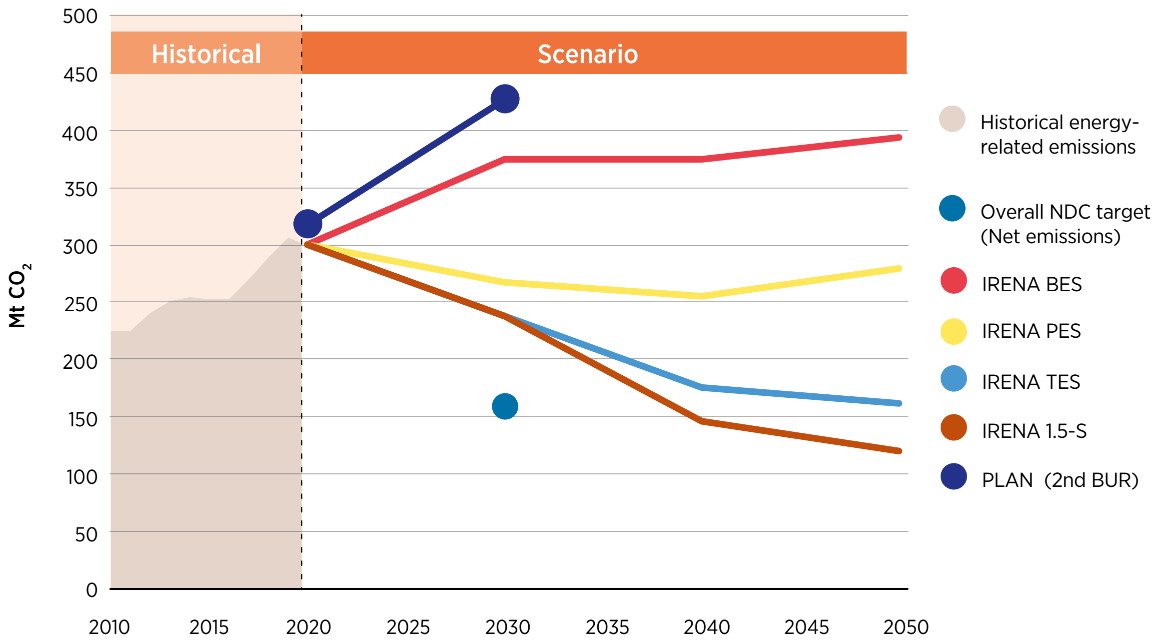
Malaysia's Nationally Determined Contribution towards reducing emissions under the Paris Agreement sets an unconditional target for a 45% reduction in the country's greenhouse gas emission intensity (tonnes of $CO_2$ emissions per unit of GDP) by 2030 (compared to the 2005 level) (GoM, 2020a). However, it does not elaborate specific and quantifiable energy sector emission targets.

The National Energy Policy 2022-2040, published in September 2022, outlines the strategy and action plans to achieve net zero greenhouse gas emissions by as early as 2050, including by prioritising economic resilience and security and environmental sustainability, and achieving social equitability and affordability (EPU, 2022). As part of the strategy, a new National Energy Council is planned to steer the policy's strategies and action plans, involving multiple stakeholders. Part of its mandate will be to improve the current national greenhouse gas emission accounting and reporting as well as the carbon footprint, also from the private sector.

Benchmarking IRENA's emission projection values with the upcoming LT-LEDS and other national policies and strategies will be beneficial in painting a holistic picture of Malaysia's envisioned energy transition pathways for reaching net zero emissions by 2050 or sooner. IRENA's 1.5-S aims for Malaysia to reduce its energy sector emissions (including in the power, transport and industry sectors) to almost 120 million tonnes of $CO_2$ by 2050, a reduction of 58% compared to the current pathway. Combined with other carbon offsetting measures, such as in LULUCF, a net zero emission target by 2050 for Malaysia is achievable.

***Emission projections show a wide range of possible outcomes.***

**Figure 29** Benchmarked energy-related emission projection with carbon neutrality pledges and commitments, 2010 to 2050




PLAN = the planning scenario. Historical emissions until 2020 are estimated based on Biennial Update Reports. NDC targets are estimated based on 2005 values and include emissions offsets from land use, land-use change and forestry (LULUCF)
*Source:* IRENA analysis; GoM, 2018, 2020b, 2020a.

## Buildings sector

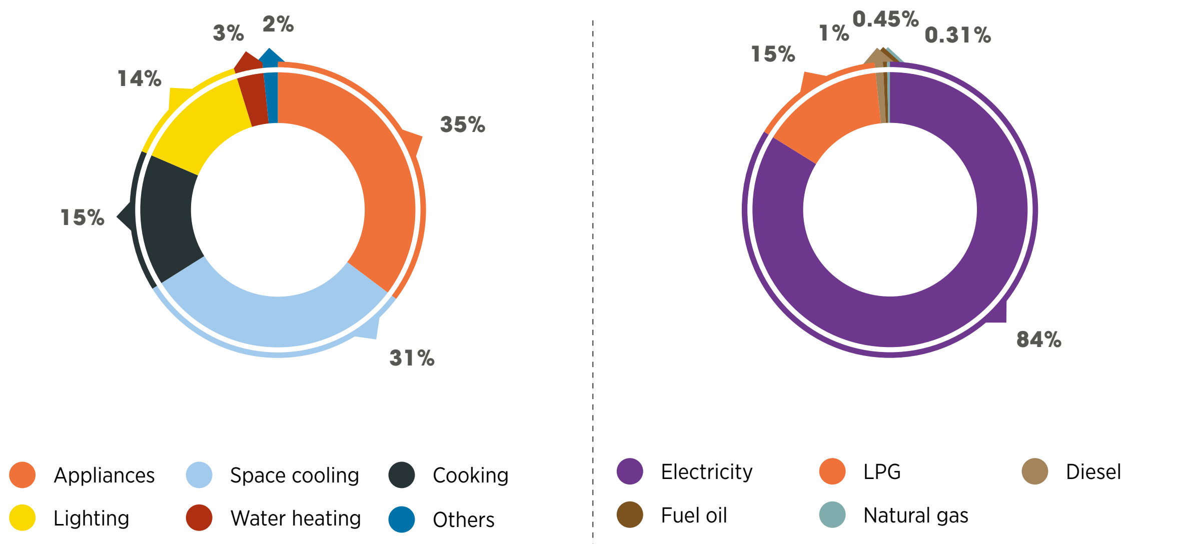
### KEY MESSAGES

**Electricity will continue to dominate energy consumption in the buildings sector, with space cooling becoming the main driver of electricity demand growth.** Energy demand in the sector is expected to grow around 2.0% annually on average until 2050.

**With stringent energy efficiency measures and standards in both the residential and commercial sectors**, energy demand growth can slow to 1.6% in the TES and 1.2% in the 1.5-S.

***Electricity dominates energy use in the buildings sector, with space cooling and appliances accounting for 80% of the sector's electricity consumption.***

**Figure 30** Energy consumption in the buildings sector by end use and carrier, 2018




*Based on:* DOSM, 2020a; ST, 2021a.

Energy use in the buildings sector in Malaysia relies primarily on electricity as a main carrier. The residential sector accounts for almost half of the energy consumption (43%) in the buildings sector. Based on national surveys, there was a rapid increase in household equipment ownership from 2010 onwards, and by 2019 almost all households owned basic electrical appliances (DOSM, 2020a). This includes rising ownership of air conditioning units, with 54% of all households owning at least one air conditioner in 2019 compared to 22% a decade prior.

In Malaysia, Minimum Energy Performance Standards (MEPS) and labelling on appliances are continuously updated to ensure that a minimum level of energy-efficient appliances are sold in the market (ST, 2022d). Meanwhile, the country has achieved 100% clean cooking penetration, with LPG as a main carrier (above 95%), driven by the presence of oil and gas industries since the 1980s.

**Table 5** Buildings sector summary for the three scenarios, 2018, 2030 and 2050

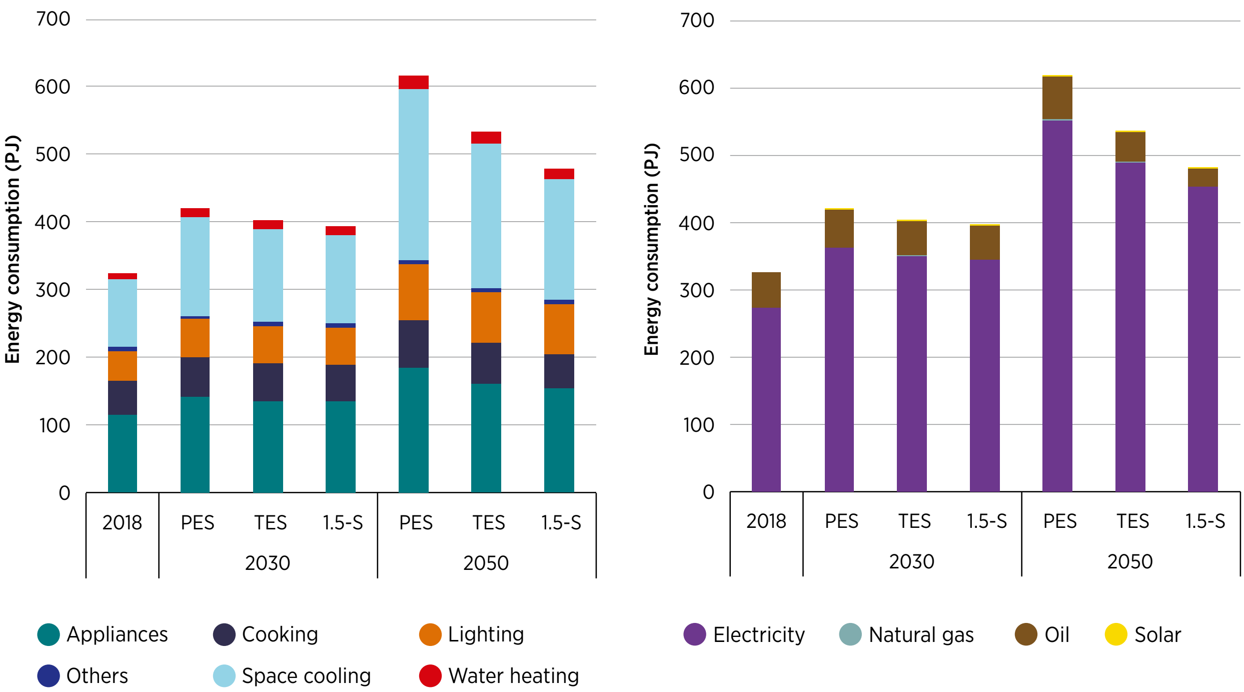
| Sector | Component | Category | Indicator | 2018 | 2030 PES | 2030 TES | 2030 1.5-S | 2050 PES | 2050 TES | 2050 1.5-S |
|---|---|---|---|---|---|---|---|---|---|---|
| BUILDINGS SECTOR | ENERGY TRANSITION COMPONENTS | ENERGY CONSERVATION AND EFFICIENCY | **Total final energy consumption** (PJ) | 325 | 420 | 403 | 395 | 617 | 534 | 479 |
| | | ELECTRIFICATION IN END-USE SECTORS (DIRECT) | **Electricity share** (%) | 84% | 86% | 87% | 87% | 90% | 92% | 95% |
| | | | **Electric stoves** (million units) | 0.8 | 1.4 | 2.6 | 3.4 | 3.0 | 7.5 | 10.4 |
| | | RENEWABLES (DIRECT USE) | **Solar thermal** (PJ) | 0 | 0.01 | 0.02 | 0.06 | 0.07 | 0.14 | 0.42 |
| | | | **Solar water heaters** (million units) | 0 | 0.04 | 0.08 | 0.23 | 0.31 | 0.61 | 1.84 |
| | | | **Renewables share** (%) – incl. traditional biomass, fuels, excl. electricity | 0% | 0% | 0.01% | 0.02% | 0.01% | 0.03% | 0.09% |
| | | | **Renewables share** (%) – incl. traditional biomass, fuels, incl. electricity | 13.5% | 20.7% | 23.8% | 28.5% | 48.4% | 88% | 94.7% |
| | EMISSIONS | | **$CO_2$ emissions** ($MtCO_2$-eq.) | 3.3 | 3.6 | 3.3 | 3.1 | 4.0 | 2.8 | 1.6 |

In the PES, electricity consumption in the country is expected to increase at an average annual rate of 2.4% until 2030. Afterwards, this growth is expected to drop to 2.1% until 2050 with the expected slowing of population growth, market saturation and slowdown in the build rate of buildings. LPG will remain the main fuel of choice for cooking, with an increased use of electric stoves in urban dwellings. As a result, energy consumption in the buildings sector will reach 420 PJ in 2030 and 617 PJ by 2050.

Under the two energy transition scenarios, energy efficiency and conservation will be key to decarbonise the sector, reducing energy consumption by 14% in the TES and 22% in the 1.5-S compared to the PES (Figure 31). Under both scenarios, only highly energy-efficient equipment can continue to be sold in the market. Because future demand will be driven by space cooling needs, energy efficiency measures will be implemented so that the overall building energy intensity is in the range of 150 kWh to 200 kWh/m², mainly through energy conservation, energy-efficient equipment and low-carbon architecture. Electric stoves should be continually promoted to replace LPG, with usage in up to 90% of households by 2050. Solar water heaters can also be a key technology to reduce electricity use.

***Energy use in the buildings sector will double by 2050 in the PES, while energy transition measures in the 1.5-S will reduce the sector's consumption by 22%.***

**Figure 31** Energy consumption in the buildings sector by energy service and carrier, all scenarios, 2018, 2030 and 2050




## Box 6 Managing energy efficiency in the residential and commercial sectors

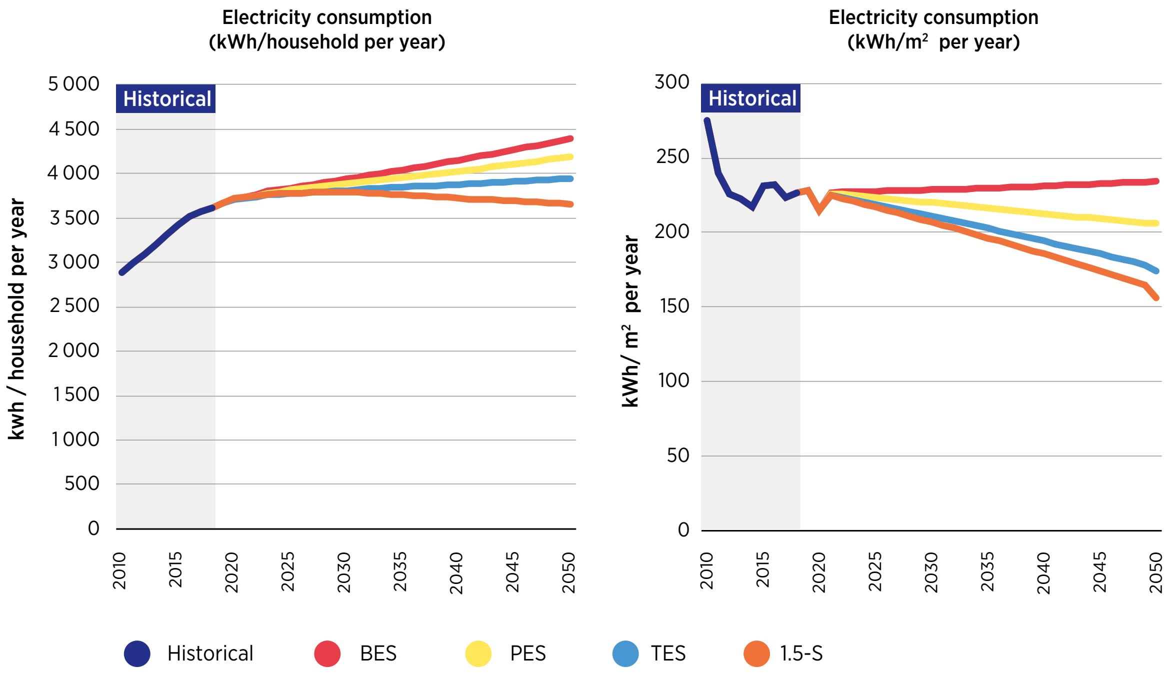
With its emerging economy and rapid urbanisation, Malaysia's buildings are highly reliant on electricity to meet the energy needs of both households and the commercial sector. Additionally, space cooling needs are expected to drive the future growth in electricity use, with average annual demand growth of between 1.8% and 2.9% in all IRENA scenarios. Therefore, energy efficiency practices and measures, passive cooling design approaches and other incentives are crucial to reduce electricity demand in the sector.

Through better demand-side management and energy efficiency measures and practices, energy consumption in Malaysia's buildings can be reduced by more than 20% in the 1.5-S compared to the PES in 2050, as shown in Figure 31 for both the residential and the commercial sectors.

**Box 6** Managing energy efficiency in the residential and commercial sectors (continued)

***Energy efficiency indicators increase in both residential and commercial buildings.***

**Figure 32** Energy efficiency indicators for residential buildings (left) and commercial and public sector buildings (right), all scenarios, 2010 to 2050



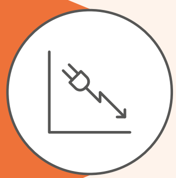

*Source:* IRENA analysis.

The implementation of efficiency labelling ratings, phase-out of inefficient technologies, and promotion of awareness campaigns and cash rebates should be continued to further encourage the use of energy-efficient appliances and reduce electricity consumption (SEDA, 2022). Additionally, expanding the current Green Building Index initiative and energy efficiency targets beyond public buildings to include commercial and private buildings can help track, benchmark and accelerate the adoption of energy efficiency measures, taking advantage of environmental, social and governance (ESG) commitments from the private sector.

## Transport sector

### KEY MESSAGES

**Malaysia's vehicle stock is projected to double by 2050 from 29 million vehicles today**, the majority of which are motorcycles and cars. Without intervening policy measures to encourage and integrate other modes of transport while also transitioning to more energy-efficient vehicles, oil demand in road transport is expected to almost triple by 2050 in the PES.



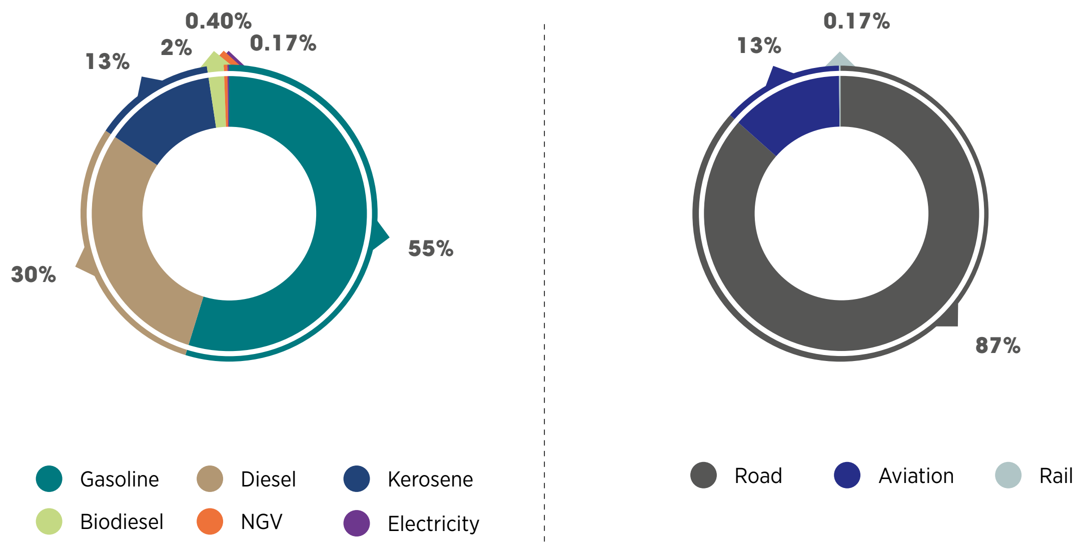
**Electrification is the most viable transition pathway to decarbonising the transport sector**. In the 1.5-S, a projected 76% of all road vehicles will run on electricity by 2050. One-third of annual sales of cars and motorcycles need to be electric vehicles from 2030 onwards, and more than 60% from 2040 onwards. To support 38 million electric vehicles by 2050, 1.3 million public charging stations need to be installed in the country.

**Biofuels will play an important role in decarbonising the hard-to-electrify road freight sector and will play a growing role in aviation**. Total demand for liquid biofuels will grow more than 20-fold despite massive electrification in the transport sector

Road transport consumed 87% of the total transport energy consumption in Malaysia in 2018 (Figure 33). Oil dominates in this energy consumption (98%), consisting of petrol, diesel and kerosene.

***Road transport dominates energy use in Malaysia's transport sector, with petrol accounting for more than half of the sector's energy consumption.***

**Figure 33** Transport energy consumption by end use and carrier, 2018




*Note:* NGV = natural gas for vehicles.

With 29.1 million vehicles on the road as of 2018, Malaysia has the highest motorisation rate in Southeast Asia, at around 850 vehicles per 1 000 people (MOT, 2021).[5] The country's vehicle stock is projected to grow to 50.5 million by 2050 (Table 6).

**Table 6** Estimated vehicle stock in Malaysia, 2018, 2030 and 2050

| (Million vehicles) | 2018 | 2030 | 2050 |
|---|---|---|---|
| **Cars** | 14.1 | 19.5 | 26.3 |
| **Motorcycles** | 13.7 | 18.5 | 21.4 |
| **Small trucks** | 0.8 | 1.1 | 1.7 |
| **Large trucks** | 0.47 | 0.65 | 1.04 |
| **Buses** | 0.06 | 0.07 | 0.09 |
| **Total** | **29.1** | **39.8** | **50.5** |

*Based on:* MOT (2021), statistic estimates from MOT's National Road Department's number of registered vehicles, vehicle sales and population projections.

The National Biofuel Policy, announced in 2006, introduced an initial biodiesel blending mandate of B5 (5% biodiesel) by 2014, which was increased to B10 by 2019 (Wahab, 2021). A B20 blending target was planned in 2020 but was delayed due to supply chain issues that were further exacerbated by the COVID-19 pandemic.

**Table 7** Transport sector summary for the three scenarios, 2018, 2030 and 2050

| | | | | 2018 | 2030 | | | 2050 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PES | TES | 1.5-S | PES | TES | 1.5-S |
| TRANSPORT SECTOR | ENERGY TRANSITION COMPONENTS | ENERGY CONSERVATION AND EFFICIENCY | **Final energy consumption** (PJ) | 990 | 1 295 | 1 240 | 1 162 | 1 787 | 1 508 | 1 249 |
| | | ELECTRIFICATION IN END-USE SECTORS (DIRECT) | **Electricity shares in transport** (%) | <1% | 1% | 3% | 3% | 3% | 11% | 22% |
| | | | **Electric cars** (million vehicles) | <0.01 | 0.2 | 2.0 | 2.9 | 2.6 | 13.1 | 20.4 |
| | | | **Electric cars – penetration rate** (%) | – | 2.5% | 11% | 19% | 6% | 70% | 80% |

*5 Motorisation rate reflects the number of registered cars and motorcycles per 1 000 population.*

**Table 7** Transport sector summary for the three scenarios, 2018, 2030 and 2050 (continued)

| Sector | Component | Category | Indicator | 2018 | 2030 | | | 2050 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PES | TES | 1.5-S | PES | TES | 1.5-S |
| TRANSPORT SECTOR | ENERGY TRANSITION COMPONENTS | ELECTRIFICATION IN END-USE SECTORS (DIRECT) | **Electric motorcycles** (million vehicles) | <0.01 | 2.8 | 3.7 | 3.7 | 3.2 | 10.7 | 17.2 |
| TRANSPORT SECTOR | ENERGY TRANSITION COMPONENTS | ELECTRIFICATION IN END-USE SECTORS (DIRECT) | **Electric two- and three-wheelers – penetration rate** (%) | – | 10% | 16% | 21% | 29% | 80% | 90% |
| TRANSPORT SECTOR | ENERGY TRANSITION COMPONENTS | ELECTRIFICATION IN END-USE SECTORS (DIRECT) | **Public electric vehicle charger installation** (million units) | < 0.00 | < 0.01 | 0.1 | 0.15 | 0.15 | 0.8 | 1.3 |
| TRANSPORT SECTOR | ENERGY TRANSITION COMPONENTS | RENEWABLES (DIRECT USE) | **Renewable energy share** (%) | 2% | 9% | 10% | 11% | 10% | 11% | 21% |
| TRANSPORT SECTOR | ENERGY TRANSITION COMPONENTS | RENEWABLES (DIRECT USE) | **Renewables share** (%) incl. electricity | 2% | 10% | 10% | 12% | 11% | 22% | 44% |
| TRANSPORT SECTOR | ENERGY TRANSITION COMPONENTS | RENEWABLES (DIRECT USE) | **Biodiesel blending rate** (%) | 5% | 30% | 30% | 30% | 30% | 30% | 50% |
| TRANSPORT SECTOR | EMISSIONS | | **$CO_2$ emissions** ($MtCO_2$-eq.) | 67.8 | 81 | 76 | 70 | 110 | 82 | 49 |

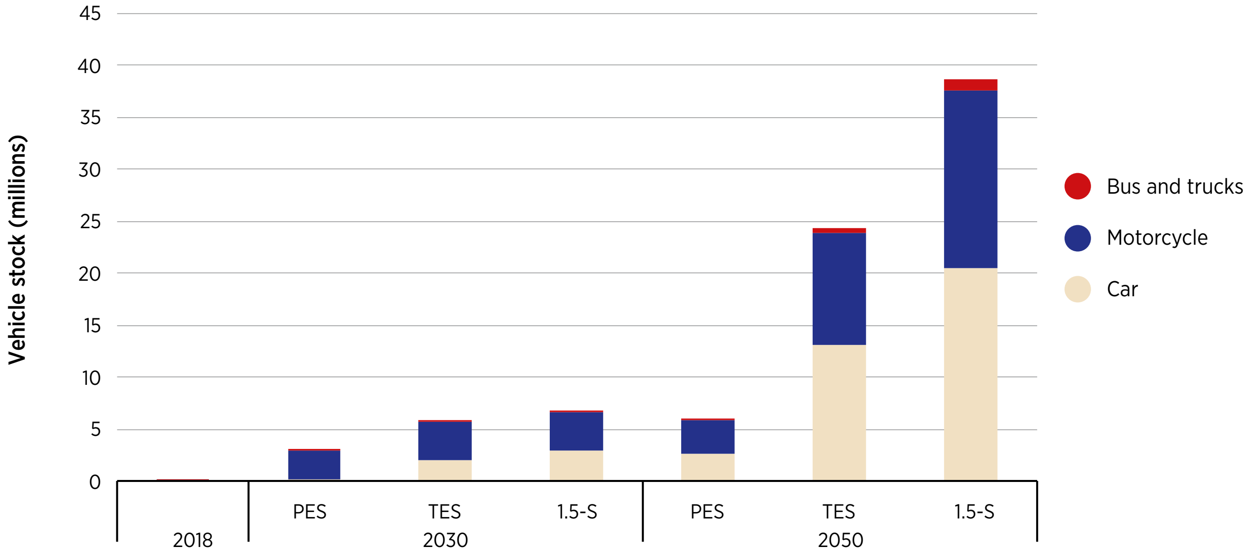
In the PES, transport energy consumption is expected to increase almost three-fold, from 989 PJ in 2018 to 1 787 PJ by 2050. A large share (86%) of the energy consumption in 2050 will remain oil-based, while electricity demand will have only a 3% share (13.1 TWh). Electric vehicle sales are expected to pick up in the near term, to reach up to 200 000 electric cars and 2.8 million electric motorcycles by 2030, as proposed in the Low Carbon Mobility Blueprint (KASA, 2021).[6] Sales are then expected to accelerate after 2030, reaching 3.9 million electric cars and 6.4 million electric motorcycles by 2050. For biofuels, the B30 blending mandate is implemented from 2030 and maintained until 2050 to reach 5.3 billion litres of annual biodiesel production, up almost 10-fold from today. Based on national plans, near-term efforts are made to increase energy-efficient vehicles and hybrid electric vehicles, since there is already an automotive industrial production base in the country.

In the TES and 1.5-S, electrification of vehicles is key to reducing emissions, with reductions of up to 40% in the 1.5-S compared to the PES by 2050. In the TES, up to 50% of all vehicles on the road will be electric, while in the 1.5-S the share is 75% (Figure 34). The 1.5-S foresees up to 20 million electric cars and 17 million electric motorcycles by 2050, with annual electric vehicle sales of more than 0.8 million annually from 2030 onwards. The bulk of electric vehicles will be passenger vehicles – motorcycles and cars – while freight trucks will still have to rely on fossil fuels and biofuels to travel long distances.

*6 The Low Carbon Mobility Blueprint 2021-2030, released in 2021, outlines a proposal to increase the use of electric vehicles and other low-carbon transport options in the country. The blueprint proposes that 15% of all motorcycles are to be electric, while 5% of cars are to be fully electric vehicles (KASA, 2021).*

***Electric vehicle numbers must grow rapidly to achieve a decarbonised future transport sector.***

**Figure 34** Electric vehicle growth projection, all scenarios, 2018, 2030 and 2050




## **Box 7** Transitioning to electric vehicles in Malaysia

The road ahead for the future of transport leads towards electro-mobility, as evidenced by the rise of electric vehicles, particularly in China, Europe, and the United States, gaining a 10% global market sales share in 2021 (IEA, 2022a). IRENA projects that in the ASEAN region alone, 108 million cars and 299 million motorcycles will run on electricity by 2050 under the 1.5-S (IRENA, 2022b). Malaysia's Low Carbon Mobility Blueprint 2021-2030 envisions a 15% share of electric motorcycles and 20 000 electric cars by 2030.

Managing the supply chain and critical materials is becoming a key topic in the transition towards electric vehicles, particularly in the production of batteries. Malaysia accounts for 11% of the global processing capacity for rare earth elements, which are integral in clean energy applications and automotive manufacturing (IRENA, 2022a). While the country may not possess other critical materials required for the energy transition, considerations must be made towards negotiating supply agreements and prices – ensuring that there are value-added contributions and that technological expertise is developed to contribute to advancing the economy before transforming the automotive industry.

Samsung Electronics' battery arm, Samsung SDI, estimates that the demand for batteries for manufacturing electrical tools and energy storage systems as well as electric vehicles will increase to 15 billion cells of cylindrical batteries in 2027. The company has broken ground on a USD 1.3 billion factory in Malaysia to take advantage of the country's solid yet inexpensive tech climate during this period of growth in the global electric vehicle battery market (Jennings, 2022).

The Chinese battery manufacturer Eve Energy, through its subsidiary EVE Energy Malaysia, is investing up to USD 422 million to set up a battery plant to supply consumers in Malaysia and other Southeast Asian countries, mainly for electric bikes and power tools. The plant is forecasted to be operational within three years (Chan, 2022). In another promising investment, Malaysia-based investment firm Hong Seng and US-based battery anode firm EoCell are partnering to manufacture electric vehicle batteries and eventually energy storage solutions to supply manufacturers, assemblers and users in Southeast Asia (Crompton, 2022).

As part of the energy transition towards electric vehicles, policies such as end-of-life vehicle schemes are necessary to ensure that older and inefficient vehicles are phased out, while also supporting measures to shift to other means of transport or towards newer and efficient vehicles. Additionally, with decades of experience in the automotive manufacturing, Malaysia is well positioned to manufacture its own competitive electric vehicles. Therefore, a clear direction and policy, apart from shifting away from subsidies in transport fuels, needs to be given to signal the private sector and buyers to accelerate the adoption of electric vehicles.

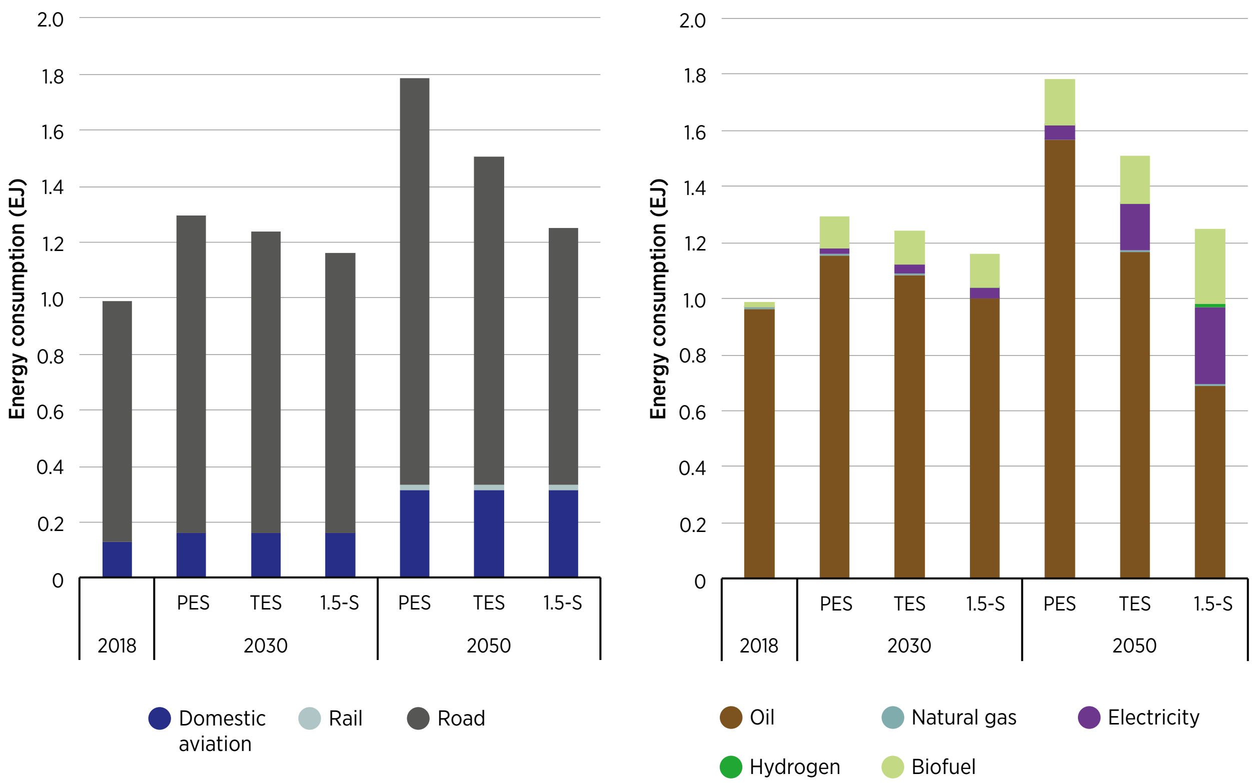
Biofuels would still play a role across all scenarios, with an increase in the blending rate of up to B30 from 2030; this would mean increasing the production capacity 20-fold from today's level. The 1.5-S also envisions the adoption of up to 5% advanced biofuels in aviation by 2050, in line with international aspirations to decarbonise the sector. To date, several airlines in Malaysia and surrounding regions have tested such fuels. A forthcoming IRENA report in 2024 will focus on analysing the potential of Sustainable Aviation Fuels (SAFs) production in the Southeast Asia region

For all scenarios, with new rail lines currently under construction for both passenger and freight use, electricity demand will grow 6% annually on average until 2030 and 11% annually on average until 2050 as more freight volume is transported via rail. However, energy consumption will remain less than 2% of the total transport consumption in the 1.5-S. Meanwhile, energy demand from the aviation sector is expected to grow 2.8% annually on average based on fuel demand and domestic passenger growth in Malaysia.

Malaysia's transport sector transformation will see the sector's energy demand reduced by 16% and 30% in the TES and the 1.5-S, respectively. Share of oil consumption will decrease from accounting for 97% in 2018, to about only three-quarter in TES 2050, and even plunges to only about little over a half of sector's consumption in 1.5-S 2050.

***Transport sector energy use is projected to grow 1.9% annually, nearly doubling by 2050 in the PES. The energy transition measures reduce the sector's energy consumption by 30% in the 1.5-S.***

**Figure 35** Transport energy consumption by end use and carrier, all scenarios, 2018 to 2050



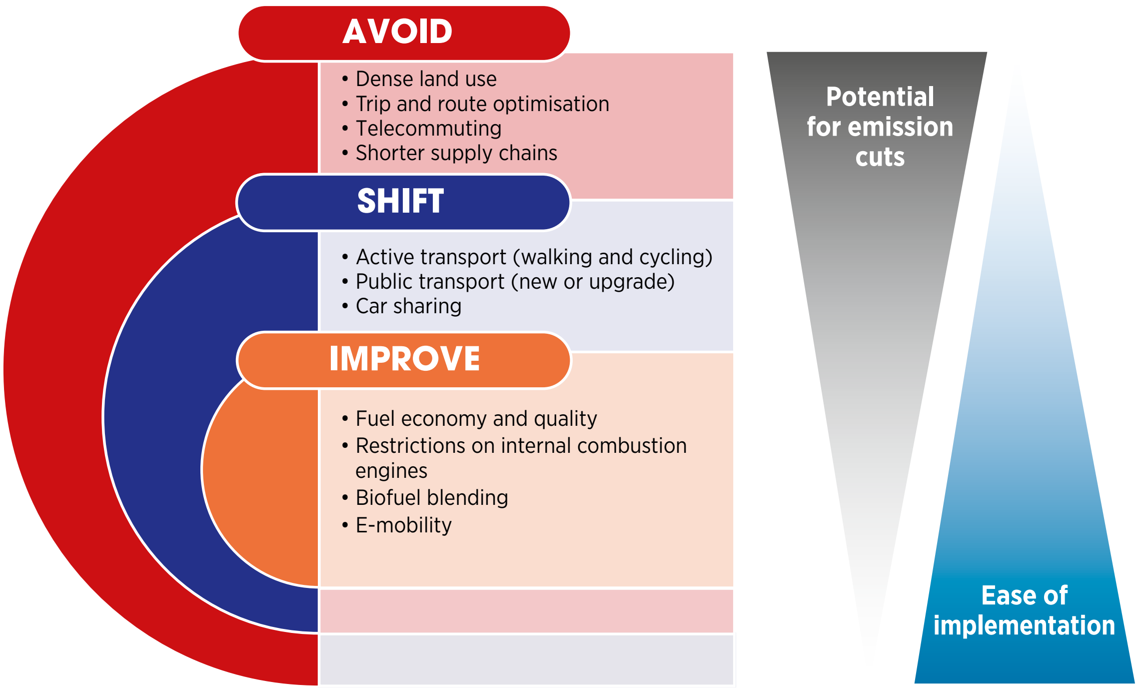
## **Box 8** Decarbonising urban transport – avoid, shift and improve policies

Electric vehicles are still in their infancy in Malaysia, with just over 300 in the country as of 2020. At the same time, the already high motorisation rate in Malaysia compared to the rest of Southeast Asia means that a majority of the population relies on private vehicles for transport. In the urban area of Klang Valley, enveloping the capital of Kuala Lumpur, less than 17% of journeys are undertaken using public transport (Chuen, Karim and Yusoff, 2014). While switching to electric vehicles might lead to long-term emission reductions in the country, this must be coupled with a long-term goal to promote sustainable and public transport. The latest National Energy Plan targets a 50% share of urban public transport by 2040 (EPU, 2022).

Urban transport policies can be categorised by how they seek to decarbonise the transport sector: that is, do they seek to avoid, shift, or improve usage of various transport modes (SLOCAT, 2021). In all three categories, decarbonisation can result from, or even contribute to, increased use of renewable energy. The *avoid-shift-improve* policy baskets offer different levels of effectiveness in curbing carbon and other forms of air pollution, with *avoid* strategies offering the greatest cuts and *improve* strategies the least (IRENA, 2021c).

IRENA's analysis in this report covers the impacts of the *improve* policy basket on emissions, mainly achieving better fuel economy, electric mobility and alternative fuels. *Avoid* policies require some of the greatest system-level changes – such as redesigning land use for greater density – and therefore could take the longest and be the most politically difficult to implement. What is clear from IRENA's analysis in the transport sector is that further investment in public transport such as increasing the number of buses and rail is required across Malaysia to shift away from high private vehicle use as well as curbing fuel subsidies in transport.

**Figure 36** Trade-offs among avoid-shift-improve transport strategies




*Source:* IRENA, 2021c, based on SLOCAT, 2021.

## Industry sector

### KEY MESSAGES

**Industry sector energy demand will grow 2.1% annually on average in the PES**, with the increase in demand driven mainly by economic growth and increased investment in different manufacturing sectors and in iron and steel. With energy transition measures such as fuel substitution, low-carbon technologies, and energy efficiency improvement, energy demand grows more slowly at 1.7% in the TES and 1.6% in the 1.5-S.

**Biomass and hydrogen will play important roles in decarbonising the industry sector**. In both scenarios, biomass use needs to grow substantially to substitute the use of natural gas in heat-intensive processes, while hydrogen production can cater to global demand for green hydrogen in the non-energy sector.

**In the energy transition scenarios, green hydrogen and its derivatives will be a key fuel for decarbonisation**. Malaysia is strategically located to use its natural resources and leverage its experience to meet global demand for green hydrogen.

**Industry sector emissions in the 1.5-S will grow in the short term, then decline and reach the same level as today in 2050**. As one of the hard-to-decarbonise sectors, industry will continue to rely on some fossil fuel use during the time horizon until 2050, with carbon capture and storage becoming a potential option to tackle the remaining emissions.

In 2018, the industry sector consumed almost 30% of the final energy consumption in Malaysia. The sector's major energy consumers – iron and steel, cement and chemicals – are modelled into the analysis. Natural gas supplied around 43% of industrial energy consumption in 2018, while electricity (34%) is employed mainly for the manufacturing and semi-conductor industry, the country's largest industry sector. Although biomass data are lacking in the national energy statistics for industry, several industry sub-sectors (mainly major cement and petrochemical companies) note the use of waste and agricultural residues in their processes as an energy-saving measure in their company annual reports.

In the PES, overall energy demand in the industrial sector is expected to grow at an average annual rate of 2.1%, from 797 PJ in 2018 to 1 564 PJ by 2050. This is based on the projected GDP growth rate in the sector and on the improved energy efficiency. Natural gas will still supply most of the energy consumption, followed by electricity. If the analysis also includes the non-energy sector, where natural gas is the main feedstock for the petrochemical sector, overall demand in the industrial sector is expected to grow from 1 352 PJ in 2018 to 2 819 PJ by 2050.

By sub-sector, iron and steel production is projected to grow 5% on average until 2030, reaching 23 million tonnes of annual production capacity due to large investments in blast furnaces already committed early in the decade. Afterwards, it is expected to grow 3% annually until 2050 to reach 42 million tonnes annually. Meanwhile, cement production will remain relatively stable until 2050, growing 1% per year on average.

Finally, the petrochemical sector, in which more than 80% of production capacity is for ammonia and methanol production, is expected to follow a modest annual growth of 4.1% until 2030, followed by a lower demand growth of 3% between 2030 and 2050.

In the two energy transition scenarios, improved energy efficiency measures and technology processes across all sub-sectors will lead to reductions in energy consumption of 11% in the TES and 16% in the 1.5-S by 2050, compared to the PES. Overall energy intensity will improve 0.7% annually in the TES and 1.0% annually in the 1.5-S, compared to 0.5% annually in the PES. Significant emission reduction can be achieved by fuel switching from natural gas and coal to biomass and waste products in the 1.5-S, although emissions from the industry sector will still represent 35% of the overall energy-related emissions in the 1.5-S in 2050.

Hydrogen is expected to also play a role in decarbonising the sector, where it can substitute natural gas in energy-intensive processes such as iron and steel, as well as serve as a feedstock for production of ammonia and methanol, where both fuels is expected to play a key role in decarbonizing the maritime sector. In this case, hydrogen consumption in the 1.5-S is expected to reach 200 PJ (around 2 600 tonnes) by 2050. Key actions in the industry sub-sectors are shown Figure 38.

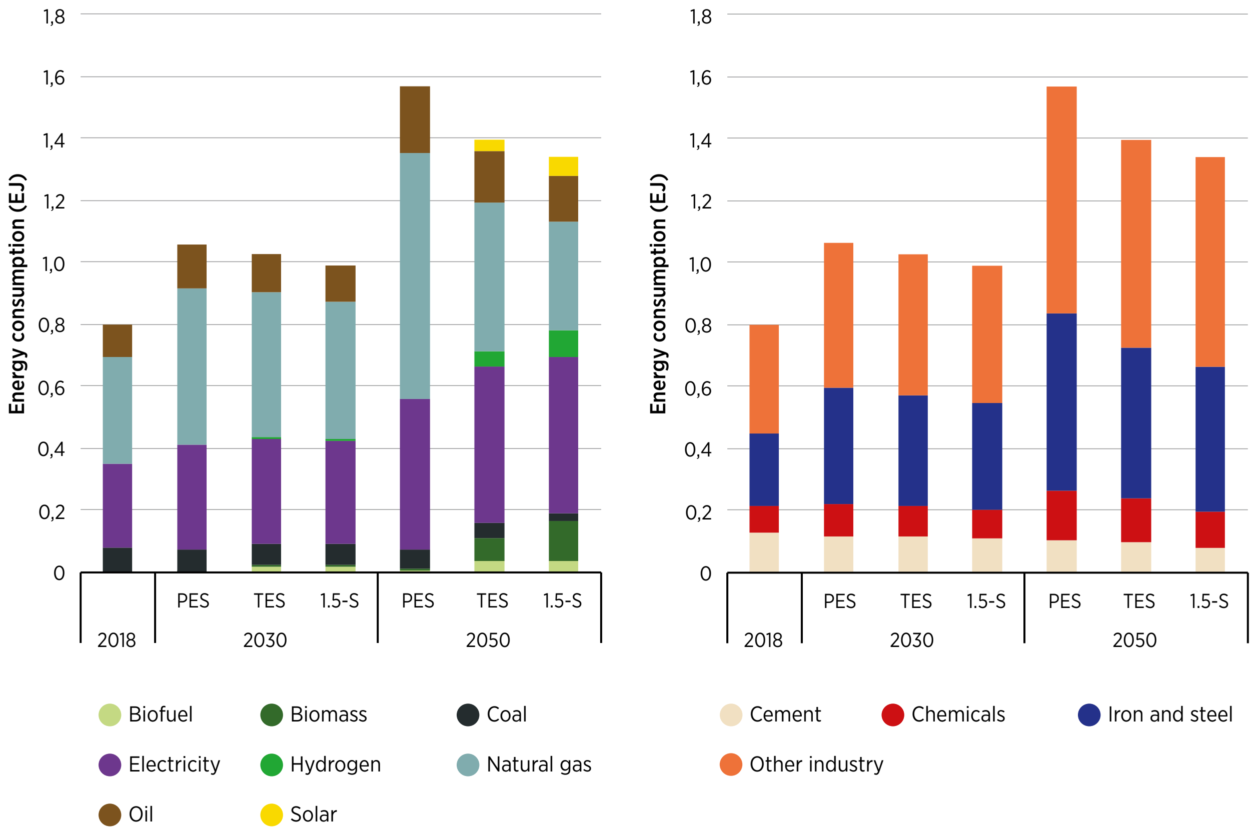
**Table 8** Industry sector summary for the three scenarios, 2018, 2030 and 2050

| | | | | 2018 | 2030 | | | 2050 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PES | TES | 1.5-S | PES | TES | 1.5-S |
| INDUSTRY SECTOR | ENERGY TRANSITION COMPONENTS | ENERGY CONSERVATION AND EFFICIENCY | **Final energy consumption** (PJ) | 797 | 1 054 | 1 024 | 986 | 1 564 | 1 393 | 1 341 |
| | | | **Non-energy use** (PJ) | 555 | 888 | 886 | 884 | 1 255 | 1 284 | 1 233 |
| | | | **Energy intensity** (kJ/USD) | 3 068 | 2 888 | 2 802 | 2 719 | 2 613 | 2 410 | 2 224 |
| | | ELECTRIFICATION IN END-USE SECTORS (DIRECT) | **Electricity share** (%) | 34% | 32% | 33% | 34% | 31% | 36% | 38% |
| | | RENEWABLES (DIRECT USE) | **Renewable energy share** (%) | <1% | 1% | 2% | 3% | 1% | 10% | 17% |
| | | | **Renewable energy share incl. electricity** (%) | 6% | 8% | 11% | 14% | 18% | 45% | 55% |
| | | | **Bioenergy** (PJ) | – | 1 | 25 | 25 | 11 | 110 | 166 |
| | | HYDROGEN AND DERIVATIVES | **Hydrogen use** (PJ), including in non-energy use | – | – | 15 | 25 | – | 111 | 213 |
| | EMISSIONS | | **$CO_2$ emissions** (Mt $CO_2$-eq) | 27 | 38 | 35 | 33 | 60 | 39 | 31 |

*Note:* kJ = kilojoule

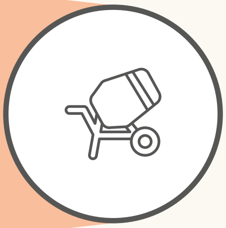
***Malaysia's industry sector is dominated by medium energy intensity industries. Iron and steel account for 30% of the sector's total energy consumption, rising to 37% by 2050.***

**Figure 37** Industrial sector energy consumption by sub-sector and carrier, all scenarios, 2018, 2030 and 2050




Successful transformation of industry while maintaining competitiveness will require consideration of the full life cycle of activities. A range of actions are needed to decarbonise the industry sub-sectors, as seen in Figure 38.

**Figure 38** Industry sub-sector key measures and actions for decarbonisation



**Cement**

- Increase clinker to cement ratio by from 86% today to 60% in 1.5-S and 65% in TES by 2050.
- Increase substitution of natural gas to waste and biomass for thermal energy process, reaching 15% by 2050 in TES, 45% for 1.5-S.

**Iron and steel**

- Limit building of blast furnaces (BF-BOF) after 2030 to build more DRI-EAF steel plants, up to 60% of total annual production capacity in 1.5-S 2050.
- Encourage the recycling of scrap metal from 0.5 MTPA in 2018 to 7.0 MTPA production capacity by 2050 in 1.5-S.
- Incorporate use of hydrogen for low-carbon DRI processes.

**Chemicals & Non-Energy Use**

- Increase energy efficiency improvement of more than 2.0% annually in TES and 1.5-S.
- Waste plastic recycling of up to 30% in 1.5-S by 2050.
- Replace of up to 10% of feedstock for production of ammonia and methanol with hydrogen.

## Box 9 Carbon capture and storage for hard-to-decarbonise sectors

In the 1.5-S, industrial emissions will still account for 25% of total energy emissions by 2050. Cutting out fossil fuels entirely is challenging, especially given the need to drive economic growth and national priorities related to the energy transition. While emissions can be offset using Land Use, Land-Use Change and Forestry (LULUCF), carbon sequestration units could help capture process emissions in hard-to-decarbonize sectors such as cement, iron and steel. Pilot projects could be deployed with the use of carbon capture and storage to gradually become commercially available in the future.

As of early 2021, 24 commercial fossil-fuel-based CCS facilities were in operation globally, with an installed capacity able to capture around 0.04 gigatonnes (Gt) per year of energy- and process-related $CO_2$ emissions (IRENA, 2022b). Malaysia will need to learn from the successes and failures of CCS projects around the world. 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.

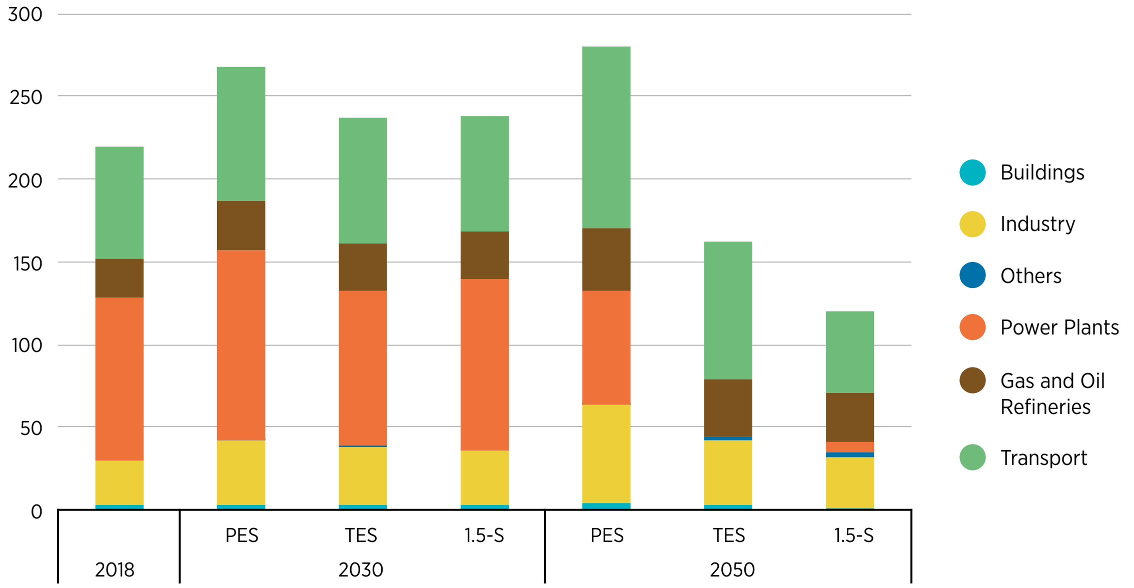
A legal and regulatory framework for storage facilities must be in place before planning a CCS facility. Overall project execution for CCS usually takes up to four to five years with several steps, such as pre-feasibility and feasibility studies (one to two years), licensing approvals (*e.g.* technical 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 from 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 to carbon capture, utilisation and storage (CCUS) include other $CO_2$ 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 39** Energy-related $CO_2$ emissions by scenario, 2018, 2030 and 2050



## 4.3 POWER SECTOR TRANSFORMATION AND FLEXIBILITY

### KEY MESSAGES

**Because electricity demand could double or more from today's levels by 2050**, how power generation capacity is expanded to meet this rising demand will be instrumental for national $CO_2$ emissions. Unless renewables deployment keeps pace with and exceeds demand growth, power sector emissions could remain at today's levels of 100 million tonnes per year out to 2050 despite significant renewables expansion.

**The hydropower potential concentrated in Sabah and Sarawak has a key role in shaping the future regional power system**. These regions are home to more than 80% of the country's hydropower potential, and high electricity demand is projected in neighbouring regions such as Kalimantan and those further afield such as Java in Indonesia. Transmitting power from generation sources to demand centres will require considerable expansion of national and international transmission capacity across the region.

**Malaysia has a vast wealth of renewable energy resources**, key among them being solar PV with an overall potential of around 337 GW. How and where these resources are developed will require integrated planning in distribution, transmission and generation capacity so that they can be effectively and meaningfully unlocked in a high-renewables pathway.

### 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. Accomplishing this will require 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 will lead the transformation, supplying up to 20% of total electricity generation by 2030 (from just over 1% today) in the ASEAN region.

Malaysia's power sector is a key source of national emissions and spans a vast area that comprises three regions, Peninsular Malaysia, Sabah and Sarawak. All regions have different populations, generation capacity mixes, local resources and electricity demands, which means that power system planning needs to account for all these differences when charting future national power system pathways and national and international integration of power systems.

Coal in recent years has represented a growing share of power generation in Malaysia and now represents around 40% of the total. The large share of coal-fired generation means that power sector emissions are mostly a result of coal's dominance in the generation mix of Peninsular Malaysia and, to a lesser extent, Sarawak. However, with a lack of substantial domestic resources, the coal fleet is not anticipated to expand further in the coming years, with further natural gas and renewable expansion expected to come online.

Achieving decarbonisation goals in a climate-compatible pathway will require higher levels of electrification across the energy system, combined with increased levels of renewables penetration. However, measures designed to achieve such goals must also have at their heart security of supply, affordability and environmental considerations. Historically, the ASEAN region has over-projected electricity growth, which is an important consideration in the context of such ambitious levels of electrification. The power sector analyses in the 1.5-S did consider the impacts of lower potential electrification levels on capacity expansion, but the systems were largely of a similar composition; this indicates that attaining a lower level would not inhibit or alter the technology mix needed at an overall high level, just its overall magnitude.

Malaysia has significant resources of both fossil fuels and renewables, but the vast majority of its renewable energy potential remains to be developed. To date, the key renewables in the power sector have been hydropower (6 GW of installed capacity as of 2021) and solar PV (1.8 GW). The untapped hydropower potential is concentrated mainly in Sarawak and is distant from the key national load centres on Peninsular Malaysia, where much of the potential has already been developed. This implies that any significant reliance on hydropower nationally would need to be in conjunction with deep national power system integration.

Although solar PV is well distributed as a resource in Malaysia, much of the country's wind potential is far from demand centres and far offshore. Both the ASEAN region and Malaysia have seen comparatively low penetrations of wind and solar PV generation to date, with the notable exception of Viet Nam, which had a combined installed capacity of around 21 GW in 2021 (IRENA, 2021d). Bioenergy also currently plays a minor role in Malaysia, with nearly 0.2 GW installed in 2021 out of a total estimated potential of 4 GW, implying significant scope for growth. The renewable energy resource potential used in this study is provided in Table 9.

**Table 9** Renewable energy potential in Malaysia

| | | POTENTIAL (GW) | INSTALLED CAPACITY IN 2021 (GW) | SHARE DEPLOYED AS OF 2021 |
|---|---|---|---|---|
| RENEWABLE ENERGY | **Biomass** | 4 | 0.2 | 5% |
| | **Geothermal** | 0 | 0 | 0% |
| | **Hydropower** | 29 | 6.2 | 21% |
| | **Onshore wind** | 0 | 0 | 0% |
| | **Offshore wind** | 53 | 0 | 0% |
| | **Solar PV** | 337 | 1.8 | 1% |

Renewable energy resource potentials used for Malaysia and the ASEAN region 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, 2022d). Given the seasonality of hydropower, its generation pattern varies in each country across the year. Thus, the model was calibrated based on the best available data that were either provided by national bodies or extracted from the PLEXOS World model (University College Cork, 2019).

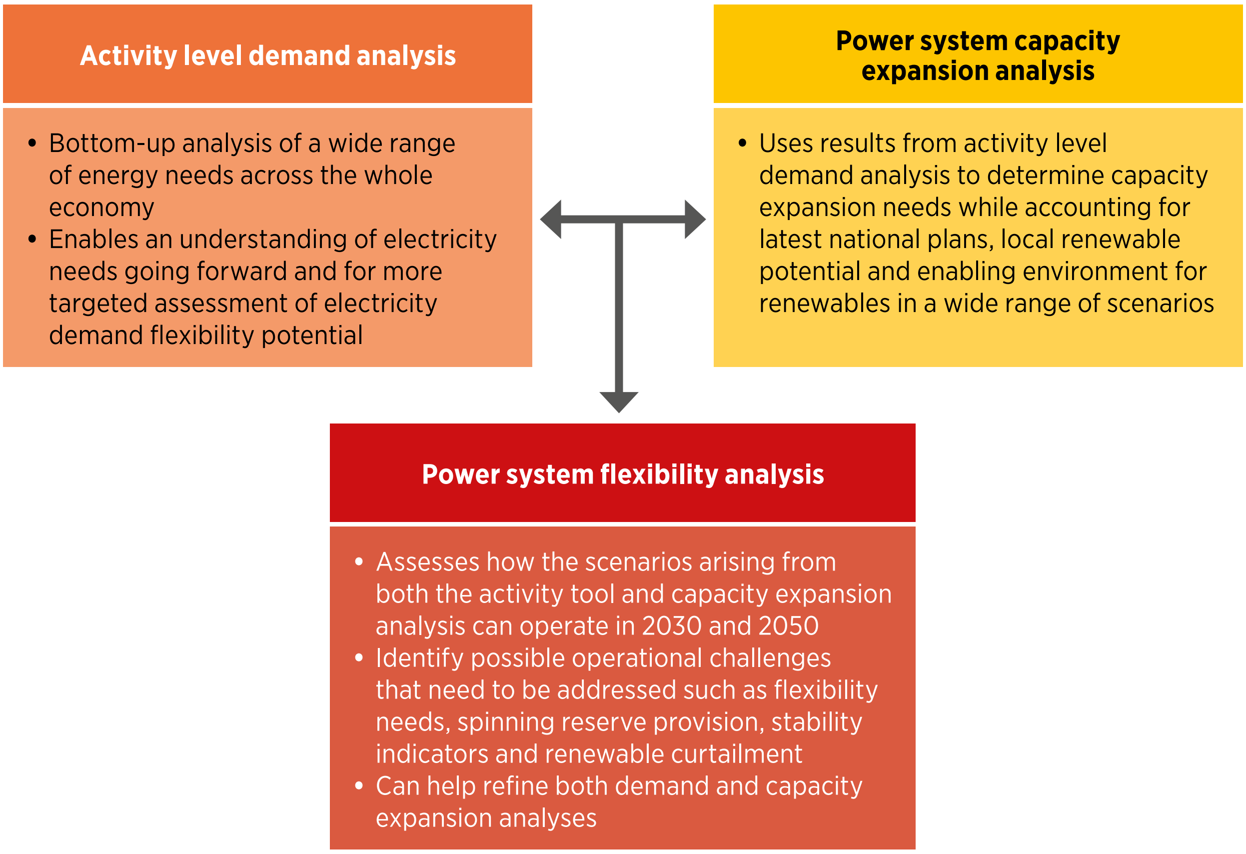
To determine the solar and wind energy potentials, an analysis was performed using a geographic information system search engine with extraction layers to derive these potentials and their hourly generation profiles for five different classes, respectively, of resource quality. This was done using the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

The methodological approach applied across this study seeks to deliver an assessment that meets the growing energy demand across Malaysia while also delivering on several key national and regional goals in terms of emission reductions, energy costs and energy security. 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 using the approach outlined in Figure 40, in which the energy supply and demand assessment comprised 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 this demand can be achieved while maintaining system reliability. This in turn enabled a tailored capacity expansion to be developed to deliver emissions and energy cost reductions while bolstering energy security and access, largely through increased deployment of renewables across Malaysia and the ASEAN region in an operationally robust power system.

*IRENA's REmap consists of many intercorrelated analyses.*

**Figure 40** The REmap multi-model approach




For the power sector, the analysis consists of two key parts. The first is 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. The second is an operational assessment of these scenarios for power system flexibility. For 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 on wide-ranging assumptions in the power system expansion modelling. Two of the scenarios – the Baseline Energy Scenario (BES) and the PES – were designed to best represent "business-as-usual" and best available national plans, respectively. Meanwhile, the TES strives to deliver higher renewable and decarbonisation ambition than the BES and the PES, and two different 1.5-S cases (a 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 Malaysia. The rationale for capacity expansion analysis is shown in Table 10, which spans four pillars.

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

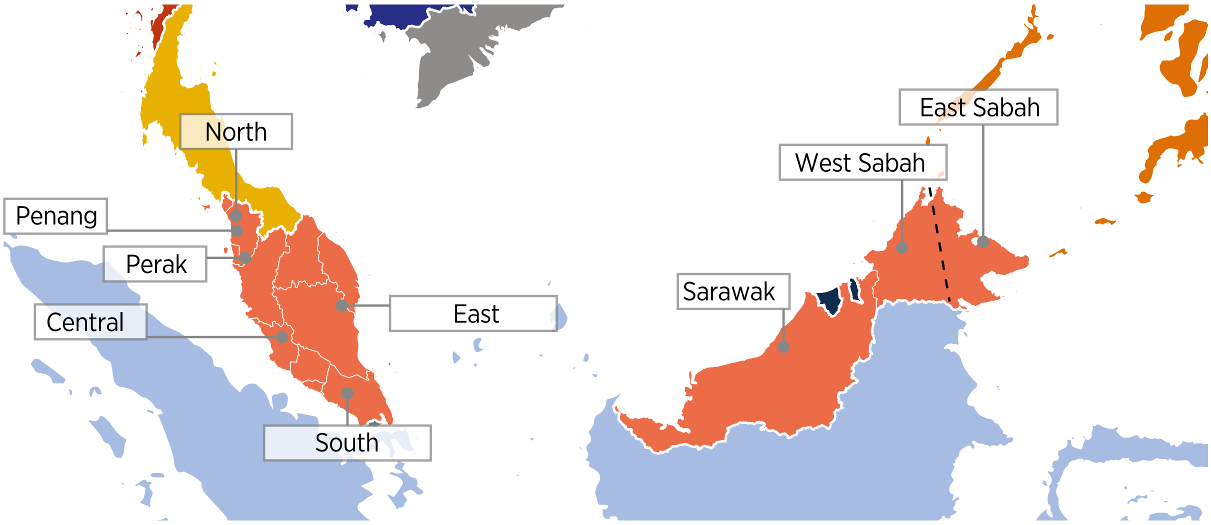
**Table 10** Guiding considerations and motivations behind long-term power sector simulations for the ASEAN region

| | | BES/PES | TES | 1.5-S RE90 | 1.5-S RE100 |
|---|---|---|---|---|---|
| SCENARIO | Guiding questions and considerations | Existing pipeline of renewable energy projects in each country. | What is the implication of not expanding fossil fuels? Is it technically feasible? Is it economical? | Which is more competitive: renewables or CCS? | How feasible is it to push further towards 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 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 fuel expansion? | | What are the additional investment needs? Is it economic and is it operationally robust |
| | Motivation | To demonstrate what can be achieved under current plans with the existing framework and endowment enabling environment (PES) for renewables, 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 (90% renewables in power generation) can be achieved while considering all technology options available such as CCS. | To explore and analyse what a climate-compatible 100% renewables pathway means for the ASEAN region and how it can be realised while excluding all fossil and nuclear technologies. |

These scenarios for the power sector were considered in a 35-node model for the ASEAN region (Figure 41), with 18 nodes in Indonesia, 9 in Malaysia and 1 in 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 nine-node representation for Malaysia 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 country.

***Modelling Malaysia within a whole-ASEAN regional model shows how regional synergies might be leveraged.***

**Figure 41** Malaysia representation with 9 nodes




*Disclaimer:* This map is provided for illustration purposes only. Boundaries and names shown 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.

To best represent national and international plans for international line expansion, the BES and PES scenarios take a more conservative approach to expansion. It can expand cost optimally in a national context but is limited internationally to lines envisaged in the most recent ASEAN Interconnection Master Plan 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.[7]

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 (such as ancillary services in the regulation of the system frequency, spinning reserve, and non-spinning reserve). 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.

## Electricity demand growth

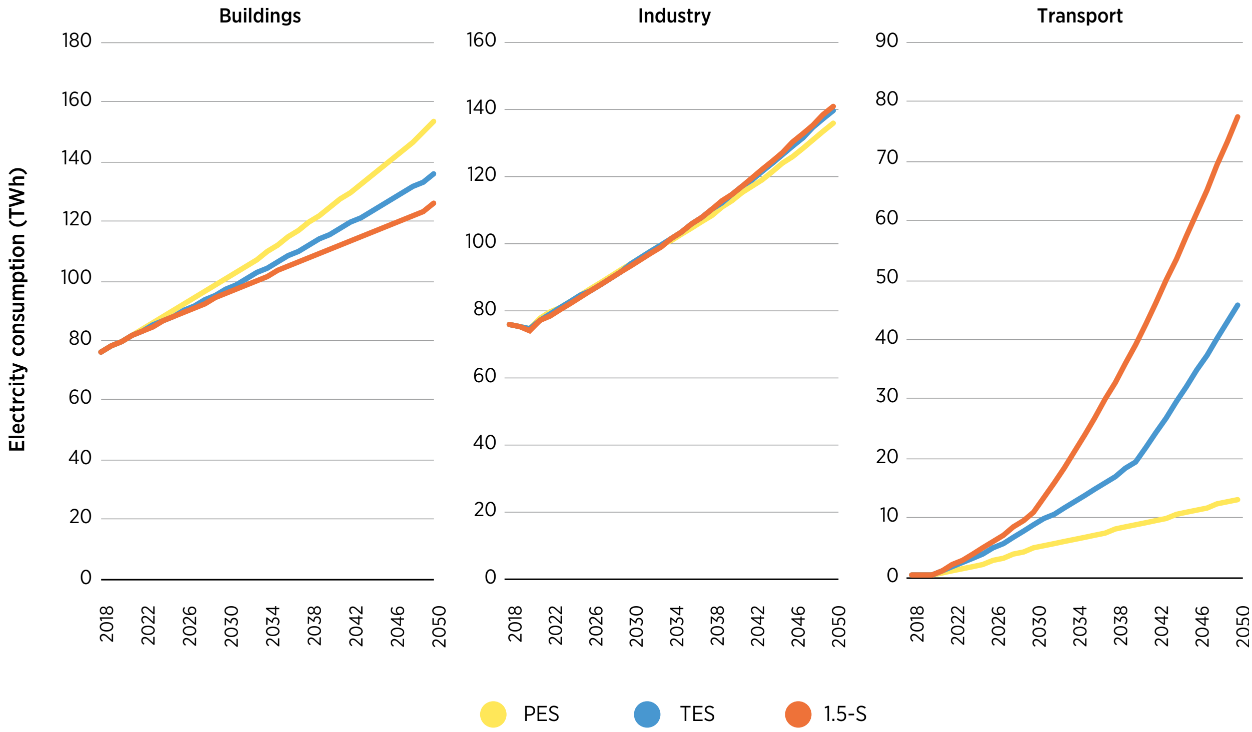
Electricity demand growth by 2050 will be very significant in all scenarios (Figure 42), reaching a range of between around 305 TWh in the PES and 350 TWh in the 1.5-S, where there is robust electrification of end uses. Electrification of end uses harnesses powerful efficiencies and, if done with renewables, can provide significant reductions in both 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 Malaysia's energy needs by 2050 are met with electricity 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.

*7 Interconnection costs and distances were calculated based on distances between regions and countries and if a high voltage alternating current (HVAC) or high voltage direct current (HVDC) line was required. These costs assumed were USD 700/MWkm for HVAC lines and USD 6 000/MWkm assumed for HVDC lines.*

***Total electricity demand in Malaysia is projected to grow 2% annually to 2050 in the PES. Electrification in the 1.5-S accelerates this growth, reaching 2.6% annually.***

**Figure 42** Electricity demand growth by sector and scenario, 2018, 2030 and 2050




## Power capacity and generation

### KEY MESSAGES

**Rollout of solar PV is a no-regrets option in all scenarios, regardless of renewable energy ambition**. By 2050 it could reach over 150 GW with most of it located in and around key demand centres due to the wide availability of the resource and land, with corresponding implications for reinforcement of transmission and distribution systems.

**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 renewables, batteries 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.

**Achieving the energy transition in a least-cost way will necessitate deeper integration of national power systems within Malaysia and regionally with neighbours**. This allows integrated energy supply planning and minimising duplication of both energy and non-energy service provision which can reduce costs overall.

Power capacity will need to grow at a pace that ensures that Malaysian electricity needs are met 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 country. 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.

The developed scenarios are the BES, the PES, the TES and the 1.5-S, comprising the 1.5-S RE90 (90% renewable power) and the 1.5-S RE100 (100% renewable power) cases. They constitute a wide range of development and provide an understanding of the impact of implementing and not implementing measures in the power sector. These five scenarios encompass varying ambitions for emission reductions and renewables, reaching renewable capacity shares by 2050 of 70% in the BES, 67% in the PES, 81% in the TES and 91%-100% in the two 1.5-S cases (Figure 43).

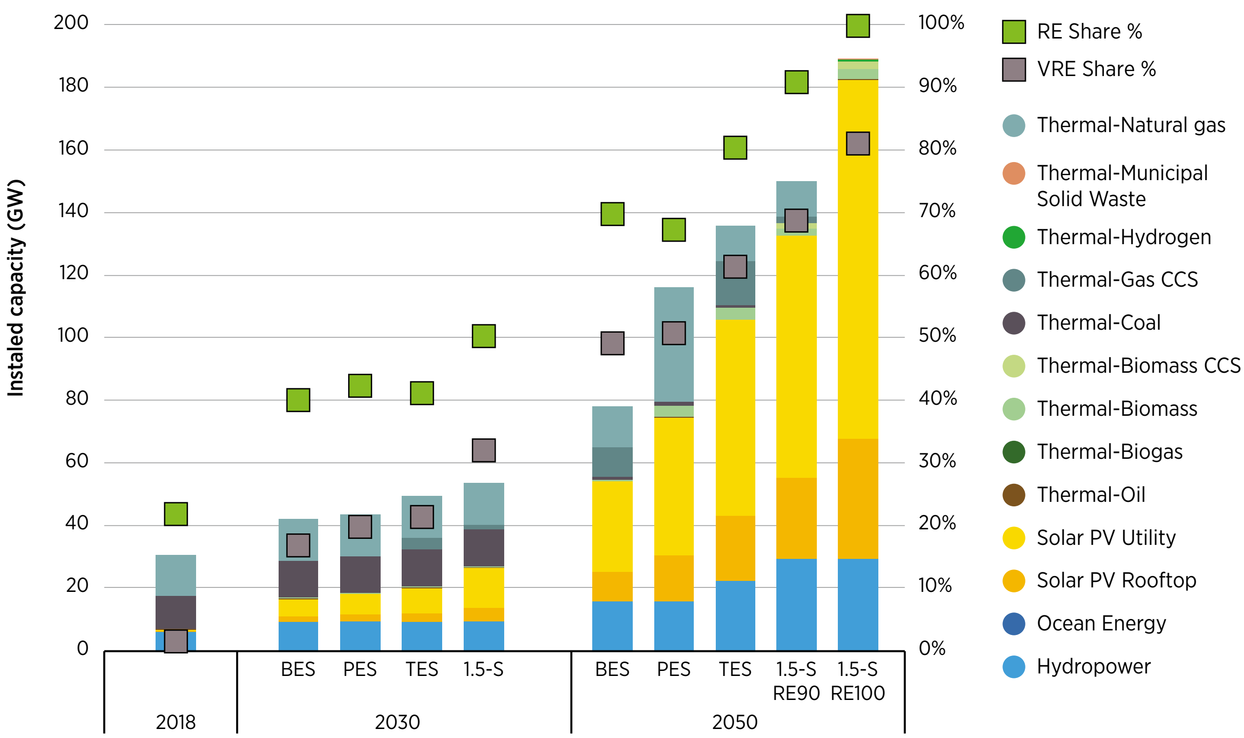
**Power capacity expansion**

National plans imply that coal power generation capacity is set to expand to 2030 in all scenarios, 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 trajectory of decarbonisation by 2060 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.

To explore the dataset for the power capacity and generation growth, please refer to IRENA's online data visualization dashboard released alongside with the regional study, *Renewable energy outlook for ASEAN: Towards a regional energy transition (2nd edition)* (IRENA, 2022b).

***Solar PV will play a key role in Malaysia in all scenarios by 2050.***

**Figure 43** Power capacity growth by scenario, 2018, 2030 and 2050




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

Solar PV is a key technology, and given its modularity and low costs, as well as the rich national resource base of Malaysia, it plays a key role regardless of ambition level. However, it would require careful operational planning and ancillary service provision to integrate effectively. Under the BES, the total capacity of solar PV reaches 39 GW, representing a generation capacity share of 49%. For the other scenarios, the solar PV capacity reaches 59 GW in the PES (51% capacity share), 83 GW in the TES (61% capacity share), and 103-153 GW in the 1.5-S RE90 and 1.5-S RE100 (69-81% capacity shares).

The vast potential for solar PV, coupled with its well-distributed nature, lead it to become the dominate generation source in most scenarios by 2050, with an average build rate in the 1.5-S of nearly 5 GW annually to 2050. 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.

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

The BES and the PES see significant increases in hydropower capacity to 2050, with the installed capacity growing from around 6 GW in 2018 to 16 GW. Because of the strong national hydropower resource in Malaysia (estimated at around 29 GW) it features in all scenarios. However, to achieve the more ambitious energy transition scenarios, these penetrations are dwarfed, reaching 22 GW in the high-renewables TES and 29 GW in both the 1.5-S RE90 and 1.5-S RE100. Here, hydropower provides an invaluable balancing resource because of its ability to balance supply–demand variability.

Biomass power capacity is also envisaged to increase from just a couple of hundred megawatts in 2018 to a maximum of 5 GW in the 1.5-S RE100 case. However, biomass power represents a lower share of the generating capacity mix than other key renewables.

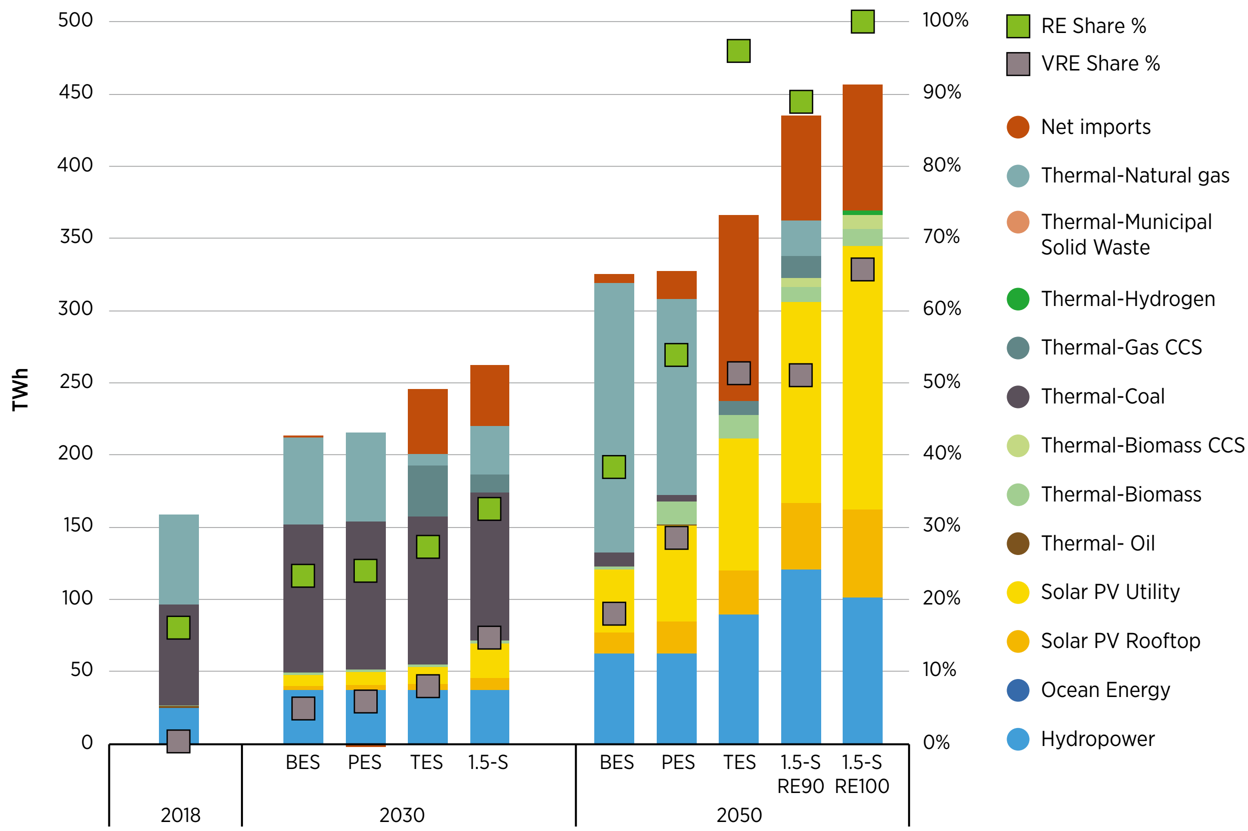
**Power generation**

Fossil fuel generation capacity with and without CCS also has a role: the combined capacity share of these fuels is 30% in the BES, 33% in the PES, 19% in the TES and 0-9% in the 1.5-S cases. These shares belie the value of fossil fuels in being able to deliver power during periods of low variable renewable energy (solar PV and wind) 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.

These scenarios translate into very different power generation profiles, as seen in Figure 44, with renewable shares achieved by 2050 of 38% in the BES, 54% in the BES, 96% in the TES and 90%-100% in the 1.5-S. The majority of this comes from solar PV, with a strong role of power imports leading to lower domestic generation needs. In the generation mix, the role of individual technologies in meeting demand across the year becomes clear. 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. The variability of renewables is mitigated in the ambitious scenarios with low- or zero-emission technologies that can be readily dispatched, such as battery storage, nuclear, and fossil fuel technologies with CCS.

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

**Figure 44** Power generation growth by technology for all scenarios, 2018, 2030 and 2050




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

There is one common factor in all scenarios: the decreasing role of fossil-fuel-fired generation and the rise of solar PV. However, this requires careful policy design and implementation if it is to be achieved successfully. In 2018, unabated fossil fuels represented over 80% of power generation, but by 2050 fossil fuels (both abated and unabated) have penetration rates in the generation mix that reach 62% in the BES, 46% in the PES, 4% in the TES and 0-11% in the 1.5-S. Meanwhile, solar PV represented less than 1% of total generation in 2018, but it rises to 18% in the BES, 29% in the PES, 51% in the TES and 51-66% in the 1.5-S. In terms of levelised power generation costs, both modes of generation have some of the lowest costs of any power generation technology today.

While coal power plants have small land requirements as a technology (albeit with many negative externalities), the same is not true of solar PV. Solar PV cannot be as easily sited near demand centres as it needs to be placed where both the land and resource are abundant, while also considering its proximity to transmission and distribution grids. This implies a substantial need for expansion of the transmission network to accommodate this solar capacity, which is explored in the following sections. This implies a substantial need for expansion of the transmission network to accommodate this solar capacity. One example of this is through the implementation of designated renewable energy zones in the country (such as the Sarawak Corridor of Renewable Energy) where proper planning can be done to evacuate power from the renewable energy sources.

Hydropower, in particular, plays a key role in meeting demand across the year and in mitigating supply–demand variability. Hydropower provides 20% of power generation needs across the year in 2050 in the BES, 20% in the PES, 38% in the TES and 27-33% in the 1.5-S. 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.

Fossil fuels with CCS also play a role in the scenarios, reaching a combined generation share of 0% in the BES, 0% in the PES, 4% in the TES and 0-4% in the 1.5-S. This implies a reliance on the dispatchability of these technologies that increases with the share of renewables achieved in the power system.

**Transmission and interconnection future expansion**

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, as seen in Table 11 below. This is particularly notable in terms of the increased import dependency in the more highly ambitious scenarios out to 2050, which reduces power system costs across the ASEAN region though integrated system planning.

***Transmission expansion needs to increase significantly in the energy transition scenarios, especially when 100% renewable power is pursued.***

**Table 11** International interconnection capacity by scenario and region, 2018, 2030 and 2050

| International interconnection capacity (MW) | | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| **REGION FROM:** | **REGION TO:** | BES & PES | TES | 1.5-S RE90 | 1.5-S RE100 | BES & PES | TES | 1.5-S RE90 | 1.5-S RE100 |
| Sarawak | Brunei | 60 | 60 | 60 | 60 | 100 | 100 | 100 | 100 |
| Sabah | Brunei | - | 895 | 253 | 924 | - | 1 825 | 2 348 | 2 781 |
| Sarawak | Kalimantan (ID) | 230 | 2 796 | 1 450 | 2 619 | 230 | 11 615 | 7 718 | 9 001 |
| Peninsular Malaysia | Thailand | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| Peninsular Malaysia | Sumatra (ID) | 600 | 1 906 | 600 | 2 801 | 600 | 9 189 | 18 934 | 18 685 |
| Peninsular Malaysia | Singapore | 1 050 | 1 921 | 3 658 | 2 115 | 1 050 | 10 086 | 4 365 | 3 039 |
| Sabah | Kalimantan (ID) | - | 2 012 | 459 | 1 953 | - | 12 151 | 6 431 | 14 611 |
| Sabah | Philippines | - | - | - | - | - | 9 352 | 9 000 | 14 828 |
| Peninsular Malaysia | Cambodia | - | - | - | - | - | 17 519 | - | - |

Most notable is the TES scenario, which sees the highest import dependency as a result of constrained renewables build-out nationally and regional interconnection being leveraged to meet demand, mostly imported from countries along the Mekong River with most coming from Viet Nam and Cambodia (due to the complementarity of their generation mixes with significant wind and hydro power capacities respectively) with small flows coming from Laos. However, in the 1.5-S RE90 and 1.5-S RE100 this line is not built, and this renewable capacity is leveraged to meet demand for countries along the Mekong River, a case that was not fully developed in the TES due to lower demand and renewables ambition. This has the useful insight of showing that national planning best not occur in isolation and benefits from a regional perspective – with higher domestic renewables ambition in Malaysia being more regionally cost-effective in a climate-compatible future than increasing import reliance.

Building a national transmission line, from planning and commissioning to full operation, may take as long as a decade. However, much of this expansion is over land and consists of grid reinforcements in Peninsular Malaysia and on Sabah (Sarawak is represented by one node in this study, so deeper integration in this region cannot be captured). In addition, building a line across large bodies of water, especially between Sarawak and Peninsular Malaysia adds a layer of complexity to the entire process (which occurs mainly in international rather than domestic line expansion for Malaysia). Therefore, planning should start as soon as possible so as not to lag behind the expansion needed under decarbonisation scenarios.

The following Figure 45 shows the key transmission candidates that need to be considered in the near term to achieve a highly renewable future.

***Transmission expansion is integral in the power sector transformation.***

**Figure 45** Key transmission lines to be expanded in the near term in the 1.5-S RE90 scenario

**Key line expansion by 2030**

- Domestic line expansion is needed primarily at a sub-regional level
- Line connections with Singapore reach 3.5 GW
- Additional 1.2 GW line between Sarawak and Kalimantan, Indonesia
- 250 MW line between Brunei and Sabah

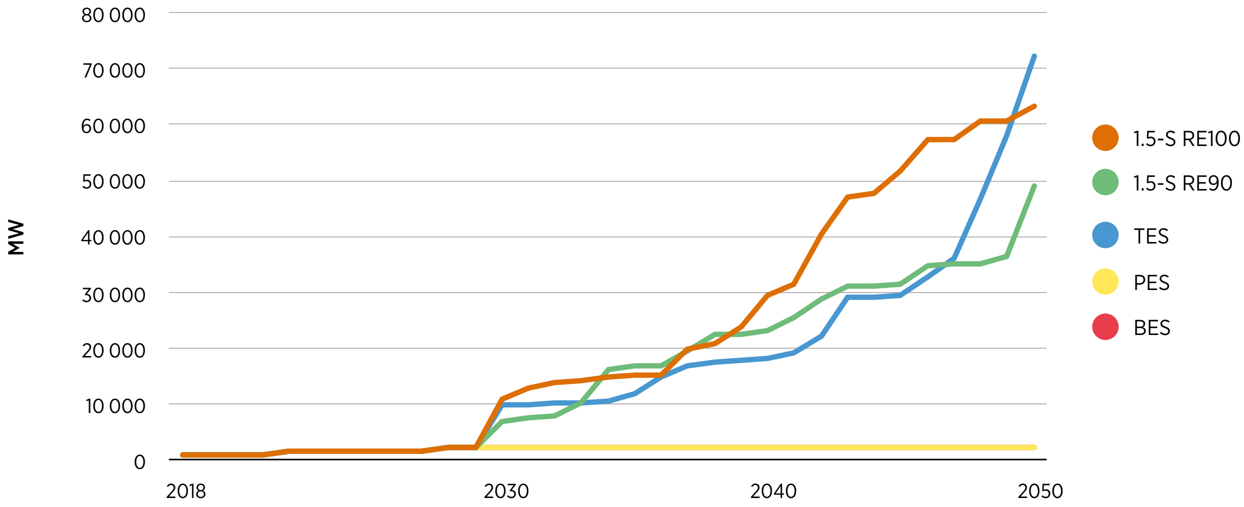
**Key line expansion by 2040**

- Domestic grid integration in Peninsular Malaysia and Sabah is crucial with increased capactiy transmission needed
- 8 GW line between Peninsular Malaysia and Sumatra
- Interconnection of Sabah and Sarawak with Kalimantan reaches a combined 9 GW
- Interconnection of Sabah with Brunei reaches nearly 600 MW

As regards international transmission, expansion is also a significant facilitator of increased renewable energy shares in both Malaysia and the ASEAN region as a whole (Figure 46). 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 the ASEAN region, the results of which can be found in the regional report (IRENA, 2022b).

***Transmission expansion starts to accelerated significantly in 2030 and beyond.***

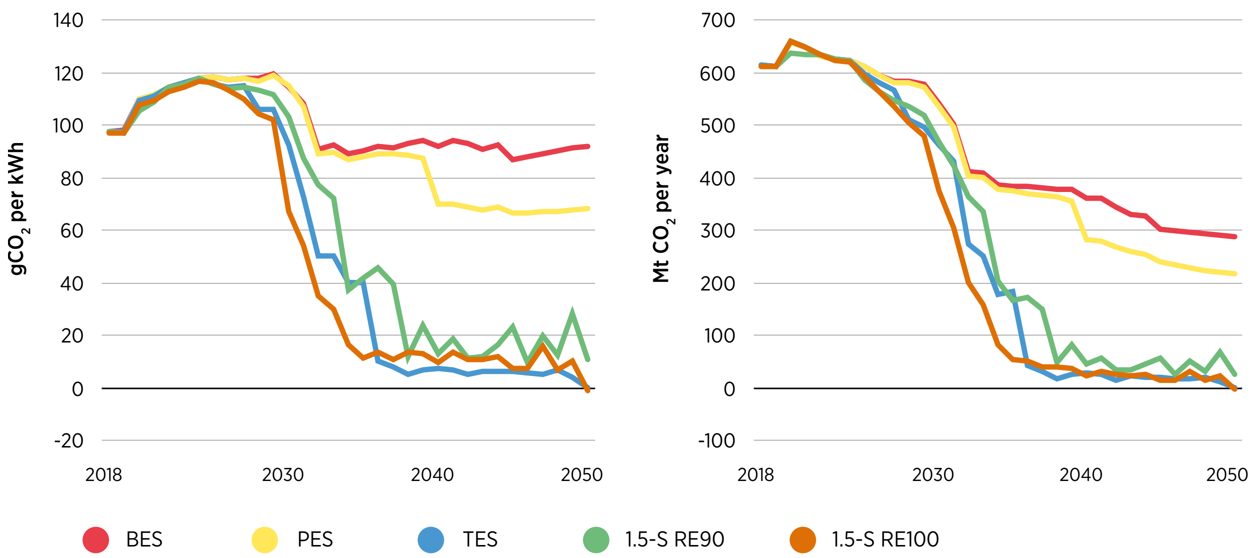
**Figure 46** Sum total of international line expansion for all scenarios, 2018 to 2030




In terms of the emissions intensity of power generation, in line with the differences in the generation mix there are vast differences in the emission reductions that can be achieved (Figure 47). Analysis of overall power sector emissions can mask this differences among 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 and on fossil fuel 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 emission intensity by 2050 through the deployment of solar PV and the expansion of national and international transmission capacity.

***The transition scenarios show declining carbon intensity of electricity generation and steep descreases in the 2030-2040 timeframe.***

**Figure 47** $CO_2$ emissions from the power sector and carbon intensity of power generation, all scenarios, 2018 to 2050



## Box 10 The role of Malaysia in a highly renewable and decarbonised ASEAN power sector

Decarbonising the power sector of the ASEAN region is a significant challenge, but Malaysia could play a key role in making it a reality. Every ASEAN member state has a unique pathway to a highly renewable future and a unique mix of renewable energy resources on which to build this future, as shown in Table 12; however, none can do this cost effectively in isolation. Interdependence can help deliver a lower-cost power sector for all by harnessing economies of scale in energy and non-energy service provision.

### Table 12 Renewable energy resources of Malaysia's regions and of its close regional neighbours

| | RENEWABLE ENERGY RESOURCES (GW) | | | | | |
|---|---|---|---|---|---|---|
| | Solar PV | Onshore wind | Offshore wind | Biomass | Hydropower | Geothermal |
| **Malaysia** | | | | | | |
| Peninsular | 157 | 0 | 52 | 2 | 4 | 0 |
| Sabah | 88 | 0 | 1 | 1 | 5 | 0 |
| Sarawak | 54 | 0 | 0 | 1 | 21 | 0 |
| **Brunei Darussalam** | 2 | 0 | 0 | 0 | 0.07 | 0 |
| **Indonesia** | 2 898 | 20 | 589 | 43 | 95 | 30 |
| **Philippines** | 123 | 4 | 69 | 0.24 | 11 | 4 |
| **Singapore** | 0.311 | 0.142 | 0 | 0 | 0 | 0 |
| **Thailand** | 3 509 | 32 | 30 | 18 | 15 | 0 |

The roles that different regions of Malaysia can play in a decarbonised ASEAN power sector depend on a host of factors, not least of which are its domestic renewable energy resources, how they are distributed and how this corresponds to the situation of neighbouring countries.

Malaysia itself has heterogenous power systems in Peninsular Malaysia, Sabah, and Sarawak, and the needs and resources of each influence capacity expansion in the 1.5-S RE90 and 1.5-S RE100 cases, with the RE100 case largely reinforcing and further expanding the interconnector line and renewable generation capacity expansion candidates.

It is a tale of two halves, with Peninsular Malaysia importing power and Sabah and Sarawak exporting power in the 1.5-S, as reflected in the international line expansion shown in Figure 48. The key influence in Sabah and Sarawak are their respective hydropower resources, which are larger than their peak electricity demand for much of the time out to 2050, even in the 1.5-S with high electrification of energy demand. This is an important resource that can balance variable renewable supply regionally and aid regional decarbonisation. Although there are offshore wind resources, as observed above, they were not built into any of IRENA's scenarios given the relatively low wind speeds and the large distances from demand centres, mainly in northern offshore region of Sabah and Peninsular Malaysia.

## Box 10 The role of Malaysia in a highly renewable and decarbonised ASEAN power sector (continued)

For Peninsular Malaysia, key imports come from Sumatra (Indonesia), owing to natural synergies between both regions in terms of resources and the more limited resource potential available for deployment in Peninsular Malaysia. Some of these imports from Sumatra are directly exported to Singapore due to its rather limited renewables potential, which is reflected in deeper integration of Singapore with Peninsular Malaysia. Despite already being interconnected with Thailand, which is of benefit and use in all scenarios and can lead to multi-national trading beyond both countries, the 1.5-S within the model does not expand it significantly beyond the planned case for direct trading. This owes to them having largely similar generation mixes with a simultaneous peak generation of the high solar PV penetrations in each which leads to a reduced benefit of increased interconnection for direct trading.

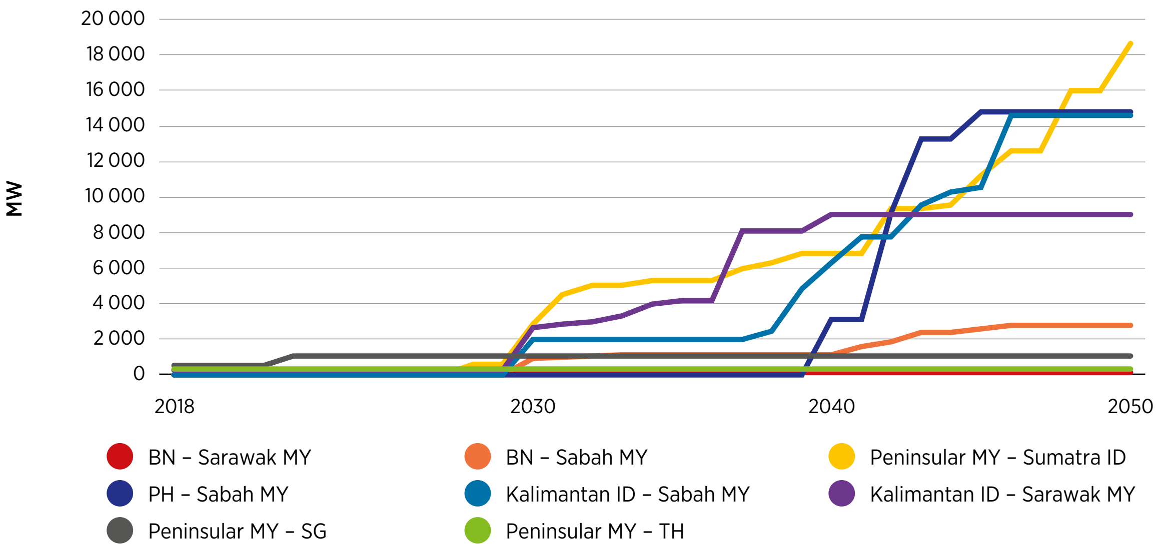
For both Sabah and Sarawak, their potential role in regional integration becomes clear in light of robust expansion of lines between both Malaysian regions, as well as deeper integration of both with Brunei and Kalimantan (Indonesia) using land-based interconnection. Similar to the case of Singapore, Brunei in the long term has low renewable potential in relation to its demand, which results in deeper integration. However, expansion of interconnection with Kalimantan is rather different and must be considered in light of the expansion of lines in the 1.5-S RE100 case for Kalimantan with the island of Java, where Indonesia's largest electricity load centre is located and where much of the power flows to from Sabah and Sarawak.

The Philippines also sees significant expansion of lines with Sabah, due largely to its comparatively low renewable energy resource potential leading to rapid scaling of this interconnection to avert the need for non-renewable power generation. In this regional least-cost optimisation modelling, the hydropower of both Sabah and Sarawak is a key resource and makes both pivotal players in a highly decarbonised ASEAN power sector with a much sought-after resource.

While beneficial at a regional level, all international expansion of transmission lines would also need to be developed with close international collaboration, which highlights the political complexity in developing these lines. This is pivotal in ensuring that their benefits and costs are fairly distributed, which should span the entire life of the projects, from the project development phase through to mutually beneficial operation in the long term.

***Interconnection with neighboring countries will be important to realise the 1.5-S.***

**Figure 48** International line expansion in Malaysia in the 1.5-S RE100, 2018 to 2050




*Note:* BN = Brunei Darussalam, ID = Indonesia, MY = Malaysia, PH = Philippines, SG = Singapore, TH = Thailand.

## Power system flexibility

### KEY MESSAGES

**Malaysia may be a net importer of electricity overall as part of an integrated ASEAN power region**. However, while Peninsular Malaysia will predominantly import power from Sumatra in the 1.5-S by 2050, Eastern Malaysia will be a net exporter to the Philippines, Brunei and Kalimantan.

**Ramping at the portion of the system that has non-variable renewable energy, including storage, becomes more frequent as solar is deployed**. Nevertheless, regions such as Southern Peninsular Malaysia, where the load peak mostly occurs during the day, do not experience extreme ramping even at higher integration levels. This is also a result of the electrification of end uses. Resources like electrolysers for the production of green hydrogen, and electric vehicles help the uptake of renewables, but pricing mechanisms for small consumers must be in place (*e.g.* time-of-use-rates).

**Power storage facilities are set to become operational during 2030-2035 and to reach large-scale cost-effectiveness from 2040 onwards**. Projects coming online before this period will likely be more focused on solving local structural issues such as critical network congestion than displacing large-scale supply over time. Storage in neighbouring countries is favourable to make solar-based imports less variable as well. The technology growth in the period 2030-2050 is very steep, and hence planning is needed for the overall industry.

**Spinning reserves equal to 10% of the load can be met at all times by available batteries and hydropower resources**. Nonetheless, stability protocols need to be redesigned as power systems move from synchronous machines to inverter-based generation. Results suggest that inertia available in the system by 2050 would not be enough to maintain stability after a hypothetical in-feed loss larger than 2 GW. The system should be planned to reliably operate with fewer and fewer synchronous machines in the future, when grid-forming inverters are likely to assume the leading role.

**The full potential of renewables requires new institutional frameworks for the exchange of power and the alignment of regulations, including operators beyond national borders**. There should be no privileges for domestic resources, ideally 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.

Malaysia's electricity generation under the decarbonised 1.5-S RE90 scenario is around 350 TWh, a mere 4% increase from the planned pathway despite significant electrification of the energy sectors, which also enhance energy efficiency at the end-use level. The share of renewables in Malaysia's power sector under the PES is 52%, of which 23% is supplied by solar generation. That increases to 81% under the 1.5-S RE90 scenario, with 27% (95 TWh) provided by hydropower and 49% (172 TWh) from solar. Therefore, roughly half of the country's electricity would be subject to the solar resource availability. Biomass is responsible for 5% (18 TWh), and wind does not have any relevant participation in any scenario for the country. Natural gas is responsible for 50 TWh and makes up 17% of generation.

Due to Malaysia's proximity to the equator, the solar profile does not change much across the year, similar to other countries in the region. The natural solar profile creates the needs for storage requirements to help match generation with demand, but long-term storage requirements tend to be reduced. This also relates to low temperature amplitudes experienced, which do not make demand stable across the year. The non-variable renewable energy portion of the system must operate flexibly to essentially follow the system net load, and flexibility must adapt, to the extent possible, to the availability of electricity in the system.

Electricity supply and demand must be equal at all time scales. Balancing them is crucial to keep system frequency at desirable levels and to ensure stability.[8] 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 time scales, 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 time scales.

This study considers a range of flexibility options to integrate solar generation in Malaysia. They rely on the assumption that there will be a price or time-based signal to consumers, or a call from transmission service 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 made under wholesale markets that also include the participation of small and medium consumers through aggregators, demand response programmes at industrial facilities, and others.

Flexibility options considered for this study are:

1) smart charging of electric vehicles (as opposed to charging when it is most convenient for the user, such as when arriving at home);
2) flexible production of green hydrogen;
3) storage assets to support both arbitrage but also the provision of spinning reserves; and
4) the expansion of the transmission grid.

**Impacts on the non-variable renewable energy portion of the system**

Flexibility from conventional generators such as thermal units and hydropower is in principle the most elementary way of adjusting supply to the availability of variable renewables. In other words, these units should modulate power to meet net load, which is the load minus solar and wind generation. However, technologies are different in doing so, with their capabilities being measured in terms of how fast they can increase or decrease power (cold, warm start or online), the lowest stable operation level they can operate (as they give room to renewables), and others.

*8 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.*

As more variable renewable energy comes into the system, the gap between the lowest and highest net load tends to increase. There will be moments in which net load will be close to zero due to massive variable renewable energy generation, while there are moments of almost no generation from variable renewables. Besides, electrification of end uses increases the overall demand, which in turn stretches the peak further.

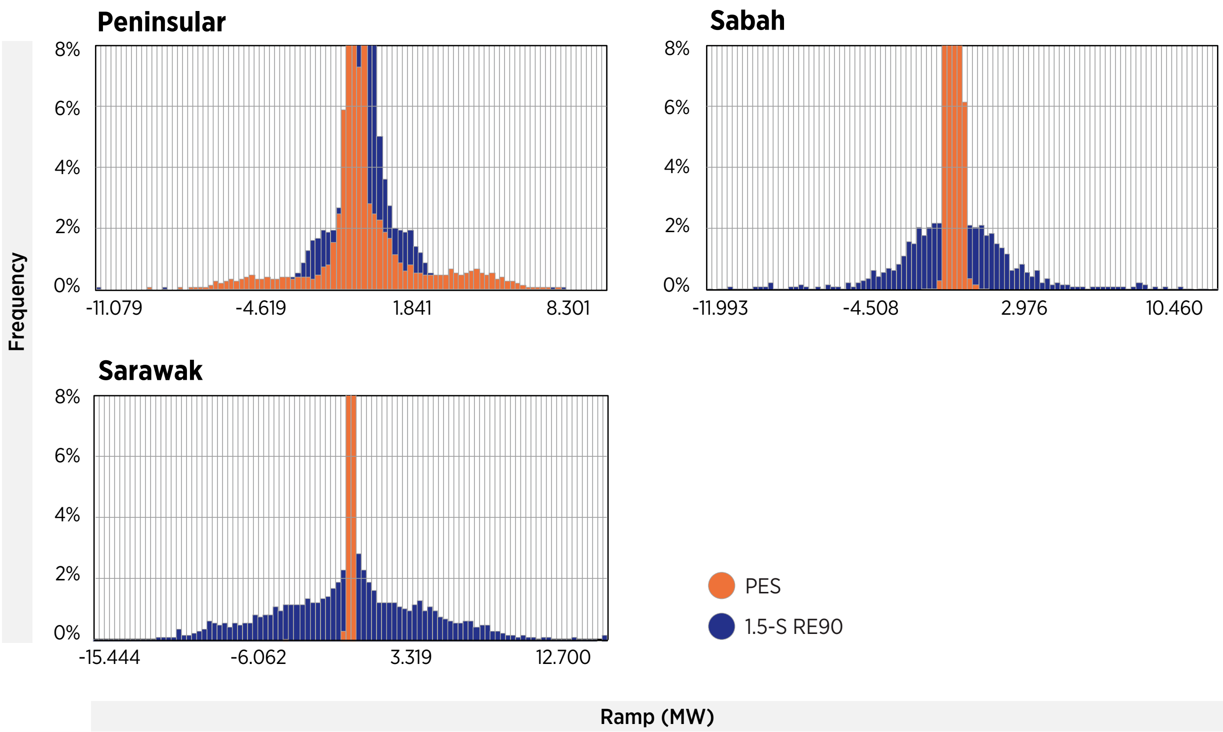
The hourly power ramping indicates the modulation of power that one or more generation units must adjust in order to follow solar generation. Typically, the more variable renewables in the system, the higher the magnitude of the ramping. Extreme ramping at conventional units in Sarawak and Sabah power systems increases significantly. In Sabah, while the range +350 MW/-350 MW accounts for almost 90% of power modulation in the PES, the same range accounts for 50% in the decarbonised 1.5-S.

In Sarawak, the range +50 MW/-250 MW accounts for 99% of ramping under the PES, which drops to only 35% in the 1.5-S. This means more frequent high-magnitude ramping in both cases, which eventually exceeds 10 GW in rare cases (Figure 49). Co-ordination is fundamental between dozens of generators to meet ramping of 6-10 GW (100-165 MW per minute), which would need to modulate power simultaneously.

The case in Peninsular Malaysia is slightly different, as the peak load in regions such as the south mostly occurs during the day. That is also a result of end-use electrification. Generally, the stronger the solar generation the lower the peak, which in turn reduces the operational range for non-variable renewable energy units. As a result, ramping increases at the mid-size magnitude, but very little at the extremes, illustrating a synergy of solar integration.

***Co-ordination between non-variable renewable energy assets helps deal with increasing extreme power ramps as a result of solar integration in Sabah and Sarawak. Yet, concurrent solar generation and peak load brings synergies and may reduce ramping in Peninsular Malaysia.***

**Figure 49** Non-variable renewable energy generation one-hour ramping by region for the PES and 1.5-S

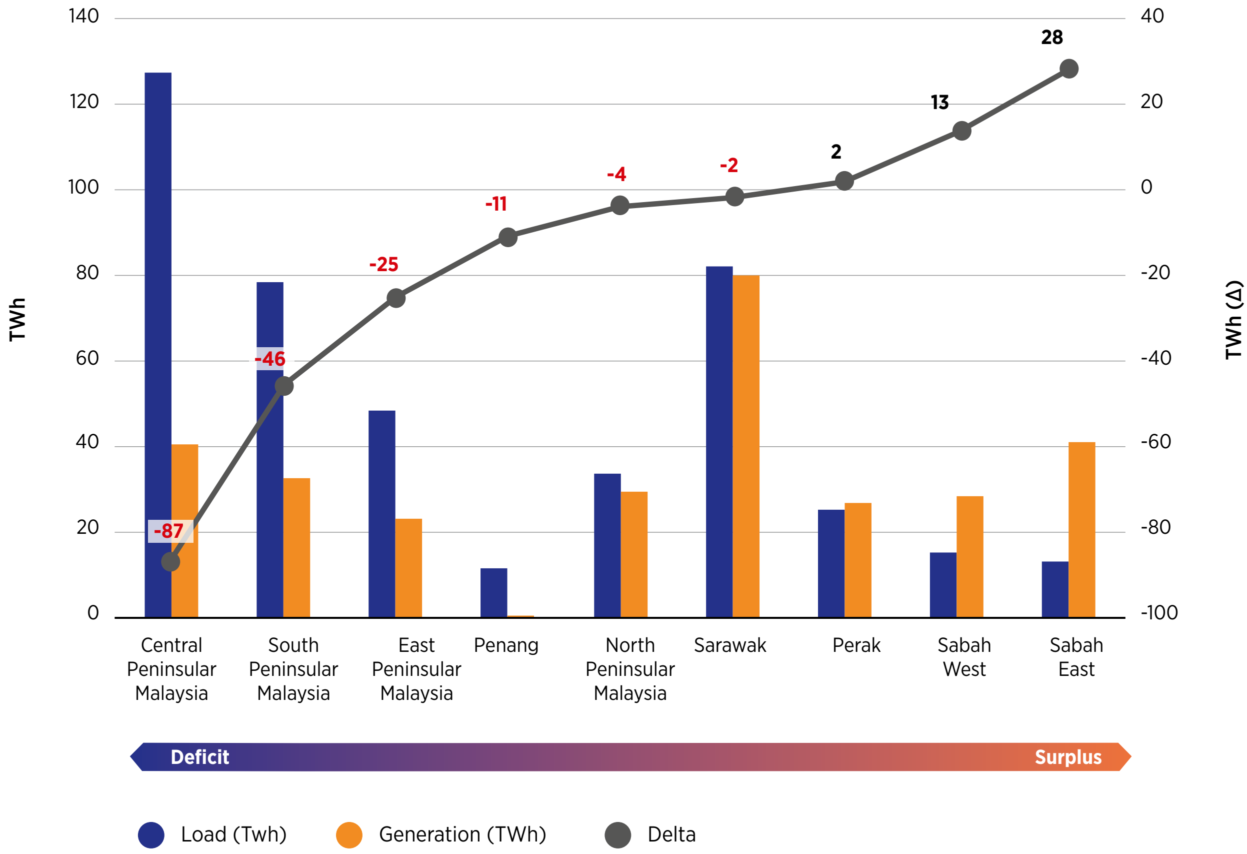


**Power exchange is the principal flexibility measure in solar-dominated environments**

From a national perspective, Malaysia may be a net electricity importer in the future (Figure 50). However, the country has an interesting role in providing renewables and flexibility to neighbouring countries, in particular from Sarawak and Sabah to Kalimantan (Indonesia) and the Philippines. Indeed, Western and Eastern Malaysia may remain separate if an interconnection linking the two is not seen as cost effective from an ASEAN region perspective. This means that the power deficit in Peninsular Malaysia would be mostly supplied by Sumatra (Indonesia).

***Energy deficit in Peninsular Malaysia results in reliance on imports, while Sabah is a net energy exporter.***

**Figure 50** Surplus/deficit of electricity in 2050 in the 1.5-S RE90 scenario, not considering power exchange with neighbouring countries

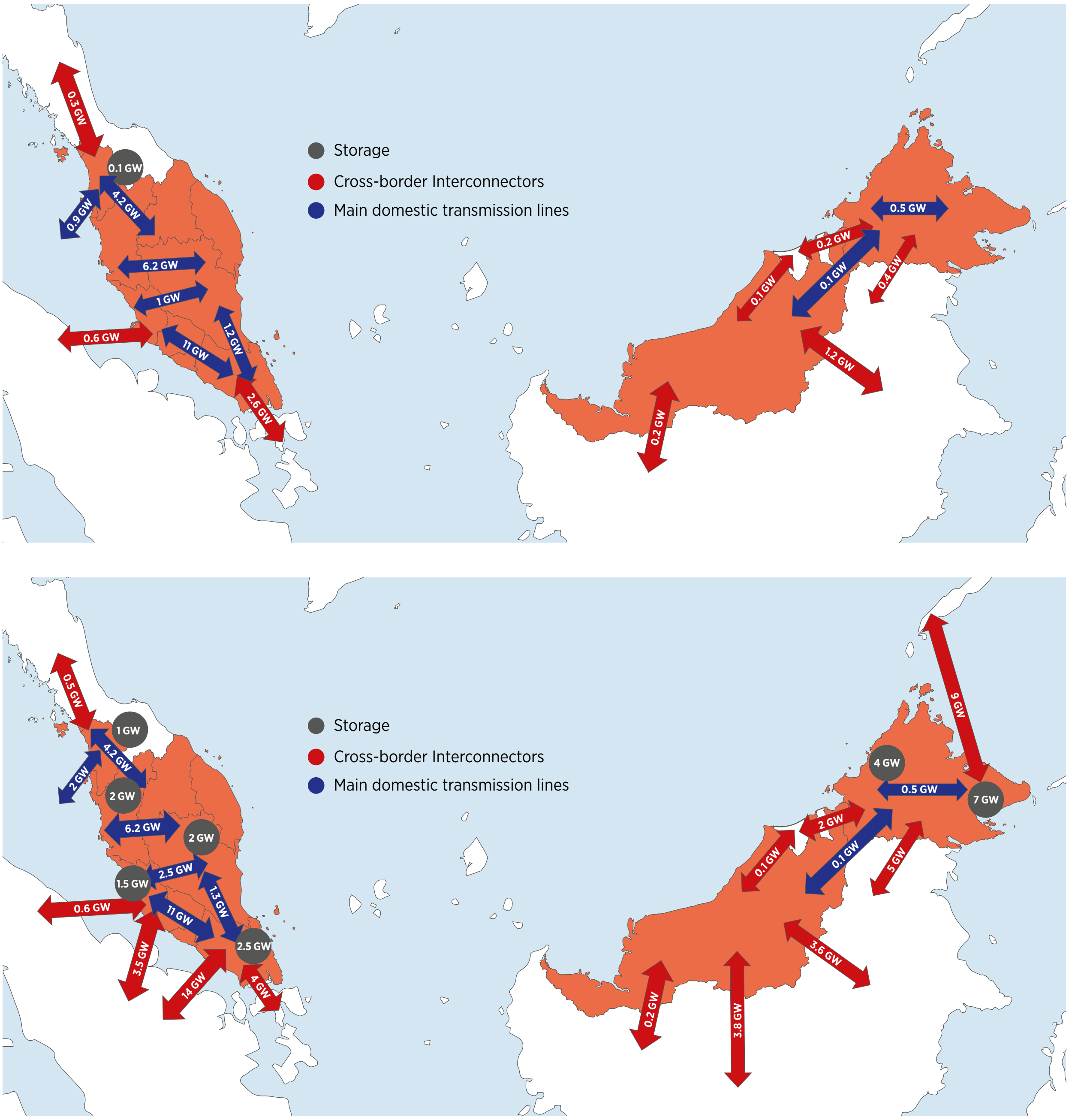



Resource-wise, the largest solar generating regions under the most ambitious decarbonisation scenarios are Central Peninsular Malaysia (23%), Sabah East (18%) and Sarawak (16%), with 25-33 TWh each. They are followed by South Peninsular Malaysia (11%), Sabah West (11%) and East Peninsular Malaysia (9%), with 12-17 TWh each. Thus, generation is split fairly evenly between Western Malaysia (53%) and Eastern Malaysia (47%). Nonetheless, Central and South Peninsular Malaysia are net importers despite generating roughly one-third of the domestic solar generation by 2050. The figure is less balanced for hydropower resources, where Sarawak produces 67%, and Sabah 18%, together comprising 85% of total generation.

The transmission infrastructure at the national level and cross-border follows the aforementioned context. Central and Southern Peninsular Malaysia rely on increasing import levels, which kicks off with a relatively small connection with north Sumatra (Indonesia) by 2030. Exchange capacity is enhanced through high-capacity connections with central Sumatra by 2050, resulting in over 150 TWh in net imports from the region (Figure 51). To a lesser extent, imports also come through Singapore (net 10 TWh), which is also a net importer from Sumatra and eventually connects with Kalimantan in the long term. Overall, there is a dominant electricity flow that goes from south to north along the peninsula, suggesting import feeds beyond connection points. Cross-border connection with Thailand is small across the study, with similar amounts flowing in either direction.

***Interconnectors permit the least-cost integration of renewables from the ASEAN region perspective. The main cross-border flows would be with Sumatra for Peninsular Malaysia, and with Kalimantan and the Philippines for Sarawak and Sabah.***

**Figure 51** Transmission lines and storage under the 1.5-S in 2030 (upper) and 2050 (lower)




*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.

In Eastern Malaysia, Sabah is a net importer with Brunei by 2030, but the situation reverses in the long term, with Sabah West predominantly selling power to Brunei in 2050 (net exports of 10 TWh). Concurrently, renewables in East Sabah would require submarine cables crossing the Sulu Sea to reach Palawan in the Philippines, operational from 2045 onwards (net exports of 33 TWh).

Sarawak mainly exchanges with Kalimantan, although the overall balance is low with exports to Southern Sumatra and imports from the north-eastern region. Additional connections with Kalimantan will follow, including a long-length line capacity to southern Kalimantan, which may benefit from the respective connection from that region to Java by then.

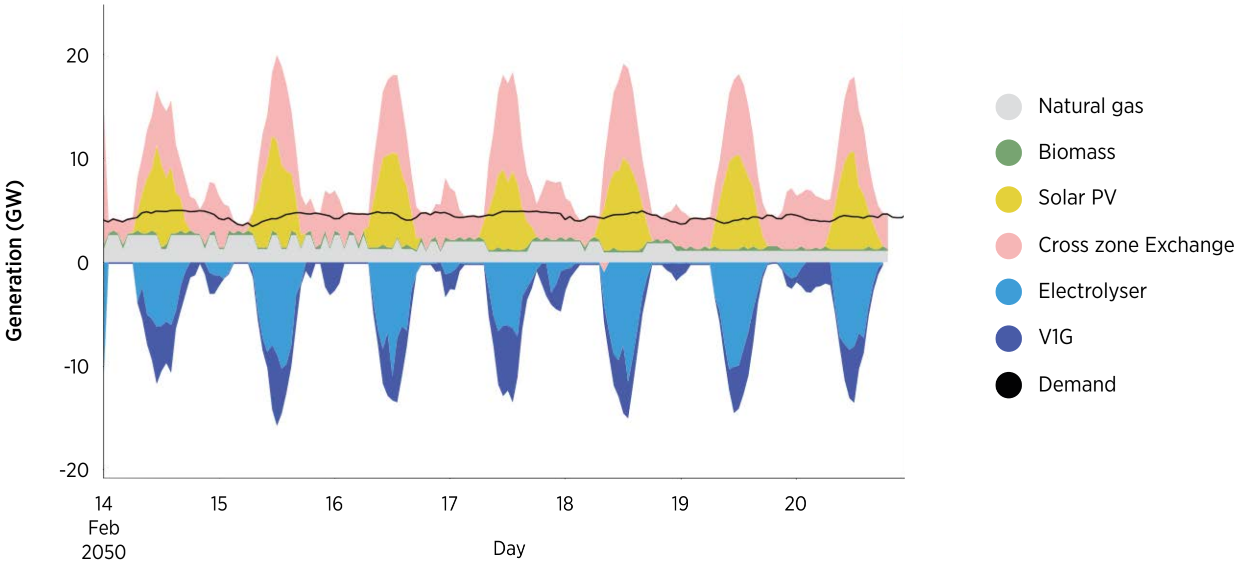
**Storage facilities interplay with transmission assets and make cross-border exchange key to the energy transition**

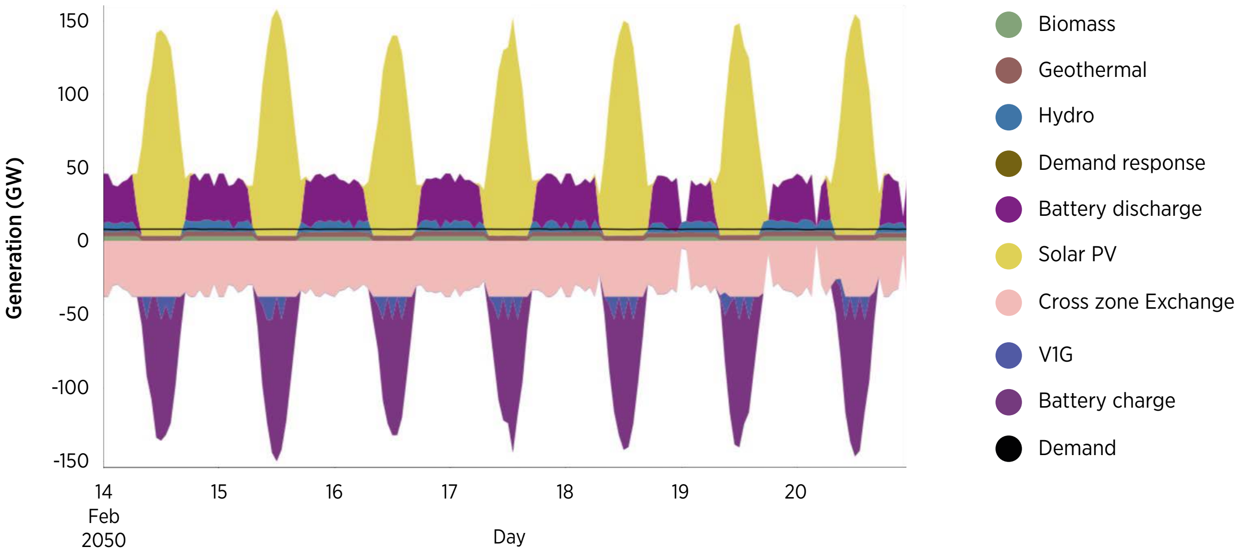
The natural profiles of solar resources make it impossible to continuously provide electricity without the use of a storage device, essentially making it possible to meet demand outside of daylight hours. Short- to medium-term storage facilities cycle daily to absorb the solar generation and, as such, operate in tight co-ordination with power generation. At the same time, interconnectors allow for delivering solar energy to where it is most needed, including through cross-border exchange.

Because Malaysia is an overall net power importer, cross-border electricity plays an important role in the peninsular dispatch by 2050. Peninsular Malaysia imports over 100 TWh of solar-based electricity from Sumatra in 2050 through the Central and South regions. Storage assets can be placed in Malaysia, making solar a reliable and stable provider of electricity throughout the day despite the resource profile (Figure 52). Natural gas-based power plants may still have a role in providing peaking flexibility. Electric vehicles make good use of low electricity prices during the day, just as electrolysers do in the south and east regions. The ability of electric vehicles and green hydrogen to support the system balance is naturally higher in regions where both vehicle fleets and green hydrogen production demand are higher.

***Peninsular Malaysia is a net electricity importer in a renewables-dominated scenario. Thus, storage projects in neighbouring countries enable reliable solar-based imports.***

**Figure 52** Dispatch operation in South Peninsular Malaysia (upper) and Central Sumatra, Indonesia (lower) in a high variable renewable energy week in 2050



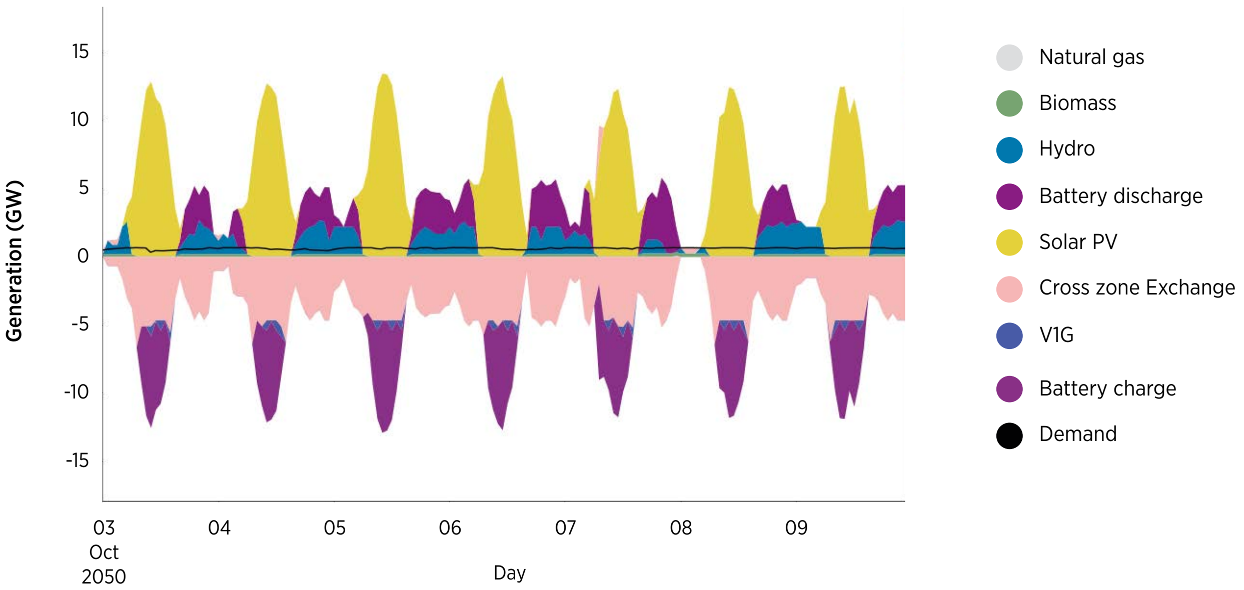




*Note:* V1G = unidirectional smart charging of electric vehicles.

With relatively low demand, Sabah is a net exporter of electricity, sending over 30 TWh (net) towards the Philippines, with the power either produced domestically in the eastern region or coming from Kalimantan. In this latter case, Sabah serves as a wheeling region (Figure 53). Net exports from the West to Brunei total 10 TWh in 2050. Internal exchange between the West and East, and between the West and Sarawak, is relatively low. Hydropower resources are also exported during the night time.

***Sabah is a solar-based net exporter, complemented by hydropower-based generation. The region eventually acts as a wheel for exports from/to Kalimantan and from/to the Philippines.***

**Figure 53** Dispatch operation in East Sabah in 2050

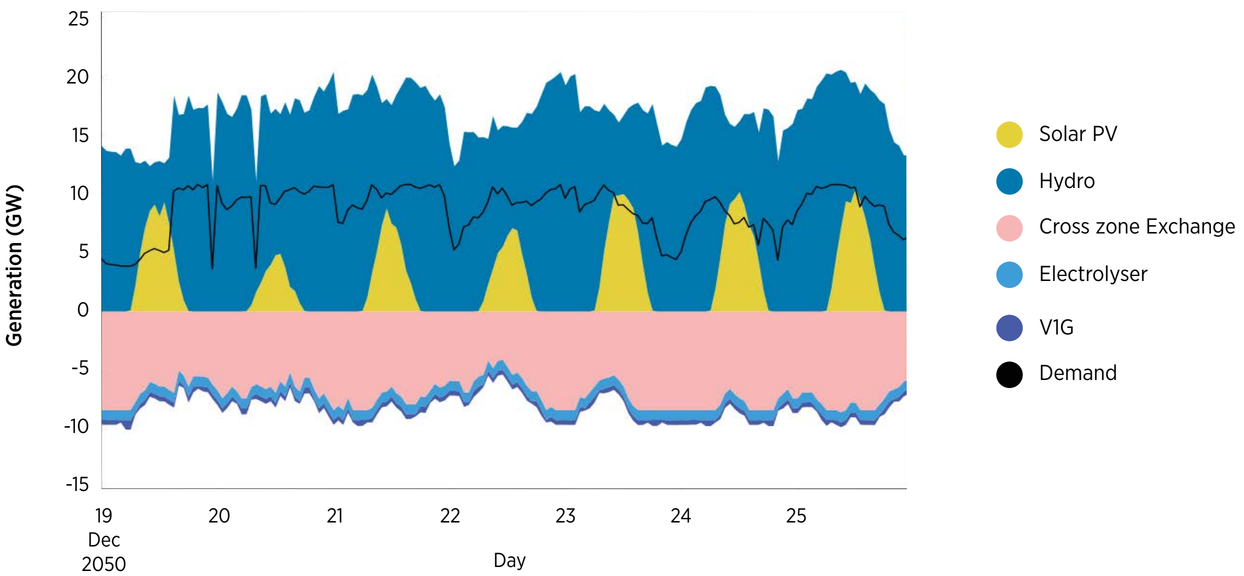



*Note:* V1G = unidirectional smart charging of electric vehicles.

At a significantly larger scale, hydropower is the main generation technology in Sarawak, contributing more than 60% of the generation. Thus, the technology operates on the base but also follows the demand tightly (Figure 54). The hydropower resource also supports neighbouring regions with flexibility in certain moments of the year, although the overall exchange balance is close to zero. Electric vehicles and electrolyser consumption are relatively small, so they neither greatly improve flexibility, nor raise flexibility problems.

***Hydropower is the base generation and flexibility provider in Sarawak. The technology eventually also supports neighbouring countries.***

**Figure 54** Dispatch operation in Sarawak in 2050

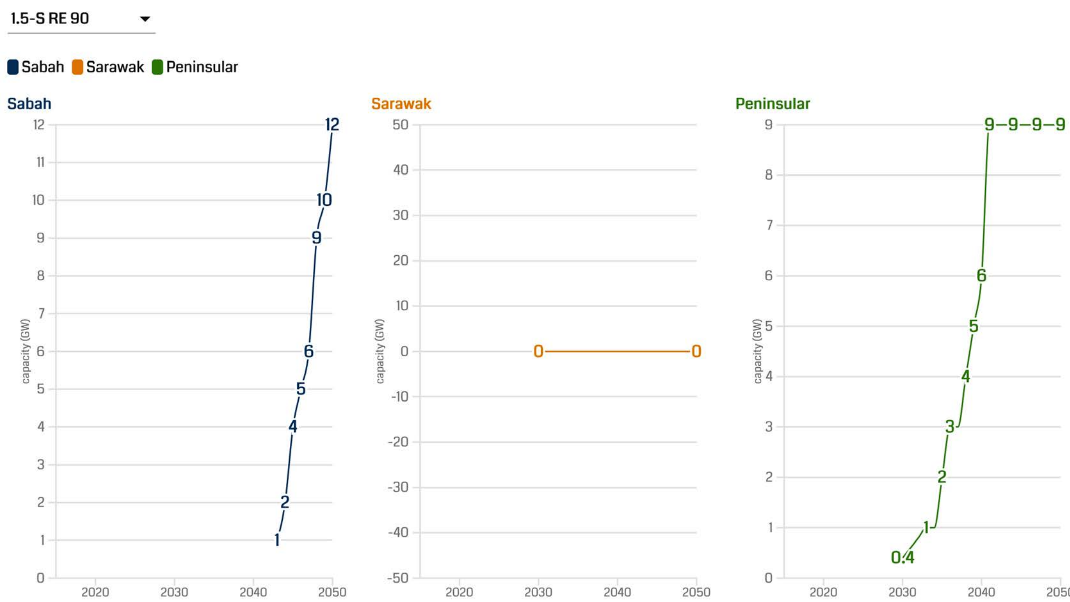



*Note:* V1G = unidirectional smart charging of electric vehicles.

Storage deployment is proportional to solar facilities. Regions in Sabah and Peninsular with solar projects also present opportunities for battery facilities. In the case of Sarawak, hydropower reservoirs act as storage, and therefore other technologies are not needed (Figure 55). This also has implications for the provision of spinning reserves in the different regions. Batteries become cost effective mainly from 2030 onwards, although sparse projects can come online before this period.

***Storage is cost effective, particularly from 2040 onwards, and the first large-scale systems come online starting in 2030-2035.***

**Figure 55** 10-hour-Li-Ion battery deployment in Peninsular Malaysia, Sabah and Sarawak under the 1.5-S RE90 scenario, 2020 to 2050




**Hydropower and batteries are sufficient to meet spinning reserves under scenarios of high renewable energy**

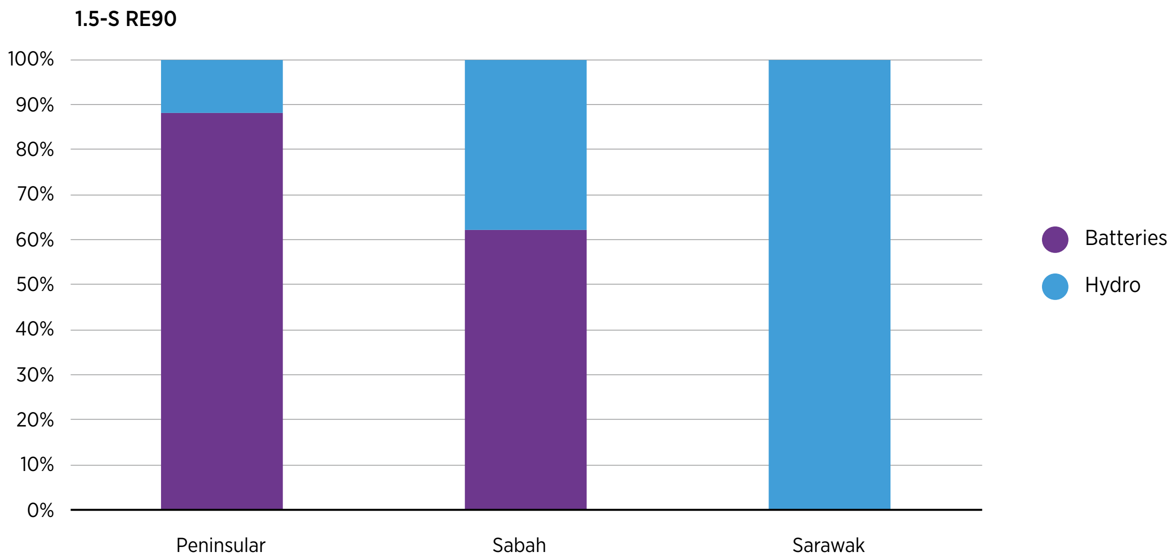
Spinning reserves are the amount of unused generation capacity at online power assets that are kept in stand-by in the event of power shortages or drops in frequency. In practice, reserve providers are required to operate below their rated value so they can quickly ramp up power when needed. Reserves requirements are typically defined based on the largest power asset (usually a generator, but also transmission lines and other assets), the so-called n-1 criteria. In renewable-dominated systems, the installed capacity of generation units tends to decrease with distributed and smaller-scale assets rather than large, centralised power plants. Therefore, reserve requirements would also reduce. However, transmission capacity tends to increase given the increasing need to take power from the best renewable resources to demand centres, which could increase requirements.

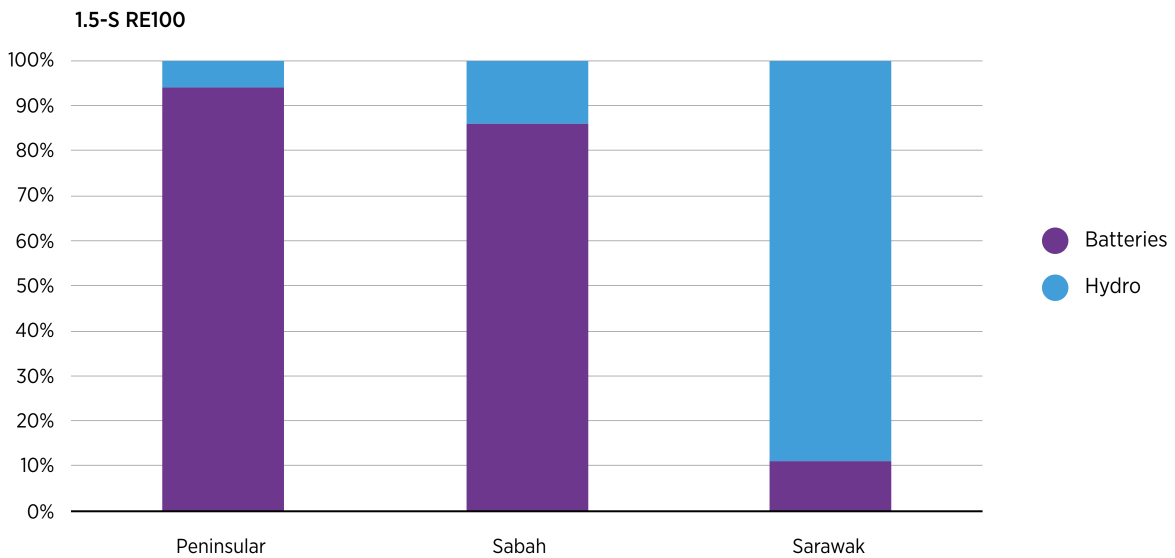
In this study, reserves were defined as 10% to 20% of the load for all three regional grids. Reserves can be shared within a region (*e.g.* Perak and East Peninsular Malaysia) but not across macro-regions (Sarawak and Sabah). Only hydropower and storage assets were allowed to provide assets by 2050 (upward/downward), to avoid having non-renewable assets lock in for this purpose. Whether 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 were set to provide downward reserves only (curtailment), although operation adjustments could also allow the technologies to offer an upward response.

The provision of reserves at 10% to 20% of the load can be met entirely by renewables, subject to the resources available in each region (Figure 56). Whereas batteries meet most of the requirements in Peninsular Malaysia and Sabah, hydropower is nearly the only provider in all scenarios in Sarawak. Nevertheless, the decarbonised scenario foresees a transmission capacity connecting Peninsular Malaysia and Sumatra of around 14 GW, or roughly one-third of the average load in the region. Even though the link should be made by two or more line circuits (reducing an eventual capacity loss), this illustrates concerns related to exchanging massive amounts of power and their impacts on the system operation.

***Spinning reserves are largely provided by batteries as solar grows in the system.***

**Figure 56** Spinning reserves provision in Peninsular Malaysia, Sabah and Sarawak in 2050 under the 1.5-S



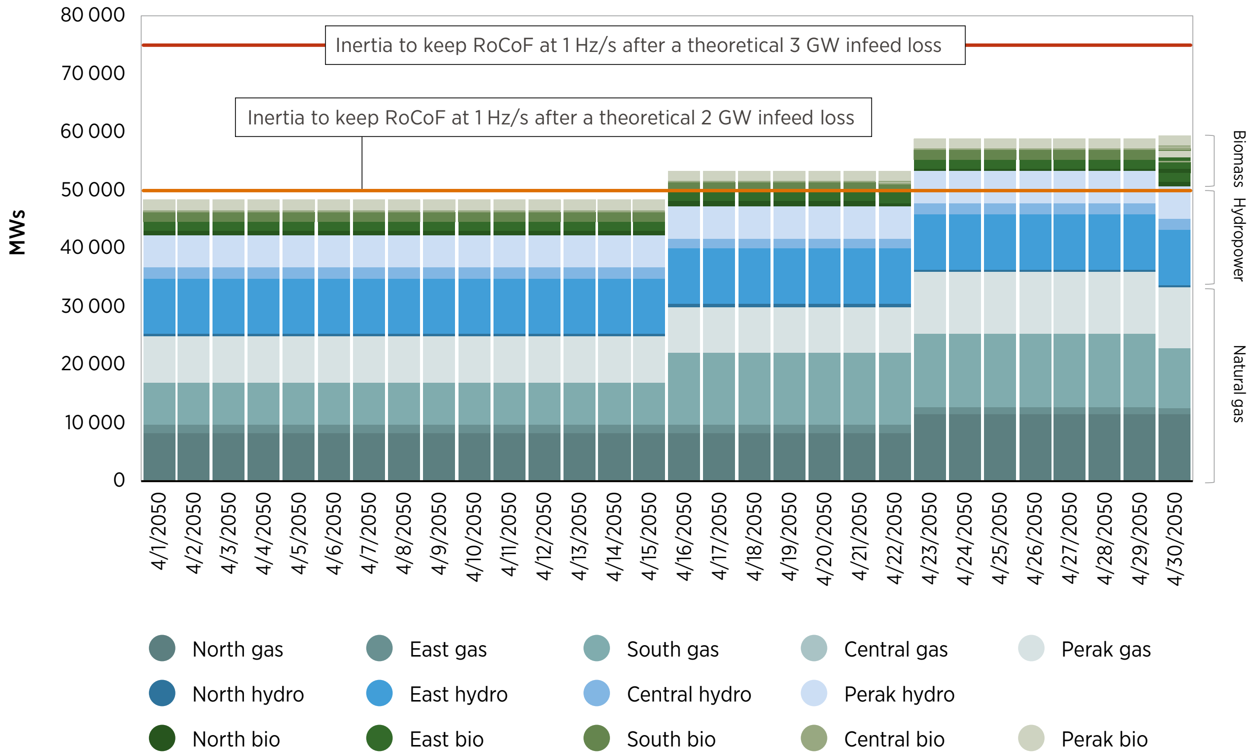
Stability protocols need to be redesigned as power systems move from synchronous machines to inverter-based generation. Gradually, less inertia will be available, with diminished ability to oppose changes in frequency after a failure, as inertia is inherently provided by synchronous generators such as thermal plants and hydropower. The reserves to be procured and the agility needed in today's power systems is a function of inertia conditions.

Based on assumptions and scenarios considered in this study, inertia provision in Peninsular Malaysia would be set at around 50 MW on average, mostly provided by hydropower and natural gas thermal generators. This would be enough to roughly maintain the rate of change of frequency (RoCoF) at 1 Hz per second after a hypothetical in-feed loss of 2 GW, which may be considered a high rate (Figure 57). Two times this number would be needed to keep it at 0.5 Hz per second, and five times this value would be needed to keep the RoCoF at 0.5 Hz per second after a loss of a 5 GW in-feed, which could potentially be a high-voltage transmission line.

This matter should be at the forefront of integration studies in Malaysia. Nevertheless, grid-forming inverters are on the verge of addressing this issue, allowing operation at very-low or even zero inertia conditions, even though further research is needed. Additionally, faster frequency response resources such as batteries and different means to signal imbalances will be needed.

***Inertia-based traditional protocols to uphold stability after a system failure will need to be redesigned, as operations move from synchronous machines to inverter-dominated generation.***

**Figure 57** Inertia contribution by synchronous machines in the Peninsular grid in April 2050 under the 1.5-S RE90



## 4.4 **SPECIAL THEMATIC FOCUS**: THE ROLE OF HYDROGEN, BIOENERGY AND LOCAL SOLAR PV INDUSTRY

### KEY MESSAGES

**Hydrogen will provide a complementary solution to Malaysia's ambitious climate objective**. Hydrogen will comprise up to 5% of total final consumption (including non-energy use) in the 1.5-S by 2050, where it will play a role in decarbonising some industrial sub-sectors and meet a growing market for green hydrogen trade.

**Bioenergy will need to play a bigger role in Malaysia's decarbonisation efforts compared to today, by promoting robust bioenergy policies and improving accounting standards across all end-use sectors**. Bioenergy demand in the 1.5-S will contribute around 14% of total final energy consumption by 2050, mostly in the form of liquid biofuel consumed in the transport sector. This will be used both in road transport and as sustainable aviation fuel (SAF), and as a substitute for fossil fuels in industrial processes.

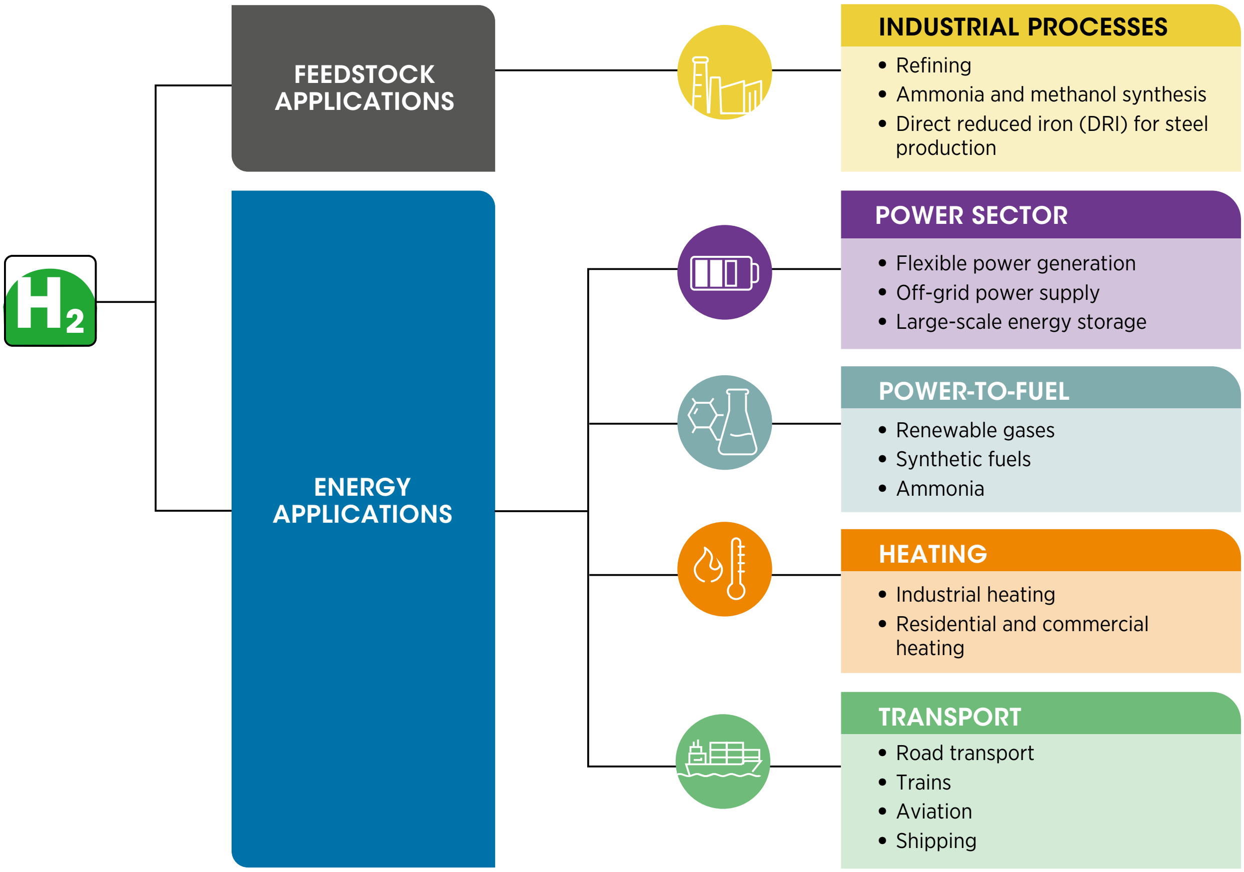
**With up to 2 400 GW of solar PV installed capacity required in a 1.5-S pathway in the ASEAN region by 2050**, Malaysia has an opportunity to expand its current PV manufacturing industry to cater to local and regional demand. Becoming a regional PV hub can bring multiple socio-economic benefits to Malaysia.

### Hydrogen demand and outlook in Malaysia

IRENA's *World Energy Transitions Outlook 2022* (WETO) envisions that global hydrogen demand in a 1.5°C scenario would be 600 million tonnes by 2050 (IRENA, 2022a). As more countries raise their ambitions to become climate neutral, green hydrogen (hydrogen produced from renewable energy) and synthetic fuels derived from green hydrogen can play a key role in the energy transition. This application is especially critical in hard-to-decarbonise sectors such as steel, fertilisers, plastics production and the maritime shipping sector, as seen in Figure 58.

***Hydrogen can have a range of applications but it is important that the hydrogen is produced in a low to zero carbon way.***

**Figure 58** Green hydrogen and its applications



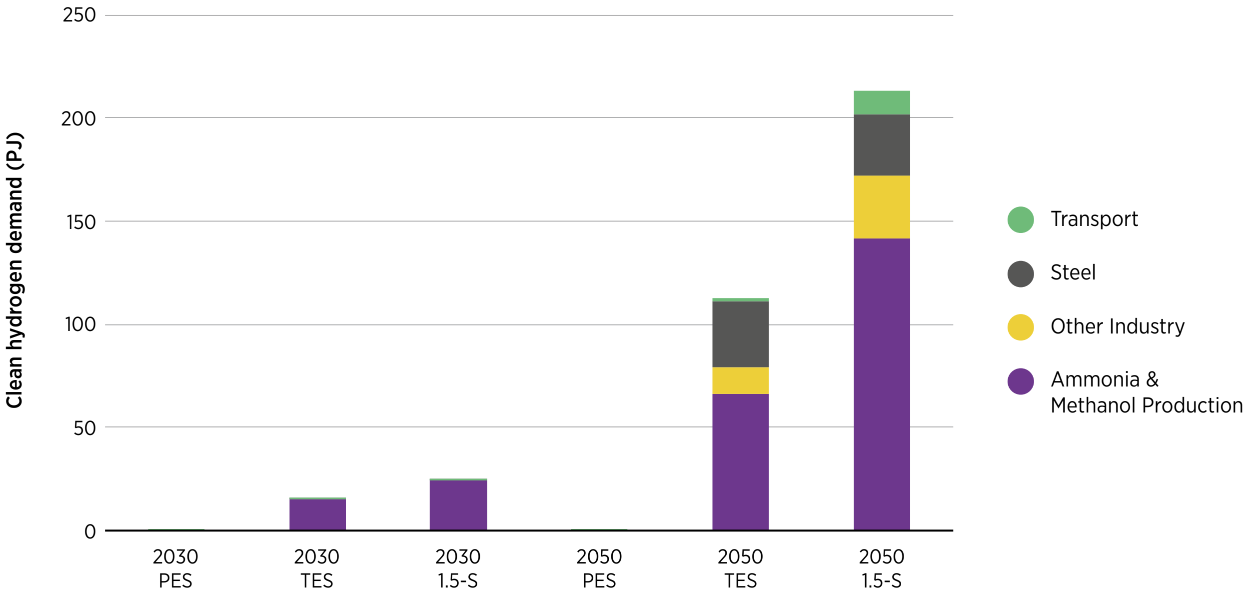

*Source:* IRENA, 2022e.

Several energy players in Malaysia have already committed to becoming hydrogen[9] supply hubs to key demand countries in Asia, such as Japan and the Republic of Korea. The national energy oil and gas company, PETRONAS, plans to produce up to 50 000 tonnes of low-carbon hydrogen by 2027 (PETRONAS, 2022). Sarawak, with its vast hydropower resources, also has plans to produce up to 1.2 million tonnes of green and blue ammonia and 0.2 million tonnes of hydrogen, not only for export but to cater to planned domestic use in transport (The Star, 2022). Additionally, the government is developing a hydrogen economy roadmap to set the policy pathways for different industry players in the region.

*9 With regards to terminology, hydrogen can be distinguished according to its source of supply. Majority being produced today is conventionally produced from fossil fuel and coal, known as grey hydrogen. Blue hydrogen is defined grey hydrogen with carbon capture and storage included, while green hydrogen is produced with renewable energy (IRENA, 2021e).*

*Hydrogen demand in Malaysia is expected to grow significantly in the 1.5-S.*

**Figure 59** Hydrogen demand projection for all scenarios, 2030 and 2050




IRENA's analysis projects that in a decarbonised energy scenario (the 1.5-S), domestic demand for hydrogen in Malaysia could reach 25 PJ by 2030, then further increase to 213 PJ (1.5 million tonnes of hydrogen) by 2050. This represents around 5% of the total final consumption. Around 55% of the hydrogen demand would be for non-energy use, such as feedstock for the production of ammonia and methanol. Apart from exporting to key markets, hydrogen can be utilised domestically in Malaysia for the industrial sector as well as in transport, especially to power trucks and buses.

Situated in one of the busiest international shipping routes, Malaysia has the potential to become a hydrogen supply hub for bunkering, and it currently captures around 0.2% of the total international bunkering market. IRENA's WETO 1.5°C Scenario proposes that by 2050, 60% of all fuel needed for international shipping will be from hydrogen and its derivatives, including ammonia and methanol; demand in Southeast Asia alone would be 1 060 PJ by 2050. Therefore, there is a wide opportunity for Malaysia to capture more of the market share either to provide bunkering fuels or to export hydrogen from its excess renewable-based electricity.

### Hydrogen supply in a global context

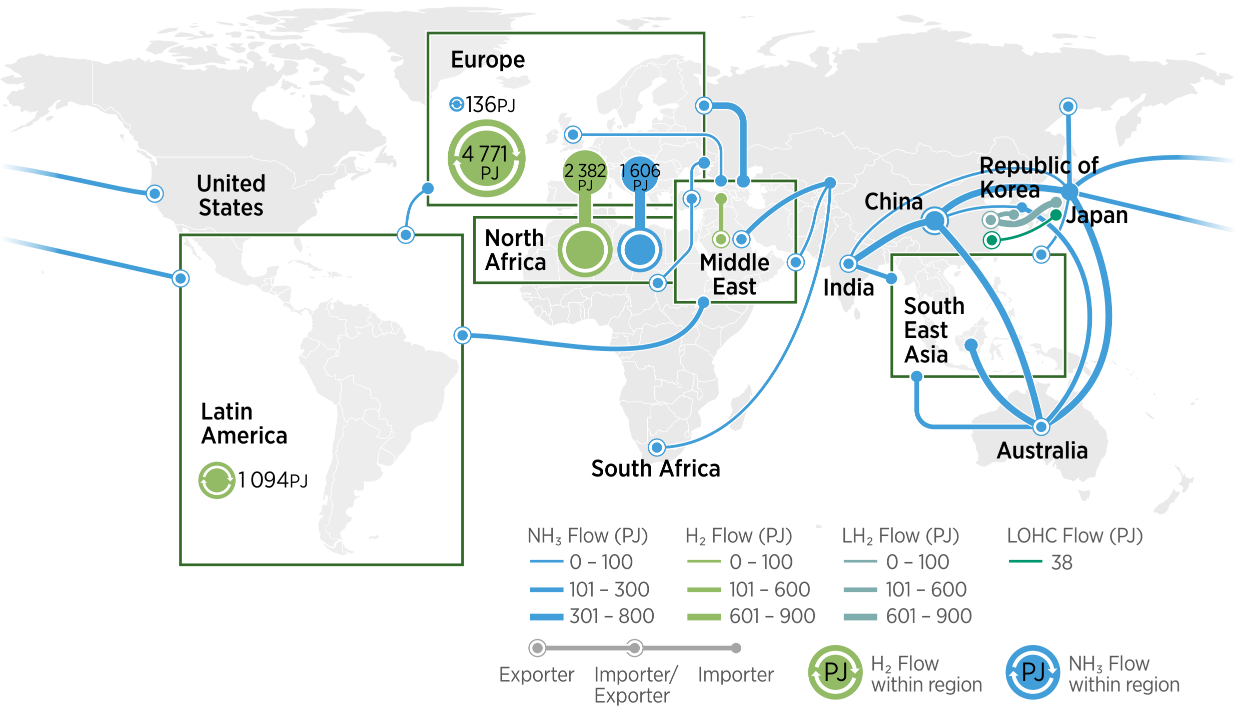
By 2050, hydrogen demand in Asia could increase nearly six times to reach around 190 million tonnes annually (IRENA, 2022g). China, India and Japan are expected to be the largest markets in the region. Beyond meeting domestic needs, Malaysia may produce green hydrogen based its strong hydropower resources, especially in Sarawak. To date however, most hydrogen export announcements in the country has been for grey hydrogen, with potential to eventually produce them from renewable resources. Therefore, there might be a need to increase the availability of low-cost capital in the region for the deployment of utility-scale solar facilities, together with incentives to reduce cost of green hydrogen production.

IRENA's recent report *Global hydrogen trade to meet the 1.5°C climate goal* (Part 1) provides a perspective on the hydrogen trade by mid-century based on scenarios from the WETO report (IRENA, 2022g). 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 likely to be the most cost-effective means of transferring hydrogen, particularly for regional trade, such as across the ASEAN region. Ammonia is the most attractive carrier for long-distance hydrogen transport given the existing infrastructure and the expanding market as fuel for shipping and power generation. Most of the ammonia to be transacted may be consumed as ammonia itself, avoiding the need for costly and challenging ammonia cracking.

The study showed that Australia is a step ahead of Malaysia and other ASEAN member states in meeting the regional demand. Australia has a vast land area of 7 million square kilometres for renewable energy production, which, combined with a low cost of capital, enables the production of green hydrogen that is competitive with fossil-fuel-based hydrogen. Australia also has a solid hydrogen roadmap and strategy. Figure 60 shows global hydrogen flows in a 1.5-S by 2050.

***Hydrogen will be increasingly traded globally.***

**Figure 60** Global hydrogen trade flows in the 1.5-S in 2050

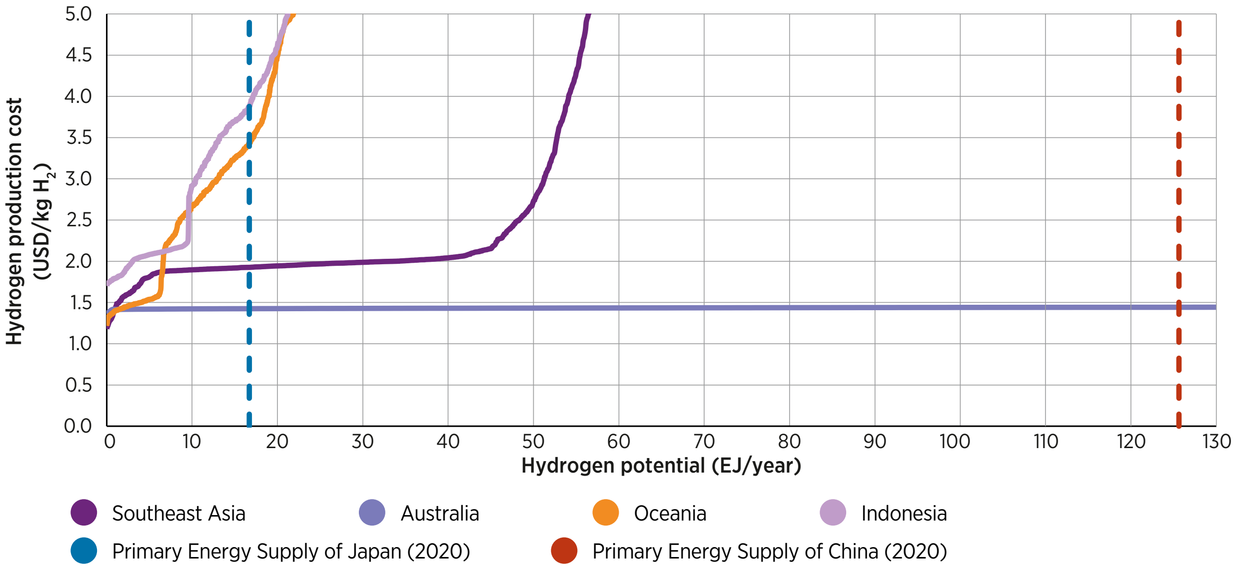



*Disclaimer:* This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA.
*Source:* IRENA, 2022f.

The cost of capital for solar and wind projects in Australia ranges from around 2.9% to 3.7%, which is significantly below that of Malaysia, at around 5.5% (IRENA, 2022b). In combination with relatively low investment costs, Australia has the potential to produce around 378 EJ per year of green hydrogen at a cost below USD 1.5 per kilogram. For illustration, this is higher than Japan and China's primary energy supplies in 2020, at 16 EJ and 126 EJ respectively (blue/red vertical lines in Figure 61). Based on current assumptions, the cost of capital for the new solar and wind projects necessary to produce green hydrogen would be much higher in Malaysia and other ASEAN member states than in other potential world hydrogen exporters such as Australia and Chile.

*Hydrogen production costs rise considerably in some countries as volume increases.*

**Figure 61** Hydrogen cost curve potential based on 2030 values




*Source:* IRENA, 2022b.

However, taking into account transport costs, Malaysia's position as a hydrogen exporter might be more favourable compared to Australia, due to the shorter distance to important markets such as China, Japan and the Republic of Korea. It would also increase the competitiveness of Malaysia to serve the hydrogen market in Asia and the Pacific, where hydrogen production facilities are already being planned in both Peninsular Malaysia and Sarawak. Malaysia may also export hydrogen through existing and new pipelines to other ASEAN member states and beyond. Malaysia is currently developing a hydrogen technology and economy roadmap, outlining opportunities and strategies to become a key hydrogen player and unlock green growth across several industries (MGTC, 2021).

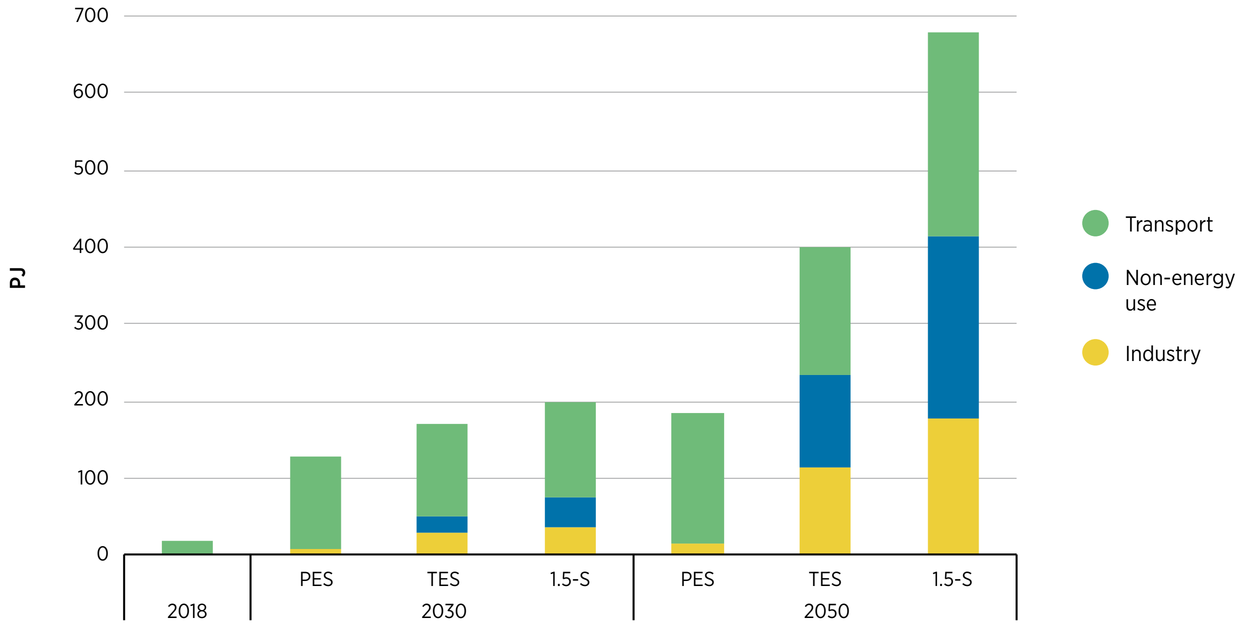
A forthcoming report in 2023 will go into more detail on hydrogen supply in the ASEAN region.

**Bioenergy**

With large arable lands and forests, Malaysia has vast bioenergy potential from its agricultural industry. IRENA's decarbonisation pathway in the 1.5-S envisions up to 680 PJ of bioenergy to be used by 2050 (Figure 62), consisting of biofuels, biogas, biomass and waste products. This represents around 16% of the total final consumption. Biomass will also play a key role in substituting fossil fuels in the industry sector and will serve as an alternative to crude oil to produce bio-based plastics.

***Bioenergy will play an important role in decarbonising the transport, industry, as well as non-energy sectors.***

**Figure 62** Bioenergy demand in Malaysia, all scenarios, 2018 to 2050




IRENA's study shows that in addition to palm oil, biomass energy resources can be tapped from other crops in Malaysia such as rubber and acacia, amounting to 10.4 million tonnes, or 197 PJ by 2050 (IRENA, 2022d). These can be used in industrial processes and in combined heat and power plants of up to 4.2 GW capacity. Additionally, the Malaysia Biomass Industry Action Plan, released in 2013, has identified major bioenergy potentials from agricultural residues and municipal solid waste, which can be used to help reach decarbonisation targets (GoM, 2013). Under the feed-in tariff programme, a total of 224 MW of biogas and 165 MW of biomass power plants had been approved as of the end of 2020, with most of the increase in capacity being biogas plants (SEDA, 2021b). A key challenge is understanding national target and policies when there are competing demands for bioenergy for food consumption and global export markets.

### Biofuels

Under the National Biofuel Policy enforced in 2006, Malaysia has implemented a biodiesel blending programme in the transport sector. Blending biofuels for road transport started in 2010, and within five years biomass reached a 7% biodiesel blending rate. Today, Malaysia's biodiesel caters to both the domestic market and the export market, with a B10 blending mandate for road transport and a B7 mandate for industrial use (Wahab, 2021). A B20 blending target was planned in 2020 but was delayed due to supply chain issues that were further exacerbated by the COVID-19 pandemic.

The total biodiesel production capacity in Malaysia as of 2021 was 2.4 billion litres, with 19 biorefineries in place. Around one-third of the crude palm oil collected is used for biodiesel production, with actual production totalling 860 million litres in 2021 (Wahab, 2021).

IRENA's energy transition pathways envision the biodiesel production capacity to increase four-fold from the current capacity in the 1.5-S, and two-fold in the TES, with the blending target raised to B50 starting in 2040. However, a key challenge in further ramping up biodiesel production in Malaysia is competing demand from the global market for crude palm oil, as well as a lack of labour in the plantation sector, decreasing yields and affecting production. A co-ordinated ministerial approach – from a labour, economic, industrial and energy planning perspective – is needed to tackle this challenging sector.

For bioenergy as a whole in Malaysia, the key barrier in the past has been a lack of agreement between policy makers and line ministries regarding the strategies that are best suited to reaching the nation's proposed targets (IRENA, 2022d). Stronger inter-institutional co-ordination that builds on a prioritised and sustained implementation strategy is required, building on successful cases, piloting best practices to scale pilot projects and generating institutional capacity to foster minimal agreements that aim to accomplish step-wise goals towards targets that foster the country's bioenergy potential. Finally, monitoring and integrating waste (including municipality waste) and bioenergy into energy statistics – especially the use of bioenergy in industry – can be a step forward to inform future energy planning.

Additionally, embarking on pilot and research studies into characterising different industrial, agricultural and municipality waste profiles can be instrumental to build up financially sustainable (via reasonable tipping fees), small-scale waste-to-energy plants throughout Malaysia. More importantly, waste-to-energy plants should be seen primarily as a waste management strategy to reduce waste in the landfill, while also helping in mitigating climate change effects.

**Local solar PV industrialisation opportunities**

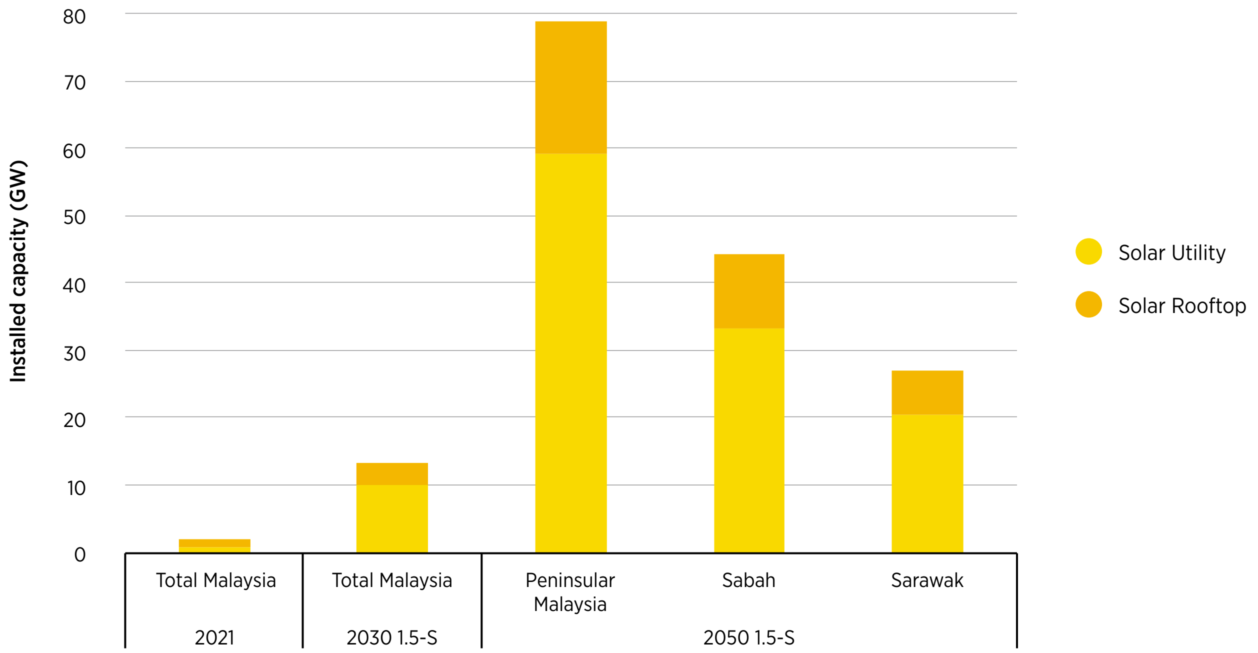
Solar energy is widely seen to dominate the energy transition future. In 2021 alone, around 257 GW of new renewable power generation capacity was added worldwide, and more than half of this was solar PV. Around 133-140 GW of newly installed systems were commissioned during 2021 alone at the alternating current (AC) level, with more than 180 GW of modules at the direct current (DC) level. China dominates today's global PV production, accounting for 66% of all polysilicon, more than 95% of wafers, 78% of cells and 72% of modules. By the end of 2022, China was expected to have 500 GW of annual module production capacity and 550 GW of wafer production capacity (Bellini, 2022)

Malaysia was the leading solar PV module manufacturer in Southeast Asia until 2019, when rapid solar PV expansion and production in Viet Nam overtook the top spot (IEA, 2022b). By 2021, Malaysia accounted for around 4% of global solar PV module production, only 1% less than Viet Nam and just above Thailand (the third leading Southeast Asian producer representing 2% of the total global solar PV production) (IEA, 2022b). Nevertheless, Malaysia's solar PV industry is on the rise, as a result of continuous government support, expanding renewable energy policies and investments, and falling costs. Malaysia and Viet Nam have been the ASEAN region's biggest solar PV employers in recent years (IRENA, 2020).

With Malaysia's current national renewable energy targets, as well as various schemes that favour installation of solar PV plants across the utility, residential, and commercial sectors, a requirement for more robust local solar PV manufacturing can present additional socio-economic benefits. In the 1.5-S RE90, 1.4 GW of solar capacity expansion is needed annually until 2030, rising to 4.3 GW annually until 2050 (Figure 63). Installations would be spread across Peninsular Malaysia, Sabah, and Sarawak, with a mix of rooftop and utility-scale systems – taking into careful consideration the availability of resources, land and demand centres.

***Malaysia's solar PV capacity additions will need to increase by 1.4 GW annually until 2030 and 4.3 GW annually until 2050 in the 1.5-S RE90 scenario.***

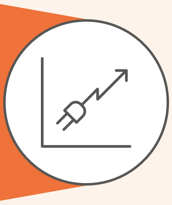
**Figure 63** Solar PV installed capacity in Malaysia, 2020, 2030 and 2050



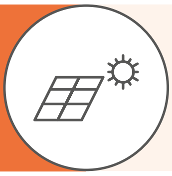

Closer co-ordination among the relevant stakeholders from government, industry and the private sector is needed to encourage further investments in the PV module manufacturing industry. Greater attention is also needed to its synergies with battery storage and grid flexibility, especially considering the region's anticipated boom in solar PV in the coming decades. In total, IRENA's 1.5-S anticipates up to 2 400 GW of solar PV installed capacity in the ASEAN region by 2050 (IRENA, 2022b).

## 4.5 INVESTMENTS, COSTS AND BENEFITS

### KEY MESSAGES



**The total investment requirement in the 1.5-S is double that in the PES by 2050, totalling USD 375 billion to USD 415 billion**. Power sector investment accounts for between 60% and 70% of the total investment required, while the rest are allocated to investments into energy efficiency and EV-related infrastructure.



**In the short term until 2030, significant investments are needed for renewable energy installation capacities in Malaysia** – especially for Solar PV. This is equivalent of installing 1.4 GW of Solar PV new capacity to the grid every year.

**Overall in 2050, the annual incremental energy system cost in the 1.5-S is USD 9 billion lower than in the PES**, and the avoided externalities due to health and climate change is between USD 4.0 billion and USD 9.5 billion annually in the 1.5-S compared to the PES. Thus, transitioning to renewable energy in the 1.5-S will save Malaysia between USD 13 billion and USD 18.5 billion annually.

### Investment needs

In the decade to 2030, a substantial increase in investment is required to accelerate Malaysia's energy transition and to keep the country on a climate-safe pathway (Table 13). Policy support in the energy sectors is critical to enable the reallocation of capital towards sustainable solutions and to ensure active participation from the private sector. The required clean and renewable energy investment towards 2030 in a 1.5-S amounts to USD 47 billion, with around USD 27 billion going into power capacity expansion of the grid and energy storage.

***Investment in decarbonising the power sector and EV infrastructure in this decade is key to the energy transition in the 1.5-S.***

**Table 13** Short-term investment requirement to 2030 in the 1.5-S

| 1.5-S SHORT-TERM INVESTMENT REQUIREMENT (2018-2030) | | | 2018 | 2030 (1.5-S) | REQUIRED INVESTMENT (USD billion) |
|---|---|---|---|---|---|
| | POWER | **Solar PV** installed capacity | 0.4 GW | 17.1 GW | USD 10.8 |
| | | **Bioenergy** installed capacity | 0.2 GW | 0.4 GW | USD 0.6 |
| | | **Hydropower** installed capacity | 6.1 GW | 9.4 GW | USD 7.1 |
| | GRID AND FLEXIBILITY | **Transmission** (national) | 37 km | 50 km | USD 4.8 |
| | | **Distribution** | 412 km | 555 km | USD 3.6 |
| | | **Storage** | 0 MWh | 62 MWh | USD 0.023 |
| | ENERGY EFFICIENCY | **End-use sectors** | - | - | USD 13.6 |
| | BIO-FUELS | **Biofuels supply** | 530 million litres | 4 482 million litres | USD 3.2 |
| | ELECTRIFI-CATION | **Electric vehicle chargers** | < 0.1 million units | 150 000 units | USD 3.7 |

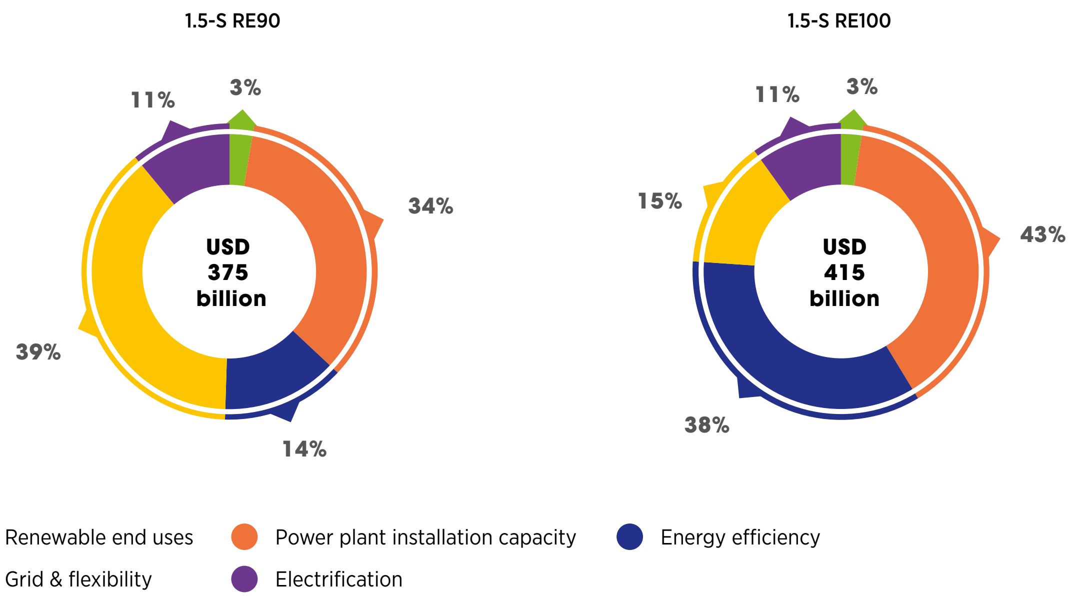
*Note:* km = kilometres

To ensure a sustainable and low-carbon future in Malaysia in the 1.5-S RE90, a total of USD 375 billion would be needed over the period until 2050. This represents over two-and-a-half times more investment compared to the PES, or an additional USD 8 billion invested annually. Malaysia's required annual investment in the energy sector would need to represent around 4% of the total GDP by 2050. In the 1.5-S RE100, an additional USD 40 billion would be required to fully transition and decarbonise the power sector.

The charts in Figure 64 show that three-quarters of the investment in the two 1.5-S cases is dedicated to power and grids and storage infrastructure, with the rest going to energy efficiency and electrification in the end-use sectors. A more detailed investment breakdown is shown in Table 14. Investments in the end-use sectors include additional infrastructure to enhance energy efficiency in all three sectors, new industrial plants and retrofits, and critical electric vehicle charging infrastructure for the transport sector. The cost of vehicles is excluded from this analysis but would represent an additional USD 60 billion investment in electric vehicle sales compared to the PES.

***Installing renewable power capacity, providing infrastructure and implementing energy efficiency account for the bulk of the energy transition investment.***

**Figure 64** Cumulative investments required by component in the 1.5-S RE 90 and 1.5-S RE100 by 2050



***Higher upfront investment is needed in the energy transition scenarios.***

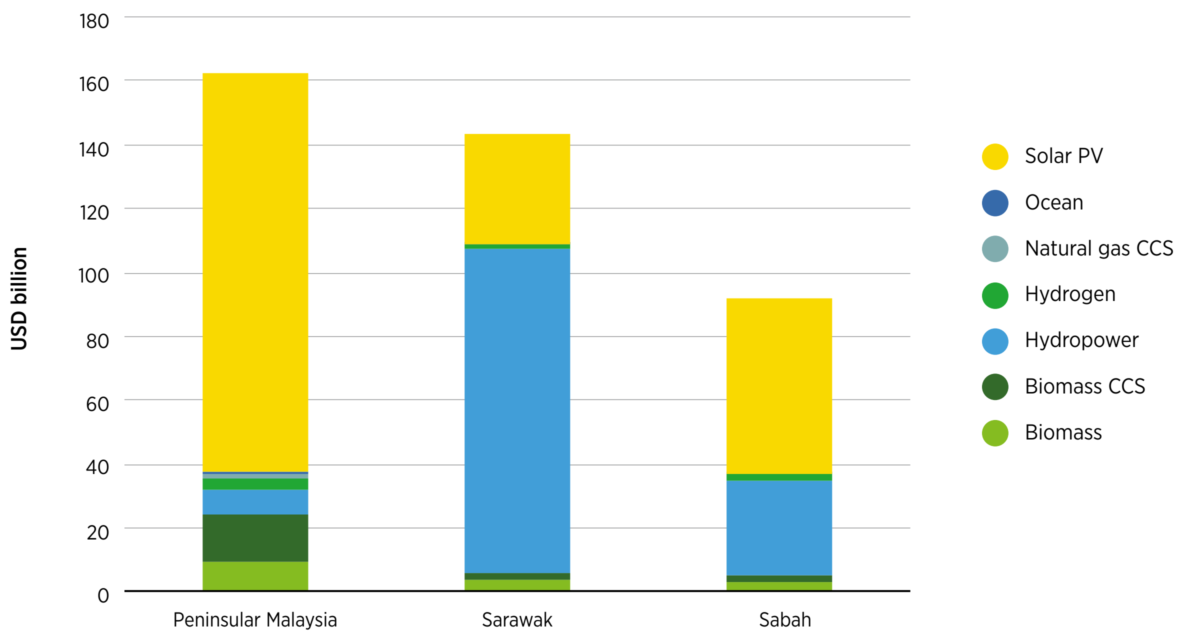
**Table 14** Total investment requirement, by scenario, 2018 to 2050

| INVESTMENT REQUIREMENT (BILLION USD) | | | | 2018-2050 (USD billion) PES | TES | 1.5-S RE90 | 1.5-S RE100 |
|---|---|---|---|---|---|---|---|
| | POWER | Renewable energy | Solar PV | 29 | 41 | 58 | 81 |
| | | | Hydropower | 20 | 33 | 46 | 46 |
| | | | Biomass | 6 | 6 | 4 | 6 |
| | | | Hydrogen | – | – | – | 6 |
| | | | Ocean power | – | – | – | 0.3 |
| | | Carbon capture and storage (CCS) | Biomass CCS | – | – | 8 | 11 |
| | | | Natural gas CCS | – | 13 | 2 | – |
| | | Fossil fuels | Coal | 4 | 4 | 4 | 4 |
| | | | Natural gas | 23 | 5 | 5 | 5 |
| | GRID AND FLEXIBILITY | Transmission | | 13 | 18 | 26 | 26 |
| | | Distribution | | 10 | 13 | 20 | 20 |
| | | Storage | | 2 | 3 | 5 | 13 |
| | RENEWABLE END USES | Biofuels supply | | 6 | 8 | 10 | 10 |
| | ENERGY EFFICIENCY | Buildings | | 1 | 18 | 34 | 34 |
| | | Industry | | 29 | 29 | 44 | 44 |
| | | Transport | | 13 | 31 | 67 | 67 |
| | ELECTRIFICATION | Electric vehicle chargers | | 3 | 21 | 41 | 41 |
| **TOTAL INVESTMENT REQUIREMENT:** | | | | **159** | **243** | **375** | **415** |

Power sector investments (in installed capacities) in renewable energy technologies vary across the different regions in Malaysia, but are balanced according to energy demand and availability of resources (Figure 65). Solar PV would account for a large share of all power sector investments, especially in Peninsular Malaysia where most of the population is concentrated. Meanwhile, large hydropower investments will be crucial in Sarawak and Sabah to further meet the growing electricity demand, both locally and for export to neighbouring countries, in the form of either electricity or hydrogen.

***Renewable energy investment in the power sector is spread out evenly across the country in the 1.5-S RE90.***

**Figure 65** Total clean and renewable energy investments required in Peninsular Malaysia, Sarawak and Sabah to 2050 in the 1.5-S RE90



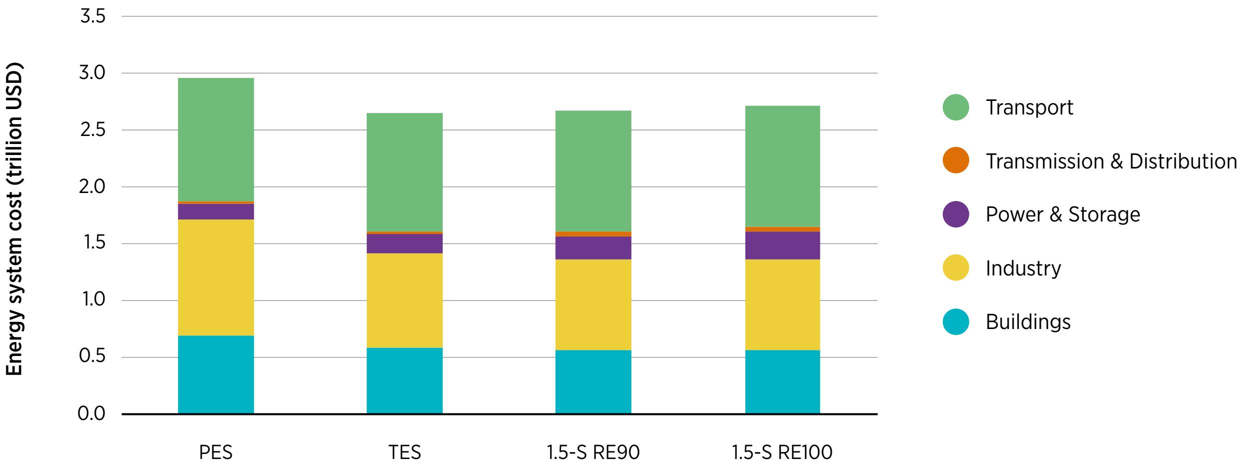

## Energy system costs and savings

The total energy system cost includes investment in the new power installed capacities, storage and other transmission infrastructure, operations and maintenance, fuel costs and investments, and energy efficiency and end-use technology costs. IRENA's estimates for future fuel costs are based on national and historical data, while also considering inflation and price increases for fossil fuels. This was estimated for each fuel source – namely oil, coal, natural gas, biofuels and others used in end-use sectors, as well the fuel costs required for power generation.

As seen in Figure 66, total energy system costs in the 1.5-S are comparable to the costs incurred in the PES, with total annual savings of USD 7-9 billion in the two 1.5-S cases compared to the PES. While there is more spending on low-carbon infrastructure in the 1.5-S compared to the PES, savings can be realised through lower fuel costs. Given that Malaysia's expenditures on fuel subsidies have grown in recent years due to rising energy demand, up to USD 240 billion to USD 280 billion in avoided costs can be realised when comparing the 1.5-S to the PES in cumulative terms to 2050.

***Total cumulative energy costs in all of the energy transition scenarios are more economical when compared to the PES.***

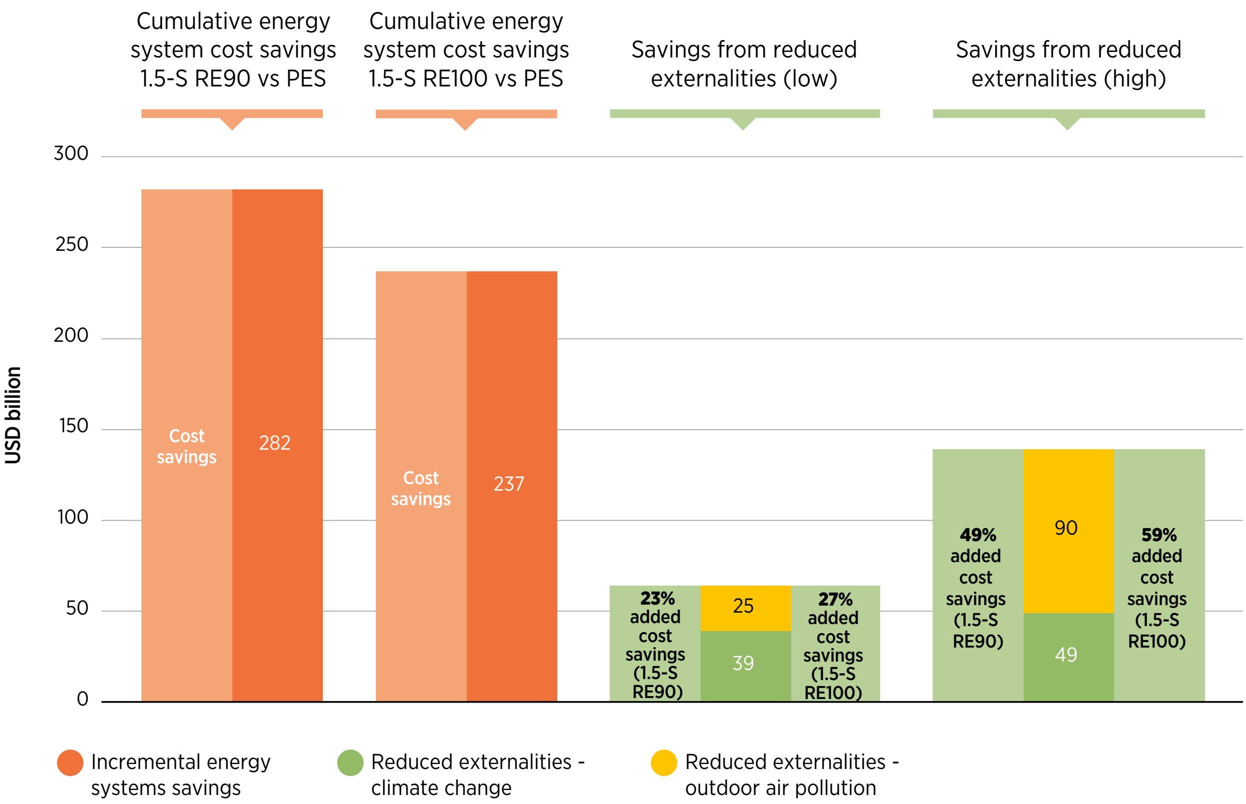
**Figure 66** Total energy system cost by sector and scenario, 2018 to 2050




The reduced externalities associated with health, environment, and climate change damages in the 1.5-S yield an annual avoided cost of between USD 2 billion and USD 4 billion. This implies that the country can potentially save between USD 9 billion and USD 13 billion annually, or around 2% to 4% of its current GDP, by transitioning to the 1.5-S by mid-century (Figure 67).

***The 1.5-S RE90 is the least-cost energy pathway when compared to the PES.***

**Figure 67** Total energy system cost of transitioning towards the 1.5-S over the PES, 2018 to 2050



# 5 KEY CHALLENGES AND RECOMMENDATIONS

This section presents a set of short- to medium-term recommendations to address key challenges, support the development of the renewable energy market and accelerate the energy transition in Malaysia, based on consultation process throughout out the Renewable Readiness Assessment (RRA) study as well the outcome from the Renewable Energy Roadmaps (REmap) analysis on Malaysia.

These recommended actions focus on providing a solid basis for creating a more conducive investment environment for renewables. Already, the government is making progress towards the realisation of these actions.

## 5.1 ENERGY SYSTEM AND POLICY PLANNING

To meet rising energy demand while ensuring energy security and affordability in the future, Malaysia stands at a crossroads. It must either continue to use its diminishing oil and gas resources, while also turning to volatile international oil and gas markets to import energy, or harness the huge untapped potential of renewable energy sources that can provide local and affordable alternatives to fossil fuels. The report shows that it is cheaper to do the latter, with the share of renewable energy reaching 40% of the country's primary energy mix, up from just 3% today. Such a transition would not only save USD 7 billion per year, but also reduce the need to budget for fuel subsidies.

The energy landscape in the country would change from one dominated by fossil fuels, which represent around three-quarters of primary energy demand, to one that sees deep electrification across all end-use sectors – making up 40% of final energy consumption, with another 20% coming from renewables. This entails scaling up electricity demand from around 150 TWh in 2018 to more than 348 TWh by 2050, while also scaling key renewable resources such as bioenergy, geothermal and hydrogen.

IRENA's analysis also shows that there are various gaps and opportunities in the buildings, transport and industry sectors in Malaysia. Each of these end-use sectors can play a larger role in reducing energy sector-related emissions in the long term. A key measure is electrification in the transport sector, greatly increasing the uptake of electric vehicles while also considering urban planning and transport policies that will reduce private vehicle use and energy demand in the long term. Another measure is to emphasise energy efficiency measures across all sectors – using low-carbon technology, strengthening standards and labelling practices, recycling waste materials and integrating renewables as much as possible into the energy mix.

Meanwhile, there is a growing demand for low-carbon fuels such as bioenergy, biofuels, e-fuels and hydrogen globally in IRENA's 1.5-S towards 2050 (IRENA, 2022a). Malaysia can position itself as a reliable partner and supplier of these alternative fuels – given that national targets, needs and mandates are met first.

**Action 1** Utilise the long-term opportunities of the energy transition – through the development of cohesive and integrated long-term energy planning strategies

*Malaysia has taken important steps to transform its energy system to a more secure, clean and affordable one in the future. However, more attention is needed to integrate various policies including, and beyond, the power sector towards a more comprehensive and transparent long-term energy policy and planning strategy, aimed at energy transition and achieving climate targets. This includes streamlining targets and policies from different sectors: power, utilities, manufacturers, automotive, transport, industry and trade, natural resources, environment, etc. IRENA's Malaysia energy transition outlook (METO) can be good starting point and reference towards modelling further Long-Term Low Emission Development Strategies (LT-LEDS) and energy scenarios, whose progress can be reviewed and updated on a periodic basis. The strategy and policies should prioritise clean energy investments that are consistent between national and regional (renewable) energy policies. These can also help to operationalise Malaysia's climate action plans and net zero targets in the long term while helping to align the ambition level of the country's NDC with the goals of the Paris Agreement.*

Privatisation of Malaysia's energy sector has been in place since the 1990s. The New Enhanced Dispatch Arrangement (NEDA), established in 2015, arranges the scheduling and dispatch of generation used by the Single Buyer. However, since the fourth quarter of 2020, when solar energy reached the maximum allowable capacity, the NEDA is no longer available for application for the price takers, although it should be open as long as the requirements are met.

An important initiative is called MESI 2.0 which aims to open the market to diversity and competition to improve flexibility and cost efficiency and to empower consumers. It is a crucial step in Malaysia's power reforms. Renewable energy is a central theme of this package, with a focus on consumers. However, as of the time of this writing, only some initiatives of the MESI 2.0 were ongoing, with others either under review or delayed in implementation.

**Action 2** Advance electricity market design

*It is crucial to continue the MESI 2.0 implementation and to widen opportunities for renewable energy investors to participate in the electricity market, in order to increase transparency, reduce financing costs for investors and make electricity prices more realistic, while remaining affordable to consumers. At the same time, any improvements to the electricity market design must ensure the financial sustainability of its participants (from utilities, suppliers, system operators, prosumers, and consumers) to future-proof it against fluctuation and uncertainties of global energy market, whilst having the long-term goal of reducing government spending on fossil-fuel related subsidies.*

## 5.2 REGULATORY AND LEGAL FRAMEWORK

Using Malaysia's renewable energy potential to reach its current targets and then go beyond them requires an enhanced regulatory framework for renewables. Several areas require further attention in achieving these targets.

The feed-in tariff mechanism has enabled the generation of more than 4 TWh of electricity annually from renewable energy resources. Half of this total came from biomass and biogas and another 40% from solar PV. Project developers interviewed during the study have noted that in addition to e-bidding requirements, other criteria could be included to assess the projects. Independent third-party assessment of the technical and financial viability of projects could be helpful.

Another challenge for small hydropower FIT holders was to secure and finalise the water supply agreement, *e.g.* the Water Rights Agreement, according to industry players. To sign a financing agreement, first a power purchase agreement needs to be secured. This agreement is under the authority of the state governments, where each state has its own decision-making and different permit approval processes. In some states, it is based on gross revenue, whereas in others it is based on other schemes.

According to stakeholder interviews, while financing is available, financiers are looking for projects with good rate of returns. When the tariffs are too low, this makes financing challenging. At the same time, the FIT has limited opportunities to grow further because it is challenging to reflect this in the surcharges applied in tariffs.

The bids received under the Large Scale Solar programme that started in 2016 show that renewables are gaining a business case in Malaysia. The tender guidelines of the LSS programme have improved greatly, and more criteria are now included to make sure projects are delivered. This has also helped financiers. The operational issues faced during the initial rounds of the LSS programme have been resolved. Additionally, outlier bids with very low bid offers can be disqualified, where in the initial LSS phases, land-acquisition and other unforeseen financial and material costs has led to project cost overruns.

From the interview process conducted with stakeholders, available sub-station and grid capacity issues were mentioned that might limit the success of projects under the LSS programme. Due to high solar irradiance, the LSS plants in northern Malaysia are very full and causing grid connection issues. This results in investors competing for land acquisition. The process for land acquisition can take 1-2 years, which is a lengthy period from an investor perspective (and also increases upfront investment costs), making this an important financing issue. Because of this, many LSS projects have been penalised in the past, and the approval time could be long.

Because of land issues, the eastern and southern parts of the country could offer better areas for solar development. However, LSS plants located in some remote area face interconnection infrastructure limitations. Since the interconnection facilities fall under the scope of LSS developers, this increases their project costs and may make them less competitive. Finally, the number of new LSS rounds is not clear, which presents difficulties for investor planning and for policy consistency. The project size at a single site could also be increased.

The role of TNB, as the sole electricity provider in Peninsular Malaysia, could be defined better in the LSS programme. Because TNB is the sole provider of transmission infrastructure, one view is that its scope could be limited to expanding the grid infrastructure instead of competing for renewable energy capacity through its subsidiary. Another view is that it should also be allowed to compete for renewable energy capacity build out.

**Action 3** Develop a stronger regulatory framework by enhancing the LSS programme and a well-functioning FIT mechanism

*Malaysia's renewable regulatory framework has advanced considerably with an availability of options for renewable energy investments. There is a need to strengthen the e-bidding system of the FIT with respect to project selection criteria and to overcome financing issues. To ensure the continued success of the LSS programme, regularity and periodicity are needed for a predictable investment environment, and solutions will need to be developed related to land use and grid connection issues.*

While the solar PV market in Malaysia is dominated by grid-connected PV systems driven by the LSS programme, the distributed renewable energy market is also growing thanks to the Net Energy Metering programme. Off-grid remains a niche market, while rooftop PV and distributed energy systems could be crucial in attaining full electrification in the Sabah and Sarawak regions and increasing the share of renewables in the entire country. Although electrification is nearly 100% in Peninsular Malaysia, it was around 96.9% in the Sarawak region (Afrouzi *et al.*, 2021).

A more decentralised electricity system in Malaysia is expected to impact the market in the future. Measures will be needed to integrate the potential excess electricity generation from an increasing share of solar PV systems. In addition, the ST and market operators (not yet established, as currently it is a Single Buyer market) would need to consider adopting rules and practices that are conductive to integrating distributed resources into the wholesale market. There is no timeline yet for this, and the distributed resources are connected to the distribution grid, requiring system operators to develop solutions for integration. In addition, network tariffs need to be made more efficient to reap the benefits of distributed energy resources (OIES-UNITEN, 2021).

During the NEM 1.0 and NEM 2.0, several reasons for slow progress include the insufficient tariff payments, caps on sales back to the grid and restrictions of third-party installation. Initially, the NEM had limited tariff payments and aimed for self-consumption rather than grid sales. It started off with payment at a displaced cost, which then later improved to one-to-one offset. Since then, together with the financing scheme offered by the solar PV investor, capacity installations accelerated. Under the NEM 3.0, customers in the residential and governmental segment continue to enjoy the one-to-one offset rate. However, this is not the case for the commercial and industrial segments, where the aim is still self-consumption (and the tariff is at the system marginal price, which is much lower).

The NEM contract is for 10 years only, which provides only a small incentive for customers and investors. The payback period is 5-6 years, but by year 10 customers can no longer sell electricity to TNB and may need to invest in additional battery storage, which increases the capital costs. There are also uncertainties in the regulatory framework that will follow the NEM. This is especially important for residential customers. The commercial and industrial customers can claim tax incentives, resulting in a shorter payback period of 3-5 years. Finally, it is not clear how the NEM will continue in the coming years once the current cycle concluded by the end of 2023.

NEM 3.0 programme implementation can be enhanced. In the earlier phases of the NEM, investments were far below the quotas. There is readily increased awareness and interest in rooftop solar PV from all segments, but limited quotas and the lack of incentives seem to hamper growth in this segment. Reducing the payback periods of investments is an area that deserves more attention, considering the available business and finance models (leasing or PPA services) offered in the retail market for solar PV systems. Additionally, via the Supply Agreement of Renewable Energy, the payment for solar energy is channelled directly to the solar PV investor (ST, 2022e). The direct payment to the financial institutions that financed the PV investors' project is still under discussion.

Additionally, the government announced the Corporate Green Power Programme (CGPP) in late 2022, where the private sector can undertake a corporate PPA with a solar PV producer, further incentivising the uptake of renewables (ST, 2022b). The CGPP also encourages the trading of renewable energy certificates between both parties, fulfilling their environmental, social and corporate governance (ESG) commitments.

Electricity tariffs are the determining factor in the further uptake of rooftop solar PV systems. The opportunities that an Enhanced Time of Use tariff offers for different types of customers to enable more rooftop solar PV investments need to be better understood. In light of the increase in fuel costs that directly impacts consumer electricity prices globally, having the correct electricity price signal and educating consumers can trigger behavioural change to reduce demand, invest in energy-efficient appliances and vehicles, and consider investing in rooftop solar PV as an energy-saving measure.

**Action 4** Develop new policy mechanisms for increased participation of various consumers and open new renewable energy markets, including using models beyond the traditional PPAs

*It is necessary to develop new policy mechanisms to increase economic viability and to encourage the participation of various consumers and clarify the next steps in the rooftop solar PV market once the NEM 3.0 has ended.*

*To ensure the success of the NEM programme, new business and financing models should be developed. These should be tailored to the economic viability of such systems for various consumer groups, including the effective use of voluntary markets such as renewable energy certification and corporate sourcing, complemented with an enhanced time-of-use electricity tariff.*

*Overcoming the regulatory and market barriers in power purchase agreements and renewable energy certificates along with the development of a corporate sourcing framework can help Malaysia create new markets for renewable energy investments. Reviewing the current terms and conditions of renewable energy PPAs to address concerns raised by investors might be needed. With the roll-out of the corporate PPAs in late 2022, feedback from the private sector needs to be solicited on a regular basis, as well as having strong monitoring and accounting standards to report the various renewable energy programmes available.*

Given Malaysia's export-oriented economy and the many emerging business entities that are looking for renewable energy sources to meet their emission reductions, corporate sourcing of renewables is expected to become an important business model in the country. A scheme for corporate sourcing of renewables has been in place since 2022 with the GET programme. Earlier, TNB offered myGreen+ as a premium scheme for customers who want to deliberately procure renewable energy via the TNBX (a subsidiary of TNB) and the Malaysia Green Attribute Tracking System (mGATS) as a national marketplace for renewable energy certificates (MGATS, 2022). Effective operation of such voluntary markets through regulatory support and platforms to monitor and validate certificates could create new opportunities.

Additionally, rooftop solar PV and small hydropower plant developers have shown interest in peer-to-peer electricity trading, and a pilot project was implemented by SEDA. This would be a particularly interesting option following the ending of the NEM 3.0 in 2023.

Corporate PPAs could be a new option to sell power directly to end users. There is significant interest in this model from investors, given the limitations of the NEM and self-consumption, while solutions will be needed to overcome the power wheeling charges.

## 5.3 TECHNOLOGY AND INNOVATION

Given Malaysia's significant renewable energy resource availability, there is a realistic potential for the share of renewable capacity in the total generation mix to exceed what is already planned. This will be important given Malaysia's dispersed population centres and economic activity. It may require the development of additional measures to ensure system flexibility. However, there is limited country-wide analysis that investigates the extent to which the transmission grid can accommodate renewable energy resources.

Especially for Peninsular Malaysia, the renewable energy shares can rise significantly, as suggested by some grid integration studies. In addressing system stability concerns due to higher shares of renewables, the master plan for the region foresees the development of five units of a battery energy storage system with a capacity of 100 MW planned for installation annually into the system from 2030 to 2034 (ST, 2021b). Depending on how the renewable energy share increases, energy storage could come into the system much earlier (including potentially more cost-effective behind-the-meter and distribution grid-connected systems). Analysis suggests that currently it is more profitable to install large-scale solar only compared to systems that have integrated battery energy storage. Storage becomes more profitable at smaller storage capacity integrated with large-scale solar systems (Laajimi and Go, 2021). Pumped hydropower storage could also be a viable option for hydropower plants in Malaysia, but the viable areas need to be identified and the business case needs to be understood better (IRENA, 2019).

Most of the population centres in Sabah are located along the coasts in the western and eastern parts of the country, with mountains dividing the two coasts. Currently, infrastructure availability is insufficient to connect the major towns of Sabah. This was a major reason to achieve full electrification in the region. Additionally, electrification becomes more expensive because land access limits grid connections. The grid that is divided between the western and eastern coasts of Sabah is connected via the 275 kV Kolopis-Segaliud transmission line. This provides electricity to the east coast, while other areas rely on off-grid connections. There is a need to meet growing electricity demand to grow economic activities in major towns and tourist areas, while also addressing frequent grid interruptions.

Also, combined-cycle gas turbines run inefficiently to support spinning reserves on Sabah during off-peak periods. The east coast is dependent on electricity flows from the west coast. Generation capacity is currently supported by inefficient and costly diesel generator sets (ST, 2019). To minimise cost issues related to the transmission grid connection, the Ministry of Rural Development could also contribute to financing the projects in certain areas.

TNB already aims for a more flexible and enhanced grid for Peninsular Malaysia that should allow for the grid integration of renewables and enable the charging of electric vehicles. Grid modernisation with smart meters and a system to optimise voltage flows will be essential to achieve a smarter, more efficient and more resilient grid, such as the one being planned in Sarawak (Sarawak Energy, 2020). The approved share of the capital investments between 2018 and 2021 that dealt with energy transition was equivalent to 12.3%. In the proposed investment plan to 2024, this share was higher at 19.3%.

Some biomass plants face grid connection issues. Interconnection costs could limit investments in remote locations far from the grid. High interconnection costs limit the number of viable investment sites to around one-third of the country's mills. According to developers, for projects located more than 7 kilometres from the grid, the connection needs to be set up by the developer. This additional cost makes projects economically unfeasible (EY, 2021). For instance, to connect to the grid in the Sabah region, renewable energy producers need to build transmission lines to the nearest sub-station or existing transmission grid. The FIT is not sufficient to cover grid costs (Hashim, Khairuddin and Ibrahim, 2015; ST, 2019). Many issues for biomass are similarly valid for wind and small hydropower plants, which are also constrained by resource-driven location choices and are far from population centres.

Additionally, limitations in the capacity of the grid where the project will be connected may impact project size. For instance, this results in scaling down the project size to be able to connect to the grid, making financing a challenge due to economies of scale; meanwhile, the same transmission cost applies to the investor irrespective of the project size.

Accelerating the regional grid infrastructure capacity and expanding interconnectors with neighbouring countries will be an important enabler for realising higher shares of variable renewable energy resources. Currently the government allows for cross-border sales through a pilot project to wheel 100 MW of power.

**Action 5** Improve system flexibility for cost-effective integration of renewables

*Harnessing Malaysia's significant renewable energy resource potential is limited by grid issues. There is a need for an ambitious and long-term plan with an emphasis on specific regions that shows the extent that renewables can be integrated to the transmission grid, with solutions to overcome the current challenges of grid integration and to create the flexibility 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 with smart cooling and electric vehicle charging systems).*

Innovation is an important driver in the end-use sectors towards aligning these sectors with a net-zero energy pathway. Changes are needed not just in the fuels that are consumed, but also user habits and structural change, infrastructure and technology. Several emerging technologies stand-out as of particular importance. One is electric-mobility, where wide-scale adoption of electric vehicles will need to take place across road transport. This will entail significant investment in electric charging infrastructure. In industry, greater electrification is necessary, but so is shifting energy demand to clean energy carriers such as green hydrogen and biomass based residues and waste. This will necessitate some changes to the types of technologies used in industry, and the upstream fuel supply chain. In heavy industry some level of carbon dioxide removal will also be required. Large demand sectors will also require more active participation in the power markets, shifting demand to times of peak supply, and also potentially offering means of flexibility, though, for instance, storage provision.

**Action 6** Support enabling technologies in the end-use sectors with a focus on hard-to-abate sectors

*Transforming how end-use sectors consume energy is crucial in enabling a net-zero energy system. Attention needs to be paid to challenging sectors, such as transport and industry. The government needs to consider programmes that support key enabling technologies in these sectors, for instance by focusing on electric vehicles in transport and related charging infrastructure. In industry, clean fuels will be required, including support for green hydrogen. Wider principles of supporting changes to use habits, wider structural change and circular economy should also be considered and supported through government policy.*

## 5.4 RENEWABLE ENERGY FINANCING

For large-scale projects in Malaysia, current experiences show that financing is not a major issue. However, project bankability for some technologies is an area that warrants further attention. For instance, financial challenges are the main reasons for withdrawing from the FIT. In the case of solar energy, financing may prove to be a challenge as the country has been practicing PPAs that provide a secured revenue.

Uncertainties in the MESI 2.0 implementation may not provide a clear direction for a merchant market, including for renewable energy. The merchant market via the NEDA uses the system marginal price that is predominantly determined based on the PPA. This does not provide strong incentives for merchant plants including renewable energy. Additionally, it creates a challenge for banks to provide loans. If the formulation and parameters to determine the system marginal price can be made public, this can help financing.

The solar industry in Malaysia also faces challenges because of the lack of knowledge and awareness on the financial returns from solar PV investment and benefits, as well as the lack of an easy application process and reasonable loan interest rates (Vaka *et al.*, 2020). There are some difficulties in accessing financing for small-scale projects and projects where TNB is not the off-taker, such as in East Malaysia. For small-scale projects, major limitations include grid access, the availability of feedstock for biogas projects and counterparty strength. Typically, small-scale projects are financed on a corporate finance basis because project financing is not often available.

At the start of 2021, only 7 out of the total 47 projects in the pipeline reached the development stage. This highlights the difficulty in accessing funding (EY, 2021). In the future, if the off-takers are planned to be other than TNB, it would be necessary that these institutions are financially credible, which would avoid any financing challenges.

The Green Technology Financing Schemes (GTFS) is a crucial tool of Malaysia to accelerate renewable energy uptake. Currently, most investments are in the local currency, as required to benefit from the GTFS. Earlier experiences, however, have shown that currency devaluation may impact investors. Although the government has taken actions to increase the tariffs in response to investor requests, potential risks related to currency need to be addressed. Additionally, the GTFS provides a subsidy on the loan. This is not typically used for the financial modelling due to the lack of clear guidelines, especially on GTFS 2.0. As a result, financiers could develop the financial models without the GTFS.

The GTFS 3.0 is restricted with a minimum investment of USD 50 million (MYR 200 million), but for wider use it can be open for all volumes, since the current setting offers only limited opportunity to small-scale investors. Additionally, the GTFS application and approval processes are complex, and they require a long time, discouraging investors from taking benefit of them.

After years of experience with the FIT and the LSS schemes, investors are more confident about project returns, and there are cases where investors are willing to accept returns below 10%. Biomass industries are eligible for renewable energy categories under the GTFS supported by 28 participating financial institutions. Eligible business models range from waste cooking oil to biofuel, energy pellets, dried long fibre, biofertiliser, animal feed, biogas and biomass power plants, etc. However, out of 626 approved GTFS projects between 2011 to 2017, 37 projects were for biomass pellets or biomass power plants and another 38 for biogas plants.

GTFS certificate holders do not get a guaranteed approval for automatic loans from the participating financial institutions, since these institutions have their own project evaluation criteria. The majority of GTFS projects approved by participating financial institutions focus on solar PV because banks have a better understanding of this business model. Typically, biomass pellet and biogas plants are financed. More engagement with bankers is needed for the purpose of accessing finance for a wider range of biomass projects such as biofertiliser, animal feed, bio-plastic, bioengineering products, etc.

As the case of solar energy has shown, engagement of banks with investments creates knowledge and competency. But most commercial banks find financing certain types of renewable energy projects rather risky, since such projects are still a relatively new field. The absence of long-term feedstock supply agreements between the renewable energy project developers and feedstock owners is another factor (Leong, 2021). For other types of renewables, studies highlight that banks remain sceptical about the viability of renewable energy projects due to uncertainties about their cost effectiveness, profitability, scalability and high development costs (Lawrence *et al.*, 2020).

For banks, the three major barriers to the success of green technology financing are considered to be a lack of project viability, a lack of track record or success studies, and a lack of knowledge concerning green technology (Amran *et al.*, 2018). There are examples where smaller banks are more pro-active in financing renewable energy projects; however, they are constrained by capital availability. In the case of small hydropower, data reliability is questionable: although a lot of data mining is needed, and many resources are used, the data could still not be correct or suitable, which creates uncertainty in financing. GITA, concluding at the end of 2023, has been a helpful mechanism for cash flow, providing tax relief for a period of 13 years.

**Action 7** Accelerate renewable energy finance

*Ensuring financing of renewable energy investments remains an important barrier to accelerating Malaysia's energy transition. There is a need to assess and understand the barriers and needs of the market to develop suitable financing products and models tailored to individual renewable energy technologies and to strengthen the capacity of national financing institutions to enable their use, coupled with a transparent electricity market design.*

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