ASEAN Green Future Project Phase 2.1 Report

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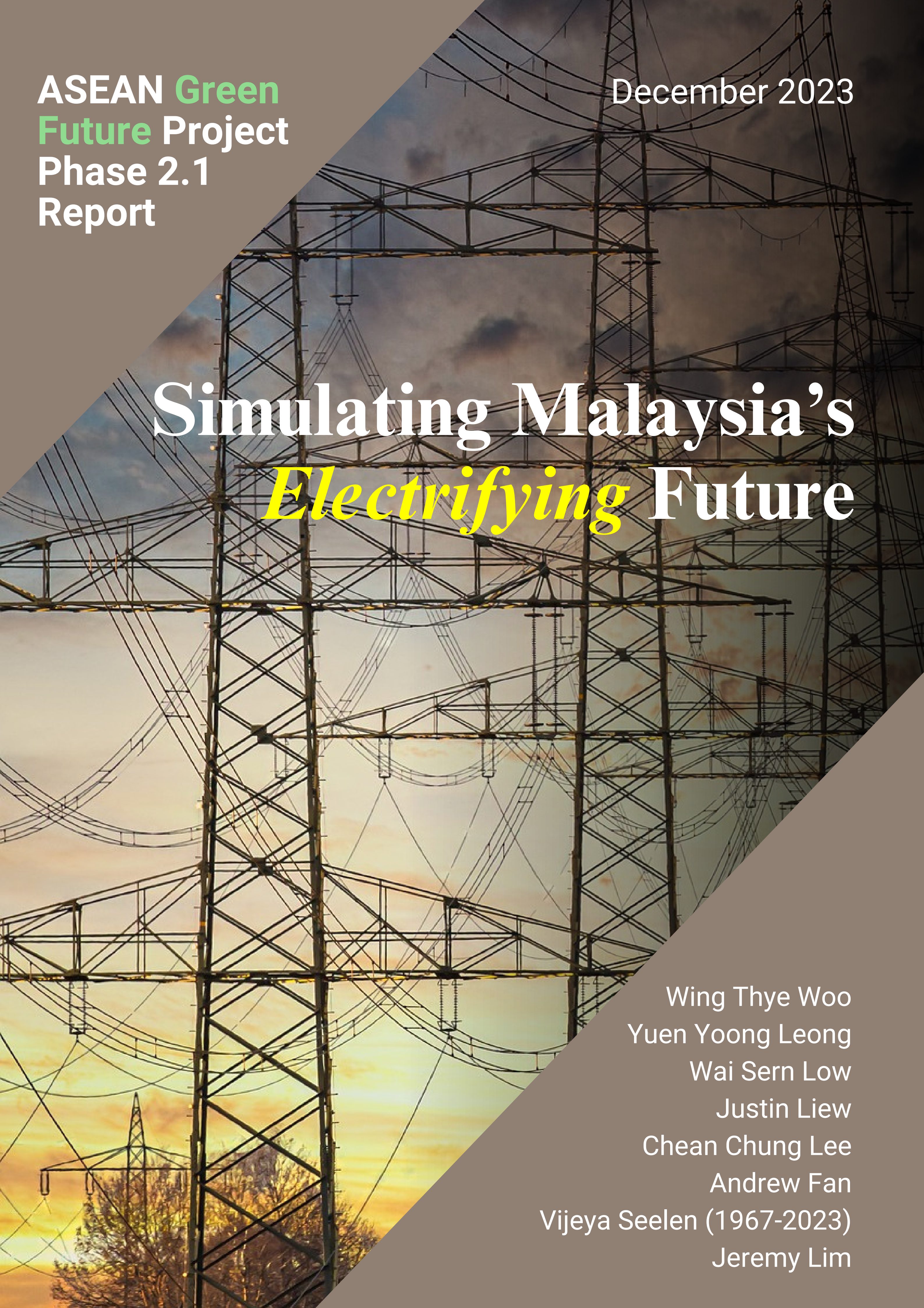

Simulating Malaysia's *Electrifying* Future

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About ASEAN Green Future

ASEAN Green Future is a multi-year regional research project that involves the UN Sustainable Development Solutions Network (SDSN), Climateworks Centre and nine country teams from leading universities and think tanks across Southeast Asia (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam). The researchers undertake quantitative and qualitative climate policy analysis and develop net zero pathways to inform policy recommendations and support the strategic foresight of policy makers.

The Phase 1 country reports present priorities and actions to date, and key technology and policy opportunities to further advance domestic climate action. The Phase 1 regional report positions Southeast Asia's low carbon transition pathways within a global context using the country reports and other studies. This series of reports, produced through a synthesis of existing research and knowledge, builds the case for advancing the region’s climate agenda. Phase 2 of the ASEAN Green Future project uses modelling to quantitatively assess the different decarbonisation pathways for Southeast Asia.

Acknowledgements

The authors are deeply grateful to Dimas Fauzi, Uttam Ghimire, Charlie Heaps, Pimolporn Jintarith, Kuntum Melati and Silvia Ulloa, from the Stockholm Environment Institute (SEI) for their wholehearted support in training and mentoring the ASEAN Green Future (AGF) researchers on the implementation of the Low Emission Analysis Platform[1] (LEAP) for energy planning and climate change mitigation assessment since March 2023. LEAP gave the AGF researchers across Southeast Asia a common language, shared tools, and a transparent platform for communication and collaboration. The initial model that SEI prepared for AGF initiated the regional modelling process, allowing the AGF researchers to continue building the power model on a solid foundation and independently conduct their own analysis. By reducing dependence on external expertise, this fosters long-term sustainability in regional energy planning and empowers stakeholders to participate in the energy transition process and contribute to well-informed decision-making.

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Disclaimer

This ASEAN Green Future report was written by a group of independent experts acting in their personal capacities. Any views expressed in this report do not necessarily reflect the views of any government or organisation, agency, or programme of the United Nations.

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1 Heaps, C.G., 2022. LEAP: The Low Emissions Analysis Platform. [Software version: 2020.1.107] Stockholm Environment Institute. Somerville, MA, USA. https://leap.sei.org

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EXECUTIVE SUMMARY

ASEAN Green Future

- ASEAN Green Future is a multi-year regional research project that involves the UN Sustainable Development Solutions Network (SDSN), Climateworks Centre and nine country teams from leading universities and think tanks across Southeast Asia. The researchers undertake quantitative and qualitative climate policy analysis and develop net zero pathways to inform policy recommendations and support the strategic foresight of policy makers.

- This report is the first in a three-part series of ASEAN Green Future phase two for Malaysia:

  2.1 Existing Policy and More Ambitious Policy (simulation)
  2.2 Near Zero Power Policy (optimisation)
  2.3 Regional modelling and analysis

Modelling

- The country teams received extensive training and coaching from the Stockholm Environment Institute on the use of the Low Emission Analysis Platform (LEAP) to model the power sector, which includes power generation and demand sectors such as transport, industry, residential and commercial / services. The study analyses the future structure of power generation, major decarbonisation pathways and greenhouse gas (GHG) emissions in the power system between 2019 and 2050.

- Two scenarios - Existing Policy and More Ambitious Policy – are built in this study using LEAP to investigate their potential emission reductions and sufficiency for meeting climate targets.

- In the Existing Policy scenario, gross domestic product, population, electricity access, appliance ownership, energy intensity, and sectoral value-added are the key drivers for electricity demand projection, in addition to published government projections, targets and studies up till July 2023, before the launch of the National Energy Transition Roadmap.

- The More Ambitious Policy scenario increases the share of renewable energy in electricity generation by stopping the building of new fossil fuel power generation capacities from 2030 onwards, and the penetration of energy efficiency technologies in the demand sectors compared to the Existing Policy scenario. A derivative More Ambitious Policy scenario 1 phases out coal power generation plants during 2025-2030 and phases out natural gas generation plants during 2030-2050.

- In Phase 2.1, LEAP is used in simulation mode, which excludes modelling energy storage and interconnection. These two functions will become available when LEAP is used in optimisation mode for phases 2.2 and 2.3.

Malaysia’s energy and emissions profile

- Malaysia is a country in Southeast Asia, separated by the South China Sea into two regions - Peninsular Malaysia and East Malaysia on the island of Borneo. As the fifth-largest economy in the region, Malaysia’s energy needs for boosting economic growth and increasing urbanisation are large.
- In 2018, Malaysia’s total final energy consumption was 65 Mtoe, which came from petroleum products (47.0%), natural gas (29.2%), electricity (20.3%), coal and coke (2.8%) and biodiesel (0.7%) (Energy Commission 2021).
- For electricity generation in 2019, 175 TWh of electricity was generated by coal (42.8%), natural gas (40.2%), hydro (14.8%), other renewable energy (1.7%), and diesel (0.5%) (Energy Commission 2021).
- This shows that the structure of energy systems in Malaysia - for both demand and supply sides - heavily depend on fossil fuels as the main sources of energy.
- Consequently, in 2019, the energy sector alone in Malaysia emitted around 259 MtCO2eq, which is equivalent to 78% of the entire country’s GHG emissions (excluding the land use, land-use change and forestry sector) in the country (Ministry of Natural Resources, Environment and Climate Change, Malaysia 2022).
- Without climate change mitigation actions and energy transformation interventions, the increasing energy demand over the next few decades will result in an enormous increase in GHG emissions, deepening Malaysia’s dependency on fossil fuels import, and worsen air pollution.

Mitigation

- Reducing emissions from electricity generation whilst meeting new demands from the electrification of transport, industry, residential and commercial / services will require a portfolio of generation technologies, energy efficiency measures, flexible demand and storage.
- Results from the two scenarios indicate that total final energy consumption in 2050 would reduce by 15 Mtoe or 7.9% in the More Ambitious Policy scenario compared to the Existing Policy scenario due to the increasing penetration of efficient technologies. The energy savings are expected to be even greater when efficiency measures are applied in the industry sector and when a modal shift from road freight to rail freight is pursued. Both measures are not implemented yet in the current stage of modelling.
- On the other hand, total power generation in 2050 in the More Ambitious Policy scenario is projected to be 664 TWh, which is 13% higher than the total power generation in the Existing Policy scenario (586 TWh) due to higher electrification across sectors. Renewable energy generation in the More Ambitious Policy scenario is projected to be 82% of the total electricity generation, which is a 173% increase compared to the Existing Policy scenario (30%).
- In 2050, the More Ambitious Policy scenario is projected to mitigate 149 MtCO2eq of GHG emissions in power generation, which is equivalent to a 61% reduction compared to the GHG emissions of power generation in the Existing Policy scenario. Not adding new fossil fuel power generation capacity from 2030 onwards is not enough for Malaysia to reach near zero power generation emissions in the mid-21st century.
- The More Ambitious Policy 1 derivative scenario, which phases out coal by 2030 and natural gas by 2050 for power generation, charts a rapid reduction in emissions from power generation, reaching near zero targets before 2040.

The road ahead

- The National Energy Transition Roadmap (NETR) was launched by the Ministry of Economy of Malaysia in July and August 2023. NETR, which targets to achieve 70% renewable energy installed capacity in the power mix by 2050, will not bring Malaysia to near zero power generation emissions.

- The NETR has comprehensive energy efficiency measures that cover awareness, standards, mandatory audits, green building codes, energy efficiency retrofit and financing, and is expected to make a significant difference to total energy demand, which will affect power generation, and will be modelled in the next phase of this study.

- To achieve near zero power generation emissions, higher utilisation of renewable energy, energy storage, regional grid interconnection, carbon capture and storage (CCS) and clean hydrogen are necessary. The cost curves of emerging technology such as CCS and clean hydrogen are expected to fall significantly once technology reaches an inflection point. These will be modelled in phases 2.2 and 2.3 of the ASEAN Green Future project.

1. INTRODUCTION TO MALAYSIA

Malaysia is a country in Southeast Asia, separated by the South China Sea into two regions: Peninsular Malaysia and East Malaysia on the island of Borneo. Peninsular Malaysia shares a land and maritime border with Thailand and maritime borders with Singapore, Vietnam, and Indonesia. East Malaysia shares land and maritime borders with Brunei and Indonesia, and a maritime border with the Philippines and Vietnam.

With a population of over 32 million, Malaysia is the world's 45th-most populous country. After independence in 1957, the Malaysian gross domestic product (GDP) grew at an average rate of 6.5% per annum for almost 50 years. Its current GDP and GDP per capita are USD406 billion and USD11,971 respectively (World Bank 2022). The economy has transitioned from agriculture towards services, which now contributes 51% of GDP (World Bank 2023) (Figure 1). Malaysia is an upper middle-income country (World Bank 2022) and is ranked the fifth largest economy in Southeast Asia behind Indonesia, Thailand, Singapore, and Vietnam (International Monetary Fund 2023). Its Human Development Index is classified as very high (United Nations Development Programme 2021).

Located in the tropics along the equator, Malaysia is one of seventeen megadiverse countries, home to numerous endemic species, meaning that they are found nowhere else in the world (United Nations Environmental Programme 2023). It is estimated to contain twenty per cent of the world's animal species (Alexander 2006). High levels of endemism[2] are found in the diverse forests of Borneo's mountains, as species are isolated from each other by lowland forest.

At the 1992 Rio Earth Summit, Malaysia pledged to retain at least 50% of the country's forest cover. Although this pledge by the federal government is not bound by any law that can be enforced on the states, the forest policies of individual states generally have a forest cover target of above 50%. For example, Sarawak's forest policy targets 57% forest cover, while Sabah's forest policy targets 50% (The Borneo Post 2021).

However, some third-party forest watchdogs such as Global Forest Watch and Hutanwatch have noticed discrepancies in forest cover data and questioned the official statistics of Malaysian forest cover. Malaysia follows the Food and Agriculture Organization's (FAO) definition of forest cover: "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10% of trees able to reach these thresholds in situ[3]," (FAO 2015). This definition allows certain monoculture plantations such as rubber and acacia to be considered forest (Rimbawatch 2023).

Maintaining the country's forest cover is key for Malaysia to meet its 2050 net zero ambition, as the forest absorbs 237 MtCO2e equivalent, or 72% of national greenhouse gas emissions (Ministry of Natural Resources, Environment and Climate Change, Malaysia 2022). The country is also increasing renewables in power generation, managing demand, and improving energy efficiency across sectors. An active carbon credit market is expected to change the incentives for states to increase their forest cover.

In Malaysia, most existing economic instruments for climate policy are 'second-best instruments', which produce some environmental benefit without fully addressing market failures. However, there has been a recent shift in focus towards 'first-best instruments' such as carbon pricing instruments (CPIs), ecological fiscal transfers (ETFs) and payment for ecosystem services (PES), which have the potential to balance the financial drivers of deforestation. The utilisation of these mechanisms to their full potential, however, is constrained by the chronic lack of federal funding. (Institute of Strategic and International Studies (ISIS) Malaysia 2022)

[2] WWF-BCG (2021). Securing our future: Net zero pathways for Malaysia
[3] WWF-BCG (2021). Securing our future: Net zero pathways for Malaysia

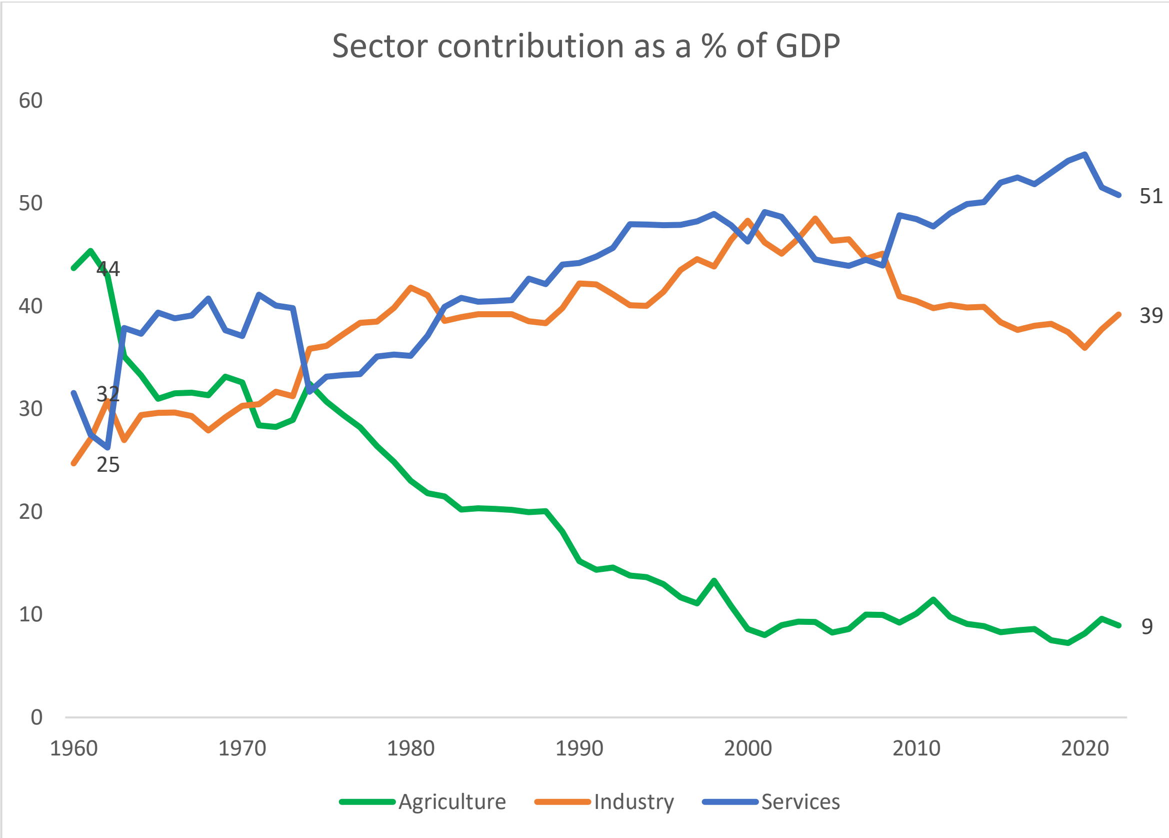


Figure 1: Sector contribution as a % of GDP (World Bank 2023)

- Agriculture includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production
- Industry includes manufacturing, mining, construction, electricity, water, and gas
- Services include wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services

This report acknowledges the government policies, roadmaps and plans since 2020, that have a direct relevance for the power sector in Malaysia (Table 1) and incorporate key details in the modelling.

Table 1: Summary of Malaysian government policies related to decarbonisation[4]

Title	Author	Year released	Period covered	Highlights
National Energy Transition Roadmap (NETR)	Ministry of Economy	2023	2023 – 2050	Reduce emissions through 6 key levers – energy efficiency, renewable energy, hydrogen, bioenergy, green mobility, and carbon capture, utilisation and storage (CCUS). Notably, it heightens ambition by targeting 70% renewable share and 0% coal share of installed capacity by 2050.
Malaysia Energy Transition Outlook	International Renewable Energy Agency (IRENA); Ministry of Natural Resources, Environment & Climate Change (NRECC)	2023	2023 – 2050	Explores two possible highly decarbonised routes of 100% renewables by 2050, and 90% renewables with carbon capture and storage by 2050. In both cases, the vast majority of capacity is solar and hydro.[5]
Sabah Energy Roadmap and Master Plan 2040 (RAMP 2040)	Energy Commission of Sabah (ECoS)	2023	2023 – 2040	Key targets include 30% renewable energy share by 2035, 100% rural electrification, and achieving a sustainable electricity tariff.
Malaysia Renewable Energy Roadmap (MyRER)	Ministry of Energy and Natural Resources of Malaysia (KeTSA); Sustainable Energy Development Authority (SEDA)	2021	2021 – 2035	Outlines the Business as Usual (BAU) scenario to reach 32% of renewable energy share by 2035, and the New Capacity Target (NCT) scenario to reach 40% renewable energy share by 2035. Focuses on hydro, solar, and bioenergy generation.
Report on Peninsular Malaysia Generation Development Plan 2020	Energy Commission	2021	2021 – 2039	Details capacity mix towards 31% renewable energy share by 2025 and 40% renewable energy share by 2035 for Malaysia. Targets 31% renewable energy share by 2039 for Peninsular Malaysia. Projects reserve margin to fall from 52% in 2021 to 21% in 2039.
Low Carbon Mobility Blueprint (LCMB)	Ministry of Water and Environment (KASA); Malaysian Green Technology and Climate Change Corporation (MGTC)	2020	2021 – 2030	Reduce transport emissions via adoption of low emission vehicles and electric vehicles, alternative fuel adoption, and modal shift towards public transport and rail
National Energy Efficiency Action Plan (NEEAP)	Ministry of Energy, Green Technology and Water (KeTTHA)	2015	2016 – 2025	Key initiatives to improve energy efficiency include efficient devices, efficient building design, and energy audits

Table 1 summarises current Malaysian government policies related to decarbonisation. The proliferation of different ministries forming decarbonisation-related policies stems from the frequent restructuring of ministries during a period of heightened political instability in Malaysia, as well as the cross-cutting nature of climate change. The responsibility of handling climate change has fallen to, in turn, the Ministry of Energy, Green Technology and Water (KeTTHA); Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC); Ministry of Water and Environment (KASA); Ministry of Energy and Natural Resources (KeTSA); and finally, the current Ministry of Natural Resources, Environment and Climate Change (NRECC)[6].

The National Energy Transition Roadmap released by the Ministry of Economy in July and August 2023 have yet to be modelled in this report.

[4] The Malaysian Biomass Industry Action Plan 2020 by the Malaysia Industry-Government Group for High Technology (MIGHT) is not included in this table as it was released in 2013 to plan towards 2020, which has passed.
[5] RE100: 81% solar, 15% hydro, 3% biomass
RE90: 68% solar, 19% hydro
[6] Official ministry acronyms do not always match its full name, as it depends on whether the English or Malay translation is used.

In addition to the official government policies, research on decarbonisation pathways in Malaysia has also been conducted by the private sector. Two noteworthy ones are by the World Wildlife Fund (WWF) and Malaysia Boston Consulting Group (BCG) Malaysia[7], and Shell Malaysia[8].

The WWF-BCG report (2021) maps out four main pathways (Figure 2): Current Forward Trajectory (net zero not achieved), Low Carbon Ambition (net zero in 2065), Net Zero Pathway (net zero in 2050), and Technical Limit (net zero in 2040). Under the Net Zero Pathway, renewable energy capacity reaches 61% in 2050, comprising of 44% solar, 13% hydro and 4% biomass; with natural gas providing the remaining 39%.

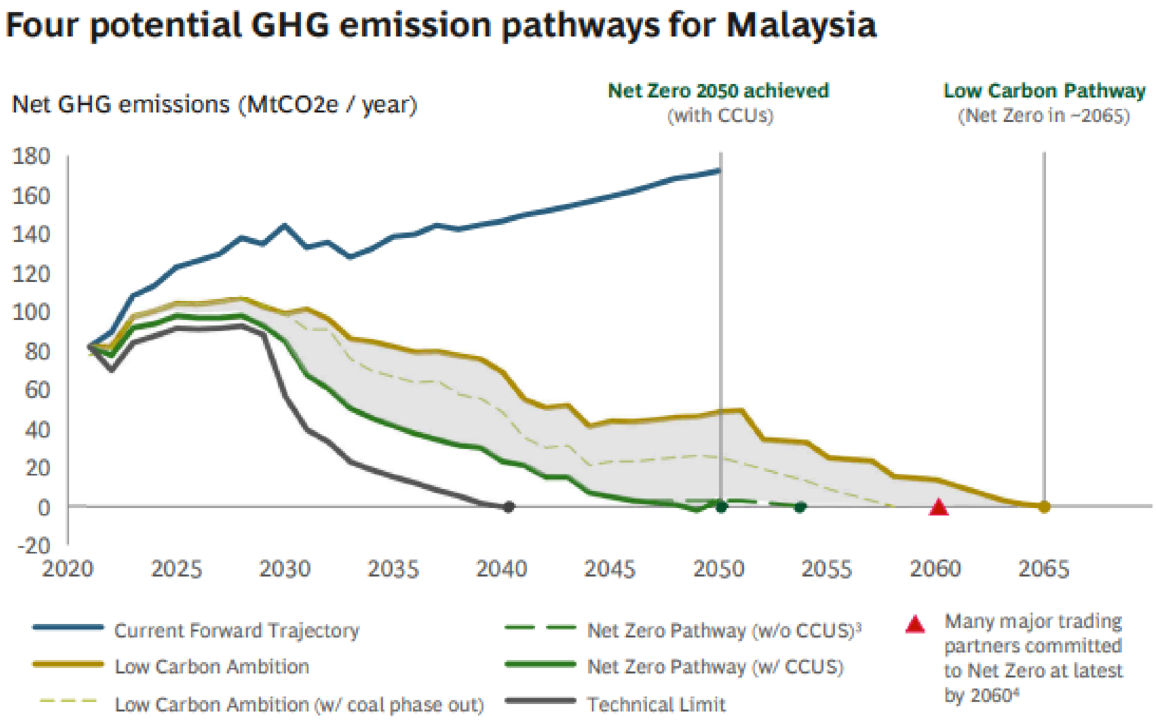


Figure 2: Four potential GHG emission pathways for Malaysia (WWF-MY and BCG-MY 2021)

The Shell report (2021) maps out five pathways (Figure 3), also with varying years of achieving Net Zero Emissions (NZE): Unambitious Pathway (NZE >2100), Modest Pathway (NZE 2099), Balanced Pathway (NZE 2080), Balanced Pathway with Reforestation (NZE 2065), and Aggressive Pathway (NZE 2054). Under the Aggressive Pathway, renewable energy capacity reaches 50% in 2050, supported by natural gas providing 45% of capacity mix[9].

[7] WWF-BCG (2021). Securing our future: Net zero pathways for Malaysia
[8] Shell (2021). The tree, the sky, the sun: A pathway towards Malaysia's carbon neutral future
[9] The report does not detail the exact numbers behind what comprises the renewables mix, or where the remaining 5% capacity comes from.

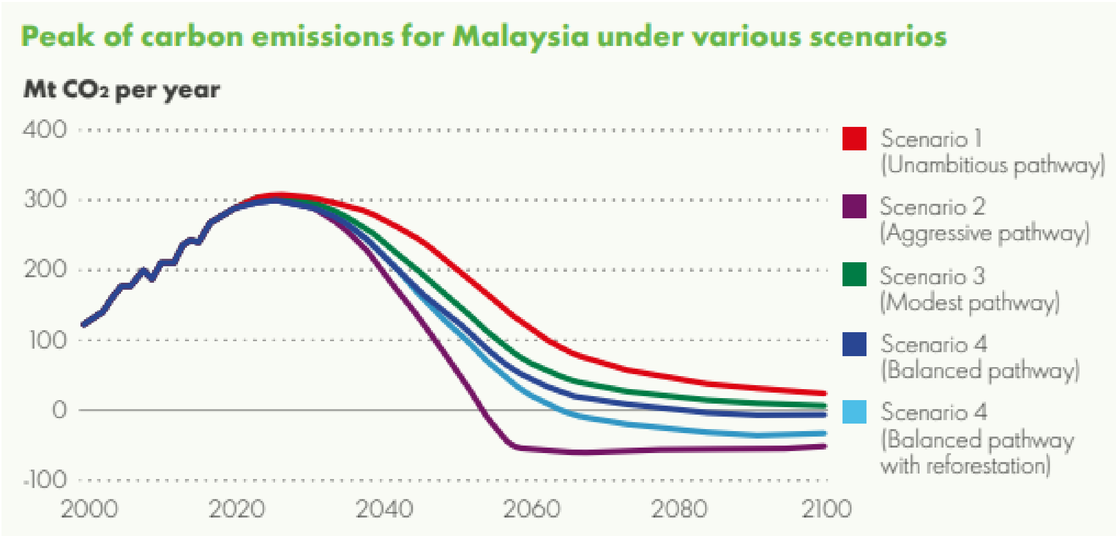


Figure 3: Peak of carbon emissions for Malaysia under various scenarios (Shell 2021)

2. HISTORICAL TRENDS OF POWER AND GREENHOUSE GAS EMISSIONS

2.1 Methodology

a) Software

The Low Emission Analysis Platform (LEAP), a widely used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute, is used to build a power sector model for Malaysia.

b) Scope

The power sector model captures supply (electricity generation) and demand (industry, transport, residential and commercial / services).

c) Time

The years of 2019 and 2001 are chosen to represent current and historical time periods for the following reasons:

2019:

- Malaysia's Fourth Biennial Update Report under the UN Framework Convention on Climate Change (2022) has data until 2019.

2001:

- Malaysia ratified the Kyoto Protocol on 4 July 2002, officially committing to the obligations for reducing greenhouse gas (GHG) emissions and contributing to global efforts to combat climate change. In the process, Malaysia benefited from the Carbon Development Mechanism (CDM) by attracting investment in renewable energy, energy efficiency, and waste management projects. Besides international funding, Malaysia was also able to access technical expertise from developed countries and international organisations to support the climate change mitigation and adaptation projects.

- Malaysia experienced significant economic changes in 2001. It marked the beginning of the Ninth Malaysia Plan, which emphasised on enhancing competitiveness, attracting investments, and promoting innovation in the manufacturing, services, agriculture, and tourism sectors.

- The Multimedia Super Corridor (MSC), launched in 1996, gained momentum in 2001. It aimed to transform Malaysia into a digital economy hub by leveraging information and communication technologies (ICT). Several key projects and infrastructure developments under MSC, such as the development of Cyberjaya as a technology hub, progressed during that time.

- Malaysia's National Automotive Policy (NAP) was introduced in 2001 to transform Malaysia into a regional automotive hub and promote the development of the local automotive industry.

d) Source of data

Data from published reports in the public domain are fed into the LEAP model.

2.2 Analysis

LEAP model SDSN_AGF_MYS_v26.10.2023 is used to inform this report.

GHG emissions from the power sector were 106.4 $MtCO_2e$[10] in 2019, which was 32% of the total GHG emissions of the country[11] (Figure 4).

These emissions largely come from the burning of coal and gas for electricity (LEAP model):

- Gas plants contribute to 28% of power emissions and provide 38% of total electricity generation.
- Coal accounts for 71% of emissions, but only 46% of generation.
- There are emissions coming from small generation sources like fuel oil (e.g. diesel), biogas and biomass. The percentages are negligible.

[10] Total estimated GHG emissions for Malaysia's energy sector in 2019 was 259 $MtCO_2e$ (Ministry of Natural Resources, Environment and Climate Change, Malaysia 2022). Electricity generation contributed 106.4 $MtCO_2e$, which is calculated from Table A-9 on p. 138 of BUR4:

CO_2: 106 Mt

CH_4: 1.47 Gg = 1,470 t; CH_4's 100-year global warming potential is 25 → 25 x 1,470 = 36,750 tCO2e

N_2O: 1.23 Gg = 1,230 t; N_2O's 100-year global warming potential is 298 → 298 x 1,230 = 366,540 tCO2e

The LEAP model (v3.1.16) estimates the electricity generation emissions in 2019 to be 115 $MtCO_2e$. Both the government and LEAP use IPCC Tier 1 default emission factors. The difference between the two estimates is 8%.

[11] Total GHG emissions in Malaysia in 2019 were 330 $MtCO_2e$ (Ministry of Natural Resources, Environment and Climate Change, Malaysia 2022)

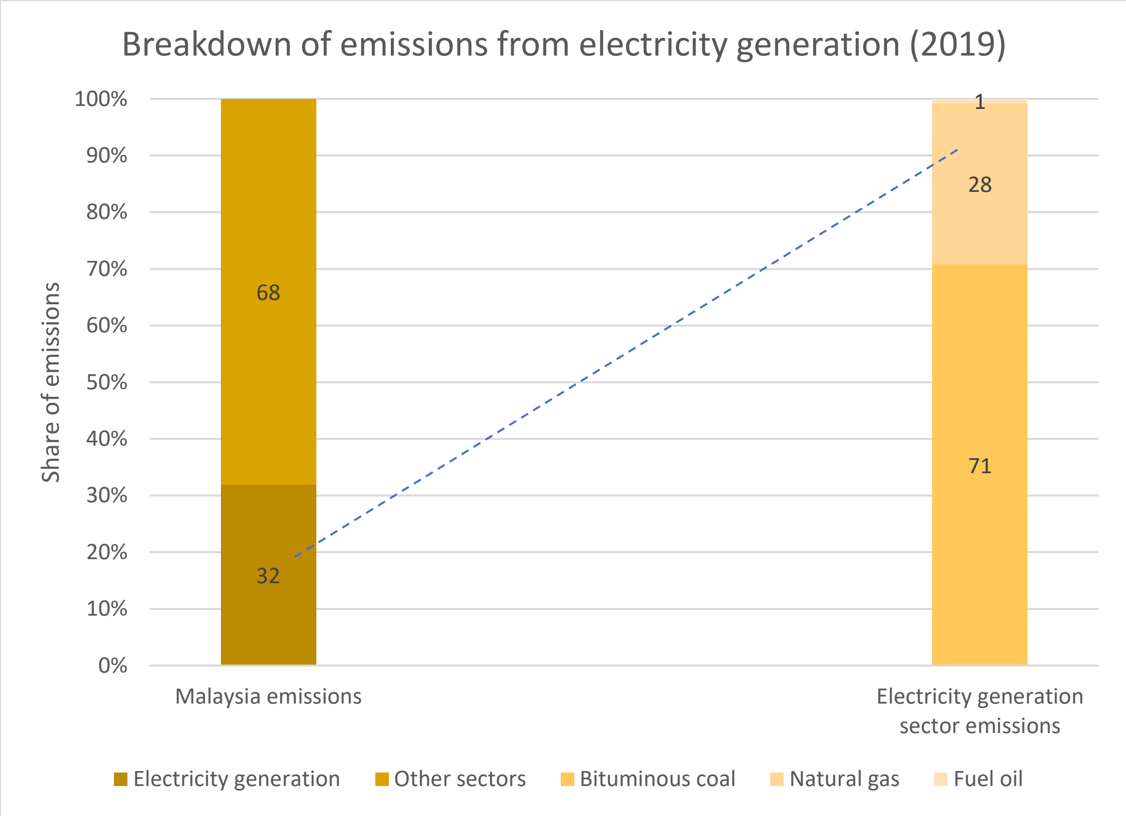


Figure 4: Breakdown of emissions from electricity generation (2019)

Based on the LEAP model, emissions from electricity generation in 2019 (115 MtCO2e) were 203% above 2001 levels (38 MtCO2e) (Figure 5). This was driven by increase in electricity demand and carbon intensity of generation as coal capacity increased 278% from 2001 (3,060 MW) to 2019 (11,560 MW) (Figure 6).

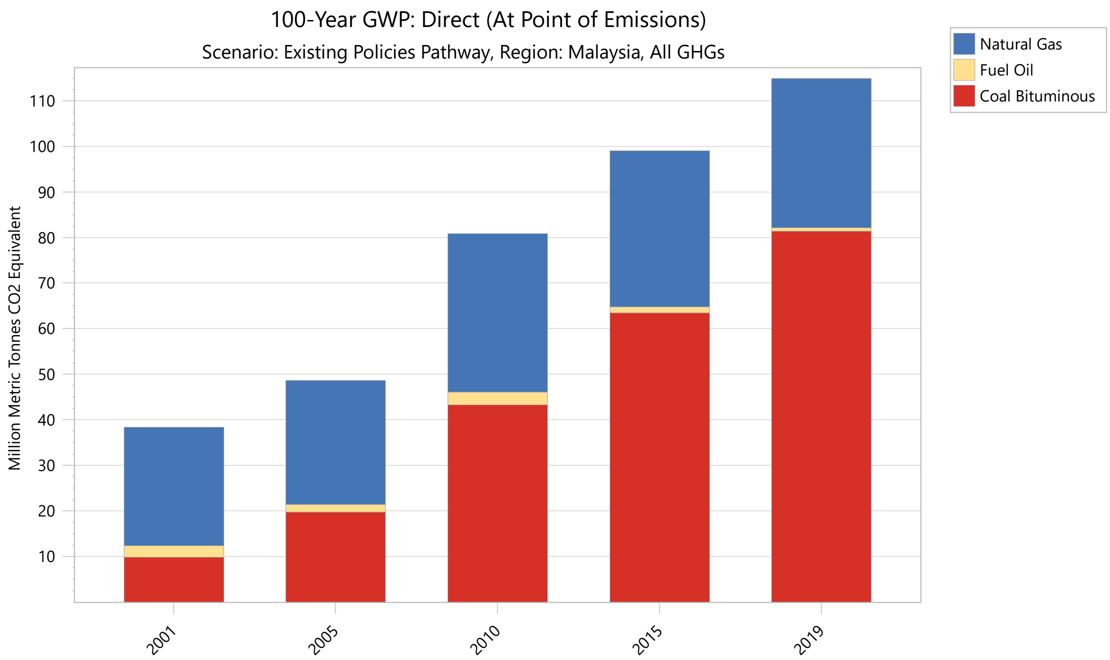


Figure 5: Breakdown of emissions from electricity generation (2001-2019)

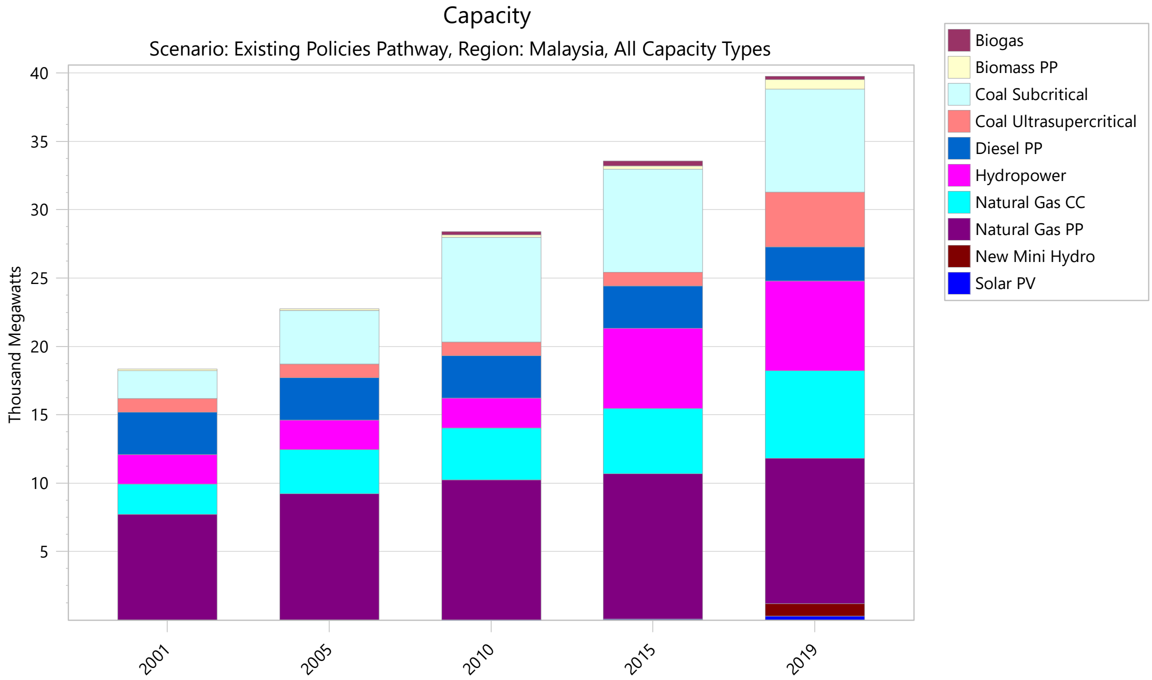


Figure 6: Installed generation capacity by technology (2001-2019)

- **Higher electricity demand.** In 2019, electricity demand was around 155 TWh. This represents an increase of 138% compared to 2001 levels (65 TWh) and has led to higher generation and hence higher emissions.

  - Residential electricity consumption increased by 163% between 2001 (13 TWh) and 2019 (30 TWh), whilst the Malaysian population grew by 43% [from 23 million (2001) to 33 million (2019)] during the period. The percentage of population with access to electricity increased 1.4% (from 98.6% to 100%) during this time (The World Bank 2023). The much faster growth in residential electricity consumption compared to the growth of population and electrification rate suggest increased use of appliances, electric stoves, electronic devices, heating and cooling systems.

  - Industrial electricity consumption increased by 126% (34 TWh to 77 TWh) between 2001 and 2019. Malaysian manufacturing output increased by 189% (USD27 billion to USD78 billion) during this period (Macrotrends 2023). This could be attributed to:
    - Industries using energy more efficiently, optimising production processes, and reducing energy waste. Promotion of efficient lighting and high efficiency motors are key programmes in the National Energy Efficiency Action Plan, launched in 2015. Malaysia also began promoting Industry 4.0 in the same year, though parts of Malaysian industry remain at the stage of Industry 2.0 today[12].
    - Industries using more efficient energy conversion technologies, such as combined heat and power (CHP) systems. Promoting CHP is a key initiative in the National Energy Efficiency Action Plan.

[12] Industry 1.0: mechanization era (late 18th to early 19th century); marked the transition from manual production to mechanized production using water and steam power.
Industry 2.0: age of mass production (late 19th to early 20th century); brought about the widespread adoption of electricity, assembly lines, and standardised components.
Industry 3.0: digital revolution (mid-20th century to late 21st century); introduced digital technologies and automation into manufacturing processes.
Industry 4.0: smart factory and cyber-physical systems (21st century); transformation of manufacturing through the convergence of digital, physical, and biological technologies.

- Industries may be adopting new production methods that require less energy intensive processes or rely on energy sources other than electricity, e.g. natural gas, steam etc.
- Changes in manufacturing mix, such as increased production of higher value-added products.

– Figure 1 shows that the Malaysian economy is transitioning towards a service-based economy because the share of services' contribution to GDP has increased whilst the industry sector's contribution has decreased during 2001-2019; agriculture's contribution has remained at around 10% since 2000. The service sector is generally less energy-intensive than the industry sector, which means that a shift towards services could slow down the increase in overall industrial electricity demand, particularly if the remaining industries continue to improve energy efficiency and processes. There is evidence that the services sector has become more efficient between 2001 and 2019, as its electricity consumption increased by 161% (18 TWh to 47 TWh – from LEAP model) while its GDP contribution increased by 330% (USD 46 billion to USD 198 billion) (The World Bank 2023) during this period of time.

– Electrification of transport and industry is expected to increase electricity demand further. Falling prices of renewable electricity and electric equipment and increasing GHG emission regulation are expected to boost consumption of electricity in these sectors which have been using fossil fuels as the standard energy source.

- **Increase in carbon intensity.** Carbon intensity of electricity generation increased by 23% between 2001 and 2019, i.e. from 512 gCO_2/kWh[13] to 631 gCO_2/kWh[14].

  – In 2001, coal generated 14% of Malaysian electricity. Following the 'dash-for-coal' due to cheaper coal price compared to natural gas[15], that share increased to 46% in 2019. The share of natural gas generated electricity fell from 72% to 38% during this time. (Figure 7)

  – Hydropower accounted for 14% of electricity generation in 2019, up from 9% in 2001. This helped to limit the increase in carbon intensity due to expansion of coal generation capacity. (Figure 7)

[13] 2001: 38.36 $MtCO_2$ / 74.92 TWh
[14] 2019: 114.96 $MtCO_2$ / 182.25 TWh
[15] Malaysia chose to import cheap coal, export domestic fossil gas and earn the monetary surplus.

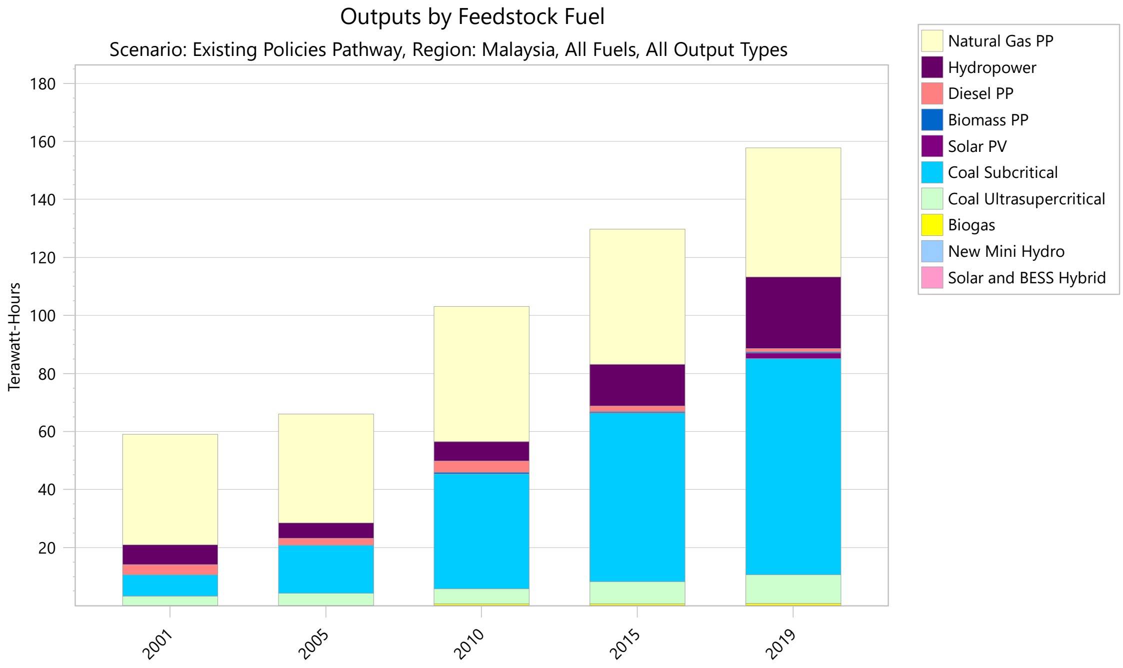


Figure 7: Electricity generation by source (2001-2019)

- GHG emissions in the energy sector[16] increased 107% from 2001 (107 MtCO2eq) to 2019 (221 MtCO2eq). Power generation and transport were the two highest emitters, followed by industry. (Figure 8)

Figure 8: Historical emissions in the energy sector

[16] Energy sector = agriculture and fishing, electricity generation, industry, residential, services and transport

3. FUTURE SCENARIOS

Reducing emissions from electricity generation whilst meeting new demands from the electrification of transport, industry, residential and commercial / services will require a portfolio of generation technologies, energy efficiency measures, flexible demand, and storage.

3.1 Methodology

a) Scope

The power sector model captures supply (electricity generation) and demand (industry, transport, residential and commercial / services).

Two scenarios are built in this study - Existing Policy and More Ambitious Policy. The two scenarios are described in detail in section (b) below.

b) Time | Assumptions

In the Existing Policy scenario, gross domestic product (GDP), population, electricity access, appliance ownership, energy intensity, and sectoral value-added are the key drivers for electricity demand projection, in addition to published government projections, targets and studies up till July 2023, before the launch of the National Energy Transition Roadmap.

Table 2: Key drivers for electricity demand projections

Drivers	Assumptions
GDP	The Shared Socioeconomic Pathway 2[17] (SSP2) is selected to be the key driver for electricity demand projections. SSP2 is characterised by a moderate rate of economic expansion, moderate population growth, and moderate technological change. It is a middle-of-the-road scenario that assumes that the world will continue to develop along current trends.
Sectoral value -added[18]	Refers to the GDP contribution to the country from different economic sectors.
Energy intensity	Refers to the energy consumed per unit of economic output (e.g. GDP). Envisions gradual improvements in energy efficiency across various sectors of the economy.
Population	A moderate population growth trajectory, with a gradual decline in fertility rates and decreasing population growth rates over time.
Electricity access	100% (The World Bank 2023)
Appliance ownership[19]	Appliance ownership numbers are available from the Household Income and Basic Amenities Survey Report (Department of Statistics, Malaysia 2019). Detailed breakdown by appliance is written in the assumptions under the residential sector. Efficiency of appliances is based on the National Energy Efficiency Action Plan (2016 -2025).

[17] SSP2 is one of five Shared Socioeconomic Pathways (SSPs) developed by the Intergovernmental Panel on Climate Change (IPCC) to help researchers and policymakers think about how different future societies might evolve and how these different pathways could affect climate change.
[18] Relevant to the industry sector.
[19] Relevant to the residential sector.

The More Ambitious Policy scenarios increase the penetration of renewable energy (generation) and energy efficiency technologies (demand) over the Existing Policy scenario. Key assumptions are set out in Table 3.

Existing Policy and More Ambitious Policy are modelled to investigate their potential emission reductions and sufficiency for meeting targets.

Table 3: Key assumptions in the Existing Policy and More Ambitious Policy scenarios

<table>
<tr><th>Sectors</th><th>Key assumptions in the Existing Policy scenario</th><th>Key assumptions in the More Ambitious Policy scenario</th></tr>
<tr><td>Power generation</td><td>

- Malaysia targets 31% RE in installed power generation capacity in 2025 and 40% in 2035. Information in the new National Energy Transition Roadmap, which include RE capacity additions beyond 2035, will be modelled in the next phase of this study.
- The Malaysia Renewable Energy Roadmap (SEDA Malaysia 2021) has designed the RE capacity mix shown below to achieve the targets.

<table>
<tr><th></th><th>2025 (MW)</th><th>2035 (MW)</th></tr>
<tr><td>Solar</td><td>4,706</td><td>7,280</td></tr>
<tr><td>Large hydro</td><td>5,862</td><td>8,062</td></tr>
<tr><td>Small hydro</td><td>1,153</td><td>1,219</td></tr>
<tr><td>Biomass</td><td>862</td><td>998</td></tr>
<tr><td>Biogas</td><td>333</td><td>406</td></tr>
<tr><td>Geothermal</td><td>-</td><td>30</td></tr>
<tr><td>Total RE capacity</td><td>12,916</td><td>17,995</td></tr>
<tr><td>Total non-RE capacity*</td><td>28,749</td><td>26,993</td></tr>
</table>

*Calculated

- Information about new generation capacity to be added and capacity to be retired from the Report on Peninsular Malaysia Generation Development Plan 2020 (2021-2039) (Energy Commission 2021) and the Sabah Electricity Supply Industry Outlook 2019 (Energy Commission 2019) are also inserted into the LEAP model.
- Dispatch merit order[20]:

</td><td>

MAP:

No new addition of fossil fuel new capacities from 2030
After 2030, LEAP adds RE capacity (e.g. solar and BESS hybrid, solar PV, hydro, biomass, wind, biogas, municipal solid waste, geothermal) to the system as needed in order to meet the total and peak electricity demands.
Dispatch merit order:
1 – solar and BESS hybrid, biomass, biogas, municipal solid waste steam turbine, wind onshore and offshore
2 – hydropower, geothermal
3 – coal, natural gas, diesel power plant

MAP 1

- Phaseout coal by 2030 and natural gas by 2050

</td></tr>
</table>

[20] The dispatch merit order is arranged this way so that the generation profile produced by the LEAP mode matches the historical generation data from government sources more closely.

Sectors	Key assumptions in the Existing Policy scenario	Key assumptions in the More Ambitious Policy scenario
	1 – solar and battery energy storage system (BESS) hybrid, wind onshore and offshore 2 – coal, natural gas, hydropower, geothermal, municipal solid waste steam turbine, biomass, biogas 3 – diesel power plant	
Residential	• Urbanisation increases from 83% in 2018 to 98% in 2059 • For urban: o Penetration rates for cooking, lighting, and other appliances are 100% in 2018 and remain constant o Cooking uses 95% LPG and 5% wood in 2018, changing to 60% electric and 40% LPG in 2060 o Lighting uses 100% electricity, which remains constant. Efficient lighting increases from 10% in 2018 to 55% in 2025, then remains constant. o Penetration rate for refrigeration is 99% in 2018 and remains constant. Efficient refrigeration increases from 30% in 2018 to 90% in 2025, then remains constant. o Penetration rate for air conditioning is 54% in 2018 and increases to 90% in 2060. Efficient air conditioning increases from 10% in 2018 to 55% in 2025, then remains constant. • For rural: o Penetration rates for cooking, lighting, and other appliances are 100% in 2018 and remain constant o Cooking uses 90% LPG and 10% wood in 2018, changing to 40% electric and 60% LPG in 2060 o Lighting uses 100% electricity, which remains constant. Efficient lighting increases from 10% in 2018 to 55% in 2025, then remains constant. o Penetration rate for refrigeration is 99% in 2018 and remains constant. Efficient refrigeration increases from 30% in 2018 to 90% in 2025, then remains constant. o Penetration rate for air conditioning is 54% in 2018 and remains constant. Efficient air conditioning increases from 10% in 2018 to 55% in 2025, then remains constant Numbers and targets are based on the National Energy Efficiency Action Plan 2016-2025, Department of Statistics Malaysia, and World Health Organisation.[21]	• Urbanisation increases from 83% in 2018 to 98% in 2059 • For urban: o Penetration rates for cooking, lighting, and other appliances are 100% in 2018 and remain constant o Cooking uses 95% LPG and 5% wood in 2018, changing to 60% electric and 40% LPG in 2060 o Lighting uses 100% electricity, which remains constant. Efficient lighting increases from 10% in 2018 to 55% in 2025 to 100% in 2060. o Penetration rate for refrigeration is 99% in 2018 and remains constant. Efficient refrigeration increases from 30% in 2018 to 90% in 2025 to 100% in 2060. o Penetration rate for air conditioning is 54% in 2018 and increases to 90% in 2060. Efficient air conditioning increases from 10% in 2018 to 55% in 2025 to 100% in 2060. • For rural: o Penetration rates for cooking, lighting, and other appliances are 100% in 2018 and remain constant o Cooking uses 90% LPG and 10% wood in 2018, changing to 40% electric and 60% LPG in 2060 o Lighting uses 100% electricity, which remains constant. Efficient lighting increases from 10% in 2018 to 55% in 2025 to 100% in 2060. o Penetration rate for refrigeration is 99% in 2018 and remains constant. Efficient refrigeration increases from 30% in 2018 to 90% in 2025 to 100% in 2060. o Penetration rate for air conditioning is 54% in 2018 and remains constant. Efficient air conditioning increases from 10% in 2018 to 55% in 2025 to 100% in 2060. Numbers and targets are based on the National Energy Efficiency Action Plan 2016-2025, Department of Statistics Malaysia, and World Health Organisation.

[21] While penetration rates of energy efficient appliances might appear optimistic, there is a lack of other data sources for this metric. Hence rates from the official government policy of NEEAP were used for the Existing Policy scenario.

Sectors	Key assumptions in the Existing Policy scenario	Key assumptions in the More Ambitious Policy scenario
Services / Commercial	• Final energy intensity reflects an overall efficiency gain of 55% in 2050 compared to 2019 levels, driven by efficient building design (40%) and energy-efficient equipment (15%). • Fuel share of electricity continues to increase due to increasing electrification • Value added of the service sector continues to increase following historical trends and Malaysia's economic development	• Final energy intensity reflects an overall efficiency gain of 70% in 2050 compared to 2019 levels, driven by efficient building design (40%), energy efficient equipment (15%) and energy audits (15%) • Fuel share of electricity continues to increase due to increasing electrification • Value added of the service sector continues to increase following historical trends and Malaysia's economic development
Transport	• 10,000 EV charging points by 2025 (Malay Mail 2023) • 1.5 million EVs by 2040 (The Star 2023) • 15% share of electric motorcycles by 2030 (Ministry of Environment and Water 2021) i. The average vehicle type split between 2018-2020 is car (47.2%), motorcycle (45.9%), bus (0.2%), freight (4.2%) and others (2.6%), respectively. The 'freight' and 'others' categories are calculated as a single variable as the composition of vehicles are similar (heavy construction vehicles, ambulances, etc.) The same percentage will be used for 2022-2030 Existing Policy scenario projection. ii. The average vehicle-kilometre travelled (VKT) for car is 15,000 km while for motorcycle is 5,000km (Briggs and Leong 2016). iii. Annual average VKT of 56,197.2 km (commercial freight vehicle) and 57,922.5 km (bus) will be used (Ho, et al. 2020) iv. Taxi, hire-and-drive car, and other types of vehicles are categorised as car in terms of usage patterns and emissions. v. The baseline fuel consumption for median freight trucks (MFT, 3.5t < GVW < ~15t) and heavy freight trucks (HFT, GVW > 15t) in Malaysia are modelled based on the proxy figure of China, which are (21.2 L/100km) and (41.6 L/100km) respectively, due to close GDP per capita and state of development (Delgado, et al. 2016) vi. The percentage split of MFT and HFT is approximated based on 2017 Road Transport Department data. vii. Since the stated fuel economy for car is the average figure across conventional internal combustion engine cars and hybridised cars, the same fuel economy will also be used for hybrid cars.	• Annual sales of 400,000 EVs by 2030 • 20 million EVs and 17 million electric motorcycles by 2050 (The Star 2023). This assumes normal rate of growth (population, GDP, vehicle ownership), without factoring in the modal shift to urban public transport. • 10,000 EV charging points by 2025, and 1.2 million by 2050 (Malay Mail 2023) • B20 blending target that was planned in 2020 will be met by 2025
Industry	Projection follows historical trends[22] for the industry sector. Data of energy usage for the industry sector in Malaysia at a disaggregated level is not available in the public domain. Fuel share for electricity increases from 34% in 2019 and 39% in 2050.	Fuel share for electricity increases from 34% in 2019 to 46% in 2050. This is the degree of electrification projected by IEA for the industry sector in a net zero by 2050 roadmap for the global energy sector (IEA 2020).

[22] Historical trends for energy Intensities and fuel shares, driven by GDP growth.

Commentary on the MAP 1 scenario for the power generation sector

In phasing out coal and natural gas, all prospective power plants using these fuels will be removed and existing capacity will be drawn down to zero at their respective deadlines. This will de-facto represent a zero fossil fuel target in generation capacity by 2050. To smooth the transition, it is assumed that the phaseout of coal will begin immediately (2025-2030) and the phaseout of natural gas will follow (2030-2050).

Solar presents the largest renewable potential in country compared to hydro, wind, geothermal and biomass which all have physical limits due to resources and/or geographical limitations. Hence a More Ambitious Policy scenario will heavily rely on switching to solar PV in combination with BESS or other storage. Any excess capacity requirements will be filled with a combination of other renewables. Large scale nuclear will not be considered due to the current unfavourable stance in Malaysia towards nuclear power in general (Bernama 2023). Nuclear also poses challenges in terms of nuclear fuel procurement and nuclear waste handling, which other renewable options in Malaysia do not face.

Solar PV will lead the energy transition in Malaysia and could reach up to 153GW of installed capacity by 2050. (Jacobo 2023)
Previous Energy, Science, Technology, Environment and Climate Change Minister Yeo Bee Yin mentioned over 4.12 million buildings with solar rooftop potential in Peninsular Malaysia, where 34,194 megawatts (MW) of electricity potential could be generated (Chu 2019).

Commentary on the MAP scenario for the transport sector

- The uptake of EVs is faster than expected amidst MITI's Battery Electric Vehicle (BEV) Global Leaders Programme that has fast-tracked international players like Tesla and BYD to setup operations in Malaysia. The government is aggressively promoting a conducive EV ecosystem, with Geely and DRB-Hicom announcing USD10 billion investment to develop the Automotive High-Tech Valley in Tanjung Malim (Bernama 2023). In 2023 alone, EV Sales in Malaysia is expected to rise by 46% to 4,469 units (which is conservative) (Foong 2022). The commitment shown by the government is reaffirming that Malaysia's EV growth will be exponential.

- Research has shown adopting B20 biofuel reduces CO_2 emissions by about 15% (US Department of Energy 2011). It will contribute to the reduced use of diesel while enhancing the use of palm oil that is renewable. In the past, the introduction of the B7 program was expected to reduce the use of diesel by 667.6 million litres, while at the same time enhance the use of biodiesel from 300,000 to 575,000 tonnes annually (Zulqarnain, et al. 2020). The B20 mandate has missed the 2022 deadline but is expected to roll out by 2025 when the in-line blending capacity is expanded.

- In 2018, Malaysia only reached 21% public transport modal share. The government targets to increase public transport usage to 50% by 2040 (Tan 2021), which is still a very conservative target.

- More urban rails (light rail transit LRT3 and possibly mass rapid transit MRT3) will become operational. Extension / rehabilitation of interstate rail lines, e.g. East Coast Rail Line (ECRL), Klang Valley Electrified Double Track Phase 2, Gemas-Johor Electrified Double Track, Johor-Singapore rapid transit system (RTS), and possibly LRT in Penang and KL-Singapore high-speed rail (HSR) will also be ready by late 2020s or early 2030s.

- Currently, only 900 of the 1,757 buses under Rapid Bus are actively operating (Gimino, et al. 2023). Klang Valley has the lowest buses per capita compared to Singapore, Greater London and Greater Vancouver. In January 2023, a total of RM2.8 billion has been allocated to improve train and bus services (Bernama 2023), and is estimated to expand the fleet size to the range and volume of Metro Vancouver.

- Aggressive availability of rail services and expanded bus fleet will see national public transport usage hitting 50% five years ahead of the planned target.

Commentary on the EP scenario for services / commercial sector

The approach used to model electricity demand in the services sector is a function of three factors:

i. **Activity,** which is represented by the value added of the service sector. This continues to increase, following historical trends. As economies develop, the value added of the service sector tends to increase in tandem.

ii. **Final energy intensity in terms of energy units per unit of value added.** This applies to the total energy consumed in the sector (i.e. all fuels and not only electricity). In this scenario, the LEAP model projects an efficiency gain of 55% in 2050 compared to 2019 levels. This matches the outcome from two key initiatives under the National Energy Efficiency Action Plan (Ministry of Energy, Green Technology and Water 2015), which are energy efficient building design (40%) and energy efficient equipment (air-con and lighting) (15%).[23]

iii. **Fuel share**, which indicates the relative fraction of the total energy demand that each fuel represents. Historical trends are used to project the continuous increase in the fuel share of electricity in the model. This results in increased demand for electricity from this sector.

The following numbers and data are obtained from the National Energy Efficiency Action Plan:

- Energy efficient building design can lead to an efficiency gain of 40% by applying the Code of Practice MS1525:2014, which can lower the energy consumption of buildings from 225kWh/m^2/year to 135kWh/m^2/year[24]. This includes practices such as optimising environmental cooling through natural means like vegetation, landscaping, and shading, as well as minimising losses in electrical power distribution (Department of Standards Malaysia 2014)

- Energy efficient equipment such as air conditioning systems and lighting can lead to a further gain of around 15%. The National Energy Efficiency Action Plan estimates that air conditioner upgrades can improve efficiency by about 15%, while lighting upgrades can improve efficiency by 25%. Therefore, we applied an overall 15% efficiency gain for efficient equipment in commercial buildings. This figure can be higher depending on the rate of technological progress.

[23] The efficiency gain of 55% came from both the model and the National Energy Efficiency Action Plan, which could be due to both relying on historical trends in their projections forward.

[24] There was a lack of complete data for services floor area in Malaysia, hence we modelled a top-down efficiency gain of 40% for this variable in the model.

Commentary on the MAP scenario for services / commercial sector

This scenario adopts the same measures from the Existing Policy scenario by modeling demand as a function of the value added of the service sector, final energy intensity and fuel share of electricity.

In addition, this scenario considers an energy saving measure - which is energy audits. This is about mapping a facility's energy consumption to identify areas for energy savings, such as avoiding energy wastage from equipment that is left on while not being used. The NEEAP estimates that this can generate about 15% more efficiency gain, which reduces the final energy intensity.

The NEEAP notes that energy audits are typically done by external consultants with expertise and will depend heavily on the number of trained auditors available. This policy will require the training of energy auditors to carry out energy audits. Therefore, this measure is placed under the More Ambitious Policies scenario.

The ASEAN Energy Manager Accreditation Scheme (AEMAS) is a regional ASEAN initiative developed and supported by the highest energy authorities and agencies of ASEAN, including ten ASEAN Ministers of Energy. 80% funded by the European Union during 2010-2014 under the SWITCH-Asia Programme, it is being implemented by ASEAN Centre for Energy (ACE) in eight ASEAN Member States - Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand and Vietnam (SWITCH-Asia). The Scheme was launched in Malaysia in 2011 (Malaysian Energy Professionals Association 2019) and implemented by the Energy Commission.

The passing of the Energy Efficiency and Conservation Bill by the parliament on 11 October 2023 will empower the Energy Commission to enforce the appointment of a Registered Energy Manager (REM) for high energy consuming installations[25]. The affected energy consumers will also be required to implement Energy Management System (EnMS), submit energy efficiency and conservation report and conduct mandatory energy audit every 5 years and submit the audit report (Optimal System Engineering 2023).

The EECA will supersede the Efficient Management of Electrical Energy Regulations 2008 (EMEER 2008).

[25] Heavy industrial and commercial users that consume 21,600 GJ per annum (equivalent to RM2.4 million in annual electricity bill or RM1 million in natural gas bill). The EECA will cover 1,500 out of 2,700 industrial consumers, and 500 out of 1.7 million commercial consumers.

4. RESULTS

The Existing Policy and More Ambitious Policy scenarios are analysed from the following five angles:

a) Demand and energy efficiency
b) Variable renewables
c) Dispatchable low-carbon generation
d) Firm power high-carbon generation
e) System flexibility

4.1 Existing policy

a) Demand and energy efficiency

The electricity demand for the residential, services / commercial, industry and transport sectors is projected to be 285 TWh in 2050, which is an 85% increase compared to 154 TWh in 2019. Figure 9 shows how each sector contributes to the increase in demand out to 2050. The majority (81%) of the increase in electricity demand is a result of changes in demand from industry and services.

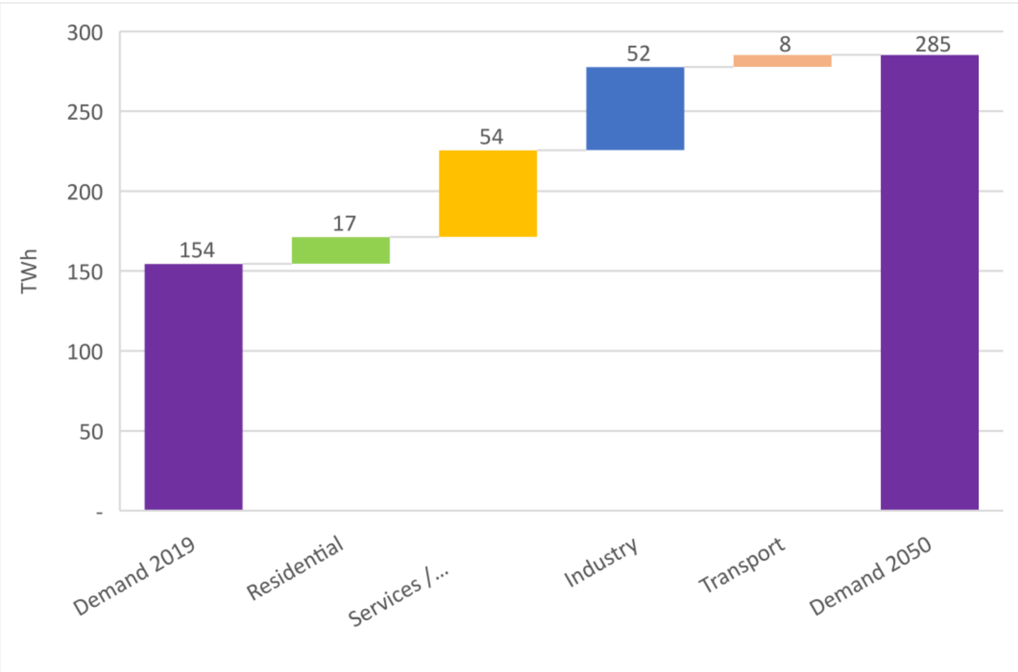


Figure 9: Contribution by sectors to increased electricity demand in the Existing Policy scenario (2019-2050)

These demand scenarios incorporate efficiency measures that limit the increase in electricity demand:

- **Residential.** The energy efficiency improvements for the residential sectors focus on lighting and appliances. The Electricity Regulations 1994 (Amendment 2013) enable the Energy Commission to regulate electrical appliances according to their energy performance and such appliances must meet the Minimum Energy Performance Standards (MEPS) and the efficiency ratings as prescribed in the Regulations.

  MEPS and energy efficiency labelling form a vital two-pronged approach to promoting energy efficiency.[26] Energy efficiency labels were introduced in 2006 by the Energy Commission and issued to electrical appliances (air-conditioner, refrigerator, television, domestic fan and lamp) manufacturers that comply with the standards and requirements of energy performance tests. Over the years, the programme has been expanded to include washing machine, microwave oven, electric rice cooker, freezer, and electric oven.

  The National Energy Efficiency Action Plan (2015) specifies estimates and targets for efficient household appliances using a five-star rating system, which have been incorporated under this scenario. Some of the increased demand for electricity in the residential sector will come from continued urbanisation as cooking and other household tasks are increasingly electrified.

  In July 2011, the Malaysian government, through the Sustainable Energy Development Authority (SEDA), launched the Sustainability Achieved via Energy Efficiency Programme (SAVE) that provided cash rebates for the purchase of energy-efficient refrigerators, air-conditioners and chillers. RM45 million was allocated to SAVE 1.0 for rebates and promotional campaign. This supported the purchases of 100,000 units of refrigerators, 65,000 units of air- conditioners and 72,000 refrigerated tonne[27] (RT) capacity of chillers for eligible domestic consumers and private companies.

  As SAVE was successful in stimulating a market for and enhancing market penetration of energy-efficient appliances, SAVE 2.0 was announced in Budget 2021 with a RM30 million allocation. Following that, SEDA launched SAVE 3.0, which introduced a second category of eligible appliances – television, washing machine, microwave oven and rice cooker – in 2022. SAVE 3.0 achieved notable results, recording 324 Gigawatt-hours (GWh) of energy savings, equivalent to an annual cost reduction of RM129.4 million, and a decrease of 281,000 tonnes of CO_2 emissions (Hakim, Mohamed and Amalina 2023).

  In December 2023, SEDA launched SAVE 4.0, which grants a maximum of RM400 e-rebate to domestic households that purchase air-conditioners and refrigerators with energy-efficient labels of 4 or 5 stars by the Energy Commission. RM50 million was allocated by the Electrical Supply Industry Trust Account (AAIBE) for the SAVE 4.0 (Hakim, Mohamed and Amalina 2023).

- **Industry.** Factors that contribute to the increase in electricity demand in industry include industrial expansion, population growth, urbanisation and infrastructure development, technological advancements, climate control and cooling needs. These factors continue to drive industry's value added to GDP, fuel share and energy intensity, which are modelled to follow historical trends.

  The development of Malaysia's energy-saving service industry concentrated in the industry sector because it has the second largest consumption of energy after the transport sector. In 2019, the industry sector's energy consumption was 26% of the country's total energy consumption (Ministry of Natural Resources, Environment and Climate Change, Malaysia 2022).

  Increasing uptake of energy efficiency improvement measures such as the following could have a significant effect on electricity demand:

  - Heating, ventilation, and air conditioning (HVAC): efficient chiller, variable speed drive, thermal energy storage

[26] MEPS is the backbone of for the labelling system. By setting minimum standards, it ensures that there is a clear differentiation in energy performance between different appliances, allowing for accurate and meaningful star ratings.
[27] Refrigerated tonne a unit of measure for the cooling capacity of refrigeration and air conditioning equipment. It is equal to the amount of heat required to melt 1 short tonne (2,000 lb; 907 kg) of ice at 0 °C (32 °F) in 24 hours.

- Equipment: compressor, high efficiency motor
- Process: heat recovery, co-generation

Tax incentives for energy efficiency were introduced through Budget 2001 in the form of waiver of import duty and sales tax on energy efficient equipment, and accelerated capital allowances or pioneer status for investment in energy efficient technologies and projects. These incentives were enhanced over the years. (Ministry of Energy, Green Technology and Water 2015)

A lack of enthusiasm and initiative in energy efficiency investments was observed in the industry sector (Goh, Chai and Goh 2019). Possible reasons include:

- Businesses' focus on short term profits
- Energy efficiency investments could be expensive upfront
- Energy efficiency investments can be complex and require technical expertise. Businesses may not have the in-house expertise to assess and implement energy efficiency measures. This is particularly true in indigenous Malaysian companies which have no direct access to new technology inputs.
- Businesses' lack of awareness of the benefits of energy efficiency investments or the resources available to help them implement energy efficiency measures

Energy-saving service companies have promoted the implementation of Energy Performance Contract[28] (EPC) projects on a large scale by using their own funds for energy-saving retrofit and sharing energy-saving benefits with industrial enterprises. However, this has put huge financial pressure on the energy-saving service companies.

As small and medium-sized energy service companies in Malaysia have difficulty securing third-party financing due to lack of credit records, most energy management projects can only be financed with their limited liquidity, which results in a small project size. The ecosystem supporting the energy service companies will need to be relooked and rejuvenated to encourage greater investment uptake by the client industries.

- **Commercial / services.** The sector's energy use is mainly in buildings, which is for space cooling and to operate equipment in the buildings. The LEAP model projects electricity demand from the commercial / service sector to contribute to 54% of the increase towards 2050. Growth factors include[29]:
  - Economic growth: increased demand for services such as healthcare, education, finance, information technology, and entertainment
  - Technological advancements: digital platforms, cloud computing, internet connectivity, data storage, smart devices, Internet of Things (IoT) devices etc.
  - Changing work environments: more digitalised and technology-driven work
  - Increasing energy-intensive services: data centres and cloud computing services

  Electricity demand growth is reined in by mandatory energy efficiency measures in new commercial buildings. In 2012, the Uniform Building By-Laws (UBBL) was amended. Section 38A of the UBBL requires new or renovated non-residential buildings with air-conditioned space exceeding 4,000m^2 to be designed to meet the Overall Thermal Transfer Value (OTTV) and the Roof Thermal Transfer Value (RTTV) of MS 1525 and be provided with an Energy Management System (EMS) (Ministry of Energy, Green Technology and Water 2015). The MS1525 is due for a revision every 5 years, taking into consideration the improving efficiency of energy consuming equipment. In the NETR, the

[28] EPC is a contract between a client and an energy service company (ESCO). The ESCO agrees to improve the client's energy efficiency, and the client agrees to pay the ESCO based on the amount of energy savings that are achieved.
[29] These growth factors are not directly modelled in LEAP but are underlying factors behind the service sector's GDP contribution, energy intensity and fuel share growth that is driving the 54% increase in electricity demand towards 2050.

government states an intention to launch a major energy efficiency retrofit initiative amongst government buildings (Ministry of Economy 2023).

Other key initiatives in the National Energy Efficiency Action Plan (2015) include implementing the Energy Performance Contract (EPC) in the government sector (approved in January 2013), commercial / services and industrial buildings. Energy-saving benefit-sharing contracts can enjoy national financial and tax incentives. Since then, Malaysia's energy-saving service industry has developed rapidly, both in terms of the number of energy service companies and the amount of investment in energy performance contract management. (Goh, Chai and Goh 2019)

However, challenges remain. For example, the government's fiscal budget system can only pay the energy cost but cannot pay the energy-saving benefits of energy service companies implementing EPC projects. This poses an obstacle to contract energy management, as evidenced by the small number of contractual energy management projects in public institutions (Goh, Chai and Goh 2019). Innovative financing instrument needs to be introduced. In developed countries like Japan, the change of equipment in large companies is undertaken by renowned engineering companies that provide energy monitoring services, a guarantee on energy savings due to the equipment purchased and periodic reporting to the Energy Conservation Centre, Japan.

Government buildings were instructed by the Ministry of Energy, Green Technology and Water (KeTTHA) to set their air conditioning temperature no lower than 24°C in 2011, unless under special circumstances such as the hospitals. In 2011, the government had the intention to table an act to compel commercial buildings to follow suit. Status of implementation is unclear. (The Star 2011)

The major challenge in promoting energy efficiency in Malaysia is the enforcement of regulatory instrument due to the lack of human capital and relatively low tariffs for commercial buildings to embark on energy efficiency measures. (Ministry of Energy, Green Technology and Water 2015)

Under the Existing Policy scenario, the model shows that final energy intensity decreases by 55% in 2050 compared to 2019 levels, which matches estimates from NEEAP for efficient building design (40%) and energy efficient equipment (15%). Despite the gains in energy intensity, there is still an overall increased electricity demand from this sector of 54TWh in 2050 compared to 2019, driven by increased value of services and fuel share of electricity.

- **Transport.** Electricity demand increases corresponding to rising share of electric vehicles (EVs) in the Total Industry Volume (TIV) (Figure 10), which is defined as the total number of new vehicles sold in a given market during a specific period, typically a year. The following elements are at play:

    - Strategic framework to develop EV charging infrastructure nationwide: the Malaysian government has set a target to install up to 10,000 public charging stations for EVs in the country by 2025 under the Low Carbon Mobility Blueprint 2021-2030;

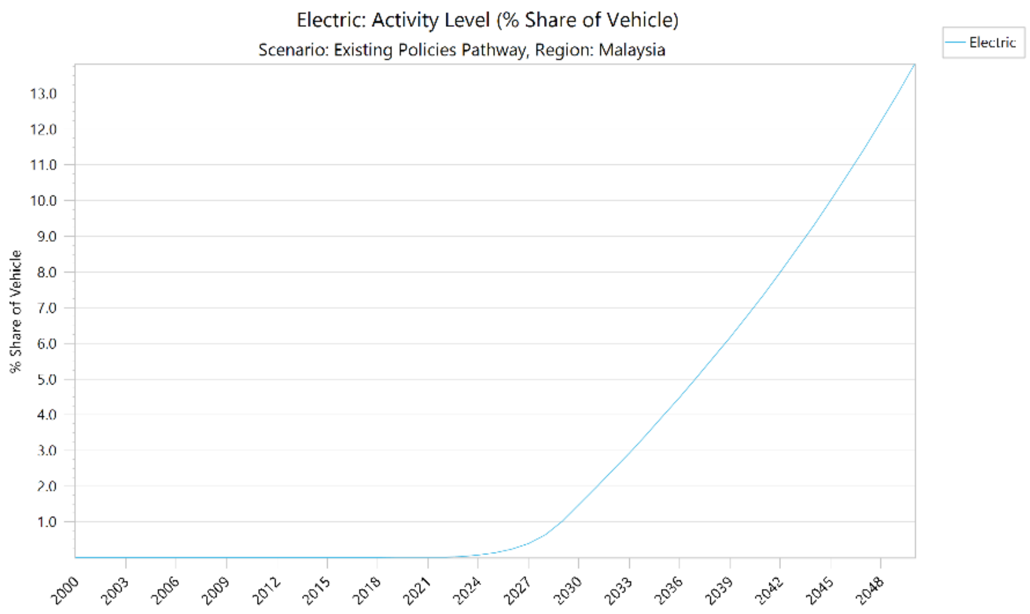
    - Tax incentives announced in Budget 2022: full exemption on import duty, excise duty and road tax for locally assembled EVs or imported as completely built-up, as well as full exemption for sales tax for EVs assembled locally and tax relief for individuals for subscription of facilities or installation of EV charging systems.

With the government incentives and falling EV prices, EVs' market penetration is expected to rise, and so will electricity demand from EVs. Nevertheless, under the Existing Policy scenario, fossil fuel (gasoline and diesel) usage in the transport sector remains dominant with EV adoption at 13.8% share of cars on the road by 2050. (Figure 11)

Due to the increase of total number of vehicles on the road, the demand on gasoline only plateaus after 2050 with diesel demand continuing to rise as there are no planned fuel replacements for the freight sector, and there is no policy to drive modal shift from road to rail for freight. (Figure 11)

Existing Policy does not control or reduce the number of vehicles on the road. The retirement timeline for internal combustion engine vehicles will become clearer when Malaysia implements an end-of-life vehicle policy by 2025.

Behavioural changes such as transitioning away from car use towards public transportation and/or active travel could reduce electricity demand from private transport. Fuel subsidy removal could be a significant factor in driving EV and public transport adoption.



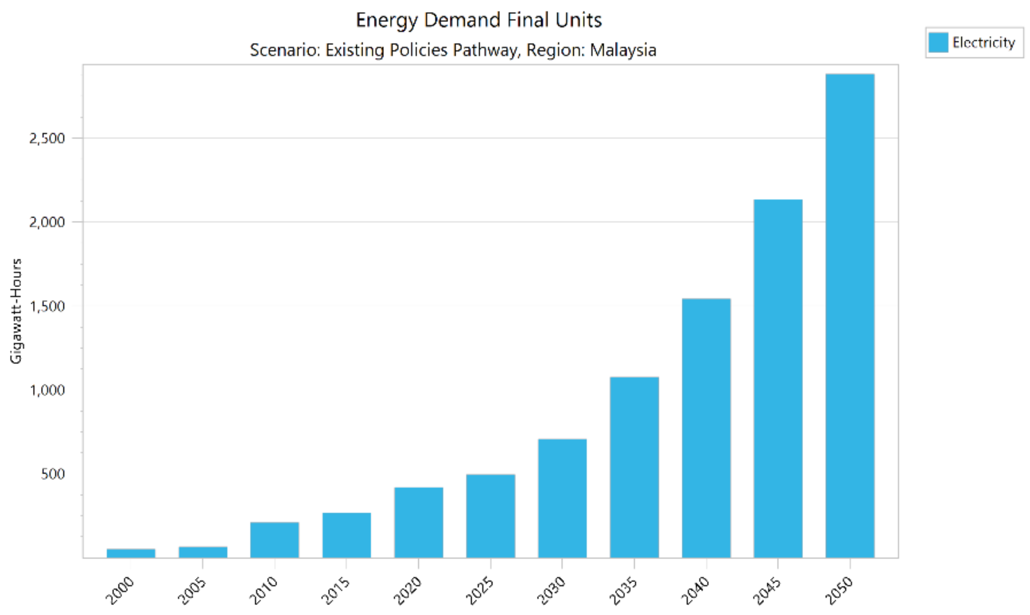


Figure 10: (Top) Share of EVs and (Bottom) electricity demand from the transport sector

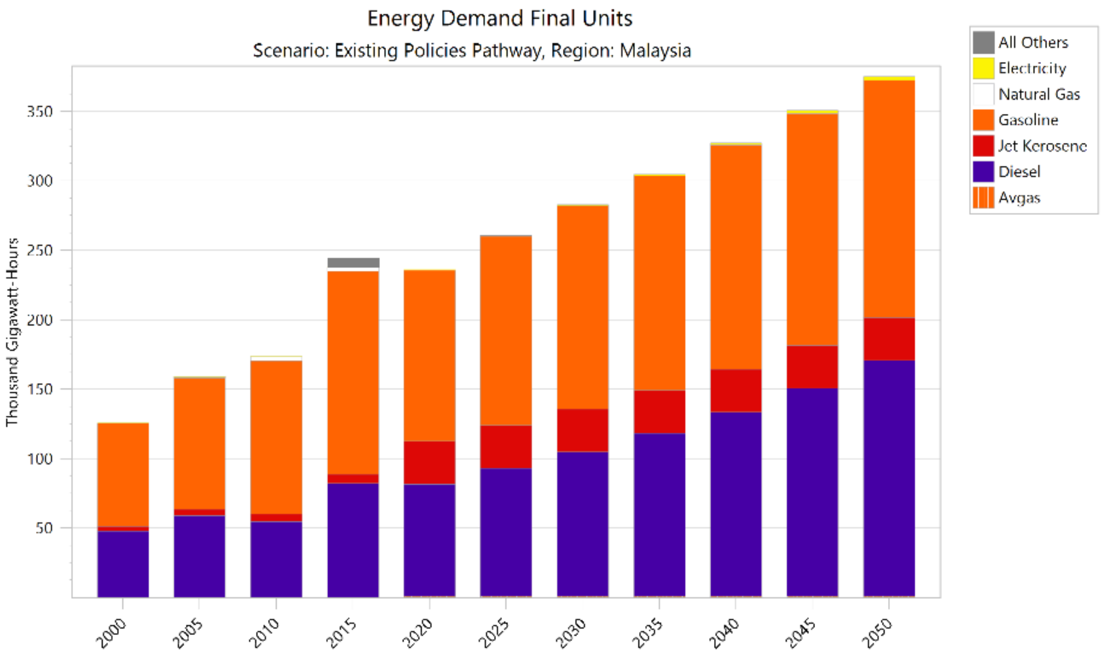


Figure 11: Final energy demand of the transport sector

Electricity demand from the transport sector remains relatively flat over the years as there is relatively little increase in EV or rail capacity. Most of the demand before 2015 comes from electrified rail. Similarly, the demand for natural gas remains steady as it is assumed that the percentage of NGVs on the road does not change by a large margin.

The current model has not considered the shift from diesel to biodiesel. Some efficiency increases and emissions reduction is included due to policies regarding B20 biodiesel but the actual demand for biofuels has not been fully modelled and hence are not currently reflected.

b) Variable renewables

Variable renewables (i.e. solar and wind) have a key role to play in the decarbonisation of electricity generation because they can provide zero-carbon electricity generation at low cost.

- **Malaysia should harness more of its extensive solar resources.**
  - The 2021 Malaysian Renewable Energy Roadmap published by the Sustainable Energy Development Authority (SEDA) indicates that Malaysia has the potential to deploy 269 GW of solar power capacity. In 2020, the installed solar capacity was 1.5 GW (SEDA Malaysia 2021) and the LEAP model projects installed capacity in 2050 to be 7.8 GW (Figure 12). The potential of solar power capacity in Sabah and Sarawak may not have been fully exploited compared to Peninsular Malaysia due to lower population density, remote and inaccessible areas, and lack of awareness and financial incentives.

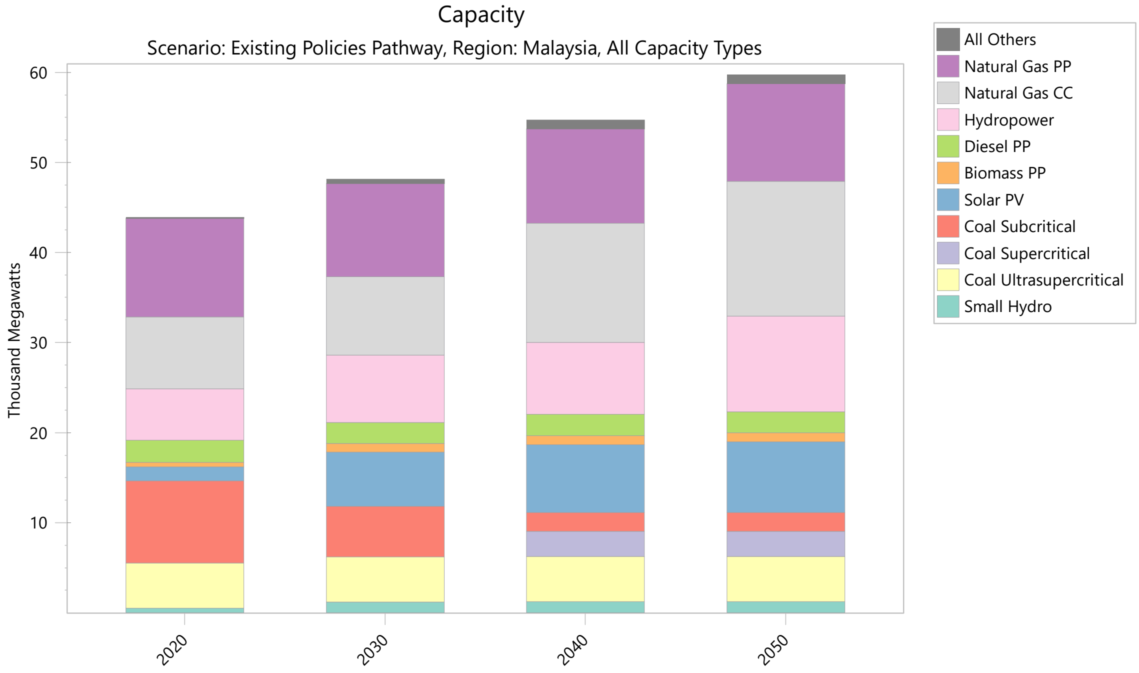


Figure 12: Installed and projected generation capacity by technology (2020-2050)

- In 2020, 2.9 TWh came from solar generation, which provided 1.1% of total Malaysian generation (numbers generated by LEAP). In 2050, the projected solar generation is 19.0 TWh, which will provide 3.2% of total Malaysian generation. (Figure 13)
- Malaysia benefits from extensive solar resources and can plan for more solar integration into the grid. This can be pursued through not just Large Scale Solar (LSS), but also more rooftop solar, which minimises land use change. Most Malaysians live in houses and have favourable geographical conditions for installing rooftop solar photovoltaic (PV). A subsidy will go a long way to encourage them to do so. In Indonesia, such a subsidy is a virtual subsidy because when the rooftop solar PV is connected to the grid, any un-utilised power by the household will be automatically fed into the grid for free.
- An analysis on the most appropriate way to subsidise consumers' solar panels from the perspective of the power grid company will be of value. For example, users normally purchase 8kW of solar panels. The power grid company could subsidise another 8kW of solar panels for the user, on the condition that excess electricity generated will be fed into the grid for free.

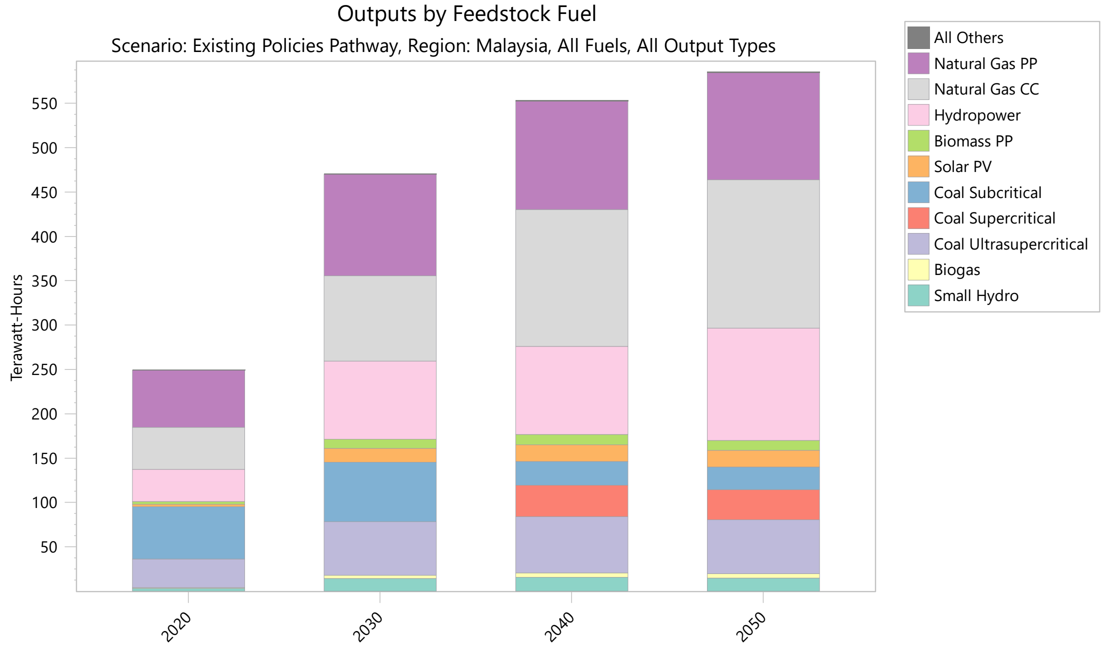


Figure 13: Historical and projected power generation by technology (2020-2050)

- **Malaysia should develop its wind power potential where feasible.**
  - Wind power is the lowest in emission and one of the cheapest forms of generation (IEA; NEA; OECD 2020), where wind availability is abundant.
  - Most areas in Malaysia have low wind speed of <2ms^{-1} (typically measured 2 meter above ground), but wind power generation potential (from a few hundred to a few thousand MW) could be found in coastal areas such as Kuala Terengganu, Mersing, Kudat and Kota Marudu (Palanichamy 2015, The Star 2017, Mohd Farizal, Lina and Narina n.d.). Megawind has planned a 1000 MW offshore wind power project in Terengganu, which is pending government approval. Kudat and Kota Marudu are in Sabah, a state that has a shortage of electricity and the highest incidence of poverty in Malaysia (Department of Statistics Malaysia 2021).
  - Seasonal variation of wind speed due to the monsoons pose a challenge and height elevation of the wind turbine makes a critical difference to technical viability (Firdaus, et al. 2017).
  - Wind energy is currently not included in the Renewable Energy Act 2011 (Act 725) as a renewable resource. However, the Malaysian Renewable Energy Roadmap (2011, p. XVI) states an intention to conduct a feasibility study and economics assessment on the implementation of onshore and offshore wind post 2025. Commissioning this study earlier will enable the Malaysian government to design supportive policy for wind power developers to implement wind power projects where feasible sooner.
  - Vietnam has huge natural potential for wind power. The country has 3,000km of coastline and winds that blow from 5.5-7.3 ms^{-1} (not accounting for seasonal variability) (Breu, et al. 2021). Malaysia can consider purchasing wind power from Vietnam or making Malaysian investment in wind power in Vietnam and transmitting the electricity back to Malaysia, as there are existing power interconnections through Cambodia and Thailand.

- **Variable renewables are a low-cost source of generation.**
  - The levelized cost of electricity[30] (LCOE) of renewables have fallen significantly over the past decade, with utility scale solar PV at 56 USD/MWh, offshore wind at 88 USD/MWh and onshore wind at 50 USD/MWh now. (IEA; NEA; OECD 2020)
  - That compares to 71 USD/MWh for combined cycle gas turbine (CCGT) generation and 88 USD/MWh for coal (IEA; NEA; OECD 2020). This means that renewables are now cheaper or comparable to fossil fuel power generation on a levelised cost basis.
  - Variable renewables will need to be accompanied by changes to the electricity system to accommodate intermittency.
  - Future modelling will need to consider both the levelised costs and the wider system changes required to accommodate generation from different sources.

c) Dispatchable low-carbon generation

Dispatchable low-carbon electricity generation that can be planned with a high degree of confidence for hours, days and even weeks ahead, and relied on to run continuously, if necessary, is needed to complement variable renewable generation. Options include hydropower, bioenergy with carbon capture and storage, natural gas with carbon capture and storage, and hydrogen plants. Malaysia's Existing Policy scenario includes hydropower, bioenergy and natural gas without carbon capture and storage.

- **Hydropower is projected to contribute 24% of total Malaysian power generation in 2050.**
  - Analysis undertaken by the SEDA (2021) suggests that Malaysia has the potential to deploy 13.6 GW of large hydro (>100 MW) and 2.5 GW of small hydro (up to 100 MW) power generation capacity. In 2020, the installed capacity was 5.7 GW for large hydro and 500 MW for small hydro (SEDA Malaysia 2021). The projected installed capacity in 2050 is 10.6 GW for large hydro and 1.2 GW for small hydro. (Figure 12)
  - In 2020, 36 TWh came from large hydro power generation, which provided 14% of total Malaysian generation (numbers generated by LEAP). In 2050, the projected large hydro power generation rises to 126 TWh, which will provide 22% of total Malaysian generation. (Figure 13)
  - In 2020, 3.2 TWh came from small hydro power generation, which provided 1.3% of total Malaysian generation (numbers generated by LEAP). In 2050, the projected small hydro power generation rises to 14.8 TWh, which will provide 2.5% of total Malaysian generation. (Figure 13)
- **Malaysia's biomass power generation is small and should be increased due to the forestry and agriculture industries here. Biomass is projected to be more expensive than renewables but could provide stability to a system dominated by variable generation.**
  - The practical reasons that have constrained biomass power generation in Malaysia include (1) reliability of feedstock (seasonality); (2) combustion efficiency (many of the feedstock is wet); (3) location - biomass plants need to be near to source of biomass due to transportation costs, which limits their uses cases to oil palm estates and palm oil mills.
  - Analysis undertaken by the SEDA (2021) suggests that Malaysia has the potential to deploy 2.3 GW of biomass power generation capacity. In 2020, the installed biomass generation capacity was 600 MW (SEDA Malaysia 2021) and the projected installed capacity in 2050 is 998 MW. (Figure 12)

[30] LCOE is a measure of the average net present cost of electricity generation for a generator over its lifetime.

- In 2020, 3 TWh came from biomass power generation, which provided 1.2% of total Malaysian generation (numbers generated by LEAP). In 2050, the projected biomass power generation rises to 11.2 TWh, which will provide 1.9% of total Malaysian generation. (Figure 13)
- The LCOE of biomass power generation is 118 USD/MWh (IEA; NEA; OECD 2020), which is a global cost estimate. Influencing factors include the cost of biomass, equipment and infrastructure costs, operational and maintenance expenses, and financing conditions. The local cost in Malaysia could be lower because the country has an advantage in fuel cost due to the forestry and agriculture industries here.
- Biomass power generation can start with 20% co-firing with coal, for example, with a view of approaching 100% biomass power generation in due course.
- Beyond serving power generation needs in Malaysia, wood pellet production is a global business. The quest for biomass power can be linked to ecosystems healing and carbon sequestration (Leong, Woo and Platts 2023).

- **Malaysia's biogas power generation is negligible.**
  - Analysis undertaken by SEDA (2021, p.41) suggests that Malaysia has the potential to deploy 736 MW of biogas power generation capacity. In 2020, the installed biogas generation capacity was 100 MW (SEDA Malaysia 2021) and the projected installed capacity in 2035 is 406 MW. (Figure 12)
  - In 2020, 0.7 TWh came from biogas power generation, which provided 0.3% of total Malaysian generation (numbers generated by LEAP). In 2050, the projected biogas power generation rises to 4.9 TWh, which will provide 0.8% of total Malaysian generation. (Figure 13)
  - Around 19% of biogas power plants (mostly at palm oil mills in Peninsular Malaysia) are connected to the grid. Feed-in Tariffs (FiT) for biogas power plants in 2023 stands at RM0.39-0.42 per kWh.

- **Natural gas plants need carbon capture and storage.**
  - Under the Existing Policy scenario, natural gas will remain a core fuel in Malaysia's energy mix in 2050, contributing 49% of total power generation for the country (Figure 11). Given this direction, and if Malaysia wants to reduce carbon emissions, capturing carbon at natural gas power plants is necessary. Otherwise, GHG emissions from natural gas power generation is projected to be nearly 125 MtCO2e in 2050, which is 54% of total power generation emissions (Figure 14).
  - Petronas' Malaysian Petroleum Management has identified an estimated 46 trillion cubic feet of potential carbon storage capacity across 16 depleted fields (Battersby 2020). A geological storage of 84-114 GtCO2 is estimated in the Malay Basin, which has enormous unoccupied deep saline aquifer (Dayang, et al. 2020).

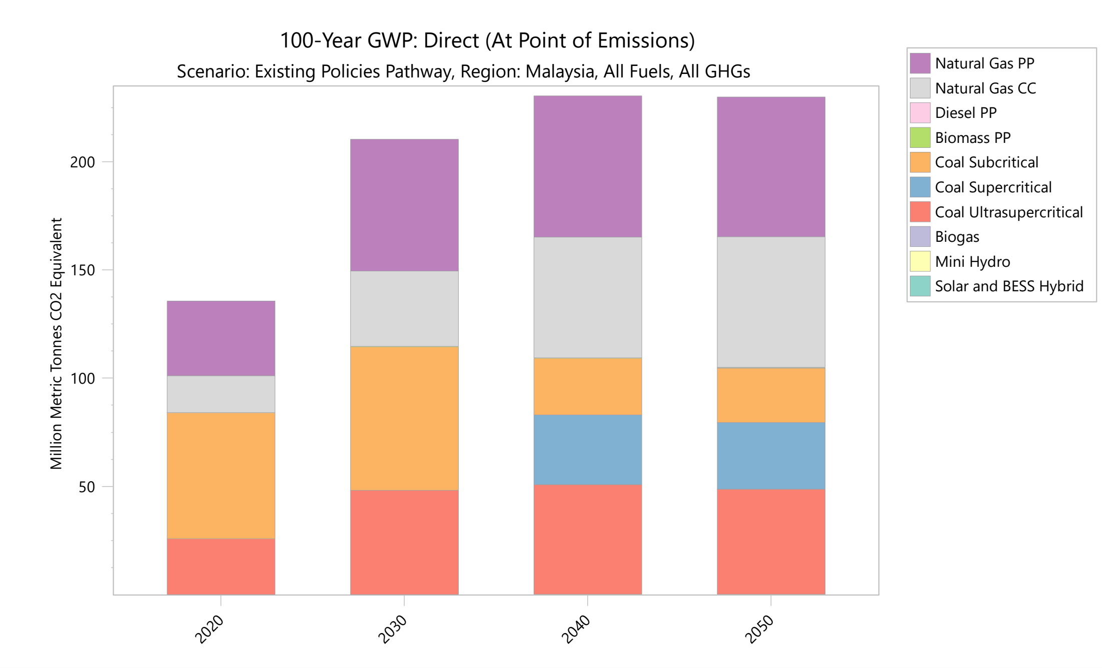


Figure 14: Historical and projected emissions from power generation by source (2020-2050)

d) Firm power high-carbon generation

Firm power high-carbon generation refers to coal generation, which is designed to run continuously.

- **Malaysia will still have substantial coal power generation in 2050.**
  - 21% of total Malaysian power generation is projected to come from coal in 2050. It will come from 9.9 GW of generation capacity, which is 17% of the capacity mix. That will generate 105 MtCO2e, which is 46% of the Malaysia's total generation emissions. (Figure 14)

Overall power generation and demand observations

- Existing Policy will not bring the RE capacity to the newly announced target of 70% of all power generation capacity in 2050 (Table 4).

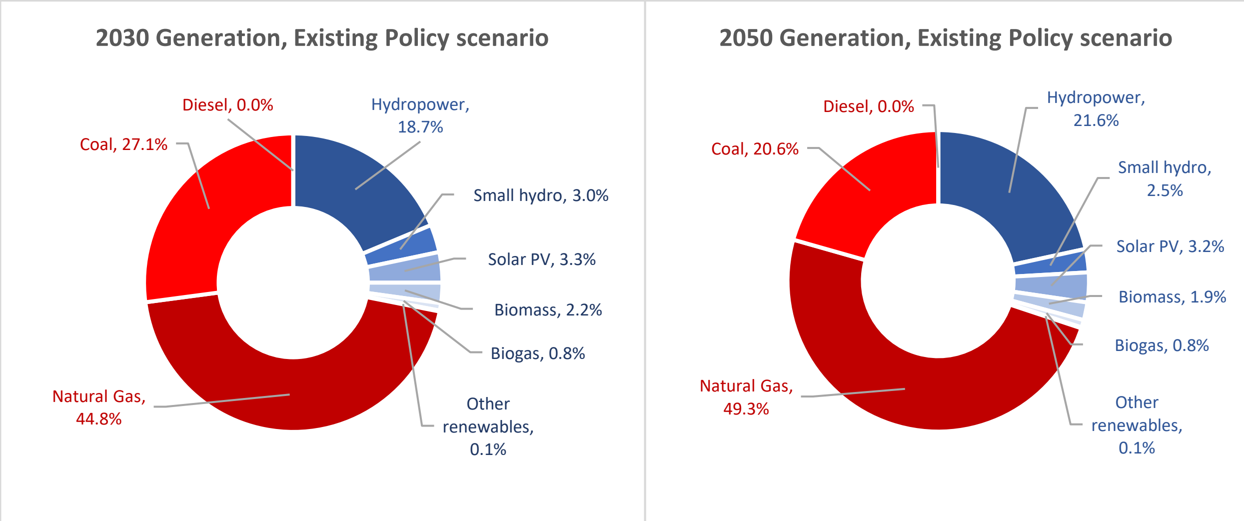


Figure 15: Comparison of generation shares in 2030 and 2050 in the Existing Policy scenario

Table 4: Comparison of capacity and generation shares in 2030 and 2050 in the Existing Policy scenario

	2030		2050	
	Capacity	Generation	Capacity	Generation
Share of RE				
Hydropower	15.5%	18.7%	17.7%	21.6%
Small hydro	2.5%	3.0%	2.0%	2.5%
Solar PV	12.6%	3.3%	13.1%	3.2%
Biomass	1.9%	2.2%	1.7%	1.9%
Biogas	-	0.8%	-	0.8%
All others	1.0%	0.1%	1.7%	0.1%
Sub-total	**33.5%**	**28.12%**	**36.2%**	**30.1%**
Share of fossil fuel				
Natural Gas	39.6%	44.8%	43.2%	49.3%
Coal	22.0%	27.1%	16.6%	20.6%
Diesel	4.9%	0.0%	4.0%	0.0%
Sub-total	**66.5%**	**71.9%**	**63.8%**	**69.9%**

– In the Existing Policy scenario, LEAP projects the amount of GHG emissions from the energy sector to be 390 $MTCO_2e$ in 2050 (Figure 15).

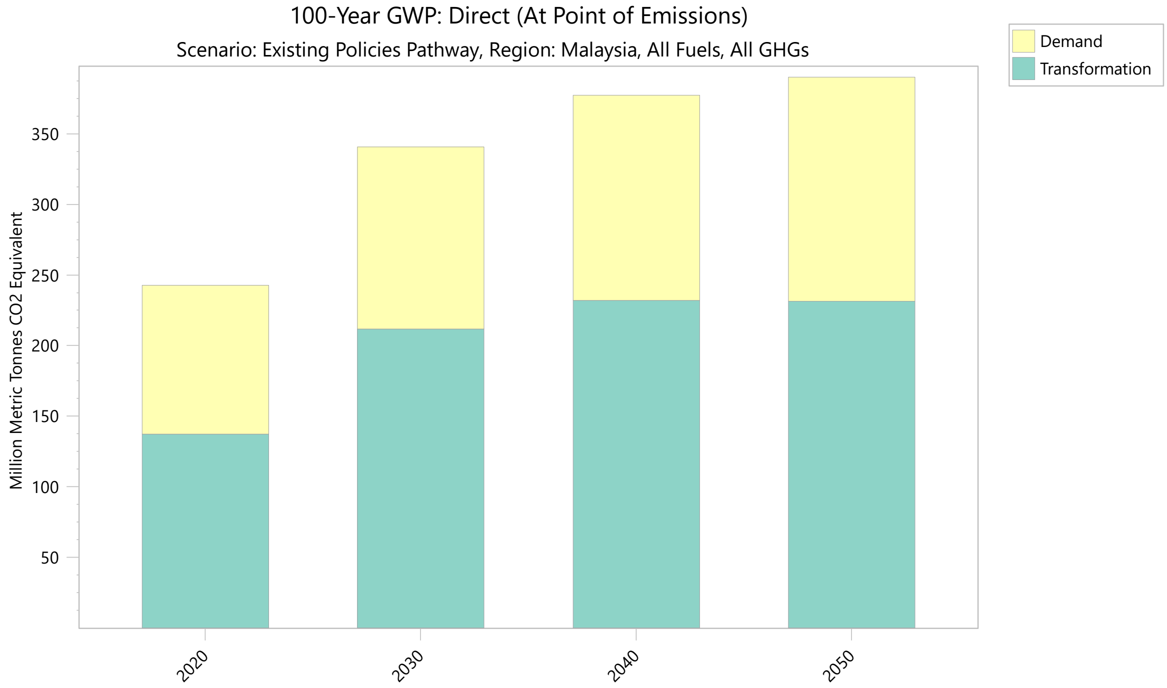


Figure 16: Historical and projected GHG emissions from the energy sector (2020-2050)

e) System flexibility

Incorporating variable renewables will require a flexible electricity system. Flexibility could come from facilitating flexibility from consumer (demand) and removing barriers to grid flexibility by increasing storage and interconnection.

- **Consumers that use EVs and energy smart appliances could provide flexibility by shifting their demand.**
  - This requires the electricity market to be reformed to reward consumer flexibility.
  - Smart technology will need to be deployed to send and manage price signals.
- **Energy storage is vital when a high percentage of electricity is produced by variable renewables.**
  - The four technological approaches to energy storage systems – battery, thermal, mechanical (dominated by pumped hydropower) and hydrogen - are suitable for accommodating demand cycles of different timescales (daily, weekly and seasonal).
  - The 100MW batteries that will be installed annually into the Malaysian power system from 2030–2034 are for grid stability, not energy storage (Leong, Platts and Amran 2021)
  - Thermal storage, pumped hydropower and hydrogen storage are not in the Existing Policy scenario.
- **Interconnectors**
  - Current interconnections between Malaysia and neighbouring countries are as follows:
    - Malaysia-Thailand high-voltage direct current (HVDC) interconnection: 300 MW

  - Malaysia-Singapore power interconnection: 1000 MW[31]
  - Sarawak-West Kalimantan high voltage alternating current (HVAC) interconnection: 80-110 MW

- Increasing interconnection capacity between Malaysia and neighbouring countries is a shared vision of the utility companies and energy authorities concerned:

  - Second link from Peninsular Malaysia to Singapore
  - Sumatra-Peninsular Malaysia interconnection
    - The Sumatra-Peninsular Malaysia interconnection has not been able to make progress because both Malaysia and Indonesia desire to be the electricity seller.
    - Given that Sarawak is currently selling electricity to West Kalimantan, Malaysia can consider balancing the purchase and supply of electricity with Indonesia by starting off as an electricity buyer in Peninsular Malaysia. This can help advance regional electricity interconnection.
    - Furthermore, purchasing electricity from Indonesia is not limited to purchasing from Indonesian companies alone. Malaysian companies can jointly develop power plants (e.g. hybrid biomass and solar PV) in Sumatra with Indonesian companies, and design electricity bundled sale with surrounding coal-fired power plants, or substituting coal with gas.
    - Agricultural burning is a common practice in Sumatra, where farmers burn crop residues to clear fields for the next planting season. This practice releases significant amounts of harmful pollutants into the air, including particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NOx), and sulphur dioxide (SO_2), which Malaysia suffers with. Increasing the power generation capacity of biomass power plants in Sumatra can reduce the pollution from agricultural residue burning.
    - In the future, electricity can also be transmitted in both directions to ensure the stability of power.
  - Sabah-Kalimantan interconnection
  - Increasing the capacity of the Malaysia-Thailand interconnection
    - This is necessary because Malaysia is a small country. Energy transformation must consider the stability of energy supply. Increasing interconnection will enhance energy stability.
    - This can also be beneficial if the LTMS-PIP expands in the future, as Singapore will need to import electricity by wheeling through this interconnection

[31] Malaysia's existing interconnections with Thailand and Singapore are part of the Lao PDR, Thailand, Malaysia, Singapore – Power Interconnection Project (LTMS-PIP), which involves the import of up to 100MW of hydropower-sourced electricity from Lao PDR to Singapore by wheeling through Thailand and Malaysia.

4.2 More ambitious policy

The key features of the More Ambitious Policy scenario are:

- Reduced demand for electricity in sectors where efficiency measures have been applied;
- Sheer increase in electricity demand in sectors where electrification is modelled without efficiency measures;
- Decreasing carbon intensity of generation.

a) Demand and energy efficiency

- **Increasing demand for electricity.** Demand is projected to increase by 94% from 2019 (155 TWh) to 2050 (301 TWh). (Figure 17)

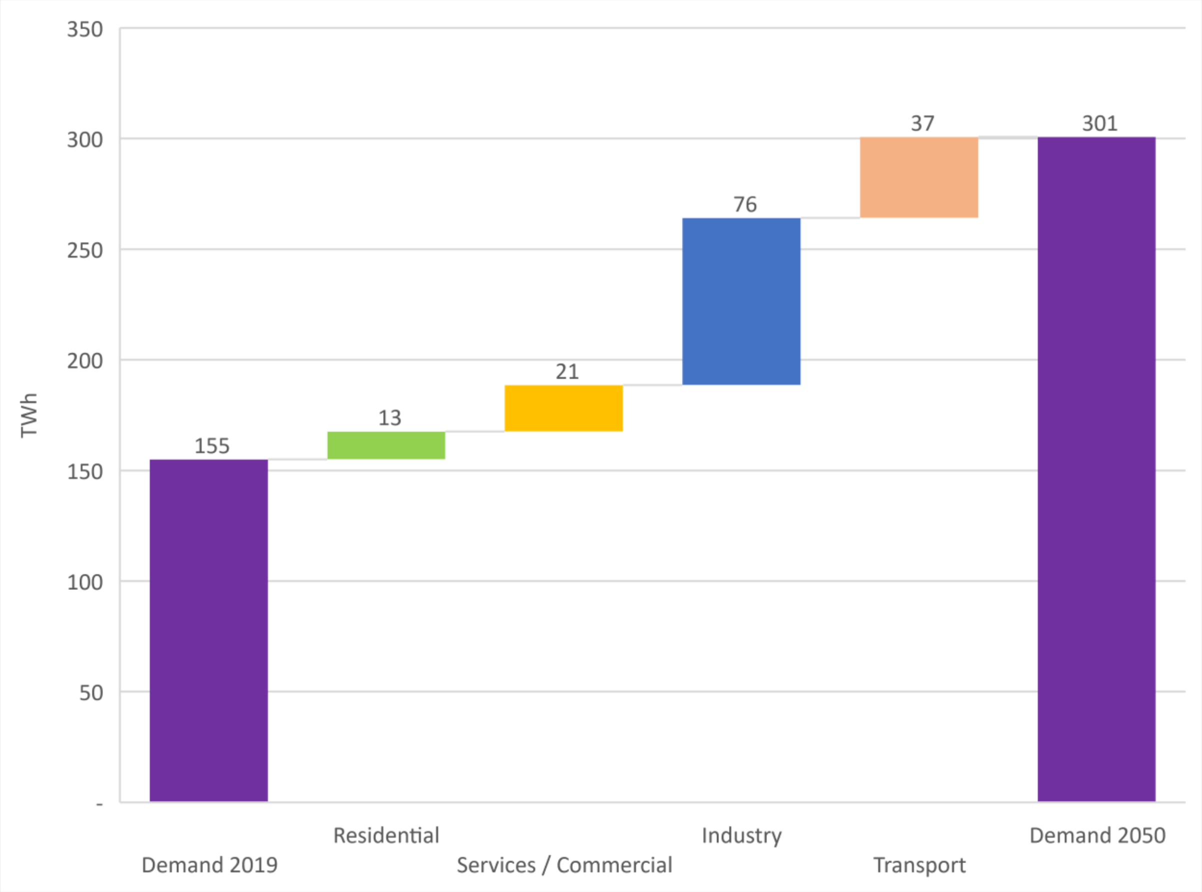


Figure 17: Contribution by sectors to increase electricity demand in the More Ambitious Policy scenario (2019-2050)

- Comparison of electricity demand in the Existing Policy and More Ambitious Policy scenarios for the different sectors are shown in Figure 18.

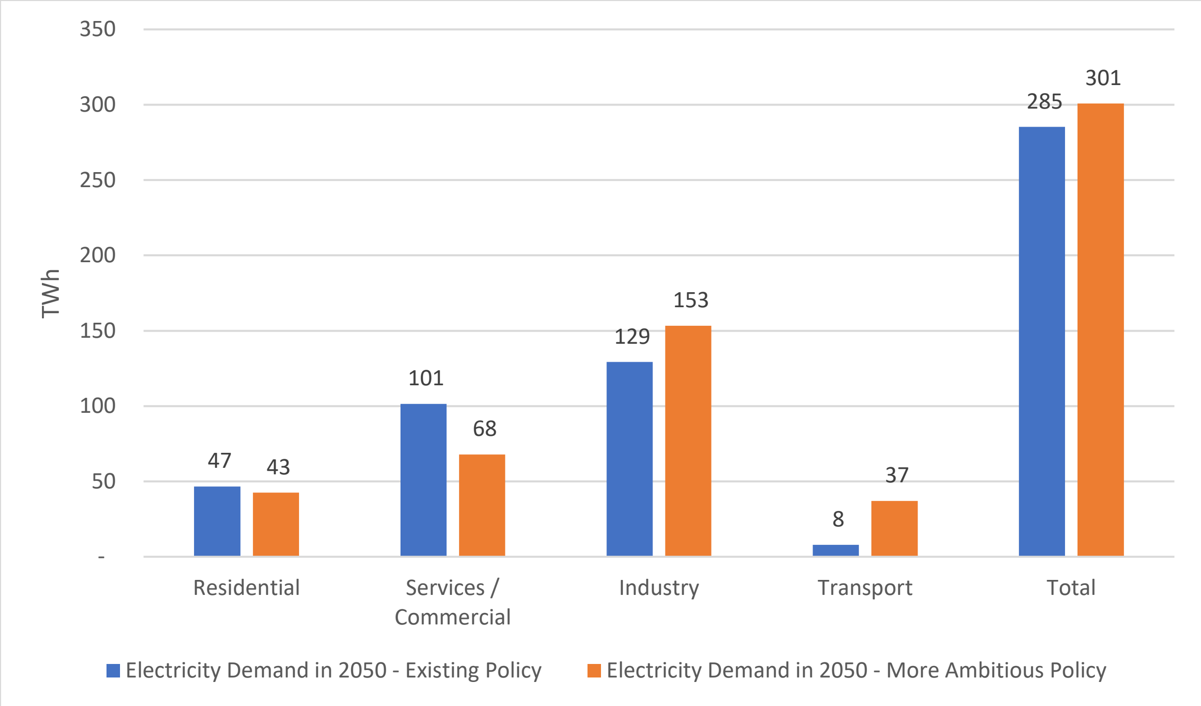


Figure 18: Comparing electricity demand in 2050 under Existing Policy and More Ambitious Policy

- **Residential.** Under the More Ambitious Policy scenario, more aggressive targets of increasing the penetration rate of energy efficient household devices (lighting, refrigeration, and air conditioning) to 100% by 2060 are implemented in the LEAP model, as well as increased electrification of cooking. As a result, the residential sector's demand for electricity is projected to increase from 30 TWh in 2019 to 43 TWh in 2050. This is a modest improvement over the Existing Policy scenario, which would have seen the electricity demand increase to 47 TWh in 2050.
- **Commercial/services.** Under the More Ambitious Policies scenario, an additional energy saving measure from the National Energy Efficiency Action Plan (NEEAP) – energy audits - is introduced into the LEAP model, which NEEAP expects to lower the energy intensity by a further 15%. This leads to an increase in electricity demand of 21 TWh in 2050 compared to 2019, which is lower than the 54 TWh increase in the Existing Policy scenario.
- **Industry.** In the industrial sector, the additional electricity demand in 2050 compared to 2019 is 76 TWh in the More Ambitious Policy scenario, which is 46% higher than the 52 TWh additional demand in the Existing Policy scenario. This is because in the More Ambitious Policy scenario, the fuel share of electricity in 2050 is set at 46%, whilst it is set at 39% in the Existing Policy Scenario.
- **Transport.** In the transport sector, electricity demand increases to 37 TWh in the More Ambitions Policy scenario compared to 8 TWh in the Existing Policy scenario. The bulk of the increase is attributable to the sharp increase in EV adoption in the former scenario, going from 13.8% share of cars on the road by 2050 in Existing Policy to over 65% in More Ambitious Policy. Adoption of electric motorcycles also sees substantial increase mirroring the EV case.

The effects of meeting the B20 blending target that was planned in 2020 in 2025 will be discussed in AGF Malaysia's phase 2.2 report.

b) Power generation

The following two measures have been implemented in the LEAP model:

1. **More Ambitious Policy (MAP): not adding new fossil fuel generation capacities from 2030 onwards**

- **RE generation capacity is projected to reach 65% of total generation capacity in Malaysia in 2050.**
  - This approaches the recently announced target of 70% RE capacity in 2050 by the government (Table 5).
  - Fossil fuel generation share in 2050 is projected to fall from 70% in the Existing Policy scenario to 18% in the More Ambitious Policy scenario. RE generation share in 2050 is projected to increase from 30% in the Existing Policy scenario to 82% in 2050 in the More Ambitious Policy scenario (Table 4 and Table 5). The breakdown of power generation based on feedstock fuel for the two scenarios is shown in Figure 20.
- **Generation from variable solar remains low at 4% in 2050.**
  - The total generation is projected to reach 30 TWh in 2050 in the More Ambitious Policy scenario compared to 19 TWh in Existing Policy scenario (Figure 20). Solar's capacity share is the highest amongst RE, but its generation share is the second lowest due to the low sunlight to electricity conversion efficiency (Table 5).
- **Dispatchable low-carbon generation reaches 68% in 2050.**
  - This refers to hydropower, small hydro, biomass, biogas, solar and BESS hybrid generation. Natural gas generation is not included because it is without carbon capture and storage.
- **Firm power high-carbon generation falls to 18% in 2050.**
  - This refers to natural gas, coal and diesel generation.
- **Decreasing carbon intensity of electricity generation.**
  - Carbon intensity of generation is projected to fall 79% from 2019 (631 gCO_2/kWh) to 2050 (135 gCO_2/kWh).
  - Power generation GHG emissions of the More Ambitious Policy scenario (90 $MtCO_2e$) is 61% lower in 2050 compared to the Existing Policy scenario (230 $MtCO_2e$) (Figure 21).

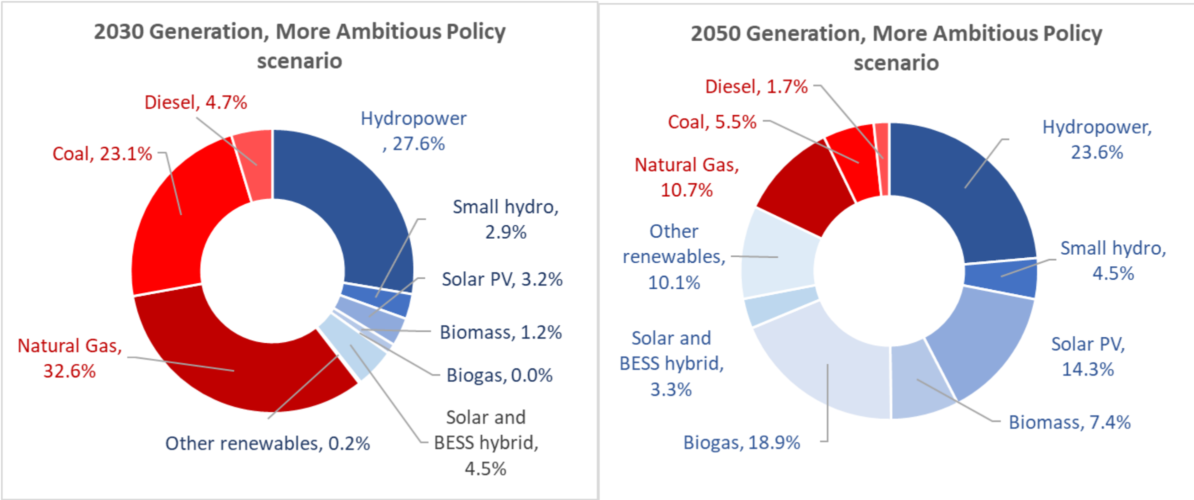


Figure 19: Comparison of generation shares in 2030 and 2050 in More Ambitious Policy scenario

Table 5: Comparison of capacity and generation shares in 2030 and 2050 in More Ambitious Policy scenario

	2030		2050	
	Capacity	Generation	Capacity	Generation
Share of RE				
Hydropower	16.79%	27.62%	12.97%	23.61%
Solar PV	11.79%	2.85%	16.49%	4.45%
Biomass	2.09%	3.22%	8.33%	14.33%
Biogas	0.68%	1.15%	3.96%	7.40%
Solar and BESS hybrid	-	-	10.13%	18.94%
Small hydro	-	4.47%	-	3.25%
All others	3.03%	0.21%	13.06%	10.10%
Subtotal	34.38%	39.52%	64.94%	82.08%
Share of fossil fuel				
Natural gas	36.54%	32.64%	21.46%	10.69%
Coal	23.82%	23.14%	10.23%	5.54%
Diesel	5.26%	4.70%	3.37%	1.68%
Subtotal	65.62%	60.48%	31.69%	17.91%

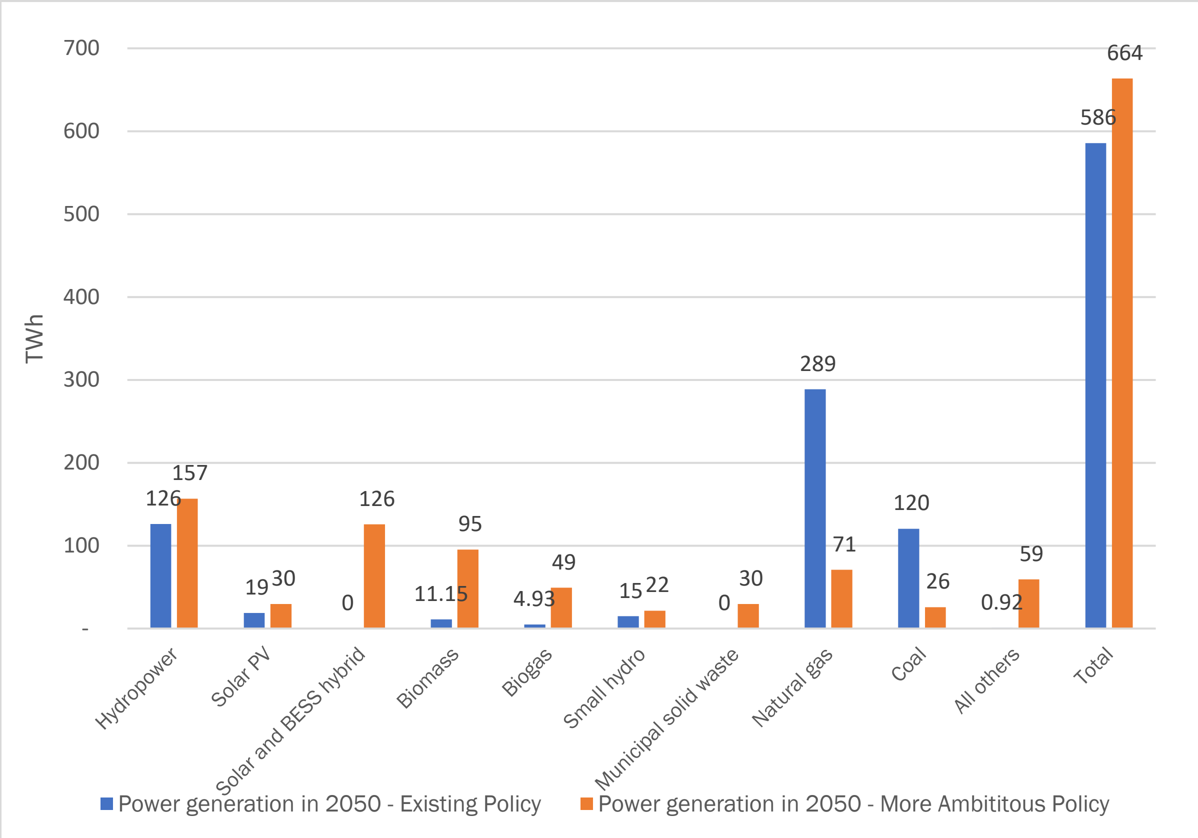


Figure 20: Comparison of electricity generation in Existing Policy and More Ambitious Policy scenarios (2050)

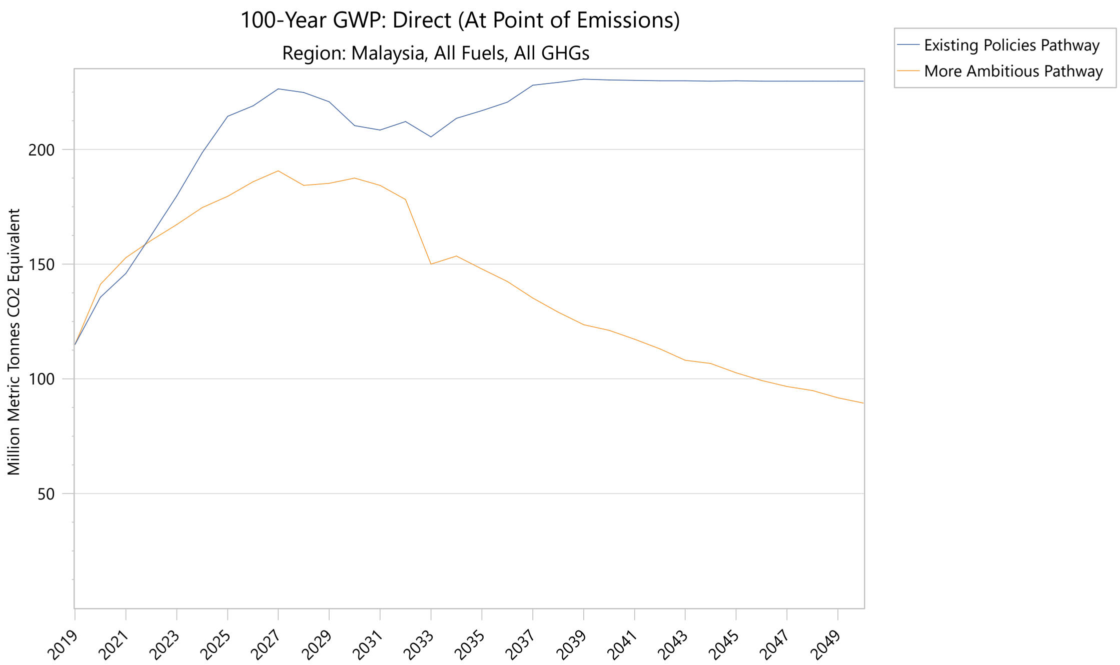


Figure 21: Emissions pathways for electricity generation in Existing Policy and More Ambitious Policy scenarios (2019-2050)

2. More Ambitious Policy 1 (MAP1)

The MAP1 scenario is largely based on the previous MAP scenario. The key difference is the complete phasing out of fossil fuels in the power generation sector by 2050. The current model has the phase out of coal from 2025 to 2030 and natural gas from 2030 to 2050. To maximise the effects of the switch, renewable power capacity is also favoured where possible. The gap in power generation is replaced incrementally by solar plus BESS hybrids, hydropower, biomass/biogas, as well as smaller amounts of other renewables including wind, MSW, and geothermal sources.

This scenario represents an idealised pathway independent of most considerations aside from physical limits (i.e. fuel or space availability, hydro resources, etc.). In this report, the thesis that rapid decarbonisation is possible with the technology currently available is examined. Constraints include financial and societal factors.

Figure 22, Figure 23 and Figure 24 show that while fossil fuel capacity is gradually phased out, generation from these sources effectively cease around 2035. At this point, the capacity in renewables is sufficient to cover most of the electricity demand, with the remaining fossil fuel capacity held in reserve. The high share of solar generation will be difficult to achieve without a storage solution to overcome the variability of solar power.

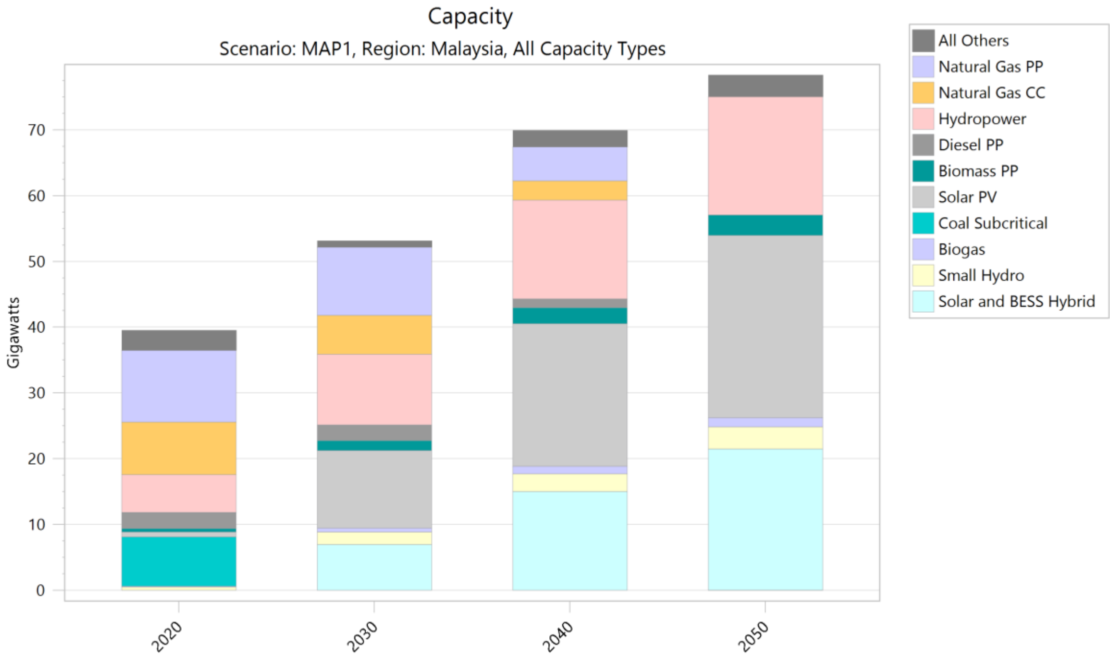


Figure 22: Installed and projected generation capacity by technology (2020 – 2050)

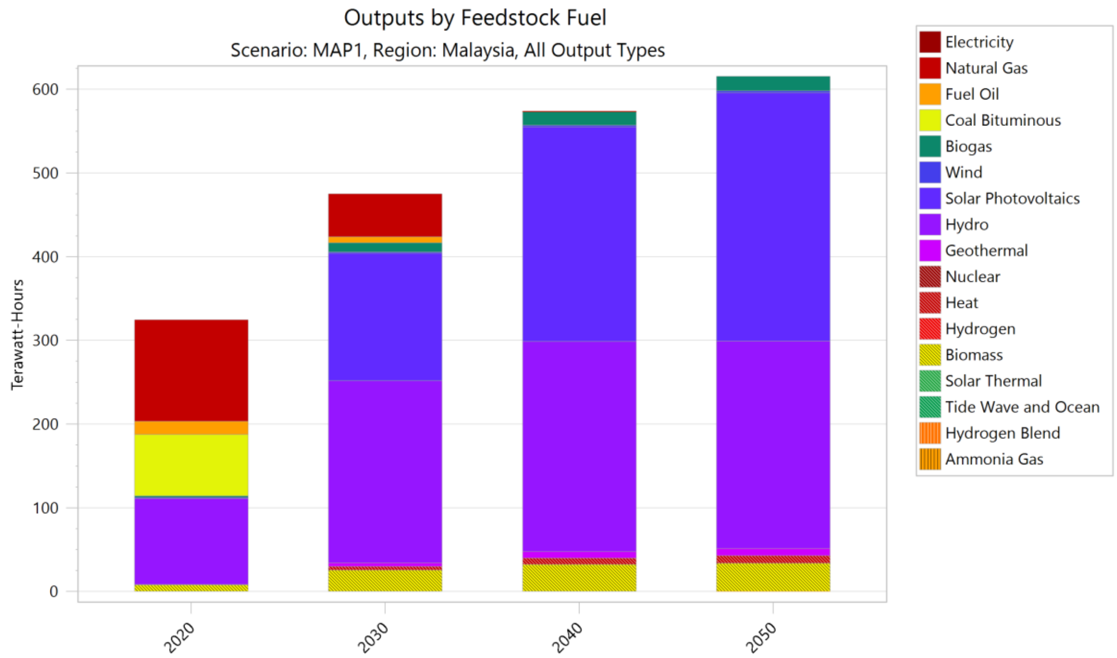


Figure 23: Historical and projected power generation by technology (2020 - 2050)

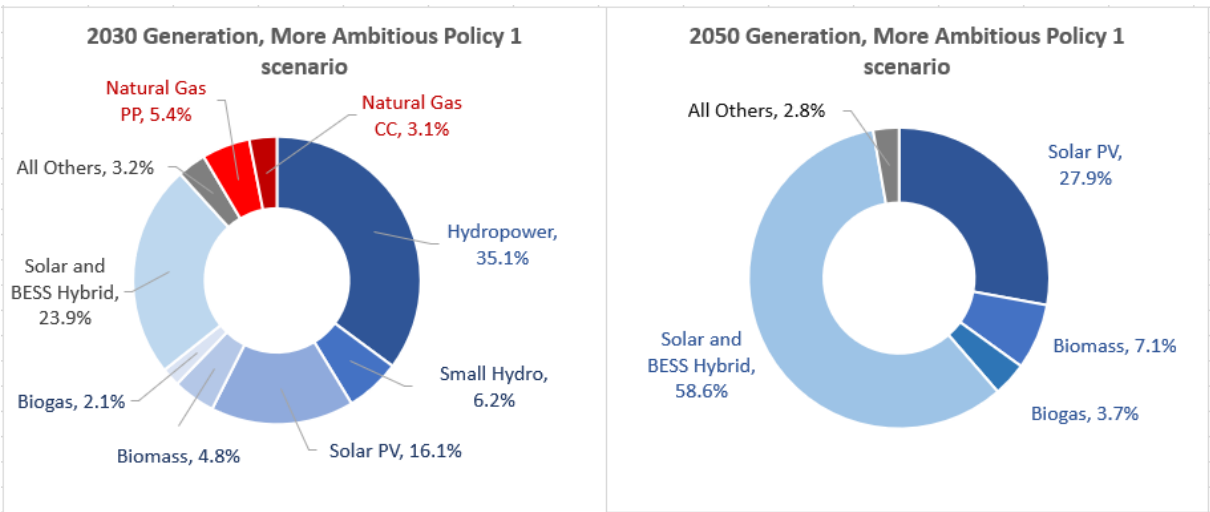


Figure 24: Comparison of generation shares in 2030 and 2050 in More Ambitious Policy 1 scenario

Given the outsized contribution of the power generation sector to GHG emissions, the rapid reduction in fossil fuel capacity predictably reduces emissions in the sector sharply to near zero, as shown in Figure 25 and Figure 26.

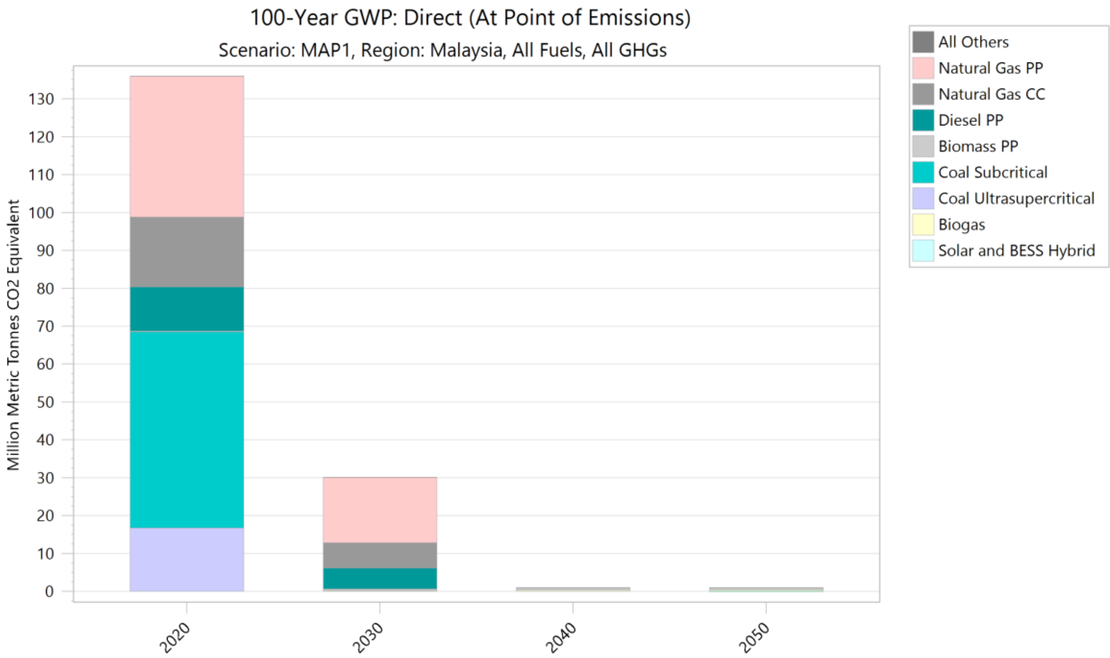


Figure 25: Historical and projected emissions from power generation by source (2020 -2050)

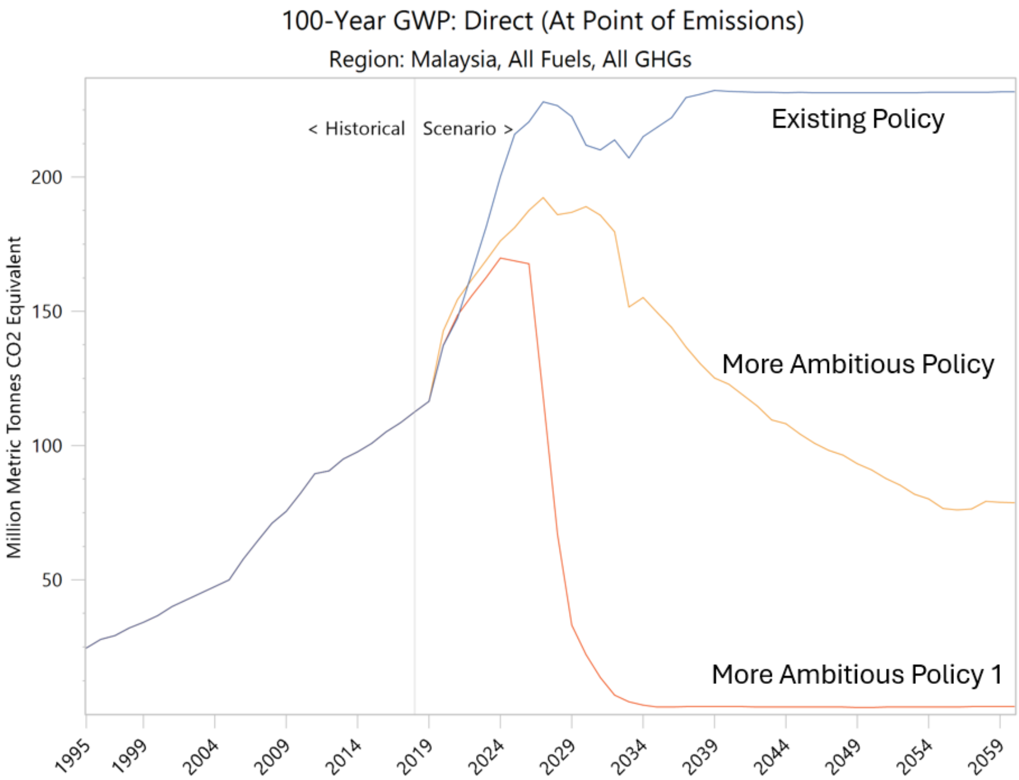


Figure 26: Emissions pathways for electricity generation for the three scenarios

5. SUMMARY AND RECOMMENDATIONS

Sectors	Summary	Recommendations
Power generation	• In the Existing Policy scenario, RE capacity is projected to reach 36% of total generation capacity in Malaysia in 2050, which is halfway to the newly announced target of 70% of all power generation capacity in 2050. • By not adding new fossil fuel generation capacity from 2030 onwards in the More Ambitious Policy scenario, RE generation capacity is projected to reach 65% of total generation capacity in Malaysia in 2050, which is approaching the 70% RE capacity target. • RE generation share in 2050 is projected to increase from 30% in the Existing Policy scenario to 82% in 2050 in the More Ambitious Policy scenario. • Power generation GHG emissions of the More Ambitious Policy scenario (90 MtCO2e) is 61% lower in 2050 compared to the Existing Policy scenario (230 MtCO2e).	• Harness more of Malaysia's extensive solar resources. To achieve a high level of variable solar penetration in the grid, invest in building smart and flexible electricity systems for Malaysia. The building blocks are as follows: ➢ Facilitating flexibility from consumer ➢ Removing barriers to grid flexibility: storage and interconnection ➢ Reforming markets to reward flexibility ➢ Digitalisation • Step up the implementation of rooftop solar PV. Conduct a study on the most appropriate way to subsidise consumers' solar panels from the perspective of the power grid company. • Increase generation from biomass due to the substantial forestry and agriculture industries in Malaysia. This can start with 20% co-firing with coal, for example, with a view of approaching 100% biomass power generation in due course. • Beyond serving power generation needs in Malaysia, wood pellet production is a global business. Link the quest for biomass power to ecosystems healing and carbon sequestration. • Develop Malaysia's wind power potential where there is enough wind energy potential, e.g. Terengganu and northern Sabah. Keep track of technology advances in low-speed turbines. • Consider purchasing wind power from Vietnam or making Malaysian investment in wind power in Vietnam and transmitting the electricity back to Malaysia. • Develop Sabah's hydropower potential • Improve Malaysia's electricity interconnection with neighbouring countries
Transport	• Malaysian government's incentives for EV ownership and falling EV prices are conducive for EV market penetration. Thus, electricity demand in the transport sector is expected to rise. However, under the Existing Policy scenario, fossil fuel (gasoline and diesel) usage in the transport sector remains dominant with EV adoption at 13.8% share of cars on the road by 2050. • Existing Policy does not control or reduce the number of vehicles on the road. Due to the increasing number of vehicles on the road, the demand for gasoline	• It is critical to decarbonise commercial vehicles in ensuring overall decrease of GHG emission in transportation sector. • To control the number of cars on the road, an end-of-life (EOL) policy for used cars is needed. • Extensive investment in public transportation, especially the first-and-last-mile connectivity, is important in achieving the 50% public transportation share target

Sectors	Summary	Recommendations
	only plateaus after 2050 with diesel demand continuing to rise as there are no planned fuel replacement for the freight sector, and there is no policy to drive modal shift from road to rail for freight. • Behavioural changes such as transition away from car use towards public transportation and/or active travel could reduce electricity demand from private transport. • Transport sector electricity demand increases to 37 TWh in the More Ambitions Policy scenario compared to 8 TWh in the Existing Policy scenario. This is largely due to EVs going from 13.8% share of cars on the road by 2050 in Existing Policy to over 65% in More Ambitious policy. Adoption of electric motorcycles also sees substantial increase mirroring the EV case. • The effects of meeting the B20 blending target that was planned in 2020 in 2025 – will be reported in AGF MY 2.2 report.	• Future transport decarbonisation modelling will include: o Modal shift from private passenger vehicle to public transport o Shift of road freight to rail freight o Impact of (1) subsidies rationalisation (electricity, fuel) and (2) incentives (EV, energy efficiency) on model assumptions
Industry	• In the Existing Policy scenario, electricity demand increases by 68% from 2019 (77 TWh) to 2050 (129 TWh). • In the More Ambitious Policy scenario, electricity demand doubles from 77 TWh in 2019 to 153 TWh in 2050.	• Ensure that electricity generated from renewable energy is affordable so that there is financial incentive for firms to adopt electrified industrial heating processes • Introduce carbon pricing to discourage continuous investment in fossil-fuel based industrial heating processes • Drive large scale, market-based financing with new policies that support innovation in business models and financing mechanisms for engineering, procurement and construction • Raise targets and strengthen incentives to promote deeper energy efficiency retrofits • Establish standards for measurement and verification of savings from energy conservation measures. Improve the practices and expand the coverage on a technical level to standardise the energy-saving services market.
Residential	• Overall electricity demand is expected to increase from 30 TWh in 2019 to 47 TWh in 2050, driven by population growth, urbanisation, and electrification of household tasks and appliances. • By increasing ambition towards 100% penetration rate for energy efficient appliances in 2060, savings of 4 TWh can be achieved under the More Ambitious Policy scenario, reducing electricity demand to 43 TWh in 2050. • The National Energy Efficiency Action Plan (2015) specifies estimates and targets of efficient appliance penetrsation (which are used in this report), but there is a lack of actual market data available. • There is a clear ceiling of maximum savings for the residential sector that is attained upon 100% penetration rate of energy efficient appliances. Thereafter, gains can only be made by further improving energy efficiency technology. For this model, LEAP's default final energy intensity values for efficient appliances were used.	• The International Energy Agency (2021) highlights that enhancing standards and labelling programmes for energy efficient appliances is highly effective and cost efficient, with typical society benefit/cost ratios of 4:1, while also delivering improved air quality and health outcomes. • Hence, focusing on the strategy of increasing penetration of energy efficient appliances is recommended. Since the current National Energy Efficiency Action Plan expires in 2025, Malaysia should continue efforts towards 100% penetration by 2060. • Malaysia's Sustainability Achieved via Energy Efficiency (SAVE) programme that provided cash rebates for purchase of energy efficient appliances in 2011 and 2021 was successful in increasing penetration of energy efficient appliances and should be continued.

Sectors	Summary	Recommendations
Services / Commercial	• The services sector models electricity demand as a function of three factors: the value added of the service sector, fuel share of electricity, and final energy intensity. The first two factors continue to increase in line with historical trends. • The final energy intensity decreases in line with historical trends. Under the Existing Policy scenario, this decreases by 55% in 2050 compared to 2019 levels, driven by efficient building design (40%) and energy efficient equipment (15%), both key initiatives under the NEEAP. Despite the gains in energy intensity, there is still an overall increased electricity demand from this sector of 54TWh in 2050 compared to 2019, driven by increased value of services and fuel share of electricity. • Under the More Ambitious Policy scenario, an additional energy saving measure from the NEEAP - energy audits, which is projected to lower the energy intensity by a further 15% - is introduced into the LEAP model. This leads to an overall increase electricity demand of 21TWh in 2050 compared to 2019, which is lower than the 54TWh increase from the Existing Policies scenario.	• The National Energy Efficiency Action Plan has good ideas for improving the energy efficiency in the Malaysian services sector. Government policy needs to continue driving the greening of buildings, supporting all commercial buildings to eventually meet green standards. This includes old buildings which will need to be retrofitted with more energy efficient features. The policies on energy efficient building design, efficient equipment, and energy audits need to be supported by diligent execution to fully realise its benefits. • The recent government announcement in August 2023 that government premises will be raising air conditioner temperatures above frigid cold and changing the dress code to suit Malaysian weather is a step forward and can be replicated in the private sector. This can reduce electricity demand from air conditioning, which is a significant source of electricity demand in services. • While these policies are sound, there is a lack of public updates. Regular announcements on the progress of these plans can improve enforcement and accountability. • Two recent mega office towers in Malaysia have commendable green credentials – the Merdeka 118 achieved triple green platinum certifications for Leadership in Energy and Environmental Design (LEED), Green Real Estate (GreenRE), and Green Building Index (GBI); while the Exchange TRX is LEED and GBI accredited. This progress should continue.

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