



Energy Transition Pathways for the 2030 Agenda

Sustainable Energy Transition

Roadmap for Iskandar Malaysia



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Energy Transition Pathways for the 2030 Agenda

Sustainable Energy Transition Roadmap for Iskandar Malaysia



Developed using National Expert SDG7 Tool for Energy Planning (NEXSTEP)

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Sustainable Energy Transition Roadmap for Iskandar Malaysia

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Foreword: ESCAP

ESCAP is pleased to partner with Iskandar Malaysia as one of the three pioneer cities to have developed a Sustainable Energy Transition roadmap using the National Expert SDG Tool for Energy Planning (NEXSTEP) methodology. The NEXSTEP methodology has been applied in several countries, to support national policymaking to achieve the SDG 7 targets and emissions reduction targets through Nationally Determined Contributions (NDCs). Efforts at a sub-national level are equally important in realising the global goals on sustainable energy and the objectives of the Paris Agreement on climate change.

Much effort has been undertaken to guide Iskandar Malaysia's comprehensive development as a special economic region in southern Peninsular Malaysia. In relation to sustainable energy use and low carbon development, several notable initiatives have been launched in Iskandar Malaysia, including the Green Accord Initiative Award and the implementation of the Iskandar Malaysia Bus Rapid Transit system. ESCAP's collaboration with the Iskandar Regional Development Authority in developing a sub-national Sustainable Energy Transition roadmap further supports the region's endeavour in becoming a low carbon region.

This roadmap takes a holistic approach and carefully investigates energy efficiency opportunities across various demand sectors, including the residential, transport, commercial, and industrial sectors in Iskandar Malaysia. It looks at the potential for meeting the region's renewable energy target through local renewable electricity generation using solar PV technologies and waste-to-energy. The possibility of aligning Iskandar Malaysia's climate ambition with the conditional NDC target to achieve a 45 per cent reduction in emission intensity, relative to the 2005 levels, is analysed.

ESCAP would like to thank the Iskandar Regional Development Authority and other stakeholders for their continuous support and contribution throughout the roadmap development without which this Sustainable Energy Transition roadmap would not be possible.

Hongpeng Liu

Director, Energy Division, ESCAP

Foreword: Iskandar Malaysia

As an economic corridor, Iskandar Malaysia focuses on holistic and comprehensive growth, understanding the importance of balancing economic prosperity, quality living and a resilient environment. Much has been done to preserve the environment in this fast-growing region since its inception in 2006, and we continue to expand and enhance our efforts to ensure a more sustainable future for the region, its people and businesses.

In the light of that, this roadmap has been created to realize Sustainable Development Goal 7 (Clean and Affordable Energy) target at the international and the Iskandar Malaysia levels, and to harmonize the plan with other planning documents and targets that have already been established. There is a total of five targets and Iskandar Malaysia is honoured to be selected through a study done by our partner, ESCAP. With this recognition, we will continue to ensure that the energy utilization and supply in our region is top-notch, making us the investors' preferred destination.

This roadmap also reviews the established target for electricity demand, electricity supply, renewable energy and energy efficiency in Iskandar Malaysia. This review is crucial since the last targets were established in 2010. With ESCAP and with assistance from partners such as Tenaga Nasional Berhad and other agencies, we believe that the new roadmap can be realized.

More importantly, this roadmap is also aligned with the Low Carbon Society Blueprint for Iskandar Malaysia (LCSBPIM 2025). Launched in November 2012 at COP18 in Doha, Qatar, the blueprint illustrates strategies to cut Iskandar Malaysia's carbon intensity emissions by half by 2025 to create a greener, more sustainable yet economically dynamic environment.

The blueprint was quickly adapted to the needs of the five local authorities located in the region, thus ensuring that the many parties involved in the environmental efforts are driven by the same directions and goals.

LCSBPIM 2025 contains future Low Carbon Society scenarios based on major socio-economic development variables, quantitative modelling of CO₂ emissions and "12 Major Actions" that come under a Triple Bottom Line pillar, namely Green Economy, Green Community and Green Environment. The 12 Actions consisting of 52 Sub-Actions, 97 Measures and 281 Programmes were formulated to transform Iskandar Malaysia into a low carbon society.

Out of the 12 Actions, Action 5 focuses specifically on 'Green Energy System and Renewable Energy'. I am happy that this roadmap answers this action by establishing a scenario baseline for 2019-2030 as well as considering the current policy settings, and identifying the measures and technological options that could raise Iskandar Malaysia's efforts to align with the SDG 7 targets and the national climate goals.

I would like to thank all the parties who were involved in the creation of the 'Sustainable Energy Transition Roadmap for Iskandar Malaysia' and look forward to the change that this roadmap will move the region towards being a strong and sustainable metropolis of international standing.

Yang Berbahagia Datuk Ismail bin Ibrahim

Chief Executive

Iskandar Regional Development Authority

Abbreviations and acronyms

ACE	ASEAN Centre for Energy	LPG	liquefied petroleum gas
BAU	business-as-usual	MCDA	Multi-Criteria Decision Analysis
BEI	Building Energy Index	MIEEIP	Malaysian Industrial Energy Efficiency Improvement Project
BRT	bus rapid transit	MJ	megajoule
CASBEE	Comprehensive Assessment System for Built Environment Efficiency	MtCO ₂ -e	million tonnes of carbon dioxide equivalent
CBA	cost benefit analysis	MTF	Multi-Tier Framework
CDP	Carbon Disclosure Project	MW	megawatt
CDPii	Comprehensive Development Plan ii	NDC	nationally determined contributions
CO ₂	carbon dioxide	NDP	5-Year and 20-Year National Development Plan 2017- 2036
CPS	current policy scenario	NEMO	Next Energy Modelling system for Optimization
EE	energy efficiency	NEXSTEP	National Expert SDG Tool for Energy Planning
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific	NREL	National Renewable Energy Laboratory
GAIA	Green Accord Initiative Award	PCREEE	Pacific Centre for Renewable Energy and Energy Efficiency
GEG	Green Economy Guideline	PP	power plant
GDP	gross domestic product	RE	renewable energy
GHG	greenhouse gas	RM	ringgit Malaysia
GW	gigawatt	SDG	Sustainable Development Goal
GWh	gigawatt-hour	SEDA	Sustainable Energy Development Authority
IMBRT	Iskandar Malaysia Bus Rapid Transit	SET	sustainable energy transition
IPCC	Intergovernmental Panel on Climate Change	TFEC	total final energy consumption
IRDA	Iskandar Regional Development Authority	TPES	total primary energy supply
IRENA	International Renewable Energy Agency	TWh	terawatt-hour
IRR	Internal Rate of Return	US\$	United States Dollar
KeTTHA	Ministry of Energy, Green Technology and Water	WHO	World Health Organization
ktoe	thousand tonnes of oil equivalent	WorldGBC	World Green Building Council
kWh	kilowatt-hour	WTE	waste-to-energy
LCOE	Levelized Cost of Electricity		
LEAP	Long-range Energy Alternatives Planning		

Executive Summary

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure sustained economic growth as well as respond to increasing energy demand, reduce emissions and, more importantly, consider and capitalize on the interlinkages between Sustainable Development Goal 7 (SDG 7) and other SDGs. In this connection, ESCAP has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as Nationally Determined Contributions (NDCs) of the Paris Agreement. The initiative has been undertaken in response to the Ministerial Declaration of the Second Asian and Pacific Energy Forum (April 2018, Bangkok) and ESCAP Commission Resolution 74/9, which was endorsed by member States. NEXSTEP also garnered the support of the Committee on Energy in its Second Session, with recommendations to expand the number of countries being supported by this tool.

Iskandar Malaysia has been a participant in a collaborative project led by ESCAP and UNEP on SDG 7 localization. It aims to engage and support cities in defining, implementing and monitoring strategies for achieving global, national, and sub-national Sustainable Development Goals. This Sustainable Energy Transition (SET) roadmap has been developed to identify technological options and policy measures that will help the region navigate the transition of its energy sector in line with the 2030 Agenda for Sustainable Development and the city's own goals and targets.

A. Highlights of the roadmap

Iskandar Malaysia is a special economic region in southern Peninsular Malaysia, with a significant population and a competitive economy. It was established in 2006 with its development facilitated by the Iskandar Regional Development Authority (IRDA). In 2019, the population had reached 2.23 million while the GDP was registered at US\$23.3 billion. The development of the region is guided by the Comprehensive Development Plan ii (CDPii) and other plans such as the Low Carbon Society Blueprint for Iskandar Malaysia 2025, which together aim to lead Iskandar Malaysia into a prosperous economic future with a healthy living ecosystem and a resilient environment.

Sustainability and climate change have been the central focus of Iskandar Malaysia's development. For example, initiatives have been launched to encourage sustainable energy use in the commercial-built environment and the industry sector, which include the Green Accord Initiative Award (GAIA) and the Green Economy Guideline (GEG). Most notably, ongoing implementation of the Iskandar Malaysia Bus Rapid Transit (IMBRT) system is expected to bring in multiple benefits, such as reducing fuel demand as well as GHG emissions and easing traffic congestion.

This SET roadmap has two main objectives. First, it aims to establish a scenario baseline for 2019-2030, considering the current policy settings. Second, it identifies the measures and technological options that could raise Iskandar Malaysia's efforts to align with the SDG 7 targets and the national climate goals. The three scenarios that are presented in detail in this roadmap are:

- The current policy scenario (CPS), which has been developed based on existing policies and plans and used to identify the gaps in existing initiatives in aligning with the SDG 7 targets and the city's ambitions;
- The sustainable energy transition (SET) scenario, which presents technological options and policy measures that will help the city to achieve its own goals and targets, enhance urban sustainability as well as aligning with global goals and national unconditional NDC target;
- The Conditional NDC (CNDC) scenario explores how the GHG emission reduction can be aligned with the national conditional NDC target through a higher share of local renewable energy generation.

In addition, a business as usual (BAU) scenario has also been modelled to provide a BAU baseline where no enabling policies/initiatives are implemented, or the existing policies/initiatives fail to achieve their intended outcomes.

B. Aligning Iskandar Malaysia's energy transition pathway with the SDG 7 and NDC targets

Iskandar Malaysia has already achieved universal access to electricity and clean cooking. The projected progress towards the remaining SDG 7 targets (i.e., renewable energy and energy efficiency), and the GHG emission trajectories of the three main scenarios (i.e., CPS, SET and CNDC scenarios) is summarized as follows.

Renewable energy

The share of renewable energy (RE) in the total final energy consumption (TFEC) was 3.4 per cent in 2019. Under the CPS, the share of RE will increase to 7.4 per cent by 2030. The increase in the RE share under the current policies is driven by the high growth of renewable energy usage in the transport sector (i.e., biodiesel and bioCNG) and in grid electricity, relative to the slower growth in energy demand. In the SET scenario, RE share in TFEC increases to 10.5 per cent by 2030. This is a result of both the increased renewable power generation and further reduction of energy demand due to energy efficiency measures. The local RE electricity generation is expected to contribute around 12 per cent of total electricity requirements, meeting the region's RE target. In the CNDC scenario, the RE share in TFEC is further increased to 16.5 per cent as the amount of RE in electricity supply doubles. This doubling of RE electricity supply in this CNDC is required to align Iskandar Malaysia's emission reduction with the national conditional NDC target, which aims to achieve an emission intensity reduction of 45 per cent, relative to the 2005 level.

Energy efficiency

Iskandar Malaysia's energy Intensity is estimated at 3.97 MJ/US\$_{PPP,2011}. The establishment of the IMBRT system is projected to reduce the energy consumption in CPS by about 790 ktoe compared to the BAU scenario, while small savings are projected to come from the promotion of energy-efficient refrigerators and air conditioners under the national programmes. With that, the energy intensity is expected to decrease to 3.02 MJ/US\$_{PPP,2011} by 2030, which corresponds to an average annual improvement rate of 2.5 per cent.

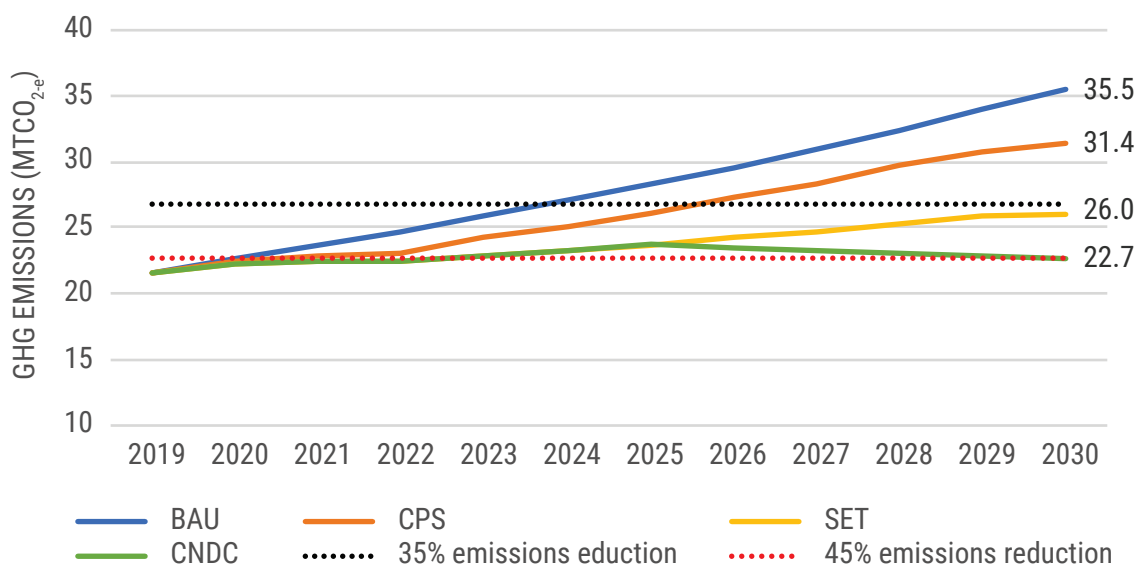
The SET scenario proposes several energy efficiency interventions across the demand sectors, which further decreases the energy intensity to 2.85 MJ/US\$_{PPP,2011} by 2030. This corresponds to a 2.98 per cent reduction per annum, aligning with the suggested global annual improvement rate of 3 per cent (UNSD, 2021). The biggest share of energy reduction comes from the proposed industrial energy saving measures, which is about 347 ktoe in 2030 or a 16 per cent reduction from the BAU/CPS baseline. Other priority areas include the commercial built environment. The adoption of energy audit in existing buildings and adherence to the Malaysia MS1525 building standards or a maximum Building

Energy Index (BEI) of new buildings shall lead to substantial energy savings.² Other measures include encouraging hybrid private passenger car adoption in the transport sector and more vigorous promotion of efficient household appliances including refrigerators, air conditioners, fans, and lighting. These are further detailed in Chapter 4. The energy intensity of the CNDC scenario is the same as SET scenario.

GHG emissions

The GHG emissions in 2019 are estimated at 21.6 MTCO₂-e, which considers the direct fuel combustion from the demand sectors, emissions attributable to the purchased (grid) electricity,³ as well as to waste management. Figure ES 1 shows the GHG emission trajectories for the different scenarios. The GHG emissions from the CPS is projected to reach 31.4 MTCO₂-e, while it is further decreased to 26.0 MTCO₂-e in the SET scenario. This corresponds to an emission intensity of 0.2 ktCO₂-e/ million RM.2005, a 37 per cent reduction from the 2005 level, aligning with the national unconditional NDC target.⁴ The CNDC scenario further raises the climate ambition to align with the national conditional NDC target by ramping up RE capacity within the economic region.

Figure ES 1. Comparison of emissions, by scenarios, 2018-2030



2 The adoption of energy audit and the MS1525 building standards are currently not mandatory in Malaysia. The exception is applied to new or renovated non-residential buildings with air-conditioned space of more than 4,000 m² in the State of Selangor, Terengganu and Penang, which will be designed to meet the requirements of MS1525 relating to the Overall Thermal Transfer Value and the Roof Thermal Transfer Value as well as be provided with an energy management system (ZICO Law, 2020).

3 The term/phrase "purchased (grid) electricity" and "purchased electricity from the central grid" throughout this document equally mean the electricity supplied from the central grid of Peninsular Malaysia

4 National unconditional NDC and conditional NDC targets stipulate a 35 per cent and 45 per cent reduction of emission intensity, respectively, compared with the 2005 level by 2030.

C. Moving forward with the Conditional NDC scenario and key policy recommendations

The CNDC scenario is the most ambitious scenario proposed in this roadmap, requiring a step-up in terms of energy efficiency improvement across all demand sectors. It also proposes a greater implementation of renewable electricity capacity within the city boundary, in allowing a 45 per cent reduction in GHG emission intensity by 2030, compared to the 2005 levels. Notwithstanding, the additional financial and environmental benefits to be realised, relative to the other scenarios, make it a pathway worth pursuing. As mentioned above, the measures proposed in the CNDC scenario raise the RE share from 3.4 per cent in 2019 to 16.5 per cent by 2030, at the same time, allowing a reduction in energy intensity at an annual average rate of 2.98 per cent. Most notably, it puts Iskandar Malaysia in alignment with the national goal, in terms of GHG emission intensity reduction. Additionally, the effort in increasing the share of local RE power generation in the overall electricity supply is expected to bring in substantial financial savings to the city, mainly through greater implementation of solar PV systems, which now provides the lowest levelised cost of electricity among other technologies.

The key policy recommendations to help Iskandar Malaysia to align its sustainable energy transition effort with the SDG 7 and NDC targets, particularly following the CNDC scenario, include:

- i. **The industry sector should be encouraged to become more resource efficient, pivoting towards a circular industrial ecosystem.** A national energy audit study shows that substantial energy savings can be realised in several industry subsectors, through the implementation of cost-effective energy efficiency measures. These include measures such as control efficiency improvement, equipment upgrades and alternative process design. Industry players should take a more active role in conducting regular energy audits and subsequently implementing the energy efficiency measures identified. They should also take advantage of the neat spatial planning of industrial clusters in Iskandar Malaysia to realise more industrial symbiosis going forward. Resource sharing between production facilities should be encouraged, transitioning from a linear industrial economy to a circular industrial economy.
- ii. **Sustainable transport measures are the key to achieving substantial energy savings and emission reduction.** The transport sector has the highest share of energy demand, making up around 53 per cent of the total energy demand and 34 per cent of the GHG emissions in 2019. Iskandar Malaysia's progressive public transport system expansion is the key in making the transport sector more sustainable. In addition, active promotion of hybrid passenger cars will allow further reductions in energy usage and GHG emissions. Promotion of electric vehicles will be done with caution, as the climate benefits of electric vehicle adoption are highly dependent on the emission intensity of the electricity supply.

- iii. Substantial energy savings can be realised with energy efficiency improvement and energy efficient designs in the commercial-built environment.** Building standards in Iskandar Malaysia can be improved through mandatory adoption of energy audit practices in existing buildings. In addition, the adherence to existing Malaysian MS1525 Building Standards or a maximum Building Energy Index (BEI) should be made compulsory, if possible. Shopping complexes should be made the number one priority as they make up around 65 per cent of the total energy demand of the commercial sector.
- iv. Ramping up of local renewable power capacity is cost-effective and contributes towards the region's climate change mitigation effort.** A rapid ramp-up of local RE capacity, particularly with solar PV technology, is required in order to achieve Iskandar Malaysia's RE aspiration, while aligning with the national unconditional and Conditional NDC targets. As analysed, installing local solar PV distributed mini-grid networks and rooftop solar PV allow financial gains, compared to purchasing electricity from the central grid, and help to avoid disrupting the restriction of a maximum 24 per cent RE share in the central grid. Waste-to-Energy (WTE) technology should be considered as an alternative solid waste management solution to existing landfilling practice, providing socio-environmental benefits.



1. Introduction

1.1 Background

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure a sustained economic growth, respond to increasing energy demand, reduce emissions as well as consider and capitalise on the interlinkages between Sustainable Development Goal 7 (SDG7) and other SDGs. In this connection, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG7 targets as well as emission reduction targets (NDCs). The initiative has been undertaken in response to the Ministerial Declaration of the second Asian and Pacific Energy Forum (April 2018, Bangkok) and Commission Resolution 74/9 which endorsed its outcomes. NEXSTEP also garnered the support of the Committee on Energy in its second session, with recommendations to expand the number of countries being supported by this tool.

The tool NEXSTEP has been specially designed to support policymakers in analysing the energy sector and developing an energy transition plan in the context of SDG 7. Further details of the NEXSTEP methodology are discussed in chapter 2. While this tool has been designed to help the development of SDG 7 roadmap at the national level, it can also be used for subnational energy planning.



Building on the “SDG 7 localization project”, Iskandar Malaysia and ESCAP have collaborated to develop a Sustainable Energy Transition (SET) Roadmap. This seeks to assess Iskandar Malaysia’s baseline and to identify technological options and policy measures that will help the city navigate the transition of the energy sector in line with the 2030 Agenda for Sustainable Development as well as the city’s own goals and targets. The SDG7 localization project is implemented in collaboration with the United Nations Environment Programme (UNEP) and with support from the Energy Foundation China. ESCAP Energy Division is supporting its member States in Asia and the Pacific to increase the capacity of cities and subnational governments in the region to accelerate development and implementation of SDG7-related actions. ESCAP directly engages cities and subnational jurisdictions in collaborative discussions. It offers a range of product knowledge, together with support in developing local sustainable energy policies and projects as well as in establishing more effective dialogues between national, subnational and local levels of governance, expert communities, donors and the private sector. See box 1 for further details.

Box 1. SDG 7 Localization status of Iskandar Malaysia based on ESCAP's assessment

In 2021, ESCAP conducted a study of 20 cities in five Association of Southeast Asian Nations (ASEAN) countries, including Iskandar Malaysia, in order to assess their local situation in terms of the efforts on SDG 7 Localization and provide recommendations for further actions.

The study is based on the methodology developed by ESCAP and answers provided by the local stakeholders in Iskandar Malaysia to the related SDG 7 Localization questionnaire (more detailed information on the methodology can be found in the ESCAP-UNEP report⁵). The key results of this situation assessment are presented in SDG 7 Localization Snapshots⁶ for each city.

An SDG7 Localization Snapshot provides a brief overview of the key areas related to implementation of (SDG7) to “ensure access to affordable, reliable, sustainable and modern energy for all” at the local level, based on the answers provided by the jurisdiction to the SDG7 Localization questionnaire. Seven areas, or SDG 7 Localization indicators, were identified for this analysis. In addition, eight sub-indicators were used to provide more detailed results of the assessment.

It is important to note that these indicators are qualitative and should not be used for assessing cities' achievement of quantitative targets under SDG 7. The results of these qualitative indicators are based on cities' self-assessment of their current conditions, efforts, resources and capacity in relation to supporting the SDG 7 localization process; they can serve as the role of the evidence base for constructing recommendations tailored to the local context as well as the baseline results for tracking cities' progress of their SDG 7 localization efforts.

The results for each indicator are presented as a nominal score from 0 to 100 (where 100 is the maximum possible score that can be achieved for each indicator or sub-indicator based on the aggregation of all answers of the questionnaire attributed to this particular indicator or sub-indicator).

As can be seen from the figure below and the results below, Iskandar Malaysia has already made notable progress on cooperation with stakeholders, and awareness-raising activities related to SDG7. Further improvements are required for strengthening necessary policies and institutions, establishing robust data collection and monitoring systems as well as ensuring the availability of various financial resources and instruments. These efforts should be aimed at supporting implementation activities on sustainable energy and should result in the actual projects deploying renewable energy and energy efficient solutions, as the figure below shows the score for Implementation is the lowest among seven SDG7 Localization indicators.

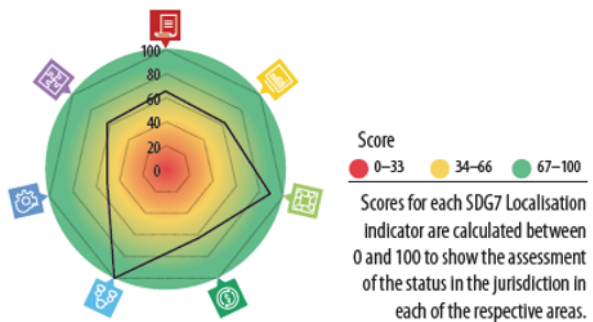
5 Available at <https://www.unescap.org/kp/2021/sdg-7-localization-affordable-and-clean-energy-asean-cities#>

6 Available at <https://city.nextstepenergy.org/knowledge/city-snapshots>

General information

Name of the jurisdiction	ISKANDAR
Country of the jurisdiction	Malaysia
Population of the jurisdiction	2.0 million people
Area of the jurisdiction (in km ²)	2,217
Predominant climate	Tropical with high humidity

SDG7 Localization score



Indicators score

66	63	89	62	100	50	63
Available policies and institutions for SDG localization	Energy data monitoring	Cooperation with national and international stakeholders	Use of financial resources	Awareness raising and capacity-building	Implementation	Linkages to other SDGs
Availability of specific policies and institutions focused on supporting the SDG 7 implementation.	Accessibility and penetration of energy monitoring and smart metering.	Efficient communication and collaboration between local stakeholders and various stakeholder groups at the national and international levels.	Availability of various financial resources and instruments for supporting SDG 7 implementation actions.	Availability of policies or actions to increase the understanding among citizens and build the capacity of professionals for SDG 7 implementation.	Presence of policies and actions to implement SDG 7 targets.	Availability of policies or actions with linkages between SDG 7 and other SDGs.
Sub-indicator score						
62 Energy access	54 Renewable energy		35 Energy efficiency			
Policies or actions taken by cities on energy access.			Policies or actions taken by cities on renewable energy.		Policies or actions taken by cities on energy efficiency.	
Sub-indicator score						
67 SDG3. Good health and well-being.	75 SDG6. Clean water and sanitation.	71 SDG11. Sustainable cities and communities.	33 SDG12. Responsible production and consumption.	67 SDG13. Climate action.		
The presence of energy-related activities or measures that support the health sector.	The presence of energy-related activities or measures that support water and sanitation.	The presence of energy-related activities or measures that support development of sustainable cities and communities.	The presence of energy-related activities or measures that support responsible production and consumption.	The presence of energy-related activities or measures that support climate action.		

1.2 SDG 7 targets and Indicators

SDG7 is aimed at ensuring access to affordable, reliable, sustainable and modern energy for all. It has three key targets, which are outlined below.


- Target 7.1. “By 2030, ensure universal access to affordable, reliable and modern energy services.” Two indicators are used to measure this target: (a) the proportion of the population with access to electricity; and (b) the proportion of the population with primary reliance on clean cooking fuels and technology.
- Target 7.2. “By 2030, increase substantially the share of renewable energy in the global energy mix”. This is measured by the renewable energy share in TFEC. It is calculated by dividing the consumption of energy from all renewable sources by total energy consumption. Renewable energy consumption includes consumption of energy derived from hydropower, solid biofuels (including traditional use), wind, solar, liquid

biofuels, biogas, geothermal, marine and waste. Due to the inherent complexity of accurately estimating traditional use of biomass, NEXSTEP focuses entirely on modern renewables (excluding traditional use of biomass) for this target.

- Target 7.3. “By 2030, double the global rate of improvement in energy efficiency”, as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production plus net imports minus international marine and aviation bunkers plus stock changes. For comparison purposes, GDP is measured in constant terms at 2011 PPP.



2. NEXSTEP methodology



The main purpose of NEXSTEP is to help design the type and mix of policies that will enable the achievement of the SDG7 targets and the emission reduction targets (under NDCs) through policy analysis. However, policy analysis cannot be done without modelling energy systems to forecast/backcast energy and emissions, and economic analysis to assess which policies or options would be economically suitable. Based on this, a three-step approach has been proposed. Each step is discussed in the following sections.

2.1 Key methodological steps

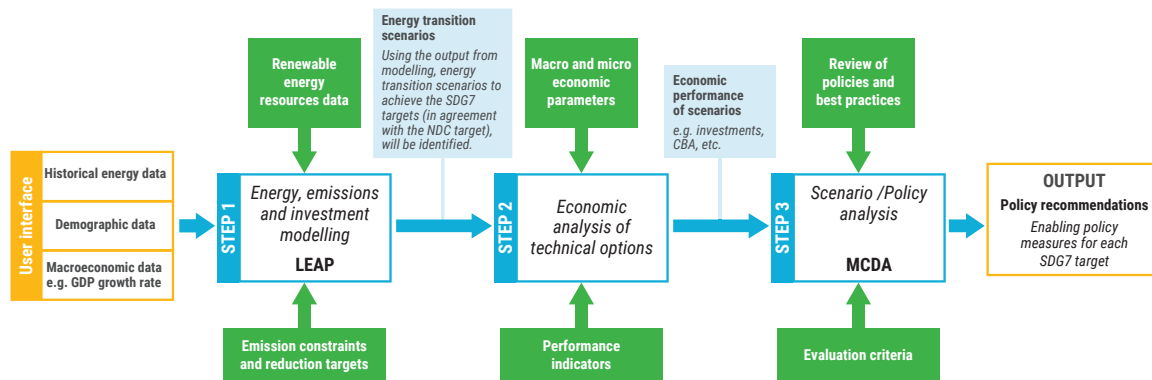
(a) Energy and emissions modelling

NEXSTEP begins with the energy systems modelling to develop different scenarios in order to achieve SDG7 by identifying potential technical options for each scenario. Each scenario contains important information including the final energy (electricity and heat) requirement by 2030, possible generation/supply mix, emissions and the size of investment required. The energy and emissions modelling component uses the Long-range Energy Alternatives Planning (LEAP). It is a widely-used tool for energy sector modelling as well as for creating energy and emissions scenarios. Many countries have used LEAP to develop scenarios as a basis for their Intended NDCs. Figure 1 shows the different steps of the methodology.

(b) Economic analysis module

The energy and emissions modelling section selects the appropriate technologies, and the economic analysis builds on this by selecting the least cost energy supply mix for the country. The economic analysis is used to examine economic performances of individual technical options identified and prioritize least-cost options. As such, it is important to estimate some of the key economic parameters such as net present value, internal rate of return and payback period. A ranking of selected technologies will help policymakers to identify and select economically effective projects for better allocation of resources. The economic analysis helps present several economic parameters and indicators that would be useful for policymakers in making an informed policy decision.

Figure 1. Different components of the NEXSTEP methodology



(c) Scenario and policy analysis

Using Multi-Criteria Decision Analysis (MCDA) tool, this prioritised list of scenarios is assessed in terms of their techno-economic and environmental dimensions to convert to a policy measure. The top-ranked scenario from the MCDA process is essentially the output of NEXSTEP, which is then used to develop policy recommendations.

This tool is unique in that no other tools look at developing policy measures to achieve SDG7. The key feature that makes it outstanding is the back-casting approach for energy and emissions modelling. This is important when it comes to planning for SDG7 as the targets for the final year (2030) are already given; thus the tool needs to be able to work its way backwards to the current date and identify the best possible pathway.

2.2. Scenario definitions

The LEAP modelling system is designed for scenario analysis, to enable energy specialists to model energy system evolution based on current energy policies. In the NEXSTEP model for Iskandar Malaysia, three main scenarios have been modelled: (a) the BAU scenario; (b) the CPS scenario; and (c) the SET scenario. In addition, one ambitious scenario, (d) the CNDC scenario, has been modelled; it explores the possible pathway in aligning Iskandar Malaysia’s emission reduction with the national conditional NDC target.

(a) The BAU scenario. This scenario follows historical demand trends, based on simple projections, such as using GDP and population growth. It does not consider emission limits or renewable energy targets. For each sector, the final energy demand is met by a fuel mix reflecting the current shares in TFEC, with the

trend extrapolated to 2030. Essentially, this scenario aims to indicate what will happen if no enabling policies are implemented or the existing policies fail to achieve their intended outcomes.

(b) CPS scenario. Inherited and modified from the BAU scenario, this scenario considers all policies and plans currently in place. These include, for example, the Iskandar Malaysia Bus Rapid Transit (IMBRT) expansion plan.

(c) SET scenario. This scenario aims to align Iskandar Malaysia’s energy transition pathway with the SDG 7 targets, including substantially increasing the renewable energy share and doubling the rate of energy efficiency improvement. Energy efficiency improvement has been modelled in alignment with the global energy intensity improvement rate. Finally, an emission intensity reduction on a par with the national unconditional NDC target is achieved in this scenario (an emission intensity reduction of 35 per cent relative to the 2005 levels), due to proposed energy efficiency measures, while meeting the 12 per cent renewable electricity generation target within the region’s boundary.

(d) CNDC scenario: Similar to the SET scenario, this ambitious scenario aims to align the region’s energy transition pathway with the SDG 7 targets. At the same time, it investigates the potential in align the region’s emission intensity reduction target with the national conditional NDC target (45 per cent reduction of emission intensity relative to the 2005 level).

2.3 Economic analysis

The economic analysis considers the project’s contribution to the economic performance of the energy sector. The purpose of a Cost-Benefit Analysis (CBA) is to make better informed

policy decisions. It is a tool for weighing the benefits against costs and facilitating an efficient distribution of resources in public sector investment.

2.3.1 Basics of economic analysis

The economic analysis of public sector investment differs from a financial analysis. A financial analysis considers the profitability of an investment project from the investor's perspective. In an economic analysis the investment profitability considers the national welfare, including externalities. A project is financially viable only if all the monetary costs can be recovered in the project lifetime. Project financial viability is not enough in an economic analysis; contribution to societal welfare should be identified and quantified. For example, in the case of a coal power plant, the emissions from combustion process contain particulate matter that is inhaled by the local population, causing damage to health and acceleration of climate change. In an economic analysis a monetary value is assigned to the GHG emission to value its GHG emissions abatement.

2.3.2 Cost parameters

The project cost is the fundamental input in the economic analysis. The overall project cost is calculated using the following:

- (a) Capital cost – capital infrastructure costs for technologies based on country-specific data to improve the analysis. They include land, building, machinery, equipment and civil works;
- (b) Operation and maintenance cost – this comprises fuel, labour and maintenance costs. Power generation facilities classify operation and maintenance costs as fixed (\$/MW) and variable (\$/MWh) cost;
- (c) Decommissioning cost – retirement of power plant costs related to environmental remediation, regulatory frameworks and demolition costs.;
- (d) Sunk cost – existing infrastructure investments are not included in the economic analysis, since no additional investment is required for the project;
- (e) External cost – refers to any additional externalities which place costs on society;
- (f) GHG abatement – avoided cost of CO₂ generation is calculated in monetary value terms based on carbon price. The 2016

Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories is followed in the calculation of GHG emission for the economic analysis. The sectoral analysis is based on the Tier 1 approach, which uses fuel combustion from national statistics and default emission factors.

2.3.3 Scenario analysis

The scenario analysis evaluates and ranks scenarios, using the Multi Criteria Decision Analysis (MCDA) tool, with a set of criteria and weights assigned to each criterion. Ideally, the weights assigned to each criterion should be decided in a stakeholder consultation. If it is deemed necessary, this step can be repeated using the NEXSTEP tool in consultation with stakeholders; the participants may wish to change weights of each criterion, where the total weight needs to be 100 per cent. The criteria considered in the MCDA tool can include the following criteria; however, stakeholders may wish to add/remove criteria to suit the local context:

- Access to clean cooking fuel;
- Energy efficiency;
- Share of renewable energy;
- Emissions in 2030;
- Alignment with the Paris Agreement;
- Fossil fuel subsidy phase-out;
- Price on carbon;
- Fossil fuel phase-out;
- Cost of access to electricity;
- Cost of access to clean cooking fuel;
- Investment cost of the power sector;
- Net benefit from the power sector.

This step is generally applied to all countries utilizing NEXSTEP in developing the national SDG 7 or the subnational SET roadmap, as a means of suggesting the best way forward for the countries or cities by prioritising the several scenarios. Nevertheless, it has not been applied to Iskandar Malaysia as a limited number of scenarios have been developed.



3. Overview of Iskandar Malaysia's energy sector

3.1 Overview of Iskandar Malaysia

Created in 2006, Iskandar Malaysia is a special economic region located within Malaysia's State of Johor. The overall development of the region is facilitated by Iskandar Regional Development Authority (IRDA), which is a Malaysia Federal Government statutory body tasked with developing Iskandar Malaysia into a strong and sustainable metropolis of international standing (IRDA, 2021a). Iskandar Malaysia is located on the southernmost tip of mainland Asia, neighbouring Singapore. Its strategic location gives access to the world's busiest shipping routes and is within close reach (by air) of major Asian cities (IRDA, 2021b). With a total area of 2,217 square kilometres, the administrative jurisdiction of the region falls under five local authorities.⁷

Since the inception of Iskandar Malaysia, its population grew substantially from just 1.34 million in 2006 to 2.23 million in 2019. This corresponds to an annual growth rate of 4 per cent. Economically, Iskandar Malaysia's GDP has grown at an annual growth rate of 8 per cent, from around US\$8.6 billion in 2006 to US\$23.3 billion in 2019, accounting for around 68 per cent of the State of Johor's GDP. Such tremendous economic growth also resulted in a 3.8 per cent growth in GDP per capita, reaching more than US\$10,000 per capita in 2019 (IRDA, 2020a).

The holistic development of Iskandar Malaysia is guided by its Comprehensive Development Plan ii (CDPii) (IRDA, 2014). On the economic development front, its economic sector is made up of both industry and services, with special focus on nine promoted sectors.⁸

Its economic development is boosted with a cumulative committed investment of US\$78 billion between 2006 and 2019, across a diverse range of sectors (IRDA, 2020a). Socially, several programmes and initiatives have been put into motion to create a healthy living ecosystem for its people. In addition, Iskandar Malaysia is being developed as a Smart City (IRDA, 2021b).

The development of Iskandar Malaysia places high emphasis on low carbon development. Iskandar Malaysia is recognized as an "A-List" city by CDP (formerly the Carbon Disclosure Project) for its exemplary climate actions (IRDA, 2020a). For example, the Iskandar Malaysia Low Carbon Society Blueprint was developed in 2013 to provide guidance on low carbon development. Other initiatives include the Comprehensive Assessment System for Built Environment Efficiency (CASBEE), a certification scheme to promote green building design as well as Green Economy Guidelines (GEG) to promote green industries.

3.2 Regional development frameworks in the context of the energy sector

Iskandar Malaysia's energy sector development is guided by several development plans and blueprints. These strategic documents have been used as guiding references for the NEXSTEP modelling, to provide recommendations in adherence with the region's overarching direction and aspiration. The main guiding development plans and blueprints relevant to the energy sector development are briefly described below.

The Comprehensive Development Plan ii, 2014-2025 (CDPii) (IRDA, 2014) is the main guiding development plan for Iskandar Malaysia in materializing its vision to become a strong and sustainable metropolis of international standing. The Circle of Sustainability, anchored by core elements – wealth generation, wealth sharing and inclusiveness, and resource optimization and low carbon intertwined in a continuous cycle – acts as the comprehensive economy-wide strategic framework. More specifically, the resource optimization and low carbon element proposes several low-carbon strategic thrusts and initiatives. The CDPii stipulates a GHG intensity reduction target of 58 per cent compared with 2005 levels as well as a renewable energy target of 12 per cent by 2025. An energy savings target

⁷ Johor Bahru City Council, Johor Bahru Tengah Municipal Council, Pasir Gudang Municipal Council, Kulai Municipal Council and a part of the Pontian District Council

⁸ These are the electrical and electronics, petrochemical and oleo-chemical, food and agro-processing, logistics, tourism, creative, health care and financial sectors.

of between 20 and 30 per cent reduction by 2025 has also been set for the industrial, commercial and residential sectors.

The Low Carbon Society Blueprint for Iskandar Malaysia 2025 (UTM-Low Carbon Asia Research Center, 2013) provides a scenario-based analysis and proposes 12 major actions within three strategic pillars (i.e., Green Economy, Green Community and Green Environment), which is intended to develop Iskandar Malaysia as a low carbon society. The scenario-based analysis shows that the proposed actions, which cover wide-ranging aspects including transportation, industry and buildings, allow a 58 per cent reduction of GHG intensity, with reference to the 2005 level.

The Renewable Energy and Energy Efficiency Blueprint for Iskandar Malaysia (IRDA, 2010) outlines the renewable potentials within or near Iskandar Malaysia's boundary, including potential power capacity from palm oil agricultural waste and municipal waste. It further introduces the energy efficiency potential in the industry, commercial and the residential sectors.

Several energy sector and emission targets have been set out for Iskandar Malaysia, as per the CDPii.

These are:

- Energy saving targets for domestic, commercial, and industrial sectors by 2025;
- Renewable power target of 12 per cent by 2025; and
- Emission intensity reduction target of 58 per cent by 2025 relative to the 2005 level.

3.3 Regional energy profile

The population of Iskandar Malaysia is 2.23 million, with an estimated average household size of 3.8 people. Correspondingly, in 2019 the number of households in Iskandar Malaysia were estimated to be 586,800, all of whom have access to electricity and clean cooking. In 2019, approximately 90 per cent of its population utilized

LPG cooking stoves for their cooking needs, while the remaining 10 per cent used electric cooking stoves.

Renewable energy delivered approximately 3.3 per cent of TFEC in 2019. The electricity requirement is fulfilled almost exclusively by purchased electricity from the central grid. The percentage share of renewable energy considers the share of renewable electricity of the central grid, which was estimated 4.8 per cent⁹ in 2019. Other usage of renewable energy includes a small amount of biodiesel consumption in the transport sector. Iskandar Malaysia aims to increase its renewable power generation to 12 per cent by 2025. The planned renewable power capacity within Iskandar Malaysia's boundaries includes 33.3 MW of solar PV in 2021 and 8 MW of biogas plant in 2023. The SET scenario further explores how Iskandar Malaysia could ramp up its current effort to achieve its target.

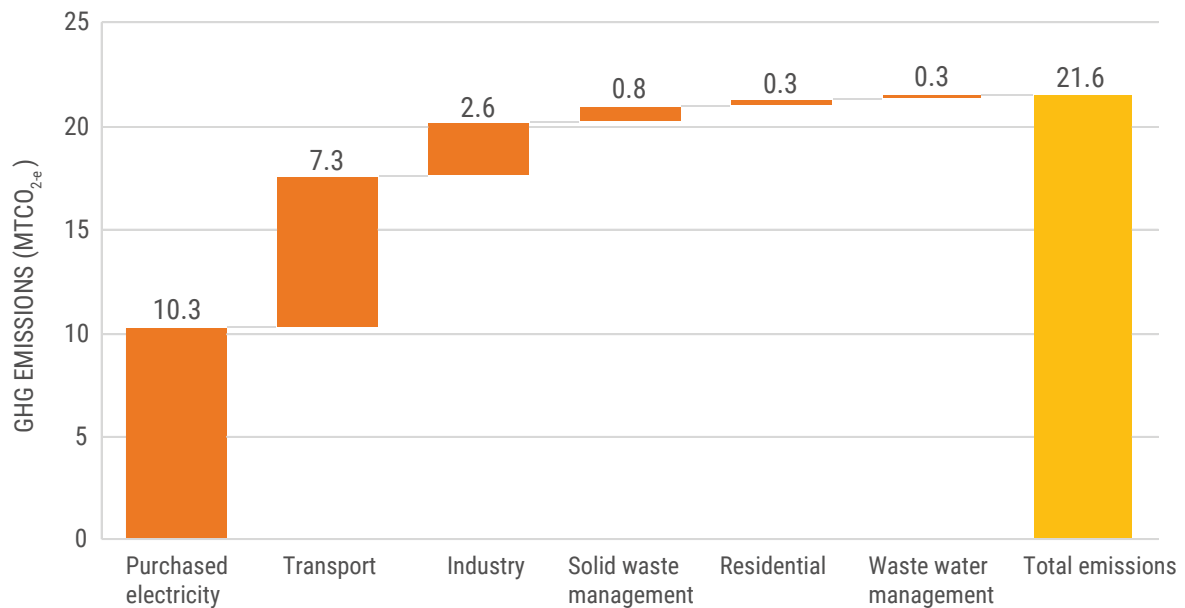
The energy intensity in 2019 was calculated as 3.97 MJ/US\$₂₀₁₁.¹⁰ Around 53 per cent of the total primary energy supply is used to fulfil the demand from the transport sector. The consumption from the transport sector in 2019 was an estimated 2,560 ktoe. Notwithstanding this, the planned Iskandar Malaysia Bus Rapid Transit expansion will allow substantial demand reduction from the transport sector, as detailed further in subsection 3.7. The GHG emission in 2019 was an estimated 21.6 MTCO₂-e.¹¹ The GHG emissions breakdown is shown in figure 2.

The 2019 progress of Iskandar Malaysia's energy sector against the SDG indicators and emission reduction baseline is summarized in Annex I.

9 Estimated based on 2018 statistics in Energy Commission, 2020a.

10 Authors' calculation.

11 The emissions in this study have been estimated using the bottom-up approach, which may differ from the emission inventory of Iskandar Malaysia due to differences in the quantification approaches.

Figure 2. GHG emissions in 2019

3.4 Regional energy resource assessment

The utilization of local energy resources within the boundaries of Iskandar Malaysia is currently limited to solar electricity generation of 36MW. Due to its geographical location close to the equator, Iskandar Malaysia enjoys relatively high average solar irradiation of 1,575 kWh/m² per annum, distributed throughout the year. Generation potential can be found on rooftops of residential and commercial buildings as well as on brownfield sites scattered throughout the area.

GIS analysis conducted in 2010 identified a total of 14 brownfield sites that have the potential to be developed into solar farms (IRDA, 2010). On the other hand, the UTM-Low Carbon Asia Research Center (2013) suggests that the annual electricity generation potential may be around 47.8 TWh per year. Nevertheless, in-depth research and feasibility studies should be performed to provide the most up-to-date picture of implementation feasibility. Table 1 presents details of the potential for solar PV-based electricity generation in Iskandar Malaysia.

Table 1. Solar generation potential in Iskandar Malaysia

	Available area (hectares)	Energy potential (GWh/yr) ¹²
Solar farms – vacant land	17,382	41,065
Solar for residential use ¹³	9,725	4,595
Solar for commercial and public use ¹²	15,379	2,112
Total	3,1476	47,771

Source: UTM-Low Carbon Asia Research Center, 2013.

¹² Calculated based on average solar irradiation of 1,575 kWh/m² per annum and capacity factor of 15 per cent (UTM-Low Carbon Asia Research Center, 2013).

¹³ Assuming 20% of the total area is suitable for solar PV installation.

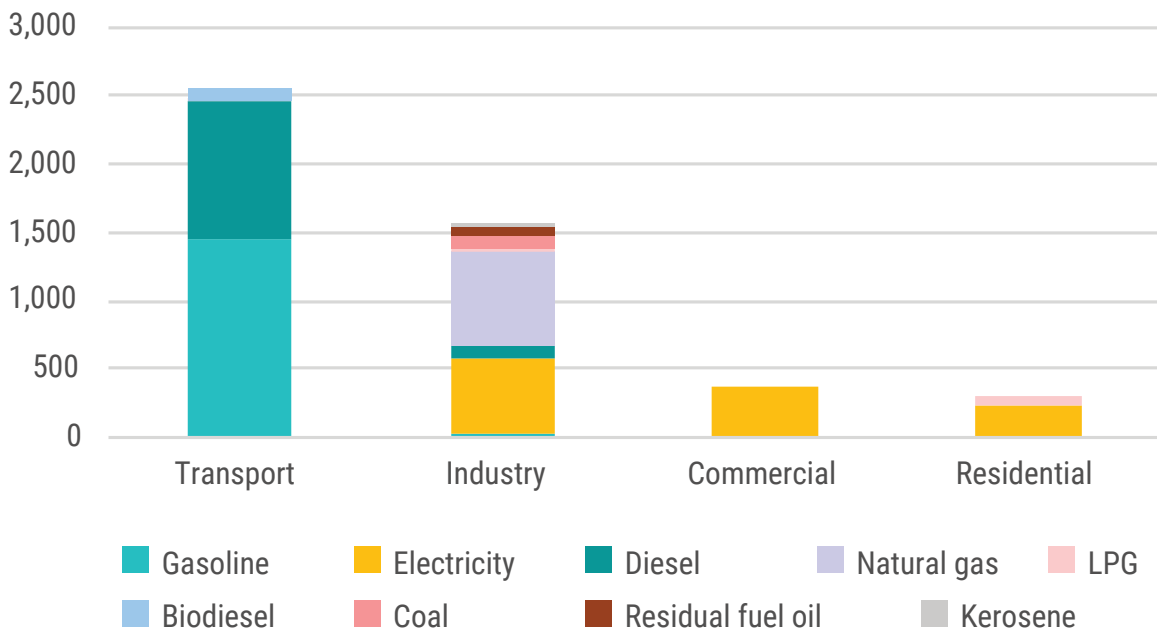
Other resources include palm oil production, waste and effluents, which are of limited potential. The projected potential in 2025 is 5.50MW of biomass energy from empty fruit bunches and 1.75MW of biogas from palm oil mill effluent (IRDA, 2010). Such potential is estimated based on the area of land used for palm oil plantations, which are expected to decrease during the coming years. Municipal solid waste is another potential source for electricity generation. The daily amount of waste, which was an estimated 1,870 tonnes in 2016, is expected to increase as the population in Iskandar Malaysia increases. Based on a preliminary study conducted in 2018 by the State of Johor, waste-to-energy based on the pyrolysis endothermic treatment and gasification energy recovery technology could provide 5.1 MW generation capacity for every 200 tonnes of daily waste production.¹⁴ It is noted that there is potential to generate methane from sewage sources and generate electricity from mini-hydro dams, but the generation potential for these sources is unclear (IRDA, 2010).

3.5 Regional energy balance, 2019

The majority of the following 2019 energy data have been provided by IRDA, in consultation with various stakeholders, including Tenaga Nasional Berhad (TNB) and the Road Transport Department of Johor. Other publicly available resources (i.e., governmental reports and journal articles) were also consulted. When direct data are not available, statistical extrapolation and estimation are performed based on informed judgement to fill in the data gaps. Further details on the data sources and assumptions used are given in Annex II.

In 2019, TFEC was 4,799 ktoe. The main energy consuming sector was the transport sector, consuming 2,559 ktoe, around 53 per cent of TFEC in 2019. The existing transport fleet in 2019 was almost exclusively made up of internal combustion engine vehicles, consuming gasoline (57 per cent), diesel (39 per cent) and a small amount of biodiesel (4 per cent).

Figure 3. TFEC breakdown by sector and fuel type, 2019



The energy consumed in the industry sector was 1,548 ktoe, 32 per cent of TFEC. Natural gas is the dominant fuel (44 per cent), followed by electricity (35.9 per cent). Other types of fuel consumed in the industry sector include coal, diesel oil and residual fuel oil. Residential and commercial sectors make up around 6.5 per cent and 7.7 per cent, respectively, of the total final energy consumed. Around 30 per cent of the energy demand in the residential sector is attributable to household cooking with LPG stoves, with the remaining usage from electricity to power residential appliances. The energy consumed in the commercial sector is exclusively electricity. A very small amount of electricity of about 9.8 ktoe is used for public street lighting purposes. Figure 3 shows the fuel

demand from the five main demand sectors, while figure 4 shows the TFEC breakdown by fuel type in 2019.

Figure 5 shows the TPES breakdown by fuel type in 2019. The total primary energy supply is 4,871 ktoe, around 72 ktoe higher than the TFEC. The small difference can be attributed to the electricity transmission and distribution losses of around 5.8 per cent.¹⁵ The fuel breakdown of TPES is very similar to TFEC, as localised electricity generation is very limited – only around 5.3 ktoe of solar PV generated electricity. The electricity requirement of the region is fulfilled mainly by electricity from the central grid.

Figure 4. TFEC breakdown by fuel type, 2019

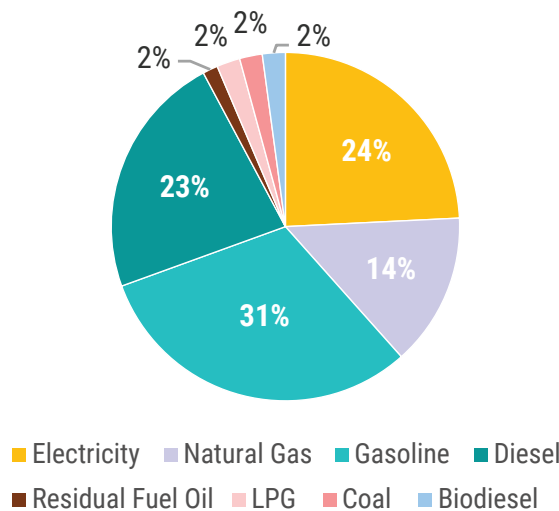
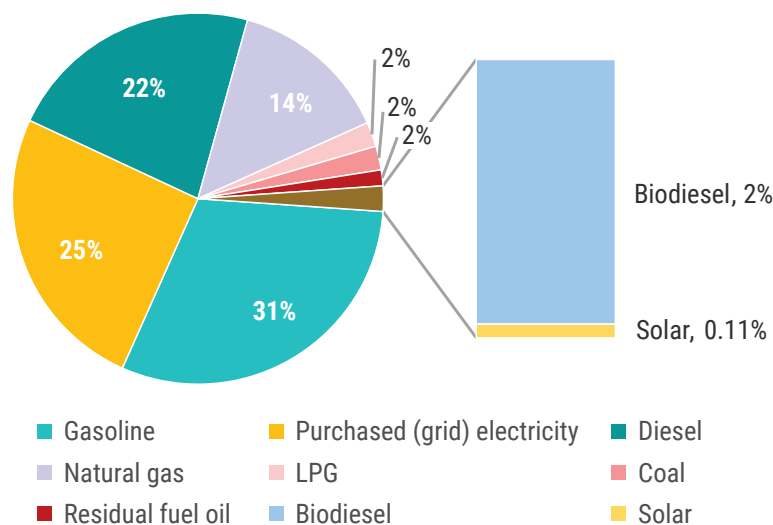


Figure 5. TPES breakdown by fuel type, 2019



15 Based on 2014 data provided for Malaysia in World Bank, 2021.

3.6 Energy modelling projections

Future energy demand is projected based on a bottom-up approach, using activity levels and energy intensities, with the LEAP model. The demand outlook throughout the NEXSTEP analysis period is influenced by factors such as annual

population growth, annual GDP growth as well as other demand sector growth projections. The assumptions used in the NEXSTEP modelling are further detailed in Annex II, while table 2 provides a summary of the key modelling assumptions for the three main scenarios (i.e., BAU, CPS and SET scenarios).

Table 2. Important factors, targets and assumptions used in NEXSTEP modelling

Parameters	BAU	CPS	SET
GDP growth	6 per cent per annum		
Population growth	4 per cent per annum		
Commercial floor space	7.28 million square metres, annual growth rate of 6.4 per cent per annum		
Transport activity	Transport activities in 2019: 56 billion passenger-kilometres and 24.7 billion tonne-kilometres, with assumed growth of 4 per cent per annum		
Industry	Annual growth rate of 4.6 per cent		
Energy efficiency	Additional energy efficiency measures not applied	Improvement based on current policies/ initiatives	Economy-wide efficiency improvement
Electricity generation	Based on 2019 existing RE installation. Purchased electricity from the central grid is assumed to have the same fuel mix throughout the period	Based on current expansion plan within the city boundary. The purchased (grid) electricity mix is estimated based on capacity mix (Energy Commission, 2020b). ¹⁶	Local RE generation meets the 12 per cent RE generation target from 2025 onwards. The purchased (grid) electricity mix is estimated based on capacity mix (Energy Commission, 2020b). ¹⁶

¹⁶ The estimated fuel mix of the grid electricity is used in calculating the RE share in TFE and GHG emissions attributable to the purchased (grid) electricity. Full details of the calculations are provided in Annex IV. It is noted that a more recent document was published on 24 March 2021. However, it has not been included in the analysis as the analysis was concluded prior the publication of the document.

3.7 Iskandar Malaysia's energy system projections in the current policy settings

The Current Policy Scenario (explores how Iskandar Malaysia's energy system may evolve under the current policy settings. It considers several initiatives implemented or scheduled to be implemented during the 2020-2030 analysis period. These include initiatives within the city boundary as well as national initiatives/policies also covering the region of Iskandar Malaysia. The policies/initiatives considered in the modelling of CPS are:

(a) Energy efficiency measures

- (i) Iskandar Malaysia Bus Rapid Transit (IMBRT) system implementation, with an expected increase in public transport modal share from existing 15-40 per cent by 2030. The expected change in fuel has been considered (see Annex III for further details on the assumptions used).
- (ii) Sustainability Achieved Via Energy Efficiency (SAVE) Programme (SEDA, 2021a). A rebate incentive programme to promote the adoption of 4- or 5-star rated air conditioners. The expected savings in comparison to a conventional air conditioner is 15 per cent (KeTTHA, 2015). An appliance stock-turnover analysis has been conducted with reference to the expected penetration as envisioned in the National Energy Efficiency Action Plan (NEEAP) (KeTTHA, 2015) with a shifted timeline as the programme has just been initiated in 2021. A penetration of 30 per cent efficient appliances is expected in 2021, gradually increasing to 75 per cent in 2030.¹⁷
- (iii) Similar to above, the SAVE programme to promote the adoption of 4- or 5-star rated refrigerators, with expected savings of 25 per cent compared to conventional refrigerators (KeTTHA, 2015). A penetration of 30 per cent efficient appliances is expected in 2021, gradually increasing to 90 per cent in 2030.¹⁷

(b) Renewable energy power capacity expansion

New power capacity to be built as part of the regional or consumer initiatives within the region's boundary. These include a new solar PV installation of 33 MW in 2021 and 8 MW of landfill biogas plant in 2023.

In addition, it is expected that the national grid emissions (limited to peninsular Malaysia) will decrease over the years, as RE capacity ramps up. Grid emission factor projections (in terms of tonne/MWh, as required for modelling purposes) are not readily available. As such, it has been calculated based on expected power capacity by fuel type provided in (Energy Commission, 2020b), with some author's assumptions for parameter values (i.e., efficiency and load factor). The estimated grid emission factors throughout the analysis period and the assumptions used are provided and detailed in Annex IV.

The following section further describes the energy and emission outlook in the current policy settings.

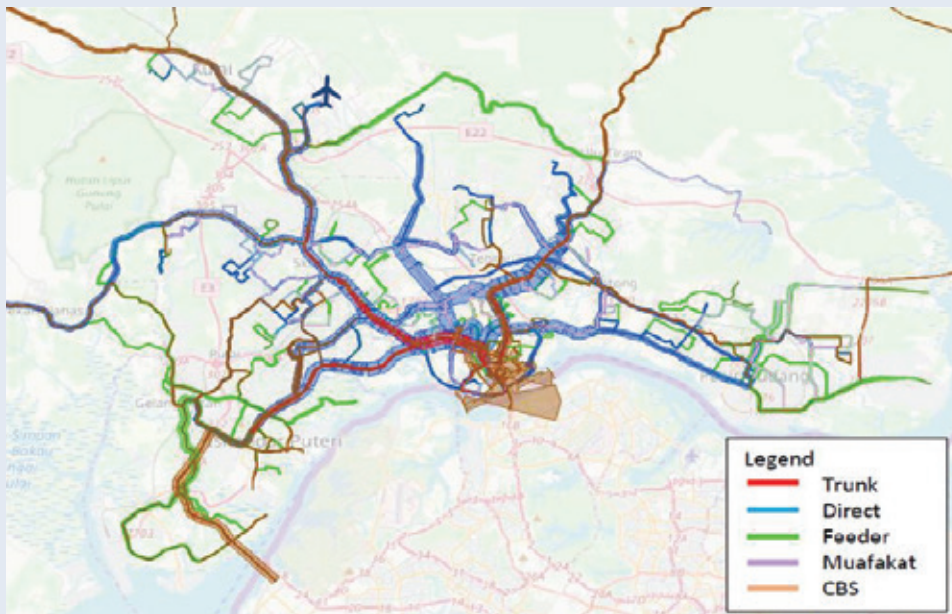
¹⁷ Caveat: It is unsure if the recently launched SAVE programmes may lead to the expected outcome envisioned in NEEAP.

Box 2. Iskandar Malaysia Bus Rapid Transit System

Iskandar Malaysia has embarked on a large-scale sustainable transport project, in establishing a Bus Rapid Transit (BRT) system in the economic region. The project aims to not only improve transport connectivity, but also enhance social and economic inclusivity as it will allow the reduction of transportation costs and spur more possibilities for employment and business growth (IRDA, 2020b).

The BRT system will increase the coverage of public transport from just 30 per cent to 90 per cent of the Iskandar Malaysia region. This will be made possible by having bus service lines totalling up to 2,051 km. It consists of the main trunk (3 lines – 51 km), direct (44 lines – 1,247 km) and feeder (55 lines – 741 km) services. It is estimated that 2.35 million people will benefit from such wide connectivity coverage (IRDA, 2020b).

Expected route coverage of the BRT system



Source: IRDA, 2021c.

3.7.1 Energy demand outlook

In the current policy settings, TFEC is projected to increase from 4,799 ktoe in 2019 to 6,908 ktoe in 2030. In the BAU scenario, the energy demand is projected to increase to 7,726 ktoe. Such a substantial decrease in energy demand in the current policy scenario (around 820 ktoe) can be attributed to the above-mentioned energy efficiency measures, particularly, the expansion of the BRT system in the Iskandar Malaysia region.

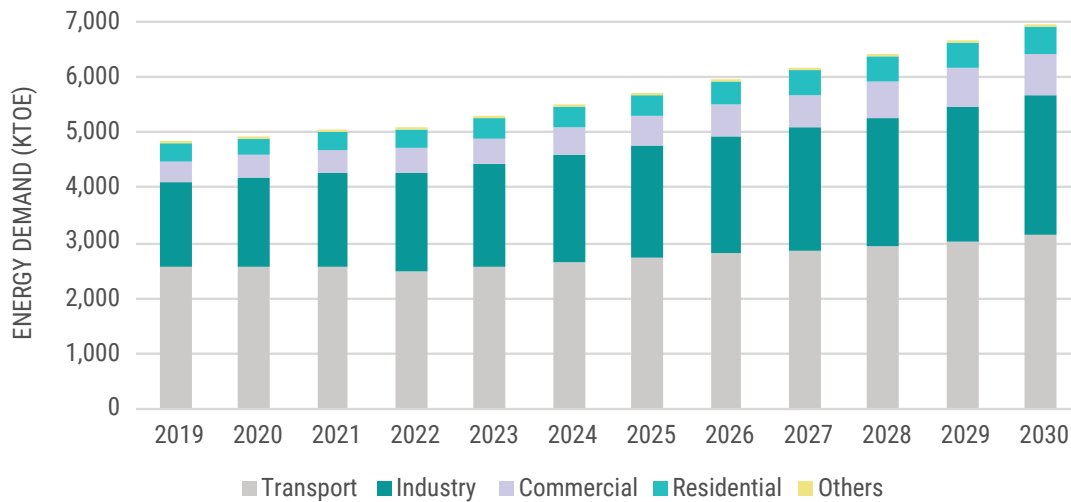
In 2030, the transport sector will have the largest share of TFEC at 3,141 ktoe (45.5 per cent), followed by the industrial sector at 2,538 ktoe (36.7 per cent), the commercial sector at 733 ktoe

(10.6 per cent), the residential sector at 486 ktoe (7.0 per cent) and others (i.e., public street lighting) at 9.8 ktoe (0.1 per cent). The sectoral overview of energy demand in CPS is discussed below and is illustrated by figure 6.

(a) Transport sector

The transport sector energy demand will continue to dominate Iskandar Malaysia's TFEC, and is projected to increase from 2,559 ktoe in 2019 to 3,141 ktoe in 2030. In 2030, the sub-sector share of transport energy demand is projected to be road passenger transport 1,784 ktoe (56.8 per cent) and road freight transport 1,357 ktoe (43.2 per cent).

Figure 6. Iskandar Malaysia's energy demand outlook, CPS 2019 - 2030



Road passenger transport is subdivided into six subcategories, i.e., private cars, motorbikes, taxis and E-hailing, buses, BRT and others. The BRT expansion is projected to increase the rate of use of public transport (i.e., taxis and E-hailing, buses and BRT) from 17 per cent in 2019 to 41 per cent (in terms of passenger-km travelled) in 2030,¹⁸ while reducing the use of private passenger cars and motorbikes by 18.5 per cent and 5 per cent,¹⁹ respectively. In turn, this allows substantial energy demand reduction due to increased uptake of more efficient transport modes (i.e., BRT). The passenger transport demand is expected to decrease by 789 ktoe in 2030, compared to the BAU scenario.

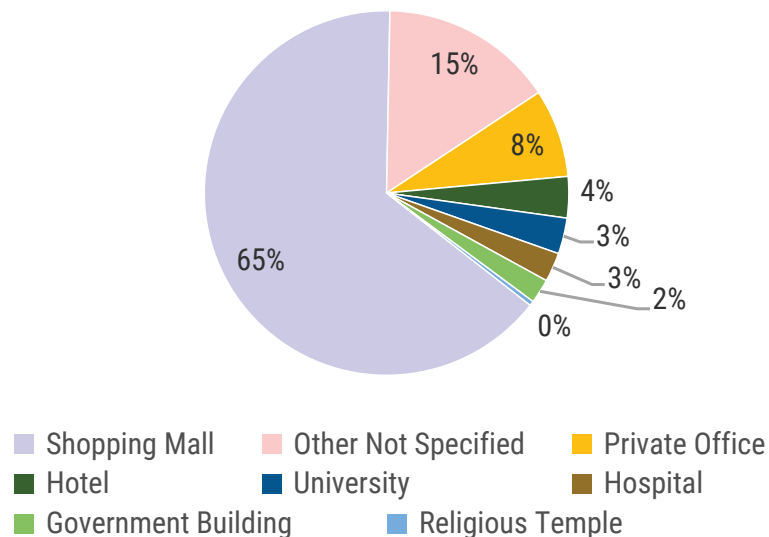
(b) Residential sector

The residential sector energy demand is projected to increase to 486 ktoe by 2030, compared to 312 ktoe in 2019. The projected savings from the implementation of SAVE programmes are 10.1 ktoe and 9.0 ktoe for air conditioners and refrigerators, respectively.

(c) Commercial sector

The commercial sector energy demand is projected to increase from 371 ktoe in 2019 to 733 ktoe in 2030. The sector is divided into seven subcategories, of which the floorspace of each category is projected to grow by 6.4 per cent per annum. The energy demand distribution in 2030 is shown in figure 7.

Figure 7. Energy demand distribution by commercial sector subcategories, CPS in 2030



18 See Annex III for further details.

19 Author's assumption.

(d) Industry sector

Energy demand from the industry sector is expected to grow from 1,548 ktoe in 2019 to 2,538 ktoe in 2030. The industry sector is divided into 11 subcategories. The modelling of CPS assumes that the energy intensity of the industrial sector remains constant throughout the analysis period, while industrial energy productivity increases by 4.6 per cent annually. Figure 8 shows the energy demand distribution by industry subcategories in 2030.

3.7.2 Electricity generation outlook

The 2030 demand for electricity in the current policy scenario will be 23.6 Terawatt-Hours (TWh), increased from 13.5 TWh in 2019. The demand will be the highest in the industry sector - 10.6 TWh (45 per cent) followed by the commercial sector - 8.5 TWh (36 per cent), the residential sector - 4.1 TWh (17 per cent), transport - 0.3 TWh (1.2 per cent) and others 0.1 TWh (0.5 per cent).

The electricity required to fulfil the demand in Iskandar Malaysia is almost exclusively purchased from the grid, as local generation capacity is limited. The RE power capacity is expected to expand by another 41.3 MW – from a 33.3 MW solar PV and an 8 MW biogas plant. The total installed capacities expected by 2030 are 69.3 MW of solar PV and 8 MW of biogas. Notwithstanding

this, the locally generated electricity is minimal as 99.5 per cent of the electricity requirement will be met with purchased electricity from the central grid. The electricity generation from the solar PV and biogas plant is estimated at 125.3 GWh and 6.3 GWh in 2030, respectively.

3.7.3 Energy supply outlook

In the CPS, TPES is projected to increase from 4,871 ktoe in 2019 to 7,034 ktoe in 2030. The fuel consumption in 2030 is projected to be: oil products, 3,271.7 ktoe; biomass (including biodiesel, bioCNG and biogas), 321.6 ktoe; coal, 166.0 ktoe; and solar, 10.2 ktoe. Figure 9 shows the TPES breakdown by fuel type. One notable change is in the share of gasoline in the TPES, which is estimated to decrease from 31 per cent in 2019 to 22 per cent in 2030. This is primarily due to the decreased use of gasoline in private passenger cars as adoption of public transportation increases.

3.7.4 Energy sector emissions outlook

The energy sector emissions, from the combustion of fuels, is calculated based on the IPCC Tier 1 emission factors assigned in the LEAP model. The combustion of biomass products (i.e., biodiesel and bioCNG) is considered carbon neutral. The emissions attributable to purchased (grid) electricity has been included, while considering the projected decrease in grid emission factor throughout the analysis period. The grid emission

Figure 8. Energy demand distribution by industry sector subcategories, CPS in 2030

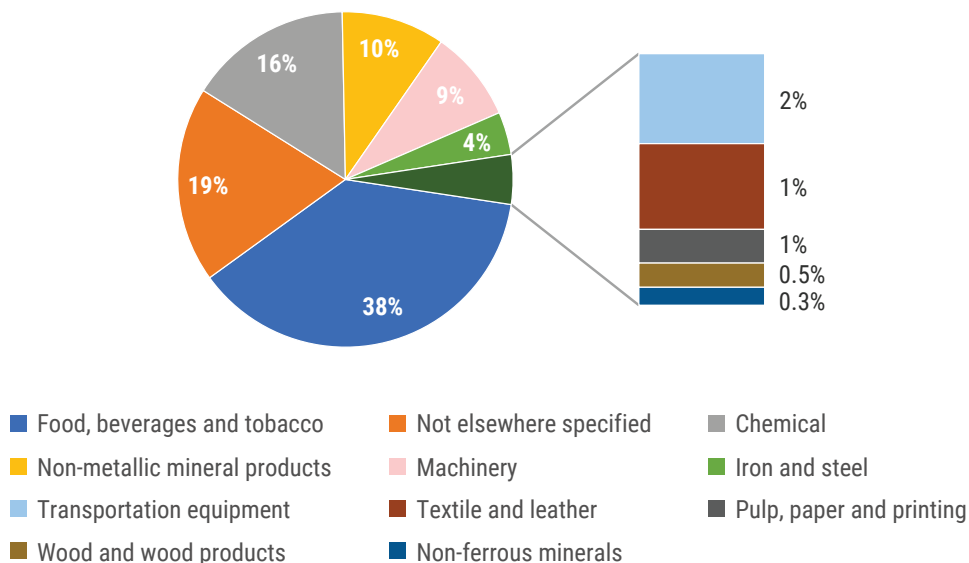
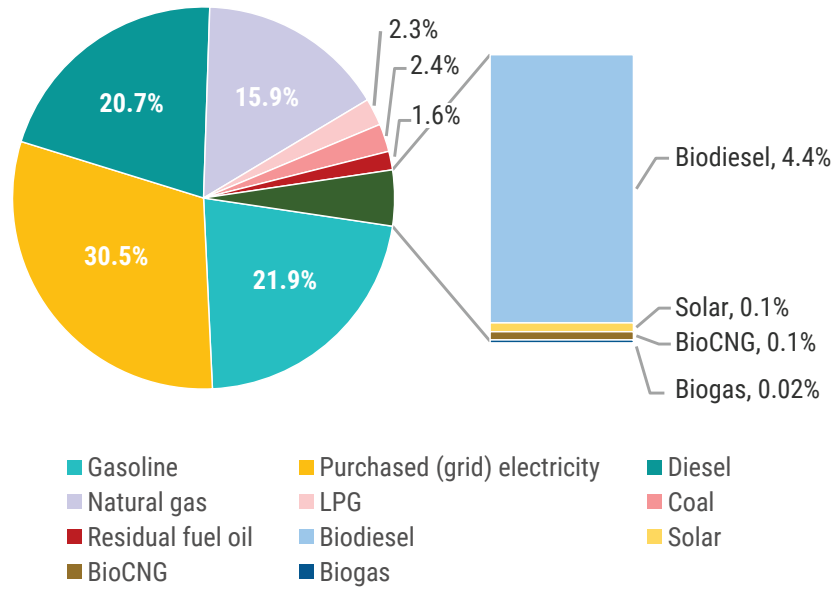


Figure 9. TPES breakdown by fuel type, CPS in 2030

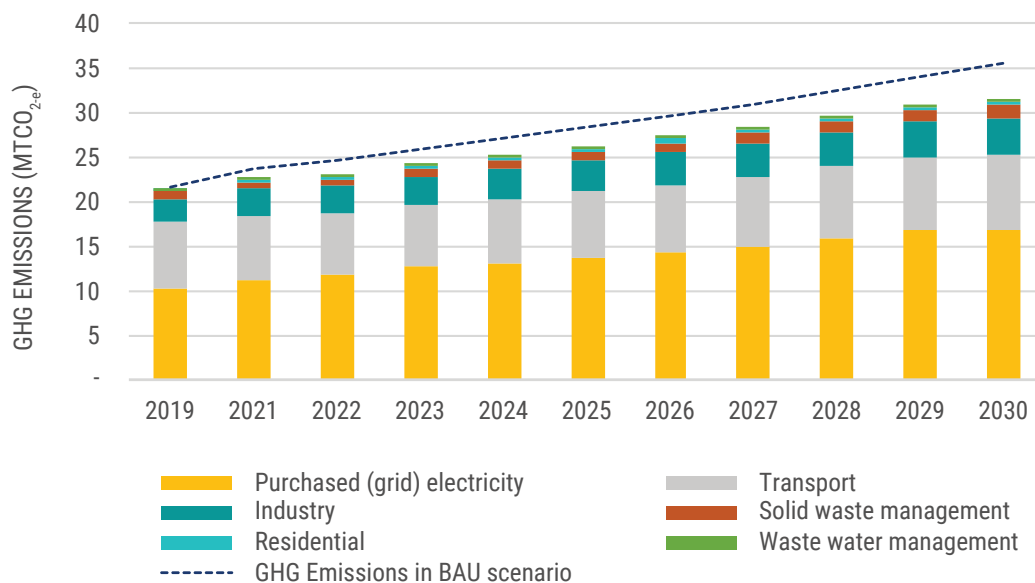


factors have been estimated by the author based on the projected capacity mix provided in (Energy Commission, 2020b) as well as other assumed factors (i.e., load factor and efficiency). Further details on the grid emission factor estimation can be found in Annex IV.

In the CPS, the total GHG emissions from the energy sector increase from 21.6 MTCO₂-e to 31.4 MTCO₂-e (figure 10). The emissions attributable

to purchased (grid) electricity make up about 53.4 per cent of the total emissions. For the demand sectors, the largest contributor of GHG emissions in 2030 will be the transport sector (26.6 per cent), followed by the industry sector (13.7 per cent) and residential sector (1.3 per cent). The waste management sector makes up the remaining 5.7 per cent – solid waste management 4.1 per cent and wastewater management 1.6 per cent.

Figure 10. Iskandar Malaysia's energy sector emissions outlook, CPS, 2019-2030





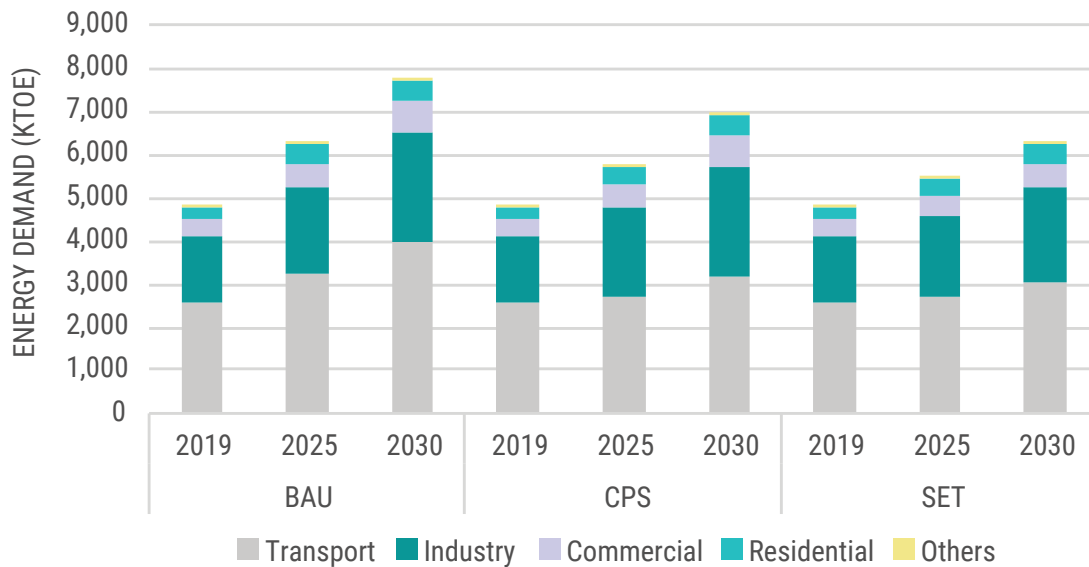
Both subnational and national efforts are imperative to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. In particular, cities around the world contribute around 75 per cent of global anthropogenic emissions and represent about 66 per cent of global energy demand (REN21, 2019). This chapter provides details of the SET scenario, exploring how economy-wide efforts may improve the energy and climate sustainability of the Iskandar Malaysia region. It starts with the energy demand forecast and then discusses the energy sector in relation to SDG 7 targets. It also examines the potential for Iskandar Malaysia to increase its RE generation within the region's boundary while aligning its emission reduction with the national unconditional NDC target.

4.1 SET energy demand outlook

In the SET scenario, TFEC increases at a much slower pace than CPS, i.e., from 4,799 ktoe in 2019 to 6,256 ktoe in 2030. The reduction of 654 ktoe in TFEC in this scenario, compared with the CPS, is due to the improvement in energy efficiency across the demand sectors. The proposed energy efficiency interventions are further described in subsection 4.2.3. In 2030, the transport sector will have the largest share of TFEC at 3,052 ktoe (48.8 per cent), followed by the industry sector at 2,192 ktoe (35 per cent), the commercial sector at 542.6 ktoe (8.7 per cent), the residential sector at 459.4 ktoe (7.3 per cent) and others at 9.8 ktoe (0.2 per cent). Figure 11 shows TFEC by scenarios in 2030.

4. SET scenario – sustainable energy transition pathway for Iskandar Malaysia

Figure 11. Projection of TFEC, by sector, 2030



4.2. SDG7 targets

4.2.1. SDG 7.1: Universal access to modern energy

Iskandar Malaysia has already achieved 100 per cent access to electricity and clean cooking technologies. The cooking practices in the region are dominated by cooking with LPG stoves, with a small percentage of households depending on electric cooking stoves. Both technologies cause little-to-no indoor air pollution, with LPG stoves and electric cooking stoves classified as Level 4 and 5 in the World Bank Multi-Tier Framework (MTF) for Indoor Air Quality Measurement, respectively (Bhatia and Angelou, 2015).

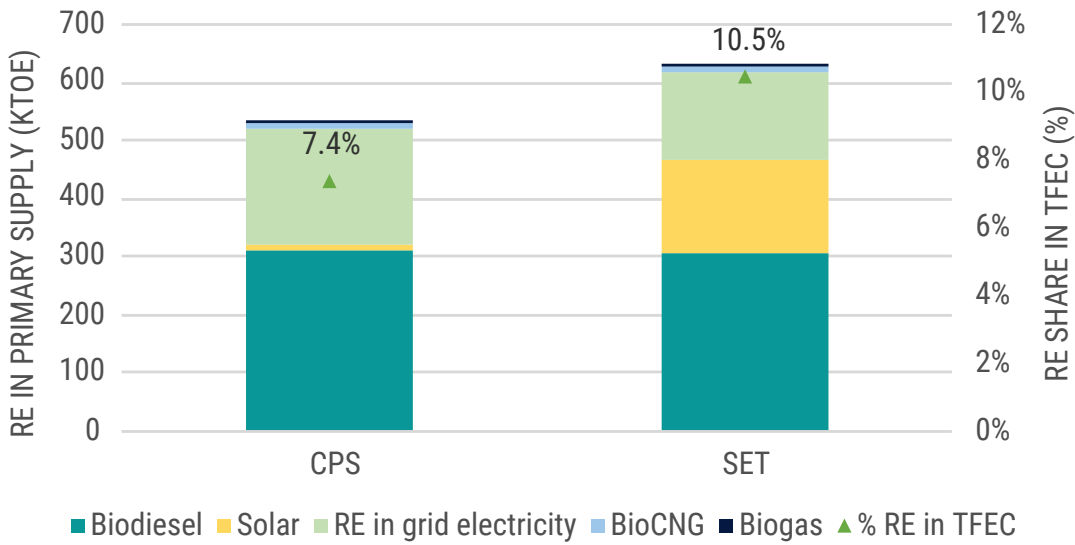
4.2.2. SDG 7.2: Renewable energy

SDG 7.2 does not have a quantitative target but requires a substantial increase of renewable energy share in TFEC. The RE share in TFEC for Iskandar Malaysia is determined using the required improvement in energy efficiency as: (a) a constraint in which it is assumed that Iskandar Malaysia’s annual average energy efficiency improvement will be aligned with the global

improvement rate (detailed further in section 4.2.3); and (b) will meet Iskandar Malaysia’s 12 per cent RE generation target by 2025 (discussed in further detail in section 4.3). It also considers the increasing RE percentage in the grid electricity mix.

The share of renewable energy in TFEC in 2030 will be 7.4 per cent by 2030 in the current policy scenario (figure 12). This increases from just 3.4 per cent in 2019, driven by the high growth of renewable energy usage in the transport sector (i.e., biodiesel and bioCNG) and grid electricity, relative to the slower growth in energy demand. In the SET scenario, the renewable energy share in TFEC increases to 10.5 per cent. This is a result both of the increased renewable power generation and further reduction of energy demand due to energy efficiency measures. Renewable power generation proposed for the region is discussed further in section 4.3.

Figure 12. Renewable energy in TPES and TFEC, 2030

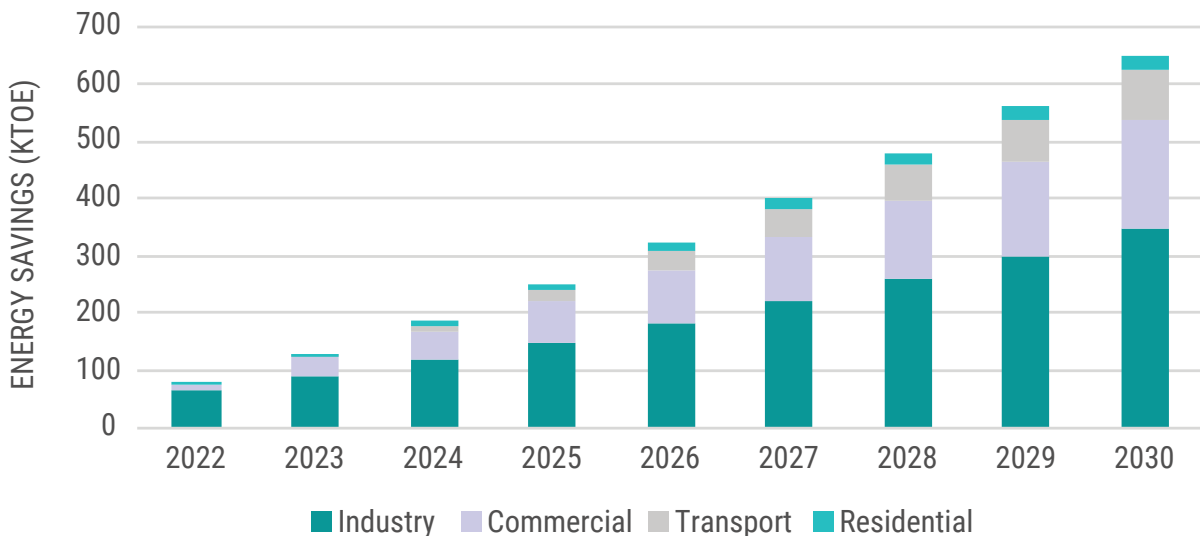


4.2.3. SDG 7.3: Energy efficiency

The primary energy intensity, a proxy for the measurement of energy efficiency improvement, is calculated as 3.02 MJ/US\$₂₀₁₁ in the CPS, which corresponds to an annual rate of improvement of 2.5 per cent. The primary energy intensity is further reduced to 2.85 MJ/US\$₂₀₁₁ in the SET scenario, made possible by the proposed economy-wide energy efficiency improvement measures. This corresponds to an average annual rate of improvement of 2.98 per cent, on a par with the suggested global improvement rate of 3 per cent (UNSD, 2021).

Figure 13 shows the energy savings that may be achieved through the implementation of energy efficiency measures across the demand sectors, compared with the CPS. The industry sector has the largest contribution (346.6 ktoe in 2030), with the projection that energy efficiency measures are gradually adopted across all industry subsectors. Energy efficiency interventions proposed for several commercial subcategories may allow an estimated energy demand reduction of 190.4 ktoe in 2030. Further energy demand reduction can also be realised with a more vigorous uptake of efficient vehicle types and household appliances. Further details of the energy efficiency measures and their impacts are provided below.

Figure 13. Energy efficiency savings in the SDG scenario, compared with CPS



(a) Industry sector

The total energy savings in 2030 for the industry sector is estimated at 346.6 ktoe. Table 3 breaks down the energy savings potential for each industry subsectors and the annual savings estimated for 2030. The modelling assumes a gradual adoption of energy efficiency measures, reaching full adoption by 2030.

The energy savings potential for food, beverages and tobacco, pulp, paper and printing, iron and steel, and wood and wood products are as suggested by the

Malaysian Industrial Energy Efficiency Improvement Project (MIEEIP) audit results, assuming that zero- to high-cost measures are implemented (van der Akker, 2008; UNDP, 2006).²⁰ Energy savings potential for ceramic, cement and glass industries were also provided separately by the MIEEIP audit results. Due to data aggregation for the three industries as the non-metallic mineral industry, NEXSTEP assumes an average 10 per cent savings potential. For the other sub-industrial sectors, a 10 per cent energy savings potential is assumed, in alignment with the suggestion by the UTM-Low Carbon Asia Research Center (2013).

Table 3. Energy savings potential and annual savings in 2030, by industry subsector

Industry subsector	Energy savings potential (%)	Annual savings in 2030 (ktoe)
Food, beverages and tobacco	20	191.1
Not specified elsewhere	10	47.9
Chemical	10	40.1
Non-metallic mineral industry	10	25.3
Machinery	10	22.4
Iron and steel	6	6.3
Transportation equipment	10	4.3
Textile and leather	10	4.1
Pulp, paper and printing	16	2.6
Wood and wood products	6	1.6
Non-ferrous minerals	10	0.9
Total		346.6

(b) Commercial sector

Table 4 shows the energy efficiency measures applied in the commercial subcategories and their respective estimated savings in 2030. NEXSTEP proposes two types of energy efficiency strategies for the commercial sector: mandatory implementation of investment grade audit (IGA) for existing buildings; and making it compulsory for new buildings to adhere to the MS1525 building standards or a maximum Building Energy Index (BEI). Completing mandatory IGAs for all buildings in the next nine years would be challenging, but enabling policy measures, government incentives (particularly for small businesses) and targeted capacity-building

programmes would help to achieve this target. Implementation of IGA is expected to provide a minimum 15 per cent energy savings potential (KeTTHA, 2015). It is assumed that the implementation of IGA will reach a 100 per cent adoption rate by 2030 in the scenario modelling. On the other hand, adherence to the Code of Practice MS1525:2014²¹ on energy efficiency and use of renewable energy for non-residential buildings could reduce the BEI of regular buildings (i.e., government buildings and private offices) to about 135 kWh/m² (KeTTHA, 2015), compared to the baseline estimated at 367 kWh/m² and 280 kWh/m² for private offices and government buildings, respectively.

20 The MIEEIP study divides the suggested energy efficiency measures into three categories: (a) no-cost measures; (b) low-cost measures; and (c) high-cost measures (van der Akker, 2008). No-cost measures do not incur any additional cost. Low-cost measures incur some investments that can be recovered within a period of two years. High-cost measures require substantial upfront investments, although the benefits can be significant.

21 Buildings with a BEI of 136 kWh/m² or less are considered as EE buildings. The most recent revision of the building standard is the MS1525:2019.

Table 4. Energy efficiency measures applied and estimated annual savings in 2030, by commercial subcategory

Subcategory	Energy efficiency measures	Annual savings in 2030 (ktoe)
Governmental buildings	Encouraging the implementation of IGA for existing buildings.	1.4
	From 2023 onwards, new buildings to adhere to MS1525 building standard.	3.1
Private offices	From 2023 onwards, new buildings to adhere to MS1525 building standard.	14.1
Shopping malls	Encouraging the implementation of IGA for existing buildings.	43.3
	New buildings to have a maximum BEI of 450 kWh/m ² . ²²	128.1
Total		190.4

(c) Transport sector

The current share of hybrid vehicles in the existing fleet is very low – estimated at less than 0.5 per cent in 2019. However, promotion of hybrid vehicles is an effective way of reducing oil products consumption in the transport sector as well as lowering GHG emissions. In the SET scenario, NEXSTEP proposes that the uptake of hybrid private passenger cars should be promoted. Scenario modelling assumes the market sales penetration to be 10 per cent in 2023, gradually rising to 50 per cent by 2027. Based on the vehicle stock-turnover analysis, the share of hybrid vehicles in the private passenger car fleet will reach 18.5 per cent

in 2030. The estimated annual saving is as shown in table 5.

(d) Residential sector

Additional energy savings can be realized in the residential sector, albeit the potential is smaller than in the other sectors. As described in section 3.7, initiatives such as SAVE programmes have been launched to encourage the uptake of more efficient household appliances. The SET scenario shows how a more vigorous promotion and a broader scope in covering more appliances may lead to additional energy savings, compared to the CPS. These are as described in table 6.

Table 5. Energy efficiency measure applied and the estimated annual savings in 2030 in the transport sector

Subcategory	Energy efficiency measures	Annual saving in 2030 (ktoe)
Private passenger cars	Encouraging the adoption of hybrid vehicles	88.5

²² The baseline electricity intensity is estimated at 1458 kWh/m², calculated based on total floorspace data provided by IRDA and electricity consumption data provided by TNB. It is noted that a typical Malaysian shopping mall has an electricity intensity of 450 kWh/m², with potential to reduce to 300 kWh/m² when green building measures are applied (IEN Consultants, 2021).

Table 6. Energy efficiency measures applied and the annual savings in 2030 in the residential sector

Household appliances	Energy efficiency measures	Annual saving in 2030 (ktoe)
Air conditioners	30% market penetration of 4- or 5-star rated appliances in 2021 and quickly ramping up to 100% by 2025. ²³	5.4
Refrigerators	30% market penetration of 4- or 5-star rated appliances in 2021 and quickly ramping up to 100% by 2025. ²⁴	3.1
Fans	30% market penetration of highly efficient appliances in 2023 and quickly ramping up to 100% by 2025. ²⁵	12.1
LED lighting	100% market penetration of LED lighting from 2023 onwards.	5.8
Total		26.3

4.3 Power generation in the context of sustainable energy transition

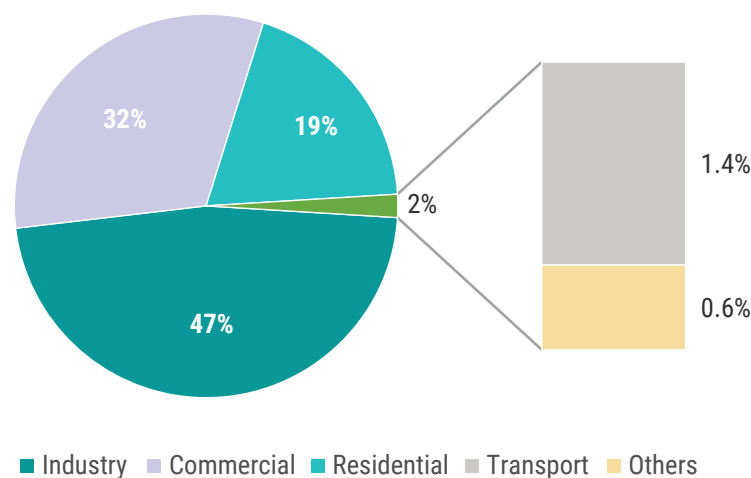
4.3.1 Electricity demand in 2030

The demand for electricity in 2030 will be 19.9 TWh in the SET scenario, a decrease of 3.7 TWh compared with the CPS. The electricity demand in the industry sector will be 9.4 TWh, the commercial sector, 6.3 TWh, the residential sector, 3.8 TWh, the transport sector, 0.3 TWh and others, 0.1 TWh (figure 14).

4.3.2 Power generation capacity and output mix

The CDPII stipulates a 12 per cent RE target by 2025.²⁶ The electricity requirements (taking into consideration final electricity demand, and transmission and distribution losses) are projected to be 17.8 and 21.1 TWh in 2025 and 2030, respectively. Correspondingly, RE generation within the city boundary should reach a total of 2.1 TWh in 2025. The total planned power capacity as modelled in the CPS is expected to bring the total

Figure 14. Electricity demand in 2030, by demand sector



²³ In the CPS, the SAVE programme is expected to stimulate a sales penetration of 30 per cent efficient air conditioners in 2021, gradually increasing to 75 per cent in 2030.

²⁴ In the CPS, the SAVE programme is expected to stimulate a sales penetration of 30 per cent efficient refrigerators in 2021, gradually increasing to 90 per cent in 2030.

²⁵ It is assumed that highly efficient fans are two times more efficient than conventional fans, which have a power rating of 100W (Ahmed and others, 2017)..

²⁶ NEXSTEP treats this target as a percentage of total electricity requirements.

RE generation within the region’s boundary to 125 GWh, substantially falling short of the 12 per cent RE target.

NEXSTEP proposes two main interventions in the power generation sector within the region’s boundary:

- (a) Setting up WTE facilities (75 MW in 2025, increasing to 90 MW by 2030); and
- (b) Quick ramp-up of distributed solar capacity (total solar PV capacity of 920 MW by 2025, increasing to 1,084 MW by 2030).

The above-mentioned interventions not only allow Iskandar Malaysia to meet its 12 per cent RE target by 2025, but also allow substantial GHG emission reductions. In addition, setting up WTE facilities is also a means to promote more sustainable waste management and reduce the land requirements for solid waste disposal in landfills as well as reduce methane emissions from landfills. The proposed

WTE as a more sustainable waste management practice is further detailed in box 3.

Figure 15 shows the power capacities projected under the SET scenario, whereas figure 16 shows the electricity output by fuel type. As modelled, Iskandar Malaysia will meet its 12 per cent RE generation target (within the region’s boundaries) in 2025, with a 74 per cent share from solar power generation. The remaining 88 per cent of electricity requirements will be fulfilled by purchased electricity from the central grid. As noted in table 1, the generation potential within the city is estimated at more than 40 TWh, mainly from establishing solar farms on vacant lands. The total solar generation is projected to reach 1.86 TWh, well within the generation threshold. Notwithstanding this, rooftop solar installations on residential and commercial buildings should also be encouraged.

Figure 15. Power capacities 2019-2030, SET scenario

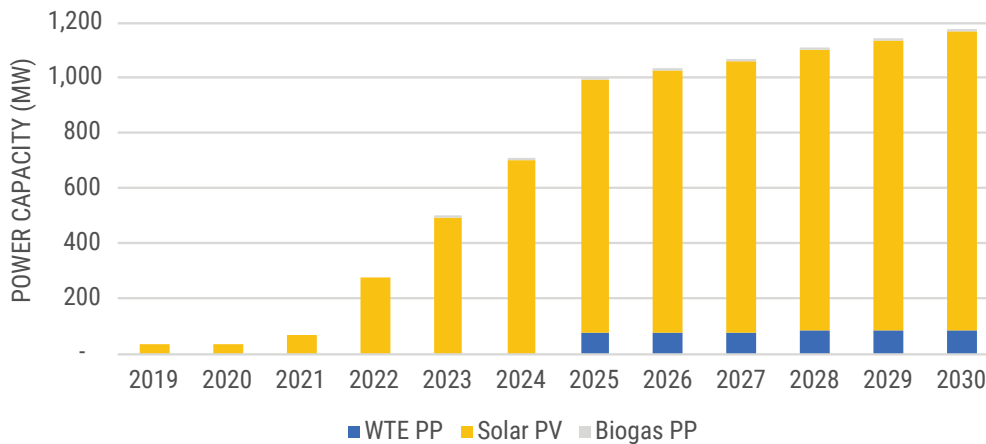
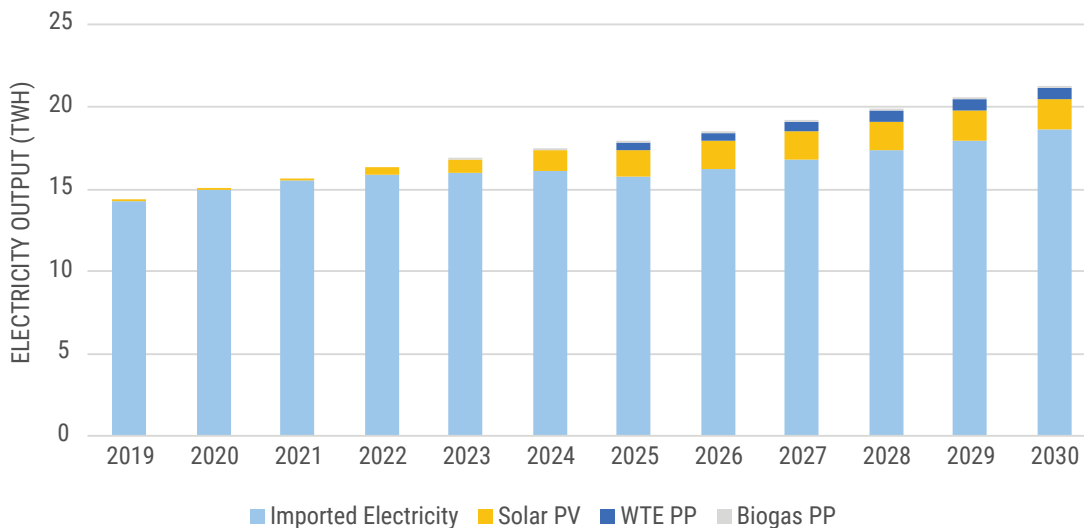


Figure 16. Electricity output 2019-2030, SET scenario



As noted by the Energy Commission (2020b), the central grid (in peninsular Malaysia) allows a maximum solar penetration of around 24 per cent of peak demand. Therefore, RE and solar installation in fulfilling IM's RE target should aim for having a distributed mini-grid system arrangement to avoid capacity conflict with generation connected to the central grid. Otherwise, a well-coordinated expansion plan should be strategized with the central grid planning committee in order to facilitate smooth grid integration with the central grid with possible solutions such as integrated storage.

4.3.3. Investment costs and net benefits

The total investment costs incurred throughout the analysis period stand at approximately US\$1.54 billion, with a total net benefit of US\$319 million (table 7).

Solar PV installation is expected to provide a substantial benefit of US\$393 million over the analysis period. However, WTE and biogas PP are projected to be a negative business case due to the relatively high upfront investment cost. Notwithstanding that, they provide large societal and environmental benefits through sustainable waste management solutions such as avoiding the use of landfills and the emissions of methane. Annex V provides the cost assumptions for the different power plants.

Box 3. Sustainable solid waste management via WTE facilities

The current solid waste disposal practice, landfilling, is unsustainable in the longer term. With the estimated population growth rate of 4 per cent per year, the amount of waste disposed can be expected to increase at the same rate (unless recycling, waste avoidance or other measures improve among communities, which reduces the amount of waste disposed). This, in turn, increases the GHG emissions emitted from landfills. Therefore, WTE could be a solution for addressing the ever-expanding landfills, while producing useful electricity.

NEXSTEP explores the capacity requirement of WTE that is sufficient to process all the expected solid waste production from 2025 onwards. The proposed WTE technology refers to the preliminary study conducted in 2018 by the State of Johor, which suggested the pyrolysis endothermic treatment and gasification energy recovery technology. Such technology could provide 5.1 MW with every 200 tonnes per day of waste. It is estimated that there is a potential for a total capacity of 90MW by 2030, based on the current disposal rate and projected population growth.

Further studies should be conducted to assess the possible logistics and technical barriers, and to come up with an optimal arrangement for WTE facilities.

Table 7. Total investment cost and net benefits by power technology, SET scenario

Technology	Total investment cost (Million US dollars)	Total net benefit (Million US dollars)
Solar PV	969.6	393.0
Biogas	20.0	-19.0
WTE	551.7	-55.0
Total	1,541.3	319.0

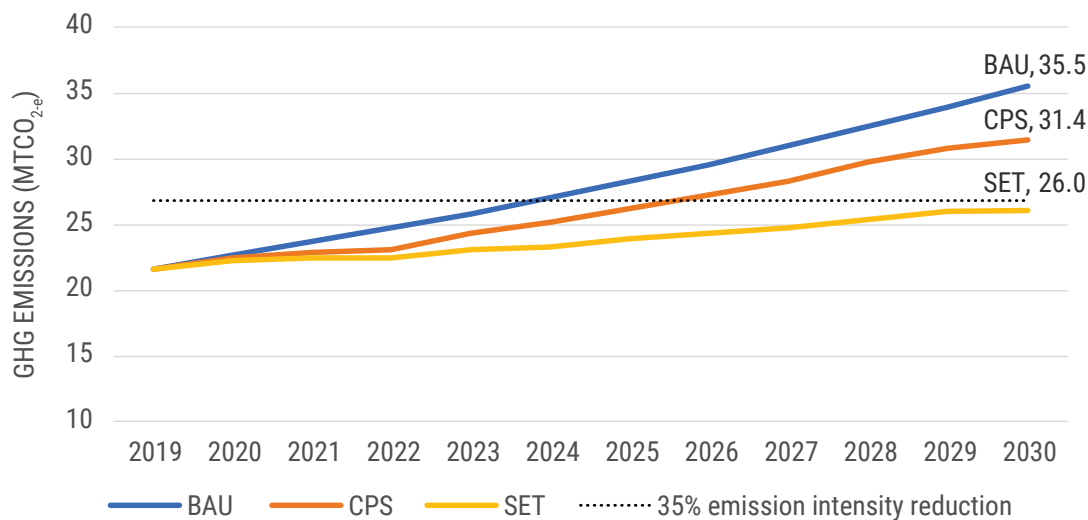
4.4. GHG emission reduction aligns with national unconditional NDC target

The GHG emissions in 2030 are projected to be 26 MTCO₂-e. This considers the GHG emissions from the direct fuel combustion in the demand sectors, localised electricity generation within the region's boundary, waste management as well as emissions attributable to purchased grid electricity.

The GHG emissions in 2030, in the SET scenario, correspond to a 27 per cent reduction from the BAU scenario, or a 17 per cent reduction from the CPS scenario (figure 17). The emission intensity is estimated to be 0.2ktCO₂/million RM₂₀₀₅,²⁷ a 37 per cent reduction from the 2005 emission intensity (UTM-Low Carbon Asia Research Center, 2013), thus meeting the national unconditional reduction target of 35 per cent by 2030, relative to the 2005 level.

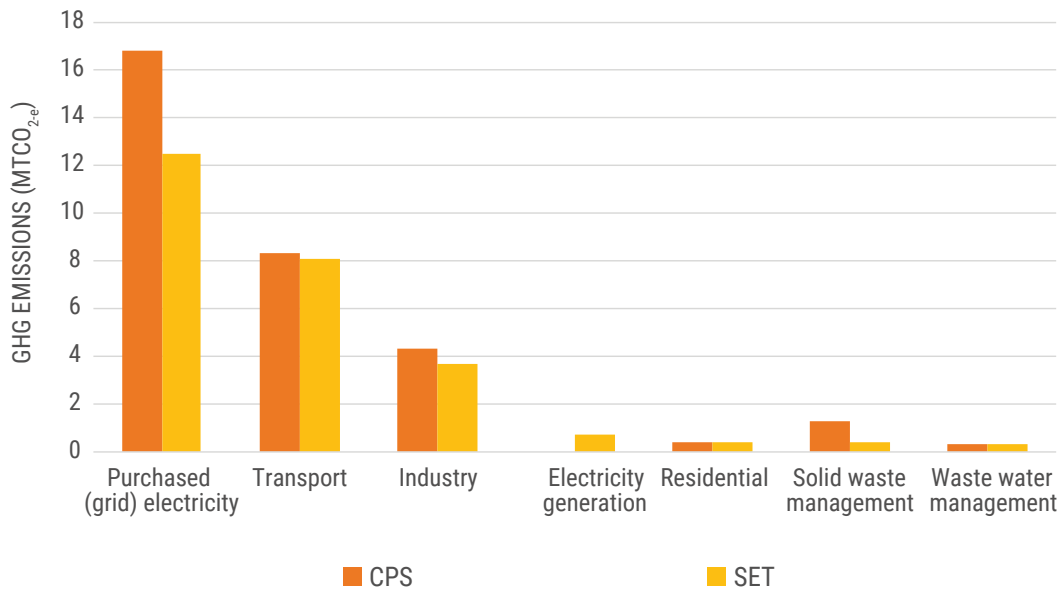
The substantial reduction in GHG emissions is achieved through the energy efficiency measures applied in the demand sectors as well as the ramping-up of RE power generation to meet the 12 per cent RE generation target. As shown in figure 18, the most substantial emission reduction is in purchased (grid) electricity, estimated at 4.3 MTCO₂-e. This is created by the reduced electricity demand (-2.7 MTCO₂-e) and the increase in RE local generation (1.6 MTCO₂-e). Reduced fuel combustion from the industry sector also leads to an emissions reduction of 14 per cent, compared to the CPS. On the other hand, the utilization of municipal waste in electricity generation is expected to contribute slightly towards the GHG emissions. This is, however, compensated by the reduction in methane emissions from landfill, leading to a net negative GHG emissions.

Figure 17. GHG emission trajectories, 2019-2030, by scenario



²⁷ The GDP in 2019 was reported as RM 94,176 million, which corresponds to RM 67,955 million at currency base year 2005. The conversion is made using the CPI inflation calculator (see https://www.dosm.gov.my/cpi_calc/index.php), taking the June data for both comparative years. The GDP in 2030 is then projected onwards with an assumed annual growth rate of 6%.

Figure 18. Emissions reduction, by sector, 2030



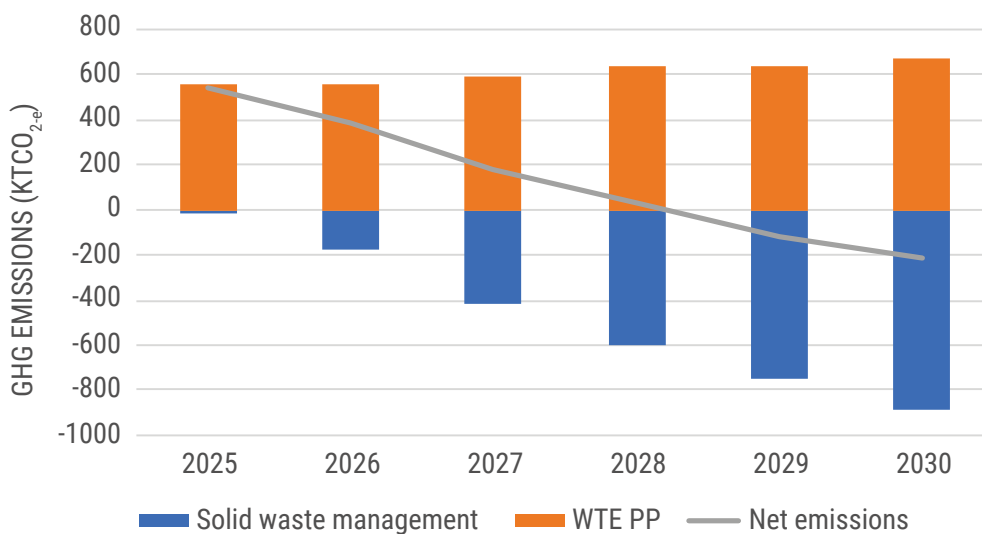
4.4.1. GHG emissions associated with WTE waste management practice

Figure 19 shows GHG emissions associated with the alternative waste disposal practice.

The GHG emissions from solid waste management are expected to decrease rapidly over the five-year period, as landfills are closed and methane emissions reduced over time. On the other hand, emissions are expected from the WTE

plant burning of the non-biomass component of municipal solid waste.²⁸ Nevertheless, net zero emissions are expected to be reached between 2028 and 2029, whereby net negative emissions can be expected from 2029 onwards, gradually becoming more negative over time. On the other hand, the continued adoption of landfill waste management practices will see the emissions from solid waste disposal continue to increase to 1,282 kTCO_{2e}, under the BAU and the CPS scenarios.

Figure 19. GHG emissions – solid waste disposal²⁹



²⁸ The emission factor is assumed to be 0.69kg CO₂/kg solid waste. It assumes that municipal solid waste has a 40 per cent carbon content (referring to IPCC emission factor database – ID: 62943), of which 40 per cent is fossil-based (referring to IPCC emission factor database – ID: 62947). GHG Inventory Iskandar Malaysia 2016 assumed that 60 per cent of the waste is bio-based (i.e., food waste, garden waste, paper/cardboard and wood).

²⁹ GHG emissions relative to the BAU/CPS scenario. BAU/CPS assumes continued solid waste disposal in landfills, with an annual increase of solid waste disposal of 4 per cent. The GHG emissions from solid waste management are quantified using formulas similarly to those used in GHG Inventory Iskandar Malaysia 2016 Excel calculations.



5. Increasing climate ambition with the CNDC scenario

5.1. Power generation in the CNDC scenario

5.1.1. Electricity generation and power capacity

As shown in the SET scenario, ramping up localised RE capacity can make a substantial contribution to emission reduction. Henceforth, a more ambitious level of power supply decarbonization can be considered in order to achieve the GHG emission reduction target.

NEXSTEP analysis suggests that an additional localised renewable energy generation of 4,981 GWh is required. This reduces the need for purchased (grid) electricity, which is assumed to have a grid electricity emission factor of 0.672 kgCO₂/kWh in 2030. This raises the total RE generation from within the city boundary to 7.5 TWh, or 35.6 per cent of total electricity requirements, out of which 6,841 GWh is from solar PV.

Solar PV power technology is considered the most appropriate RE technology for Iskandar Malaysia. As noted in subsection 3.4, Iskandar Malaysia enjoys an average solar irradiation of 1,575 kWh/m² per annum, leading to a high level of solar energy generation potential of 47.8 TWh per year. The expected generation from solar PV – 6,841 GWh – is well within the available yield (see table 1). Vacant land alone within the Iskandar Malaysia boundary has the potential to cater for the required capacity installation; however, Iskandar Malaysia may consider promoting the uptake of solar PV rooftop installations. Such a strategy will reduce the financial burden on the local authorities from installing mini-grids. Assuming a capacity factor of 19.6 per cent, an additional solar PV capacity of 2,901 MW is required to meet the generation target.

Figures 21 and Figure 22 show the installed power capacities and electricity output during 2019-2030. The ramping up of solar PV capacity in

Figure 21. Installed power capacities, 2019-2030, CNDC scenario³⁰

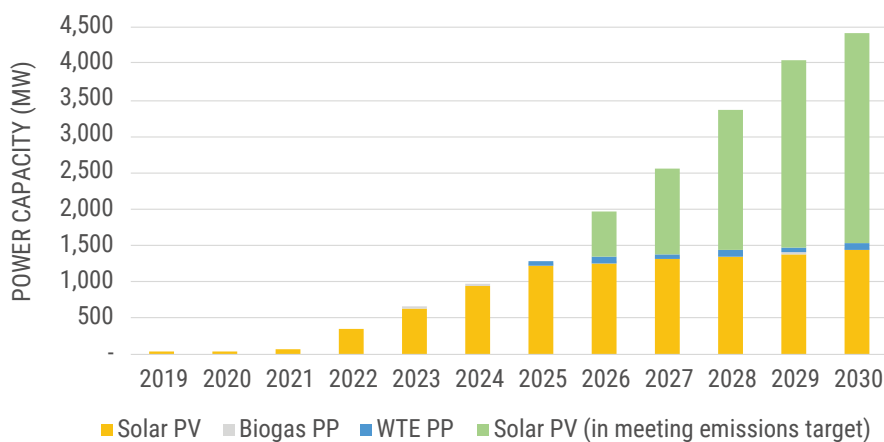
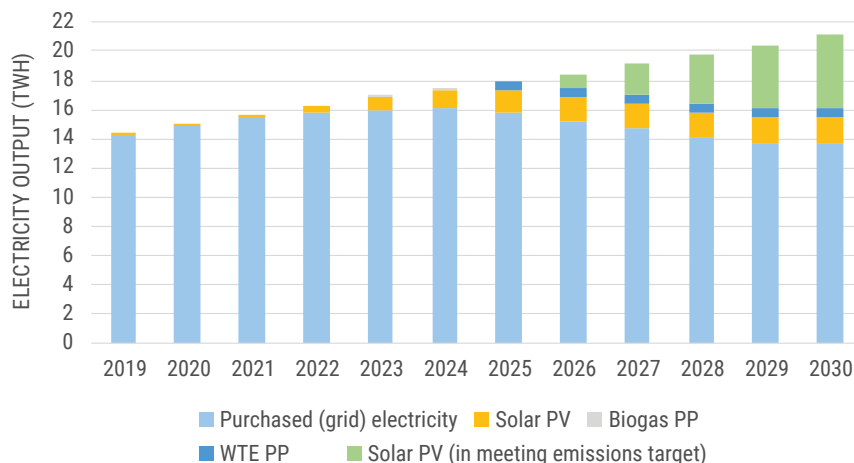


Figure 22. Electricity output, 2019-2030, CNDC scenario³⁰



³⁰ Solar PV refers to the solar PV capacity as projected in the SET scenario in meeting Iskandar Malaysia's RE target of 12 per cent, while Solar PV (in meeting emissions target) refers to the additional capacity required to align Iskandar Malaysia's GHG emissions reduction with the national conditional NDC target.

meeting the emission target by 2030 is modelled to start from 2026 onwards, gradually increasing to the optimal level by 2030.

Integration of such a substantial capacity of solar PV into the central grid may be a challenge. As already mentioned, the Energy Commission (2020b) stated a maximum limit on solar penetration of 24 per cent of peak demand, above which battery storage systems will be required to balance the grid. As such, Iskandar Malaysia should consider maximizing the potential from establishing a distributed mini-grid network within its boundary. However, further power system studies should be conducted, while integrated storage solutions may facilitate a smooth grid integration.

5.1.2. Power sector investment cost and net benefits

The total investment costs for all RE installations are \$4.2 billion, with a total net benefit of \$748.7 million. The total net benefit (throughout period 2019-2030) for all solar PV capacities is estimated at \$823 million, showing that increased RE penetration in electricity generation does not only provide environmental benefits, but also financial gains.

Table 8. Total investment cost and net benefits by power technology, CNDC scenario

Technology	Total investment cost (Million US dollars)	Total net benefit (Million US dollars)
Solar PV (In meeting emissions target)	2,685.1	429.7
Solar PV	969.6	393.0
Biogas	20.0	-19.0
WTE	551.7	-55.0
Total	4,226.4	748.7

Box 4. Iskandar Malaysia's 58 per cent emission intensity reduction target

Iskandar Malaysia aims to reduce its emission intensity by 58 per cent by 2025, compared with 2010 levels. This corresponds to a 2025 emission intensity target of 0.1043 ktCO₂-e/ million RM2010 (IRDA, 2019). With a projected GDP (at constant 2010 price) of RM 109,711 million* in 2025, the emission limit is 11.4 MTCO₂-e in 2025 – a difficult target to achieve. By comparison, the 2025 emissions in the CP scenario are projected to reach 26.1 MTCO₂-e, or an emission intensity of 0.28 ktCO₂-e/ million RM2010. The NEXSTEP analysis recommends Iskandar Malaysia to reconsider a renewed target (such as aligning with the national NDC reduction target). Deep decarbonization may be difficult to achieve by local jurisdictions alone, without a further push from national policies.

* Estimated from 2019 GDP (converted to 2010 prices using DOSM's CPI inflation calculator) and projected with an assumed growth rate of 6 per cent.

The current policies and initiatives are expected to create substantial energy savings and GHG emissions reduction, particularly through the implementation of the BRT system, which will encourage the uptake of public transport. Notwithstanding this, chapters 4 and 5 demonstrate further how sustainable energy transition can be accelerated, propelling Iskandar Malaysia into a low carbon future. This chapter presents several policy recommendations that further elaborate the proposed interventions.

6.1. Sustainable and more competitive industries

Iskandar Malaysia has a strong industry sector, which contributes around 44 per cent of its GDP. In turn, the energy consumption of the sector is also considerably high at around 1,548 ktoe or 32.3 per cent of the total final energy consumption in 2019. This gives a substantial energy savings potential through transitioning industry into a more energy-knowledgeable sector. As modelled in SET, the proposed energy efficiency interventions may allow an energy demand reduction of 347 ktoe – a 16 per cent reduction.

The suggested energy savings potential for several industries is based on the MIEEIP energy audit results, considering no-, low- and high-cost measures. As defined, no-cost measures refer to measures that are easily implemented, dealing mostly with measurement and control maintenance (i.e., combustion and steam blow-down control, improvement of electricity supply and distribution network). Low-cost measures require low investment and proven technologies to be implemented, which may involve the replacement of existing equipment with more efficient apparatus (i.e., burners, efficient air conditioning and compressed air systems) as well as process improvements. High-cost measures involve large investments and the incorporation

6. Policy recommendations for a sustainable energy transition

of innovative technologies (e.g., co-generation) or process modifications. Additional savings can also be realised through more capital-intensive upgrades (UNDP, 2006).

However, the estimated potential is based on studies conducted more than a decade ago, as more recent findings are not available. More in-depth energy audits and baseline studies should be conducted regularly in order to understand the energy efficiency and fuel switching potential in the industry sector. Industrial companies in Iskandar Malaysia should be encouraged to perform regular energy audits to assess their energy efficiency improvement potential as well as implementation of energy savings measures (i.e., using more efficient appliances).

In addition, the potential in establishing industrial symbiosis within the industrial clusters should be explored. Industrial symbiosis can be described as a process that allows material or energy sharing between production facilities, where the unwanted material from one facility becomes a raw material for the other. This promotes a more sustainable industry based on a circular economy. One advanced example of industrial symbiosis can be found in the Kalundborg industrial cluster in Denmark, which involves energy, material and water sharing between 12 companies (Kalundborg Symbiosis, 2021). The combined effort from the different industry players has led to GHG emissions savings of 635 ktCO₂, energy savings of 100 GWh as well as material savings of 87 kt, on an annual basis. Notwithstanding, it also comes with an annual combined financial benefit of Euros 24 million (Ellen MacArthur Foundation, 2021).

6.2. Sustainable transport strategies for a cleaner, more liveable city

Iskandar Malaysia's embarkation on a sustainable transport transition through the establishment of the BRT system is expected to provide multiple benefits. Primarily, energy consumption in the transport sector is projected to decrease by around 790 ktoe in 2030. Consequently, the reduced fuel combustion by the transport sector allows an estimated GHG emission reduction of

2.9 MTCO₂-e, a 35 per cent reduction compared to the BAU scenario. The benefit of such an initiative also extends to other socio-economic benefits unquantifiable by the modelling. For example, it is a means of reducing traffic congestion – a major problem in cities. With the population expected to grow at a rate of 4 per cent annually, traffic congestion is likely to worsen without intervention. In addition, air pollution can be substantially decreased by taking cars off the road. Such initiatives pave the way for a more liveable city.

Raising the transport decarbonization ambition further, NEXSTEP analysis shows that adoption of hybrid passenger vehicles can be an effective means of reducing fuel consumption as well as GHG emissions. The current share of hybrid vehicles in the existing fleet is estimated to be less than 0.5 per cent. The SET scenario assumes a gradual increase in sales penetration, with the hybrid share in the private passenger car fleet reaching 18.5 per cent in 2030. This will result in energy demand reduction of 89 ktoe and GHG emission reduction of 0.25 MTCO₂-e. Further reductions can be expected if the uptake of hybrid cars exceeds the levels modelled.

While electric vehicles have created great interest that has been growing exponentially over the past decade globally, transport electrification is not proposed by NEXSTEP. Electric vehicles do not require direct fuel combustion; hence they reduce direct emissions from the transport sector. However, it could be more polluting than hybrid vehicles when the emissions attributable to the consumed grid electricity are considered. This is particularly the case for passenger cars, where the emission intensity of electric cars is expected to be higher than their hybrid counterparts. Electric vehicles may, however, be the better option if the grid emission factor is reduced substantially, possibly past 2030, by substantially increasing the RE share in the central grid. Box 5 shows the emission analysis, comparing the emission intensity of conventional internal combustion engines (ICE), and hybrid and electric passenger cars. Charging stations need to be established if the electric vehicle share is to increase.

Box 5. Emission analysis for passenger cars

Table 9 presents analytical results on the emission intensity (in terms of kg per 100 passenger-km) of three different types of passenger cars in peninsular Malaysia, for 2030. Conventional ICE is expected to have the highest emission intensity, estimated at 13 kgCO₂-e/ 100 passenger-km. This is followed by electric vehicle at 8.9 kgCO₂-e/ 100 passenger-km. The hybrid version has the lowest emission intensity, about 44 per cent reduction from the ICE counterpart. The higher emissions associated with the electric vehicle is due to the relatively high grid emission factor of 0.67 kgCO₂/kWh. This is the emission factor estimated for 2030,^a the lowest throughout the 2019-2030 period. The emissions from electric vehicles can be expected to be higher prior to 2030.

Table 9. Emission analysis for passenger cars in Malaysia

	ICE (gasoline)	Hybrid car	Electric
Fuel economy (GJ/100 passenger-km or kWh/100 passenger-km) ^b	0.19	0.11	13.30
Emission factor (kg/GJ gasoline or kg/kWh)	68.6	68.6	0.67
Emissions (kg/100 passenger-km)	13.0	7.3	8.9

A study by the Penang Institute investigated further the comparative emissions from the different types of vehicles under different degrees of RE penetration (Joshi, 2018).

6.3. Implementation of energy efficiency measures will lead to huge electricity savings in the commercial built environment.

Iskandar Malaysia has taken the initiative to promote a green built environment through the Green Accord Initiative Award (GAIA). The GAIA programme aims to promote greater awareness of sustainably-built environment by honouring outstanding business organizations in Iskandar Malaysia that have contributed towards the adoption of sustainable design, planning, retrofitting and operation in the built environment (IRDA, 2021d). In addition, the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Iskandar Malaysia has been developed to facilitate built environment-efficiency performance evaluation in Iskandar Malaysia on variable scales (IRDA, 2016). Nevertheless, substantial energy savings of 190 ktoe in 2030, as modelled in the SET scenario, can only be realised through widespread adoption of best practices. The proposed energy efficiency measures as modelled in the SET scenario are projected to produce electricity savings of 190 ktoe in 2030, indirectly reducing GHG emissions.

Investment Grade Audit (IGA) and the subsequent implementation of the identified energy savings

opportunities can be an effective measure in improving the standards of existing buildings, i.e., governmental buildings and shopping malls. The performance of an energy audit is important to the establishment of the baseline consumption patterns and identification of the measures to be taken in improving energy efficiency, while IGA can be regarded as the most detailed energy audit practice. As suggested in KeTTHA (2015), the total savings that can be achieved from the energy savings measures identified through an IGA are a minimum 15 per cent – a substantial figure. IGA can be promoted for all existing government buildings, reducing energy demand by 1.4 ktoe. Shopping malls, as the largest energy consumers in the sector and which contributed around 60 per cent of the total commercial energy demand in 2019, should be actively encouraged to perform an IGA. For example, the Energy Audit Conditional Grant (EACG 2.0) has been initiated by the federal authorities, providing conditional financial assistance to enable eligible commercial and industry players to conduct an energy audit (SEDA, 2021b).

In addition, adherence to the MS1525 building standard or a maximum BEI can be encouraged or made compulsory (depending on the regulatory feasibility) for new buildings. The MS1525 building standard, which was first introduced in 2001, is

a The emission factor is as estimated by the author, based on the capacity mix set forth by the Energy Commission (2020b), together with some assumptions.

b Fuel economy for ICE is estimated based on fuel consumption of 8.17 litres/100km (Saifuddin, Diana and Karim, 2019), while fuel consumption for hybrid is assumed as 4.5 litres/100km (or 52 miles per gallon). Electricity consumption of electric car is assumed as 18.64 kWh/100km (Saifuddin, Diana, & Karim, 2019). Passenger load factor is 1.4.

currently a voluntary standard, providing guidance on energy efficiency designs such as the use of architectural and passive design strategy, efficient lighting, air conditioning systems etc. (Department of Standards Malaysia, 2014). Adherence to the voluntary standard is expected to bring the electricity consumption of regular buildings to around 135 kWh/m² (KeTTHA, 2015), as modelled for new governmental buildings and new private offices in the SET scenario. On the other hand, maximum BEI can be established in guiding sustainable development of new shopping mall buildings.

The benefits of green buildings or energy efficient buildings do not end with just energy demand and GHG emission reduction. Active promotion of a sustainably built environment could lead to a growing green building industry in the region and increased employment. From the perspective of building owners and operators, benefits come in the form of increased building valuation and reduced electricity bills. Socially, sustainability-guided building designs also promote better well-being and health as well as an increase in work productivity (WorldGBC, 2021).

6.4. Pursuing a high renewable power share as a means to achieve climate goals

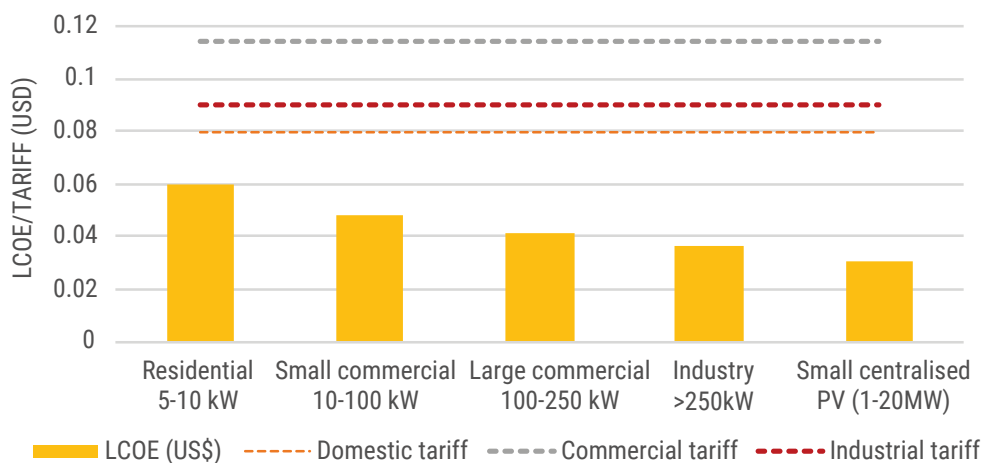
Renewable capacity has increased significantly across the globe amid climate change concerns. The CDPii has stipulated a 12 per cent RE target by 2025, which together with the energy efficiency measures proposed in the SET scenario, allows

a 37 per cent reduction in emission intensity relative to 2005 levels. NEXSTEP analysis has also explored how Iskandar Malaysia may increase its localised RE generation to around 35.6 per cent, in realising a further 8 per cent reduction in emission intensity, to align with the national conditional NDC target.

The pursuance of such a high share of RE generation, particularly with solar PV, is feasible in the region. Wind energy is not viable due to the low wind speed in Iskandar Malaysia (IRDA, 2010). As noted in table 1, Iskandar Malaysia has abundant solar energy generation potential of 47.8 TWh, primarily available from vacant land in the region. The potential for residential and commercial/industrial rooftop installation is comparatively smaller but still substantial. Figure 23 shows the LCOE³¹ for different scales of solar installation, calculated based on Malaysia-specific system cost data for 2019. It shows that the LCOE of solar PV systems in all cases, is lower than the tariffs.³²

Other than solar PV rooftop installation, NEXSTEP proposes that distributed mini-grid generation be the priority option in ramping up the RE capacity within the Iskandar Malaysia region. As noted by the Energy Commission (2020b), solar penetration into the central grid is limited to 24 per cent of the maximum peak demand. As such, a high RE capacity integration into the central grid from Iskandar Malaysia may possibly jeopardize central grid stability. However, further power analysis in examining the opportunities and barriers of a high RE capacity will be conducted, whereby battery storage may be a necessity at a high RE capacity.

Figure 23. Levelized cost of electricity for the different scale of solar PV



31 Calculated using capital cost provided in SEDA, 2020, assuming a fixed operational and maintenance cost of 0.9 per cent of capital cost, a discount rate of 5.37 per cent and a lifetime of 30 years. The calculation does not include land leasing.

32 Quoted tariffs referenced the electricity average selling price for TNB in 2018 (Energy Commission, 2021).



7. Conclusion

The 2030 Agenda for Sustainable Development and the Paris Agreement provide a common goal for achieving sustainability and climate objectives. While achieving the SDG 7 and NDC targets is principally a national effort, it requires a combined contribution from stakeholders at various levels, such as subnational jurisdictions and cities. Iskandar Malaysia recognises that a sustainability-guided urban planning and development is the key to creating a sustainable, competitive and liveable region. This is reflected in its CDPii, 2014-2025, while being recognized as an “A-List” city by CDP for its exemplary climate actions (IRDA, 2020). This Roadmap provides a scenario baseline for Iskandar Malaysia, exploring how its energy system and GHG emission trajectory may evolve under the current policies/initiatives settings, while at the same time it proposes several interventions that could enhance Iskandar Malaysia’s sustainable transition.

The GDP of Iskandar Malaysia is projected to grow at 6 per cent per annum, while the population is expected to increase by 4 per cent each year. This, in turn, will lead to a high growth in energy demand. Under the current policy settings, the establishment of the Iskandar Malaysia Bus Rapid Transit system, which aims to promote the uptake of public transport, will lead to substantial energy savings and GHG emissions reduction. It will also reduce road traffic congestion and reduce air pollution as the public transport modal share increases from around 17 per cent in 2019 to 40 per cent by 2030. Considering the other energy saving initiatives and RE capacity expansion in the region and in the central grid, energy demand is projected to rise to 6,907 ktoe and GHG emissions to rise to 31.4 MTCO₂-e by 2030.

The SET scenario suggests that there are ample opportunities that would lead to energy savings and GHG emissions reduction. The industry sector provides the highest energy potential, whereby adoption of energy efficiency measures may lead to a 16 per cent reduction in energy demand, or 347 ktoe, in 2030. This calls for a more active role for the industry players in “greening” their operations through energy audits and the implementation of energy efficiency measures. On the other hand, two

strategies may be undertaken to encourage energy savings in the commercial sector. An investment grade energy audit will be promoted, which will provide at minimum 15 per cent energy savings. In addition, setting a maximum Building Energy Index (BEI) for new buildings or making it compulsory for new buildings to adhere to the building standard could lead to substantial savings. At the individual or household level, energy savings can be realised through the adoption of more efficient appliances and private vehicles. The final energy demand in the SET scenario is projected to be 6,253 ktoe in 2030, which is a reduction of 652 ktoe from the CPS.

The CDPii stipulates a 12 per cent local RE target by 2025. Achieving the target requires a quick ramping up of RE capacity in the economic region, raising the local RE generation share from less than 1 per cent in 2019 to 12 per cent by 2025. The SET scenario proposes the setting up of WTE facilities as a more sustainable solid waste management practice than landfilling, while contributing towards the RE generation share. Solar PV technology will play a dominant role, whereby a total capacity (existing and new buildings) of 1,432 MW will be required for meeting the RE target. The 2030 GHG emissions of the SET scenario are projected to be 26 MTCO₂-e, or 0.2ktCO₂/million RM2005, a 37 per cent reduction from the 2005 emission intensity. The climate ambition may be raised with a higher share of locally-generated RE electricity, achieving a 45 per cent reduction from the 2005 emission intensity. This would require the total solar PV capacity within the region to be raised to 5,275 MW, which would increase the share of local RE generation to 35.6 per cent of total electricity requirements.

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Annexes

Annex I. Iskandar Malaysia's status against SDG 7 indicators and emission reduction baseline

The following table summarizes Iskandar Malaysia's status against the SDG 7 indicator and emission reduction baseline in 2019 and 2030. The projection for 2030 is based on the SET scenario. The following sections describe further the calculation methodologies in determining (a) the energy intensity, (b) energy efficiency improvement rate and (c) the renewable energy share in TFEC.

Table 10. Targets and indicators for SDG 7

Target	Indicators	2019	2030
7.1. By 2030, ensure universal access to affordable, reliable, and modern energy services.	7.1.1. Proportion of population with access to electricity.	100% access rate already achieved	100% access rate already achieved
	7.1.2. Proportion of population with primary reliance on clean fuels and technology for cooking.	100% access rate already achieved	100% access rate already achieved
7.2. By 2030, substantially increase the share of renewable energy in the global energy mix.	7.2.1. Renewable energy share in total final energy consumption.	3.4%	10.5%
7.3. By 2030, double the global rate of improvement in energy efficiency.	7.3.1. Energy intensity measured as a ratio of primary energy supply to gross domestic product.	3.97 MJ/\$(2011) PPP	2.85 MJ/\$(2011) PPP
GHG emissions	GHG emission intensity reduction relative to the 2005 level	0% reduction	37% reduction

SDG 7.3: Energy Efficiency.

"By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production plus net imports minus international marine and aviation bunkers plus stock changes. For comparison purposes, GDP is measured in constant terms at 2011 PPP.

Energy intensity (MJ/US\$₂₀₁₁) is calculated with the following formula:

$$\text{Primary energy intensity} = \frac{\text{Total Primary Energy Supply (MJ)}}{\text{GDP (US\$ 2011 PPP)}}$$

Energy efficiency improvement rate is calculated with the following formula:

$$\text{CAGR} = \left(\frac{EI_{t2}}{EI_{t1}} \right)^{\frac{1}{(t2-t1)}} - 1$$

where EI_{t1} is energy intensity in year t1 and EI_{t2} is energy intensity in year t2. In the case of Iskandar Malaysia, t1 refers to the baseline year (2019) and t2 refers to the analysis end year (2030)

SDG 7.2: Renewable Energy.

Share of renewable energy in total final energy consumption is calculated with the following formula, where TFEC is total final energy consumption, ELEC is gross electricity production.

$$\%TFEC_{RES} = \frac{FEC_{RES} + \left(TFEC_{ELEC} \times \frac{ELEC_{RES}}{ELEC_{TOTAL}} \right)}{TFEC_{TOTAL}}$$

Annex II. Key assumptions for NEXSTEP energy modelling

(a) General parameters

Table 11. GDP and GDP growth rate

Parameter	Value
PPP (2019, constant 2011 US dollar) ³³	51.3 billion
GDP (2019, constant 2005 RM) ³⁴	68.0 billion
GDP (2019, constant 2010 RM) ³⁴	77.3 billion
GDP growth rate ³⁵	6%

Table 12. Population, population growth rate and household size

Parameter	Value
Population (2019)	2.23 million
Population growth rate ³⁶	4%
Number of households (2018)	586,642
Household size (constant throughout the analysis period)	3.8

(b) Demand-side assumptions

Industry

The industrial GDP is estimated to be 44 per cent of the total GDP in 2018. It is assumed that the industry sector will grow at an annual rate of 4.6 per cent, as per the recorded 2019 growth rate for the State of Johor. The industrial sector is further split into 11 different subsectors with an estimated baseline energy consumption (table 13).

Electricity consumption data are provided by Tenaga Nasional Berhad (TNB), which are then recategorized based on the classification used in the National Energy Balance. Other fuel consumption data are not readily available. However, they are approximated using final energy consumption data provided for 2016 in table 36 of the National Energy Balance 2016, by using the measured electricity consumption data as a proxy assuming that the fuel shares are similar to the national level. The energy intensity is assumed constant throughout the analysis period in the absence of energy efficiency interventions (such as in the BAU and CPS scenarios).

33 The GDP in 2019 was recorded as RM94.2 billion. The figure is converted into PPP (current US dollar) with a conversion factor of 1.6 (<https://data.worldbank.org/indicator/PA.NUS.PPP?locations=MY>), and adjusted to 2011 US dollars based on consumer price index (CPI) provided in <https://www.inflationtool.com/us-dollar?amount=100&year1=2011&year2=2019>

34 The GDP in 2019 was reported at RM 94,176 million, which corresponds to RM 67,955 million at currency base year 2005 and RM77,342 for currency base year 2010. The conversion is done using the CPI inflation calculator (https://www.dosm.gov.my/cpi_calc/index.php), taking into account the June data for both comparative years.

35 The CDPii stipulates a GDP growth target of 6 to 8 per cent. The modelling considers a conservative growth rate of 6 per cent, considering the impacts of the COVID-19 crisis, as suggested by IRDA.

36 Based on historical growth between 2006 and 2019.

Table 13. Consumption in 2019

Subsector	Share of energy demand	Consumption in 2019 (ktoe)						
		Natural gas	Petrol	Diesel	Fuel Oil	LPG	Electricity	Others
Food, beverages and tobacco	37.7%	484.3	7.84	10.66	7.84	0.31	73	-
Chemical	15.8%	99.2	4.36	23.10	25.20	0.81	92	-
Non-metallic mineral products	10.0%	7.5	-	3.22	7.23	-	35	Coal: 100.92
Non-ferrous metals	0.3%	1.1	-	-	-	-	4.26	-
Iron and steel	4.1%	39.1	-	7.79	1.10	1.93	14	-
Wood and wood products	0.5%	0.3	0.05	0.75	1.12	-	5	-
Pulp, paper and printing	0.6%	2.0	0.13	1.16	-	-	7	-
Textile and leather	1.6%	7.9	0.25	1.92	0.71	0.05	14	-
Machinery	8.8%	1.8	17.66	20.10	-	-	97	-
Transportation equipment	1.7%	1.9	-	15.35	-	0.03	9	Kerosene: 0.06
Not specified elsewhere	18.8%	38.0	1.73	8.06	24.19	14.97	204	-

(c) Transportation:**Road transport**

The road transport sector is modelled with a bottom-up approach, using vehicle statistics, passenger load factor, annual travel mileage and estimated fuel economy. Registered vehicle statistics for the State of Johor are provided by the Road Transport Department Malaysia. This is further approximated for Iskandar Malaysia based on the Iskandar Malaysia/Johor population ratio of 0.59 and the assumption that 70 per cent of the total registered vehicles are active on the road. Annual travel mileage, load factor and fuel economy for the different vehicle types are referenced from Saifuddin, Diana and Karim (2019). The exception is the assumptions used for BRT, which are further detailed in Annex IV.

Transport activities in 2019 are estimated to be 56 billion passenger-kilometres and 25 billion tonne-kilometres. The growth rate, both in passenger transport and in freight transport activities, is assumed to be the same as the IM population, at an annual average growth of 4 per cent.

Table 14. Road transport

Passenger transport	Billion passenger-km 2019	Share of transport activity in 2019 (%)
Private passenger cars	24.8	44.3
Motorbikes	21.2	37.9
Taxis and e-hailing	0.7	1.2
Buses	8.0	14.3
BRT	0.9	1.6
Others	0.4	0.7
Freight transport	Billion tonne-km in 2019	Share of transport activity in 2019
Freight trucks	25	100

(d) Residential***Household appliance ownership and electricity intensity***

Household appliance ownership (as a percentage of all households) for 2019 is based on data provided by IRDA, with reference to DOSM (2020). Owing to the existing high saturation of appliance ownerships, these are assumed constant throughout the analysis period. The exception is applied to air conditioners which are projected to increase from 52 per cent saturation to 64.1 per cent, growing at a rate similar to the growth of GDP per capita.

The average electrical demand per owning household for the different appliances referenced (Ahmed, Mohamed, Homod, & Shareef, 2017) or are estimated based on educated guess. These are assumed constant throughout the analysis period unless further energy efficiency measures are implemented (such as in the CPS and SET scenarios).

Table 15. Household appliances ownership

Appliance	Appliance ownership(%)	Baseline electricity intensity (kWh/owning household-year)
Lighting	100	237.3
Air conditioner	52	2,628.0
Refrigerator	99	1,069.5
Television	98	146.0
Fan	100	492.8
Other	100	146.0
Water heater	82	109.5
Iron	97	255.5
Washing machine	97	155.1
Electric kettle	100	401.5

(e) Commercial

The assumed data for the commercial sector are provided here. The baseline electricity consumption (kWh/m²) is calculated based on the floor space data compiled by IRDA and electricity consumption data provided by TNB. It is assumed that the commercial sector will grow at an annual growth rate of 6.4 per cent, as per the recorded 2019 growth rate for the State of Johor.

Table 16. Commercial floor space

Space type	Baseline electricity consumption (kWh/m ²)	Floor space (Million m ²) in 2019	Total electricity consumption (ktoe)
Private offices	367.0	0.92	29.1
Government buildings	280.2	0.33	8.0
Shopping malls	1458.2	1.913	239.8
Hotels	358.9	0.44	13.6
Hospitals	65.2	1.71	9.6
Universities	77.9	1.76	11.8
Religious temples	86.9	0.20	1.5

Annex III. Assumptions used in estimating BRT modal share by fuel type

The public transport modal share in 2019 is estimated to be 17.1 per cent: taxis, 1.2 per cent; buses, 14.3 per cent; and BRT 1.59 per cent. The modal shares for passenger cars, motorbikes and other vehicles are 44.3 per cent, 37.9 per cent and 0.73 per cent, respectively. These are quantified with a bottom-up approach using the number of vehicles, annual travel mileage and passenger load factor. In the CP scenario, NEXSTEP assumes a rapid increase in BRT modal share, from less than 2 per cent to 25 per cent in 2030, coinciding with the scheduled increase in the number of BRT buses (figure 24), as well as the gradual increase in passenger load factor. It is assumed that the modal share of private cars and motorbikes decrease by 18.4 per cent and 5 per cent, respectively.

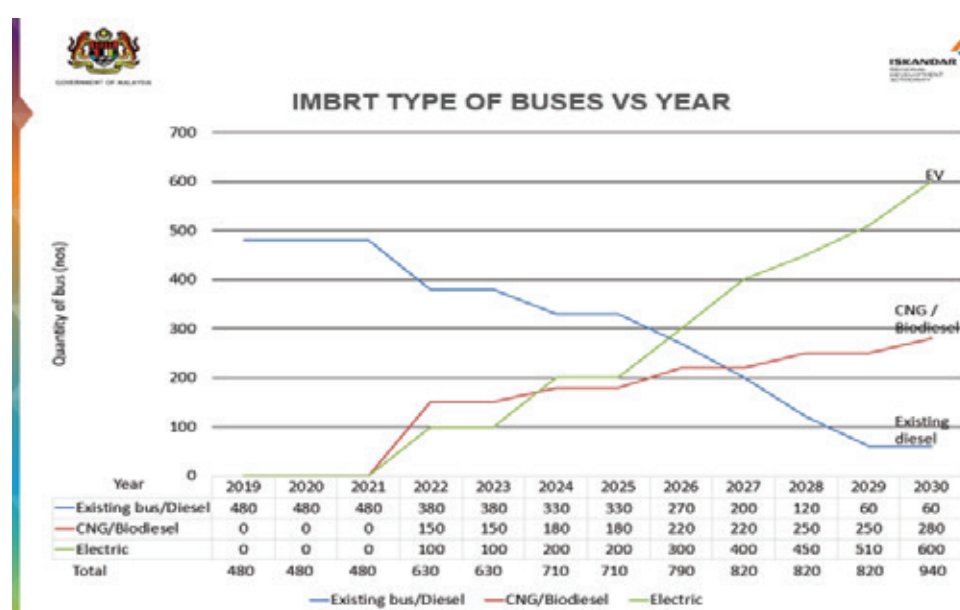
Table 17 and Table 18 shows the projected annual passenger-km travelled and the assumptions used in the calculations.

Table 17. Projected passenger-km (billion passenger-km/year) – BRT by fuel type

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing bus/diesel	0.9	3.6	5.8	5.1	5.1	4.5	4.5	3.6	2.7	1.6	0.8	0.8
CNG/ biodiesel	0.0	0.0	0.0	2.0	2.0	2.4	2.4	3.0	3.0	3.4	3.4	3.8
Electric	0.0	0.0	0.0	2.9	2.9	5.7	5.7	8.6	11.4	12.8	14.5	17.1
Total	0.9	3.6	5.8	10.0	10.0	12.6	12.6	15.2	17.1	17.8	18.7	21.7
Modal share (%)	2	6	10	16	15	18	18	21	22	22	23	25

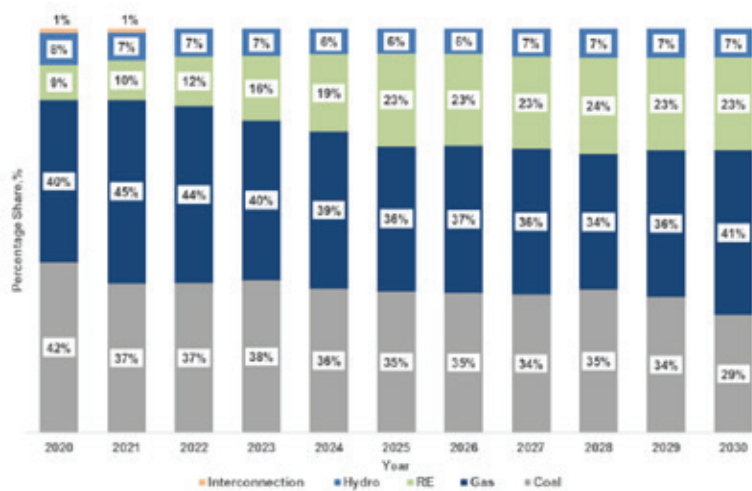
Table 18 Assumptions used in projecting the passenger-km travelled per year

Year	Passenger load factor				Annual travel mileage (km)	Fuel economy (kJ/passenger-km or (kWh/passenger-km)
	2019	2020	2021	2022		
Existing bus/diesel	18	25	40	45	300000	0.215 (Load factor = 45)
CNG/biodiesel	-	-	-	45	300000	0.215
Electric	-	-	-	95	300000	0.016
Assumptions	<ul style="list-style-type: none"> - Based on own assumptions - Assumed gradual increase in uptake, hence a gradual increase in the passenger load factor is assumed for existing buses - Passenger load factor for CNG/ biodiesel and electric buses are not considered for 2019-2021 as there are no expected buses - Electric buses are assumed to have a higher passenger load factor considering the longer (i.e., 18m) bus used on the main trunk lines 				Own assumption; assuming 70km/hour, operating 12 hours a day, 365 days per year	

Figure 24. Number of BRT buses, by fuel type

Annex IV. Calculating national grid emission, 2020-2030

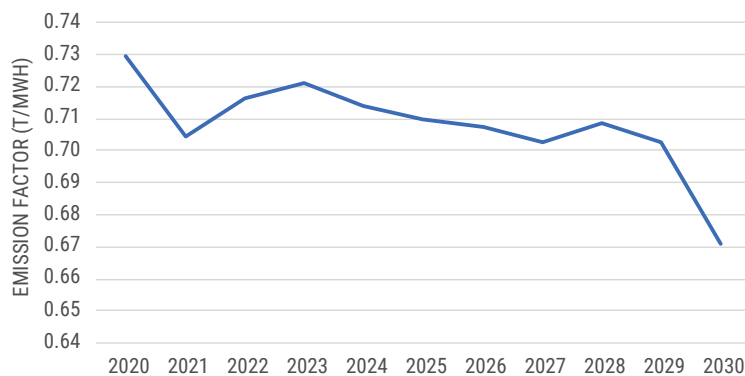
Based on the Energy Commission (2020b), the expected capacity share 2020-2030 in peninsular Malaysia is illustrated in figure 25. While carbon emission intensity (of GDP) has been estimated based on the projected capacities, no direct indicator (in terms of carbon emissions per kWh electricity) is available to estimate carbon emissions attributable to the purchased (grid) electricity. Hence, the carbon emissions per kWh of purchased (grid) electricity are estimated by ESCAP using parameters shown in Figure 25. Figure 26 shows the estimated emission factors, while Table 21 shows the estimated RE share in the central grid, throughout the 2020-2030 period.

Figure 25. Power capacity share, 2020-2030

Source: Energy Commission, 2020b.

Table 19. Grid emission factor calculation assumptions

Fuel	Load factor ³⁷ (%)	Efficiency (%)	Emission factor (kgCO ₂ /GJ primary fuel)
Gas	50.9	40	55.8
Coal	78.4	35	92.6
Hydro	23.2	-	
Renewable energy and others	12.4	-	

Figure 26. Estimated grid emission factor, 2020-2030**Table 20. Estimated renewable energy share in the central grid of peninsular Malaysia**

Generation mix, 2020-2030											
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Coal	58	52	53	55	54	55	54	54	56	54	47
Gas	36	41	41	38	38	37	37	37	35	37	43
Hydro	3	3	3	3	3	3	3	3	3	3	3
RE	2	2	3	4	5	6	6	6	6	6	6
Total RE	5	5	6	7	7	8	8	9	9	9	9

37 Estimated based on measured data in 2018, Energy Commission, 2020a..

Annex V. Cost data for power technologies

The following cost and technical parameters were used in the estimation of investment cost and net benefits for the power sector. Electricity output tariff is assumed at 0.08 USD/kWh (RM 0.33 per kWh equivalent)³⁸.

Table 21. Cost and technical parameters for power technologies

Technology	Capital cost (Million US\$/MW)	Fixed O&M(Million US\$/MW-year)	Variable O&M(US\$/MWh)	Load factor(%)	Efficienc(%)
Solar PV ³⁹	0.9255	0.9% of CAPEX	-	19.6	-
WTE ⁴⁰	6.13	-	3.73	85.0	17
Biogas ⁴¹	2.5	0.125	0.1	9.0	34

Annex VI. Summary results for the scenarios

	Current Policy Scenario	Sustainable Energy Transition Scenario	Conditional NDC Scenario
Universal access to electricity in 2030	100%	100%	100%
Universal access to clean cooking in 2030	100%	100%	100%
Energy efficiency in 2030	3.02 MJ/US\$	2.85 MJ/US\$	2.85 MJ/US\$
Renewable energy share in TREC in 2030	7.4%	10.5%	16.4%
GHG emissions in 2030	31.4 MTCO ₂ -e	26.0 MTCO ₂ -e	22.7 MTCO ₂ -e
Power generation optimization	Current expansion plan	Meets 12% RE generation target	Meets 12% RE target and achieves 45% emission intensity reduction (relative to 2005 level)
Share of local RE power generation in 2030	0.5%	12.0%	35.6%
Net benefits from the power sector	US\$52.4 million	US\$319.0 million	US\$748.7 million
Total investment for the power sector	US\$50.8 million	US\$1,541.3 million	US\$4,226.4 million

38 This references TNB's domestic tariff for 2018 (Energy Commission, 2021)

39 Capital cost based on cost provided for the large commercial (100-250kW) category in (SEDA, 2020), assuming a currency conversion rate of 1 US\$:RM 4.13. Fixed O&M is based on findings in ACE, 2016, while the capacity factor is based on the highest capacity factor indicated in Khan and Go, 2019..

40 Efficiency is estimated based on energy content of solid waste of 12.4 GJ/tonne and suggestive electricity output of 5.1MW with every 200 tonnes per day of waste. The capital cost and variable O&M is estimated based on cost figures provided in Yahya, 2012 for plasma gasification.

41 IM's GHG Emission Reporting 2016 estimated CH₄ recovered from Seelong landfill to be 1264 ton/year. With the biogas capacity expected to be 8MW, this corresponds to a 9% load factor. Efficiency, capital cost and fixed O&M are as suggested in National Energy Council, Indonesia, 2017.

