Energy Transition Pathways for the 2030 Agenda

Sustainable Energy Transition Roadmap for Jakarta

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

NEXSTEP
National Expert SDG Tool for Energy Planning

*The shaded areas of the map indicate ESCAP members and associate members.**

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

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United Nations publication

August 2021

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Acknowledgements

The preparation of this report was led by the Energy Division of the Economic and Social Commission for Asia and the Pacific (ESCAP) in collaboration with Murdoch University, Australia, and Daerah Khusus Ibukota (DKI) Jakarta.

The principal authors and contributors of the report were Anis Zaman and Charlotte Yong. A significant contribution to the overall work was from Ms Quartiana Granita, Mr Drs. Maksum and Ms Yeni Lindawati from the Development Planning Agency at Sub-National Level (BAPPEDA) of DKI Jakarta Province, and Mr Abra Talattov and Mr Dino Fitriza from the SDGs Secretariat of DKI Jakarta Province and Dr. Hakimul Batih, national consultant.

The review and valuable suggestions were provided by Hongpeng Liu, Director of the Energy Division, ESCAP, Michael Williamson, Section Chief of the Energy Division, ESCAP, and Ksenia Petrichenko, Economic Affairs Officer, Energy Division, ESCAP.

The cover and design layout were created by Xiao Dong.

Administrative and secretariat support was provided by Prachakporn Sophon, Sarinna Sunkphayung, Nawaporn Sunkpho and Thiraya Tangkawattana.

The financial support from the Energy Foundation China (EFC) to develop this roadmap is gratefully acknowledged.

JAYA RAYA

NEXSTEP
National Expert SDG Tool for Energy Planning

Murdoch UNIVERSITY

Foreword: ESCAP

Following our successful collaboration with the National Energy Council (NEC), the Ministry of National Development Planning (BAPPENAS) and the SDG Secretariat in developing the national Sustainable Development Goal 7 (SDG 7) roadmap for Indonesia, ESCAP is pleased to extend the similar effort to the City of Jakarta. The City of Jakarta is also one of the three pioneers in localizing the National Expert SDG Tool for Energy Planning (NEXSTEP) methodology at the sub-national level.

Achievement of the Sustainable Development Goals (SDGs) and climate ambition under the Paris Agreement requires not only effort from the national level, but also a bottom-up effort from the sub-national regions and cities. Particularly for the megacity of Jakarta, its sustainable energy transition shall have a substantial impact on the national achievements towards SDG 7 and Indonesia's Nationally Determined Contributions (NDCs).

The City of Jakarta, as the heart of Southeast Asia's largest economy, faces several challenges concerning energy use and environmental sustainability. Various initiatives related to sustainable energy have been undertaken by the city, such as developing the world's largest Bus Rapid Transit (BRT) system. The city has also announced an emission reduction target to cap its 2030 emissions at 31.5 million tonnes of carbon dioxide equivalent (MtCO2-e). Collaboration with ESCAP came timely at the start of the Decade of Action, assisting Jakarta to re-examine its current policies, whilst suggesting opportunities to align the city's energy system with the global and city's own goals and targets.

The Sustainable Energy Transition (SET) roadmap proposes several energy transition opportunities that provide multi-fold benefits. Sustainable mobility options, particularly the use of public transport and electric vehicles, shall redefine the means for city dwellers' mobility and travel, whilst reducing energy demand and related air pollution. Building sector also offers a notable energy-saving potential. The roadmap also suggests a substantial increase in the share of renewable energy in the electricity supply chain by, for example, undertaking renewable energy auction, to achieve the city's emission reduction target.

A well-guided energy planning is imperative for the city's endeavour in sustainable energy transition amid the COVID-19 pandemic. ESCAP would like to thank our local partner, Daerah Khusus Ibukota (DKI) Jakarta and local stakeholders for their continuous support and contribution throughout the roadmap development process.

Hongpeng Liu

Director, Energy Division, ESCAP

Foreword: Jakarta

The United Nation's 2030 Agenda for Sustainable Development and the Paris Agreement offer a blueprint for sustainable low-carbon energy transition. While these are national level targets, cities around the world are also adopting these targets to support the national government in achieving these targets as well as to reap the multi-dimensional benefits of a sustainable energy future. As a megacity, with economic and political significance not only in Southeast Asia but across the Asia-Pacific region, Jakarta wishes to place itself as a sustainable city in the region. Adopting a low-carbon energy transition which would address the current and future energy related concerns as well as aligns with the national, regional and global goals and targets, is critically important.

The City has been undertaking several measures to improve its energy sustainability such as developing the world's largest Bus Rapid Transit system, setting-up an emission reduction target, etc. The plan to move the capital to a new city in Borneo is expected to reduce the city congestion and local air pollution. However, all these goals, targets and ambitions require a holistic approach which will consider the cross-sectoral impacts of energy demand and supply as well as identify cost-effective approaches to energy transition. For example, the transport sector needs a special focus as it is the largest energy consuming and emission contributing sector of the City. Furthermore, Jakarta also aims to align its energy system with the 2030 Agenda for Sustainable Development, namely the SDG 7 goal and targets.

Our collaboration with UNESCAP, along with the National SDG Secretariat, in developing the Sustainable Energy Transition Roadmap using the National Expert SDG Tool for Energy Planning (NEXSTEP) explored different pathways for the City of Jakarta to align the energy sector with global goals and targets. The Roadmap also provides valuable suggestions on further improving city's transport sector, particularly in relation to reducing local air pollution and traffic congestion, to enhance the liveability of the city for its people. It also sheds light on how the sustainable energy transition may help us build back better from the impact of the COVID-19 pandemic. We are confident that the recommendations developed through this process will strengthen City's energy planning capacity and support the achievement of targets and ambitions set by the City.

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Head of Regional Development
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Abbreviations and acronyms

ADB	Asian Development Bank
BAU	business-as-usual
CBA	cost benefit analysis
CCGT	combined cycle gas turbine
CO2-e	carbon dioxide equivalent
CPS	current policy scenario
DKI	Daerah Khusus Ibukota (Special Capital Region)
EE	energy efficiency
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EU	European Union
EV	electric vehicle
GDP	gross domestic product
GHG	greenhouse gas
ICS	improved cooking stove
IDR	Indonesian Rupiah
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ktCO2-e	thousand tonnes of carbon dioxide equivalent
ktoe	thousand tonnes of oil equivalent
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LEAP	Long-range Energy Alternatives Planning
LED	light emitting diode
LPG	liquified petroleum gas
MCDA	Multi-Criteria Decision Analysis
MEPS	minimum energy performance standard
MJ	megajoule
Mmbtu	metric million British thermal unit
MTF	Multi-Tier Framework
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWh	megawatt-hour
$MtCO_{2-e}$	million tonnes of carbon dioxide equivalent
NEMO	Next Energy Modelling system for Optimization
NEXSTEP	National Expert SDG Tool for Energy Planning
PP	power plant
PPP	purchasing power parity
RE	renewable energy
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
TFEC	total final energy consumption
TPES	total primary energy supply
US$	United States Dollar
WHO	World Health Organization

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 a sustained economic growth, respond to increasing energy demand, reduce emissions and, more importantly, consider and capitalize 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) to support member States in developing energy transition pathways.

In 2020, ESCAP, in collaboration with the National Energy Council (NEC), the Ministry of National Development Planning (BAPPENAS) and the SDG Secretariat, supported developed the Indonesia national SDG roadmap. This roadmap highlighted several key policy directions for Indonesia for transitioning the energy in line with the 2030 Agenda for Sustainable Development and the Paris Agreement. These include more focus on providing access to clean cooking fuels and technologies to bridge the remaining gap, revisiting plans for new investment in coal-fired power plants and stepping up efforts to further increase its energy efficiency.

While SDG7 and NDCs are national level targets, cities around the world are also adopting targets on sustainable energy to support the achievement of these targets at the national level. The City of Jakarta, following the completion of the Indonesia national SDG7 roadmap, showed interest in developing a sustainable energy transition roadmap 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.

Jakarta is a megacity of economic and political significance not only in Southeast Asia but across the entire Asia-Pacific region. It is the heart of Southeast Asia's largest economy, home to the secretariat of the Association of Southeast Asian Nations (ASEAN) and an emerging business hub of Asia. The city faces several challenges in relation to energy use and environmental sustainability, including local air pollution, traffic congestion and greenhouse gas (GHG) emissions. The city is undertaking several measures to improve its sustainability such as developing the world's largest Bus Rapid Transit system. The plan to move the capital to a new city in Borneo is expected to reduce the city congestion and local air pollution. Notwithstanding this, it is important that Jakarta plans for a sustainable energy transition to enhance the liveability of the city for its people and to align its energy system with regional and global goals and targets. The city has announced an emission reduction target to cap its 2030 emissions at 31.5 million tonnes of carbon dioxide equivalent ($MtCO_2$-e). However, it needs to develop a holistic approach to achieve this target. The transport sector needs a special focus as it is the largest energy consuming and emission contributing sector. Furthermore, Jakarta also aims to align its energy system with the 2030 Agenda for Sustainable Development, namely the SDG 7 goal and targets. The COVID-19 pandemic has added even more urgency to embark on a sustainable energy transition plan, as such a plan will help the city to build back better from the pandemic, create economic opportunities and safeguard the energy sector. A sustainable energy transition plan would provide a blueprint for the city to achieve its emission reduction target, meet the SDG 7 goal as well as support broader sustainable development efforts to make it a better and more liveable city for its people.

This Sustainable Energy Transition Roadmap analyses Jakarta's entire energy demand and supply system. It considers the targets that the city aims to achieve and develops several scenarios to inform policymakers the best pathway to navigate the transition. The four scenarios that are presented in this roadmap are:

- The current policy (CP) scenario, which has been developed based on existing policies and plans – it is used to compare other scenarios and to identify the gaps in existing policies.
- The sustainable energy transition (SET) scenario presents technological options and policy measures that will help the city to achieve its own goals and targets, enhance urban sustainability, as well as align with global goals and targets.
- The sustainable transport (ST) scenario shows how different sustainability measures can be implemented in the transport sector not only to reduce energy consumption and related emissions, but also to reduce traffic congestion.
- Finally, this study has developed a Towards NetZero scenario with an aim to present various strategies and policy directions that will help the city to move towards NetZero Carbon city.

The following is a summary of key results and findings with respect to the targets of SDG 7 – energy access, renewable energy and energy efficiency; as well as GHG emissions.

Energy access

Jakarta has already achieved universal access to electricity as reported by the Directorate General for Electricity (Direktorat Jenderal Kelistrikan) in 2013. The city has reported that access to clean cooking fuels and technologies had reached 98.48 per cent in 2020, close to universal access, but there remain about 42 thousand households which do not have access to clean cooking fuels and technologies. At a current annual improvement of 2 per cent, the city is on-track to achieve 100 per cent universal access to clean cooking technology and fuels by 2022, which is also in line with Indonesia's national improvement rate.

Renewable energy

The share of renewable energy in Total Final Energy Consumption (TFEC) was 4.8 per cent in 2018. This includes a renewable energy share of 9.6 per cent in imported electricity from the Java-Bali network. Based on current policies, the share of renewable energy in TFEC will increase to 8.4 per cent by 2030, mainly due to the implementation of the biofuel roadmap and increase of solar energy in Jakarta's power generation from 2 MW in 2018 to 32.5 MW by 2030. In the sustainable energy transition scenario, the share of renewable energy in TFEC will be 13.3 per cent by 2030. For a more ambitious target that aims to increase sustainability in the transport sector, the share of renewables in TFEC would increase to 18.3 per cent by 2030. The roadmap suggests that the city should increase the share of renewable energy in the electricity supply chain by for example, undertaking renewable energy auctions to meet its own electricity needs for key municipal services. Recent experiences in the region suggest that the cost of electricity from utility-scale solar could be as low as US$ 0.038 when sourced through the renewable energy auction mechanism.

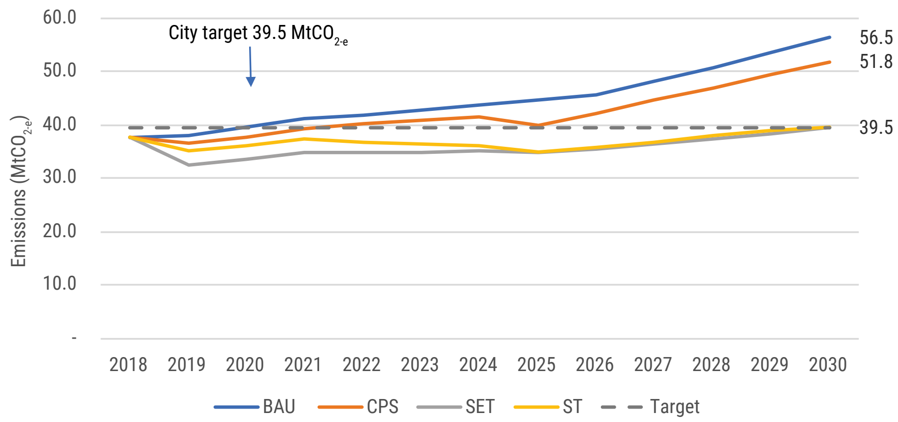
Energy Efficiency

Energy efficiency, measured in terms of primary energy intensity, is calculated as 2.05 MJ/US$ for Jakarta in 2018. There are ample opportunities for Jakarta to further improve its energy efficiency. These include, for example, rapid deployment of electric vehicles and improving energy efficiency in the building sector. With such measures implemented in the sustainable energy transition and sustainable transport scenarios, the energy intensity will reduce to 1.71 MJ/US$ and 1.66 MJ/US$ respectively by 2030.

Greenhouse Gas Emissions

The city of Jakarta has set an emission reduction target through the Governor's regulation No. 131/2012, which states that the city will reduce its emissions by 30 per cent by 2030 compared to business-as-usual (BAU) emissions. The 2030 emissions in the BAU scenario would be 56.5 $MtCO_2$-e, which will decrease slightly to 51.8 $MtCO_2$-e in the current policy scenario, falling short of the Governor's target of 39.5 $MtCO_2$-e (70 per cent of the 2030 BAU value). The SET scenario ensures that the emissions target of 39.5 $MtCO_2$-e is fully achieved (Figure ES 1) through increased energy efficiency measures and high uptake of renewable energy in the power sector.

Figure ES 1. **Emissions by scenario and comparing with the city target**



The key policy recommendations to help Jakarta accelerate the sustainable energy transition and achieve emission reduction target are summarised below:

a) ***Increase the share of renewable energy in the electricity supply chain.*** Currently, half of Jakarta's electricity supply is imported from the national grid which has 9.6 per cent share of renewable energy. The other half is generated within the city with 0.3 per cent share of renewables. There are several ways that can help the city increase the share of renewables, such as by renewable energy auction mechanism and the promotion of rooftop solar. Auctions can establish renewable energy supply contracts for large electricity users at competitive prices. The city has the potential to save a substantial amount of financial resources over the next 10 years by switching to renewable energy auction with a minimum of 51.6 per cent share of RE, which will also ensure the achievement of the emission reduction target.

b) ***Energy efficiency improvement in the building sector has the potential to achieve substantial energy saving from both residential and commercial sectors with low- or no-cost.*** The currently implemented Green Building Codes (GBC) is an important starting point, however, the coverage and requirement of energy efficiency measures would need to further increase to mandate, for example, more energy efficient appliances and requirement in the residential and commercial sectors. The NEXSTEP analysis identifies that the city has potential to further revise and expand the energy efficiency requirements under this code and benefit from implement low hanging fruits. While the GBC focuses on building envelope to reduce energy consumption, this analysis suggests retrofitting with more efficient appliances in residential buildings to take advantage of the enhanced energy saving potential.

c) ***Sustainable mobility options can save both energy and emissions in the transport sector.*** The transport sector is responsible for about 40 per cent of city's energy consumption - consumes about 4 Mtoe of energy, 52 per cent of the city's total energy consumption and is fully imported. The NEXSTEP analysis indicates that a combination of all measures - electrification of public buses, increasing the use of public transport and non-motorized mobility - would yield a total energy saving in 2030 of 1,553 ktoe, equivalent to a 5.9 $MtCO_2$-e reduction in emissions.

d) ***Transition to a Towards NetZero Carbon city.*** Reaching the goal of carbon neutrality is challenging for a mega city like Jakarta. However, a number of strategies have been proposed that would help the city to move towards NetZero by 2030. Major strategic directions include switching from LPG cookstoves to high-efficient induction type electric cookstoves in households, replacing half of the current two-stroke motorbike stock with electric versions, promoting the uptake of rooftop solar PV on buildings and increasing investment in bicycle infrastructure. Increased bicycle commuting should be given a high priority in the Towards NetZero Carbon scenario - an increase in 10 per cent cycling passenger-km has the potential to reduce city's energy consumption by 215 ktoe annually.

The roadmap also highlighted how a sustainable energy transition will help Jakarta build back better from COVID-19, which further reinforces the importance of the policy recommendations set out in this report.

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, and, more importantly, consider and capitalise on the interlinkages between Sustainable Development Goal 7 (SDG 7) and other SDGs. In this regard, 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 SDG 7 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 the Commission Resolution 74/9, which endorsed its outcomes. NEXSTEP has 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 NEXSTEP tool 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 the next chapter. While this tool has been designed to help develop SDG 7 roadmaps at the national level, it can also be adapted for sub-national energy planning.

As a participant of the "SDG 7 localisation project", the City of Jakarta and UNESCAP has collaborated to develop a Sustainable Energy Transition (SET) roadmap, which seeks to assess Jakarta'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 localisation 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 sub-national governments in the region to accelerate development and implementation of SDG7-related actions by directly engaging cities and sub-national jurisdictions into collaborative discussions, offering a range of knowledge product and support in developing local sustainable energy policies and projects, as well as in establishing more effective dialogues between national, sub-national and local levels of governance, expert communities, as well as donors and the private sector. See Box 1 for further details.

Box 1. SDG 7 Localisation status of Jakarta based on ESCAP's assessment

In 2021, ESCAP conducted a study of 20 cites from 5 ASEAN countries, including Jakarta, in order to assess their local situation in terms of the efforts on SDG 7 Localisation and provide recommendations for further actions.

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

SDG7 Localisation Snapshot provides a brief overview of the key areas related to implementation of the Sustainable Goal 7 (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

Localisation questionnaire. Seven areas, or SDG 7 Localisation indicators, were identified for this analysis. Additionally, 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 the SDG 7. The results for these qualitative indicators are based on cities' self-assessment of their current conditions, efforts, resources and capacity in relation to supporting SDG 7 localization process and can serve 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.

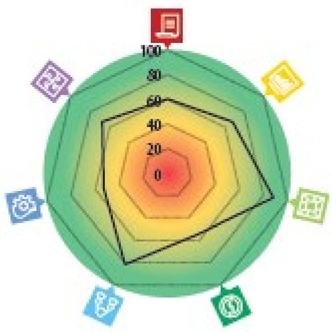
The results for each indicator are presented as a nominal score from 0 to 100 (where 100 is the maximum possible score, that can be achieved for each indicator or sub-indicator based on the aggregation of all answers of the questionnaire attributed to this particular indicator or sub-indicator).

As can be seen from the figure and the results below, Jakarta has already made notable progress on cooperation with stakeholders, and awareness-raising activities related to SDG 7. 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 to support implementation efforts on scaling up sustainable energy.

General information

Name of the jurisdiction	DKI JAKARTA
Country of the jurisdiction	Indonesia
Population of the jurisdiction	10.5 million (2019) people
Area of the jurisdiction (in km²)	661.5
Predominant climate	Tropical

SDG7 Localization score



Score
0–33 34–66 67–100

Scores for each SDG7 Localisation indicator are calculated between 0 and 100 to show the assessment of the status in the jurisdiction in each of the respective areas.

Indicators score

61	**Available policies and institutions for SDG localization**	Availability of specific policies and institutions focused on supporting the SDG 7 implementation.
68	**Energy data monitoring**	Accessibility and penetration of energy monitoring and smart metering.
89	**Cooperation with national and international stakeholders**	Efficient communication and collaboration between local stakeholders and various stakeholder groups at the national and international levels.
55	**Use of financial resources**	Availability of various financial resources and instruments for supporting SDG 7 implementation actions.
82	**Awareness raising and capacity- building**	Availability of policies or actions to increase the understanding among citizens and build the capacity of professionals for SDG 7 implementation.
54	**Implementation**	Presence of policies and actions to implement SDG 7 targets.
68	**Linkages to other SDGs**	Availability of policies or actions with linkages between SDG 7 and other SDGs.

Sub-indicator score

62	**Energy access**	Policies or actions taken by cities on energy access.
56	**Renewable energy**	Policies or actions taken by cities on renewable energy.
44	**Energy efficiency**	Policies or actions taken by cities on energy efficiency.

Sub-indicator score

84	**SDG3. Good health and well-being.**	The presence of energy-related activities or measures that support the health sector.
46	**SDG6. Clean water and sanitation.**	The presence of energy-related activities or measures that support water and sanitation.
78	**SDG11. Sustainable cities and communities.**	The presence of energy-related activities or measures that support development of sustainable cities and communities.
67	**SDG12. Responsible production and consumption.**	The presence of energy-related activities or measures that support responsible production and consumption.
67	**SDG13. Climate action.**	The presence of energy-related activities or measures that support climate action.

1.2 SDG 7 Targets and Indicators

SDG7 aims to ensure 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 total final energy consumption (TFEC). It is calculated by dividing the consumption of energy from all renewable sources by the 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. It should be noted that energy intensity is only an imperfect proxy indicator for energy efficiency, which can be affected by a number of factors, such as climate, structure of the economy, nature of economic activities etc. that are not necessarily linked to pure efficiency.

2. NEXSTEP methodology

The main purpose of NEXSTEP is to help design the type and mix of policies that would 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

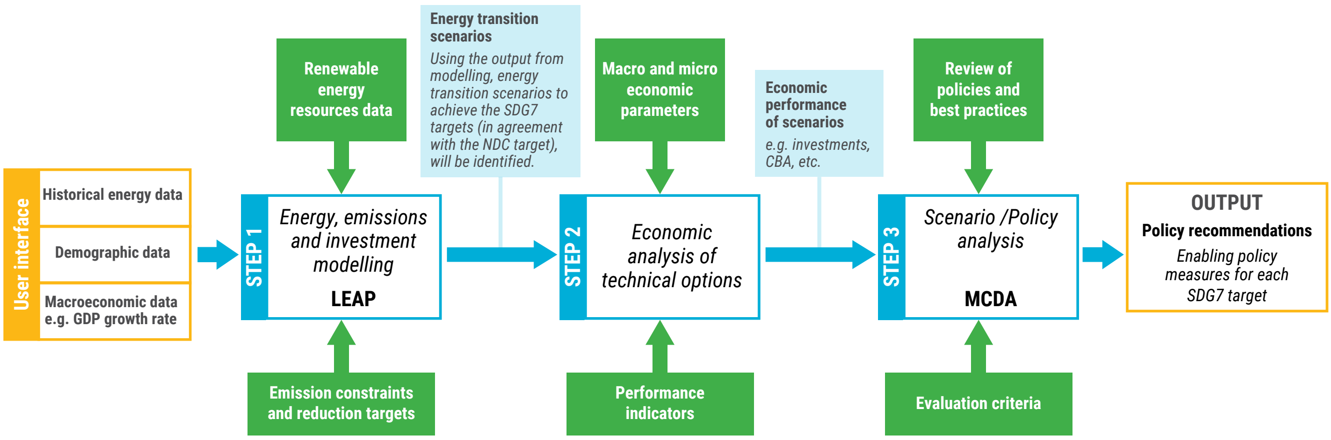
I. Energy and Emissions Modelling

NEXSTEP begins with the energy systems modelling to develop different scenarios 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) software tool. It is a widely used tool for energy sector modelling and to create energy and emissions scenarios. Many countries have used LEAP to develop scenarios as a basis for their Intended Nationally Determined Contributions (INDCs). Least Cost Optimisation method is used to calculate the optimal expansion and dispatch of the electric power system. Figure 1 shows different steps of the methodology.

II. 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, including net present

Figure 1. Different components of the NEXSTEP methodology



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.

III. Scenario and policy Analysis

Using Multi-Criteria Decision Analysis (MCDA), this prioritis ed list of scenarios is assessed in terms of their techno-economic and environmental dimensions to convert to policy measures. 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 a way that no other tools look at developing policy measures to achieve SDG7. The key feature that makes it outstanding is the backcasting approach for energy and emissions modelling. This is important when it comes to planning for SDG7 as the targets for the final year (2030) is already given and thus the tool needs to be able to work its way backward 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' model energy system evolution based on current energy policies. In the NEXSTEP model for Jakarta, three main scenarios have been modelled – (a) business-as-usual (BAU) scenario, (b) current policy scenario (CP) scenario and (c) Sustainable Energy Transition (SET) scenario.

I. Business-as-usual (BAU) scenario: This scenario follows historical demand trends based on simple projections by 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, the trend is 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.

II. Current policies scenario: Inherited and modified from the BAU scenario, this scenario considers all policies and plans currently in place. In addition, a target of 15 per cent decrease of GHG emissions by the energy sector by 2030 compared to the BAU scenario is set, according to the unconditional NDCs of Indonesia.

III. Sustainable Energy Transition (SET) scenario: This scenario and its sub-scenarios aim to achieve the SDG7 targets, including universal access to electricity, universal access to clean cooking fuel, substantially increasing the renewable energy share and doubling the rate of energy efficiency improvement. For clean cooking, different technologies (electric cookstove, LPG cookstove and improved cookstove) have been assessed. Energy intensity has been modelled to help achieve the SDG7 target. Finally, the emission reduction target has been used to estimate the optimum share of renewable energy in TFEC, which is considered to be a substantial increase.

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 to weigh the benefits against costs and facilitate 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 profitability of the investment considers the national welfare, including externalities. A project is financially viable only if all the monetary costs can be recovered in the 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 emits particulate matter which is inhaled by the local population, damaging health and accelerating climate change. In an economic analysis, a monetary value is assigned to the GHG emission to set a price on its GHG emissions abatement.

2.3.1.1 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, these are based on country-specific data to improve the analysis. They include land, building, machinery, equipment and civil works.
b) Operation and Maintenance Cost – consists of fuel, labour and maintenance costs. Power generation facilities classify operation and maintenance costs as fixed (US$/MW) and variable (US$/MWh) cost.
c) Decommissioning Cost - retirement of power plants costs related to environmental remediation, regulatory frameworks and demolition costs.
d) Sunk Cost – existing infrastructure investments are not included in the economic analysis, since it does not have any additional investment required for the project.
e) External Cost – refers to any additional externalities which place costs on society.
f) GHG Abatement – avoided cost of CO_2 generation is calculated as monetary value based on the 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.

3. Overview of the Jakarta’s energy sector

Located on the northwest of the island of Java, Jakarta is the capital and largest city of Indonesia. It covers an area of 661 square kilometres with a population of 10.56 million recorded in 2018. Economically, Jakarta plays an important role in several aspects. Firstly, it is the central focus for country's key economic activities. Second, it is a significant industrial hub as well as an important commercial centre that makes a substantial contribution to the national and regional economy. A relatively small portion of city's population (less than 5 per cent) live in informal settlements or inadequate housing.

This chapter provides an overview of the energy sector of Jakarta, covering the entire spectrum of energy demand and supply, resources available in the country and lists key assumptions and data sources that have been used to develop growth projections to 2030. It also discusses how different scenarios have been developed and provides a summary of projections of energy demand in the BAU and the CP scenarios.

3.1 Energy profile of the city

The large population base, coupled with huge commercial and industrial activities, has led to a very high consumption of energy in the city. The bulk of its demand is supplied primarily by imported energy sources, mainly petroleum products. While the city has some electricity generation plants, half of its electricity demand is imported through the national grid, generated elsewhere in the country.

SDG 7 is a goal set at the national level and, therefore, it does not explicitly apply to the local level. However, the City of Jakarta is implementing policies and projects that take into account existing national SDG 7 related commitments to ensure that local efforts on SDG 7 implementation are aligned with the national commitments and plans. To this end, the city has already established the necessary institutional set-up and appointed dedicated staff to support SDG 7 implementation. Various sustainable energy policies for the transport and building sectors have been implemented or are currently under implementation. The city has established data collection and monitoring systems in the following areas: energy efficiency, renewable energy, energy access, sustainable energy/ SDG 7, and different SDGs, but some of the data are still not detailed enough.

Renewable energy targets exist at the national level. However, these targets are currently not being implemented at the city level. Targets for reducing GHG emissions/air pollution are being implemented at the city level. The city has set an emission reduction target to cap its emissions to 31.5 $MtCO_2$-e by 2030, as per the Governor's Regulation 131/2012 (DKI Jakarta 2019b).

3.2 Baseline data and assumptions

The base year for analysis is 2018, which has been selected based on the year with most comprehensive data availability, and the analysis period is 2020 -2030. The energy and emissions modelling has been performed using the LEAP tool, which is an integrated tool used for energy policy analysis and climate mitigation assessment developed by the Stockholm Environment Institute (SEI).

Most of the data has been obtained from the city with additional data collected through communications with the city staff as well as from published literature. In 2018, Jakarta's population was recorded to be 10.56 million. The average household size (number of people per household) was found to be 4.0, higher than the national average of 3.8. The population is expected to grow at 1.19 per cent per year and the gross domestic product (GDP) growth rate would be 5.89 per cent annually. Table 1 presents important demographic and macro-economic data that has been used for modelling.

3.3 Overview of Jakarta energy demand and supply

The TPES for Jakarta was reported at 9.22 Mtoe in 2018 (Figure 2), which is largely dominated by fossil fuels. The largest share was oil products 4.1 Mtoe (45 per cent), followed by natural gas 2.7 Mtoe (30 per cent), electricity 2.2 Mtoe (23 per cent), and renewables 0.2 Mtoe (2 per cent).

The TFEC for Jakarta was reported as 7.5 Mtoe in 2018 (Figure 3). Oil products dominated the mix at 3.9 Mtoe (52 per cent), electricity 2.8 Mtoe (37 per cent), natural gas 0.67 Mtoe (9 per cent) and renewables 0.16 Mtoe (2 per cent). The sectoral shares of TFEC for Jakarta were: transport - 2.9 Mtoe (39 per cent), commercial - 1.57 Mtoe (22

Table 1. Demographic and macro-economic data for Jakarta, 2018

Population	10.56	Million
Household	2.76	Million households
Household Size	4.00	Person / household
GDP	192,618	Million US$
GDP Per Capita	18,244	US$
Population Growth Rate	1.19	%
GDP Growth Rate	5.89	%
Commercial Floor Space	178.99	Million m^2

Source: Collected by the national consultant in consultation with the city authority.

Figure 2. Total Primary Energy Supply (TPES), 2018

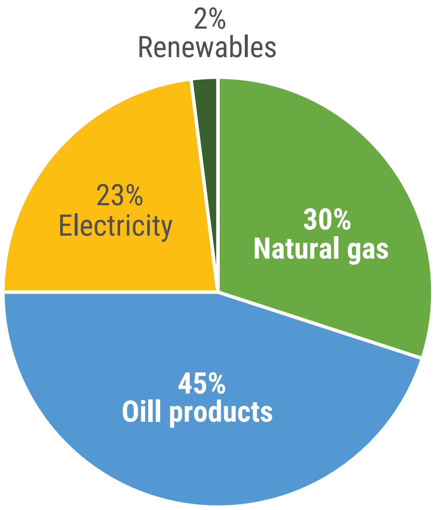
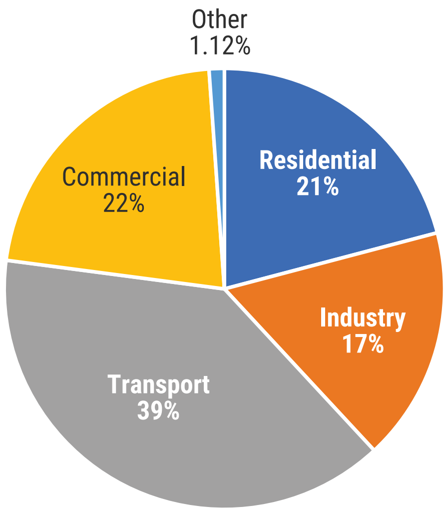


Figure 3. Total Final Energy Consumption (TFEC), 2018



per cent), residential - 1.64 Mtoe (21 per cent), industry - 1.3 Mtoe (17 per cent) and others - 0.1 ktoe (1 per cent).

3.4 Status of SDG 7 targets and indicators in Jakarta

Based on the energy balance data for Jakarta, the energy model is constructed in LEAP. The SDG 7 indicators are calculated at the city level. Universal access to electricity has been achieved and is reported at 100 per cent in Jakarta. Renewable energy share in the TFEC is calculated based on a standard formula (see below) for Jakarta and is estimated at 4.8 per cent. Energy efficiency measured in terms of primary energy intensity is calculated as 2 MJ/USD. Table 2 presents some of the sustainable energy indicators for Jakarta.

Standard formula to calculate the share of renewable energy in total final energy consumption

$$\%TFEC_{RES} = \frac{TFEC_{RES} + \left(TFEC_{ELEC} \times \frac{ELEC\_RES}{ELEC\_TOTAL}\right) + \left(TFEC_{HEAT} \times \frac{HEAT\_RES}{HEAT\_TOTAL}\right)}{TFEC_{TOTAL}}$$

where TFEC is total final energy consumption, ELEC is gross electricity production and HEAT is gross heat production.

3.5 Demand analysis

Energy consumption analysis across all sectors is based on data received from the city. The structure of the model for each energy demand sector is explained below:

Table 2. Sustainable energy indicators for Jakarta

Percentage of population with access to electricity	100.00 per cent
Proportion of population with primary reliance on clean fuels and technology	98.48 per cent
Renewable energy share in the total final energy consumption	4.80 per cent
Energy intensity measured in terms of primary energy and GDP	2.00 MJ / USD

- Industrial sector includes major energy intensive subsectors such as cement, pulp and paper and iron and steel industries. These are modelled at the process share level of heating systems, cooling systems, on-site power plants and motor driven machinery for energy efficiency analysis.
- Residential sector energy consumption is further divided into small, medium and large households. The bottom-up modelling approach is applied to model individual appliances such as lighting, air conditioners, refrigerators and fans used by households in Jakarta to model the average energy consumption of households. Cooking energy consumption is classed separately to analyse the stove technology and fuel consumption in households.
- Transport sector analysis is divided into two main subsectors passenger and freight vehicles. The passenger-km and freight-km are calculated based on formula using registered vehicles, annual vehicle travel distance and vehicle occupancy / load factor.
- Commercial sector analysis is based on floor space occupied by the sector and the energy intensity per square meter. The sector is divided into government buildings and private buildings, the rationale is that energy efficiency measures will first be applied in government buildings before being rolled out across the country.
- Agricultural sector energy consumption is quite small compared to other sectors and is modelled at the fuel consumption level.

3.6 Transformation analysis

Transformation refers to the conversion of primary energy to final energy. The transformation sector consists of electricity generation, transmission, and distribution (Table 3). Electricity generation is based on the current generation mix data. Transmission and distribution losses are modelled at 9.4 per cent for Jakarta.

Table 3. **Installed capacity for electricity generation, 2018**

Power generation technologies	Installed Capacity (MW)
Combined Cycle Gas Turbine PP	3,739
Steam Oil PP	400
Solar PP	2
Total	**4,140**

3.7 Resource analysis

Indonesia has abundant conventional energy resource potential including coal, oil and natural gas. However, estimating the fossil fuel reserves at the city level is less relevant as the city would be able to draw on national energy resources on demand. Similarly, the renewable energy resource potential (see Table 4) in Jakarta is based on the data available for the Java-Bali Islands (Handayani, Krozer, and Filatova 2019). The utilisation of renewable energy potential is very low in Jakarta, this indicates that there is significant potential for expansion.

3.8 Growth Projection

Modelling energy demand under the BAU growth projection is important to understand future energy requirements. The methodology is explained for each demand sector:

- Residential sector energy growth is influenced by the population growth rate of 1.19 per cent per year, the decrease in household size to 3.8 in 2020 and 3.7 in 2025 and it is assumed that the urbanisation rate remains the same. Ownership of appliances is projected to increase over the period in line with the increase in per capita GDP.

Table 4. Renewable Energy Potential

Renewable Energy	Potential in Gigawatt (Java-Bali Islands)
Hydro	4.2
Hydro pumped storage	3.9
Mini Hydro	2.9
Geothermal	6.8
Biomass	7.4
Solar	2,747.0*
Wind	24.1

* In Gigawatt Peak
Source: (Handayani, Krozer, and Filatova 2019)

- Transport sector energy growth is directly influenced by population growth rate 1.19 per cent per year and an increase in passenger-km due to an increase in per-capita GDP of 3 per cent per year (estimated). Similarly, freight-kilometres are also projected to increase by 3 per cent per year over the analysis period.
- Industry sector energy use is projected to grow with a GDP energy elasticity of 1.14 per year.
- Commercial sector energy use forecast is based on Indonesia's national growth in commercial floor space from 2008-2018, which is extrapolated to 2030, while energy intensity remains constant.
- Agriculture sector energy use is projected to increase at a GDP energy elasticity of 0.64 per year.

3.9 Current Policy (CP) Scenario

The CP Scenario is based on the current energy policies of Jakarta. Example of these policies include:

a) The Governor's Regulation No. 131/2012, which states that the city would reduce its emissions by 30 per cent compared to the baseline in 2030 which will be equivalent to 31.5 $MtCO_2$-e emissions reduction from the energy sector.

b) The Governor's Decree No. 38/2012 on Green Building (Pergub 38/2012) which has set a new vision for 2030 in reducing 30 per cent energy consumption, 30 per cent CO2 emission, and 30 per cent water consumption. This is translated to a reduction in electricity consumption of 3.78 TWh and an emission reduction of 3.37 $MtCO_2$-e by 2030 compared to business-as-usual (GBC 2021).

c) The Minister of Energy and Mineral Resources Regulation No.12 of 2015 on the biofuel mandate of 30 per cent biodiesel and 20 per cent bioethanol utilization by 2035. This regulation equally applies at the sub-national levels.

3.9.1 Energy demand outlook

The energy demand in the current policy scenario will grow from 8.1 ktoe in 2020 to 12.1 ktoe in 2030 (Figure 4). The transport sector will have the highest demand with 4.2 Mtoe (34.5 per cent), followed by the commercial sector 3.2 Mtoe (26 per cent), the industry sector at 2.6 Mtoe (21 per cent) and the residential sector at 2.1 Mtoe (17 per cent).

The current policy scenario has considered the Green Building Code and has modeled both electricity and emission reduction targets of 3.78 TWh and 3.37 $MtCO_2$-e respectively. These reduction measures have been primarily applied to the commercial sector both in government buildings and private offices by reducing the energy intensity per meter square of floor space. Figure 5 shows electricity reductions in the current policy scenario compared to the BAU scenario.

Figure 4. Final energy demand in the current policy scenario, 2020-2030

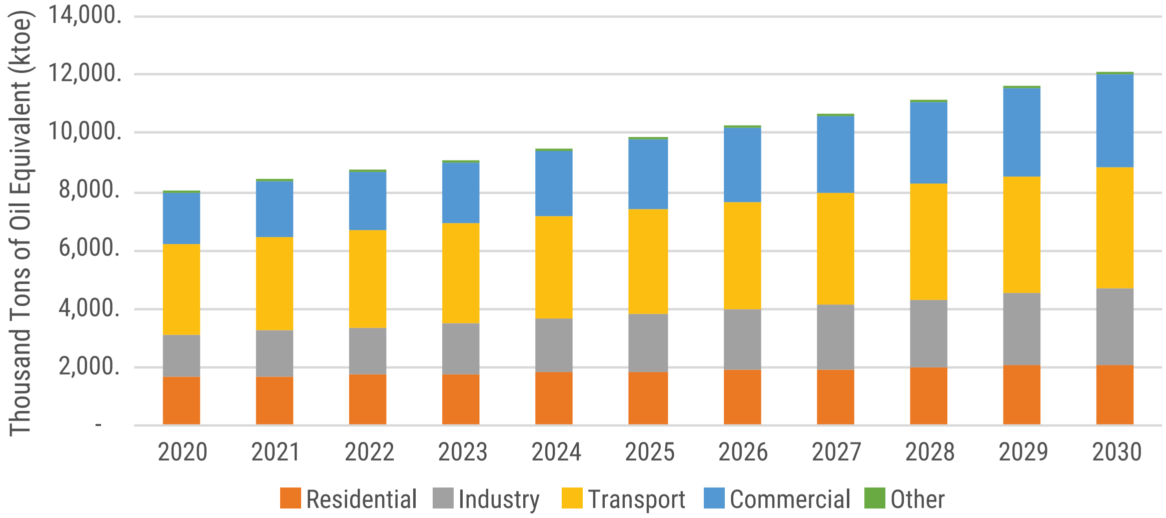
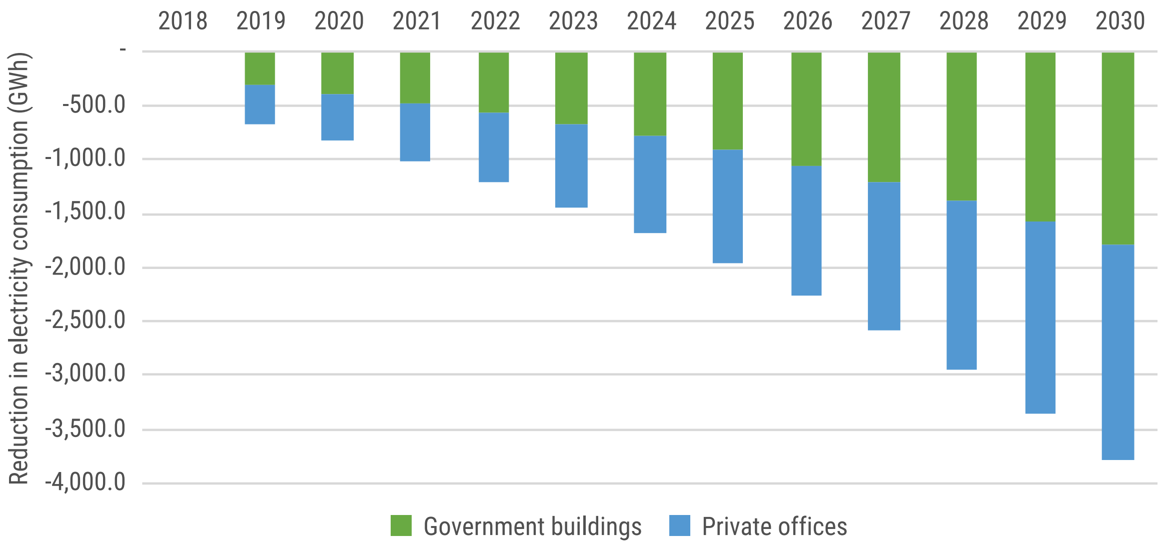


Figure 5. Reduction in electricity demand as per Green Building Code compared to BAU scenario



Box 2 provides a summary of the Green Building Code Jakarta.

3.9.2 SDG 7 targets and indicators

Universal access to electricity has already been achieved in Jakarta. Access to clean cooking fuels and technology was reported as 98.15 per cent in 2015 and reaching 98.48 per cent in 2020. This relatively slow progress is because the last mile is always hard to reach. With this progress, the city is on-track to achieve universal access to clean cooking technology and fuels by 2022 (Figure 6).

In this scenario, the renewable energy share in Jakarta is projected to increase to 10.5 per cent by 2030, following the implementation of biofuel policy and planned renewable energy-based electricity generation capacity expansion. The energy intensity at the end-use level is projected to decrease from 2 MJ/USD in 2018 to 1.94 MJ/USD in 2030.

3.9.3 Electricity demand and supply

Electricity demand in the current policy scenario is expected to increase by 59 per cent, from 34.8 TWh in 2020 to 55.2 TWh in 2030 (Figure 7). The bulk of this increase is expected in the commercial sector, which is set to double by 2030 compared to 2020 demand of 13.9 TWh. In 2030, the largest demand for electricity would be in the commercial sector 27.8 TWh (50 per cent), followed by residential

Box 2. Green Building Code Jakarta

In 2012, the city enacted the Green Building Code through the Governor Regulation of DKI Jakarta No. 38/2012. It regulates the planning, construction, utilization, maintenance, and deconstruction of buildings in Jakarta. The code focuses on the key sustainability areas including energy efficiency, water efficiency, indoor air quality, waste and soil treatment, and construction activities. The Regulation applies to specific building sizes and types. These include:

- Apartment buildings, office buildings, trade buildings, and buildings which have more than one function within one building, with floor space larger than 50,000 m^2;
- Buildings for business, hotel, social and cultural functions, and health care buildings with floor size greater than 20,000 m^2;
- Buildings for social and cultural functions, educational service buildings, with floor size greater than 10,000 m^2

The regulation requires all new buildings and 60 per cent of existing buildings to comply with Jakarta Green Building in 2030. New buildings must consider:

- Efficiency of the building veil systems, ventilation systems, air systems, lighting systems, building transportation systems, and electrical systems.
- Planning of water-saving sanitary equipment and planning of the use of water.
- Improvement in the indoor air quality.
- Land and waste management both on the inside and outside of the building and planning of rainwater reservoir systems, supporting facilities, and solid and liquid waste management.

GBC aims to achieve a reduction of electricity demand of 3.78 TWh, water demand of 2.4 billion litres and emissions of 3.37 $MtCO_{2-e}$ by 2030 compared to business-as-usual.

Source: (GBC 2021; IEA 2019)

Figure 6. Progress in access to clean cooking fuel and technology

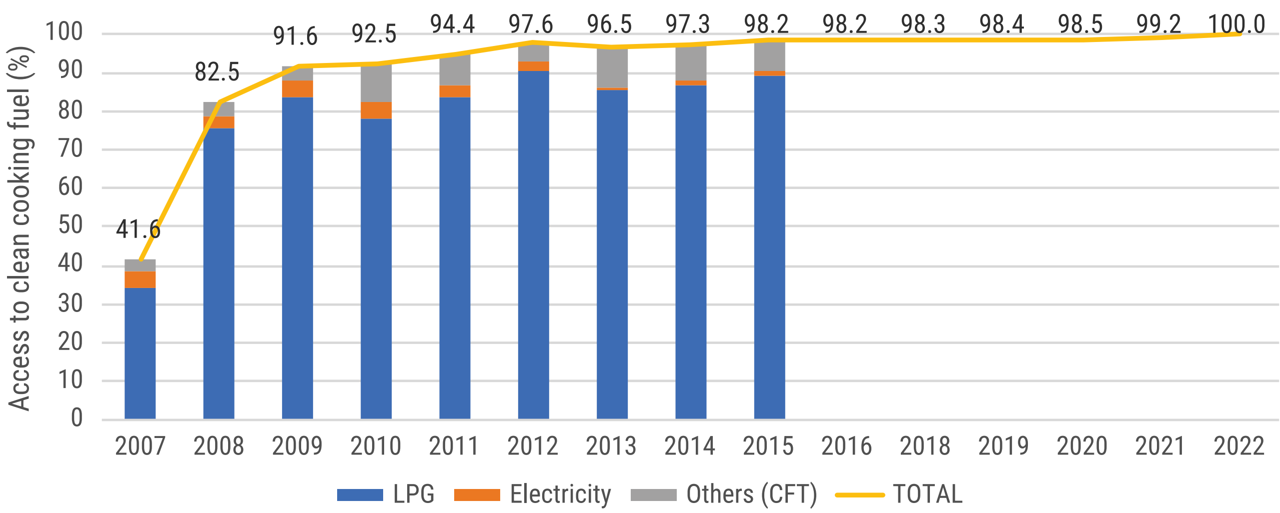
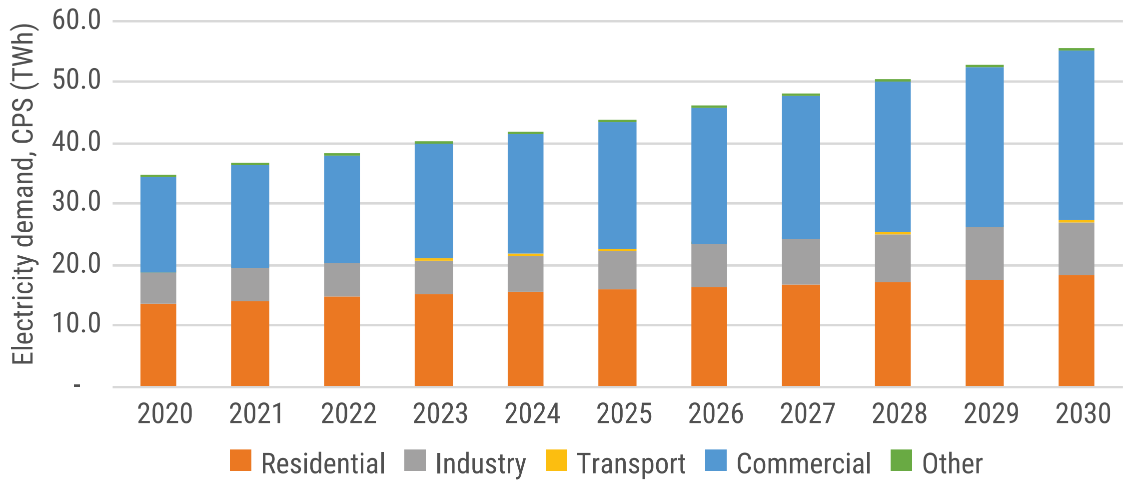


Figure 7. Electricity demand in CPS, 2020-2030



sector 18.2 TWh (34 per cent) and industry sector 8.8 TWh (16 per cent). The demand for electricity in the transport sector would remain very small, less than 1 per cent.

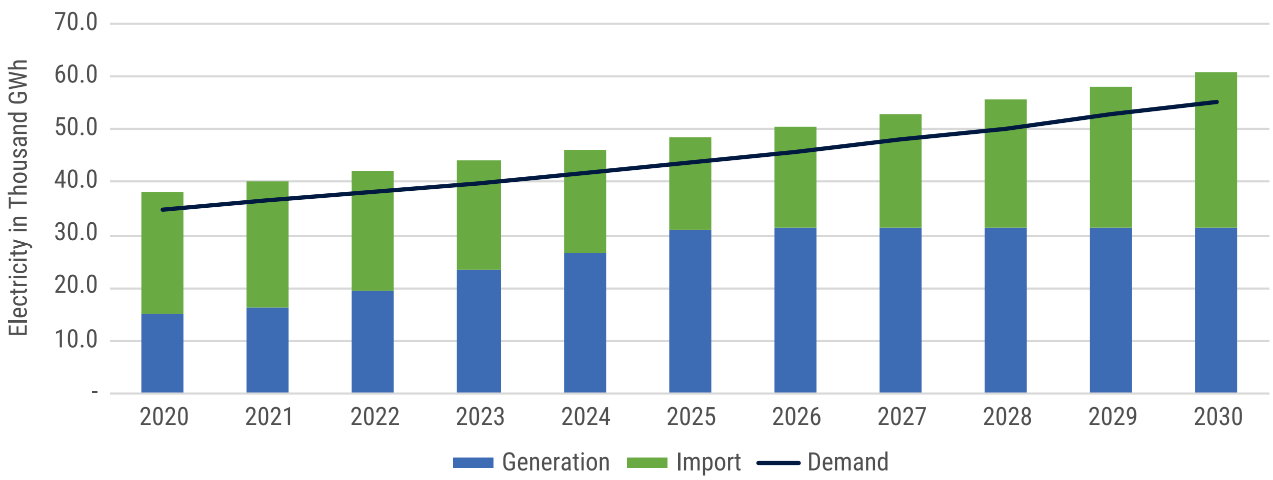
The city's electricity supply consists of two streams – own generation and purchase from the Java-Bali grid network. In 2018, the city generated about 22 per cent of its total supply of 32.2 TWh and purchased the remaining 78 per cent. Under the power generation expansion plan, the city aims to add another 917 MW of power generation capacity, most of which (700 MW) will be combined cycle gas turbine (CCGT). In this context, by 2030, the generation will increase to 31.3 TWh whereas the supply requirement will be 61 TWh. So, the city will continue to import a major share of its needed supply, however, the share will decrease over time as the new local generation capacity is gradually added to the system until 2025. Figure 8 shows the demand for electricity in the current policy scenario and also shows how this demand is met with a combination of imported and own generation.

3.9.4 Emissions

Revisiting the emissions reduction target

The emissions reduction target (30 per cent reduction below the baseline in 2030) was set based on a baseline developed in 2010, which

Figure 8. Electricity demand, generation and import in the CP scenario



estimated the 2018 emissions to be 56.2 $MtCO_{2-e}$ (DKI Jakarta 2019a). However, based on the 2018 energy data collected from Jakarta as part of this roadmap development, the 2018 emissions are estimated to be 37.7 $MtCO_{2-e}$. This suggests that due to the changes in economic and demographic indicators since 2010, the baseline has significantly reduced. Based on the emission trajectory developed in this roadmap, the 2030 emissions would be 56.5 $MtCO_{2-e}$ and the 30 per cent reduction target would be equivalent to 17 $MtCO_{2-e}$ reduction in emissions.

Based on the current policies, GHG emissions for Jakarta are projected to increase from 37.8 $MtCO_{2-e}$ in 2020 to 51.8 MtCO2-e in 2030 (Figure 9) of which 14.1 $MtCO_{2-e}$ (27 per cent) will be from the demand side, 16.1 MtCO2-e (31 per cent) from electricity generation and the remaining $MtCO_{2-e}$ (42 per cent) will be from purchased electricity. The emissions for purchased electricity for 2020-2030 have been estimated based on the grid emission factor (EF) of the JAMALI network, including the changes of EF year-by-year due to the planned changes in the generation mix as per the National Electricity Supply Business Plan

Figure 9. Emissions in the CP scenario, 2020-2030

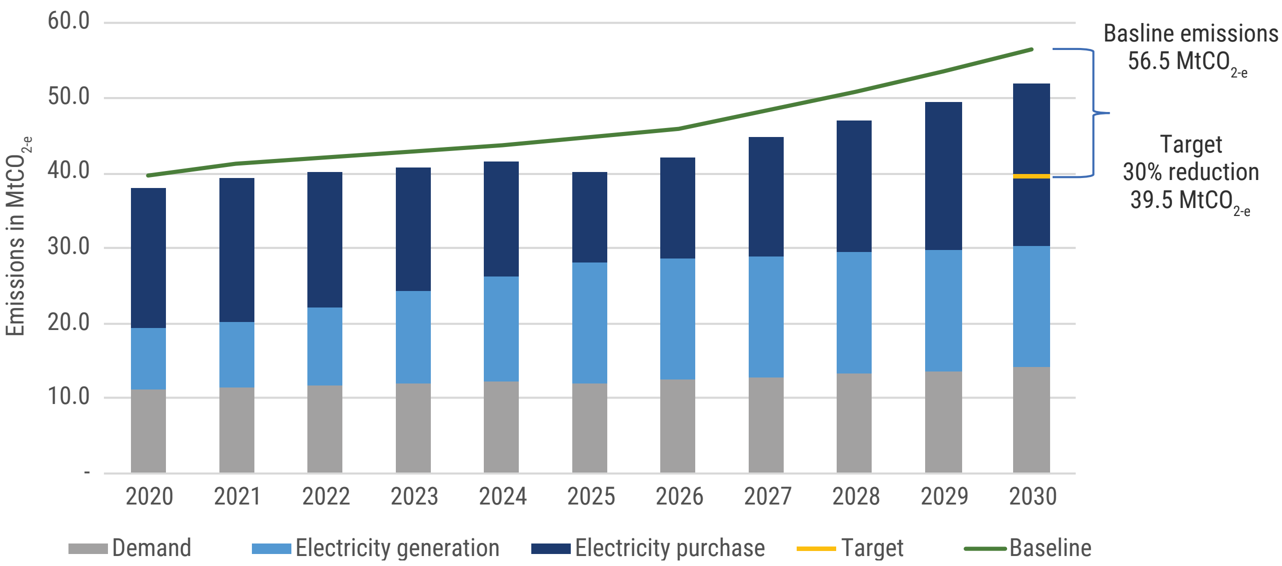
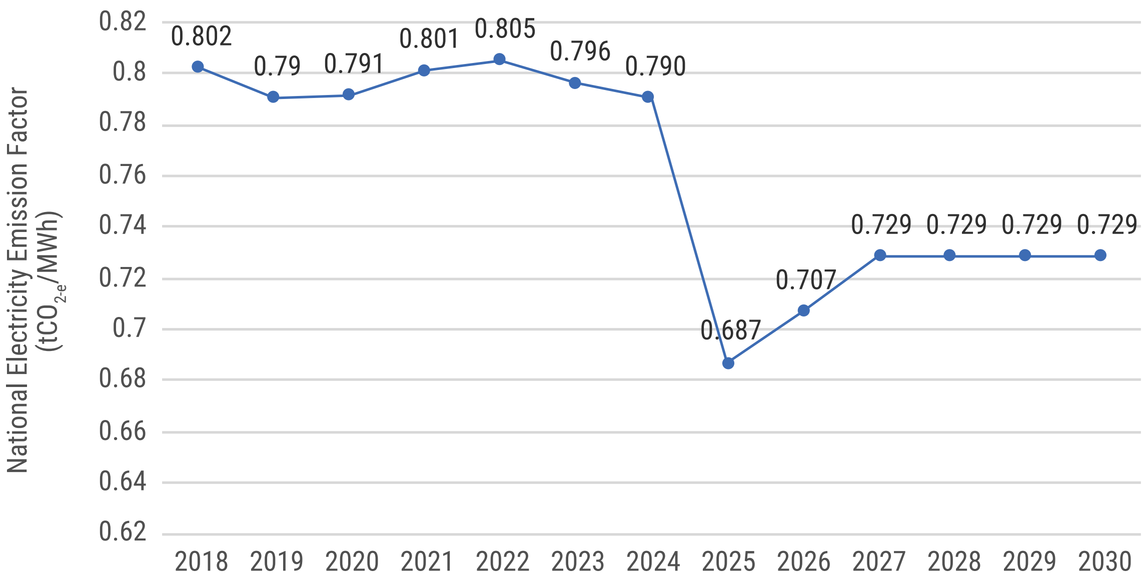


Figure 10. National electricity emission factors of Indonesia 2018-2030



Source: Adapted from (ESDM 2018).

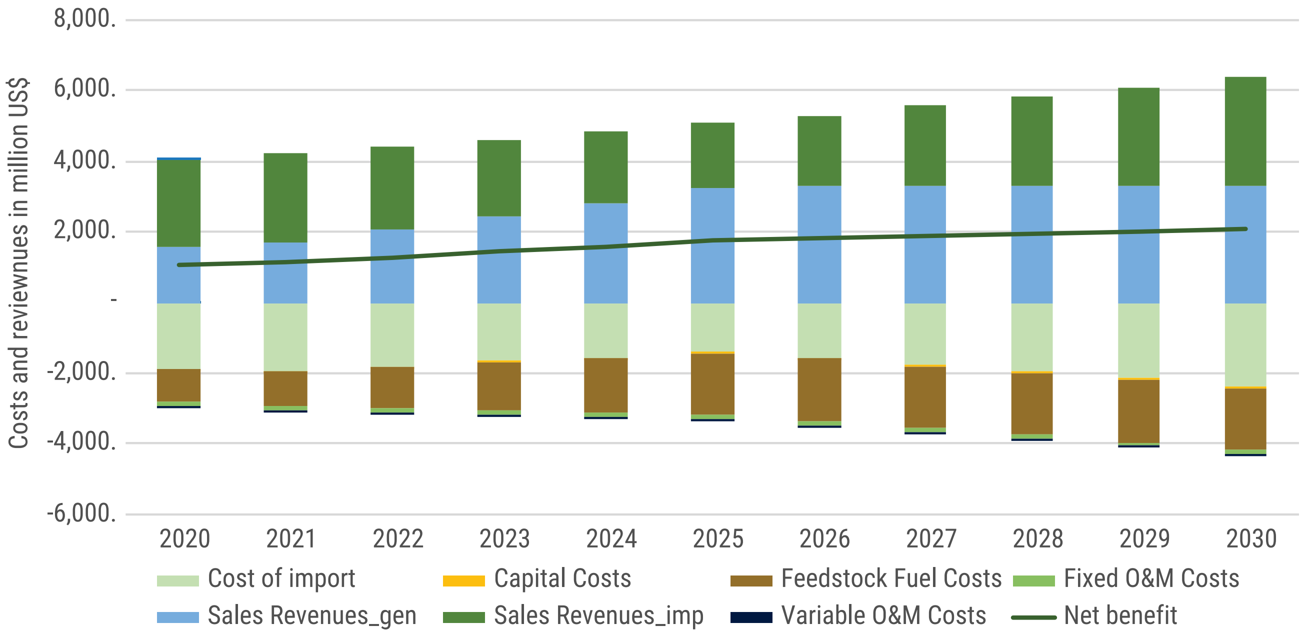
(RUPTL) 2008-2027 (Figure 10). While the values in this figure are for the national level, the JAMALI network represent about 75 per cent of the country's supply and therefore, are considered to be very similar. Figure 9 also shows a comparison of the emissions trajectory with the city's emission reduction target of $MtCO_{2-e}$ from the energy sector by 2030.

It is clear from Figure 9 that the city will not be able to achieve its emission reduction target under the current policy scenario - there will be a gap of 17 $MtCO_{2-e}$ which the city would need to reduce from the energy sector. The achievement of this target has been modelled in the next scenario (Sustainable Energy Transition scenario) which is discussed in the following section along with options to achieve this emission reduction target.

3.9.5 Investment

The investment cost in the power sector is estimated at $867 million based on the current share of technologies and planned capacity expansion. The capital cost for technologies is included in the NEXSTEP analysis using national technology data for the Indonesian power sector. Net Benefits in the CP scenario are estimated at $12.6 billion over the period 2020-2030. Note that this cost excludes the purchase of electricity which is estimated, based on the wholesale purchase cost of $0.08/kWh, to be about $20 billion over the next 10 years. Figure 11 shows all cost and revenue types for both the city's own generation and imported electricity.

Figure 11. Cost of electricity supply in the CP scenario, 2020-2030



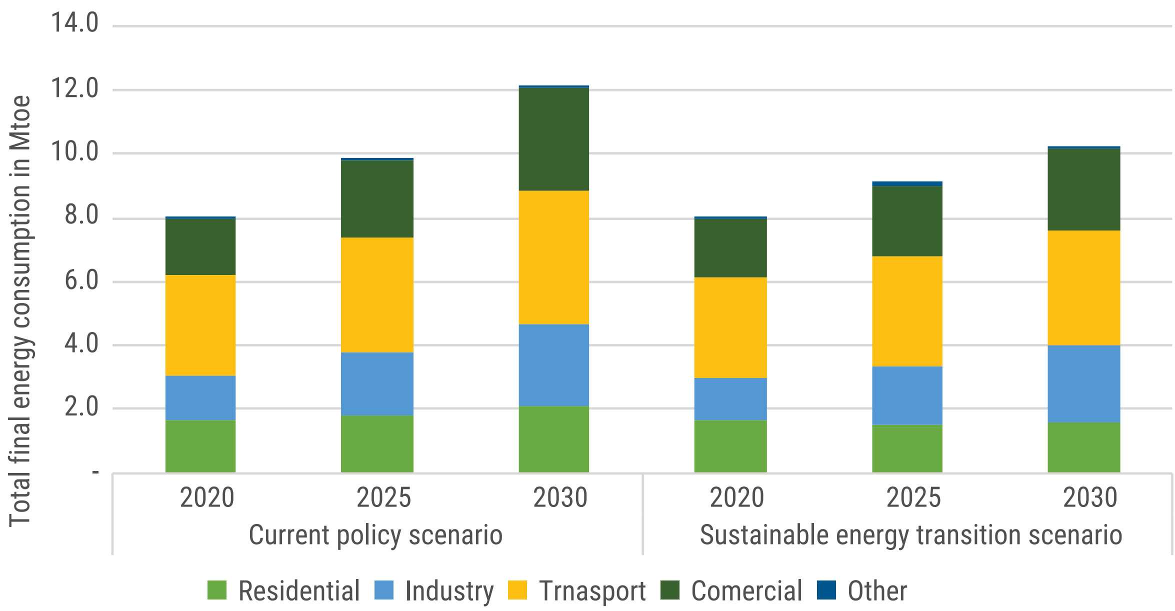
4. Sustainable Energy Transition (SET) scenario

Cities are at the focus of the sustainable energy transition, as 55 per cent of the world's population lives in cities and they account for 75 per cent of global anthropogenic emissions and represent about 66 per cent of global energy demand (REN21 2019, 21). With a sustainable energy transition approach, cities can improve air quality, increase resilience to climate change impacts, create local jobs and increase economic development, which will create more liveable urban areas and enable an improved quality of life. Additionally, SDG 7 offers a blueprint for transitioning to a sustainable energy future while ensuring modern, clean and affordable energy services for all. The City of Jakarta has enormous opportunities to embark on its journey towards a sustainable energy transition, not only because it would reduce emissions, improve public health and create more jobs but also it is more economic to move away from the current fossil fuel-based energy system. The city is also aiming to increase its efforts to align the energy system in line with the SDG 7 targets. This scenario presents a detailed analysis of the city's energy system and informs technological options and policy instruments for the city to transition to a sustainable and low-carbon energy future. In addition to ensuring the achievement of the SDG 7 targets, this scenario looks at further increasing the share of renewable energy in the power sector, reducing import of electricity to increase energy security at the local-level and increasing energy efficiency beyond what is required for SDG 7.

4.1 Energy demand outlook

In this scenario, TFEC increases from 8.1 Mtoe in 2020 to 10.2 Mtoe in 2030. In 2030, the transport sector will have the largest share of TFEC at 3.58 Mtoe (35.1 per cent), followed by the commercial sector at 2.52 Mtoe (24.7 per cent), industry sector at 2.47 Mtoe (24.2 per cent) and residential sector at 1.56 Mtoe (15.3 per cent). Figure 12 shows the total final energy consumption by scenario and sector for 2020-2030.

Figure 12. Projection of TFEC by scenario and sector in SET scenario



4.2 SDG 7 targets

4.2.1 Access to affordable, reliable and modern energy services

The city has already achieved universal access to electricity and is very close to achieving access to clean cooking fuel and technologies. Based on an evaluation of different clean cooking technologies, this scenario recommends that LPG cook stove technology be used to provide clean cooking access to the remaining 41,932 households at a cost of about $2 million. The LPG cook stove has lower indoor air pollution compared to Improved Cook Stoves (ICS). It is classified as Level 4 in the World Bank Multi-Tier Framework (MTF) for cooking exposure and reduces indoor air pollution by 90 per cent compared to traditional cook stoves. Box 3 provides a summary of the evaluation of different clean cooking technologies and a comparison of the annualised cost of different clean cooking technologies is given in Table 5.

4.2.2 Renewable energy

SDG 7.2 does not have a quantitative target; however, an increase in renewable energy is required to meet the emissions reduction target of the city. The NEXSTEP methodology first estimated the net increase in energy demand in response to

Table 5. Annualized cost of cooking technologies

Technology	Annualized cost
ICS	IDR 412,090 (US$29)
Electric stove	IDR 838,390 (US$59)
LPG stove	IDR 866,810 (US$61)
Biogas digester	IDR 1,833,090 (US$129)

Box 3. Evaluation of Clean Cooking Technologies

Electric Cook Stove

The technology is classed as Level 5 in the World Bank MTF for Indoor Air Quality Measurement. Electric cookstoves are more efficient than other cookstoves, including gas stoves. Electric cookstove can be generally divided into two types – solid plate and induction plate. While solid plate cookstove uses a heating element to pass radiant energy onto the food and reaches about 70 per cent efficiency, induction plate cookstove, on the other hand, uses electromagnetic energy to directly heat pots and pans and can be up to 90 per cent efficient. However, feedback from the stakeholder consultation workshop suggests that the cooking practice in Jakarta is unlikely to support the use of electric cookstoves.

Improved Cook Stove

Studies suggest that ICS programs often have low adoption rates due to inconvenience of use, preference for traditional cookstoves, need for frequent maintenance and repairs. ICS programmes initially require strong advocacy to promote adoption, after which they require ongoing follow-up, monitoring, training, maintenance and repairs in order to ensure continuing usage. Based on WHO guidelines for emission rates for clean cooking, only certain types of ICS technology comply, particularly when considering that cookstove emissions in the field are often higher than they are in the laboratory settings used for testing. Based on the need ongoing follow-up, ICS serves better as a temporary option, but is not well suited as a long-term solution.

Biogas Digester

Biogas Digesters have high upfront capital costs (about ($1,000) for a standard size that is suited for a four-member family) and require substantial subsidies due to their longer payback period. The technology is not favoured in rural areas due to the cultural aspects of using animal or human waste for cooking. Additionally, a standard size biogas digester requires 2-4 cows, depending on the size of the cow, to produce enough feedstock for the daily gas demand for a household. This would be a big challenge for the households in urban areas and, therefore, is deemed to be unsuitable.

Natural Gas Stove

While clean cooking with natural gas can be a viable solution for urban households, it is assumed that the remaining households are not suitable to be connected with the natural gas supply network. Table 5 summarizes the annualized cost of different cooking technologies.

LPG Cook Stove

An LPG cook stove creates lower indoor air pollution compared to ICS and is classified as Level 4 in the World Bank Multi-Tier Framework (MTF).[a] It reduces indoor air pollution by 90 per cent compared with traditional cook stoves. Given the small number of households to be covered and considering these households are not suitable for natural gas connections, LPG would be a suitable technology to provide access to clean cooking technologies.

a http://documents.worldbank.org/curated/en/937711468320944879/pdf/88699-REVISED-LW16-Fin-Logo-OKR.pdf universal access to clean cooking technologies as well as energy efficiency improvements. It then used the city's emission reduction target (31.5 $MtCO_{2-e}$ by 2030) for the energy sector to estimate the renewable energy share in TFEC. Details of the steps in determining the share of renewable energy are discussed below:

1. Energy efficiency has been applied to the residential and commercial sectors with recommendation to introduce minimum energy efficiency for most appliances, including lights, televisions, air conditioners, elevators, refrigerators and electric fans.
2. Energy efficiency improvement has been modelled to introduce a mandatory 20 per cent reduction in electricity consumption across all industries.
3. Emissions have been calculated with the reduced energy consumption in this scenario to estimate the gap.
4. The required share of renewable energy in the imported portion of electricity has been estimated to eliminate the emissions gap.
5. This share is then added to the share of city's own generation and then converted to TFEC.
6. The renewable energy share in electricity and other fuels have been summed up to estimate the final RE share in TFEC.

The renewable energy share in the city's own generation is expected to remain as per the capacity expansion plan in CPS as there are already plans for 32.5 MW of solar PV, 85 MW of waste to energy and 1 MW of wind (wind resources in the city are very low). Therefore, in this scenario the emission reduction has been fully realised by changing the supply mix of purchased electricity.

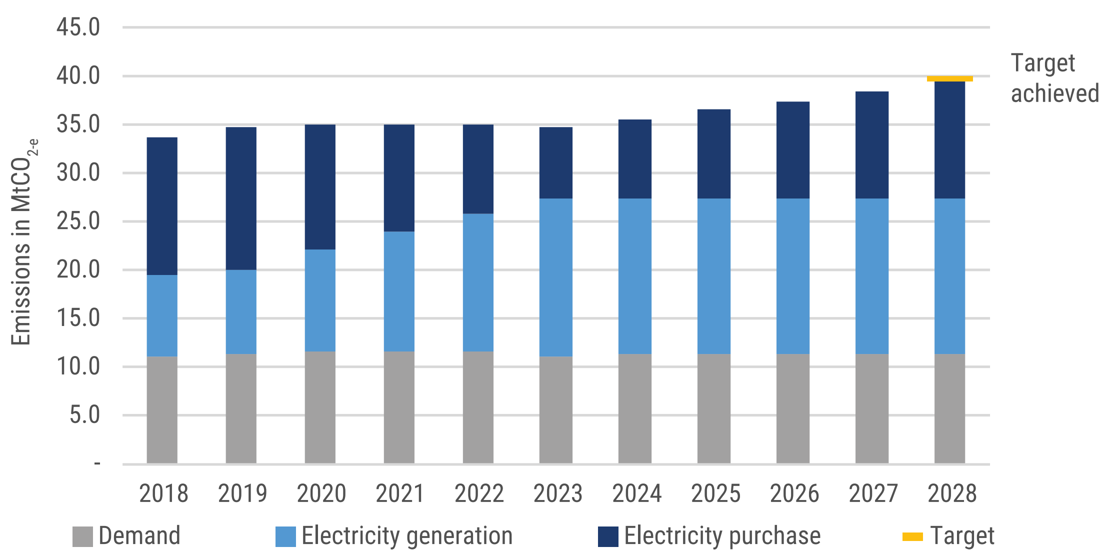
Based on the approach described above, Jakarta will need to ensure that its electricity has a renewable energy share of at least 51.6 per cent to be able to achieve its 30 per cent emission reduction target. Under this condition, the share of renewable energy in TFEC in this scenario will be 13.3 per cent. Figure 13 shows a breakdown of emissions in the power sector by different components – from energy consumption (demand), city's own generation of electricity and imported electricity. It also compares the total in 2030 with the city's emission target.

Increasing the share of renewable energy in imported electricity

Significant challenges exist for the city to increase the share of renewable energy in purchased electricity as the city currently does not have any control over how the electricity is produced on the JAMALI network. The following section outlines several pathways that the city can utilize to explore how to achieve this objective, without which Jakarta would not be able to achieve its emission reduction target.

a) Power purchase agreement (PPA): The city can enter into a special power purchase agreement with interested suppliers who are located along the JAMALI grid and will

Figure 13. Emissions in the SET scenario for the electricity sector by components



generate electricity at the required rate of renewable energy share (51.6 percent). In this process, there is a chance that the city will end up paying a premium for special condition, which could eventually increase the cost.

b) Renewable energy auction: A more workable solution and the recent trend is the renewable energy auction (see Box 4 for further information). This approach is likely to substantially decrease the cost of electricity supply and return a greater net benefit. The recent auctions e.g. the 60 MW solar PV auction in Cambodia has achieved US cents 3.87 per kWh (ADB 2019).

Box 4. Renewable energy auctions explained

A renewable energy auction, also known as a "demand auction" or "procurement auction", is essentially a call for tenders to procure a certain capacity or generation of renewables-based electricity. The auction participants submit a bid with a price per unit of electricity at which they are able to realize the project. The winner is selected on the basis of the price and other criteria, and a power purchase agreement is signed. The auctions have the ability to achieve deployment of renewable electricity in a well-planned, cost-efficient and transparent manner. Most importantly, it makes the achievement of targets more precise than would be possible by other means, such as a Feed-in-Tariff (FiT). Auctions are flexible and they allow Governments to combine and tailor different design elements to meet deployment and development objectives. Unlike FiTs, where the Government decides on a price, auctions are an effective means of discovering the price appropriate to the industry, which is the key to attracting private sector investment. In addition, an auction provides greater certainty about future projects and is a fair and transparent procurement process. However, the administrative and logistic costs associated with auctions are very high unless multiple auctions are undertaken at regular intervals.

- It is imperative that an auction be appropriately designed to (a) avoid the risk of underbuilding and project delays, and (b) allow sufficient competition among different levels of bidders in order to drive down the cost. IRENA suggests the following key design elements:

- Auction demand. Governments need to clearly indicate the scale or size of each auction, the preferred technology (technology neutral of a specific technology), auction frequency, and the upper and lower limits of projects size and price.

- Pre-qualification. A strict or high pre-qualification for bidders will leave out the smaller entities, while a relaxed pre-qualification may undermine the quality of the project and increase the administrative costs. Governments need to make a trade-off, depending on the project size and other development objectives.

- Selection criteria. Commonly two selection criteria are used: (a) the lowest bid where only the lowest bidder will win; and (b) lowest bids plus other objectives where in addition to the price, other objectives such as local content and jobs are taken into consideration.

- Payment modalities. The pay-as-bid model is good to minimize the cost; however, the marginal cost payment model, where the same price (selected based on the highest cost winner) is paid to all winners is also practised.

- Penalties for non-compliance. There could be cases where the developer either delays the project or fails to complete. To avoid such cases, penalties should be in place. There are two modes of penalty. In the monetary penalty, money will be deducted from bidder's "bond" or the price of energy will be reduced for a delayed completion. A form of non-monetary penalty can be the exclusion of the bidder from future auctions.

c) Promotion of urban solar PV. As Jakarta has a strong solar energy resource, the options to integrate solar PV in new buildings and to retrofit existing buildings as well as ground mounted, and floating solar PV systems should be investigated. The City of Jakarta could incentivize these developments through the planning requirements for new buildings, power offtake agreements for larger projects and establishing special zones for PV deployment including floating and ground mounted solar. Box 8 provides more detail on urban solar PV potential in Jakarta.

The City of Jakarta can implement any or a combination of the above approaches to achieve the 51.6 per cent RE share in purchased electricity. If renewable energy auctions alone were considered, the city would save $5.3 billion over the next 10 years, compared to the current policy, due to lower costs of renewable energy-based generation than fossil fuel. Table 6 presents cost of supply and potential savings in 2020, 2025 and 2030.

In Indonesia, the Central Government regulates how the RE auction should be implemented, however, there is no mention that it cannot be implemented at the local level. The city would need to work with the central government policymakers and the utility (PLN) for guidance on how an auction can be implemented and to determine what role the central government can play in the whole process. More importantly, the city government should advocate for a higher renewable energy share in the JAMALI grid which will accelerate the city's as well as Indonesia's effort to reduce its emissions and help achieve the 2030 target.

The city also has a great potential for waste to energy (WTE). The current waste management crisis means that it has become an urgent need to puts every effort to install WTE plants. Bantargebang, the city's largest landfill in West Java, is expected to reach its full capacity in 2021. Rapid installation of WTE plants can sustainably manage part of this crisis by diverting solid waste to WTE facilities.

To date, the only WTE pilot plant was installed in Bantargebang in March 2019 with a waste input of up to 100 tons per day and electricity generation capacity of up to 700 kW (Purningsih 2019). This pilot has been installed mainly for research and testing purpose, which will pave the way for

Table 6. Comparison of costs for different modes of electricity purchase and estimated savings for selected years

	2020	2030
Supply		
Electricity purchased from RE sources (TWh)	12.00	15.28
Electricity purchased at current mix (TWh)	11.26	14.33
Costs		
Cost of purchase from RE	465	592
Cost of purchase at current mix (million US$)	901	1,147
Total cost at 51.6% RE mix (million US$)	1,366	1,739
Savings		
Cost of purchase without increasing RE (million US$)	1,864	2,369
Savings for switching to high RE (million US$)	495	630

larger and commercial-scale WTE plants. With total waste generation of about 7,000 tons/day in the city, the potential for WTE is huge, and should be a top priority. WTE plants offer dual benefits – they address the waste management problem and generate emission-free electricity. An in-depth techno-economic assessment would help the city to better estimate the WTE potential and plan for future installations.

4.2.3 Energy Efficiency

Improvement in energy efficiency is of particular importance for the city to reduce its overall energy consumption, which will reduce the level of investment required in the energy sector and decrease the city's emissions level. Jakarta has great potential for improving its energy efficiency in all sectors, notably in the residential, commercial and transport sectors.

Energy efficiency in the residential sector at the city level

Energy efficiency in these sectors is implemented through the implementation of the Green Building Codes (GBC). The Jakarta Provincial Government, with the support of the International Finance Cooperation (IFC), the Swiss Government and the Government of Hungary, initiated GBC to realise the implementation of buildings that take into account the aspects of energy conservation and improvement in resources efficiency. This is mandated through the Governor's Decree No. 38/2012 on Green Building (Pergub 38/2012). This initiative aims to save 3,785 GWh of energy, 2.4 billion litres of water and 3.37 $MtCO_{2-e}$ of emissions.

Several mitigation measures in the energy sector have been listed as part of this initiative with more than 90 per cent savings coming from fuel switching in the power sector (Figure 14), which has already been modelled in this scenario under power generation. For buildings, GBC focuses on building envelope to reduce energy consumption. This scenario suggests retrofitting with more efficient appliances in residential buildings to take advantage of the enhanced energy saving potential.

Table 7 provides a list of appliances which should be replaced with more energy efficient versions. It also provides estimates of energy saving for each appliance. This estimation of energy saving has been based on the stock turnover analysis

Figure 14. Share of emission reduction by mitigation actions

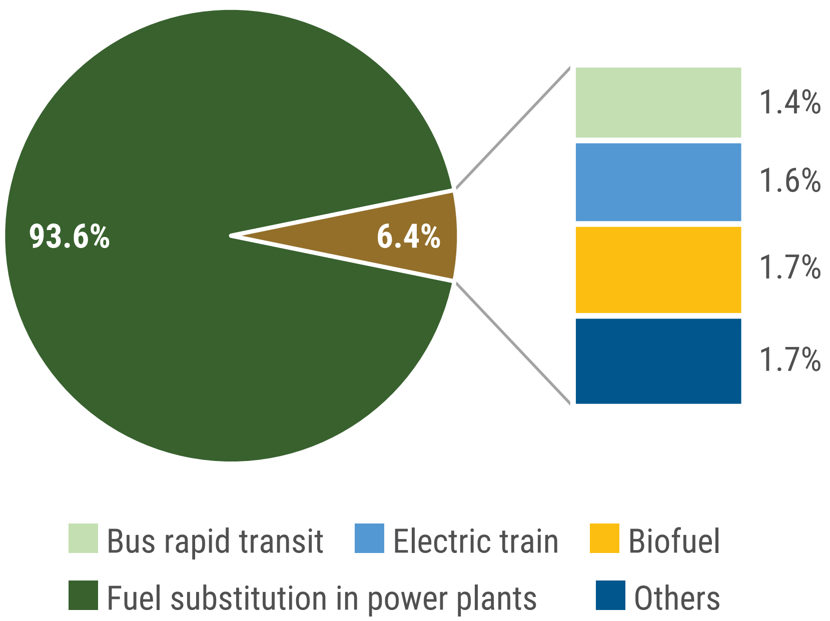


Table 7. Energy efficiency improvement potential in residential buildings

Appliance	Description of measure	Commencement Year	Annual saving (GWh)
Light	Replace CFL 14W by LED 5W	2022	1,250
Air conditioner	Replace old air conditioners with efficient version	2022	299
Refrigerator	Replace old refrigerators with efficient version	2022	1,077
Television	Replace old televisions with efficient version	2022	2,057
Electric fan	Replace old fans with efficient version	2022	796
Total annual savings			5,479

of appliances and using the energy efficiency database for appliances as presented in Annex 9.1. Assessment of energy efficient appliances, particularly for air conditioners, has been done in comparison with the minimum requirement for energy efficiency as outlined in the user guide for air conditioning and ventilation system under the Jakarta Green Building Code (DKI Jakarta 2011). For example, the code requires a split type air conditioner to have a minimum efficiency requirement of 1.3 kW per Ton of Refrigeration (TR), whereas the highly efficient air conditioners suggested in this analysis would have 1.0 kW/TR.

Similar energy efficiency measures have been applied in the commercial sector for appliances and equipment including lights, air conditioners and elevators. The combined annual average savings from this sector would be 2,473 GWh. Further energy saving measures are also suggested in the transport and industry sectors. These include:

- Convert 100 per cent of passenger buses to electric buses by 2030, this will save 517 ktoe annually by 2030. See an example of electric busses in China in Box 5.
- Change the wet process of clinker production in the cement industry to pre-heated process using pre-calciner kilns, this will save 73 ktoe annually by 2030.

All these measures will reduce city's 2030 energy intensity from 2.05 MJ/US$ in the BAU scenario to 1.71 MJ/US$ in the SET scenario. It is important to note that while electrification of vehicles increases energy efficiency, it does not necessarily a low-carbon measure unless the electricity supply is decarbonised. This reinforces the need for increasing the share of renewable energy in electricity generation.

4.3 Investment

The investment costs for city's own generation in the SET scenario are estimated at $869 million by 2030, same as in the CP scenario. This is because the generation side in this scenario has been modelled to remain unchanged. The cost of supply, including the cost of electricity purchase for both at the current mix and 51.6 per cent RE mix, has been presented in section 4.2.2.

Box 5. Electric Buses in Shenzhen, China

Shenzhen is located in southeast China with a population of 12.13 million people and was designated as a special economic zone in 1980. Shenzhen is a leader in electric buses with the world's largest and first fully electric bus fleet. In the period 2013 to 2018, bus passenger ridership on Shenzhen Bus Group Co. Ltd (SZBG) declined by an average of 8 per cent every year due to the development of the metro system. However, the trend was reversed following the full electrification of bus fleet in 2017 with passenger ridership increasing by 2.4 per cent. The electrification of bus fleet has provided multiple benefits to the city, a comparative analysis on GHG emissions by SZBG indicated a significant reduction in GHG emissions and local air pollutants saving 194,000 tons of carbon dioxide annually based on a total annual bus operation mileage of 374.11 million km in 2018. (Berlin, Zhang, and Chen 2020)

5. Ambitious scenarios

The SET scenario has been further analysed to identify the best way forward for Jakarta in transitioning its energy sector to 2030. This analysis shows that there are opportunities and benefits for Jakarta from raising its ambition e.g. to promote low-carbon transport initiative and fully decarbonising the power sector. These options are discussed in this chapter.

5.1 Sustainable Transport (ST) Scenario

Currently, as well as under the CP scenario, the transport sector is the highest energy consuming sector in Jakarta with 34.4 per cent share of TFEC in 2020. Additionally, a large number of vehicles are old and inefficient, as there are no strict standards, which creates massive air pollution and GHG emissions. This high energy consumption in the transport sector also places a lot of pressure on the imported petroleum fuel. Development of a sustainable low-carbon-based transport system, therefore, is, very important for Jakarta. This section discusses the current situation of the transport system and the pattern of energy consumption, presents future growth and explores opportunities for reduced energy consumption to recommend a sustainable transport scenario for Jakarta.

5.1.1 Status of transport system and future growth

In 2020, the total travel distance for passenger vehicles was recorded at 262 billion passenger-km, which is projected to grow by 3 per cent annually to over 350 billion passenger-km in 2030. The shares in 2020 were private car, 13.5 per cent; bus, 68.5 per cent; motorbike, 17.8 per cent; and non-motorized vehicles (e.g. bicycle), 0.2 per cent. Additionally, there are freight vehicles and other commercial vehicles. Jakarta is well known for traffic congestion. The Ministry of Transportation of Indonesia estimated that the economic losses due to traffic congestion in 2010 was about $1.3

billion, which was expected to rise to $6.5 billion by 2020 (Sinaga 2015). Several policy options were developed by the Ministry to ease the traffic congestion. One of these is increasing public transport from 24 per cent in 2016 to 60 per cent in 2029.

Jakarta's Bus Rapid Transit (BRT) Transjakarta, began in January 2004, is undergoing continuous improvement and is helping to ease peak hour traffic congestion. At 251.2 kilometres long, the world's longest BRT system has received the Sustainable Transport Award 2021 (ITDP 2020). Jakarta is also working on expanding its cycling network to 500km and the first 63km has already been built. The initial response from cyclists is very good – showing an increase of cycling practice by up to 1,000 per cent (in some places), see Box 6 for further information.

5.1.2 Sustainable transport strategy

In light with the above initiatives and considering best practices in other cities, the following strategies have been applied in the sustainable transport scenario model:

a) Fuel economy standards: Fuel Economy Standards for Light Duty Vehicles (LDVs) to improve average fuel economy from 12 km/l to 20 km/l, based on the promotion of hybrid vehicles.
b) Modal Shift: Encouraging public transport (BRT, MRT) by improving services is modelled in the scenario with the passenger km for public transport increasing by 10 per cent by 2030 from the current state, which is expected to reduce private car passenger-km from 13.5 per cent in 2020 to only 6 per cent in 2030.
c) Electric vehicles: Electrification of buses to increase from 3 per cent in 2020 to 100 per cent in 2030.
d) Non-motorized mobility (bike pathways): As the bike pathway network is at an initial stage of development and its completion date is unclear, only a 1 per cent increase in non-motorized mobility by 2030 has been modelled in this scenario.

5.1.3 Energy demand outlook

In this scenario, TFEC in the transport sector decreases significantly with the implementation of the above-mentioned strategies – reducing 2030 energy demand to 2.8 Mtoe compared to 4.2 Mtoe in the current policy scenario. This also leads to an overall reduction of TFEC for Jakarta – dropping to 9.5 Mtoe in 2030, compared to 10.2 Mtoe and 12.1 Mtoe in the STE and CP scenarios,

Box 6. Bus Rapid Transit system of Jakarta wins the sustainable transport award 2021

This prestigious win is the culmination of the years of hard work that Jakarta has put in to improve its transportation system. Transjakarta, opened in 2004, has a total system network of 251.2 kilometres and is considered the world's largest BRT system. In the past few years, the city has created a system of bus-only lanes and stations that zip passengers around the city, circumventing regular traffic. It has a network that connects smaller vehicles, like local buses and paratransit operators, alongside BRT buses and their lanes. The BRT system is gaining more popularity over time as commuters discover the benefits and more improvements are being made to the system e.g. the integration of Transjakarta with medium sized bus operators and informal microbus operators. In February 2020, the authorities recorded the highest ridership, which passed 1 million per day. In the future, the authorities plan to implement multimodal integration with light rail transit and mass rapid transit to enable more people to cover greater distances with fewer transfers.

Jakarta also aims to increase bicycle commuting in the city and is in the process of constructing a 500km cycling network, the first 63 km of which are already in place. ITDP has recorded a 500 per cent increase in bicycle commuting city wide and a 1000 per cent increase in specific stations, measured in mid-2020 compared to the same time the previous year. The Chief Executive Officer of ITDP informed the city government that constructing car-based infrastructure is no longer a good option for the city dwellers, instead focus should be given on alternative transport modes, including a mass rapid system and non-motorised mobility.

Source: (ITDP 2020)

respectively. Figure 15 shows reduction of energy consumption the in the transport sector and Figure 16 shows energy savings for different passenger car categories from fuel efficiency standards under the ST scenario in comparison with the current policy scenario.

It is expected that the cycling network, when fully completed, would significantly reduce the use of motorized vehicles, including public transport. This will contribute to a significant energy and emissions savings and improve the local environment. As it is difficult to estimate what would be the correct figure of such an increase once the 500 kilometre cycling network is completed, an assumption of 1 per cent has been made to include its impacts. Further analysis would be needed as the construction of the cycling network progresses and more data of passenger kilometres becomes available.

5.1.4 Emissions

In this scenario, Jakarta's overall emissions in 2030 reduce from 51.2 $MtCO_{2\text{-}e}$ in the current policy scenario to 39.6 $MtCO_{2\text{-}e}$ – a 22.6 per cent drop. This decrease is mainly due to the measures implemented in the transport sector, including introducing fuel economy standards and electrification of buses. In the BAU and current policy scenarios, the transport sector contributes to three-quarters of the demand side emissions (73 per cent in CPS, equal to 10.2 $MtCO_{2\text{-}e}$), of which 71 per cent from the consumption of

Figure 15. Reduction of TFEC in the sustainable transport scenario compared to CP scenario

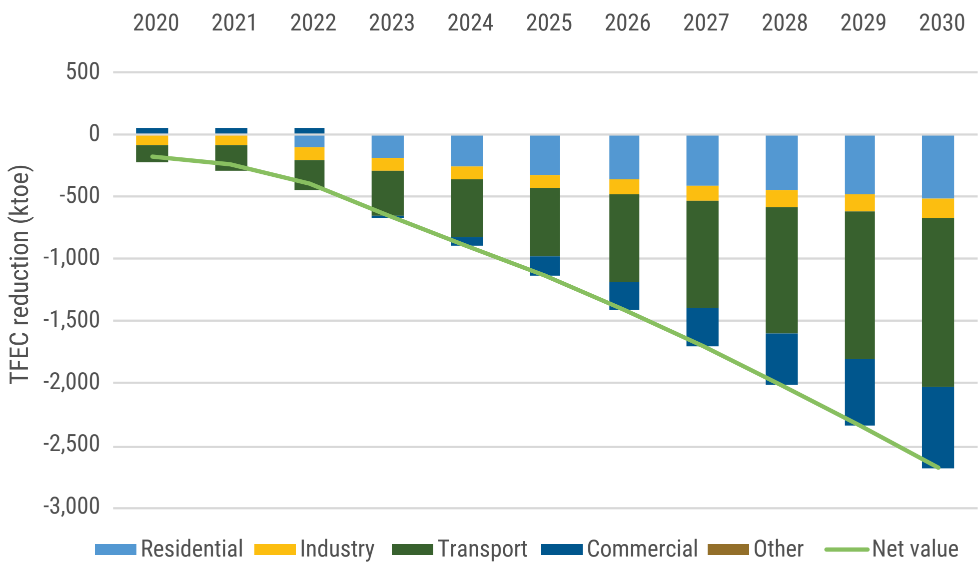
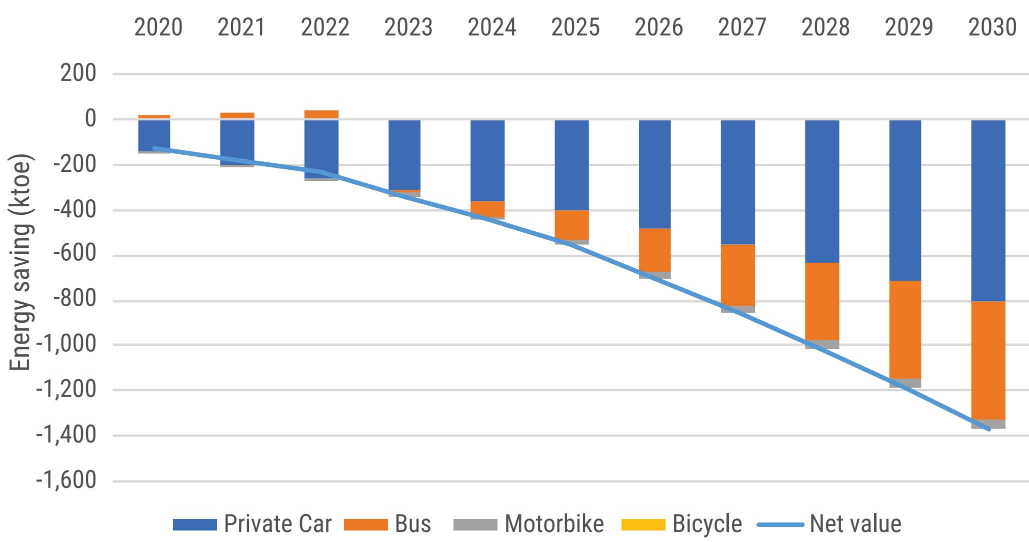


Figure 16. Energy savings from fuel economy standard in LDVs



gasoline fuel and the remaining from diesel. In the sustainable transport scenario, emissions are reduced significantly to 7.5 $MtCO_{2-e}$ due to the implementation of sustainable transport strategies. Figure 17 shows the reduction of emissions from different fuel use in the sustainable transport scenario in comparison with the current policy scenario.

5.1.5 Interventions already in progress

The City of Jakarta has been already implementing several interventions in relation to sustainable transport. This include, for example:

Infrastructure development

- Prioritising pedestrian movement and encouraging non-motorized vehicle use. The development of the Kendal Tunnel Arrangement has enabled movement of up to 5,000 pedestrians per hour during peak hours. The length of the sidewalk lane has been increased to about 200 kilometres in 2019.
- Optimizing public transportation use as the backbone of the transportation system.
- Increasing bike pathway to 63 kilometres (2-way) with a target to increase to 200 km.
- Encouraging emission-free vehicles as a solution to Jakarta's air pollution.
- Two units of electric bus trials have been completed for 6 months from 1 July 2020 - 31 December 2020. The next trial will be in 2021 with 100 buses.

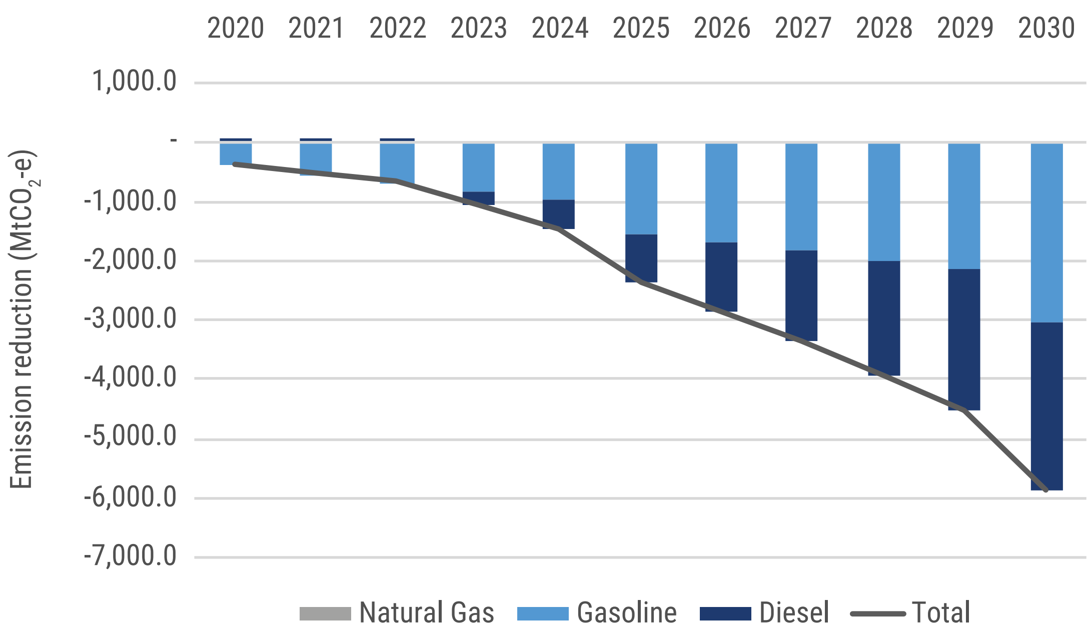
Enabling policies

- Cost of transfer (BBN) tax exemption for electric vehicles.
- Electric vehicles are exempted from the odd even policy.

Innovations for reforming the transportation sector:

- The DKI Jakarta Provincial Government is collaborating with ITDP, DKI Jakarta society and other organizations in order to create a better system transportation, such as by:
  - Making way finding Signage at Cipete Raya MRT Station.
  - Cycling-friendly school activities at Gandaria Selatan.
- Increased mobility for society, the Jaklingko (integration of tariffs and payments) is now serving about 2 million passenger/day.
- Increased access and safety for pedestrians and cyclists.
- Contribution of transportation in sector reducing GHG and air pollution data. The use of Transjakarta reduces 78,016 tCO_{2-e} while the MRT reduces 6,681 tCO_{2-e} per year.

Figure 17. Reduction of emissions from different fuel consumption in the ST scenario compared to the CP scenario



5.2 Towards NetZero (TNZ) scenario

This scenario, in line with the global move towards NetZero Carbon cities, has been developed to provide a range of analytical information for the City of Jakarta on policy directions that will help its aspiration to transition towards NetZero city. This scenario, inherited from the ST scenario, includes further ambitious measures with an aim to reduce GHG emissions from both energy demand and supply. However, careful thoughts have been applied to ascertain what can be achieved during the 10-year analysis period (by 2030) without causing negative impact on the economy. The analysis informs that an absolute NetZero Carbon cannot be achieved in this short analysis period unless some substantial changes in the energy system is undertaken without affecting the economy. For example, the achievement of NetZero will require early retirement of the existing combined cycle gas turbine power plants, which will cause financial losses. Therefore, this scenario has taken a rather conservative approach and avoided making such recommendations. Such strategies/assumptions have reduced the ability to completely eliminate emissions, but the overall emission has reduced substantially, making it a pathway TOWARDS NetZero Carbon. These strategies are discussed in the following sections.

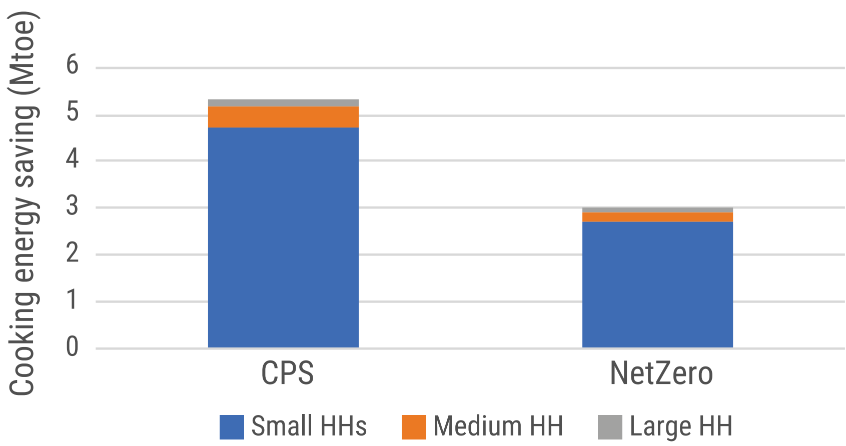
5.2.1 Increasing energy efficiency in cooking with induction cookstoves

Currently, over 80 per cent of households use LPG for their cooking energy supply. While LPG is a clean fuel, compared to biomass and kerosene, most LPG is imported, which is subject to price volatility and supply disruption. LPG burning for cooking is also very inefficient. High-efficient induction-type electric cooking stoves, on the other hand, are highly efficient. These use electromagnetic energy to directly heat pots and pans and are 70 - 90 per cent efficient in converting electrical energy to heat. Induction cookstoves and utensils are widely available in the market these days and are relatively inexpensive. Even using the lower band of efficiency (70 per cent), the residential sector would save 2.3 Mtoe over 10 years, compared to CPS (Figure 18). The move to induction-type electric cookstove will increase electricity demand in the residential sector by about 11 per cent compared to SET scenario but will remain significantly less than CPS.

As shown in Table 5, the annualized cost of electric cookstove is lower than LPG cookstove, however, some government incentives maybe needed to encourage households to make the shift. For example, the City Government may offer 50 per cent cost subsidy for induction cookstoves which will cost about $60 million over 10 years. This measure would not only reduce overall energy consumption but also will reduce import of LPG for Indonesia.

Electric cooking is increasingly gaining momentum globally. The primary motive of this move is to provide access to clean cooking fuel and to replace use of traditional biomass for cooking. However, several studies suggest that cooking with induction-type electric cookstoves save both money and time. The Modern Energy Cooking Services (MECS) initiative presents a comparison between LPG cookstove and induction-type electric cookstove and argues that while LPG is a clean fuel and provides some

Figure 18. Savings in cooking energy by switching to induction cookstove



levels of flexibility e.g. easy flame control; electric cooking is much more efficient and reduces price volatility and the cost of additional infrastructure such as distribution networks (Parikh et al. 2020). While discussing the case of rural areas without access to clean cooking, MECS suggests that electric cooking is a better option in areas where electricity is available, even when compared to LPG. Therefore, at the city level, where continuous electricity supply is available, electric cooking with high-efficient induction stoves is an appropriate technology choice.

5.2.2 Electric motorbikes for a cleaner city environment

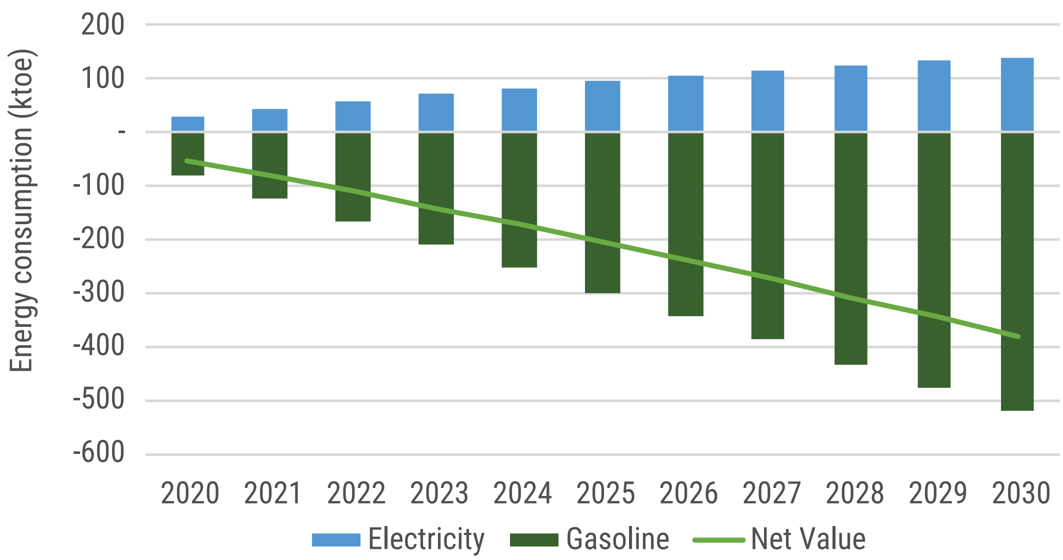
Motorbikes are an important mode of transportation in Jakarta. In 2018, there were about 3 million motorbikes registered in the city which travel over 43 billion passenger-km annually. These motorbikes are primarily gasoline, generating about 1.7 $MtCO_{2\text{-}e}$ of emissions annually, which is expected to rise to 2.3 $MtCO_{2\text{-}e}$ by 2030. The previously discussed ST scenario suggested reducing private car use by increasing mobility in public buses, which is expected to reduce private car travel down to about 6 per cent in 2030. In this Towards NetZero scenario, full electrification of private cars has been recommended. More importantly, this scenario recommends up to 50 per cent electrification of motorbikes, which would reduce annual energy consumption in the motorcycle category only by 382 Ktoe by 2030, compared to the ST scenario (Figure 19). The assumption of 50 per cent (a precise share was not available) has been based on the fact that a large number of motorcycles is used for passenger transportation, owned and operated by low income group who may not be able to afford the increased cost of electric motorcycles.

Myth about operating cost and emissions from electric vs petrol motorcycle

There are views in the community that electric motorcycles cost more to operate and they emit more emissions compared to petrol versions. (Koossalapeerom et al. 2019) undertook an in-depth study to compare energy consumption, operating costs and GHG emissions in Khon Kaen City of Thailand. The study involved measuring speed, duration of trip, energy consumption and emissions from the exhaust pipe under the real-world driving patterns. Several measuring instruments and sensors were fitted to target motorcycles e.g. a rear wheel speed sensor, mobile exhaust gas analyzer, fuel consumption sensor and an electric flow meter. The study suggests that electric motorcycles cost 5.7 times less to operate, consume 8.16 times less energy and generate 2.24 times less emissions compared to standard internal combustion powered motorcycles[1].

1 The emissions estimation in this study, however, has been found to be conservative which may have been the way it has been measured. In fact, the emissions from burning 2.43 liters of petrol would be 5.8 $kgCO_2$ resulting in 58.32 gCO_2/km in which case, petrol motorcycles will emit 4 times more emissions.

Figure 19. Energy consumption in motorcycle category by switching to 50 per cent electric version, compared to ST scenario



Parameters	Unit	Electric motorcycle	Petrol motorcycle	Difference/ ratio (petrol vs electric)
Avg. speed	km/h	22.50	22.60	0.4%
Avg. acceleration	m/s2	0.64	1.42	121.8%
Energy consumption	L/100 km		2.43	-
	kWh/100 km	2.80	22.84*	8.16
Energy cost	Baht/km	0.113	0.646	5.7
Emissions	gCO_2/km	14.17	31.81	2.24

* Calculated using 1 L of gasoline ≡ 34 MJ ≡ 9.4 kW h

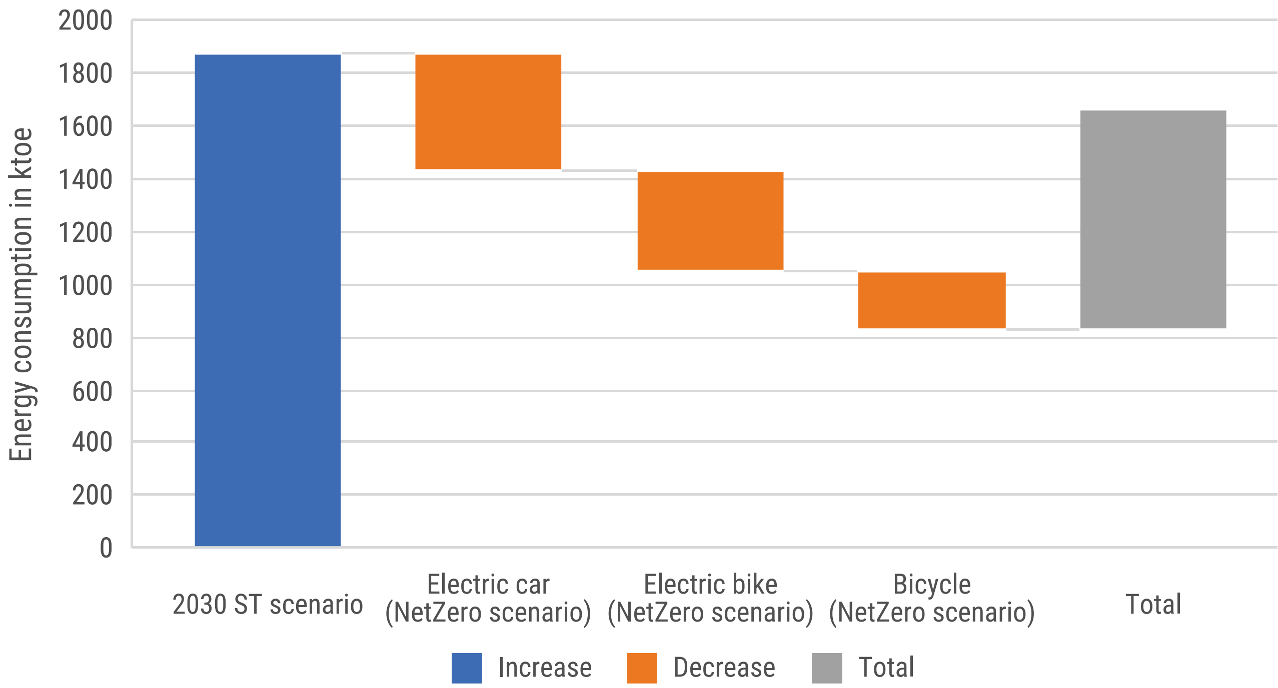
5.2.3 Cycling for better health, better environment

In this scenario, in addition to switch to electric cars and electric motorbikes as discussed in the previous section, increased use of bicycles as a form of transport is recommended. The popularity of cycling in city settings is increasing all over the world, including in Asian cities and thus it is important that a conducive environment for cycling is created. Also, availability of cycling infrastructure and mechanisms to motivate cycling are critical elements in building a smart NetZero city, (see Box 7). In this scenario, a 10 per cent increase in cycling has been modelled which is considered to reduce car and motorbike related passenger kilometres by the same percentage. Figure 20 shows the reduction of energy consumption by different transport types in the Towards NetZero scenario compared to the total consumption in the ST scenario.

5.2.4 Electricity demand and supply

The demand for electricity by 2030 in this scenario will increase from 35.4 TWh in 2020 to 50.7 TWh

Figure 20. Reduction in energy consumption by vehicle type in NetZero scenario compared to ST scenario



Box 7. Mobility with bicycles for a smart city

The concept of smart city is the underpinning principle of a sustainable city, and non-motorised mobility such as cycling is one of the key features of a smart city. The use of bicycles as a mode of city mobility is getting increasing popularity – not only in Europe and the US but also in Asia. The benefits of cycling in cities are far reaching:

- Bicycles use less space on the road than cars and increased cycle use with modal change from cars can lead to less congestion. Also, parked cycles use less space than parked cars and free up valuable space in the city environment.
- Bicycles do not emit any air pollutants while most other engine driven transport modes emit, for example, PM and NOx.
- Cycling is a more affordable transport mode than a car.
- Regular physical activity reduces the risk of diabetes, some sorts of cancer, obesity and many other diseases.
- Cycling makes the city a more pleasant place to live. A healthier, safer and less polluted city makes it more liveable. People who commute by bicycle are healthier and more productive. A study of 30,604 people in Copenhagen revealed that those who travel to work by bicycle has a 40 per cent lower risk of death over the course of the study than those who didn't. Also, bike commuters had fewer days of sick leave each year than others (smartcity 2019).

The need to introduce and encourage cycling in Asian cities is more important given the severe traffic congestion on roads that waste time and fuel and reduces overall productivity. Some cities in Asia are gearing up to increase cycling in a bid to improve mobility and reduce local air pollution. Seoul has a long cycling route running through the heart of the city. There are paths alongside both sides of the Han River with a total length of more than 100km, and paved bicycle pathways that are lit up at night. The Housing and Urban Affairs Ministry of India has launched India Cycle4Change Challenge, where in the first phase, 10 cities will be selected and will receive technical support from the central government to create extensive cycling networks and supporting infrastructure (SCCI 2020).

Cities need to develop cycling strategies and mobilise investment in creating cycling infrastructure as well as incentives to encourage cycling. While doing cycle plans, it is important that cyclists are recognised as essential aspects of city planning and design and treated equally.

in 2030 (Figure 21 - an increase of about 8 per cent compared the ST scenario but 8 per cent lower than CPS. This increase compared, to the ST scenario, is due to higher rate of transport electrification – mainly motorcycles and switching to electric cookstoves.

On the supply side, the following measures are recommended:

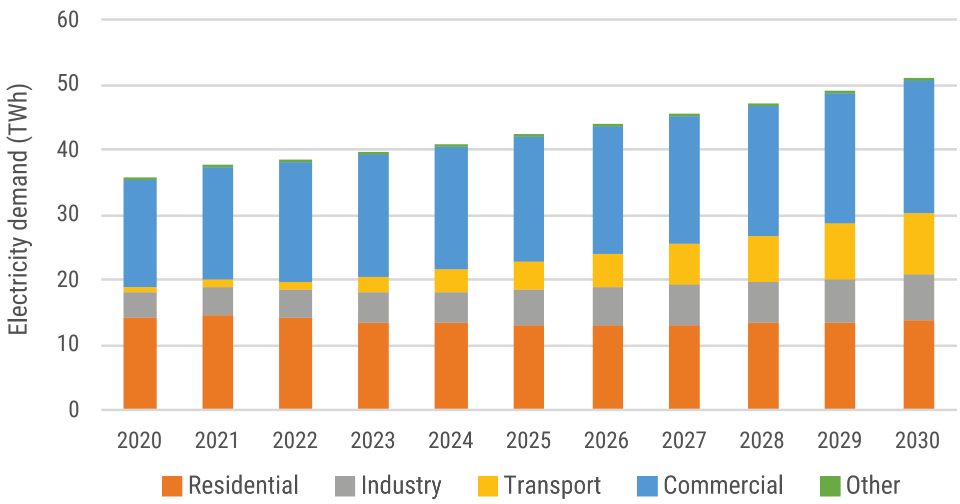
City's own generation:

- The city will continue to generate electricity from the already installed 3.7 GW of CCGT power plants. However, it is recommended to discontinue the plan for additional 700 MW of CCGT. This assumption, compared to immediately stopping all gas-based generation, has been made to avoid any financial losses from the existing assets that are already in operation. Instead, the plan recommends that no more investment in fossil fuel-based generation is made.
- The oil steam generation is gradually reduced to zero by 2030. This is because the cost of oil-based generation is already expensive (LCOE of oil-based is $125.13/MWh compared to $51.79/MWh for CCGT) and the cost is expected to increase further over time.
- Utility-scale solar PV should continue as planned (32.5 MW by 2030).
- Waste-to-energy should continue as planned (85 MW by 2030).
- Wind should continue as planned (1 MW by 2030).
- Rooftop solar PV should be introduced in the city, aiming for 900 MW by 2030.
- This study has avoided making recommendations to further increase city's own generation for the following reasons – (a) power plants are investment intensive – city would be better off increasing the share of renewable energy through specifically designed power purchase agreement (PPA) and/or renewable energy auction. Rooftop solar PV, on the other hand, would not be city's own investment rather would be done by the business, communities and households. The City may need to provide some forms of incentives and facilitation to kick start the market. See Box 8 for more information on rooftop solar PV.

Electricity

- In this scenario, the city will continue to import electricity from the central grid, on an average 24.5 TWh per year. As it has been recommended

Figure 21. Electricity demand by sector in the Towards NetZero scenario



in the SET scenario that the city should invest through renewable energy auction to increase the share of RE in imported electricity, this Towards NetZero scenario recommends two different options – a 50 per cent renewable energy mix (note that this is slightly less than the SET scenario because a higher electricity import requirement due to the increased in demand compared to the SET scenario) and a 100 per cent renewable energy mix (Table 8). These options are to demonstrate the impact of emissions in increasing the share of renewable energy, city would be able to make a right judgement of the choice of the renewable energy mix depending on its financial resource availability. Emissions and cost of import for these two options are discussed in section 5.2.5.

5.2.5 Emissions

As mentioned above, two different options for renewable energy mix have been suggested for imported electricity – (a) 50 per cent and (b) 100 per cent, to demonstrate the cost of import and emission reduction potential. In both cases, renewable energy auction has been chosen as the preferred mechanism due its comparatively lower cost compared.

Emissions in this scenario reduce to 27.8 $MtCO_{2\text{-}e}$ and 17.2 $MtCO_{2\text{-}e}$ for the 50 per cent and 100 per cent renewable energy mix options respectively. While in both these options, emissions from the demand side as well as from imported electricity are reduced substantially, the emissions from city's own generation remains almost unchanged. They reduce slightly in this scenario due to no new investment in fossil fuel, elimination of oil steam-based generation by 2030 and introduction of solar rooftop PV.

Table 8. Cost comparison between 50 per cent and 100 per cent RE mix options for imported electricity 2020-2030

	Segments of electricity import	Total 2020-2030 (million US$)
Option 1: 50% renewable energy mix	Cost of 50% RE-based supply	5,220
	Cost of current mix-based supply	10,771
	Total cost of import	15,991
Option 2: 100% renewable energy mix	Cost of 100% RE-based supply	10,440
	Cost of current mix-based supply	-
	Total cost of import	10,440

Box 8. City community can become prosumers through rooftop solar PV

There is a good potential for solar rooftop PV in the greater Jakarta. Estimates indicate that the technical rooftop PV potential on the city's government buildings, ministerial buildings, state hospitals, universities and big shopping centers is up to 22 MW. However, adding to this the potential on residential buildings (with an assumption of 2 kW system each on eligible rooftops), total rooftop solar potential in the greater Jakarta would be about 1200 MW (Caroline 2019; Tumiwa and Damayanti 2019). However, in the Towards NetZero scenario, up to 900 MW has been modelled by 2030 – this is to allow for 25 per cent of households (assumption) that may not be able to install systems by 2030.

Solar rooftop is also a national interest. In line with the 23 per cent renewable energy target, the Government of Indonesia planned to install solar rooftop systems on at least 800 public buildings across the country in 2020. In this regard, the Ministry of Energy and Mineral Resources (MEMR) has allocated $12.76 million to support the installation of such systems on several buildings types including boarding schools, clinics, orphanages, government offices and police stations. Of the 800 systems, the majority (51 per cent) will be less than 5 MW each, 32 per cent up to 25 MW each, 11 per cent up to 50 MW each and the remaining are very large (above 50 MW each). However, the plan has now been delayed due to the COVID-19 pandemic.

6. Rebuilding better in the recovery from COVID-19

Energy plays a key role in rebuilding better in the recovery from the COVID-19 pandemic. Energy services are essential to supporting health-care facilities, supplying clean water for essential hygiene, enabling communication and IT and powering refrigeration with off-grid renewables for vaccine storage. Economic challenges resulting from the pandemic have the potential to force countries in the Asia-Pacific region to focus on short-term fixes to revive GDP growth, potentially undermining long-term sustainable development. In the energy sector, this can result in the decline of investment in clean energy development – slowing progress in renewable energy and energy efficiency, and eventually, impeding national economic growth.

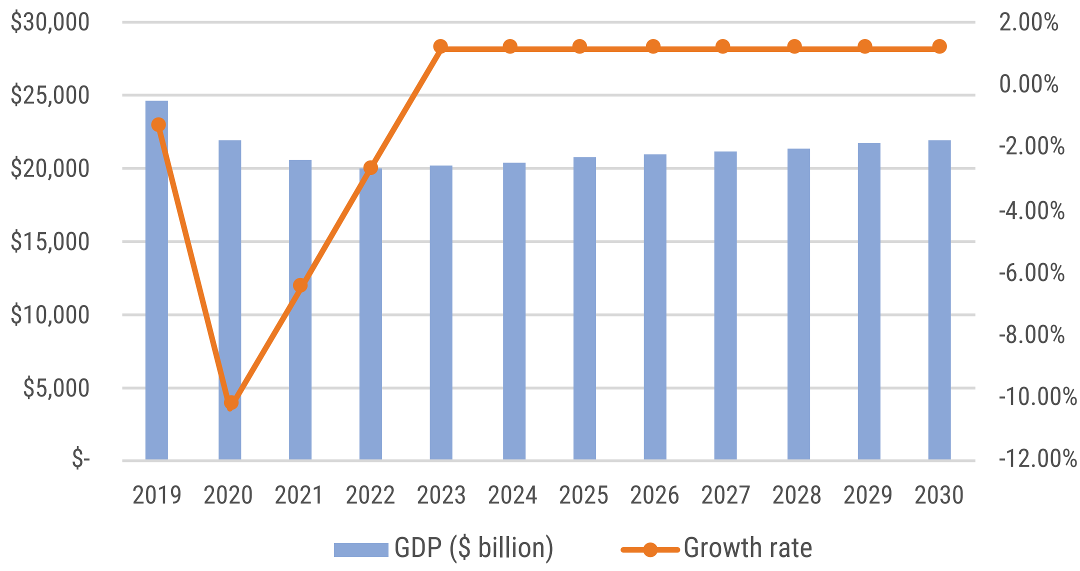
The lockdown measures to contain COVID-19 have led to economic contraction in Jakarta and are expected to cause a short-time impact on energy demand. In December 2020, the Indonesian Government announced a 2.2 per cent GDP contraction, driven by shrinking household spending (Jakarta Post 2020), dropping to 3.7 per cent for Jakarta. The World Bank (World Bank 2020) estimates that in a quick recovery scenario, the economy will rebound to 4.4 per cent growth in 2021. However, for a slower recovery the organisation projects that GDP will further contract in 2021 to 3.1 per cent before it starts to regain to 3.8 per cent in 2022. At this rate, it is assumed that Jakarta's economy will return to the current growth rate of 5.89 per cent in 2025.

Additionally, the manufacturing industry in Jakarta has experienced a decline in GDP of 1.22 per cent in 2019 and a further decline of10.34% in 2020[2]. Figure 22 shows how the industrial GDP will be impacted, even considering that it would recover in 2023.

This will impact the final energy consumption in

2 values suggested by the City Authority

Figure 22. Impact of COVID-19 on the manufacturing sector



the industry sector – a drop of about 55.5 per cent, which will reduce the future growth in the overall energy consumption for Jakarta to 10.7 Mtoe – a drop of 12.2% compared to the CP policy (Figure 23).

6.1 Accelerating access to clean cooking

About 42,000 of Jakarta's households still lack access to clean cooking fuel. One medium-term impact of COVID-19 could be decreased investment in energy access, as budgets come under strain and priorities shift. Under-investment in this area would have an impact on the quick recovery from COVID-19. As vaccines are currently being rolled out, cold storage and refrigerated transportation around the city are needed. Renewable energy technologies such as solar can offer enormous opportunity for large-scale immunisation efforts.

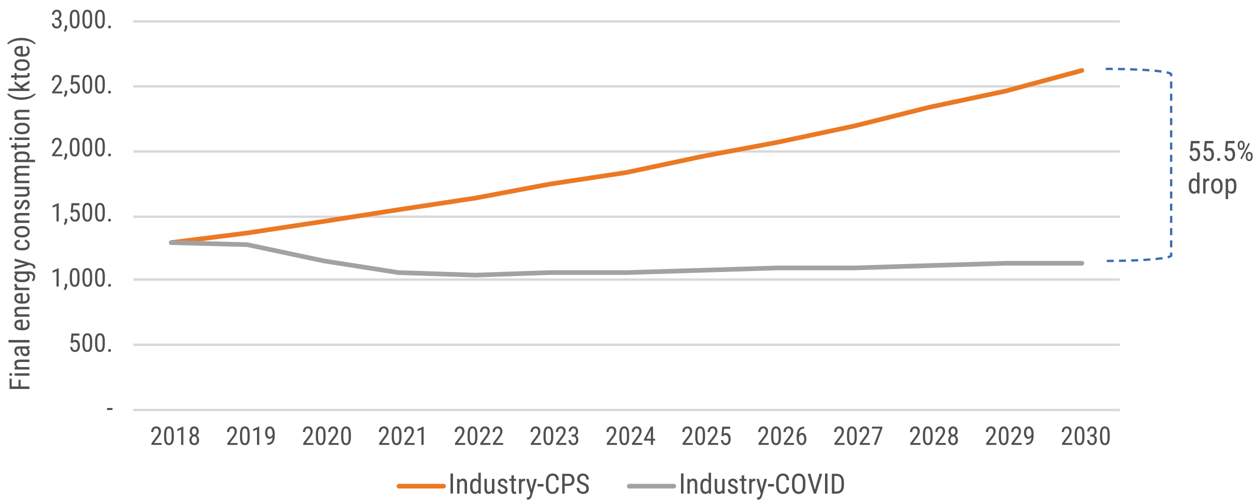
Access to clean cooking technologies is a development challenge that is often forgotten. WHO has warned about the severity of health impacts arising from the exposure to traditional use of biofuel for cooking and is encouraging policymakers to adopt measures to address this challenge. Moreover, scientists are already investigating links between air pollution and higher levels of coronavirus mortality, with preliminary results showing a probable correlation between the two (Aarhus University 2020).

The SET roadmap has analysed and identified technical options for connecting the remaining population to cleaner fuel for cooking and has estimated the cost of the measure. The benefits resulting from this measure, in the form of reduced mortality and health impact, will exceed the required investment of $1.67 million.

6.2 Reducing financial risks by reshaping the power sector

Lower electricity demand, if continued over a longer period, may place the CCGT generators in Jakarta in a difficult economic position of constrained output and dwindling revenues - requiring larger subsidies for their survival. By contrast, renewable energy power plants face relatively lower economic impacts compared to their fossil fuel counterparts. In many power systems, renewable outputs are dispatched first to the power market, meaning they can continue to sell their energy unimpeded. As a result, many national grids have seen the penetration of renewable energy shoot up to levels not expected for the next decade – thus providing both a stress test of the system and a glimpse of a high renewables future.

Figure 22. Impact of COVID-19 on the manufacturing sector



6.3 Savings from the energy sector will help to build other sectors

The NEXSTEP analysis shows that there are ample opportunities for the City of Jakarta to save energy by improving energy efficiency beyond the current practices. As highlighted in the previous chapters of this report, several cost-effective energy efficiency measures can be implemented in the residential, commercial, transport and industrial sectors that will result in net financial gain – with annual energy savings of over 1,100 ktoe. Savings from this improvement can help investment in other sectors, such as health, social protection and stimulus, which are critical in responding to and recovering from the COVID-19 pandemic.

An example of energy saving measures is the Government's current policy through the Green Building Code. The SET scenario, however, has recommended a further reduction of energy consumption in buildings through benchmarking energy performance at the appliance-level. There is also potential for implementing energy efficiency in the transport sector, e.g., by promoting electric vehicles. This has a multitude of other related benefits (in addition to energy saving), including the reduction of expenditure on importing petroleum products, reducing local air pollution as well as the potential for Indonesia to become a manufacturing hub for electric vehicles where Jakarta is likely to be core centre of business. This will provide a large number of jobs. At the same time, other options for sustainable transport also need to be explored. These include: (a) avoiding the need to travel through integrated land-use planning and transport demand management; (b) shifting travel to the most efficient or clean mode, e.g., non-motorised (bicycle) or public transport; and (c) improving the environmental performance of transport through technological improvements to make vehicles more energy-efficient and less carbon-intensive. Such measures are very important to solidifying the pathway to recovery from COVID-19 and rebuilding better.

7. Policy recommendations

7.1 Share of renewable energy in the power sector

The City of Jakarta can increase the share of renewable energy in the power sector to achieve the Governor's emission reduction target. Currently, half of Jakarta's electricity supply is imported from the national grid, the other half is generated within the city. Given that the city would need to increase the share of renewables in the externally sourced electricity, the NEXSTEP analysis suggests that the city should consider investing more in renewable energy-based electricity supply.

In 2018, the city imported about 68.7 per cent of its total 32 TWh of electricity needs from the Java-Bali network which has a 9.6 per cent share of renewable energy. The remaining approximately 10 TWh, was generated within the city with a 0.3 per cent share of renewable energy. When combined, the weighted average of the share of renewables in the power sector is 6.7 per cent. In the current policy scenario, the share is likely to be reduced further as the city plans to expand its fossil-fuel based generation.

This is an impediment to the city's target of emission reduction to 31.5 $MtCO_{2-e}$ by 2030. The NEXSTEP analysis identifies and suggests that the best way forward for the city is to invest more in sourcing renewable energy-based electricity supply. There are several ways that the city can progress this objective. One option is to negotiate with potential suppliers/generators, for a special power purchase agreement that ensures a higher share of renewable energy in the generation mix. The minimum RE mix required to achieve the Governor's emission reduction target (31.5 $MtCO_{2-e}$ by 2030) is 51.6 per cent. The other option is to take advantage of renewable energy auction mechanism, which helps to achieve a competitive price than a mutually negotiated PPA.

Section 4.2.2 provides details of cost-benefit analysis of increased share of renewable energy in the supply system and Box 4 provides details of renewable energy auction mechanism.

7.2 Improvement in energy efficiency in the building sector is the low hanging fruit

Energy efficiency improvement in the building sector offers a cost-effective and large potential for energy saving from both the residential and commercial sectors. While the Building Code is already in place in Jakarta, there are opportunities for further expansion of this code to mandate adoption of energy efficient technologies and benefit from a greater savings in energy. The city should consider implementing such measures in the residential and commercial sectors across the most energy consuming appliances to take advantage of the least-cost measure and reduce overall energy consumption and associated emissions.

Jakarta being the business hub and the capital of the nation, has a large building stock, particularly in the commercial and residential sectors, which consumes about half of Jakarta's energy demand. Energy efficiency measures in the building sector has the potential to significantly reduce energy demand, which are also considered to be low-cost options. Additionally, these measures will contribute to the achievement of city's emission reduction target.

The Government has already put in place the Green Building Codes (GBC) through the Governor's Decree No. 38/2012 on Green Buildings (Pergub 38/2012), which aims to save 3,785 GWh energy, 2.4 billion litres water and 3.37 $MtCO_{2-e}$ emissions. The NEXSTEP analysis identifies that the city has potential to further revise and expand the energy efficiency requirements under this code and benefit from these low hanging fruits. While the GBC focuses on building envelopes to reduce energy consumption, this analysis suggests retrofitting with more efficient appliances in residential buildings to take advantage of the enhanced energy saving potential.

The city would need to mandate more energy efficient appliances be used in the building sector. For example, use of high-efficient air conditioning units can save substantial amount of energy as peak cooling load in a climate like Jakarta's is enormous. Sustainable cooling options should be explored and enabling policy framework would need to be developed. Jakarta can benefit from the research being undertaken by ESCAP and UNEP on the sustainable cooling. On the lighting part, inefficient light bulbs should be banned and the efficient versions like compact fluorescent light (CFL) and/or light emitting diode (LED) should be encouraged to save more energy without reducing lumen levels. A large number of elevators used in Jakarta are old and high energy consuming equipment, which can be replaced with efficient versions.

A list of appliances has been presented in section 4.2.3 that should be replaced with energy efficient versions. It also provides estimates of energy saving for each appliance. For example, the code requires a split type air conditioner to have minimum efficiency requirement of 1.3 kW per Ton of Refrigeration (TR), whereas the high-efficient air conditioners suggested in this analysis would have 1.0 kW/TR. The combined annual average savings from the building sector would be 2,473 GWh.

7.3 Alternative mobility options can save energy and emissions

The transport sector has major potential for energy efficiency savings and reducing emissions in Jakarta. Several measures, including electrification of buses, increasing the share of public transport, increasing non-motorised mobility and introduction of congestion charges, are found to increase the sustainability of the transport sector and return large savings.

The transport sector is responsible for about 40 per cent of city's energy consumption. More importantly, it consumes about 4 Mtoe of energy, 52 per cent of the city's total energy consumption and is fully imported. Therefore, this should be seen as a major concern for the city's energy security, as well as a key barrier to achieving the emission reduction target. Additionally, an increasing number of inefficient vehicles on the city road are contributing to one of the most severe traffic congestions in the world, polluting the local environment and increasing emissions.

The NEXSTEP analysis informs that by converting all passenger internal combustion engine buses to electric buses will save 517 ktoe annually. When combined with other measures e.g. increasing the use of public transport and non-motorized mobility, the total energy saving in 2030 would be 1,553 ktoe, which is equivalent to reducing 5.9 $MtCO_{2-e.}$

For large cities like Jakarta, non-motorized mobility option is becoming an important agenda. Various cities in the world are investing heavily in walking and bicycle infrastructure to take advantage of a range of benefits, including traffic congestion reduction, pollution reduction, increase in public health and overall in creating a more liveable city for its dwellers. The NEXSTEP analysis identified that by increasing a 10 per cent cycling passenger kilometre, the city can reduce its energy consumption by 215 ktoe annually. Further information on benefits and potential strategies of bicycle-based mobility is presented in section 5.2.3.

7.4 Increasing ambition Towards NetZero City should be considered as the pathway to 2030

With the growing number of cities joining the race for NetZero Carbon, it is important that the City of Jakarta raises its ambition to set its pathway towards this direction. This not only helps to achieve sustainable energy transition, reduce emissions and increase public health but it also makes the city a better liveable place for its dwellers.

This roadmap has developed one special scenario named Towards NetZero Carbon scenario, which provides a range of analytical information for the City of Jakarta on policy directions that will help its aspiration to transition towards NetZero city. While developing this scenario, careful thought has been applied to minimise any negative impact on the economy. Being carbon neutral is not an easy task, particularly for a mega city like Jakarta, however, a number of strategies have been suggested that would help the city to move towards NetZero by 2030.

For example, adoption of high-efficient induction type electric cookstove should be adopted in households, where possible. This would significantly reduce energy consumption (by 2.3

Mtoe in the next 10 years). From the economic side, this recommendation is based on the fact that the annualized cost of electric cookstove is lower than LPG cookstove and thus would cost less money for households in the long run. Some incentives by the Government to help with the capital cost would make it easy for households to adopt this technology.

Motorbikes are an important mode of transportation in Jakarta, but these two-stroke engines create significant pollution by incomplete fuel combustion. This segment of transport also generates about 1.7 $MtCO_{2\text{-}e}$ emissions annually, which is expected to rise to 2.3 $MtCO_{2\text{-}e}$ by 2030. While motorbikes would need to remain as an important mode of transport, particularly for the average socio-economic group of population, replacing the current type with electric motorbikes would be a good way forward. This study recognizes that it would impractical to replace 100 per cent of 3 million motorbikes with electric version by 2030 therefore, it suggests at least 50 per cent replacement. Like induction cookstoves, capital cost incentives from the City authorities would accelerate the transition.

As discussed in the previous section that an increase in the current 10 per cent bicycle commuting share will reduce private car usage in the city and reduce pollution, improve public health and more importantly make the city a better place to live. The City Government would need to increase its expenditure in creating bicycle compatible infrastructure as well as introduce programs to encourage cycling in the city. While the demand for electricity in this scenario will increase due to the introduction of electric motorbikes and induction cookstoves, there will be an overall reduction of energy demand. Furthermore, as it has been suggested in other scenarios, the city would need to move towards increasing the share of renewable energy in its power supply by investing in different purchase mechanisms such as renewable energy auction. Installation of rooftop solar PV on households and commercial buildings is also suggested to be considered as a pathway to increase renewables. This way the city would reduce its emission intensity in electricity supply, which justifies the move towards more electricity-based systems compared to petroleum fuel-based options.

8. Conclusion

The City of Jakarta recognises the need to transition to a low-carbon sustainable energy future, however, the current policy setting is unlikely to support this move. The city would need to undertake a major transformation to make this transition happen. While the SDG 7 targets have been developed to apply to the national rather than city level, the authorities have expressed a desire to align the city energy sector's indicators with those of SDG 7. The Governor of Jakarta has put forward an emission reduction target for 2030.

The Sustainable Energy Transition roadmap developed using the NEXSTEP tool suggests that, at a minimum, the city should consider the implementation of the SET scenario. For the power sector, this will mean substantially increasing the share of renewable energy in the electricity supply mix. The city would need to invest in renewable energy auctions to secure a higher share of renewable energy in the supply chain. RE auctions have been proved to secure very low cost of electricity supply with recent experiences suggest that solar utility scale levelized cost of electricity has been as low as $0.038, which is less than half of the LCOE of current generation mix of the Java-Madura-Bali interconnection. The roadmap also recommends that the city needs to enhance its efforts to improving energy efficiency in all sectors but most importantly in the residential, commercial and transport sectors. The Green Building Code, which is currently in place in the city, would need to further enhance by increasing the level of energy efficient appliances in buildings. The roadmap also suggests improving energy efficiency in the transport sector through various measures such as electrification of buses and motorbikes and introducing non-motorised mobility options.

The roadmap further suggests that the city can do even more by increasing its ambition and set up a strategy to move towards a NetZero Carbon city. Such an ambition has far reaching benefits – including saving energy and resources, reduced emissions and local pollutions, reduced traffic congestion but overall, it creates a better liveable place for the city's dwellers. The road map has identified several measures that should be used to constitute the Towards NetZero Carbon strategy. For transport, the most energy consuming area sector, the city should convert all petroleum-fuelled passenger buses and private cars to electric versions, replace half of the current motorcycle stock with electric versions, invest in creating cycling infrastructure. The roadmap recognises the city's excellent progress with the bus rapid transit system, which has started to attract a large number of commuters. In addition to further enhancing the energy efficiency in the building sector under GBC, the Towards NetZero would also require replacing LPG-based cookstoves with highly efficient induction-type electric cookstoves. For the power sector, the roadmap recommends that the city takes advantage of renewable energy auctions to secure high share of renewables-based electricity supply at a low cost. Additionally, the city would need to construct a policy to strongly implement rooftop solar PV in residential and commercial buildings. The strong role of educational, promotional and awareness building programs should not be ignored. Changes in user behaviour on energy consumption and driving patterns have the potential to cost-effectively reduce substantial amount of energy and therefore, should be given preference.

Importantly, this city roadmap would need to link up with the national SDG 7 roadmap developed for Indonesia. The national roadmap has strongly recommended that the country would need to move away from coal-based power generation by immediately stopping new investments in coal-fired power plants, not only because the pollution they generate and incompatibility with achieving the Paris Agreement but also such investments are highly uneconomic, with analyses suggesting that investments in coal power plants are extremely likely to lead to stranded assets. Increasing the share of renewables in the generation mix was also recommended. The road map also suggested to substantially increase energy efficiency in the transportation sector by increasing fuel efficiency standards in vehicles and electrification of busses and passenger cars. Energy efficiency improvement has also been suggested in the residential and commercial sectors e.g. by introducing minimum energy performance standards (MEPS) for electrical appliances. This indicates that the implementation of these recommendations by the central Government would make the City of Jakarta's transition to sustainable energy future as well as Towards NetZero Carbon easy. Therefore, engaging with the central Government to advocate to implement the national SDG 7 roadmap would be an essential element of the city's sustainable energy transition strategy.

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Annexes

Annexes I Energy efficiency database for appliances for the residential and commercial sectors

Technology Type	Efficiency Rating	Capacity/ Size (Tons)	Watts	kWh/yr	Life Cycle Cost ($)	$tCO_{2\text{-}e}$/ year	Op. cost and em. Red. through increased EE (%)
Air Conditioning (Window)							
Variable Speed Compressor	Medium	1 Ton	1,222	709.74	1,033.15	0.48	Base tech for comparison
Fixed/Single Speed Compressor	Medium	1 Ton	1,166	902.95		0.61	-27.22
Fixed/Single Speed Compressor	High	1 Ton	1,080	836.35		0.57	-17.84
Variable Speed Compressor	Medium	1 Ton	1,100	638.88		0.43	9.98
Variable Speed Compressor	High	1 Ton	1,050	609.84		0.41	14.08
Fixed/Single Speed Compressor	Medium	1.5 Tons	1,610	1,246.78		0.85	-75.67
Fixed/Single Speed Compressor	High	1.5 Tons	1,463	1,132.95		0.77	-59.63
Variable Speed Compressor	Medium	1.5 Tons	1,700	987.36		0.67	-39.12
Variable Speed Compressor	High	1.5 Tons	1,670	969.94		0.66	-36.66
Fixed/Single Speed Compressor	Medium	2 Tons	2,145	1,661.09		1.13	-134.04
Variable Speed Compressor	Medium	2 Tons	2,260	1,312.61		0.89	-84.94
Variable Speed Compressor	High	2 Tons	2,190	1,271.95		0.86	-79.21
Air Conditioning (Split)							
Fixed/Single Speed Compressor	Low	1.5 Tons	1,649	1,276.99	1,466.46	0.87	Base tech for comparison
Fixed/Single Speed Compressor	Low	1 Ton	1,132	876.62		0.6	31.35
Fixed/Single Speed Compressor	High	1 Ton	841	651.27		0.44	49
Variable Speed Compressor	Medium	1 Ton	1,025	595.32		0.4	53.38
Variable Speed Compressor	High	1 Ton	822	477.42		0.32	62.61

Fixed/Single Speed Compressor	Low	1.5 Tons	1,649	1,276.99		0.87	0
Fixed/Single Speed Compressor	High	1.5 Tons	1,315	1,018.34		0.69	20.25
Variable Speed Compressor	Low	1.5 Tons	1,571	912.44		0.62	28.55
Variable Speed Compressor	High	1.5 Tons	1,290	749.23		0.51	41.33
Fixed/Single Speed Compressor	Low	2 Tons	2,225	1,723.04		1.17	-34.93
Fixed/Single Speed Compressor	High	2 Tons	1,741	1,348.23		0.92	-5.58
Variable Speed Compressor	Low	2 Tons	2,090	1,213.87		0.82	4.94
Variable Speed Compressor	High	2 Tons	1,775	1,030.92		0.7	19.27
Residential Lighting							
Incandescent	Low	850	20	36.5	160.72	0.02	Base tech for comparison
Incandescent	Low	450	40	73		0.05	-100
CFL	Medium	450	11	20.08		0.01	45
LED	High	450	5	9.13		0.01	75
Incandescent	Low	800	60	109.5		0.07	-200
CFL	Medium	800	14	25.55		0.02	30
LED	High	800	8	14.6		0.01	60
Incandescent	Low	1,100	75	136.88		0.09	-275
CFL	Medium	1,100	20	36.5		0.02	0
LED	High	1,100	12	21.9		0.01	40
Incandescent	Low	1,600	100	182.5		0.12	-400
CFL	Medium	1,600	25	45.63		0.03	-25
LED	High	1,600	18	32.85		0.02	10
Commercial Lighting							
T5 TFL	96	2,600	36	86.4	102.05	0.06	Base tech for comparison
T12 Tubular Fluorescent Light	65 lumens/W	2,600	40	96		0.07	-11.11
T8 Tubular Fluorescent Light	94 lumens/W	2,600	28	67.2		0.05	22.22
T5 Tubular Fluorescent Light	96 lumens/W	2,600	27	64.8		0.04	25
T8 LED Light	130 lumens/W	2,600	20	48		0.03	44.44
T5 LED Light	140 lumens/W	2,600	19	45.6		0.03	47.22

Fans							
Ceiling	Low	1,200	90	270	276.12	0.18	Base tech for comparison
Pedestal	Low	400	100	300		0.2	-11.11
Pedestal	High	400	28	84		0.06	68.89
Ceiling	Low	1,200	70	210		0.14	22.22
Ceiling	Medium	1,200	50	150		0.1	44.44
Ceiling	High	1,200	24	72		0.05	73.33
Refrigerator							
Single Door	Direct Cool	Low	200	10	448.15	0.15	Base tech for comparison
Single Door	Direct Cool	Low	100			0.21	-38.64
Single Door	Direct Cool	High	100			0.16	-6.82
Single Door	Direct Cool	Low	170			0.16	-6.82
Single Door	Direct Cool	Medium	170			0.11	25
Single Door	Direct Cool	High	170			0.09	40.91
Single Door	Direct Cool	Low	180			0.16	-10.45
Single Door	Direct Cool	Medium	180			0.11	25.45
Single Door	Direct Cool	High	180			0.07	52.73
Single Door	Direct Cool	Low	195			0.14	5.91
Single Door	Direct Cool	Medium	195			0.12	22.27
Single Door	Direct Cool	High	195			0.07	51.36
Single Door	Direct Cool	Low	200			0.15	1.36
Single Door	Direct Cool	Medium	200			0.12	20.45
Single Door	Direct Cool	High	200			0.07	51.36
Single Door	Direct Cool	Low	225			0.15	-1.82
Single Door	Direct Cool	Medium	225			0.12	18.64
Single Door	Direct Cool	High	225			0.16	-10.45

Double Door	Frost Free	Low	220			0.17	-14.09
Double Door	Frost Free	Medium	220			0.15	0.45
Double Door	Frost Free	High	220			0.13	14.55
Double Door	Frost Free	Low	234			0.21	-37.73
Double Door	Frost Free	Medium	234			0.13	10
Double Door	Frost Free	High	234			0.11	27.73
Double Door	Frost Free	Low	240			0.17	-15.45
Double Door	Frost Free	Medium	240			0.16	-6.36
Double Door	Frost Free	High	240			0.13	10
Double Door	Frost Free	Low	255			0.17	-12.73
Double Door	Frost Free	Medium	255			0.14	9.55
Double Door	Frost Free	High	255			0.11	27.73
Double Door	Frost Free	Low	280			0.18	-20
Double Door	Frost Free	Medium	280			0.14	6.36
Double Door	Frost Free	High	280			0.11	25.45
Double Door	Frost Free	Low	307			0.17	-15
Double Door	Frost Free	Medium	307			0.14	3.64
Double Door	Frost Free	High	307			0.11	23.18
Double Door	Frost Free	Low	327			0.18	-20.91
Double Door	Frost Free	Medium	327			0.15	2.27
Double Door	Frost Free	High	327			0.12	21.82
Televisions							
LCD	Low	40 Inches	250	456.25	755.73	0.31	Base tech for comparison
LCD	Low	32	152.9	279.04		0.19	38.84
LCD (LED)	Medium	32	62.5	114.06		0.08	75
LCD	Low	40	237.2	432.89		0.29	5.12
LCD (LED)	Medium	40	97	177.03		0.12	61.2
LCD	Low	42	260.3	475.05		0.32	-4.12
LCD (LED)	Medium	42	106.3	194		0.13	57.48
LCD	Low	50	362.2	661.02		0.45	-44.88
LCD (LED)	Medium	50	148.5	271.01		0.18	40.6
OLED	High	50	48.8	89.06		0.06	80.48
LCD	Low	55	438.4	800.08		0.54	-75.36
LCD (LED)	Medium	55	179.7	327.95		0.22	28.12
OLED	High	55	58.6	106.95		0.07	76.56

This database is available with interactive option at www.nexstepenergy.org/database