Energy Transition Pathways for the 2030 Agenda

Sustainable Energy Transition Roadmap for the City of Cauayan, the Philippines

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

The shaded areas of the map indicate ESCAP members and associate members[1]

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Foreword: ESCAP

The City of Cauayan was one of the pioneers in using ESCAP's National Expert SDG Tool for Energy Planning (NEXSTEP) methodology to develop a Sustainable Energy Transition Roadmap. ESCAP is pleased to partner with the City of Cauayan in its endeavour to realize a vision for the city's future based on holistic and sustainable development.

The City of Cauayan, which has been nominated as the Ideal City of the North, has been a strong advocate for the Sustainable Development Goals (SDGs). Much effort has been undertaken in Cauayan in localizing the SDGs at the city level to improve the livelihood of its citizens, and it is regarded as the first smart city in the Philippines. ESCAP's collaboration with the City of Cauayan in developing this Sustainable Energy Transition (SET) roadmap further raises the city's sustainable development ambition, by identifying the opportunities for city's sustainable energy transition.

This roadmap takes a holistic approach to Cauayan' s energy system. It evaluates the city's current progress towards the SDG7 targets, identifies the priorities for action and suggests opportunities for improvement. For instance, the roadmap highlights the current gap in universal access to modern energy in the city and proposes the appropriate long-term solutions in closing this gap, which also enhance socio-economic development.

The roadmap also details a range of technical opportunities and policy options for reducing emissions and saving energy across the residential, transport, commercial and agricultural sectors. These opportunities include transport electrification, adoption of energy efficiency in buildings as well as substantial reduction in city's emissions through decarbonization of its power supply, while paving the way towards a net-zero society.

ESCAP would like to thank the City of Cauayan and other stakeholders for their continuous support and contributions, without which the development of this Sustainable Energy Transition roadmap would not be possible. I look forward to the City of Cauayan's continuing leadership in building a sustainable energy future.

Hongpeng Liu

Director, Energy Division, ESCAP

Foreword: City of Cauayan

Cauayan City was given the recognition as the Philippines’ First Smarter City on 25 March 2015 in recognition of its excellence in the delivery of social services through digital governance. When the United Nations launched the 17 Sustainable Development Goals, Cauayan City took the lead in localizing these goals, which we call *Labing pitong hamon sa bawat cauayeno* (17 challenges for every citizen of Cauayan), where all plans and programmes of the local government unitsf (LGUs) are aligned for the achievement of these goals, with the aim to evolve as a smarter and sustainable Cauayan City.

The Smart Cities Project is a tripartite agreement with the Department of Science and Technology and the Isabela State University as well as the localization of the UNSDGs which have become the flagship projects of Cauayan City. These projects have opened opportunities for the city to build partnerships with different international organizations and stakeholders. One important example is the is the Smart Cities Network, which through its Chairman, Mr. Kok-Chin Tay played a significant role in creating the linkage between Cauayan City and the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP).

On 17June 2020 Cauayan City expressed its interest in being among the pilot cities for the Deep Dive Program in the localization of SDG7. This partnership not only allowed for the development of the Sustainable Energy Transition (SET) roadmap that helps the city in identifying priority areas that need to be addressed in order to meet the objectives of SDG7; more importantly, it enabled the city to establish a working relationship with different government agencies and offices in the Philippines for the creation of a Local Energy Audit Team. That was another milestone for the city in its efforts to fully assess and formulate programmes that play an important role in achieving energy efficiency.

Cauayan City is greatly privileged to be among the roster of cities that have been given the opportunity to be drafted with the SET Roadmap. Our sincerest thanks go to ESCAP as well as to Isabela State University through the expertise and supervision of Dr. Orlando F. Balderama for their unwavering support and assistance to Cauayan City throughout the Deep Dive Program. We have high hopes that the SET Roadmap can soon serve as a blueprint and inspiration for other cities in the Philippines. If this project can be successful in a small, poor and highly agricultural city like Cauayan City, it can certainly be done in bigger and highly urbanized cities with the objective of creating more sustainable cities in the Philippines.

Bernard Faustino La Madrid Dy

City Mayor, Cauayan City, Isabela

Abbreviations and acronyms

ADB	Asian Development Bank
BAU	business-as-usual
CBA	cost benefit analysis
CDP	Comprehensive Development Plan
CES	clean energy scenario
CLUP	Comprehensive Land Use Plan
CO_2	carbon dioxide
CPS	current policy scenario
DOE	Department of Energy
DOST	Department of Science and Technology
DPS	decarbonization of power sector
DPWH	Department of Public Works and Highways
EE	energy efficiency
ESCAP	(United Nations) Economic and Social Commission for Asia and the Pacific
GB Code	Green Building Code
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt
GWh	gigawatt-hour
IEA	International Energy Agency
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ktoe	thousand tonnes of oil equivalent
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LEAP	Long-range Energy Alternatives Planning
LGUs	local government units
LPG	liquified petroleum gas
MCDA	Multi-Criteria Decision Analysis
MJ	megajoule
$ktCO_2$-e	thousand tonnes of carbon dioxide equivalent
MTF	Multi-Tier Framework
MW	megawatt
MWh	megawatt-hour
NEXSTEP	National Expert SDG Tool for Energy Planning
PHP	Philippine peso
RE	renewable energy
REF	reference scenario
SDG	Sustainable Development Goal
SET	sustainable energy transition
TFEC	total final energy consumption
TGFA	total gross floor area
TNZ	towards NetZero
TPES	total primary energy supply
TWh	terawatt-hour
UNEP	United Nations Environment Programme
UNSD	United Nations Statistics Division
US$	United States dollar
WHO	World Health Organization
WorldGBC	World Green Building Council

Executive Summary

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

The City of Cauayan has been a participant of a collaborative project led by ESCAP and UNEP on SDG7 localization. It aims to engage and support cities in defining, implementing and monitoring strategies for achieving global, national and subnational sustainable development goals. This Sustainable Energy Transition (SET) roadmap has been developed to identify technological options and policy measures that will help the city to navigate the transition of its energy sector in line with the 2030 Agenda for Sustainable Development.

A. Highlights of the roadmap

The City of Cauayan is an agricultural city in the coastal province of Isabela, on the island of Luzon, the Philippines. A city with a population of just over 150,000, Cauayan is well-known for becoming the first smart city in the Philippines in 2015, offering its citizens a wide variety of digital services (City of Cauayan, 2021). It has also been selected to host the proposed Isabela Special Economic Zone and the Regional Agro-Industrial Growth Centre. The development of the city is guided by the Sustainable Development Goals (SDGs). Various initiatives and programmes have been launched for advancing the city's progress across all SDGs (City of Cauayan, 2017), including SDG7. However, more can be done to accelerate Cauayan's sustainable development towards meeting the SDG7 targets by 2030.

This SET roadmap has two main objectives. First, it aims to establish a scenario baseline for 2019-2030, taking into consideration the current policy settings. Second, it identifies the measures and technological options that could raise Cauayan's efforts to align with the SDG7 targets as well as achieving deep decarbonization of its energy system. The four scenarios that are presented in detail in this roadmap are:

- The current policy scenario (CPS), which has been developed based on existing policies and plans, and used to identify the gaps in existing initiatives in aligning with the SDG7 targets and the city's ambitions;
- The sustainable energy transition (SET) scenario presents technological options and policy measures that will help the city to align its development with the 2030 Agenda for Sustainable Development, particularly SDG7;

- The Decarbonization of Power Sector scenario (DPS) explores the impact of a decarbonized electricity supply on the city's GHG emissions, and presents multiple pathways that the city can undertake in decarbonizing its electricity supply;
- The Towards Net Zero (TNZ) scenario, the most ambitious scenario, looks at a pathway for moving towards a net zero society through decarbonizing the electricity supply and the adoption of electricity-based technologies.

An additional scenario – the business as usual (BAU) scenario – has also been modelled to provide a BAU baseline where no enabling policies/initiatives have been implemented, or the existing policies/initiatives have failed to achieve their intended outcomes.

B. Aligning the City of Cauayan's energy transition pathway with the SDG7 targets

Access to modern energy

As of 2019, 9.6 per cent of Cauayan's population lacked access to electricity, while 23.3 per cent lacked access to clean cooking fuels and technologies. More attention is required to set up initiatives and channel funding in closing the access gap. NEXSTEP proposes that decentralised renewable electricity systems may be the best way forward in electrifying the remaining households.

More attention is required to providing universal clean cooking access to the population of Cauayan. Nearly a quarter of the population rely on unclean cooking fuel and technologies for household cooking, specifically traditional biomass stoves (18.7 per cent) and kerosene stoves (4.7 per cent). The phase-out of unclean cooking practices is a means of improving health through reducing household indoor air pollution as well as ensuring more gender empowered socio-economic development. Electric cooking stoves stand out as the most appropriate long-term solution, due to their cost-effectiveness (relative to the more commonly used LPG stoves), zero air pollution and required minimal maintenance. In addition, coupling this technology with a decarbonized electricity supply results in a zero-carbon solution.

Renewable energy

The share of renewable energy (RE) in the total final energy consumption (TFEC) in Cauayan was 5 per cent in 2019. Under the CPS, the share of RE will increase to 10.6 per cent by 2030. The increase in the RE share under the current policies is driven by the high growth of the renewable energy share in grid electricity, which is projected to increase from 14 per cent in 2019[2] to 34.1 per cent in 2030, and a slight increase in biofuel usage in the transport sector. In the SET scenario, the RE share in TFEC increases to 14.8 per cent. This additional increase of 4.2 per cent from the CPS is a result both of increased use of RE due to a higher share of electricity in energy consumption and a further reduction of energy demand due to energy efficiency measures.

[2] Based on the Department of Energy's 2020 Power Statistics, gross generation per grid, by plant type.

The RE share in TFEC for the DPS and TNZ scenario is expected to be high, as both the scenarios envision a decarbonized electricity supply. The latter also aims to position the energy system towards achieving net-zero carbon. In the DPS scenario, the RE share in TFEC is further increased to 37.1 per cent as the RE share of electricity supply reaches 100 per cent. As described later in this roadmap, there are several pathways for achieving a decarbonized electricity supply, with the most promising and cost-effective one being through renewable energy auctions. On the other hand, the RE share in TFEC increases to 56 per cent in the TNZ scenario, as more electricity-based technologies are adopted in the transport and residential sectors, reducing overall energy demand and increasing renewable energy usage with a 100 per cent electricity supply.

Energy efficiency

Cauayan's energy intensity is estimated to have been 5.85 MJ/US$_{PPP,2011}$ in 2019. It is expected to be reduced to 5.67 MJ/US$_{PPP,2011}$ by 2030 in the CPS, as GDP growth outpaces the growth in energy demand. This corresponds to an annual improvement rate of 0.3 per cent.

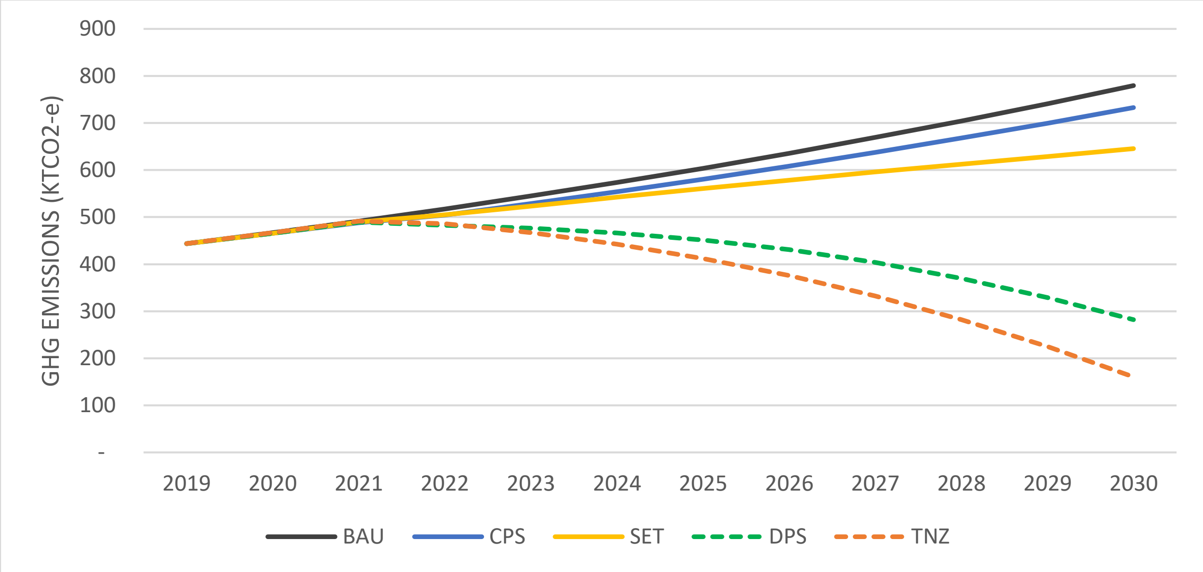
The SET scenario proposes several energy-efficiency interventions across the demand sectors, which further decreases the energy intensity to 4.21 MJ/US$_{PPP,2011}$ by 2030. This corresponds to a 3 per cent reduction per annum, aligning with the suggested global annual improvement rate of 3 per cent (UNSD, 2021). The transport sector accounted for around 69.4 per cent of the total energy demand in 2019, and energy efficiency measures in the sector may provide substantial savings. NEXSTEP proposes an increase of in the electric vehicle share in the transport fleet to between 25 per cent and 50 per cent by 2030. The projected result – a 42 ktoe reduction in energy demand from the CPS due the high efficiency of electric vehicles. Other measures include mandating the compliance of the national green building code to all new commercial buildings regardless of floorspace area as well as phasing out of inefficient lighting appliance in the residential sector. The phasing out of inefficient, polluting cooking practices allows an estimated energy reduction of 7.1 ktoe, clearly demonstrating the positive interaction between clean cooking access and energy efficiency. The proposed measures are further detailed in chapter 4.

The energy demand reduction can be significant should Cauayan follow a net zero carbon pathway, as suggested in the TNZ scenario. The energy intensity is projected to decline to 3.41 MJ/US$_{PPP,2011}$, corresponding to a 4.8 per cent energy efficiency improvement per annum.

GHG emissions

The GHG emissions in 2019 are estimated to have been 443.6 ktCO$_2$-e, when considering the direct fuel combustion and emissions attributable to the purchased (grid) electricity. Figure ES 1 shows the GHG emission trajectories for the different scenarios. The GHG emissions from the CPS are projected to reach 733 ktCO$_2$-e, while further decreased to 646 ktCO$_2$-e in the SET scenario. Drastic decreases can be observed in the DPS and TNZ scenarios. Decarbonizing the electricity supply further reduces the GHG emissions to 282 ktCO$_2$-e in the DPS scenario. The most ambitious reduction of 161 ktCO$_2$-e can be achieved with increased adoption of electricity-based technologies in the transport and residential sectors. This entails having 100 per cent electric vehicle sales from 2023 onwards, and phasing out of (almost) all LPG stoves for residential cooking. In the agricultural sector, diesel-power water pumps are replaced with solar irrigation systems. The remaining emissions are from conventional vehicles yet to be phased out within the short nine-year period, a small amount of LPG stove usage in households connected to decentralised RE systems as well as the use of large-scale diesel-powered agricultural machinery (i.e., harvester, rotovators and tractors) where electric-powered versions have not yet reached commercialization stage.

Figure ES1. Comparison of emissions by scenarios 2018-2030



C. Key policy recommendations

As described above, there are ample opportunities for Cauayan to transform its energy system in alignment with the SDGs, while at the same time substantially reduce its GHG emissions. The key policy recommendations to help Cauayan in its sustainable energy transition, are:

1. **Access to electricity and clean cooking technologies should be the number one priority.** Decentralised RE electrification systems should be considered for quick implementation. Induction-type electric cooking stoves provide the most appropriate long-term solution in achieving 100 per cent access to clean cooking, while LPG stoves can be considered for households with insufficient power supply to support the use of electric cooking stoves;
2. **Green building code and the use of RE systems can be made mandatory for all new commercial buildings in the city, regardless of the floorspace area.** The existing national green building code is obligatory for buildings above a certain minimum floorspace area. Widening the requirements to all new commercial buildings, regardless of the floorspace area, from 2023 onwards wall allow an estimated saving of 1.2 ktoe. Compulsory use of RE systems (i.e., solar PV) can be similarly introduced;
3. **Transport electrification is the key to energy demand reduction and GHG emission reduction.** Setting a high bar for transport electrification will result in substantial GHG emissions reduction, particularly when coupled with a highly decarbonized electricity supply;
4. **Raising the RE share in electricity supply through urban RE electricity generation, PPA and RE auctions.** Among the options for increasing the RE generation share, RE auctions provide the best financial case and financial savings due to low solar PV generation costs. The opportunity for utilizing the biomass resource potential of the city for energy generation can also be explored;

5. **Moving towards net-zero carbon.** A net-zero society requires a concerted effort both by the city authorities and citizens. Total decarbonization of the power supply is essential, while increased electrification in the demand sectors is required, including the phasing out of internal combustion engine vehicles, LPG stoves and diesel-powered water pumps;
6. **Strengthening institutional capacity and mainstreaming energy transition in executive and legislative agendas.** Strong institutional and policy support are imperative in ensuring successful adoption and roll-out of technology options and policy recommendations. The City of Cauayan should also consider several important next steps, such as coming up with a strategic action plan and monitoring mechanisms in tracking its progress towards the energy and climate targets.

1. Introduction

A. 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 sustained economic growth as well as respond to increasing energy demand, reduce emissions, and consider and capitalise on the interlinkages between Sustainable Development Goal 7 (SDG7) and other SDGs. In this connection, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions that support the achievement of the SDG7 targets as well as emission reduction targets (NDCs). The initiative has been undertaken in response to the Ministerial Declaration of the Second Asian and Pacific Energy Forum (April 2018, Bangkok) and Commission Resolution 74/9, which endorsed its outcomes. NEXSTEP 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 SDG7. Further details of the NEXSTEP methodology are discussed in chapter 2. While this tool has been designed to help develop SDG7 roadmaps at the national level, it can also be used for subnational energy planning.

As a participant in the “SDG7 localisation project”, the City of Cauayan (Cauayan) and ESCAP have collaborated in developing a Sustainable Energy Transition (SET) roadmap, which seeks to assess Cauayan’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. The SDG7 localisation project is implemented in collaboration with the United Nations Environment Programme (UNEP), and with support from the Energy Foundation China. The ESCAP Energy Division is supporting its member States in Asia and the Pacific in increasing the capacity of cities and subnational governments in the region to accelerate development and implementation of SDG7-related actions. ESCAP directly engages cities and subnational jurisdictions in collaborative discussions. It offers a range of knowledge products and support in developing local sustainable energy policies and projects as well as in establishing more effective dialogues between national, subnational and local levels of governance, expert communities, donors and the private sector. See box 1 for further details.

Box 1. SDG7 localization status of the City of Cauayan, based on ESCAP’s assessment

In 2021, ESCAP conducted a study of 20 cities in five ASEAN countries, including the City of Cauayan, in order to assess their local situation in terms of the efforts on SDG7 localization, and to provide recommendations for further actions.

The study is based on the methodology developed by ESCAP and the answers provided by the local stakeholders in Cauayan to the related SDG7 localization questionnaire (more detailed information on the methodology can be found in the ESCAP-UNEP report, SDG7 localization: Affordable and Clean Energy in ASEAN Cities[3]). The key results of this situation assessment are presented in the SDG7 Localization Snapshots[4] for each city.

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

It is important to note that these indicators are qualitative and should not be used for assessing cities' achievement of quantitative targets under SDG7. The results for these qualitative indicators are based on cities' self-assessment of their current conditions, efforts, resources and capacity in relation to supporting the SDG7 localization process. They can serve as the role of evidence base for constructing recommendations tailored to the local context as well as the baseline results for tracking cities' progress of their SDG7 localization efforts.

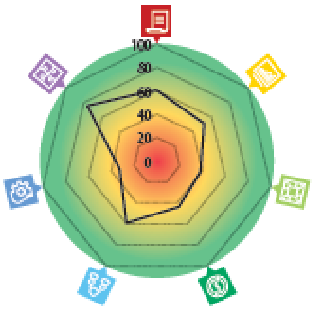
The results for each indicator are presented as a nominal score from 0 to 100 (where 100 is the maximum possible score that can be achieved for each indicator or sub-indicator, based on the aggregation of all answers to the questionnaire attributed to this particular indicator or sub-indicator).

As can be seen from the figure and the results below, most of the efforts related to SDG7 in the City of Cauayan are taking place in the areas linked to other SDGs, which corresponds to a relatively high score for the indicator on linkages to other SDGs. That might be an indication that SDG7 has not been high on the list of the city's policy priorities, which is confirmed by a relatively low result for the indicator on Implementation. This suggests that projects and initiatives directly focused on SDG7 implementation (i.e., energy efficiency, renewable energy and energy access) are quite limited at present, and need additional support and acceleration from the local government. This is especially the case when it comes to disbursement of financial resources, improving energy data collection and monitoring as well as more active collaboration with national and international stakeholders in the field of sustainable energy.

[3] Available at https://www.unescap.org/kp/2021/sdg-7-localization-affordable-and-clean-energy-asean-cities#
[4] Available at https://city.nexstepenergy.org/knowledge/city-snapshots

General information	
Name of the jurisdiction	CAUAYAN
Country of the jurisdiction	Philippines
Population of the jurisdiction	143,443 people
Area of the jurisdiction (in km²)	336.4
Predominant climate	Relatively wet from May to November (29°C-32°C), dry for the rest of the year (35°C-41°C)

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.
52	Energy data monitoring	Accessibility and penetration of energy monitoring and smart metering.
39	Cooperation with national and international stakeholders	Efficient communication and collaboration between local stakeholders and various stakeholder groups at the national and international levels.
43	Use of financial resources	Availability of various financial resources and instruments for supporting SDG 7 implementation actions.
59	Awareness raising and capacity- building	Availability of policies of actions to increase the understanding among citizens and build the capacity of professionals for SDG 7 implementation.
32	Implementation	Presence of policies and actions to implement SDG 7 targets.
75	Linkages to other SDGs	Availability of policies of actions with linkages between SDG 7 and other SDGs.

Sub-Indicator score

59	Energy access	Policies of actions taken by cities on energy access.
25	Renewable energy	Policies of actions taken by cities on renewable energy.
11	Energy efficiency	Policies of actions taken by cities on energy efficiency.

Sub-Indicator score

68	SDG3. Good health and well-being.	The presence of energy-related activities of measures that support the health sector.
20	SDG6. Clean water and sanitation.	The presence of energy-related activities of measures that support water and sanitation.
85	SDG11. Sustainable cities and communities.	The presence of energy-related activities of measures that support development of sustainable cities and communities.
100	SDG12. Responsible production and consumption.	The presence of energy-related activities of measures that support responsible production and consumption.
100	SDG13. Climate action.	The presence of energy-related activities of measures that support climate action.

B. SDG7 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 total energy consumption. Renewable energy consumption includes consumption of energy derived from hydropower, solid biofuels (including traditional use), wind, solar, liquid biofuels, biogas, geothermal, marine and waste. Due to the inherent complexity of accurately estimating traditional use of biomass, NEXSTEP focuses entirely on modern renewables (excluding traditional use of biomass) for this target.

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

2. NEXSTEP methodology

The main purpose of NEXSTEP is to help design the type and mix of policies that 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 for achieving 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 Long-range Energy Alternatives Planning (LEAP). It is a widely-used tool for energy sector modelling and for creating energy and emissions scenarios. Many countries have used LEAP to develop scenarios as a basis for their Intended Nationally Determined Contributions (INDCs). **Error! Reference source not found.** shows the different steps of the methodology.

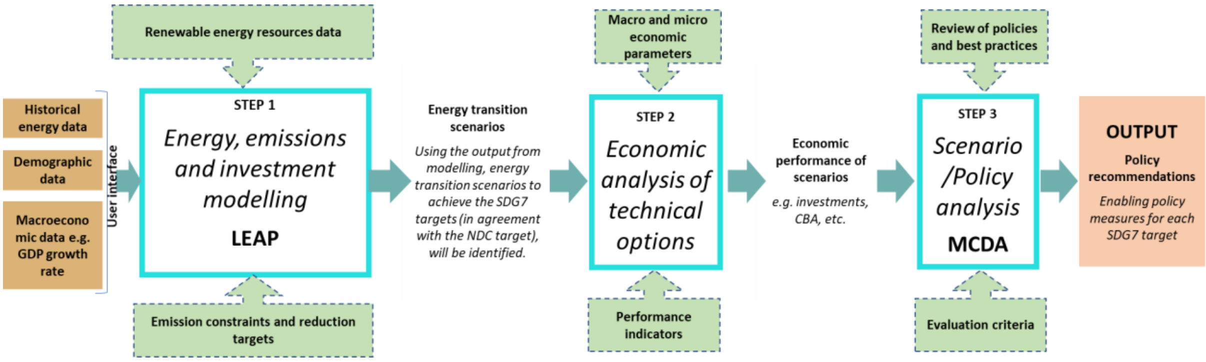
(ii) Economic analysis module

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 such as net present value, internal rate of return and payback period. A ranking of selected technologies will help policymakers to identify and select economically effective projects for better allocation of resources. The economic analysis helps to present several economic parameters and indicators that would be useful to policymakers in making an informed policy decision.

(iii) Scenario and policy analysis

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

Figure 2. Different components of the NEXSTEP methodology



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 to model energy system evolution based on current energy policies. In the NEXSTEP model for the City of Cauayan, three main scenarios have been modelled: (a) BAU scenario; (b) Current Policy Scenario (CPS); and (c) Sustainable Energy Transition (SET) scenario. In addition, two ambitious scenarios, (d) Decarbonization of the Power Sector (DPS) scenario and (e) Towards Net Zero (TNZ) scenario, have been modelled, which explore the possible decarbonization pathways through decarbonizing its power supply as well as the energy system as a whole:

(a) The BAU scenario. This scenario follows historical demand trends, based on simple projections, such as using GDP and population growth. It does not consider emission limits or renewable energy targets. For each sector, the final energy demand is met by a fuel mix reflecting the current shares in TFEC, with the trend extrapolated to 2030. Essentially, this scenario aims to indicate what will happen if no enabling policies are implemented or the existing policies fail to achieve their intended outcomes;

(b) CPS. Inherited and modified from the BAU scenario, this scenario considers relevant local and national policies and plans already in place. Examples are the proposed B5 biodiesel implementation and the ambition to reach the 100 per cent electrification rate by 2022, set out in the Philippine Energy Plan 2018-2040 and Philippine Development Plan 2017-2022;

(c) SET scenario. This scenario aims to align Cauayan's energy transition pathway with the SDG7 targets. Energy efficiency improvement has been modelled in alignment with the global energy intensity improvement rate, while the renewable energy share has substantially increased with a higher energy efficiency and projected increase in the share of renewable electricity of the grid supply;

(d) DPS scenario. This scenario explores the impact of a decarbonized electricity supply on the city's GHG emissions, and presents multiple pathways that the city can undertake in decarbonizing its electricity supply;

(e) TNZ scenario. This is the most ambitious scenario of all, which looks at a net-zero pathway for Cauayan through decarbonizing the electricity supply and the adoption of electricity-based technologies in the demand sectors.

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 enable better informed policy decisions to be made. It is a tool to weigh benefits against costs and to 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. 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 the combustion process emits particulate matter that is inhaled by the local population, which results in health damage and accelerates climate change. In an economic analysis, a monetary value is assigned to the GHG emission to value its GHG emissions abatement.

2.3.2. Cost parameters

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

(a) Capital cost – capital infrastructure costs for technologies, based on country-specific data to improve the analysis. They include land, building, machinery, equipment and civil works;

(b) Operation and maintenance cost – this 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 – this comprises retirement of power plant costs related to environmental remediation, regulatory frameworks and demolition costs;

(d) Sunk cost – existing infrastructure investments are not included in the economic analysis, as the project does not require any additional investment;

(e) External cost – this refers to any additional externalities that place costs on society;

(f) GHG abatement – the avoided cost of CO_2 generation is calculated in monetary value terms based on carbon price. The 2016 Intergovernmental Panel on Climate Change's (IPCC) Guidelines for National Greenhouse Gas Inventories is followed in the calculation of GHG emission for the economic analysis. The sectoral analysis is based on the Tier 1 approach, which uses fuel combustion from national statistics and default emission factors.

2.3.3. Scenario analysis

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

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

This step is generally applied to all countries utilizing NEXSTEP in developing the national SDG7 or the subnational SET Roadmap as a means of suggesting the best way forward for the countries or cities by prioritising the several scenarios. Nevertheless, it has not been applied to the City of Cauayan as only a limited number of scenarios have been developed.

3. Overview of the City of Cauayan's energy sector

3.1. Overview of the City of Cauayan

The City of Cauayan is a landlocked city in the coastal province of Isabela, on the island of Luzon. It has a total land area of 335.4 square kilometres. The city consists of 65 *barangays*, the smallest political unit in the Philippines. The city was founded as a town in 1852 and received the status of a third-class component city in 2001, following its rapid economic growth (World Heritage Encyclopedia, 2021).

Cauayan had a total population of 150,118 in 2019, a substantial growth of around 20,600 people from its 2015 population statistics. The city has a rather young population, whereby 50 per cent of its population is under the age 25 (PhilAtlas, 2021). The city's GDP in 2019 is estimated to have been US$344.8 million and a GDP per capita of $2,297. Cauayan's main economic activities consist of agriculture, commercial and services, industrial, fisheries and mining. Notably, it has been selected to host the proposed Isabela Special Economic Zone and the Regional Agro-Industrial Growth Center. The agricultural sector is highly active in Cauayan, whereby 69.9 per cent of its land area is utilized for rice and corn production (*World Heritage Encyclopedia*, 2021)..

Cauayan was recognized as the first smart city in the Philippines in 2015, offering its citizens a wide variety of digital services (City of Cauayan, 2021). The development of the city is also well guided by the SDGs. Various initiatives and programs have been launched in advancing the city's progress across all SDGs (City of Cauayan, 2017). Initiatives in relation to SDG7 include, for example, the Litre of Light Project to help and encourage the citizens to make use of recycled bottles for light as well as the development of e-tricycles with solar roofs with a local manufacturer. In addition, the city has been an advocate of e-vehicles since 2017 (ESCAP, 2021a). To date, there are a total of 12 operating e-vehicles in the city. In addition, the city is part of the launching of the Hybrid Electric Rail Train project developed by the Department of Science and Technology (DOST) (Edale, 2019).

Cauayan's vision is to become the Ideal City of the North. It has formulated the Comprehensive Land Use Plan (CLUP), 2018-2027. It is also in the midst of drafting its Comprehensive Development Plan, 2022-2031. The two documents aim to provide blueprints for sustainable development of the city in all areas including social, economic, infrastructure and institutional development.

However, the findings by ESCAP (2021a) highlighted the fact that there are limited existing projects and initiatives directly focused on SDG7 implementation (i.e., energy efficiency, renewable energy and energy access). Accelerated effort by the city government is required in advancing progress towards SDG7.

3.2. City energy profile

Cauayan's population of 150,118 in 2019 comprised 35,946 households. In 2019, the percentage of access to electricity was an estimated 90.4 per cent, leaving around 3,364 households that had yet to be connected to any form of electricity supply. All of these were small residential households. The clean cooking access rate was lower, at 76.7 per cent in 2019, corresponding to 8,152 small residential households lacking access to clean cooking fuels and technologies. These remaining households were relying on the usage of traditional biomass stoves (18.6 per cent) and kerosene stoves (4.7 per cent) for residential cooking purposes.

Renewable energy delivered approximately 5 per cent of TFEC in 2019. A total of 4.5 MW solar PV system capacity has been installed within the city boundary, which produced 6.34 GWh in 2019, assuming a 16 per cent capacity factor.[5] The electricity requirement of the region is met almost exclusively by purchased electricity from the central grid, i.e., the Luzon grid. The percentage share of renewable energy considers the share of the central grid, which was an estimated 14 per cent in 2019.[6] Other usage of renewable energy includes a small amount of biofuel consumption in the transport sector. The current blend of biofuel in the Philippines is 2 per cent and 10 per cent for biodiesel and bioethanol, respectively (DOE, 2021a). In the agricultural sector, 200 kW of solar irrigation systems have been installed to fulfil irrigation needs for a total land size of 100 hectares.

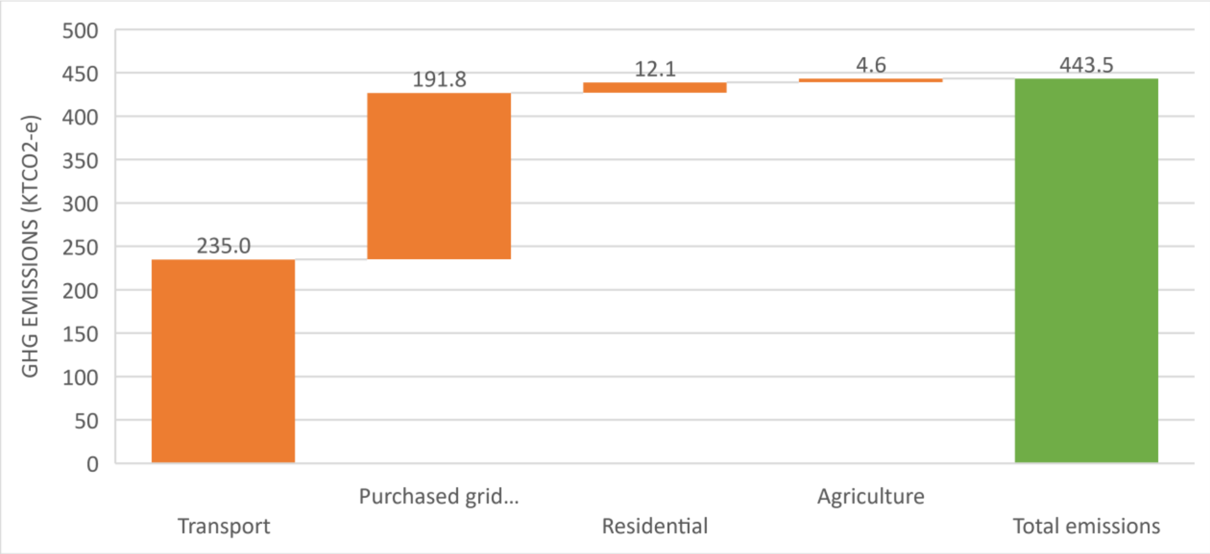
The energy intensity in 2018 was calculated as 5.85 MJ/US$$_{2011}$.[7] Around 69.4 per cent of the total primary energy supply is used to fulfil the demand from the transport sector.

The GHG emissions in 2019 are estimated to have been 443.6 ktCO_2-e. The GHG emissions breakdown is shown in Figure 3. The emissions from the residential sector were from the the use of LPG and kerosene in household cooking as well as kerosene for lighting purposes in non-electrified households. The transport emissions were from direct fuel combustions in internal combustion engines. The agricultural sector contributed around 1 per cent of the emissions, through diesel combustion in water pumps and agricultural machinery (i.e., tractor, rotovators and harvesters). Emissions related to electricity usage are not attributable to the electricity consuming demand sectors, but are attributable to the supply side, i.e., purchased grid electricity. As electricity is the only energy supply in the commercial and industry sectors (Figure), emissions attributable to these sectors are already accounted for in the electricity supply category. The grid emission factor considered for the base year 2019 is 0.641 tCO_2/MWh. This is the average of the combined margin emission factors for the Luzon grid, 2015-2017 (DOE, 2021b).[8] The transmission and distribution losses of grid electricity are assumed to have been 9.41 per cent (World Bank, 2021); the emissions attributable to such losses are also included in Cauayan's emission profile.

The current progress of Cauayan's energy sector in accordance with the SDG indicators are summarized in Annex I.

[5] Based on actual national data for 2019-2020, provided by the Philippines Department of Energy. See https://www.foi.gov.ph/requests/aglzfmVmb2ktcGhyHQsSB0NvbnRlbnQiEERPRS02MDg5OTkyMDk2OTQM
[6] Based on DOE's 2020 Power Statistics, gross generation per grid, by plant type.
[7] Authors' calculation.
[8] More recent emission factor data cannot be found in the public domain.

Figure 3. GHG emissions in 2019



3.3. Regional energy resource assessment

The utilization of indigenous energy resources (i.e., solar and wind) in local electricity generation within the boundaries of the City of Cauayan is currently limited to solar of around 4.5 MW capacity. Limited assessment of the renewable energy potential in Cauayan has been done. Nevertheless, it is noted that its geographical location in the tropical zone allows the city to enjoy an estimated annual solar irradiation (in terms of global horizontal irradiation) of around 1,600-1,800 kWh/m^2.[9] On the other hand, wind energy potential is limited compared to the other parts of the Philippines. The mean power densities at 50 metres and 200 metres hub height are estimated to only be 70W/m^2 and 170 W/m^2, respectively.[10]

Nearly 70 per cent of the city's area is utilized for agricultural purposes, primarily rice and corn production. However, the agricultural waste potential from Cauayan's active agricultural activities has not been explored through formal studies. Based on NEXSTEP preliminary resource potential quantification, the agricultural waste from rice and corn cultivation may have up to 5 MW of power generation potential, while electricity generation potential from animal manure is estimated to be 2 MW. This is further elaborated in box 3 (subsection 5.1.1).

3.4. City energy balance, 2019

The estimated energy consumption made by using data collected with a bottom-up approach, such as activity level and energy intensity data, is detailed below. The majority of the following 2019 energy data

[9] Information obtained from the "Global Solar Atlas 2.0, a free, web-based application, is developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilizing Solargis data with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information see https://globalsolaratlas.info

[10] Information obtained from the "Global Wind Atlas 3.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 was released in partnership with the World Bank Group, utilizing data provided by Vortex, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information see https://globalwindatlas.info

has been provided by ESCAP's local consultant, Dr. Orlando Balderama and his team, unless stated otherwise. Further details on the data and assumptions used can be found in Annex II.

The total final energy consumption (TFEC) in 2019 was 113.1 ktoe. The main energy consuming sector is the transport sector, which consumed 78.6 ktoe, around 69.4 per cent of TFEC, in 2019. The existing transport fleet (in 2019) was almost exclusively made up of internal combustion engine vehicles, consuming diesel (87.3 per cent), gasoline (10.4 per cent) and a small amount of biodiesel (1.6 per cent) and ethanol (0.7 per cent). The residential sector comes second in terms of the final energy consumption, consuming 17.7 ktoe, or 15.6 per cent of Cauayan's TFEC in 2019. Nearing half (48.1 per cent) of the energy consumed was in the form of electricity, while biomass (34.3 per cent) and LPG (16.7 per cent) were used for residential cooking purposes. The energy consumed in the commercial sector and industry sector is exclusively electricity, at 12.3 ktoe (10.9 per cent) and 3.0 ktoe (2.7 per cent) in 2019, respectively. Figure shows the fuel demand from the demand sectors, while Figure shows the TFEC breakdown by fuel type in 2019.

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

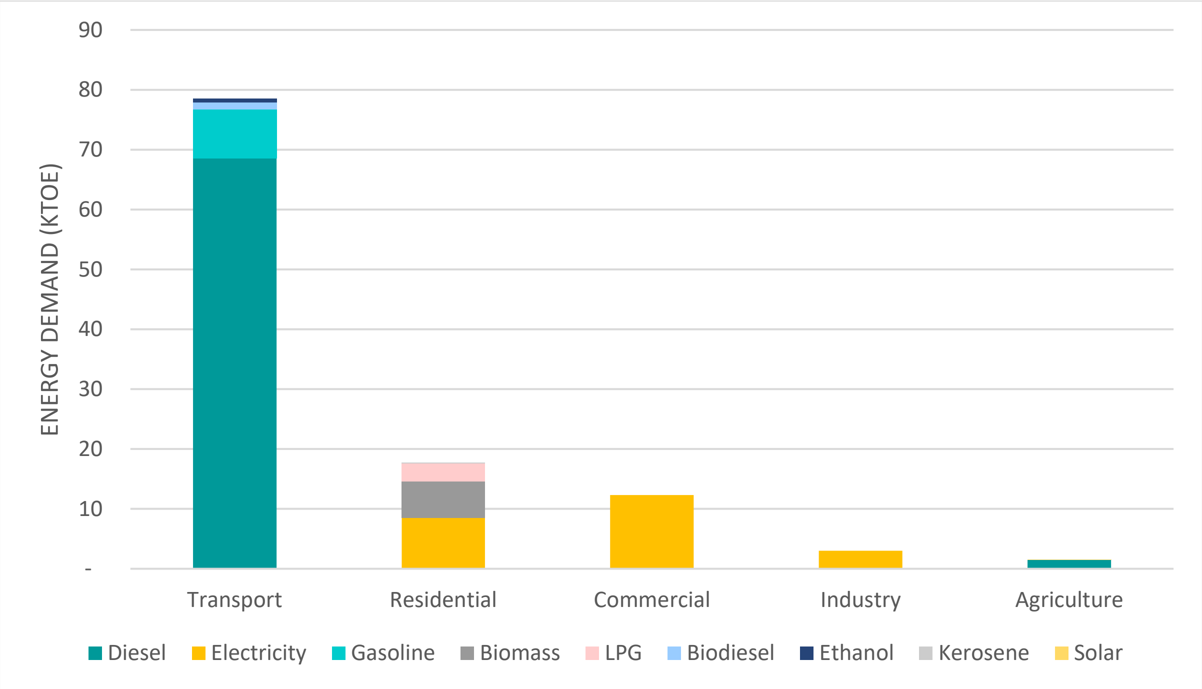


Figure 4. TFEC breakdown by fuel type, 2019

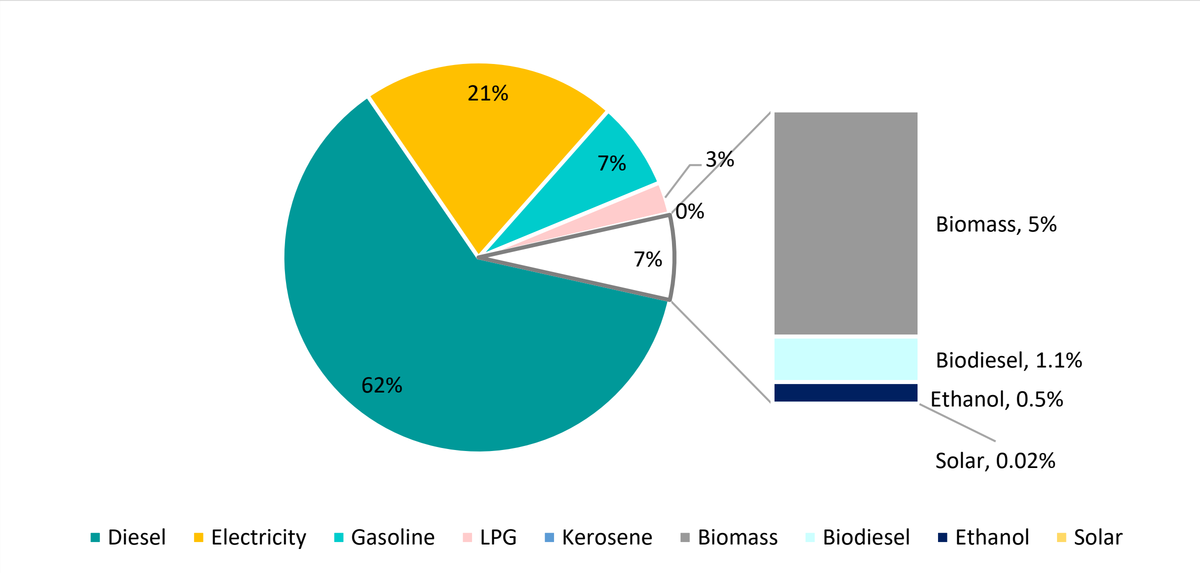
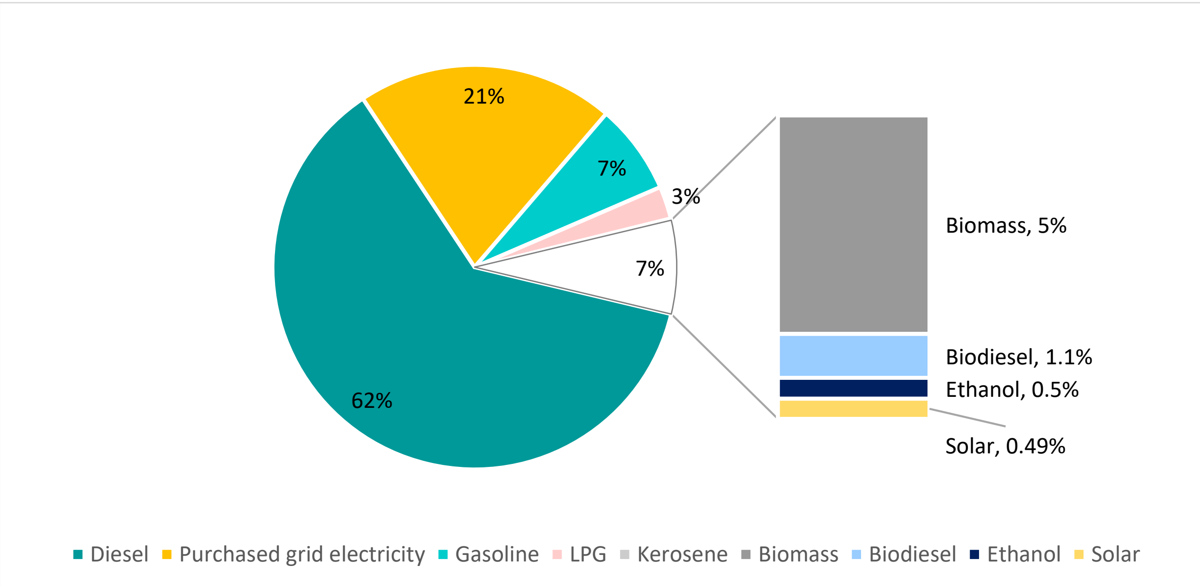


Figure shows the total primary energy supply (TPES) breakdown by fuel type in 2019. The total primary energy supply was 113.1 ktoe, similar to TFEC, as local electricity generation was minimal. Cauayan is connected to the Luzon grid, importing almost all (98 per cent) of its electricity required from the central grid. A small amount of electricity was supplied through solar installations within the city boundary, with an estimated generation in 2019 at 6.34 GWh.

Figure 5. TPES breakdown by fuel type, 2019



3.5. Energy modelling projections

The future energy demand is projected based on a bottom-up approach, using activity levels and energy intensities, with the LEAP model. The demand outlook throughout the NEXSTEP analysis period is influenced by factors such as annual population growth, annual GDP growth and other demand sector growth projections. The assumptions used in the NEXSTEP modelling are further detailed in 0, while Table 1. provides a summary of the key modelling assumptions for the three main scenarios (i.e., the BAU, CPS and SET scenarios).

Table 1. Principal factors, targets and assumptions used in NEXSTEP modelling

Parameters	BAU	CPS	SET
GDP growth	US$344.8 million in 2019, assumed growth rate of 5.5% per annum.		
Population growth	150,118 in 2019, assumed growth rate of 3.18% per annum.		
Commercial floor space	0.63 million square metres in 2019, assumed growth rate of 5.5% per annum.		
Transport activity	Transport activities in 2019: 2.8 billion passenger-kilometres and 1.4 billion tonne-kilometres, with assumed growth of 5.5 per cent per annum.		
Industry	GDP contribution in 2019: US$8.5 million; annual growth rate of 5.5%		
Energy efficiency	Additional energy efficiency measures not applied	Improvement based on current policies/initiatives.	Economy-wide efficiency improvement
Electricity generation	Based on 2019 existing RE installation within the city boundaries. Purchased electricity from the central grid is assumed to have the same fuel mix throughout the period.	Based on 2019 existing RE installation within the city boundaries. The purchased (grid) electricity mix in 2030 references the projected generation mix in the reference (REF) scenario in the Philippine Energy Plan 2018-2040.[11]	Based on 2019 existing RE installation within the city boundaries. The purchased (grid) electricity mix in 2030 references the projected generation mix in the reference (REF) scenario in the Philippine Energy Plan 2018-2040. [11]

3.6. City of Cauayan's energy system projections in the current policy settings

The Current Policy Scenario (CPS) explores how Cauayan's energy system may evolve under the current policy settings. It considers several initiatives implemented or scheduled to be implemented during the analysis period of 2020-2030, both at the city level and the national level. The policies/initiatives considered in the modelling of CPS are detailed below:

(a) Universal electricity access to be realised by 2022

The Philippine Energy Plan, 2018-2040 and the Philippine Development Plan, 2017-2022 have set out ambitions to provide access to basic electricity for all Filipinos by 2022.

[11] The estimated generation mix of the grid electricity is used in calculating the RE share in TFEC and GHG emissions attributable to purchased (grid) electricity. Full details of the calculations are provided in Annex III.

(b) Power sector development and future grid emission factor

The power sector development in the Philippines will evolve over time, with increasing RE penetration. This should also result in a reduced grid emission factor throughout the analysis period. The Philippine Energy Plan, 2018-2040 stipulates two scenarios for the national power sector, i.e., the Reference Scenario (REF) and the Clean Energy Scenario (CES). NEXSTEP utilized the projected electricity generation of REF scenario in projecting the emission factor for 2030. The author's estimated emission factor in 2030 is 0.567 tCO_2/MWh. Further details can be found in Annex III.

(c) Philippines Green Building Code

The Philippines Green Building Code (GB Code) was launched in 2015 and is applied to all new construction and/or alteration of buildings with a minimum total gross floor area (TGFA) as follows (PGBI, 2016),(table 2).

Table 2. Minimum TGFA for different building types to comply with the Philippines Green Building Code

Building type	Minimum total gross floor area (TGFA)
Residential condominium	20,000
Hotel/resort	10,000
Educational school	10,000
Institutional hospital	10,000
Business office	10,000
Mercantile mall	15,000
Mixed occupancy	10,000

NEXSTEP assumes that the new and old buildings in Cauayan do not meet the minimum TGFA, hence the mandatory building code does not apply to the buildings in Cauayan.

(d) Solar and RE technologies in buildings (Department Circular, 2020-12-0026)

The recently issued department circular mandates the use of solar PV and other RE technologies in new and existing buildings. This applies to buildings with electrical loads of at least 112.5 kilovolt-ampere or with a total gross floor area of at least 10,000 square metres. Similar to the above, NEXSTEP assumes that the new and existing buildings do not meet the implementation requirements.

(e) Minimum Energy Performance Standards and Energy Labelling Standards

The Minimum Energy Performance Standards (MEPS) and/or energy labelling standards have been introduced for various household appliances, covering window-type air-conditioners (since 1993) and split-type room air-conditioners (since 2000), refrigerators and freezers (since 1999, applicable to sizes between 142-227 litres), compact fluorescent lamps (CFL), linear fluorescent lamps (LFL), ballasts and circular fluorescent lamps (Hemandez, n.d.). As MEPS for household appliances were introduced between1993 and 2010, NEXSTEP assumes that existing appliances have already conformed to the minimum energy performance standards set out by DOE, where applicable. Hence, no additional potential savings are to be achieved.

(f) B5 biodiesel blend target

As noted in the Manila Bulletin (2021), DOE is targeting an increase in the current biodiesel share, from 2 per cent by volume to 5 per cent in 2021. NEXSTEP assumes that this will be implemented from 2022 onwards.[12]

(g) Solar Irrigation system programme

Cauayan is advocating the use of solar irrigation systems in its agricultural sector. The programme is expected to implement five solar irrigation system sets each year.[13]

Cauayan is participating in the launching of the Hybrid Electric Rail Train (HERT) developed by the Department of Science and Technology (DOST) (Edale, 2019). However, as there are insufficient data to indicate how the future commercialized deployment of HERT may affect the structure of city's transport sector, it has not been considered in the modelling. However, deployment of HERT may possibly lead to reduced use of other forms of transport, i.e., tricycles and passenger cars. In addition, the City recently introduced tax incentives for businesses implementing RE electricity system with a capacity of 3 kW or more, through its Renewable Energy Ordinance.[14] The expected outcome is challenging to estimate; hence, it is not modelled in the CPS.

The following subsection r describes the energy and emission outlook in the current policy settings in more detail.

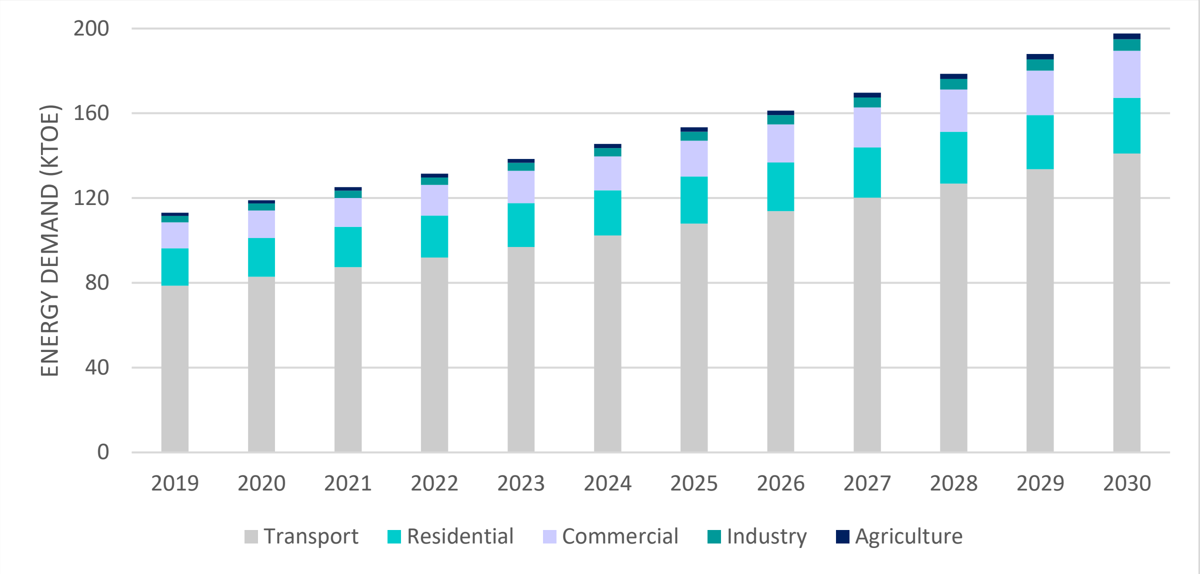
3.6.1. Energy demand outlook

In the current policy settings, TFEC is projected to increase from 113.1 ktoe in 2019 to 197.7 ktoe in 2030, similar to the projected demand in the BAU scenario (198 ktoe). The transport sector consumption will remain the largest at 141.1 ktoe (71.4 per cent), followed by the residential sector at 26.2 ktoe (13.3 per cent), the commercial sector at 22.2 (11.2 per cent), the industry sector at 5.4 ktoe (2.7 per cent) and the agricultural sector at 2.7 ktoe (1.4 per cent).

The sectoral overview of energy demand in the CPS is discussed below figure.

[12] This target had not been implemented as of June 2021, therefore, NEXSTEP assumes that the target will take effect sometime around the end of 2021 or early 2022.
[13] Each set of solar irrigation systems is assumed to have a capacity of 9.6 kW.
[14] See https://www.facebook.com/cityofcauayanofficial/photos/pcb.5807656575940953/5807638779276066

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

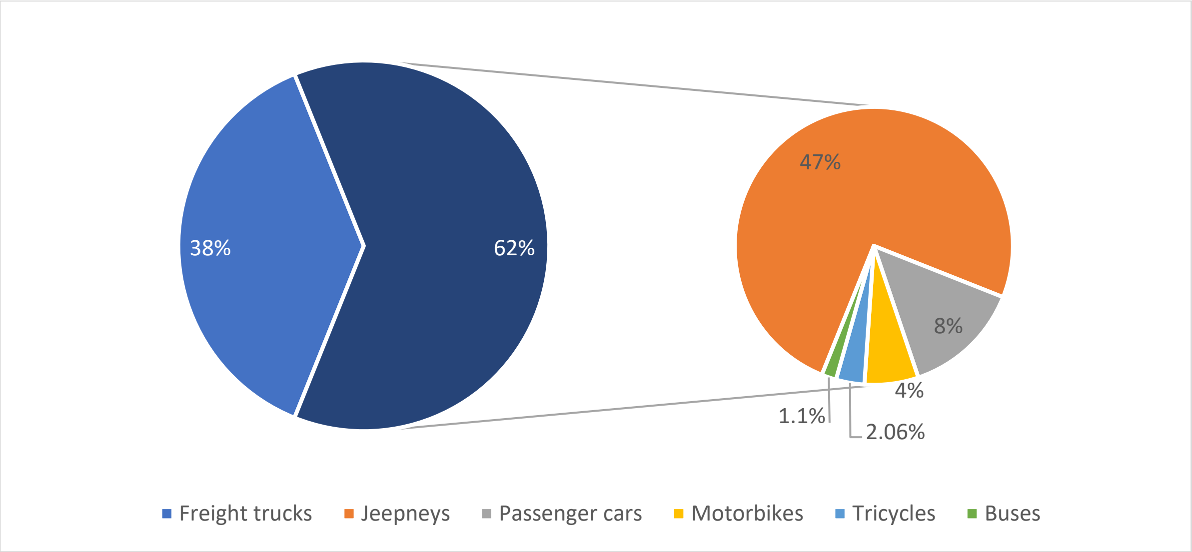


*(*a) Transport sector

The transport sector energy demand will continue to dominate Cauayan's TFEC and is projected to increase from 78.6 ktoe in 2019 to 141.1 ktoe in 2030. In 2030, the subsector share of transport energy demand is projected to be passenger road transport at 87.8 ktoe (62.2 per cent) and road freight transport at 53.3 ktoe (37.8 per cent).

Road passenger transport is subdivided into four subcategories, i.e., private cars, motorbikes, tricycles, jeepneys and buses, while freight transport consists of only freight trucks. The demand share in 2030 by transport subcategories is as shown in Figure . The left-hand chart shows the share of freight transport (i.e., freight trucks) and passenger transport, while the right-hand chart provides the demand breakdown of passenger transport subcategories. As indicated, 75 per cent of the passenger transport energy demand is expected to come from jeepneys.

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



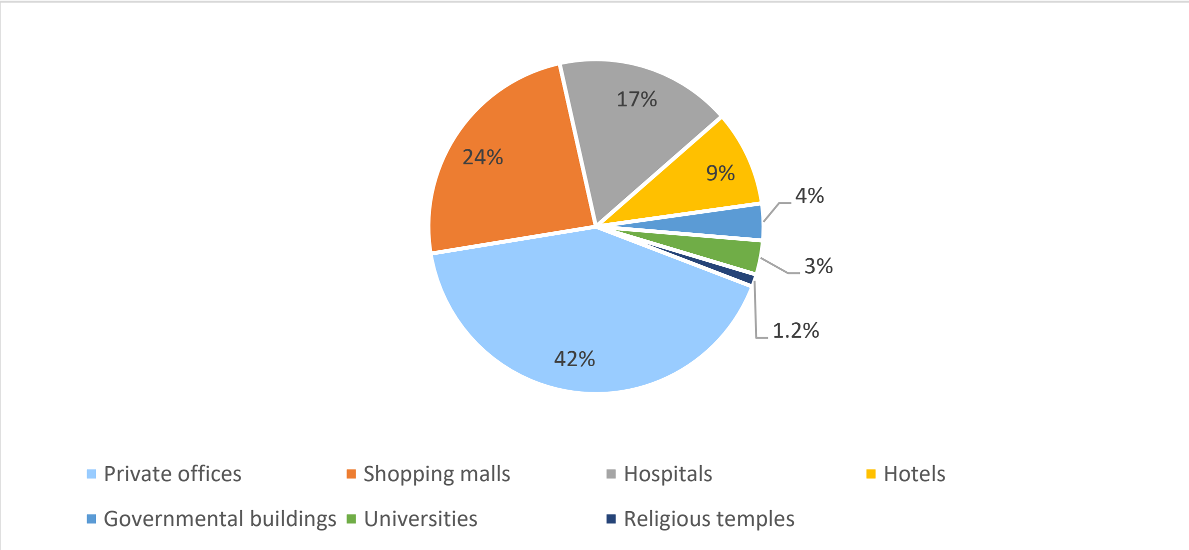
(b) Residential sector

The residential sector energy demand is projected to increase to 26.2 ktoe by 2030, compared with 17.7 ktoe in 2019. The residential sector is further differentiated into three residential categories, classified by sizes, i.e., small, medium and large residential. The energy demand from the small residential category is the highest, at 14.4 ktoe (54.9 per cent), followed by large and medium residential categories, at 6.7 ktoe (25.5 per cent) and 5.2 ktoe (19.6 per cent), respectively.

(c) Commercial sector

The commercial sector energy demand is projected to increase from 12.3 ktoe in 2019 to 22.2 ktoe in 2030. The sector is divided into seven subcategories, of which the floorspace of each category is projected to grow by 5.5 per cent per annum. The projected energy demand distribution in 2030 is as shown in Figure .

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



(d) Industry sector

Energy demand from the industry sector is expected to grow from 3.0 ktoe in 2019 to 5.4 ktoe in 2030. The modelling of CPS assumes that the energy intensity of the industrial sector remains constant throughout the analysis period, while industrial energy productivity increases by 5.5 per cent annually. The industry activities are quite limited and can be classified into three main categories. In 2030, the energy demand is projected to be: machinery and transportation equipment (3.5 ktoe, 65 per cent), food and beverage (1.1 ktoe, 20 per cent), and wood and other wood products (0.8 ktoe, 15 per cent).

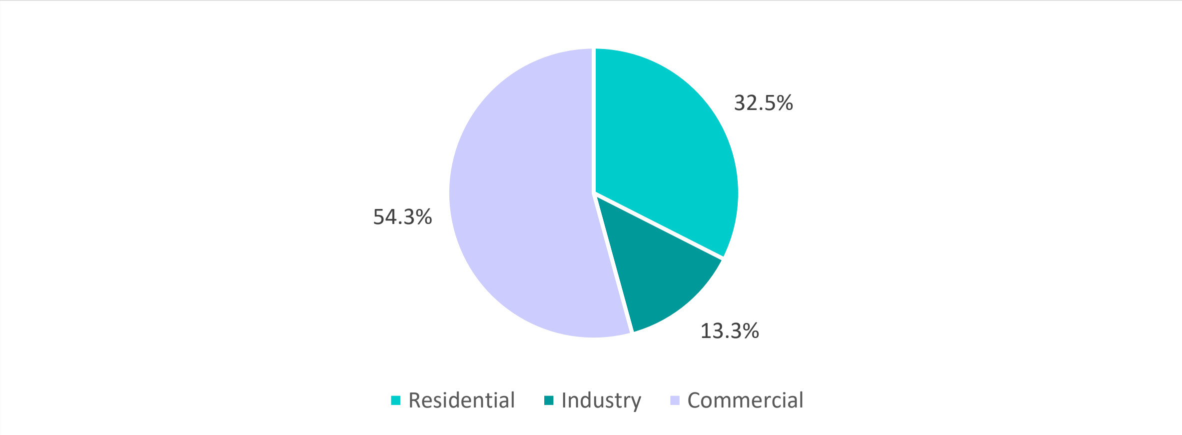
(e) Agriculture sector

The energy demand from the agriculture sector was relatively insignificant at 1.7 per cent in 2019. The energy demand is expected to increase from 1.5 ktoe in 2019 to 2.7 ktoe in 2030. The increase in energy demand stems from the increasing need for water pumping and agricultural machinery to increase crop productivity. As mentioned above, the solar irrigation programme is expected to install five sets of solar irrigation systems each year. At the same time, the demand for small diesel water pumps is expected to increase by 100 pumps per annum. The energy demand from agricultural machinery (i.e., harvesters, rotovators and tractors) is projected to grow at an annual rate of 5.5 per cent, as productivity increases.

3.6.2. Electricity generation outlook

The 2030 demand for electricity in the current policy scenario is projected to be 476.5 Gigawatt-hours (GWh), increasing from 277.5 TWh in 2019. The demand will be the highest in the commercial sector at 258.5 GWh (54.3 per cent) followed by the residential sector at 154.7 GWh (32.5 per cent) and the industry sector at 63.2 GWh (54.3 per cent) (Figure).

Figure 9. Electricity demand distribution by demand sector in 2030, CPS

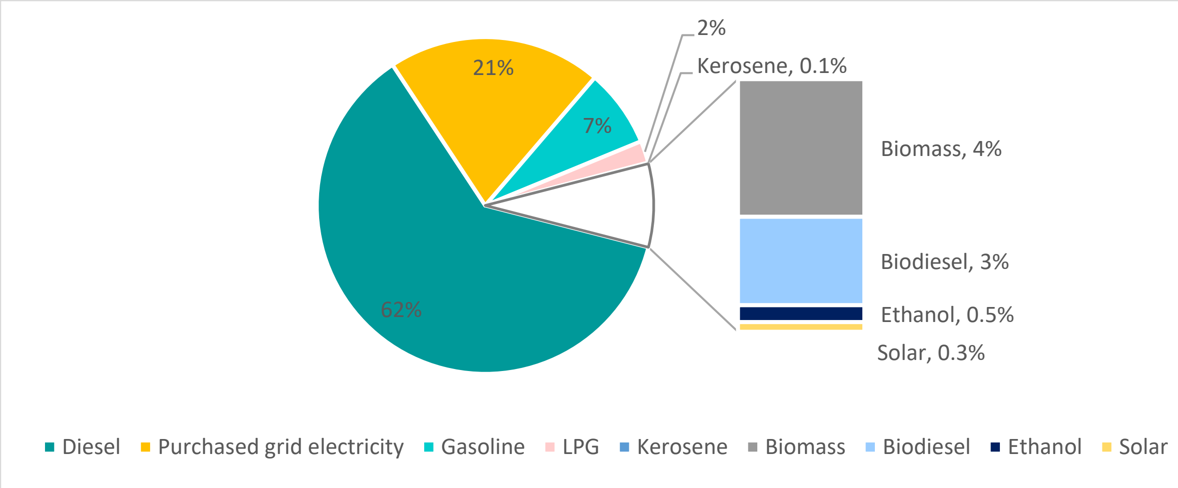


The electricity required to fulfil the demand in Cauayan is almost exclusively purchased from the grid, as local generation units are limited. Currently, installation of RE power capacity in governmental buildings is still in the planning stage. The recently issued Renewable Energy Ordinance may see rooftop solar PV installations picking up in the city. However, without further information on future installed capacity, the NEXSTEP analysis projects the existing capacity of 4.5 MW solar PV with an annual estimated generation of 6.3 GWh throughout the analysis period in the CPS. The remaining demand is expected to be fulfilled with central grid electricity from the Luzon grid.

3.6.3. Energy supply outlook

In the CPS, TPES is forecast to increase from 113.1 ktoe in 2019 to 197.7 ktoe in 2030. The fuel consumption in 2030 is projected to be diesel at 122.4 ktoe, electricity at 40.4 ktoe, gasoline at 14.8 ktoe, biomass at 8.6 ktoe, LPG at 4.2 ktoe, ethanol and biodiesel at 5.5 ktoe, solar at 0.6 ktoe and kerosene at 0.2 ktoe. Figure shows the TPES breakdown by fuel type.

Figure 4 TPES breakdown by fuel type, CPS, 2030



3.6.4. Energy sector emissions outlook

The energy sector emissions, from the combustion of fuels, is calculated based on the IPCC Tier 1 emission factors assigned in the LEAP model. The combustion of biomass products (i.e., biodiesel and ethanol) is considered carbon-neutral. The emissions attributable to purchased (grid) electricity have been included, while considering the projected decrease in grid emission factor throughout the analysis period. The grid emission factors have been estimated by the author, based on the projected generation mix of the REF scenario in 2030, stipulated in the Philippine Energy Plan, 2030 as well as other assumed factors (e.g., efficiency). Further details of the grid emission factor estimation can be found in Annex III.

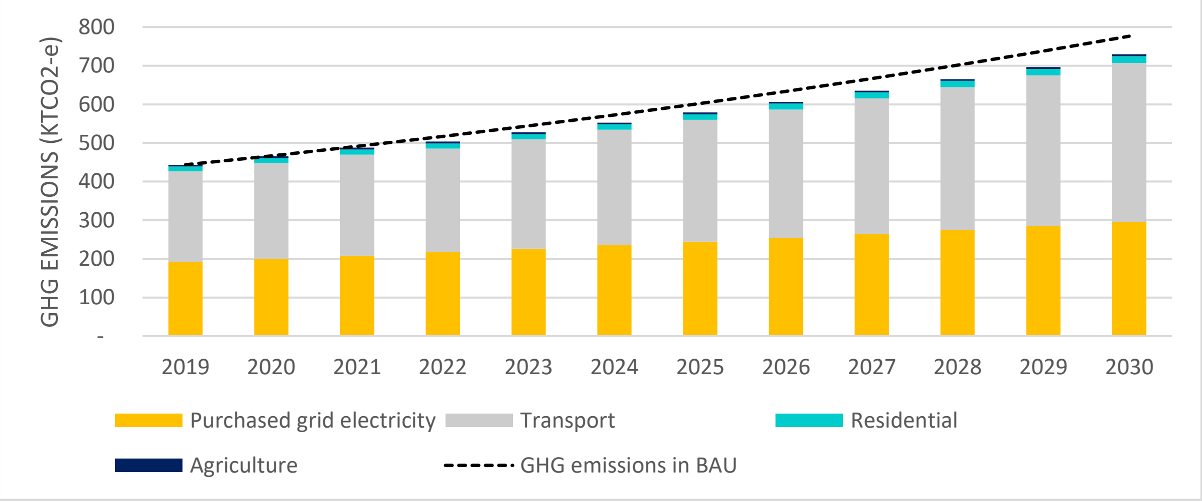
In the CPS, the total GHG emissions from the energy sector increase from 443.6 $ktCO_2$-e to 732.8 $ktCO_2$-e (f

Figure). The emissions attributable to purchased (grid) electricity make up about 40.4 per cent of the total emissions. For the demand sectors, the largest contributor of GHG emissions in 2030 will be the transport sector (56.5 per cent), followed by the residential sector (2.3 per cent) and the agriculture sector (0.7 per cent).

The emission reduction is 6 per cent, relative to the BAU scenario. The decreasing emission factor of the central grid electricity is the major contributing factor to emission reduction. However, in the event that the share of RE in the electricity mix increases less rapidly than modelled, the emission reduction will be much less substantial. For example, the total GHG emission is estimated as 769.6 $kTCO_2$-e in

2030 if the emission factor remains similar to the 2019 level, which is a 10 $ktCO_2$-e reduction compared to the BAU scenario (figure 11).

Figure 5 Cauayan's energy sector emissions outlook, CPS, 2019-2030



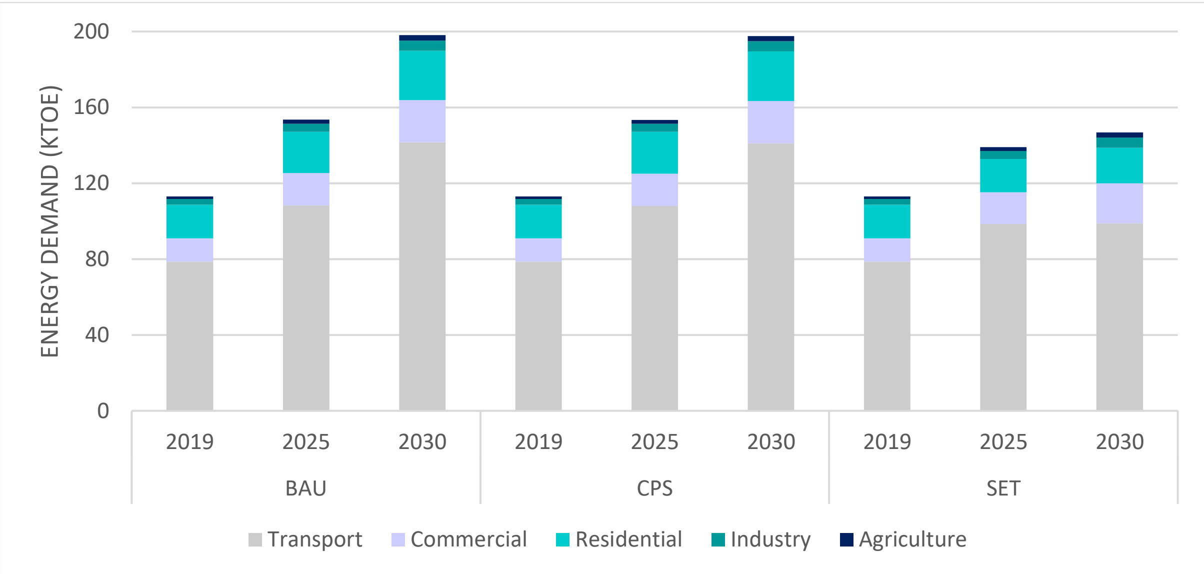
4. SET scenario – sustainable energy transition pathway for the City of Cauayan

Subnational and national efforts are both imperative to achieving the 2030 Agenda for Sustainable Development and Paris Agreement on climate change. In particular, cities around the world contribute around 75 per cent of global anthropogenic emissions and represent about 66 per cent of global energy demand (REN21, 2019). This chapter provides details of the SET scenario, exploring how economy-wide efforts may improve the energy and climate sustainability of the City of Cauayan. It starts with the energy demand forecast and then discusses the energy sector in relation to SDG7 targets.

4.1. SET energy demand outlook

In the SET scenario, TFEC increases at a much slower pace than CPS, from 113.1 ktoe in 2019 to 145.7 ktoe in 2030. The reduction of 51 ktoe in TFEC in this scenario, compared with the CPS, is due to the improvement in energy efficiency across the demand sectors. The proposed energy efficiency interventions are further described in subsection 4.2.3. In 2030, the transport sector will still have the largest share of TFEC at 98.8 ktoe (67.4 per cent), followed by the commercial sector at 21.1 ktoe (14.4 per cent), the residential sector at 18.7 ktoe (12.7 per cent), the industry sector at 5.4 ktoe (3.7 per cent) and the agricultural sector at 2.7 ktoe (1.8 per cent). Figure shows TFEC by scenarios in 2030.

Figure 12. Projection of TFEC by sector, 2030



4.2. SDG7 targets

4.2.1. SDG7.1.1. Universal access to electricity

Electrification rate is expected to reach 100 per cent by 2022, as set out in the Philippines Energy Plan, 2018-2040 and the Philippine Development Plan, 2017-2022. The NEXSTEP analysis proposes that decentralised renewable electricity systems, such as solar mini-grids and solar home systems, could be provided to the unconnected households. The ease of implementation, compared to extending the grid infrastructure, should allow the 100 per cent electrification target to be reached within the stipulated timeline.

4.2.2. SDG7.1.2. Universal access to clean cooking

Accelerated effort is required to achieve universal access to clean cooking. As of 2019, 23.3 per cent of households relied on polluting cooking technologies, including traditional biomass stoves and kerosene stoves. NEXSTEP analysis proposes the use of (induction-type) electric cooking stoves as the most appropriate technology in filling in the gap due to:

(a) Zero household air pollution;
(b) Minimal follow-up required (as opposed to improved cooking stoves);
(c) Cost effectiveness compared to the more commonly used LPG stove.

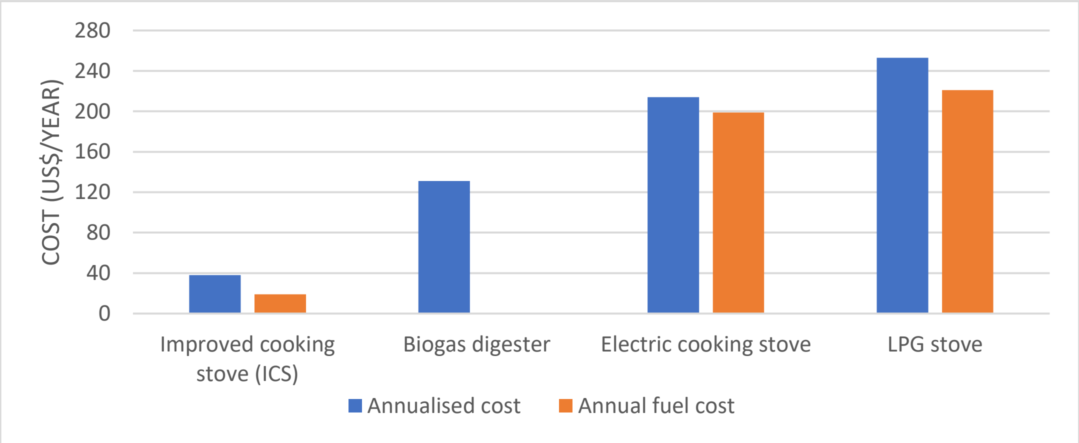
However, the operation of electric cooking stoves requires substantial power supply capacity that may not be met solely by decentralised RE systems proposed for currently unconnected households. In that case, the LPG stove is the most appropriate technology.

Box 2 provides a summary of cost analysis and qualitative analysis of the pros and cons of different clean cooking technologies, in supporting the adoption of electric cooking stoves and LPG stoves as the most appropriate technologies.

Box 2. Cost and qualitative analysis of clean cooking technologies

Figure below summarizes the annualized cost and annual fuel cost of the different cooking technologies in the context of Cauayan. Annex IV summarises the cost and technical assumptions used in the economic analysis.

Annualised cost and annual fuel cost of different cooking technologies



While ICS and biogas digesters are estimated to have a lower annualised cost than electric cooking stoves, concerns have been raised by various studies of their suitability as a long-term clean cooking solution for the general population, particularly the urban population. A short qualitative analysis on the pros and cons of the different clean cooking technologies is detailed below.

(a) Electric cooking stoves

Electric cooking technology is classed as Level 5 in the World Bank MTF for Indoor Air Quality Measurement. Electric cooking stoves are more efficient than other cooking stoves, including gas stoves. Electric cooking stoves can generally be divided into two types – solid plate and induction plate. While solid plate cooking stoves use a heating element to transmit radiant energy to the food and reach about 70 per cent efficiency, induction plate cooking stoves use electromagnetic energy to directly heat pots and pans, and can be up to 90 per cent efficient.

(b) Improved cooking stoves

Studies suggest that ICS programs often have low adoption rates due to inconvenience of use, preference for traditional cookstoves and the 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 facilitate continuing usage (ESCAP, 2021b). In addition, based on the WHO guidelines for emission rates for clean cooking, only certain types of ICS technology comply, particularly when considering that cooking stove emissions in the field are often higher than they are in the laboratory settings used for testing.

(c) Biogas digesters

Biogas digesters have high upfront capital costs (about US$1,000 for a standard size that is suitable for a four-member family) and require a substantial subsidy due to their longer payback period. A standard size biogas digester requires two to four cows, depending on the size of the cow, to produce enough feedstock for a household's daily gas demand. While the high number of livestock in Cauayan may provide the necessary feedstock for biogas digesters, cultural reluctance to use animal or human waste for cooking may be an impediment to a successful roll out of biogas digesters as a primary cooking method.

(d) LPG cooking stoves

LPG cooking stoves generate lower indoor air pollution compared with ICS. They are classified as Level 4 in the World Bank Multi-Tier Framework (MTF) for cooking exposure and reduce indoor air pollution by 90 per cent compared with traditional cooking stoves. However, the LPG stove is estimated to have a higher cost than the electric cooking stove, as shown in the above figure.

4.2.3. SDG7.2. Renewable energy

SDG7.2 does not have a quantitative target but requires a substantial increase in the renewable energy share in TFEC. The RE share in TFEC for Cauayan is determined using the required improvement in energy efficiency as a constraint, for which NEXSTEP considers the alignment of Cauayan's annual average energy efficiency improvement with the suggested global improvement rate of 3 per cent per annum (UNSD, 2021) (detailed further in subsection 4.2.3). The RE share in TFEC also considers the increase in RE percentage in the grid electricity mix.

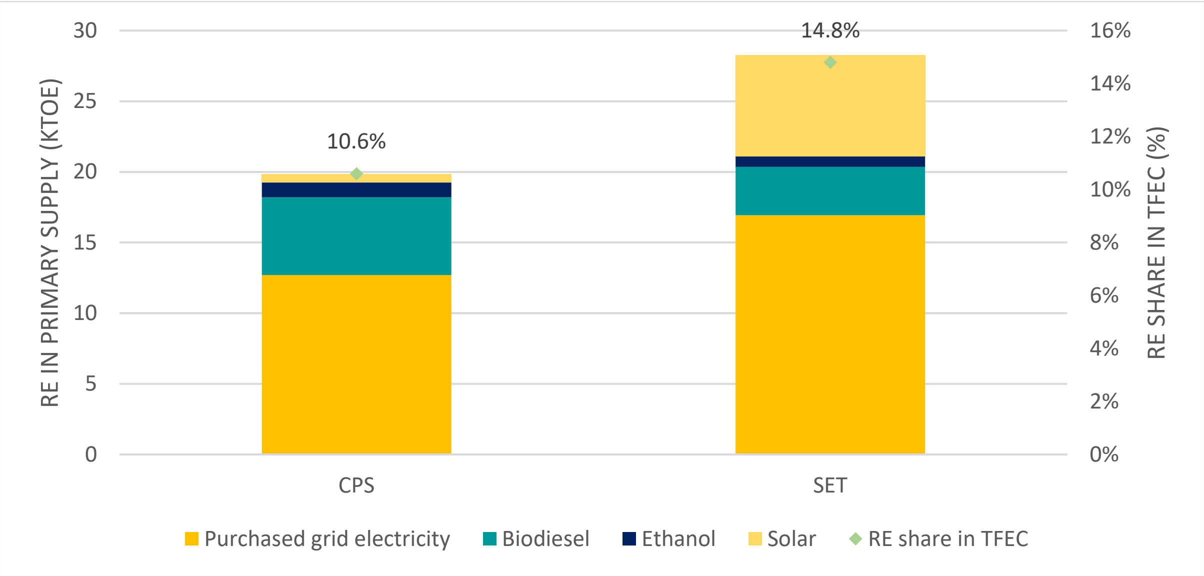
The share of renewable energy in TFEC in 2030 will be 10.6 per cent by 2030 in the current policy scenario (Figure). This increases from just 5 per cent in 2019. The increase is mainly driven by two factors:

(a) The projected increase in RE share of the grid electricity, from 14 per cent in 2019[15] to 34.1 per cent in 2030, based on the REF scenario in the Philippine Energy Plan 2018-2040;

(b) Increased biodiesel usage in the transport sector.

In the SET scenario, the renewable energy share in TFEC is projected to increase to 14.8 per cent by 2030. This is a result of further reduction of energy demand due to energy efficiency measures in the demand sectors (see subsection 4.2.3), and increased use of grid electricity (in the transport sector) which has a relatively high share of RE generation.

Figure 13. Renewable energy in TPES and TFEC, 2030



4.2.4. SDG7.3. Energy efficiency

The primary energy intensity, a proxy for the measurement of energy efficiency improvement, is calculated as 5.68 MJ/US$$_{2011}$ in the current policy scenario, which corresponds to an annual rate of improvement of 0.3 per cent. The primary energy intensity is further reduced to 4.21 MJ/US$$_{2011}$ in the SET scenario, made possible through the proposed economy-wide energy efficiency improvement measures. This corresponds to an average annual rate of improvement of 3 per cent, on a par with the suggested global improvement rate of 3 per cent (UNSD, 2021).

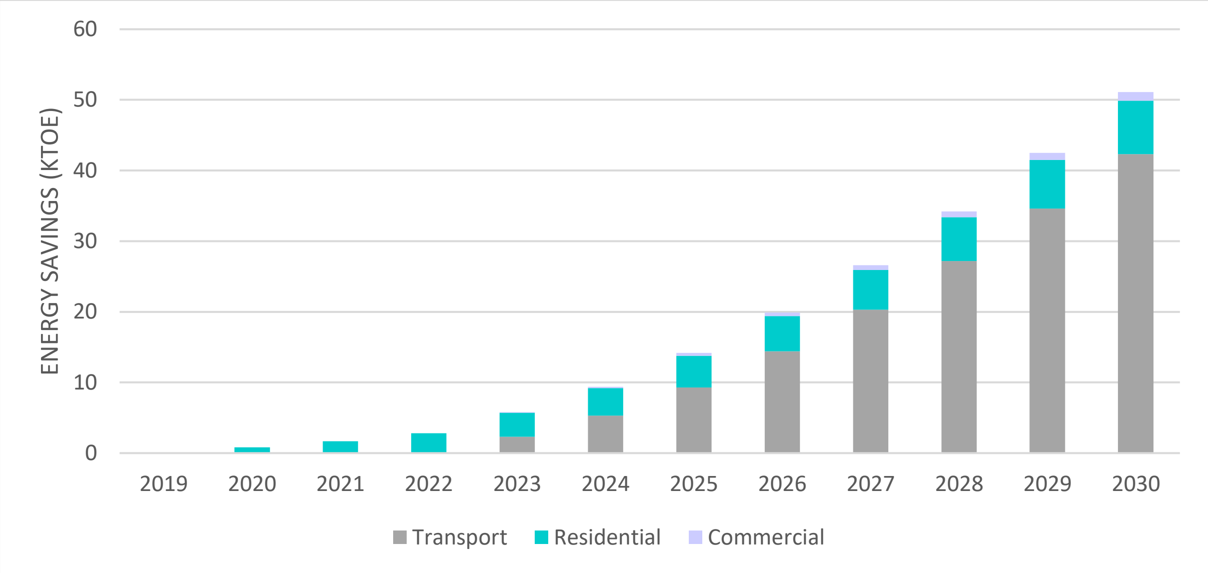
Figure shows the energy savings that may be achieved through the implementation of energy efficiency measures across the demand sectors, compared with the CPS. The transport sector is the largest energy consuming sector in Cauayan; it can also be expected to have the largest contribution (42.3 ktoe in 2030), through the increased adoption of electric vehicles in multiple transport subcategories.

[15] Based on the DOE 2020 Power Statistics, gross generation per grid, by plant type.

Energy demand reduction can also be realised through the phasing out of inefficient technologies in residential households. The city may consider a special policy that requires all new commercial buildings to adhere to the national green building code (from 2023 onwards), regardless of floorspace size, thereby allowing an estimated energy demand reduction of 1.2 ktoe in 2030. Similarly, the city may consider mandating the adoption of the department circular on the use of solar and RE systems in all new commercial buildings. This is discussed in subsection 4.3.2.

Further details of the energy efficiency measures and their impacts are provided below.

Figure 14. Energy savings in the SET scenario, compared to CPS



(a) Transport sector

The current share of electric vehicles in the existing fleet is very low. The total number in the city is around 12 vehicles. However, the promotion of electric vehicles is an effective way to reduce demand consumption in the transport sector as well as GHG emissions. In the SET scenario, NEXSTEP proposes that uptake of electric vehicles can be promoted across the different vehicle categories, reaching a considerable share of the transport fleet by 2030. Further details and the estimated annual savings are shown in Table .

Table 3. Energy efficiency measure applied and estimated annual savings in 2030 (relative to CPS) in the transport sector

Subcategory	Energy efficiency measures	Annual savings in 2030 (ktoe)
Jeepneys	Encouraging the adoption of electric jeepneys, reaching a share of 50 per cent by 2030.	29.0
Freight trucks	Encouraging the adoption of electric freight trucks, reaching a share of 25 per cent by 2030.	8.7
Private passenger cars	Encouraging the adoption of electric passenger cars, reaching a share of 25 per cent by 2030	2.4

Motorbikes	Encouraging the adoption of electric motorbikes, reaching a share of 25 per cent by 2030	1.1
Tricycles	Encouraging the adoption of electric motorbikes, reaching a share of 50 per cent by 2030	1.1
Total		**42.3**

An increase in market penetration of electric vehicles is required to reach the targeted shares by 2030. For example, the annual sales of electric-type motorbikes, passenger cars and trucks should slowly pick up from the current zero per cent to 50 per cent by 2028. On the other hand, electric vehicles can be more vigorously promoted for public transport (i.e., tricycles and jeepneys), quickly ramping up to 100 per cent electric vehicle penetration by 2029.

(b) Residential sector

Energy demand reduction can also be realised in the residential sector, particularly through achieving a 100 per cent access rate to clean cooking technologies. As inefficient cooking practices are gradually replaced by electric cooking stove and LPG stove usage, substantial energy savings can be expected. In addition, the use of more efficient household appliances (e.g., LED lighting) provides energy saving opportunities.

Table 4. Energy efficiency measures applied and the annual savings in 2030 in the residential sector

Household appliance	Energy efficiency measures	Annual Saving in 2030 (ktoe)
LED Lighting	Phasing out of compact fluorescent lamps (CFL) with LED lighting	0.5
Cooking	Achieving 100 per cent clean cooking access rate through induction electric cooking stoves and LPG stoves	7.1
Total		**7.6**

(c) Commercial sector

The Philippines launched its national green building code in 2015, mandatory for buildings above a certain minimum total gross floor area (TGFA) (see Table). However, a similar effort can be sought by commercial buildings of all floorspace sizes in Cauayan. NEXSTEP proposes a special policy to be implemented by the city, requiring all new commercial buildings to conform to the national green building from 2023 onwards (table 5).

Table 5. Energy efficiency measures applied and the estimated annual savings in 2030 by commercial subcategory

Subcategory	Energy efficiency measures	Annual saving in 2030 (ktoe)
Private office	A special policy by the city that will require, from 2023 onwards, all new buildings, regardless of floorspace size requirements as in the national	0.48
Government building		0.04
Shopping mall		0.28

Hotel	policy, to conform to the green building code. The expected savings is 15 per cent (IFC, 2017)	0.11
Hospital		0.20
University		0.04
Religious temple		0.01
Total		**1.16**

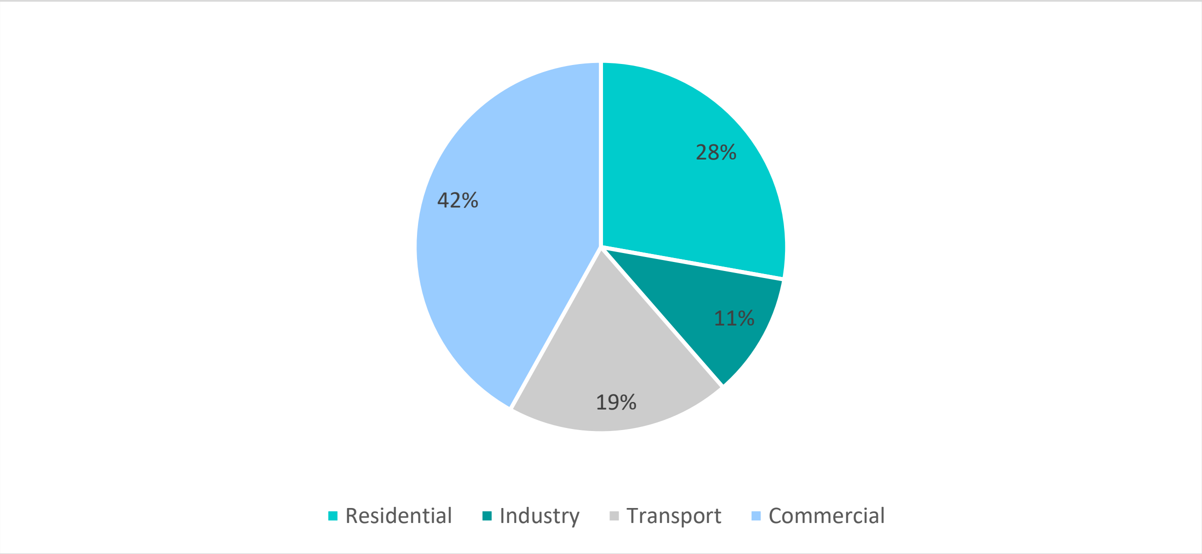
4.3. Electricity supply and demand in the context of sustainable energy transition

4.3.1. Electricity demand in 2030

The demand for electricity in 2030 is projected to be 584.8 GWh in the SET scenario, an increase of 108.3 GWh compared with the CPS. A reduction in electricity demand by the commercial sector can be expected as new buildings become more efficient with mandatory compliance to the national green building code. On the other hand, electricity demand from the residential and transport sectors will increase, due to the adoption of electric cooking stoves and electric vehicles.

The electricity demand in the commercial sector will be 245 GWh, while in the residential, transport and industry sectors it will be 162.5 GWh, 114 GWh and 63.2 GWh respectively (Figure).

Figure 15. Electricity demand in 2030, by demand sector



4.3.2. Electricity supply

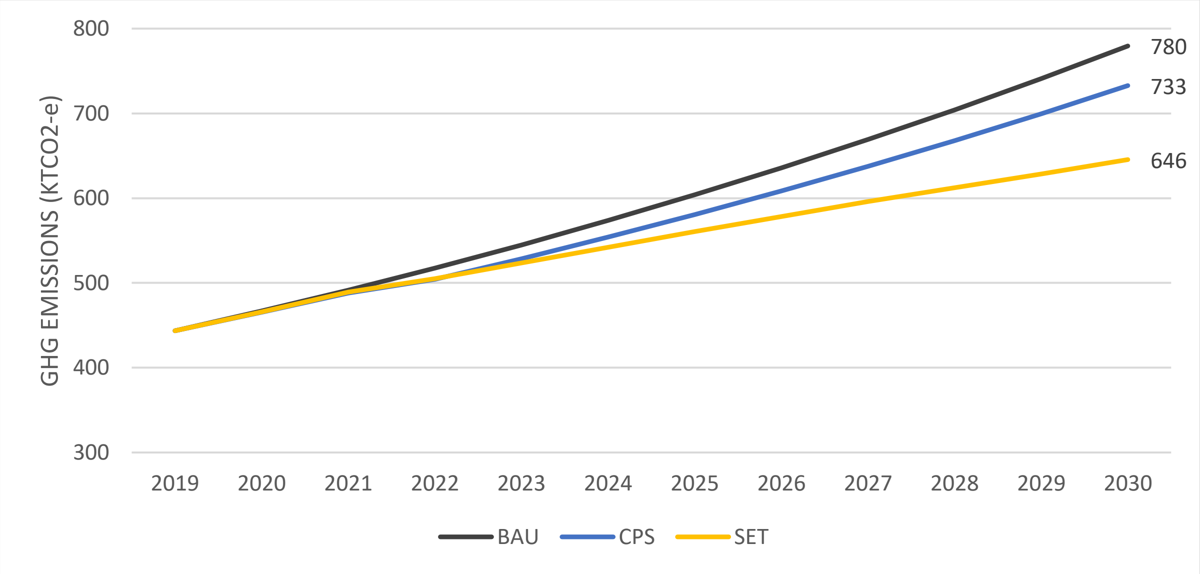
The existing solar PV capacity in the city is an approximate annual generation of 6.3 GWh. The NEXSTEP analysis proposes mandating the use of solar and other RE systems for all new commercial buildings, regardless of the floorspace size, in fulfilling (at a minimum) 1 per cent of their projected annual energy requirements. With an implementation timeline from 2023 onwards, it is estimated that 765 MWh of electricity demand from the commercial sector will be fulfilled by solar and/or other RE systems. Assuming that the demand is fulfilled by solar PV installation with a capacity factor of 16 per cent, the total installed capacity through this mandate is approximately 546 kW.

The remaining 99 per cent (577.7 GWh) will be fulfilled by grid electricity from Luzon, assuming that there is no other additional RE capacity within the city.

4.4. GHG emission reduction with sustainable energy transition

The GHG emission in 2030 is projected to be 645.5 ktCO_2-e, a reduction of 87.3 ktCO_2-e from CPS. This corresponds to a 17.2 per cent reduction from the BAU scenario, or a 12 per cent reduction from the CPS (Figure).

Figure 16. GHG emission trajectories, 2019-2030, by scenario



The GHG emissions reduction by demand sectors, relative to CPS, in 2030 is explained further below, by considering the emissions attributable to their respective electricity usage:

(a) **Residential** – a net increase of 2.5 ktCO_2-*e*. Phasing out polluting cooking technologies (i.e., biomass and kerosene stoves) through replacement with electric and LPG stoves reduces direct GHG emissions from fuel combustion by 2.6 ktCO2-e. Phasing out less efficient lighting reduces electricity demand by 5.4 GWh – a GHG reduction of 3.59 ktCO_2-e, while the use of electric cooking stoves increases electricity demand by 13.2 GWh – an increase of GHG emissions by 8.7 ktCO_2-e;

(b) **Transport** – a net reduction of 80.9 ktCO_2-*e.* The proposed transport electrification measure reduces the GHG emissions from direct fuel combustion by 152.3 ktCO_2-e. However, indirect emissions due to the increased electricity usage becomes 71.4 ktCO_2-e.

(c) **Commercial** – *a* net reduction of 8.97 ktCO_2-e*.* The reduced use of electricity through the implementation of green building measures in new buildings as well as the installation of solar/ RE systems will result in reduced GHG emissions.

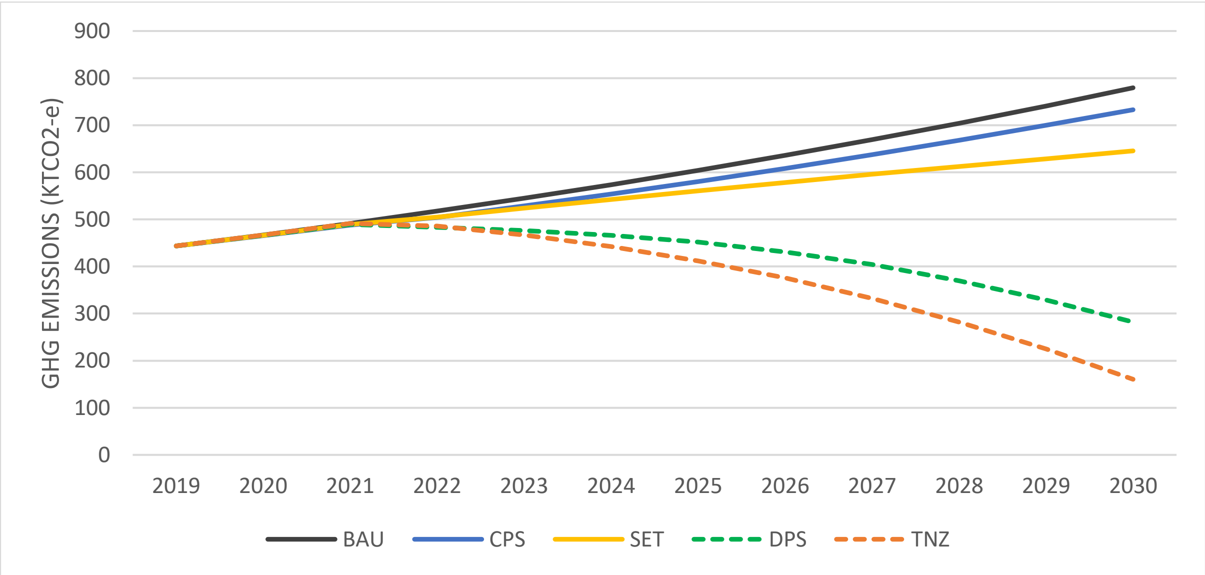
5. Moving towards a net zero society with climate ambitious pathways

The SET scenario sets out various strategies for facilitating an economy-wide, energy-efficiency improvement in alignment with the global goal as well as appropriate technology options in advancing modern energy access in the City of Cauayan. These allow a GHG emissions reduction and an increase in the renewable energy share in TFEC. However, the City of Cauayan could consider more climate ambitious pathways, moving towards a net zero society.

Substantial energy demand and emission reduction have been achieved in the SET scenario through energy-efficiency improvement measures. These measures have allowed an energy demand reduction of 51 ktoe and emission reduction of 87.3 ktCO_2-e, (12 per cent) relative to CPS. This corresponds to a 17 per cent reduction from the BAU scenario. With countries and cities pledging net-zero emissions by 2050, two ambitious scenarios, the Decarbonization of the Power Sector (DPS) scenario and the Towards NetZero (TNZ) scenario, have been developed to explore how Cauayan can raise its ambitions in moving towards net zero in its power supply as well as its energy system as a whole.

The DPS scenario focuses on the opportunities in decarbonizing the electricity supply by increasing the share of RE electricity. It provides a plausible decarbonization pathway that seeks commitments from the city to promoting urban electricity generation and RE power supply arrangement through renewable auctions or power purchasing agreements. On the other hand, the TNZ scenario aims to move the whole of Cauayan's energy system towards net zero, which requires cooperation from its citizens, by adopting cleaner, more efficient technologies (i.e., electric vehicles and induction type cooking stoves). The GHG emissions that may be achieved with these two ambitious scenarios are as shown in Figure . The two ambitious scenarios are further described in the following sections.

Figure 6 GHG emission trajectories, 2019-2030



5.1. Ambitious scenario 1: Decarbonization of the Power Sector (DPS) scenario

The Decarbonization of the Power Sector (DPS) scenario investigates how Cauayan may further decarbonize its electricity supply with a 100 per cent share of RE electricity. This is in addition to the ambition set forth for the central grids by the national Government, in reaching a 35 per cent RE generation share by 2030.

5.1.1. Electricity requirements and pathways for a decarbonized electricity supply

The electricity demand in 2030 is projected to be 584.8 GWh. Cauayan currently purchases almost all of its electricity required from the Luzon grid. Significant challenges exist for the city in increasing 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 Luzon grid. Nevertheless, there are a few pathways that the city could explore in order to achieve a net-zero carbon power supply objective. These four pathways are explained below.

(a) Promotion of agricultural waste-to-energy generation

As already noted, Cauayan has an active agricultural sector with nearly 70 per cent of its land being utilized for rice and corn production, of which the agricultural residues could possibly be used for electricity generation or other forms of energy generation. NEXSTEP's preliminary resource potential estimation found that the available agricultural waste may allow up to 7 MW of power generation (box 3). A formal feasibility study should be conducted to investigate its biomass resource potential as well as the business case for agricultural waste-to energy facilities. Section 6.4 provides two proposals on how Cauayan may best promote agricultural waste-to-energy generation.

(b) Rooftop solar PV installation for new and existing buildings

Incentivising rooftop solar PV installation will provide two benefits to the city by reducing (1) the financial burden on the city for establishing its own solar PV system, and (2) the land-use requirement from ground-mounted PV. As noted by IEEFA (2018), rooftop solar PV costs range between PHP 2.50 per kWh ($ 0.052 per kWh; without financing expenses) and PHP 5.30 per kWh (US$0.11 per kWh) with financing expenses). By comparison, the average retail electricity tariff in the Philippines is around US$0.149 per kWh.[16] This provides a substantial financial gain to the solar PV owners. However, ground-mounted solar PV on vacant land within the city boundaries can also be considered. While solar PV installations are being promoted through the recently announced Renewable Energy Ordinance, the city government should continuously promote and closely monitor the outcome of the initiative.

(c) Establishing power purchase agreements

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[16] The average generation cost in Luzon grid in 2018 was PHP 4.3648. The electricity tariff includes many components – generation costs (45.8%), transmission (8.62%), system loss (3.15%), distribution (26.3%), subsidies (0.5%), government taxes (9.41%), universal charges (4.09%) and FiT allowances (2.13%) (Chemrock, 2018).

The city can enter into a special renewable energy power purchase agreement (PPA) with interested suppliers who are located along the Luzon grid. In turn, the supplier will supply Cauayan with an agreed RE share of electricity at an agreed price. However, this may not allow the city to take advantage of the lower generation costs available, such as through renewable energy auctions.

(d) Lowering cost through renewable energy auctions

A more workable solution and the recent policy instrument is the renewable energy auction. This approach is likely to substantially decrease the cost of electricity supply through competitive pricing bidding and, therefore, return a greater net benefit. Recent auctions, e.g., the 60 MW solar PV auction in Cambodia, have achieved US$0.0387 per kWh (ADB, 2019).

The above options are four different pathways that the city can pursue. A combination of two or more pathways, specifically with urban solar PV and waste-to-energy plants, and renewable energy auction may be a good solution. Further details of a renewable auction are given in box 4.

Box 3. Agricultural waste potential in Cauayan

Cauayan has an active agricultural sector, specifically in rice and corn production. The total area of cultivation is estimated at 24,463 hectares in 2017, consisting of 11,461 hectares for rice cultivation and 12,271 hectares for corn production. Other food crops include coconut, mango and vegetables with a total cultivation area of 731 hectares (City of Cauayan, 2018). Several studies have suggested the potential use of agricultural waste (i.e., rice husks and corn cobs) for energy-use purposes – for example, in electricity generation. In addition, the large number of livestock in Cauayan also provides a possible source of feedstock (i.e., manure) for biogas production. Preliminary resource potential analysis by NEXSTEP suggests that the agricultural waste and manure waste potential for electricity generation is around 5 MW and 2 MW, respectively, as detailed below.

Electricity generation potential for different residue types in Cauayan

Residue type	Electricity generation potential
Rice husks	2 MW
Corn cobs	2.9 MW
Animal manure	2 MW

(a) Rice husks

The agricultural waste associated with rice production consists of rice husks and rice straw. Rice straw is most effectively used if it is incorporated in fields to maintain soil organic matter levels and to enhance nitrogen fixation, making rice husks the only viable feedstock for bioenergy applications (Ang and Blanco, 2017). The annual rice yield is around 122,000 tonnes, which yields approximately 24,400 tonnes of rice husks upon milling.[17] This assumes that the rice husks make up 20 per cent of

[17] Annual rice yield as of 2017 statistics in table 4 of the City of Cauayan, 2018.

the total grain weight. The realistic potential is dependent on factors such as recovery efficiency and availability of biomass for energy, of which final availability is estimated to be about 16,200 tonnes.[18] Considering an estimated biomass feedstock requirement of 8,150 tonne/MW (table 7, Ang and Blanco, 2017), the electricity generation potential stands at 2 MW.

(b) Corn cob

The cultivation area for corn production is 12,271 hectares, with a total yield of approximately 135,000 tonnes per annum.[19] While maize stalks are abundant, harvesting of maize stalks for bioenergy application is considered unsustainable in the tropical regions due to concerns such as soil erosion as well as the depletion of nutrients and organic matter in the soil. Corn cobs are, however, a viable residue for bioenergy application, as they make up about 27 per cent of the total grain weight and have recovery efficiency ranges between 40 per cent and 80 per cent. The recovery efficiency is higher during the dry season (50 per cent to 80 per cent) and low during the wet season (40 per cent to 50 per cent) (Ang and Blanco, 2017). Assuming an average recovery efficiency of 50 per cent, the amount of corn cobs available for bioenergy application is approximately 18,200 tonnes/year. This corresponds to an estimated electricity generation potential of 2.9 MW.[20]

(c) Animal manure

The total amount of livestock in Cauayan is approximately 580,000 head, consisting of poultry (532,000), swine (34,000) and other large-sized livestock (12,200). The animal manure collected from farms has the potential for use in biogas production, which can subsequently be used for electricity generation. The annual biogas potential and electricity generation potential (assuming a 35 per cent efficiency) are as estimated below.

Biogas and electricity generation potential for different livestock types in Cauayan[21]

Livestock type	Methane yield (GJ/year)	Electricity yield (MWh/year)
Poultry	71,000	2,800
Swine	29,000	6,900
Large-size livestock	54,000	5,300

Assuming a capacity factor of 85 per cent, the electricity generation capacity is approximately 2 MW with 100 per cent utilization of manure from all livestock types.

[18] Both the recovery efficiency (0.91*0.90) and availability of biomass for energy (0.81) are based on estimates provided in table 8 of Ang and Blanco, 2017. The recovery efficiency is a typical estimate for the Philippines and is dependent on two factors – 3 per cent of the total rice production is used for seed, while another 6 per cent is used for livestock feed and other purposes. The recovery efficiency is again lowered due to the use of "*kiskisan*" – a small village rice mill which does not produce rice hull. Such a milling method is responsible for 10 per cent of all rice produced in the Philippines.

[19] Based on 2017 statistics in table 4, City o Cauayan, 2018.

[20] Based on an estimated biomass feedstock requirement of 6,378 tonne/MW in table 4 of Ang and Blanco, 2017.

[21] The biogas and electricity generation potential are estimated using the factors provided in table 3 of Scarlet and others, 2018. The estimation for the poultry category is based on factors for the "laying hens" category in the Scarlet and others, 2018, while the swine category is based on "other pigs" and large-size livestock assumes the factors for "other cows".

5.1.2. Cost-benefit of decarbonized power supply

The financial benefits to be gained through a decarbonized power supply are dependent on the pathways a city undertakes. Considering the low auction price that has been reached in the Association of Southeast Asian Nations (ASEAN) region of US$0.0387 per kWh and assumed grid generation cost of US$0.092 per kWh (PHP 4.365 per kWh), the annual saving will be US$31 million in 2030. The financial savings are considered as the difference between the grid generation costs, with the current generation mix of the Luzon grid, and the RE costs for a total electricity demand of 577.7 GWh.[22]

However, the RE price is likely to decrease further in the near future as the technology costs decline. On the other hand, the grid generation cost may also decrease as RE penetration increases, lowering the average generation costs. Table 6 shows the estimated financial savings at different uncertainty points. It can be seen that, in almost all cases, financial savings are positive. Considering the low solar PV generation costs compared with other conventional power plants (

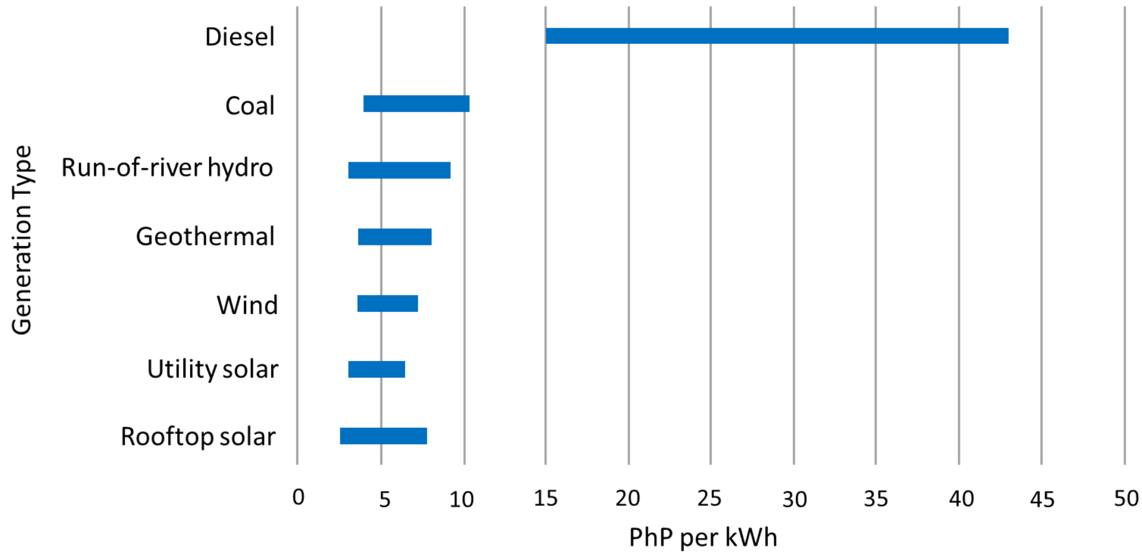
Figure), financial gains through 100 per cent renewable-based electricity are guaranteed.

Table 6. Sensitivity analysis showing financial savings at different RE prices and grid tariff costs

		Financial savings (million US dollars)				
		Change in RE price				
		50%	25%	0%	-25%	-50%
Change in average grid generation cost grid tariff	50%	46	51	57	63	68
	25%	33	38	44	49	55
	0%	19	25	31	36	42
	-25%	6	12	17	23	29
	-50%	-7	-1	4	10	15

[22] The total electricity requirement in 2030 is projected to be 584.8 GWh, while the local RE self-generation will reach an estimated 7.11 GWh by 2030.

Figure 18. Generation costs of different power technologies in the Philippines



Source: IEEFA, 2018.

5.1.3. GHG savings at different level of decarbonization

A 100 per cent RE-based electricity supply will allow a total decarbonization of the electricity supply. However, should Cauayan consider a different level of RE ambition, the emission reduction for the whole energy system, compared to the BAU scenario, is as shown in Table . The RE target only considers RE installed within the city boundary, as well as RE generation arranged through a PPA and renewable auction exclusively for the city. It should be noted that the remaining electricity supplied by the central energy mix is expected to have a 34.1 per cent share of RE generation.

Table 7. GHG emissions and financial savings at different levels of RE target, DPS

	RE target			
	25%	50%	75%	100%
City's self-arranged RE supply in 2030 (GWh)	146	292	439	585
Emissions from electricity supply ($ktCO_{2-e}$) from the Luzon grid in 2030	276	184	92	0
Total emissions in 2030 ($ktCO_{2-e}$) (including demand sectors)	555	463	371	279
Emission reduction relative to BAU in 2030	28.5%	40.4%	52.2%	64.1%

Financial savings (US$ million) in 2030	7	15	23	31

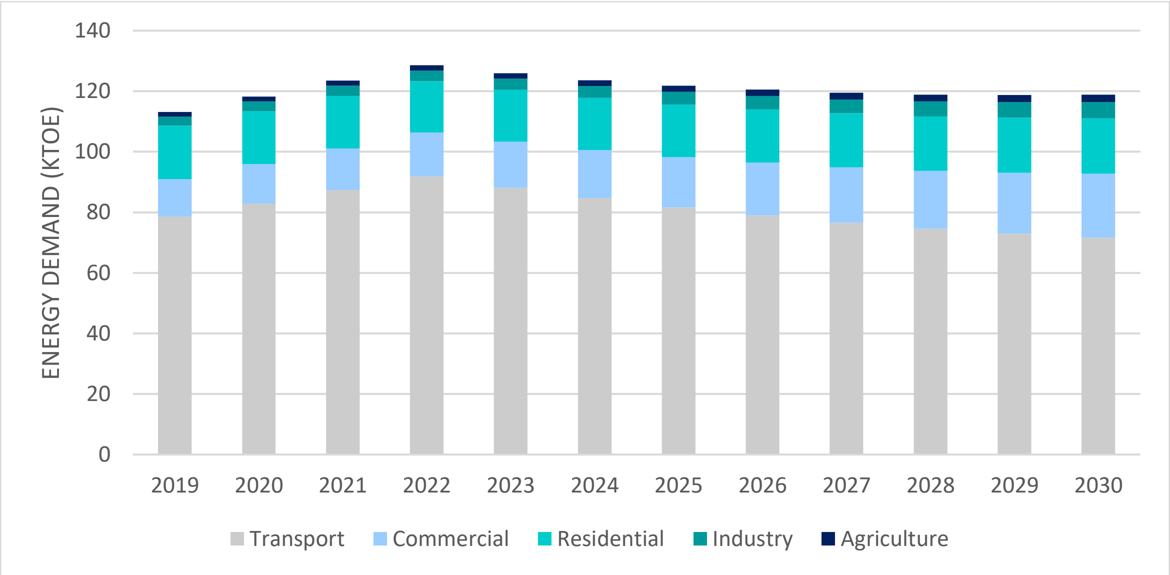
5.2. Ambitious scenario 2: Towards Net Zero (TNZ) scenario

Stepping up from the DPS scenario, the Towards Net Zero (TNZ) scenario aims to not only decarbonize Cauayan's electricity supply but also to widen the effort to cover the residential and transport sectors through increased electrification. This requires a collateral effort both from the city government and its citizens, w the latter moving towards the use of cleaner and more efficient technologies. This scenario is described further below.

5.2.1. Energy demand and GHG reduction

The total energy demand is expected to increase slightly from 113.1 ktoe in 2019 to 118.9 ktoe in 2030, a reduction of about 27.8 ktoe relative to the SET scenario. The transport sector consumption will remain the largest at 60.2 per cent, followed by the commercial sector at 17.7 per cent, the residential sector at 15.4 per cent, the industry sector at 4.6 per cent and the agriculture sector at 2.1 per cent. The energy demand reduction mainly stems from increased ambition in transport electrification. Figure 7 shows the projected TFEC by sector under the TNZ scenario.

Figure 7 Energy demand by sector, TNZ scenario



Cauayan is well-positioned for moving towards a net zero carbon economy. Many of the enabling technologies have been commercialised such as, for example, electric vehicles. The measures proposed for the TNZ scenario are summarized in table 8. The annual GHG emission reduction in 2030 assumes that the electricity supply is carbon-free with 100 per cent RE, as it has been proposed in the Decarbonation of the Power Sector scenario.

Table 8. Proposed measures and their respective annual energy savings and GHG emission reduction in 2030, TNZ scenario

Subcategory	Measures	Annual energy saving in 2030 (ktoe)	Annual GHG emission reduction in 2030 ($ktCO_2$-e)
Transport			
Freight trucks	The market sales of electric vehicles should be 100 per cent from 2023 onwards.	13.0	58.9
Jeepneys		7.2	24.2
Private passenger cars		4.1	14.5
Motorbikes		1.9	6.4
Buses		0.7	2.7
Tricycles		0.4	1.4
Total		**27.2**	**108.0**
Residential			
Residential cooking	Replacement of LPG stove with electric cooking stove[23]	0.4	12.8
Agriculture			
Irrigation system	Replacement of diesel water pumps with solar irrigation system	0.2	0.8

While not quantitatively assessed in this scenario due to the lack of data availability, future use of electric-powered and solar-powered agricultural machineries can be pursued, allowing further reduction in energy demand and GHG emissions. With the decreasing cost of solar panels and batteries, sustainable farm production through widespread use of non-diesel-powered machineries can become cost-effective.

5.2.2. Electricity requirements and supply

The electricity demand is 743.9 GWh, an increase of 159.1 GWh from the SET scenario. The increase in electricity demand is as expected with a higher penetration of E-vehicles and electric cooking stoves. To reap the full benefits that electrification can offer, in terms of GHG reduction, Cauayan should aim to achieve a 100 per cent RE share in its electricity supply. Similarly, the four different pathways described in 5.1.1 can be considered. However, it should be noted that a higher amount of RE generation is required as electricity demand increases with a higher level of electrification.

5.2.3. Cost-benefit of decarbonized power supply and GHG reduction

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[23] With the exception of households connected to decentralised network, as the power supply may not be sufficient to support the use of induction- type electric cooking stoves.

Table 9 shows further the financial savings and GHG reduction that can be achieved with different levels of the RE target. For example, for a 100 per cent RE target, the financial savings are the largest, at US$36 million, and the GHG emissions are reduced to only 157.2 $ktCO_2$-e. The remaining GHG emission is attributable to a small usage of LPG stoves for residential cooking, existing internal combustion engine (ICE) vehicles yet to be phased out, and the use of diesel-powered agricultural machinery (i.e., tractors, rotovators and harvesters). A net-zero society can be realized in the coming decades as ICE vehicles are gradually retired from the transport fleet as well as with the commercialisation and adoption of electric agricultural machinery. In addition, the phase-out of LPG may be pursued once in the future, when all the population has been provided with sufficient power supply capacity.

Table 9. GHG emissions and financial savings at different RE target levels, DPS

	RE target				
	0%[24]	25%	50%	75%	**100%**
City's RE generation in 2030 (GWh)	7.1[25]	186	372	558	744
Emissions from electricity supply ($ktCO_{2-e}$) from the Luzon grid in 2030	464	351	234	117	0
Total emissions in 2030 ($ktCO_{2-e}$)	621	508	391	274	157
Emission reduction relative to BAU in 2030	20.0%	34.5%	49.6%	64.7%	79.8%
Financial savings (US$ million) in 2030	0	9	19	29	39

[24] This refers to the RE target for the city through self-generated/self-arranged renewable electricity; the central grid is assumed to have a 34.1% share of RE by 2030.
[25] This refers to generation from the projected total capacity of rooftop solar PV installations in 2030.

6. Policy recommendations for a sustainable energy transition

Chapter 4 demonstrates how sustainable energy transition can be accelerated to progress the City of Cauayan's development in line with the 2030 Agenda for Sustainable Development, specifically SDG7. Chapter 5 provides information on tangible low carbon transition pathways for Cauayan, with the most ambitious pathway reaching GHG emissions as low as 157 ktCO_2-e by 2030. This chapter presents several policy recommendations, which elaborate further the interventions proposed.

6.1. Achieving the modern energy access target allows enhancement of socio-economic development

In 2019, 9.6 per cent and 23.3 per cent of Cauayan's population lacked access to electricity and clean cooking technologies, respectively. Thus, providing universal energy access should have the utmost priority for the city to enhance socio-economic development and reduce social inequalities.

The meta-analysis conducted by ESCAP found that providing electricity access is highly beneficial in enhancing socio-economic development as well as gender empowerment. Positive impacts can be seen in increased household income and consumption, children's study time and years of schooling, and time spent working, both by men and women. In addition, the impacts are more prominent for women and far-reaching whereby women experience a higher level of social and economic change, i.e., increased social participation and financial autonomy (ESCAP, 2021c). NEXSTEP proposes the use of decentralised renewable energy systems as a cost-effective and quick solution to closing the access gap. However, continuous improvement in the technologies given should be sustained in order to meet the growing need for better electricity provision.

Equally important is access to clean cooking fuels and technologies, yet it generally lacks attention from the policymakers. In turn, the inaction in closing the gap has led to substantial premature deaths due to household air pollution caused by unclean cooking practices. Nearly a quarter of Cauayan's population still relies on the use of traditional biomass stoves and kerosene stoves. Positive benefits that can arise from adoption of clean cooking technologies include fuel savings (as evidenced in the SET scenario), less time spent on cooking and less use of cooking fuels, and reduced health risks from indoor air pollution.

NEXSTEP proposes that initiatives should be launched by providing electric cooking stoves as a long-term clean technology substitute. LPG stoves are a strong contender; however, electric cooking stoves, particularly the efficient induction-type, are more cost-effective and cleaner in terms of household indoor air pollution. In addition, the use of electric cooking stoves paves the way towards net zero emissions when the electricity supply is decarbonized. LPG stoves may, however, be promoted to households that lack sufficient power supply capacity, i.e., households utilizing decentralised renewable energy systems.

6.2. Implementation of a national green building code to promote a sustainable commercial built environment

The Philippine Green Building Code (GB Code) was first launched in 2015, with the objective of improving building efficiency through a set of standards that will enhance sound environmental and resource management, without a significant cost increase. The mandatory compliance to the GB Code is currently limited to buildings above a minimum TGFA. The energy reduction that may arise from GB Code compliance is estimated to be 15 per cent, a substantial benefit for the environment by reducing GHG emissions, while at the same time reducing electricity bills (IFC, 2017). With the proposed measure in the SET scenario, introducing the GB Code for all new commercial buildings from 2023 onwards may allow an estimated energy demand reduction of 1.6 ktoe, and a reduction of GHG emissions of 8.5 ktCO_2-e. The provisions set out in the GB code for reducing energy demand involve the adoption of efficient practices, designs, methods and technologies. In addition, the adoption of the Department Circular 2020-12-0026, which calls for the use of solar PV and/or other RE systems in meeting minimum 1 per cent of the projected requirements, further reduces the need for imported electricity.

The benefits of GB Code compliance do not end with just energy demand and GHG emission reductions. The GB Code also stipulates a set of standards for areas including water efficiency, material sustainability, site sustainability and indoor environmental quality. For example, an estimated 30 per cent of water savings may be realised with the adoption of water efficiency measures set out in the GB Code (IFC, 2017). The GB Code also promotes the efficient use of resources and non-hazardous material selection and use as well as efficient waste management practices. Conserving the well-being of the existing ecosystems and water resources is also part of objective of the GB Code (DPWH, 2015).

Active promotion of a sustainably-built environment could lead to indirect socio-economic benefits – for example, a growing green building industry in the city and increased employment. From the building owners' and operators' perspectives, benefits come in the form of increased building value and reduced electricity bills. Socially, sustainability-guided building designs also promote better well-being and health as well as increase work productivity (WorldGBC, 2021).

6.3. Transport electrification for a more sustainable transport sector

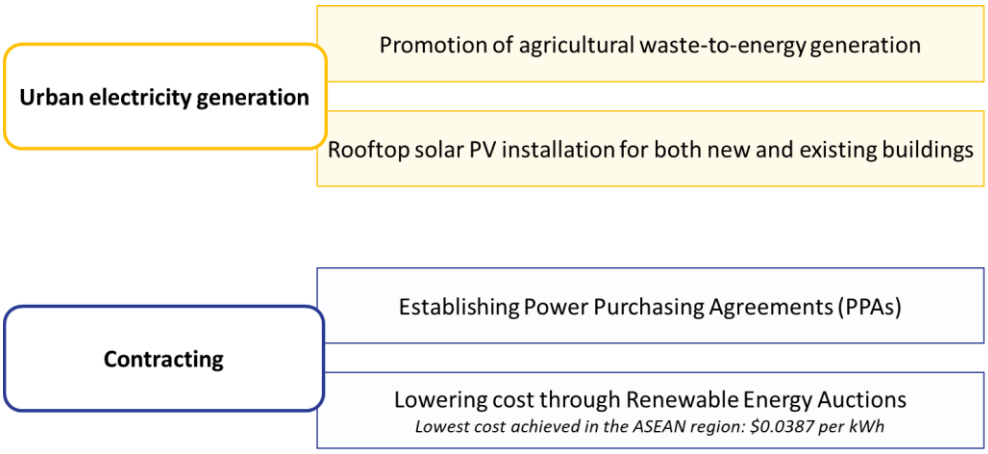
In 2019, Cauayan's transport sector accounted for about 66 per cent of the total energy demand and contributed nearly half of the city's GHG emissions. Hence, ambitious policy actions for the transport sector are critical to Cauayan realising substantial energy efficiency improvement and contributing towards climate mitigation. Transport electrification is one critical strategy that allows energy demand savings and GHG emission reduction.

Electric vehicles have attracted great interest globally, growing exponentially during the past decade. Electric car sales passed the 2 million mark globally in 2019, with a projected compound annual growth rate of 29 per cent through to 2030 (Deloitte, 2020). Several governmental policies have been introduced that directly or indirectly promote the adoption of electric vehicles as a means to achieve environmental and climate objectives. For example, 17 countries have ambitioned phasing out internal combustion engines through 2050, while the European Union's stringent CO_2 emissions standard has accelerated the electric vehicle adoption (IEA, 2020).. NEXSTEP notes that adoption of electric vehicles should be promoted. For example, in the SET scenario, increasing the share of electric vehicles to between 25 per cent and 50 per cent in a number of vehicle categories would allow an estimated energy savings of 42.3 ktoe (30 per cent) relative to CPS. The annual net reduction in GHG emissions is estimated to be 80.9 $ktCO_2$-e. However, it is important to note that GHG emissions reduction by using electric vehicles can only be realised with a sufficient share of zero emission energy mix. Not only that, the full potential of GHG emissions reduction will be realised when the electricity supply is decarbonized. Other positive impacts include reducing pollutant emissions due to zero-tailpipe emissions.

6.4. Pursuance of a high renewable power share through cost-effective pathways

Renewable capacity has increased significantly across the globe amid climate change concerns. The decarbonization of the power sector is generally regarded as the low-hanging fruit, as the cost of renewable power technologies decreased rapidly during the past decade. With electricity constituting around a quarter of the total fuel consumption and more than 40 per cent of GHG emissions in 2019, decarbonizing the electricity supply provides a quick decarbonization pathway to reaching a substantial GHG emissions reduction, while providing financial benefits. NEXSTEP proposes four different pathways that may be considered in decarbonizing the electricity supply, as described in subsection 5.1.1. A combination of these four pathways can also be adopted.

Figure 20. Four pathways in decarbonizing the electricity supply



Urban renewable electricity generation can also be promoted. The local stakeholders of Cauayan have a keen interest in utilizing their local agricultural waste for energy generation. As already noted, there are currently industrial-scale agricultural waste-to energy plants and ethanol plants in neighbouring towns that receive process feedstock from Cauayan. Similar establishments may be replicated in Cauayan, using the potential biomass resources from its agricultural sector, which has an electricity generation potential of approximately 7 MW (see box 3). Such initiatives may come in two forms of arrangement, to be considered by the city government. First, the city government may opt to self-invest and self-govern the biomass facility. This may, however, require huge investment and operational responsibilities. A better solution may be to attract potential investors to establishing such facilities, while contributing positively to the city's economy and providing job opportunities. A power purchase agreement can be set up with the respective suppliers, supplying the city with renewable electricity at an agreed price. On the other hand, citizen initiatives in setting up rooftop installations on both new and existing buildings should be promoted. For example, the city government is providing a tax incentive to small businesses that establish a minimum of 3 kW of RE systems, in the form of a 10 per cent discount from their gross sales for their corresponding business taxes in the city. The outcome of the initiative should be closely monitored to make sure that it aligns with the city's aspirations.

Renewable energy auctions may, however, be the best and cheapest option, whereby contracts and agreements are awarded through competitive bidding. The Department of Energy of the Philippines was planning to launch a 2,000 MW renewable energy auction around mid-2021 (Rivera, 2020). While the renewable energy auction mechanism and its associated standards are set at the national level, the City of Cauayan can work with the central Government to implement RE auctions at the city level, Box 4 explains further the renewable energy auction in detail.

Box 4. Mechanism of a renewable energy auction

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 realise 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 the Government to combine and tailor different design elements to meet deployment and development objectives. Unlike a FiT, 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.** A government needs to clearly indicate the scale or size of each auction, the preferred technology (technology neutral or 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 for minimizing 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 it. 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.

6.5. Moving towards NetZero Carbon

Limiting temperature rise to 1.5^{o}C requires climate mitigation efforts on an unprecedented scale and speed in order to reduce GHG emissions by about 45 per cent from 2010 levels by 2030, and reaching net zero around 2050. Failing to act on the most pressing issue may lead to catastrophic impacts on livelihoods and the environment. The Philippines is highly vulnerable to the impacts of climate change. These include more frequent extreme weather events and natural hazards as well as sea level temperature rise. The agricultural sector is one of the many areas to be adversely impacted by climate change (Climatelinks, 2021).

Efforts from all levels and sectors are imperative in the emissions race to net zero. Cities, in particular, can play a significant role, as around the world they contribute around 75 per cent of global anthropogenic emissions and represent about 66 per cent of global energy demand (REN21, 2019). As of April 2021, more than 700 cities in 53 countries had committed to a net zero target by 2050, with a medium target of halving emissions by 2030 (C40 Cities, 2021). The energy system of Cauayan is well positioned for an accelerated decarbonization effort as the required net-zero technologies in decarbonizing its energy systems are readily available and mature – i.e., electric vehicles, electric cooking stoves, solar irrigation systems and renewable power technologies.

As detailed in sections 5.1 and 5.2, decarbonizing its electricity supply is the key for deep decarbonization as it contributed around 43 per cent of the total GHG emissions in 2019. A decarbonized electricity supply is also required to complement the rapid adoption of electricity-based technologies, such as electric vehicles and electric cooking stoves. Further studies should be conducted to identify possible challenges to the electricity grid resulting from a high electricity load and a high level of RE penetration. Possible mitigating solutions may be required, such as integrated energy storage, demand side management and smart ICT solutions in managing the possible burden that large-scale demand electrification may place on the electricity grid.

6.6. Capacitating the local government in mainstreaming energy transition in the executive and legislative agenda

The roadmap presents several technological options and policy recommendations that will help the City of Cauayan to navigate the transition of its energy sector in line with the 2030 Agenda for Sustainable Development, while at the same time moving towards a net-zero carbon society. This cannot be done without strong institutional support and leadership from the LGUs. The DILG-DOE Joint Memorandum Circular No. 2020-01 provides important guidelines to the LGUs, including Cauayan, for strengthening their institutional capacity to facilitate implementation of energy projects. Its main purpose is to promote the integration of existing and future national energy plans and policies into the local development plans. For example, the joint memorandum circular calls for the activation of the Energy Sector Committee within the LGUs in incorporating energy policies and programmes into its spatial plan and comprehensive development plan. In addition, it highlights the importance of educational awareness among the stakeholders and constituents on the topics.

To ensure that the SDG7 targets and the climate ambition are achieved, the City of Cauayan should consider integrating the policy recommendations from this roadmap into its comprehensive development plan as well as in other future policy and planning documents. Further cost-benefit analysis on the technological options and the development of a strategic action plan may be the next important steps. For example, implementation programmes should be comprehensively planned, taking into consideration the capital cost and stakeholder support required, and the implementation timeline, while also addressing the possible challenges. At the same time, institutional and policy support mechanisms should be established to ensure the continuity of the programmes. The City of Cauayan may also consider establishing a monitoring mechanism for tracking its progress towards achieving the targets.

7. Conclusion

The 2030 Agenda for Sustainable Development and the Paris Agreement provide a common goal of achieving sustainability and climate objectives. While achieving the SDG7 targets is principally a national effort, it requires combined contributions from stakeholders at various levels, such as subnational jurisdictions and cities. Cauayan is an active advocate for localizing SDGs, by various initiatives and programmes benefiting its citizens. As a participant of the “SDG7 localization project”, Cauayan and ESCAP have collaborated in the development of a Sustainable Energy Transition (SET) roadmap, which aims to inform the city about sustainable energy transition pathways tailored to its local context.

Cauayan is best recognised for its smart city initiatives and agricultural-centric economy. The GDP of Cauayan is projected to grow at 5.5 per cent per annum, while the population is expected to increase by 3.18 per cent each year. Under the current policy settings, Cauayan will benefit from the national Government’s aspiration to provide universal electricity access by 2022. On the other hand, it may fall short of achieving universal clean cooking access. The overall energy demand is projected to rise by an annual average rate of 5.2 per cent, to 197.7 ktoe. Considering the renewable energy generation share in the grid generation mix reaching the aspirational target of 35 per cent, GHG emission is projected to be 732.8 ktCO_2-e, a GHG emission reduction of 46.7 ktCO_2-e, compared to a business-as-usual baseline.

The SET scenario proposes an energy transition pathway that strategically allows Cauayan to close its existing gaps in electricity and clean cooking access. It also suggests several energy efficiency opportunities that would lead to energy savings and GHG emission reduction. NEXSTEP proposes decentralised renewable electricity systems as the most appropriate and time-efficient solution to electricity supply to the remaining unelectrified households. Qualitative and quantitative analyses have suggested that electric cooking stoves may be the best way forward in closing the clean cooking gap. However, clean cooking technology selection between electric cooking stoves and LPG stoves should be done based on households’ power supply capacity. Closing the clean cooking gap will also provide a substantial energy demand reduction by phasing out polluting, inefficient cooking technologies (i.e., traditional biomass stoves and kerosene stoves).

The transport sector provides the greatest sustainable energy potential. The promotion of electric vehicle adoption in multiple vehicle subcategories is estimated to provide a total energy savings of 42.3 ktoe. On the other hand, the National Green Building Code provides a readily available sustainable building framework that can be promoted for all new commercial buildings. Mandating the compliance to the Code will lead not only to energy and GHG emissions reduction, but will also help in facilitating a more efficient resource (i.e., water and material usage) and solid waste management. On the other hand, mandating the use of solar and/or RE systems reduces the need for purchased grid electricity. At the household level, energy savings can be realised through the adoption of more efficient appliances, specifically lighting appliances. With the proposed measures, the final energy demand and GHG emissions in the SET scenario are projected to be 146.7 ktoe and 645.5 ktCO_2-e, respectively.

Climate change is one of the most pressing issues of this century, requiring rapid and widespread climate mitigation from all sectors. Cauayan may play its part by raising its climate efforts through decarbonizing its electricity supply. This roadmap explores several pathways that the city could undertake in decarbonizing its electricity supply. Renewable energy auctions stand out as the cheapest option, at the same time without the operational burden from the city government. More can be done with co-operation from its citizens to adopt more electricity-based technologies, i.e., electric vehicles and electric cooking stoves, as explored in the most ambitious Towards NetZero scenario. However, strong institutional support is imperative in supporting a successful energy transition and sustainable development.

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Annexes

Annex I. Cauayan's status against the SDG7 indicators

The following table summarises Cauayan's status against the SDG7 indicators in 2019 and 2030. The projection for 2030 is based on the SET scenario. The following sections further describe the calculation methodologies in determining the (a) energy intensity, (2) energy-efficiency improvement rate and (3) renewable energy share in TFEC.

Table 10. Targets and indicators for SDG7

Target	Indicators	2019	2030
7.1. By 2030, ensure universal access to affordable, reliable and modern energy services.	7.1.1. Proportion of population with access to electricity.	90.4%	100% access rate already achieved
	7.1.2. Proportion of population with primary reliance on clean fuels and technology for cooking.	76.7%	100% access rate already achieved
7.2. By 2030, increase substantially the share of renewable energy in the global energy mix.	7.2.1. Renewable energy share in total final energy consumption.	5	14.8%
7.3. By 2030, double the global rate of improvement in energy efficiency.	7.3.1. Energy intensity measured as a ratio of primary energy supply to gross domestic product.	5.85 MJ/US$ (2011) PPP	4.21 MJ/US$ (2011) PPP

SDG7.3. Energy efficiency. "By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production plus net imports minus international marine and aviation bunkers, plus stock changes. For comparison purposes, GDP is measured in constant terms at 2011 PPP.

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

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

Energy efficiency improvement rate is calculated with the following formula:

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

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

SDG7.2. Renewable energy. The share of renewable energy in TFEC is calculated with the following formula, where TFEC is total final energy consumption, ELEC is gross electricity production.

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

Annex II. Key assumptions for NEXSTEP energy modelling

(a) General parameters

Table 1 GDP and GDP growth rate

Parameter	Value
GDP (2019, current US dollar)	344.8 million
PPP (2019, constant 2011 US dollar)[26]	809.81 million
GDP growth rate[27]	5.5%

Table 12. Population, population growth rate and household size

Parameter	Value
Population (2019)	150,118
Population growth rate[28]	3.18%
No. of Households (2018)	35,046
Household size (constant throughout the analysis period)	4.28

(b) Demand-side assumptions

Industry:

There are three industry subcategories in Cauayan:(1) food and beverages; (2) machinery and transportation equipment; and (3) wood and wood products. The fuel consumption data (exclusively electricity consumption) provided for 2019 are shown in table 13.[29]

Table 13. Consumption in 2019

Industry subcategory	Electricity consumption in 2019 (ktoe)	Consumption share
Food and beverages	0.603	20%
Machinery and transportation equipment	1.961	65%
Wood and wood products	0.452	15%

[26] The GDP in 2019 is recorded as RM94.2 billion. The figure is converted into PPP (current US dollar) with a conversion factor of 1.6 (https://data.worldbank.org/indicator/PA.NUS.PPP?locations=MY), and adjusted to 2011 US dollars based on consumer price index (CPI) provided in https://www.inflationtool.com/us-dollar?amount=100&year1=2011&year2=2019
[27] The CDPii stipulates a GDP growth target of 6-8 per cent. The modelling considers a conservative growth rate of 6 per cent, considering the impacts of the COVID-19 crisis, as suggested by IRDA.
[28] Based on historical growth between 2006 and 2019.
[29] it should be noted that oil products are sometimes used for electricity self-generation during power outages.

The industrial GDP is assumed to grow at an annual rate of 5.5 per cent, similar to the GDP growth rate. The energy intensity is assumed constant throughout the analysis period in the absence of energy-efficiency interventions.

Transportation:

Road transport

The road transport sector is modelled with a bottom-up approach, using vehicle statistics, passenger load factor, annual travel mileage and estimated fuel economy. Transport activities in 2019 are estimated at 2.8 billion passenger-kilometres and 1.4 billion tonne-kilometres. The growth both in passenger transport and freight transport activities is assumed to be growing at the same rate as the GDP, i.e., 5.5 per cent per annum. The breakdown of passenger-km and tonne-km shares is shown in table 14:

Table 14. Passenger-km and tonne-km distribution

Passenger transport	No. of vehicles	Annual mileage (km)	Load factor (pass-km/veh-km)	% share of passenger-km
Passenger cars	2,442 (gasoline) 1,366 (diesel)	24,000	2.5	8.1%
Motorbikes	17,927	9,000	1.6	9.1%
Tricycles	5,790	24,000	12.5	2.9%
Buses	30	80,000	50	4.2%
Jeepneys	7,134	24,000	12.5	75.6%
Freight transport	No. of vehicles	Annual mileage (km)	Load factor (tonne-km/veh-km)	% share of tonne-km
Freight trucks	4,238	56,000	9.3	100%

Residential:

The residential sector is further divided into small, medium and large households. Breakdown of the distribution, as well as their respective electrification rate in 2019 is as presented in Table 15.5.

Table 15. Household distribution and electrification rate

Residential Type	Percentage share	Electrification rate
Small	71.4%	86.6%
Medium	17.74%	100%
Large	10.56%	100%

The residential appliance ownership data, cooking distribution and energy use intensity in the baseline year were provided by the local consultant. The appliance ownership is projected to grow at a rate similar to the growth in GDP per capita.

The average electrical demand per owning household for the different appliances is assumed constant throughout the analysis period, unless further energy efficiency measures are implemented (i.e., as discussed in the SET scenario).

Commercial:

The total commercial floor space was 0.625 million m^2 in 2019 and is projected to grow at an annual rate of 5.5 per cent, similar to the GDP growth rate. The energy intensity is assumed constant throughout the analysis period in the absence of energy-efficiency interventions. The commercial sector is differentiated into seven categories, modelled based on approximated commercial floor space and electricity consumption data (table 16).

Table 16. Commercial floor space and energy consumption

Category	Floor space in 2019 (million m^2)	Electricity intensity (kWh/m^2)	Consumption in 2019 (ktoe)
Private office	0.2277	262	5.13
Government building	0.0195	262	0.44
Shopping mall	0.1002	345	2.97
Hotel	0.0876	151	1.14
Hospital	0.0757	323	2.10
University	0.0398	119	0.41
Religious temple	0.0745	23	0.15

Agriculture:

The energy demand of the agricultural sector is associated with irrigation and the use of agricultural machinery. The energy demand (under the BAU scenario) is expected to rise at an annual growth rate of 5.5 per cent, similar to the GDP growth rate. The energy demand breakdown for 2019 is shown in Table .

Table 2 Energy demand by the agricultural sector in 2019

Category	Energy demand in 2019 9 (toe)	Description
Irrigation (total: 221 toe)		
Diesel water pumps – small	7.8	120 water pumps, consuming 72 litres of diesel annually per pump
Diesel water pumps – large	196.7	670 water pumps consuming 326 litres of diesel annually per pump
Solar irrigation system	16.5	Existing capacity of 200 kW
Agricultural machinery (total: 1315 toe)		
Tractors	493.9	
Rotovators	450.7	

Harvesters	370.3	

Annex III. Estimating the central grid emission factor

NEXSTEP utilizes the projected electricity generation of the Reference Scenario (REF) stipulated in the Philippine Energy Plan 2018-2040. Figure A.1 below shows the definition of the REF scenario, which considers the existing indicative projects and the national RE ambition, while Figure A.2 shows the expected generation in 2030. The emission factor is further calculated using the assumptions listed in Table 18.

Figure A.1. Definition of REF scenario, Philippine Energy Plan, 2018-2040

Scenarios	Assumptions	
	Reference Scenario ***(Business as Usual)***	**Clean Energy Scenario** ***(Alternative Scenario)***
Energy Demand	• Response to the requirements of the *Build, Build, Build* infrastructure program and *AmBisyon Natin 2040*. • Maintain 2.0 percent biodiesel and 10.0 percent bioethanol until 2040.	• Assumptions under the Reference Scenario, including the following: √ 10.0 percent penetration rate for electric vehicles for road transport (motorcycles, cars, jeepneys) by 2040; √ 3.0 percent increase in aggregate natural gas demand between 2018 and 2040; and, √ 5.0 percent aggregate energy savings from oil and electricity by 2040.
Energy Supply	• Present development trends and strategies continue. • Consider 6,300 MW committed and 33,200 MW indicative power projects as of December 2018. • Increase renewable energy (RE) installed capacity to at least 20,000 MW by 2040. • Consider the aspirational target of 35.0 percent share of renewables to the generation mix by 2030. • Adopt 25.0 percent reserve margin. • Assume 70.0 percent load factor for the total Philippines	• Assumptions under the Reference Scenario, including the following: √ Highly-efficient power technologies; √ 10,000 MW additional RE capacity by 2040; and, √ 1,200 MW from other emerging technologies by 2035.

Figure A.2. Electricity generation in 2030, REF scenario

Fuel Type	2018	2030	
	Actual	**REF**	**CES**
Coal	**51.93**	**126.31**	**121.13**
Natural Gas	**21.33**	**14.91**	**24.40**
Oil-based	**3.17**	**1.35**	**1.35**
Renewable	**23.33**	**73.86**	**68.80**
Geothermal	10.44	12.35	12.84
Hydro	9.38	31.92	28.89
Wind	1.15	6.39	7.41
Solar	1.25	21.39	18.19
Biomass	1.10	1.81	1.48
Other Technology	**0.00**	**0.00**	**0.00**
Total	**99.76**	**216.43**	**215.68**

Table 18. Grid emission factor calculation assumptions

Fuel	Efficiency	Emission factor (kgCO2/GJ primary fuel)
Natural gas	35%	55.8
Coal	37%	92.6

Oil-based	38.5%	73.3

It should be noted that the projected electricity generation is provided on the national level, covering the Luzon, Visayas and Mindanao grids. However, due to the lack of distinction in the data, NEXSTEP assumes that the electricity generation share is the same across all three grids. The estimated emission factor for 2030 is 0.57 tCO2/MWh.

Annex IV. Clean cooking technologies key assumptions

The annualised cost of the different clean cooking technologies is calculated with the parameters below, as well as a cooking heating requirement of 3840 MJ/household-year (Putti and others,2015)..

Table 3 Clean cooking technologies key assumptions

Technologies	Efficiency[30] (%)	Lifetime[31] (years)	Stove cost [32](US$)	Variable O&M [33](US$/year)	Fuel cost[34] (US$)
ICS	35	4	35	10	0.03 per kg
LPG stove	56	7	56	10	1.49 per kg
Biogas digester	50	20	950	50	-
Electric stove	84	15	40	10	0.149 per kWh

[30] Sourced from: ICS – author's estimation, LPG stove and biogas digester efficiency ranges (World Bank, 2014), electric cooking stove (induction stove) (IEA, 2012).
[31] Sourced from: ICS – author's estimation, LPG stove (Clean Cooking Alliance, 2021), biogas digester (Wang and Zhang, 2012) and electric stove (IEA, 2012).
[32] Sourced from: ICS – author's estimation, LPG stove and biogas digester – (IRENA, 2017), electric cookstove cost range (Putti and others, 2015).
[33] Variable O&M is based on own assumptions, with the exception of biogas digesters (IRENA, 2017).
[34] Wood cost is assumed opportunity cost related to wood collecting activities, LPG price is based on quoted common price of PHP 784 for April 2021 (see https://www.doe.gov.ph/sites/default/files/pdf/price_watch/%20lpg_auto-lpg_mm_2021-apr-07-14.pdf) and electricity price is based on the average tariff for August 2020 in Philippine Energy Plan, 2018-2040.

Annex V. Summary results of the scenarios

	CPS Scenario	SET Scenario	DPS Scenario	TNZ Scenario
Universal access to electricity in 2030	100%	100%	100%	100%
Universal access to clean cooking in 2030	76.7%	100%, via electric and LPG stoves	100%, via electric and LPG stoves	100%, via electric and LPG stoves
Energy efficiency in 2030	5.67 MJ/US$	4.21 MJ/US$	4.21 MJ/US$	3.41 MJ/US$
Renewable energy share in TFEC in 2030	10.6%	14.8%	37.1%	56.0%
GHG emissions in 2030	733 ktCO_2-e	646 ktCO_2-e	282 ktCO_2-e	161 ktCO_2-e
Power supply	4.5 MW of local solar PV, remaining supplied by Luzon grid	4.5 MW of local solar PV, remaining supplied by Luzon grid	100 per cent through city's self-arranged/generated RE	100 per cent through city's self-arranged/generated RE
Share of city's self-arranged/generated RE electricity	1.3%	1.2%	100%	100%