Energy Pathways for the 2030 Agenda

SDG7 Roadmap for Bhutan

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

NEXSTEP
National Expert SDG Tool for Energy Planning

Energy Pathways for the 2030 ESCAP Agenda

SDG 7 Roadmap for Bhutan

Developed using the National Expert SDG 7 Tool for Energy Planning (NEXSTEP)

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Asian Institute of Technology

Foreword: ESCAP

The continued development of the energy sector in Bhutan is key to the country's ongoing prosperity. As one of the landlocked developing countries in the Asia-Pacific region this evolution has the mountainous country on the cusp of graduation from the category of least-developed countries in 2023.

Bhutan achieved 100 per cent electricity access in 2018, ahead of the initial goal of 2020. Bhutan is endowed with renewable energy resources, and exports of hydroelectric power have been contributing substantially to the national economy. However, more efforts are needed to provide access to clean cooking fuel to more than one-quarter of the population still reliant on unclean cooking fuels and technologies. Improving energy efficiency also should be given high priority, particularly in the transport sector, which needs to shift away from its dependence on imported fossil fuels.

This Road Map for achieving the Sustainable Development Goal 7 targets presents a detailed assessment of the energy system of Bhutan. It offers a least-cost pathway to providing universal access to clean cooking fuels and technologies, growing the share of renewable energy across all sectors, and doubling the historic rate of energy efficiency improvement. Taking a holistic approach to the energy system by using the National Expert SDG Tool for Energy Planning (NEXSTEP), the Road Map was developed in close consultation with national policymakers and experts having a deep understanding of the country's resources and future direction to plan an energy transition that reflects national development strategies and is aligned with global goals and targets.

The Road Map presents a range of opportunities to achieve the Goal 7 targets while improving energy security, maintaining or deepening Bhutan's carbon-negative status, and improving the health of its citizens through reduced indoor air pollution. It sets out five key policy recommendations to increase access to clean cooking technology, improve indoor space heating technologies, electrify the transport sector, implement mandatory green building codes and energy-efficient cooking regulations, and decarbonize the industry.

The success of this collaboration between ESCAP and the Ministry of Economic Affairs is a testament to our shared ambition to deliver on the vision for energy in the Sustainable Development Goals. The Road Map presents a pathway for Bhutan to continue to prosper in the next phase of its development as it builds back better in the recovery from COVID-19. It also provides an example for other countries to better understand the opportunities to develop sustainable energy.

I look forward to the implementation of the Road Map by Bhutan and its continued success in delivering a secure, sustainable and healthy energy future as we move forward.

Ms. Armida Salsiah Alisjahbana
Under-Secretary-General of the United Nations and
Executive Secretary of the United Nations Economic and Social Commission for Asia and the Pacific

Foreword: Bhutan

Bhutan had reaffirmed it's pledged to remain carbon neutral in its first National Determined Contributions (NDCs) and maintains to remain carbon neutral as presented in the second NDC in 2021. Bhutan strives to ensure clean and sustainable energy access to its populace. In its efforts to continuously align the energy agenda with its international obligations, the Royal Government of Bhutan intends to strengthen its Sustainable Development Goal (SDG) 7 targets through an integrated system approach.

The energy sector of Bhutan needs to transition its course towards the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement. To achieve the targets by 2030, it is crucial to optimise this process by identifying the best energy system measures in which an SDG7 implementation roadmap plays a pivotal pathway that complement the endeavour, hence guiding policymakers on what policy measures are needed to achieve this transition. The development of a national SDG7 roadmap using National Expert SDG Tool for Energy Planning (NEXSTEP) would be an initial step to develop enabling policies to achieve SDG7 and NDC targets.

The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the NEXSTEP, a tool constituting technological options and policy measures which enables policymakers to make informed policy decisions to support the achievement of the SDG7 targets as well as emission reduction targets of NDCs. The tool has been customised to Bhutan's energy scenario and the roadmap features the needed energy transition pathways to achieve the targets by 2030 by employing energy efficiency improvement measures in energy intensive sectors and the optimum share of renewable energy in the energy mix. This roadmap highlights energy interventions in key sectoral areas to close the gap for cleaner energy use through access to clean energy technology and improving energy efficiency, thereby reducing the energy intensity.

The Ministry of Economic Affairs under the Royal Government of Bhutan expresses its highest gratitude to ESCAP, international experts and stakeholders involved in shaping the SDG7 Roadmap for Bhutan. The SDG7 roadmap will be used to guide our energy sector to ensure that people of Bhutan have the access to affordable, reliable and modern energy services.

H.E. Lyonpo Loknath Sharma
(Minister of Economic Affairs)
Royal Government of Bhutan

Abbreviations and acronyms

AFOLU	Agriculture, Forestry, and Other Land Use
BAU	business-as-usual
BES 2015	Bhutan Eco-stove 2015
CBA	cost benefit analysis
CO_2	carbon dioxide
CPS	current policy scenario
DRE	Department of Renewable Energy
EC	European Commission
EE	energy efficiency
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EV	electric vehicle
GDP	gross domestic product
GHG	greenhouse gas
ICS	improved cooking stove
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
$MTCO_{2-e}$	million tonnes of carbon dioxide equivalent
ktoe	thousand tonnes of oil equivalent
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LEAP	Long-range Energy Alternatives Planning
LPG	liquified petroleum gas
MAC	marginal abatement cost
MCDA	Multi-Criteria Decision Analysis
MEPS	minimum energy performance standard
MJ	megajoule
MTF	Multi-Tier Framework
MW	megawatt
MWh	megawatt-hour
NDC	nationally determined contributions
NEMO	Next Energy Modelling system for Optimization
NEXSTEP	National Expert SDG Tool for Energy Planning
OECD	Organisation for Economic Co-operation and Development
RE	renewable energy
SDG	Sustainable Development Goal
TFEC	total final energy consumption
TPES	total primary energy supply
UNSD	United Nations Statistics Division
US$	United States dollar
WHO	World Health Organization

Executive Summary

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure sustained economic growth as well as respond to increasing energy demand, reduce emissions, and consider and capitalize on the interlinkages between Sustainable Development Goal 7 (SDG 7) and other SDGs. To address this challenge, ESCAP has developed the National Expert SDG Tool for Energy Planning (NEXSTEP).[1] This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as nationally determined contributions (NDCs). 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 outcome. 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 key objective of this SDG 7 roadmap[2] is to assist the Government of Bhutan in developing enabling policy measures to achieve the SDG 7 targets. This roadmap contains a matrix of technological options and enabling policy measures for the Government of Bhutan to consider. It presents several scenarios that have been developed using national data, and which consider existing energy policies and strategies as well as reflect on other development plans. These scenarios are expected to enable the Government to make an informed decision to develop and implement a set of policies to achieve SDG 7 by 2030, together with the NDC. The scope of the NEXSTEP analysis is limited to only the emissions and decarbonisation opportunities relevant to the energy and the IPPU sectors

A. Highlights of the roadmap

Bhutan (officially known as the “Kingdom of Bhutan”) has made significant progress in increasing access to electricity in recent years and achieved almost 100 per cent access rate in 2018. However, more can be done to close the clean cooking gap, as around a quarter of the population was still relying on polluting cooking fuels and technology in 2017. Energy efficiency improvement needs to be boosted across all sectors in order to achieve a 3 per cent annual improvement, reducing energy intensity from 3.75 megajoules per United States dollar (MJ/US$) to 2.54 MJ/US$ by 2030.

Bhutan is endowed with huge hydropower potential, and had an installed capacity of 1,614 MW in 2018 (an additional 720 MW Mangdechhu hydropower plant was installed in 2019), which contributes significantly to the nation’s GDP through cross-border power trade. Biomass makes up a substantial amount of the energy demand, mainly for heating and cooking purposes in the residential and commercial sectors. Imported fuels, however, still make up around one-third of the nation’s primary energy supply, with 60 per cent of the imported fuel used to power the transport sector. While this energy dependency may be a potential threat to Bhutan, the reliance on imported fuel can be reduced through adoption of electric vehicles, allowing for the utilization of locally produced renewable energy. This is also imperative in energy demand reduction. Being the world’s only carbon-negative country, Bhutan is well-positioned to maintain its commitment towards the Paris Agreement. At the same time, it has ample opportunities to achieve more by decarbonising its energy system. The energy efficiency and GHG emission reduction measures are further examined in this roadmap.

1 The NEXSTEP tool has been specially designed to perform analyses of the energy sector in the context of SDG 7 and NDC, with the aim that the output will provide a set of policy recommendations to achieve the SDG 7 and NDC targets. .

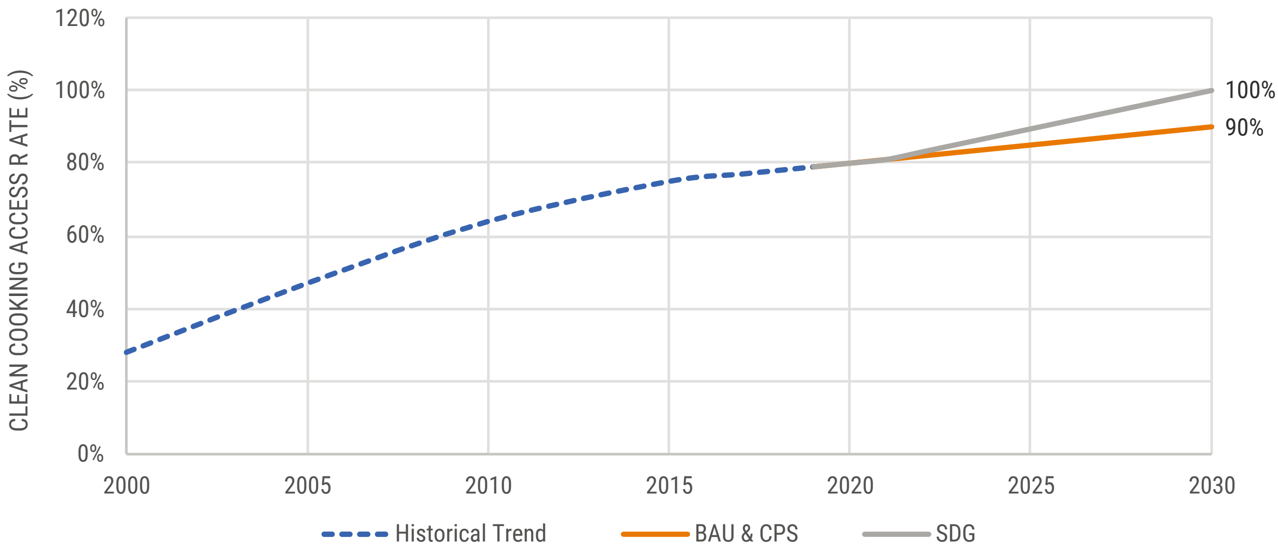
2 This roadmap examines the current status of the national energy sector and existing policies, compares them with the SDG 7 targets, and presents different scenarios highlighting technological options and enabling policy measures for the Government to consider.

B. Achieving Bhutan's SDG 7 and NDC targets by 2030

1. Universal access to clean cooking

The electricity access rate was estimated at 98.4 per cent in the baseline year of 2017, and had progressed to 100 per cent by 2018. On the other hand, in 2017 about a quarter of the population in Bhutan still relied on polluting cooking fuel and technology. Such practice exposes those people, mostly women, to negative health impacts. It is expected that the clean cooking access rate will be raised to 90 per cent by 2030, as projected based on the historical improvement trend between 2015 and 2019. Additional effort is required to ensure the achievement of the SDG 7.1 target. In consultation with stakeholders, improved cooking stoves (ICS) are considered to be the most appropriate clean cooking solution, in the context of Bhutan, in advancing progress in the near future. The efficiency of ICS is more than double that of the traditional cooking stove, thus reducing fuel consumption and cost. More importantly, it reduces harmful particulate emissions – the major culprit in air pollution-related mortality and health conditions. However, each type of ICS will need to be tested to ensure that it passes the WHO guideline[3] for clean cooking stoves.

Figure ES 1. **Bhutan's access to clean cooking under the BAU, CPS and SDG scenarios**



2. Renewable Energy

The share of modern renewable energy[4] in the total final energy consumption (TFEC) was 33 per cent in 2019.[5] Based on current policies, the share of renewable energy is projected to increase to 42.3 per cent by 2030. The increase in RE share is due to a combination of two fuel substituting measures. These are (a) replacing fuelwood and kerosene heating systems in the urban areas with electric heating systems, and (b) increasing electric vehicles to replace internal combustion engines (ICEs). The replacement of

3 See https://www.who.int/tools/clean-household-energy-solutions-toolkit/module-7-defining-clean#:~:text=The%20following%20fuels%20and%20technologies,and%20alcohol%20fuels%20including%20ethanol

4 Renewable energy excluding traditional use of biomass.

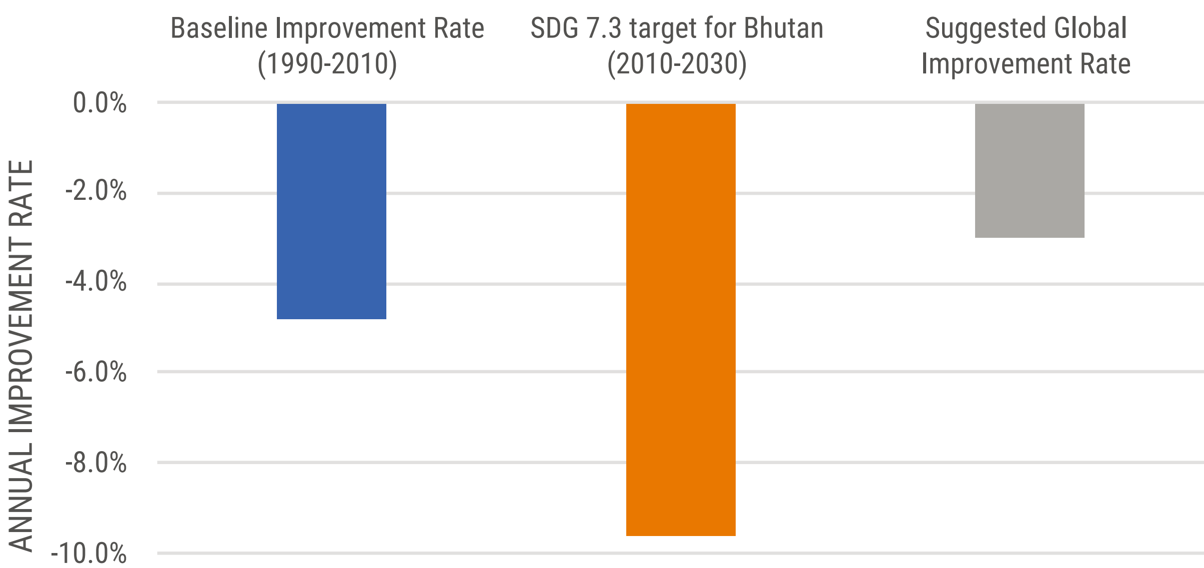
5 Excluding traditional biomass usage in residential cooking and residential space heating.

fossil fuel with 100 per cent renewable electricity in the SDG scenario will increase renewable energy share in TFEC to 54.4 per cent.

3. Energy Efficiency

Bhutan's energy intensity in 2017 was estimated to be 3.75 MJ/US$$_{2017}$. Energy intensity in Bhutan has declined at an average annual rate of 4.8 per cent between 1990 and 2010. A doubling of the 1990-2010 improvement rate is required to achieve the SDG 7.3 target, which requires an average annual rate increase of 9.6 per cent between 2010 and 2030. This would be an extremely challenging target, in which energy intensity will need to reduce to 1.25 MJ/US$$_{2017}$. In consultation with stakeholders, a conservative energy efficiency improvement target of 3.0 per cent per annum[6] has been agreed which will align with the suggested global energy efficiency improvement rate (UNSD, 2021).

Figure ES 2. Bhutan energy efficiency target[7]



Under the current policy settings, the energy intensity is projected to drop to 3.18 MJ/US$$_{2017}$ by 2030, falling short of the energy efficiency target. This is achieved in the SDG scenario, reaching an intensity of 2.54 MJ/US$$_{2017}$, through the phasing out of inefficient cooking technologies as well as polluting heating technologies. In addition, achieving this requires much effort from other sectors, most notably through the promotion of electric vehicles across all road transport categories. These opportunities are discussed in later sections of this report.

4. Nationally Determined Contribution

Bhutan is committed to maintaining its carbon-neutral status. Owing to its vast carbon sequestration potential, Bhutan is the world's only carbon-negative country. The emissions allowances for the energy sector, including Industrial Processes and Product Use (IPPU), are estimated at 7.1 MTCO2-e/annum, in total.[8] These emissions are projected to increase to 3.93 MTCO2-e under the BAU scenario, well within

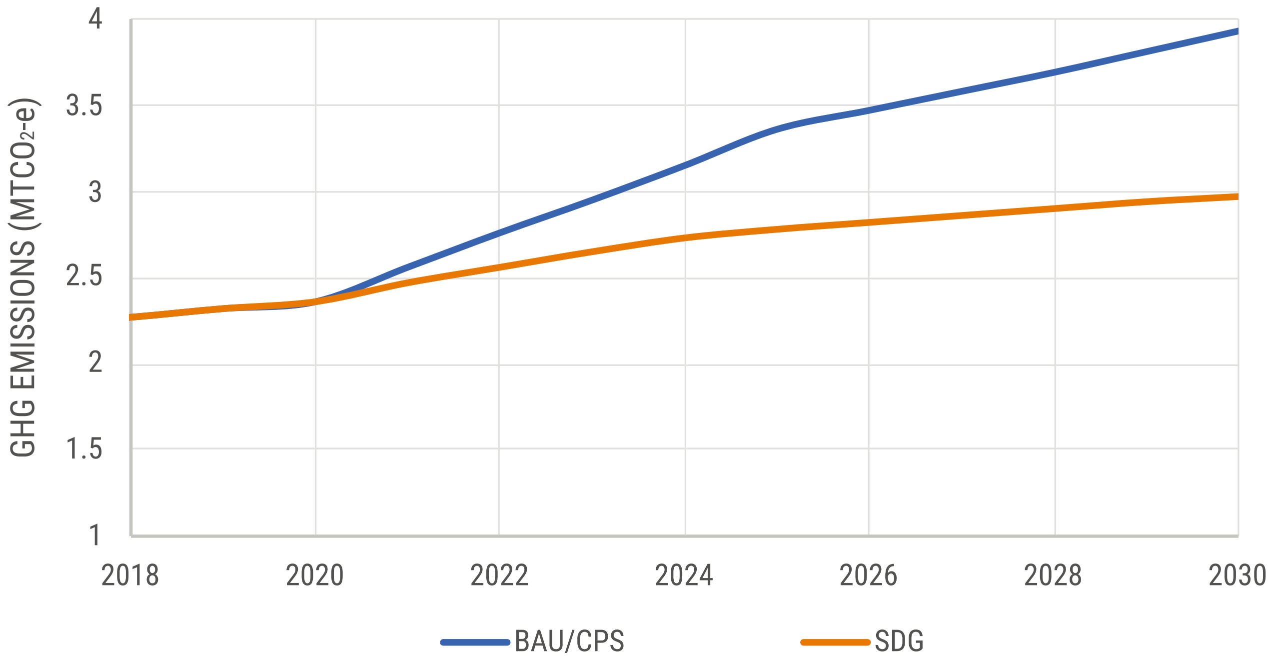
6 See global energy intensity rate of 3 per cent per year, as explained in box 2.

7 Calculated based on data from the Asia-Pacific Energy Portal.

8 Explained in detail in Section 1.3.

the emissions allowances. However, with the measures proposed in this roadmap, GHG emissions are expected to decrease further as energy efficiency measures are implemented in order to achieve the energy efficiency target. In addition, Bhutan may consider a higher GHG emissions reduction from the IPPU sector. These are further detailed in section 4.3.

Figure ES 3. **Comparison of emissions, by scenario, 2018-2030**



C. Important policy directions

The roadmap sets out five key policy recommendations to help Bhutan achieve the SDG 7 targets as well as realising a substantial decarbonisation across the economy:

1. **Access to clean cooking technologies should be the number one priority.** Improved cooking stoves that meet the WHO guidelines[9] should be promoted in order to achieve 100 per cent access to clean cooking by the end of this decade. Despite a higher up-front cost, this solution provides long-term cost savings and, more importantly, improves health;
2. **Improvement of indoor space heating technologies should be pursued to reduce impacts from indoor air pollution.** A quite substantial number of households rely on traditional fuelwood and kerosene stoves for their heating needs. Advanced *bukhari*[10] is a cost-effective alternative for lower income households, while electric heating is highly efficient, and eliminates household air pollution;
3. **Transport electrification is a key to energy demand reduction, maximising renewable energy utilization and reducing GHG emissions.** Setting a high bar for transport electrification will result in substantial GHG emissions and energy demand reduction. At the same time, it will reduce reliance on imported oil products to improve national energy security;

9 See https://www.who.int/tools/clean-household-energy-solutions-toolkit/module-7-defining-clean#:~:text=The%20following%20fuels%20and%20technologies,and%20alcohol%20fuels%20including%20ethanol

10 Advanced *bukhari* is a type of improved cooking stove used in some countries, including Bhutan.

4. **A green building code should be made mandatory, and energy efficient cooking should be encouraged for all new commercial and institutional buildings.** Energy-conscious building design will provide huge potential in reducing thermal cooling and heating needs. Commercial consumers should be encouraged to adopt energy efficient methods and appliances, such as electric cooking and energy efficient lighting, to improve energy efficiency;
5. **Decarbonisation of the industrial sector should be given importance, to reduce both energy-related and process emissions.** Industrial emissions contribute substantially to the overall national emissions. Material/fuel substitution and innovative technologies should be adopted to realise energy demand and GHG emissions reduction.

1. Introduction

1.1. Background

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure sustained economic growth, respond to increasing energy demand, reduce emissions, and consider and capitalise on the interlinkages between Sustainable Development Goal 7 (SDG 7) and other SDGs. In this connection, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as nationally determined contributions (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 the meeting's outcome. 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 ministerial declaration advises ESCAP to support its member States, upon request, in developing national SDG 7 roadmaps.

1.2. SDG 7 Targets and Indicators

SDG 7 aims to ensure access to affordable, reliable, sustainable and modern energy production for all. It has three key targets, which are outlined below.

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

In addition to the above-mentioned targets, the SDG 7 goal also includes (a) target 7.A – promote access, technology and investments in clean energy, and (b) target 7.B – expand and upgrade energy services for developing countries. These targets are not within the scope of NEXSTEP.

1.3. Nationally Determined Contribution

NDCs represent pledges by each country to reduce national emissions and are the stepping-stones to the implementation of the Paris Agreement. Since the energy sector is the largest contributor to GHG emissions in most countries, decarbonizing energy systems should be given high priority. For example, the global energy sector was responsible for 76 per cent of the global GHG emissions in 2018 (Climate Watch, 2021).

Bhutan is the only carbon-negative country in the world, owing to its significant carbon sequestration potential from its forest reserves. With reference to Bhutan's Third National Communication to the United Nations Framework Convention on Climate Change, the carbon sequestration capacity of Bhutan was 9.39 $MTCO_{2-e}$ in 2015. On the other hand, the emissions from sectors such as energy, industrial processes and product use (IPPU), agriculture, forestry and other land use (AFOLU), and waste was 3.8 $MTCO_{2-e}$ in 2015.The net GHG emissions in 2015 were -5.57 $MTCO_{2-e}$, granting the kingdom the carbon-negative status.

Bhutan is committed to maintaining its carbon-neutral status, meaning that emission of greenhouse gases will not exceed carbon sequestration by forests and sinks. NEXSTEP's modelling considers only the emissions and decarbonisation opportunities relevant to the energy and the IPPU sectors. Assuming the emissions from the AFOLU and waste sectors as well as Bhutan's carbon sequestration capacity remains constant from 2015 onwards, the emissions allowances for both the energy and IPPU sectors are estimated at 7.1 $MtCO^{2-e}$/annum in total.

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 SDG 7 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 approach, a three-step approach has been proposed. Each step is discussed in the following subsections.

2.1. Key methodological steps

(a) Energy and Emissions Modelling

NEXSTEP begins with energy systems modelling to develop different scenarios for achieving SDG 7 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 as well as to create energy and emissions scenarios. Many countries have used LEAP to develop scenarios as a basis for their Intended INDCs. Figure 1 shows different steps of the methodology.

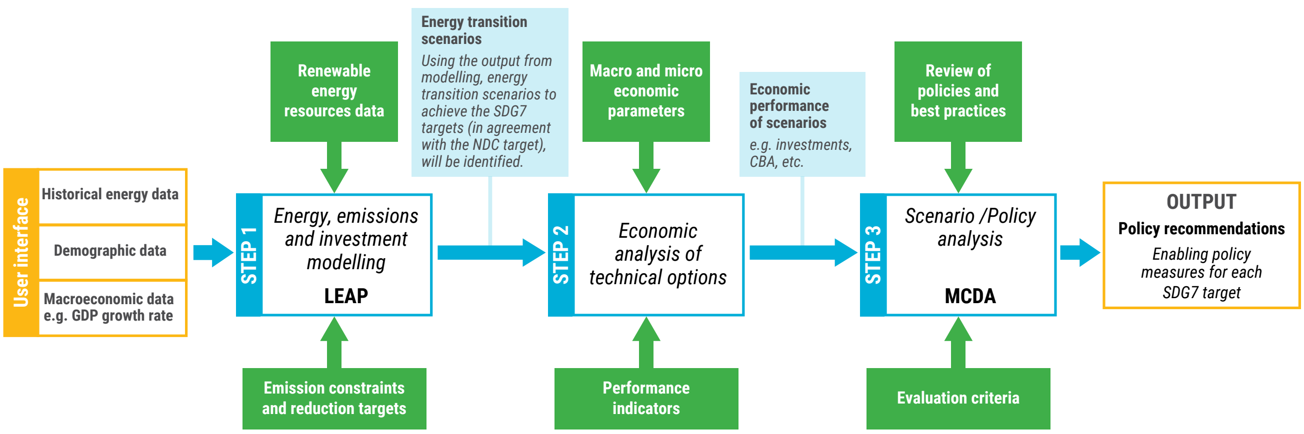
(b) Economic Analysis Module

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

(c) Scenario and policy Analysis

Using the Multi-Criteria Decision Analysis (MCDA) tool, this prioritized 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 1. Different components of the NEXSTEP methodology



This tool is unique, in that no other tools look at developing policy measures to achieve SDG 7. The key feature that makes it different is the backcasting approach for energy and emissions modelling. This is important when it comes to planning for SDG 7 as the targets for the final year (2030) are already given; thus, the tool needs to be able to work its way backward to the current date and identify the best possible pathway.

(d) Scope of analysis

The NEXSTEP analysis considers the entire energy sector and takes into account the interlinkages between targets and indicators of SDG 7 as well as the emission reduction target under NDC. It involves modelling and analysis of both demand and supply sides. For the demand side, it considers all economic sectors e.g., residential, industry, transport, commercial, agriculture etc. For the supply side, it includes all primary energy supply as well as transformation of energy from one source to the other e.g., generation of electricity. For IPPU, the analysis is limited to only the emissions and decarbonisation opportunities.

The NEXSTEP analysis, however, does not include emissions from non-energy sectors e.g., land use, land use change and forestry (LULUCF).

(e) Timeframe of analysis

The NEXSTEP analysis is performed for up to 2030 in alignment with the target year for SDGs as well as NDCs. The "base year" for this analysis is the year for which all data points were available. For the case of Bhutan, the base year is 2017. Where available, up-to-date progress of SDG 7 indicators have been provided next to base year numbers.

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 Bhutan, three main scenarios have been modelled: (a) a business-as-usual scenario; (b) current policy scenario (CPS); and (c) a Sustainable Development Goal (SDG) scenario:

(a) The BAU scenario: This scenario follows historical demand trends, based on growth 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) Current policies scenario: Inherited from the BAU scenario and modified, this scenario considers relevant policies and plans currently in place. These are, for example, the power capacity expansion plan throughout the analysis period;

(c) SDG scenario: This scenario aims to achieve the SDG 7 targets, including universal access to electricity and clean cooking fuel, substantially increasing the renewable energy share and doubling the rate of energy efficiency improvement. For clean cooking, different technologies (electric cooking stove, LPG cooking stove and improved cooking stove) have been assessed, subsequently recommending the uptake of the most appropriate technology. Energy intensity has been modelled to help achieve the SDG 7 target.

The baseline year, 2017, has been chosen, as it is the most recent year with sufficient data information for modelling. Updated data (i.e., data as of 2018 or 2019) may be available for some indicators. However, only 2017 data are referenced in this document and used in the modelling in order to maintain consistency.

2.3. Economic Analysis

The economic analysis considers the project's contribution to the economic performance of the energy sector. The purpose of a Cost-Benefit Analysis (CBA) is to make better informed policy decisions. It is a tool to weigh the benefits against costs and facilitate an efficient distribution of resources in public sector investment.

2.3.1. Basics of Economic Analysis

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

2.3.2. Cost parameters

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

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

(b) Operation and maintenance cost comprises fuel, labour and maintenance costs. Power generation facilities classify operation and maintenance costs as fixed (US$/MW) and variable (US$/MWh) cost;

(c) Decommissioning cost – retirement of power plant costs related to environmental remediation, regulatory frameworks and demolition costs;

(d) Sunk cost – existing infrastructure investments are not included in the economic analysis, since no additional investment is required for the project;

(e) External cost – 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 the carbon price. The 2016 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories is followed in the calculation of GHG emission for the economic analysis. The sectoral analysis is based on the Tier 1 approach, which uses fuel combustion from national statistics and default emission factors.

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. The criteria considered in the MCDA tool can include the following (however, stakeholders may wish to add/remove criteria to suit the local context):

- Access to clean cooking fuel;
- Energy efficiency;
- Share of renewable energy;
- Emissions in 2030;
- Alignment with 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 SDG 7 Roadmap, as a means to suggest the best way forward for the countries by prioritizing the several scenarios. Nevertheless, it has not been applied to Bhutan as only a limited number of scenarios have been developed.

3. Overview of Bhutan's energy sector

3.1. Current situation

Geography and climate: Bhutan is located on the southern slope of the Eastern Himalayas. It is a landlocked country bordering two countries – China to the north, and India to its south, east and west. The country occupies a land area of 38,394 km2, with the country's north-south border spanning more than 170 km, while the east-west dimension measures around 300 km (Kingdom of Bhutan, 2020). The country is highly mountainous, with altitude ranges from 100 metres in the foothills to more than 7,500 metres towards the north. Bhutan's geographical location and its mountainous terrains leads to a diverse climate. Bhutan is influenced by the North Indian monsoons, from which 90 per cent of the country's precipitation occurs during the monsoon season and pre-monsoon season (20 per cent). The capital city of Bhutan is Thimphu, which is also the political and economic centre of Bhutan, is situated in the western central part of the country.

Population: Bhutan is one of the least populated countries in Asia. The total population of Bhutan was estimated at 728,700in 2017. The increase in population is, in general, quite gradual. The total population recorded in 2000 was 591,000 (ESCAP, 2021), which translates into an annual growth rate of 1.2 per cent between 2000 and 2017. The population density was, on average, 19 persons per km2 in 2017, while the population in Thimphu was significant, which stood at 67 persons per km2 (Kingdom of Bhutan, 2020).

Economy: Bhutan's GDP in 2017 was estimated at US$ 2.53 billion, which translates into GDP per capita of US$ 3,472. Bhutan was once categorized as a Least Developed Country (LDC). Due to its remarkable socio-economic growth, Bhutan is scheduled to graduate from the category of LDC in 2023.[11] It is now classified as a lower-middle income economy (World Bank, 2021). The key economic sectors of Bhutan are agriculture, hydropower and the tourism sectors (Kingdom of Bhutan, 2020). Agriculture sector accounted for 17.4 per cent of GDP in 2017 and employed about 60 per cent of the total population in 2015.

Bhutan is endowed with abundant of hydropower potential, which provides a significant source of income for the country through cross-border hydroelectricity trade, which was around US$ 100 million in 2020 (SASEC, 2020). The tourism sector contributes more than 9 per cent to the GDP. Notwithstanding this fact the country's main model of development is based on the concept of Gross National Happiness, which places more emphasis on the happiness and the overall well-being of the people.

Climate change risks: Climate changes poses significant risks to Bhutan. According to the World Bank and ADB (2021), flooding is considered to be the most significant climate-related hazard. The impact of flooding will be on the country's agricultural land and infrastructure located along drainage basins, exacerbated by heavy monsoon rains and glacial outbursts. Such impact may grow to become 4 per cent of the country's GDP by 2030s. One other significant impact, among others, is the impact of climate change on Bhutan's hydropower infrastructure and power generation. Changing flow pattern and sedimentation rate, as well as hazards such as glacial lake outbursts floods and landslides, can cause direct impacts to the hydropower infrastructure.

Energy governance: The main organizations working directly on the energy sector are the Department of Hydropower and Power Systems (DHPS), the Department of Renewable Energy (DRE), the Bhutan Electricity Authority (BEA), the National Center for Hydrology and Meteorology (NCHM), the utility company Bhutan Power Corporation Ltd. (BPC), and the power generating company, Druk Green Power Corporation (DGPC). Several policy documents and key legislation have been developed to regulate the country's energy sector, such as on topics related to energy conservation and the introduction of renewable energy sources. The energy sector is part of the key areas in achieving the ambitious national objective of *Just, Harmonious and Sustainable Society through enhanced Decentralisation, as detailed in the Twelfth Five-Year Plan 2018-2023.*

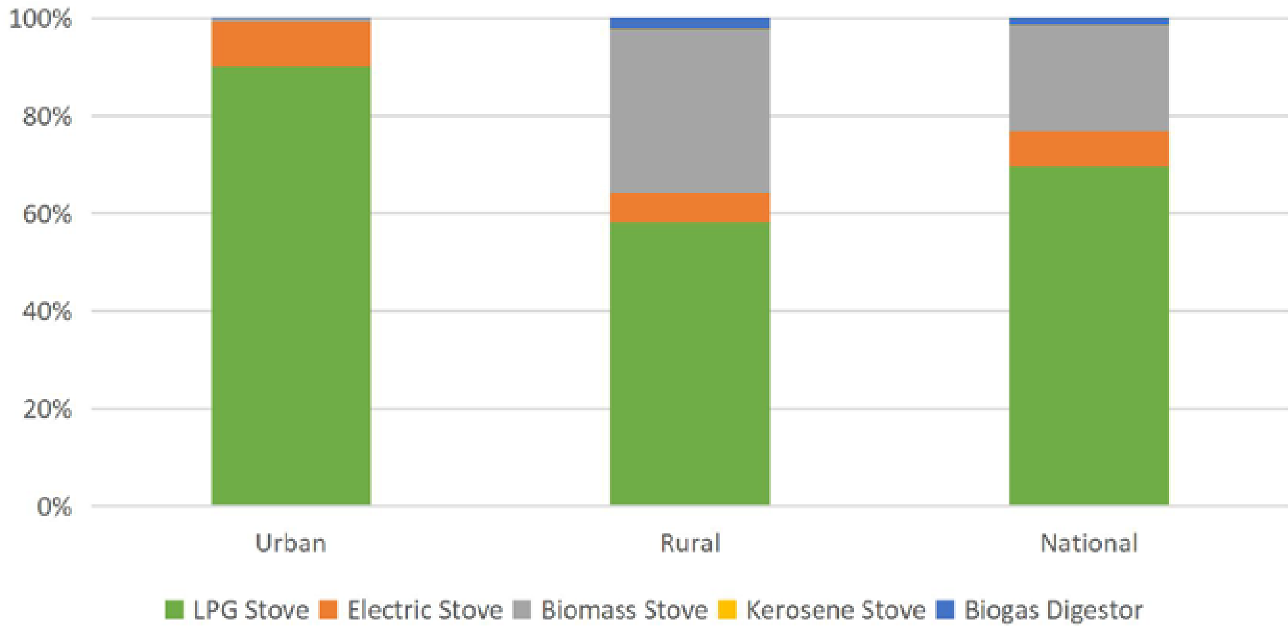
11 See https://www.un.org/development/desa/dpad/least-developed-country-category-bhutan.html

3.2. National energy profile

Bhutan's electricity access has since reached almost 100 per cent in 2018 (ESCAP, 2021). The progress is remarkable, given that the access rate stood at just 31 per cent in 2000. Electricity provision is mainly through an on-grid electricity system for 99 per cent of the country's population. Off-grid systems, such as solar home systems, are used in electrifying a very small percentage of remote, rural populations where grid extension is infeasible due to the mountainous terrain as well as environmental and forestry restrictions (World Economic Forum, 2019; IRENA, 2019). Notwithstanding this situation, power supply reliability is an issue experienced by the majority of the population (National Statistics Bureau, 2017). Therefore, improving the reliability of power supply needs to be considered.

The clean cooking access rate was an estimated 77 per cent in the base year of 2017 and increased to 79 per cent in 2019 (ESCAP, 2022). The remaining 23 per cent of the population, which corresponds to 37,700 households, still rely on inefficient and unclean traditional biomass and kerosene stoves as their primary cooking technology. Nationally, the liquefied petroleum gas (LPG) cooking stove is the most dominant primary clean cooking technology, with an estimated share of 69.7 per cent. This is followed by the electric cooking stove, which is an estimated 7.1 per cent. The remaining 1.4 per cent of the total households, mainly in the rural areas, use biogas digestors as their primary cooking technology. The cooking technology distribution is shown in figure 2.

Figure 2. Cooking technology distribution in 2017



Modern renewable energy delivered approximately 33 per cent of TFEC in 2017. This excludes traditional biomass usage in residential cooking and heating, which corresponds to an estimated 190.3 ktoe. Hydropower potential is abundant in Bhutan, contributing near-100 per cent of the electricity generated. The hydro-powered electricity not only fulfils the domestic demand, but allows close to 500 ktoe (5570 GWh) of electricity to be exported to neighbouring countries. However, Bhutan has a relatively high reliance on imported fuels (i.e., coal and oil products) to meet its heating and transport energy demands.

The energy intensity in 2017 was calculated as 3.75 MJ/US$$_{2017}$. The total primary energy supply (TPES) in 2017 was 745 ktoe and the country's GDP (in terms of PPP, US$ 2,017) was US$ 8.31 billion. The GHG emissions from the energy and IPPU sectors were an estimated 2.2 $MTCO_{2-e}$ in 2017.

3.3. National energy policies and targets

Bhutan's energy sector development is guided by several national policies and legislation. These policies have been used as guiding references for the NEXSTEP modelling, in order to better understand the country context and to provide recommendations in adherence to the Government's overarching direction. Where applicable, the currently implemented and adopted policies or regulations are considered in the current policy scenario in order to identify gaps in achieving the SDG 7 targets.[12] The policies or strategic documents consulted are detailed below:

- **The National Strategy and Action Plan for Low Carbon Development** (National Environment Commission, 2012) recommends several potential interventions and mitigation actions across demand sectors through analysing several scenarios/development pathways from 2005 to 2040.
- **The Alternative Renewable Energy Policy 2013** (Royal Government of Bhutan, 2013) seeks to provide the necessary direction for the promotion and development of renewable energy to ensure energy security, economic development, and protection of the environment.
- **The Economic Development Policy** (Royal Government of Bhutan, 2016) sets the agenda and the general direction for the development of sectors that have the highest potential. It recognises the energy sector as the main driver of the country's economy and calls for accelerated development in the hydropower and alternative renewable energy sectors to improve domestic energy supply, promoting industrial growth and enhancing revenue.
- **The Twelfth Five-Year Plan, 2018-2023** (Gross National Happiness Commission, 2019) sets out strategies and measures for achieving the ambitious national objective of *Just, Harmonious and Sustainable Society through Enhanced Decentralisation*. With regard to the low carbon development and energy front, it aims to promote renewable energy resources to supplement the national energy needs by harnessing solar and wind energy as well as promoting low emission transport system.
- **The National Energy Efficiency and Conservation Policy of Bhutan, 2019** (Ministry of Economic Affairs, 2019) was adopted to provide long-term direction for a systematic approach in implementing energy efficiency and conservation measures across demand sectors by creating an enabling environment and soliciting coordination among relevant stakeholders. Strategies/measures proposed in the policy are such as, but are not limited to:
  - o Building sector – (a) develop and implement energy efficiency building code of practice both for new buildings and for retrofits in existing buildings, and (b) mandating periodic energy audits and reporting system for energy intensive buildings;
  - o Appliance sector – (a develop and adopt the Standards and Certification Scheme to promote consumer access to energy efficient appliances, and (b) provide fiscal incentives, if viable, to accelerate penetration of energy efficiency appliances;
  - o Industry sector – (a) promote energy-efficiency upgrading measures in industrial processes, and (b) develop and implement energy audit and reporting guidelines;
  - o Transport sector – promote energy-efficient transportation, which includes mass transportation system, fuel efficient vehicles and non-motorized transportation.
- **The Climate Change Policy of the Kingdom of Bhutan 2020** (National Environment Commission, 2020) was formulated to provide

12 Only policies with concrete and implemented measures are considered in the scenario modelling for the current policy scenario. Measures mentioned in strategy policy or roadmap documents that are yet to be enforced or implemented prior to October 2021 (i.e., strategies stipulated in the National Energy Efficiency and Conservation Policy) are not considered in the modelling of the current policy scenario. The gaps and opportunities of existing national policies in meeting the SDG 7 and NDC targets are further addressed in comparison to NEXSTEP recommendations in the "Revisiting Existing Policies" chapter.

strategic guidance in ensuring that Bhutan remains carbon neutral and that climate change adaptation is managed effectively and efficiently through meaningful participation of all relevant stakeholders, adequate means of implementation and integration into relevant plans and policies.

- **The Second Nationally Determined Contribution** (Royal Government of Bhutan, 2021) stipulates Bhutan's commitment to maintaining its carbon-neutral status where emission of greenhouse gases will not exceed carbon sequestration by forests and sinks.[13]
- **The Bhutan Sustainable Hydropower Development Policy 2021** (Ministry of Economic Affairs, 2021) reinforces the strategic importance of hydropower in Bhutan in providing sustainable energy access and ensuring energy security. It covers various aspects of hydropower resource development, i.e., enhancing cross-border electricity trade, fund mobilisation, and development of energy storage technologies (e.g., hydrogen and ammonia fuels) through hydropower value chain.

The implementation of Bhutan's national policies pertaining to its energy sector development is further supported by several roadmap documents that identify priority measures/actions for several specific areas. These include the (a) *Energy Efficiency Roadmap 2019,* (b) *Renewable Energy Master Plan (2017-2032),* (c) *Bhutan Electric Vehicle Roadmap (2020-2025),* (d) *Low Emissions Development Strategies (LEDS) for Human Settlement,* (e) *LEDS for Industries* and (f) *LEDS for Surface Transport*. Together these form an invaluable foundation to NEXSTEP analysis and recommendations in achieving the country's SDG 7 and NDC targets.

3.4. National energy resource assessment

Bhutan is endowed with substantial hydropower potential. Hydropower supplies nearly 100 per cent of the country's electricity requirements and contributes significantly towards Bhutan's economy through cross-border electricity trade. As of 2017 (base year), there was a total of 1,614 MW of hydropower capacity (large, micro and mini-hydro) in 2018, generating a total of 7,721 GWh of electricity. The hydropower plants in Bhutan are primarily of run-of-river type, which are heavily dependent on the seasonality and rainfall patterns. Thus, hydropower supply peaks during the summer months (July-September) and falls to its lowest in February. During lean months (February- March), electricity is imported from India to cover the domestic supply-demand mismatch (Department of Renewable Energy, 2016).

Other indigenous renewable resources that are of utilization potential include solar, wind and biomass energy. However, site suitability is often a concern in developing solar and wind energy technologies, especially in a mountainous country like Bhutan. According to Fichtner (2016), Bhutan's solar irradiation ranges between 1,600 to 2,700 kWh/m2/year and has a theoretical potential of 6TW. Considering other restrictions and criteria (i.e., site accessibility, slope and orientation, and forest protection), the theoretical potential is only about 12GW. Many of Bhutan's high wind areas can be found above 3,000 metres, which are generally inaccessible, and Bhutan's complex topography complicates transportation of wind turbine equipment. Thus, wind power restricted development potential is estimated to be only 761 MW. Biomass resources contribute a substantial amount of Bhutan's primary energy supply for cooking and heating purposes. It can also be considered for power generation, although it is much less cost-competitive compared to other technologies, i.e., hydro and solar PV.

The theoretical potential and restricted development potential[14] are as estimated in table 1.

13 Bhutan's forest sequestration was estimated at 9.4 $MTCO^{2-e}$ in 2015.

14 The theoretical potential is calculated without any restrictions occurring in real projects. The restricted development potential describes the potential that can actually be made available by the different types of hydropower plants through incorporating general restrictions such as protected areas, forests etc.

Table 1. theoretical potential and restricted development potential of renewable resources in Bhutan

Resources	Theoretical potential		Restricted development potential	
	Capacity in MW	Energy yield in GWh/a	Capacity in MW	Energy yield in GWh/a
Total hydropower	41,088	215,959	26,683	140,246
Wind power	63,895	34,881	761	308
Solar photovoltaic (PV)	5,977,948	10,712,034	12,018	20,025
Biomass	-	5,640	-	749

Source: Renewable Energy Master Plan 2017-2032 (Department of Renewable Energy, 2016)

3.5. National energy and GHG emissions balance 2017

The following describes the estimated national energy consumption, built up using data[15] collected with a bottom-up approach, based on data such as activity level and energy intensity for the different types of demand. At the same time, guided by top-down fuel consumption measured data of various demand sectors.

In 2017, the total final energy consumption (TFEC) was 735 ktoe. Most of the demand came from the industrial sector (37.7 per cent). Within the industrial sector, the cement, ferro alloy and silicon industries account for 85.3 per cent of the sector's energy demand – i.e., the cement industry at 47 per cent, and ferro alloy and silicon industry at 38 per cent. The second-largest energy consuming sector is the residential sector.in which 91.8 per cent of energy is consumed by cooking and heating purposes – heating at 61 per cent and cooking at 30.8 per cent. Such a high share for residential cooking and heating purposes is attributable to the widespread use of inefficient traditional biomass stoves, particularly in rural households. The transport sector comes third in terms of final energy consumption (21.9 per cent), followed by commercial sector (8.8 per cent) and non-specified use (0.4 per cent).

In terms of fuel usage in the TFEC, biomass makes up about 34.1 per cent of the TFEC, which is mainly used in the residential sector. This is followed by electricity (24.9 per cent) and oil products (24.6 per cent). Electricity demand mainly comes from the industry sector – 77.4 per cent of total electricity demand. The transport sector, which operates predominantly with internal combustion engine vehicles, is the main consuming sector for oil products (88.8 per cent). Other fuel use includes coal (16.5 per cent), which is exclusively used in the industry sector. Figure 3 and figure 4 illustrate the total final energy consumption by consuming sector and fuel type.

15 National data compiled by ESCAP's national consultant with reference to publicly available and governmental sources.

Figure 3. Total final energy consumption by sector, 2017

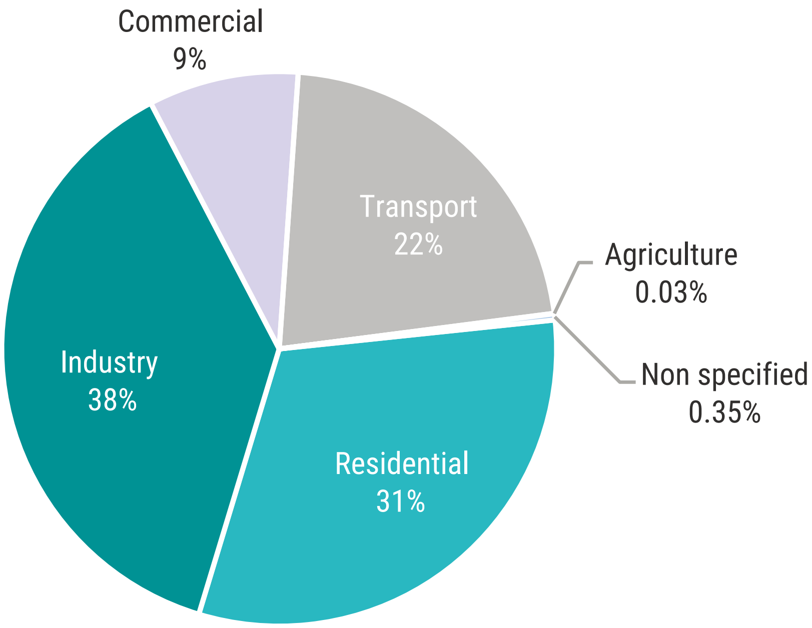
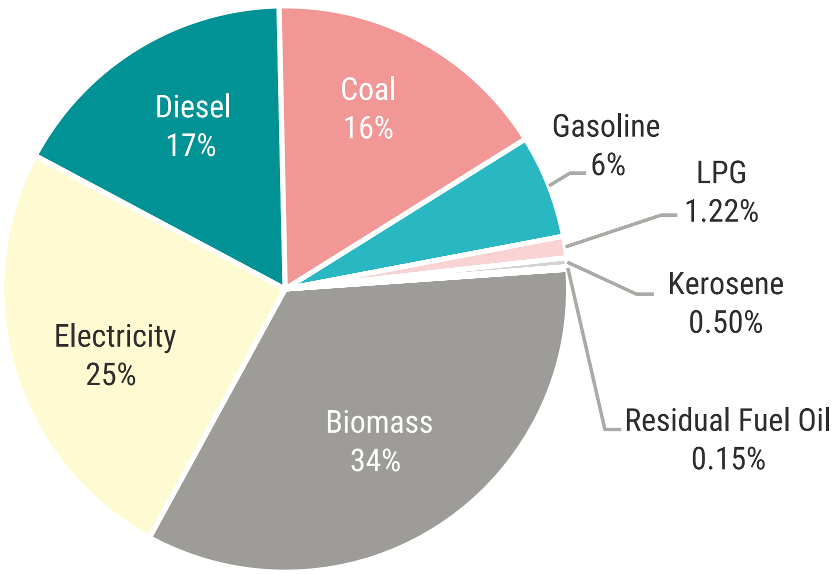
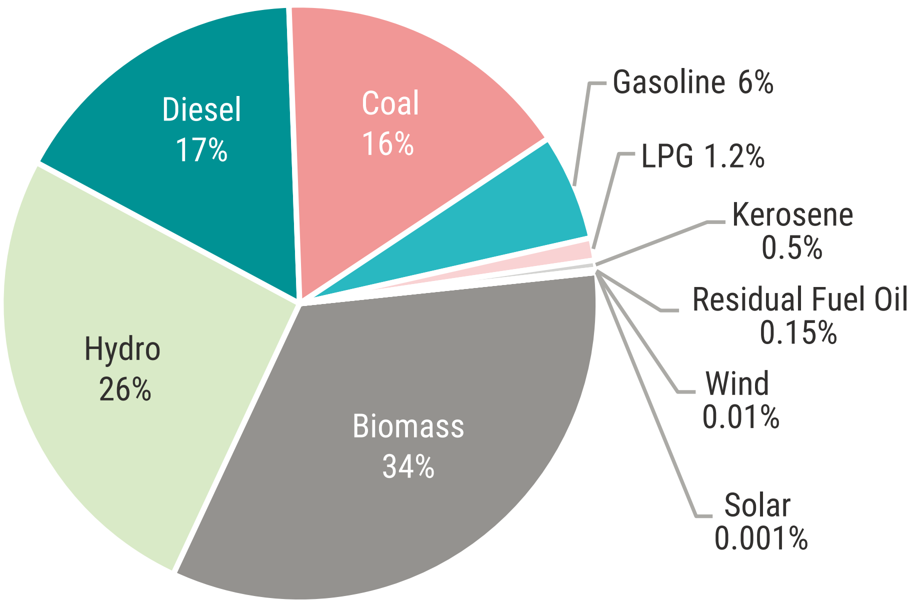


Figure 4. Total final energy consumption by fuel type, 2017



The total primary energy supply (TPES) in 2017 (figure 5) was 745 ktoe. It generally shows a fuel usage distribution similar to the TFEC. The main primary energy supply comes from biomass at 34 per cent, while hydro resources contribute a total of 25.9 per cent and are used in power generation. A very small amount of energy supply comes from solar and wind, at only around 0.01 per cent in 2017.

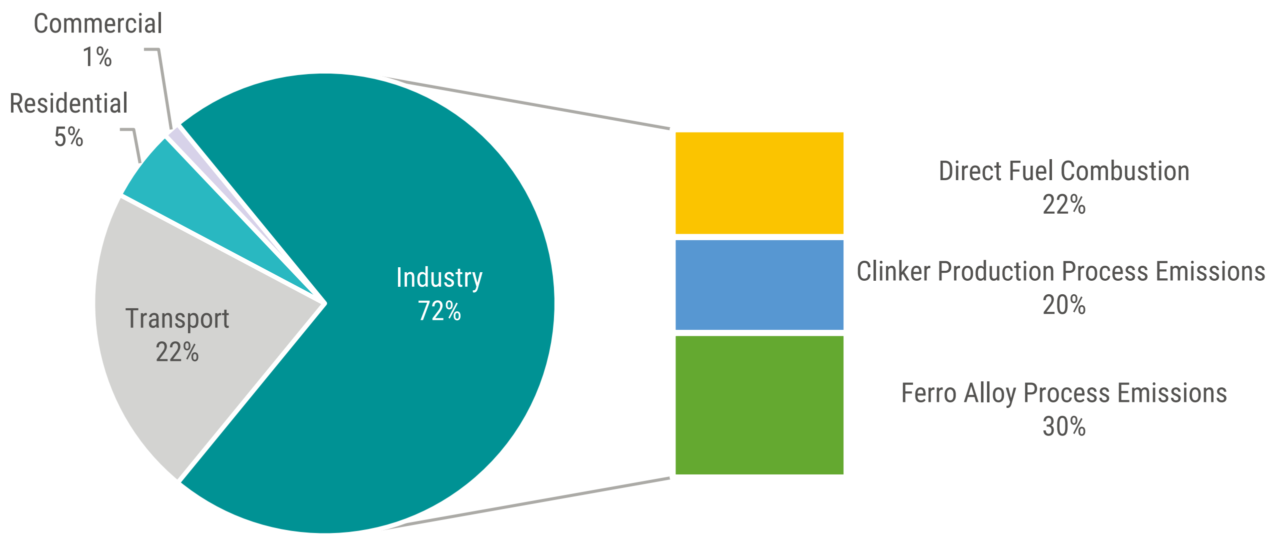
Figure 5. Total primary energy supply by fuel type, 2017



The GHG emission from the energy sector was an estimated 2.2 $MTCO_{2-e}$ in 2017 (figure 6). The emissions from the industry sector are the largest, which can be attributed to direct fuel combustion (497 $ktCO_{2-e}$) and process emissions from the ferro alloy industry and clinker production (1.1 $MTCO_{2-e}$). The transport emissions are also quite substantial at an estimated 487 $ktCO_{2-e}$, arising from direct fuel combustion in internal combustion engines. Direct combustion of fuel is also relevant to the commercial sector for heating and cooking purposes. The emission from the residential sector concerns the use of LPG, biomass and kerosene in household cooking and heating, and is estimated to be 115 $ktCO_{2-e}$. The power supply sector is emission-free, as it is exclusively powered by renewable resources, i.e., hydro.

The energy sector emissions, from the combustion of fossil fuel, for Bhutan is calculated based on IPCC Tier 1 emission factors assigned in the LEAP model and expressed in terms of 100-year global warming potential (GWP) values. For the combustion of biomass and biomass products, the carbon emissions are not attributed to the energy sector, but is for by the accounted AFOLU) as per the accounting system suggested by IPCC. Nevertheless, the emissions of other GHGs such as methane and nitrous oxide are included in the total emissions in the energy sector.

Figure 6. Energy demand distribution by transport sector sub-categories, CPS in 2030



3.6. Energy modelling projections

The energy demand is estimated using the activity level and energy intensity in the LEAP model. The demand outlook throughout the NEXSTEP analysis period is influenced by factors such as annual population growth and annual GDP growth. The assumptions used in the NEXSTEP modelling are further detailed in Annex II, while table 2 provides a summary of the key modelling assumptions for the three main scenarios (i.e., BAU, CPS and SDG scenarios).

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

Parameters	Business as usual scenario	Current policy scenario	Sustainable Development Goal (SDG) scenario
Base year	**2017 (the latest year for which all data points are available)**		
Economic growth	4.63 per cent per annum		
Population growth	0.94 per cent per annum		
Urbanization rate	35.6 per cent in 2017, growing to 45.9 per cent in 2030[16]		
Commercial floor space	Total commercial floorspace of 4.21 million m^2, assumed annual growth rate of 4.63 per cent		
Industrial activity	See Annex for further explanation		
Transport activity	Passenger transport activities in 2017 were estimated at 3.9 billion passenger-kilometres, while freight transport activities in 2017 were 2.08 billion tonne-kilometres. Assumed to be growing at an annual rate of 4.63 per cent Fuel consumption from earth-moving equipment, tractors and power tillers are estimated at 62 ktoe, 0.1 ktoe and 0.29 ktoe, respectively. These are assumed to be growing with an annual rate of 4.63 per cent.		

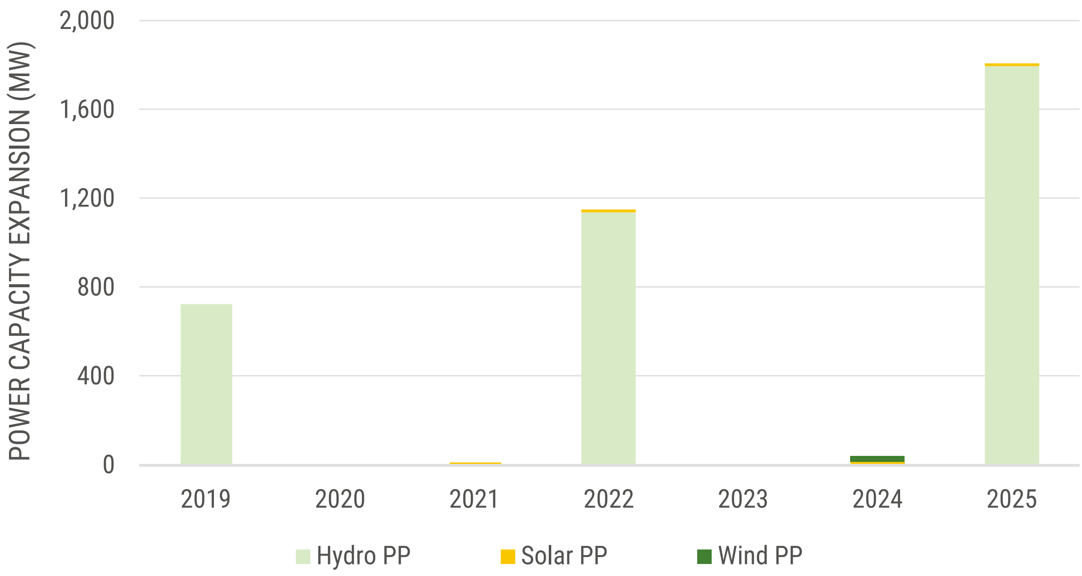
16 Projected based on the projection in Invalid source specified.

Access to electricity	Electricity access rate was estimated at 98.4 per cent in 2017		
Access to clean cooking fuels	Projected based on the historical improvement trend between 2015-2019.[17]	Projected based on the historical improvement trend between 2015-2019.[12] There are no additional governmental measures planned.	100 per cent clean cooking access rate through the promotion of improved cooking stove.
Energy efficiency	Additional energy efficiency measures not applied	No additional improvement based on current policies. See footnote ([18]) for further explanation	Three per cent annual improvement in TPES target achieved
Power plant	Capacity expansion by an additional 3,699 MW to the 2017 capacity	Capacity expansion of 3,699 MW of power capacity within 2021-2030 (see figure 7)	Capacity expansion of 3,699 MW of power capacity within 2021-2030 (see figure 7)

3.7. Bhutan's energy system projections under the current policy settings

The Current Policy Scenario (CPS) explores how Bhutan's energy system may evolve under the current policy settings. It takes into account initiatives implemented or scheduled to be implemented during the analysis period of 2018-2030. For the case of Bhutan, the CPS considers the planned power capacity expansion throughout the analysis period (see figure 7). It is noted that several roadmaps have been prepared for Bhutan, while high-level strategies have been outlined in several national policies. However, NEXSTEP modelling only takes into account policy measures that have come into force or already have a concrete implementation timeline within the analysis period, by the time of NEXSTEP analysis. Otherwise, the energy intensities from the different demand sectors are assumed to be constant throughout the analysis period, with demand growth as detailed in table 1.

Figure 7. Power Capacity Expansion Plan 2018-2030



17 The clean cooking access rate is linearly projected based on the clean cooking improvement between 2015 and 2019. The clean cooking access rate is suggested at 75 per cent in 2015 and 79 per cent in 2019 (ESCAP, 2022).

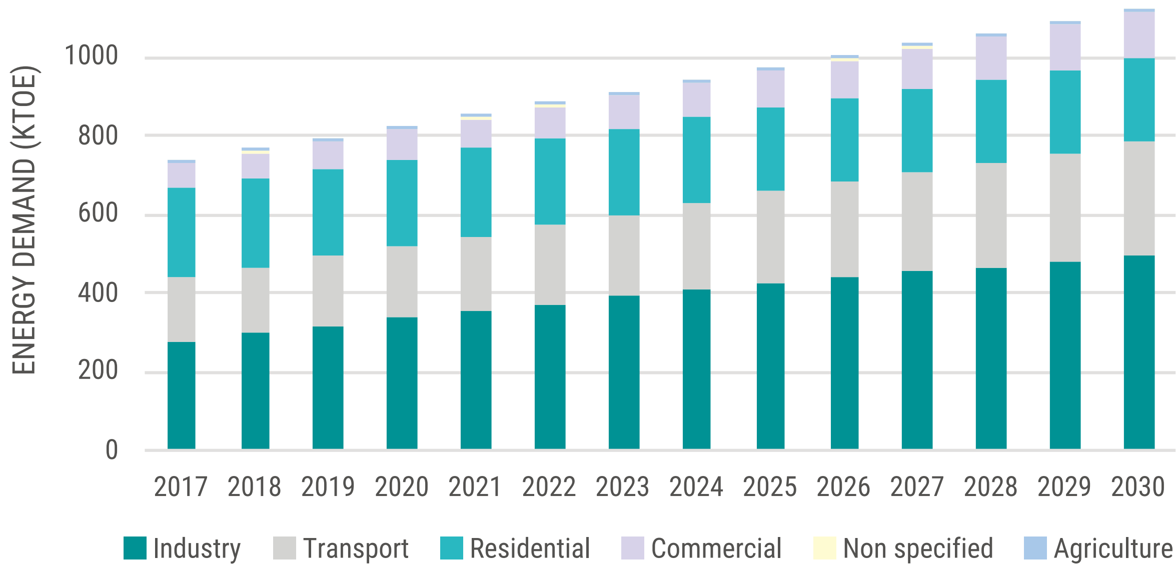
18 It is noted that several strategies and measures have been outlined in the energy efficiency roadmap and LEDS documents. However, these are not taken into consideration, as the strategies have yet to be implemented by the time of modelling.

3.7.1 Energy demand outlook

Under the current policy settings, TFEC is projected to increase from 735 ktoe in 2017 to 1,117 ktoe in 2030. This corresponds to an average annual growth rate of 3.3 per cent.

In 2030, the industry sector will remain the main consuming sector, with an estimated TFEC of 494.5 ktoe (44.3 per cent), followed by the transport sector at 289.5 ktoe (25.9 per cent), residential sector at 211.8 ktoe (19.0 per cent), commercial sector at 116.1 ktoe (10.4 per cent), non-specified at 4.7 ktoe (0.4 per cent) and agriculture at 2.3 ktoe (0.03 per cent). The sectoral overview of energy demand in the current policy scenario is discussed below and shown in figure 8.

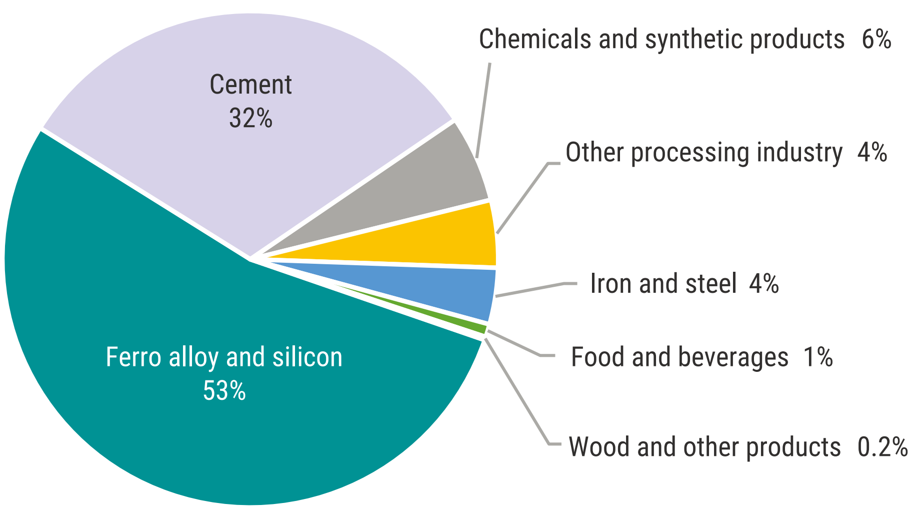
Figure 8. Bhutan's energy demand outlook, 2017-2030



(a) *Industry*

The industry sector will continue to dominate Bhutan's TFEC, with a 41.7 per cent share in 2030. It is expected to grow from 277 ktoe in 2017 to 494 ktoe in 2030, with an average annual growth rate of 4.56 per cent. The activity growth of the different industry subsectors is detailed in Annex II. This assumes a constant energy intensity of the industrial sector throughout the period, in the absence of planned initiatives or measures. The percentage share of energy demand by industry subsectors in 2030 are shown in figure 9.

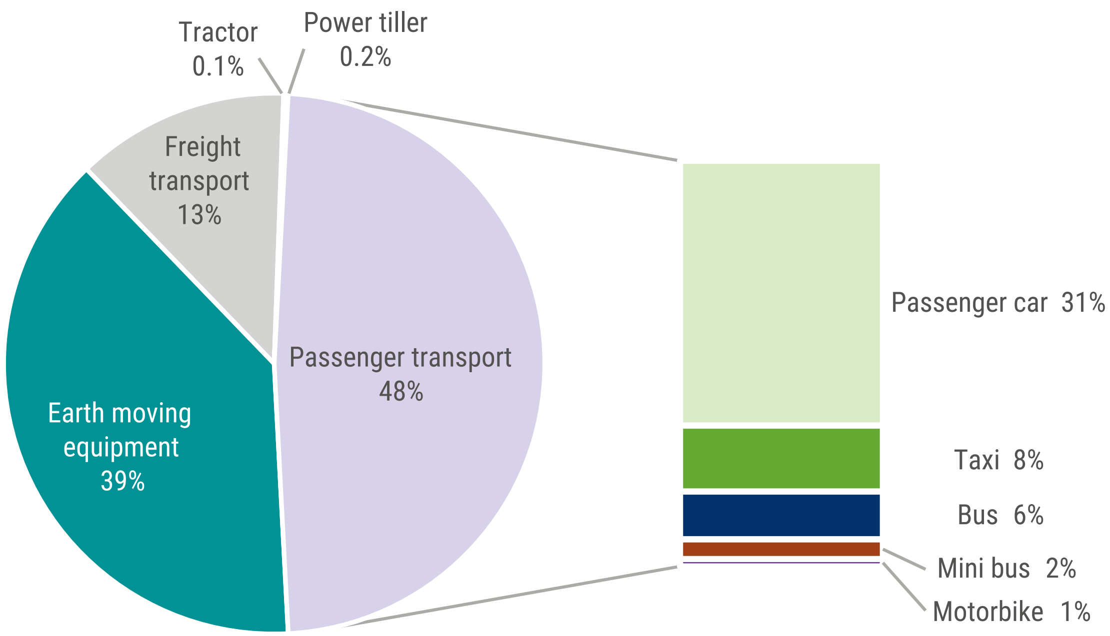
Figure 9. Energy demand by industry sub-sectors in 2030



(b) Transport

Bhutan's transport sector comprises passenger road transport, freight road transport and other vehicular equipment. The total energy demand is projected to reach 289 ktoe in 2030 (figure 10), increasing from 161 ktoe in 2017 at an annual rate of 4.63 per cent. Passenger road transport is the largest energy-consuming segment, contributing around 48 per cent to the sectoral energy demand. This is followed by earth-moving equipment and freight road transport, projected to consume around 112 ktoe and 36.7 ktoe, respectively, in 2030. The remaining demand comes from tractors and power tillers, projected to reach a negligible consumption of around 0.78 ktoe in 2030.

Figure 10. Energy demand by transport categories in 2030



(c) Residential

The energy demand from the residential sector is projected to decrease to 212 ktoe by 2030, compared with 230 ktoe in 2017. The notable decrease in energy demand is attributable to the clean cooking improvement throughout that period, as per the historical trend between 2015 and 2019. The share of traditional biomass in the cooking stove distribution is projected to decrease from 23 per cent in 2017 to 10 per cent by 2030, as more efficient cooking stoves (i.e., LPG and electric cooking stoves) are adopted. This is, however, slightly compensated for by the expected increase in energy demand as ownership for household electrical appliances increases.

(d) Commercial

The commercial sector energy demand is projected to increase from 64 ktoe in 2017 to 116 ktoe in 2030. A total of 45 per cent of the energy demand comes from commercial cooking, primarily with biomass cooking. The energy consumption for heating, specifically with biomass, contributes around 30 per cent of the sectoral energy demand, whereas demand for electric heating and cooling is around 20 per cent. The remaining demand is for powering electrical appliances, such as lighting.

(e) Non-specified and agriculture sector

The energy demand from the non-specified and agriculture sectors is projected to increase to 54.3 ktoe and 4.1 ktoe, respectively, by 2030.

3.7.2 Electricity generation outlook

The 2030 demand for electricity in the current policy scenario will be 4,339 Gigawatt-hours (GWh), increasing from 2,126 GWh in 2017. The demand will be the highest in the industry sector at 1,646 GWh (77.4 per cent), followed by the residential sector (252 GWh, 11.9 per cent), the commercial sector (195 GWh, 9.2 per cent), non-specified (30 GWh, 1.4 per cent) and the agriculture sector (2 GWh, 0.1 per cent).

Bhutan's installed electric power generation capacity in 2018 was 1,614 MW, of which 99.5 per cent was from the large hydropower capacity. The remainder is exclusively renewable, comprised of mini-hydro 0.49 per cent, wind 0.04 per cent, micro-hydro 0.01 per cent, and solar 0.01 per cent. These, in total, generated around 7,722 GWh in 2017, more than three-fold of the domestic electricity demand. The excess electricity is exported, bringing in substantial revenue to the country. A relatively small amount of electricity – around 92 GWh – is imported from India to cover the domestic supply-demand mismatch during the dry season.

A total of 3,699 MW of new capacity is expected to be installed throughout 2018-2030 (figure 7). Assuming operating at maximum availability,[19] the total electricity generation is expected to increase to 26,703 GWh as the last planned capacity is realised in 2025. The excess electricity available for exporting is projected to be around 22,124 GWh in 2030.

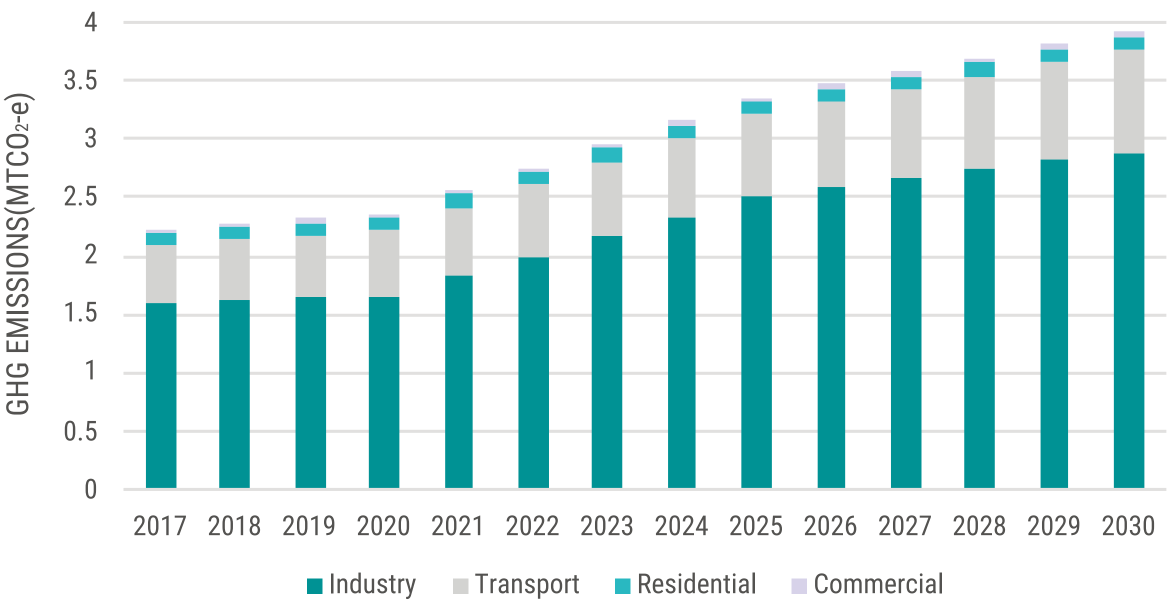
3.7.3 Energy supply outlook

In the current policy scenario, TPES is forecast to increase from 745 ktoe in 2017 to 1,137 ktoe in 2030. The fuel shares in 2017 are estimated at hydro[20] 394 ktoe, oil products 325 ktoe, biomass 267 ktoe and coal 152 ktoe. The substantial decrease in the biomass usage is due to reduced consumption in the residential cooking sector. The share of imported fuels, such as oil products and coal, will still make up about 37 per cent of the TPES in 2030, which may be a potential threat to Bhutan's energy security and exposing it to future price and supply shocks.

3.7.4 Energy sector emissions outlook

In the current policy scenario, the total GHG emissions from the energy sector increase from 2.2 $MTCO_{2\text{-}e}$ to 3.9 $MTCO_{2\text{-}e}$ (figure 11). Bhutan's electricity is emission-free, as all electricity is generated from hydro, wind and solar only. In the demand sector, the largest contributor of GHG emissions in 2030 will be the industry sector (73.6 per cent, including emissions from direct fuel combustion and process emissions), followed by the transport sector (22.4 per cent), residential sector (2.9 per cent),and commercial sector (1.2 per cent).

Figure 11. Bhutan energy sector emissions outlook in the current policy scenario



19 The maximum availability (or capacity factor) for the different power technologies is detailed in Annex V.

20 The total hydro primary supply is 2,302 ktoe, inclusive of the exported amounts. Of this,1,908 ktoe is exported electricity, which the remaining 394 ktoe is used to fulfil the domestic electricity demand.

4. SDG scenario – achieving SDG 7 by 2030

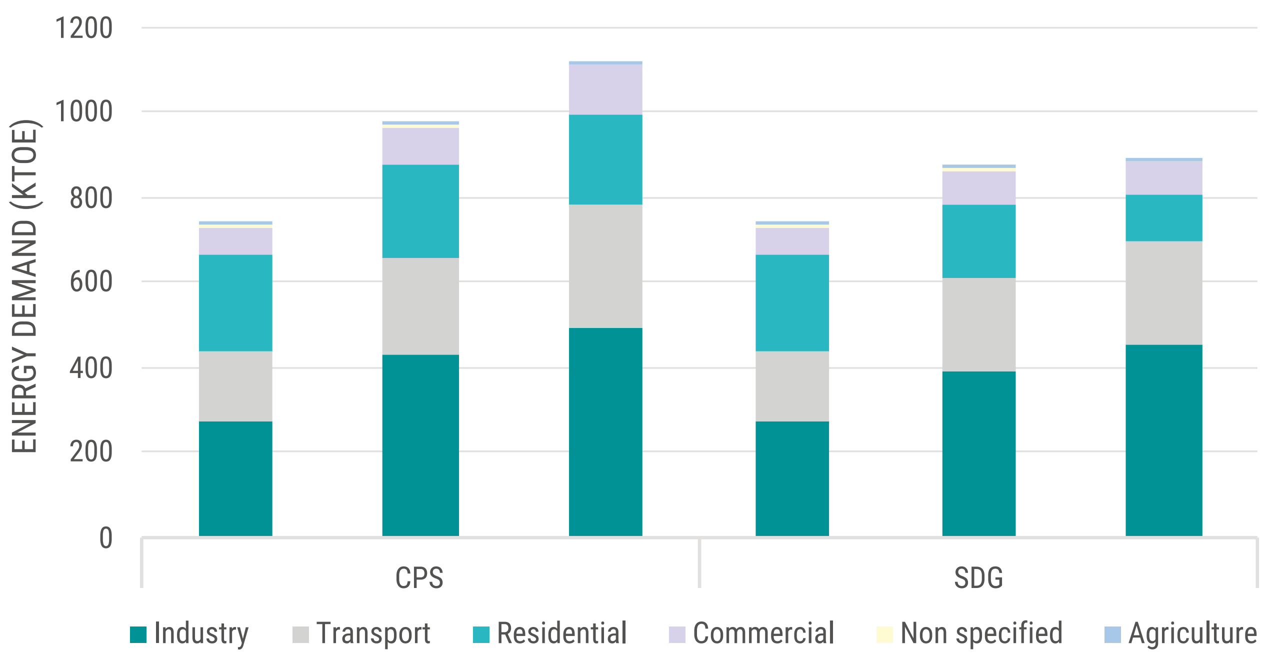
Access to affordable, reliable, sustainable and modern energy is essential to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. Bhutan has made remarkable progress in providing universal access to electricity, achieving almost 100 per cent access rate in 2018 (ESCAP, 2021). Nonetheless, small gaps still need to be closed in order to allow the achievement of all SDG 7 targets, specifically the energy efficiency and clean cooking targets, with measures recommended in the SDG scenario. This chapter details further the SDG scenario, starting with the energy demand forecast, and then discusses the energy sector in relation to SDG 7 targets.

4.1. SDG Energy demand outlook

In the SDG scenario, TFEC increases from 735 ktoe in 2017 to 888 ktoe in 2030. In 2030, the industry sector will have the largest share of TFEC at 453 ktoe (51 per cent), followed by the transport sector (243 ktoe, 27.4 per cent), residential sector (110 ktoe, 12.3 per cent), the commercial sector (78 ktoe, 8.8 per cent) and non-specified (5 ktoe, 0.5 per cent).

Figure 12 shows the projected TFEC by sector under the CP and SDG scenario. The energy demand reduction from the CP scenario is estimated as 228 ktoe in 2030. Several measures have been proposed for meeting the energy efficiency improvement across demand sectors. In addition, the SDG scenario proposes measures to close the clean cooking and clean heating gaps with more efficient technologies, which will bring multiple benefits such as reduction of household air pollution and energy demand. The proposed measures are further elaborated in the following sections.

Figure 12. Projection of TFEC by sector under the CP and SDG scenarios



4.2. SDG 7 targets

4.2.1. SDG 7.1.1 – access to electricity

Bhutan achieved universal access to electricity in 2018, up from a 98.4 per cent access rate in 2017. Despite this remarkable achievement, the Government of Bhutan should continue its effort to improve the power supply reliability.

4.2.2. SDG 7.1.2 – access to clean fuels and technologies for cooking

Under the current policy setting, it is projected that the clean cooking access rate will increase from 78.3 per cent in 2017 to 90.0 per cent by 2030. This is as projected based on the historical improvement trend between 2015 and 2019. This still leaves a gap of 10 per cent to be closed, in order to achieve universal access to clean cooking. Based both on annualised cost analysis as well as consultation with the stakeholders, improved cooking stoves may be the most appropriate technology for filling in the clean cooking gap.

Table 3 summarizes the estimated annualised cost of different cooking technologies in the context of Bhutan. The cost and technical assumptions used in the analysis are detailed in Annex III. As estimated, ICS has the cheapest annualised cost, owing to low prices for wood fuels. The Department of Renewable Energy (DRE) in collaboration with UNDP has come up with two-pot stove design named Bhutan Eco-stove 2015 (BES 2015), which has an average thermal efficiency of 21.8 per cent. In comparison; 3-stone fire stoves have efficiency of only 8 per cent. The chimneys are also designed to effectively channel the exhaust and any particulate emissions from the stoves completely, hence reducing indoor air pollution. However, studies in other geographical locations have shown that long-term adoption of ICS requires continuous follow-up and monitoring. ICS initiatives should hence be designed to ensure meeting the community needs and a long-term adoption. Considering a full government subsidy on the upfront technology cost in closing the gap by 2030, the total cost is estimated at US$ 950,000.[21]

Table 3. Annualised cost of cooking technologies

Technology	Annualised cost per household
Improved cooking stove (ICS)	US$ 39
Electric stove	US$ 61
Biogas digester	US$131
LPG stove	US$148

Alternatively, electric cooking stoves can be considered as an appropriate long-term solution, particularly for higher income households. The electric cooking stove is ranked the highest in the World Bank MTF for Indoor Air Quality Measurement, as it does not have any direct emissions. In addition, it is highly efficient, with an efficiency rate up to 90 per cent for induction-type cooking stove. One concern, however, is the additional electricity subsidy incurred by the Government of Bhutan as the domestic tariff is heavily subsidised. The additional electricity demand is estimated to be 96 GWh, if electric cooking stoves are promoted (instead of ICS) in closing the clean cooking gap. This corresponds to an additional subsidy of US$ 4 million in 2030.[22] A qualitative comparison between the different clean cooking technologies is provided in Box 1.

19 Ten per cent of the total households corresponds to 18,500 households, and the upfront technology cost is estimated at US$ 51 per stove (per household).

20 Calculated based on additional demand of 96 GWh and subsidy of 0.042 US$/kWh.

Box 1. Clean cooking technologies evaluated

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, on the other hand, use electro-magnetic energy to directly heat pots and pans, and can be up to 90 per cent efficient.

Improved cooking stoves

Studies suggest that ICS programmes often have low adoption rates due to inconvenience of use, preference for traditional cooking stoves, 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. In addition, based on the World Health Organization (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 laboratory settings used for testing. However, Tier 3+ ICS, which meet the WHO clean cooking guidelines, have the potential to reduce GHG emissions and provide socio-economic and health benefits, when promoted in carefully planned programmes. It can also play an intermediary role until cleaner options become more affordable.

Biogas digesters

Biogas digesters have high up-front 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. In addition, a standard size biogas digester requires two to four cows, depending on the size of the cow, to produce enough feedstock for daily gas demand of a household. However, a successful roll-out of the technology in remote communities with sufficient feedstock is possible with careful planning.

LPG cooking stoves

LPG use in Bhutan is constrained due to fuel import dependency and supply chain challenges. LPG cooking stoves generate lower indoor air pollution compared to ICS. They are classified as Level 4 in the World Bank Multi-Tier Framework (MTF)[23] for cooking exposure and reduce indoor air pollution by 90 per cent compared to traditional cooking stoves.

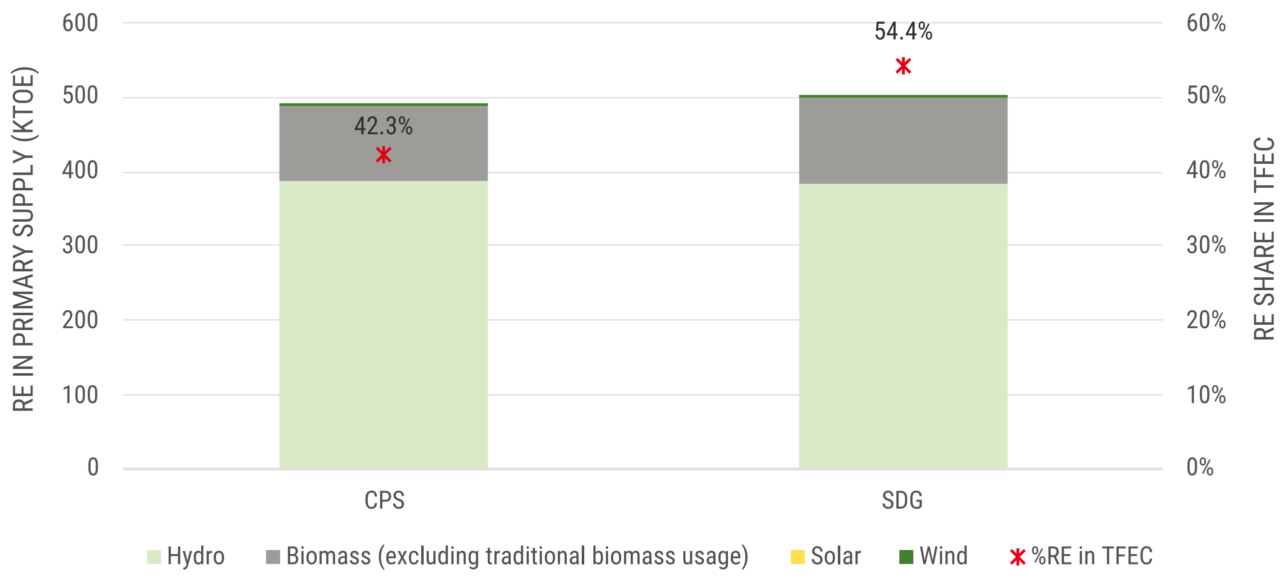
4.2.3. SDG 7.2 – renewable energy

SDG 7.2 does not have a quantitative target, but it encourages a "substantial" increase of the renewable energy share in TFEC. In normal circumstances, the NEXSTEP methodology first estimates the net increase in energy demand in response to universal energy access (both electricity and clean cooking) and energy efficiency improvement. It then uses the unconditional NDC target for the energy sector to estimate the optimum renewable energy share in TFEC.

In the context of Bhutan, the country is able to maintain its carbon-neutral status – its commitment towards the Paris Agreement – throughout the analysis period by a huge margin. Henceforth, the optimal share of renewable energy would be set at a level to achieve Bhutan's SDG 7.1 and SDG 7.2 targets, i.e., universal access to clean cooking and achieving a 3 per cent energy efficiency improvement rate.

23 See http://documents.worldbank.org/curated/en/937711468320944879/pdf/88699-REVISED-LW16-Fin-Logo-OKR.pdf

Figure 13. Renewable energy in TPES and TFEC, 2030



The share of renewable energy in TFEC in 2030 will be 42.3 per cent in the current policy scenario (figure 13). The increase in RE share is due to the improvement in energy efficiency as the clean cooking access rate gradually rises throughout the period. In the SDG scenario, the renewable energy share in TFEC is increased further to 54.4 per cent. This is a result of decreased energy demand from proposed energy efficiency measures in meeting a 3 per cent energy efficiency improvement rate as well as achieving universal access to clean cooking and heating.

4.2.4. SDG 7.3 – energy efficiency

The primary energy intensity, a proxy for the measurement of energy efficiency improvement, is calculated as 3.18 MJ/US$$_{2017}$ in the CP scenario. This corresponds to an improvement rate of 1.3 per cent. Such reduction is due to factors such as a high rate of GDP growth relative to the population growth and reduction of inefficient traditional biomass usage.

NEXSTEP proposes a 3 per cent energy efficiency improvement rate for Bhutan. Bhutan's energy system is comparatively efficient, owing to its near-100 per cent hydro-powered power sector. Hence, achieving a 3 per cent improvement rate is relatively challenging and requires efforts across demand sectors. However, there are ample opportunities, such as transitioning to more efficient heating solutions as well as clean cooking solutions, while achieving universal access to clean cooking. At the same time, it decreases GHG emissions. The proposed energy efficiency measures (including clean cooking measure) are further explained below, which altogether allows a total savings of 228.5 ktoe, compared to the CP scenario (box 2, and figures 14 and 15).

Box 2. Bhutan's energy efficiency target explained

The energy intensity of Bhutan declined at an average annual rate of 4.8 per cent between 1990 and 2010. A doubling of the 1990-2010 improvement rate is required to achieve the SDG 7.3 target, corresponding to an average annual rate of 9.6 per cent between 2010 and 2030. Consequently, the energy intensity in 2030 should be 1.25 MJ/US$$_{2017}$. Such a high rate of energy efficiency improvement and a low energy intensity is challenging and unlikely to be achieved, even with ambitious energy efficiency improvement measures. Therefore, NEXSTEP analysis suggests that Bhutan's energy intensity target be aligned with the global target of 3 per cent annual improvement (UNSD, 2021). This corresponds to a 2030 energy intensity target of 2.54 MJ/US$$_{2017}$.

Global energy efficiency improvement rate explained

The historical energy intensity improvement rate between 1990 and 2010 was 1.3 per cent. Preliminary estimates for 2018 and 2019 are 1.3 per cent and 2 per cent, respectively. This suggest that the improvement rate would reach approximately 2.1 per cent between 2010 and 2019, thus falling below the annual 2.6 per cent target rate. Therefore, meeting the SDG target will require an improvement rate of at least 3 per cent (figure 14) per year from now until 2030 (UNSD, 2021).

Figure 14. Improvement rate of primary energy intensity, 1990-2017 and 2017-2030 target rate (Percentage)

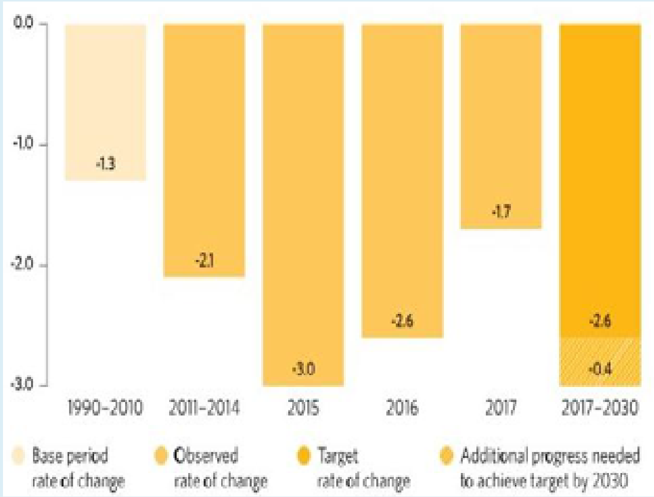
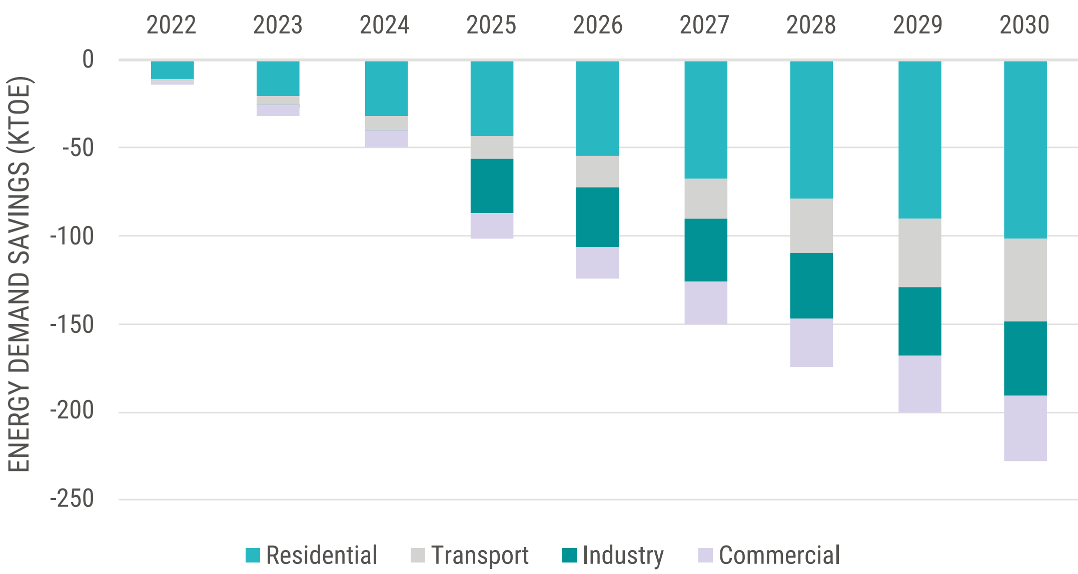


Figure 15. Energy savings by sector in the SDG scenario, compared with the CP scenario



(a) Residential sector

Achieving universal access to clean cooking via the promotion of ICS is expected to result in a considerable energy demand reduction due to the higher efficiency of ICS. In addition, clean heating solutions should be promoted – an issue that is often overlooked, yet is imperative in eliminating household pollution and associated health impacts. The energy demand reduction from such a measure is projected to be substantial, as current polluting technologies are highly inefficient. Providing universal access to clean cooking and heating solutions should be the Government's priority as it not only allows the achievement of SDG 7 targets, but also creates positive socio-economic impacts (i.e., it addresses gender inequalities).

Minimum Energy Performance Standards (MEPS) can be introduced to common household appliances – for example, air conditioners and refrigerators – as well as phasing out of inefficient lighting with LED lighting. These are often low-hanging fruits in transitioning towards a more efficient energy system (table 4 and box 3).

Table 4. Energy efficiency measure applied and the estimated annual savings in 2030 (relative to CPS) in the residential sector

Household appliance	Energy efficiency measures	Annual saving in 2030 (ktoe)
Heating	Phasing out fuelwood and kerosene heating stoves – promoting electric heating to urban households and advanced bukhari to rural households	76.9
Cooking	Phasing out traditional biomass and kerosene stoves, replaced by improved cooking stove (ICS)	19.1
Lighting	Phasing out of inefficient lighting with LED lighting	3.1
Refrigerators	Introduce Minimum Energy Performance Standards (MEPS) from 2025 onwards[24]	3.1
Air conditioners	Introduce Minimum Energy Performance Standards (MEPS) from 2025 onwards[25]	0.06
Total		**102.2**

Box3. Transitioning to high-efficient, low emissions heating technologies

Heating is a necessity for households in certain geographical locations. It is estimated that 80 per cent of the urban households and 76 per cent of the rural households in Bhutan utilize heating technologies for space heating. Of those households, around 44 per cent rely on fuelwood and kerosene heating stoves – major contributors to indoor air pollution and associated health impacts. The remaining households use electric heating as their primary heating solution.

NEXSTEP analysis identifies advanced bukhari and electric heating as the appropriate technologies in phasing out unclean heating practices. Advanced bukhari has the potential to reduce fuel consumption by half, whereas the saving from electric heating is estimated to be 80 per cent, in comparison to current inefficient technologies. The following list provides the results of an annualised cost analysis for different heating technologies.

Technology	Annualised cost
Advanced *bukhari*	US$ 53
Electric heating	US$ 74
Traditional *bukhari*	US$ 93

24 Average electricity intensities for energy efficient refrigerators are assumed to be 335 kWh/year (storage capacity of 565 litres) for urban households and 295 kWh/year (storage capacity of 440 litres), as per 2-star rating for Bureau of Energy Efficiency (India) Standards.

25 This assumes a 30 per cent demand reduction for energy efficient air conditioners from the baseline intensities.

The cost and technological assumptions are provided in Annex IV. Advanced bukhari have the lowest annualised cost, and should be promoted among the rural households, who typically are of lower income level. It also reduces the fuel cost as it is doubly as efficient as traditional bukhari, though requires a higher upfront cost. The annualised cost of traditional bukhari is high due to its short lifespan of an assumed one year. More importantly, promotion of clean heating should be promoted regardless of cost in order to eliminate indoor air pollution-related mortality and health conditions. Electric heating is suggested for the urban households – this measure is necessary in order to realise a deeper annualised energy demand reduction to meet the energy efficiency target.

Alternatively, if electric heating is recommended to both urban and rural households, it could provide an additional energy demand reduction of 34.8 ktoe in 2030. This would, however, incur a high fuel cost for the lower-income households and a higher electricity subsidy amount for the Government (around US$ 11.3 million).[26]

(b) Transport sector

The current share of electric vehicles in the existing fleet is very low. Notwithstanding, promotion of electric vehicles is an effective way to reduce demand consumption in the transport sector, as well as GHG emissions.

In the SDG 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 as shown in table 5.

Table 5. Energy efficiency measure applied and the estimated annual savings in 2030 (relative to CPS) in the transport sector

Category	Measure	Annual Saving in 2030 (ktoe)
Passenger car	Increase the share of electric passenger cars to 40 per cent by 2030 - This requires the annual sales target to reach 50 per cent by 2025 and 85 per cent by 2030	27.4
Taxi	Increase the share of electric taxis to 50 per cent by 2030 - This requires the annual sales target to grow by 15 per cent annually from 2022 onwards, reaching 100 per cent by 2027	8.4
Bus	Increase the share of electric buses to 50 per cent by 2030 - This requires the annual sales target to grow by 15 per cent annually from 2022 onwards, reaching 100 per cent by 2027	4.5
Freight truck	Increase the share of electric freight trucks to 20 per cent by 2030 - This requires the annual sales target to reach 20 per cent by 2025 and 50 per cent by 2030	3.5

26 alculation based on additional demand of 269.8 GWh and subsidy of 0.042 US$/kWh.

Minibus	Increase the share of electric mini buses to 50 per cent by 2030 - This requires the annual sales target to grow by 15 per cent annually from 2022 onwards, reaching 100 per cent by 2027	1.9
Motorbike	Increase the share of electric motorbikes to 40 per cent by 2030 - This requires the annual sales target to reach 50 per cent by 2025 and 85 per cent by 2030	0.9
Total		**46.6**

(c) Industry sector

The industry sector is Bhutan's largest energy-consuming sector, and the energy demand is projected to increase to 452 ktoe by 2030. Substantial energy efficiency improvement can be sought from the industry sector, such as through waste heat recovery and the use of efficient technologies. Other than that, it is imperative that Bhutan's industry sector realises a deep GHG emissions reduction, by cutting down process emissions and using carbon-neutral raw materials (table 6). GHG emissions reducing measures for the industry sector are discussed further in section 4.3.

Table 6. Energy efficiency measure applied and the estimated annual savings in 2030 (relative to CPS) in the industry sector

Category	Measure	Annual saving in 2030 (ktoe)
Ferro alloy	Utilize waste heat recovery to reduce electricity usage	38.0[27]
All other industries	Efficiency gains of 5 per cent in electric-powered equipment	3.7
Total		**41.7**

(d) Commercial sector

The majority of the sectoral energy consumption is for cooking and heating purposes. Commercial consumption, which makes up about 44 per cent of the sectoral demand, is primarily done with less efficient biomass cooking. This provides a substantial energy efficiency improvement opportunity by replacing current biomass cooking with electric cooking. On the other hand, heating (and electric cooling) accounts for 51.3 per cent of the sectoral demand. Such high consumption levels can be attributable to sub-optimal building designs with low thermal performance. The green building code should be mandated for newly-constructed buildings, while retrofitting of existing buildings should be encouraged to realise energy demand savings through more sustainable building designs (table 7).

27 This is calculated assuming waste heat of 54 per cent, and 30 per cent recovery of waste heat, as suggested by the National Environment Commission (2021). The modelling assumes that the measure is applied across the industry from 2025 onwards.

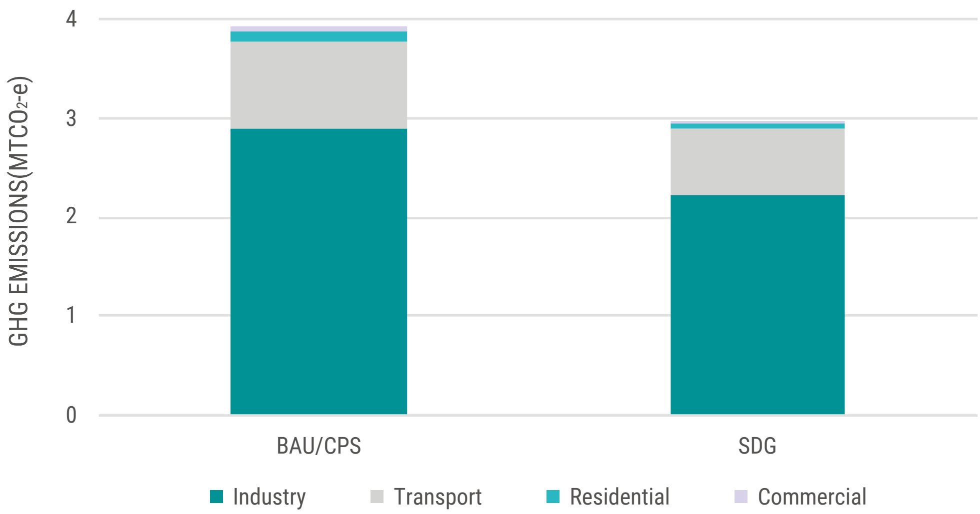
Table 7. Energy efficiency measure applied and the estimated annual savings in 2030 (relative to CPS) in the commercial sector

Sub-category	Measure	Annual saving in 2030 (ktoe)
New buildings	Phasing out of biomass cooking in new commercial buildings and institutional buildings, in replacement with electric cooking, from 2023 onwards[28]	5.7
	Mandating green building code for new commercial buildings. [29]	7.9
Existing buildings	Replacing biomass cooking with electric cooking for all existing institutional and private buildings	17.0
	Phasing out non-efficient lighting in all existing buildings[30]	1.4
	Retrofitting of existing institutional and private buildings in accordance to green building code to reduce heating demand, assuming 50% adoption rate	6.2
Total		**38.2**

4.3. Realising a substantial GHG emissions reduction with the SDG scenario

The emissions from the BAU and CP scenarios are projected to reach 3.93 $MTCO_{2-e}$. The emissions from the SDG scenario is projected to be 2.97 $MTCO_{2-e}$ in 2030, a 0.96 $MTCO_{2-e}$ reduction compared with the BAU and CP scenarios. This also corresponds to a 24.4 per cent reduction from the BAU scenario. Figure 16 shows the emissions in the different scenarios.

Figure 16. Sectoral emissions by scenario, 2030



28 Assuming an energy intensity reduction of 53 per cent, considering a cooking efficiency of 35 and 74 per cent for biomass cooking and electric cooking, respectively.

29 This assumes 30 per cent savings for heating and cooling, and a 50 per cent decrease in lighting electricity consumption through the adoption of LED lighting.

30 Assuming an energy intensity reduction of 50 per cent.

Substantial emissions reduction can be realised in the industry sector. Specifically, this means a reduction of process emissions through the use of biogenic reductants in the ferro alloy industry and from cement blending in the cement industry. The energy efficiency measures proposed in section 4.2.4 above, which reduces direct fuel combustion, also contribute towards GHG emissions reduction. Table 8 details the GHG emissions reduction realised by the proposed energy efficiency and GHG emission reduction measures.

Table 8. GHG emissions reduction by measures

Sector	Subsector	Actions	Estimated savings in 2030 ($ktCO_{2-e}$)
Industry	Ferro alloy	**(IPPU)** Substituting coal and coke with charcoal as reductants to reduce process emissions. This assumes a 50% substitution by mass.	582.6[31]
	Cement	**(IPPU)** Utilize cement blending to reduce process emissions from clinker production	57.5[31]
		Fuel substitution – substituting 10 per cent of coal usage with refuse-derived fuel (RDF)	37.2[32]
Transport	Passenger car	Increase the share of electric passenger cars to 40 per cent by 2030	108.5
	Taxi	Increase the share of electric taxis to 50 per cent by 2030	33.2
	Bus	Increase the share of electric buses to 50 per cent by 2030	25.4
	Freight truck	Increase the share of electric freight trucks to 20 per cent by 2030	23.2
	Minibus	Increase the share of electric minibuses to 50 per cent by 2030	10.5
	Motorcycle	Increase the share of electric motorcycles to 40 per cent by 2030	2.9
Commercial	New buildings	Phasing out of biomass cooking in new commercial buildings and institutional buildings, in replacement with electric cooking, from 2023 onwards[33]	5.9
		Mandating green building code for new commercial buildings[34]	1.7
	Existing buildings	Replacing biomass cooking with electric cooking for all existing institutional and private buildings	13.6
		retrofitting of existing institutional and private buildings, assuming 50% adoption rate	1.9

31 As estimated by the National Environment Commission (2021).

32 As estimated by ESCAP based on the factor considered in a minimum emission reduction of 1 tCO2e/t RDF. The modelling assumes that the energy content of RDF is half the energy content of coal, hence the emission reduction for each tonne of coal substitution is 2 tonnes of $CO2_{eq}$.

33 Assuming an energy intensity reduction of 53 per cent, considering a cooking efficiency of 35 and 74 per cent for biomass cooking and electric cooking, respectively.

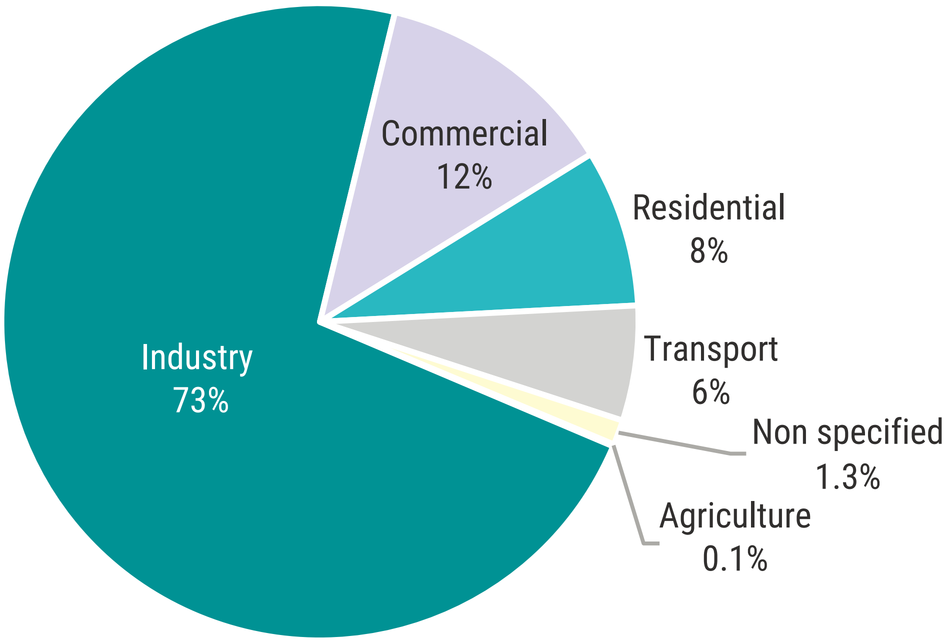
34 This assumes 30 per cent savings for heating and cooling, and a 50 per cent decrease in lighting electricity consumption through the adoption of LED lighting.

Residential	Heating	Phasing out fuelwood and kerosene heating stoves – promoting electric heating to urban households and advanced *bukhari* to rural households	44.6
	Cooking	Phasing out traditional biomass and kerosene stove, in replacement with improved cooking stove (ICS)	8.3
Total			**956.9**

4.4. Power generation in the context of SDG 7

The electricity demand in the SDG scenario is projected to increase from 2,126 GWh in 2017 to 4,275 GWh in 2030. The projected sectoral split is: (a) industry sector (3,095 GWh, 72.4 per cent); (b) commercial sector (530 GWh, 12.4 per cent); (c) residential sector (342 GWh, 8.0 per cent); transport sector (250 GWh, 5.8 per cent); non-specified (54.3 GWh, 1.3 per cent); and agriculture (4.1 GWh, 0.1 per cent) (figure 17).In the SDG

Figure 17. Share of electricity demand by sector, SDG scenario in 2030



scenario, the power capacity expansion plan is as per the CP scenario (see figure 7). By 2030, the total installed capacity is expected to reach 5,314 MW, of which 99.1 per cent would be large hydropower plants. This capacity is projected to generate around 26,703 GWh of electricity as the last planned capacity comes online in 2025. The domestic demand is significantly lower than the total generation, allowing 83 per cent (or 22,192 GWh) of the electricity generated to be exported.

The projected total investment for the planned power capacities is $3.7 billion (capital cost for power plants only). The high amount of exported electricity can be expected to bring in substantial revenue to Bhutan. Estimated using an average tariff of 0.037 US$/kWh, the sales revenue from exported electricity is around US$ 8 billion. Considering an average cost of production of 0.022 US$/kWh, the total net benefits are about US$3.4 billion throughout the analysis period. The net benefits are not estimated for domestic electricity demand due to the limited available data.

Box4. Power sector at higher RE (excluding large hydro) penetration

NEXSTEP explores the economic feasibility of a power sector with a higher renewable energy (RE) penetration. That is excluding large hydropower generation that currently contributes more than 99 per cent of Bhutan's total electricity generation. NEXSTEP hypothetically assumes a 10 per cent, 20 per cent and 30 per cent share of solar generation, starting from 2023 onwards. Further expansion of wind power is not considered due to the relatively limited potential in the country (see table 1). The following table summarizes the estimated investment cost, cost of production and net benefits that may be sought from cross-border electricity export.

Target	Solar Capacity in 2030 (MW)	Investment Cost (billion US$)	Cost of Production (billion US$)	Net Benefit (billion)
10%	2,177	5.5	5.1	1.1
20%	4,355	7.2	6.3	0.036
30%	6,532	9.0	7.5	-1.7
SDG scenario	18	3.7	3.9	3.4

As estimated, the power capacity mix as planned (which is modelled in the SDG scenario) provides the highest net benefit, and is expected to incur the least investment and production costs. At 30 per cent solar generation, the cost of production per unit of electricity is expected to be higher than the assumed export tariff (US$ 0.03/kWh), hence a negative net benefit. The technology cost assumptions are as provided in Annex V. While solar PV technology has a lower investment cost compared to large hydropower on a megawatt-basis, the lower capacity factor requires a higher amount of solar capacity to be installed in fulfilling the same amount of electricity generation. Hence, this leads to a higher overall cost.

The levelized cost of electricity (LCOE) for the different power technologies is estimated as follows, of which large hydropower technology has an LCOE as low as US$ 18/MWh. This assumes a 5.37 per cent discount rate.

Technology	Levelised cost of electricity (US$/MWh)
Large hydro	18.0
Solar PV	56.17
Onshore wind	110.1
Micro hydro	123.4
Mini-hydro	154.2

Box5. SDG scenario with EV roadmap projections

Bhutan recently developed an EV roadmap to guide its EV promotion for 2020-2035. The proposal and assumptions of the EV roadmap have been assessed by NEXSTEP in evaluating its impact on meeting the SDG targets, specifically the 7.3 energy efficiency target. The EV roadmap considers a relatively high growth rate and a modest EV annual sales target for the different vehicle categories.

Category	Vehicle number growth rate (%)[35]	EV annual sales target
Passenger vehicles		
Two-wheelers (motorcycles)	3.18	20% by 2025, 50% by 2030
Light vehicle (passenger cars)	12.14	20% by 2025, 50% by 2030
Taxis	8.59	20% by 2025, 70% by 2030
Buses	7.38	10% by 2025, 50% by 2030
Goods vehicles		
Medium vehicles (medium trucks)	5.76	5% by 2025, 20% by 2030
Heavy vehicles (heavy trucks)	8.38	Zero % by 2025, 5% by 2030

These are summarised below.

Considering the growth rate and the EV annual sales target proposed above, Bhutan is unlikely to meet a 3 per cent energy efficiency improvement rate by 2030. High growth rates of the different vehicle categories will rapidly increase the transport energy demand from 161 ktoe in 2017 to 466 ktoe, under a BAU scenario (assuming no penetration by electric vehicles). This corresponds to an average annual growth rate of 8.5 per cent. The energy saving is projected to be 406 ktoe, if the EV annual sales targets are achieved. On the other hand, the sectoral demand in the SDG scenario is projected to be 243 ktoe, assuming a growth rate of 4.63 per cent in vehicle numbers and the share of electric vehicles as proposed in section 4.2.4.

While these assumptions may not represent the actual growth rate in the next decade, this shows the difficulty that growing challenges from vehicle use pose to energy efficiency, and supports the role of high electric vehicle penetration.

35 The growth rates are estimated based on the historical data for 2000 to 2019. The recent growth rate (2018-2019) is substantially lower with an average growth rate of 5.12 per cent (pManifold, 2020).

The SDG scenario builds on the current policy settings, and proposes several measures for achieving the SDG 7 targets. These measures not only put Bhutan on a sustainable energy transition pathway, they also contribute towards socio-economic development. The following section outlines the policy recommendations and calls for a coordinated approach for a successful implementation of measures.

5.1. Achieving clean cooking target enhancement of socio-economic development

In 2017, 23 per cent of Bhutan's population lacked access to clean cooking technologies.[36] Thus, providing universal clean cooking access should have the utmost priority for the country in order to enhance socio-economic development and reduce social inequalities.

Access to clean cooking fuels and technologies often lacks policy attention. In turn, this can lead to substantial levels of health impacts and premature deaths due to household air pollution caused by unclean cooking practices. Nearly a quarter of Bhutan's population still relies on the use of traditional biomass stoves and under the current policy scenario, this is expected to be reduced to 10 per cent by 2030. Positive benefits that can arise from the adoption of clean cooking technologies include fuel savings (as evidenced in the SDG scenario), less time spent on cooking and collecting fuels, and reduced health risks from indoor air pollution. In consultation with the stakeholders, adoption of improved cooking stoves is proposed as the most appropriate solution in closing the gap within the short time frame. This builds on the traditional practice of using biomass as cooking fuel, which is abundant and cheap.

36 The clean cooking access rate grew to 79 per cent in 2019 (ESCAP, 2022).

5. Policy actions for achieving SDG 7

Nevertheless, successful uptake of clean cooking stoves on a long-term basis requires more than just providing the appropriate clean cooking technology. ESCAP (2021) outlines several important strategies in ensuring long-term adoption of clean cooking technology. For example, programme planning should employ a multisectoral and participatory approach that hinges on cooperation from actors and engagement from the local communities to ensure long-term adoption and progress towards socio-economic development. Field testing and close-up monitoring is imperative to evaluate the effectiveness of the programmes, in order to inform about future policies and initiatives. Access to clean cooking technologies requires as much attention as advancing energy efficiency and renewable energy in the country. This requires setting a comprehensive target and policy strategies by the Government to garner the necessary financing and participation from the private and public sectors.

5.1.1 Adoption of sustainable and clean heating in the residential sector for achieving multitude benefits

Sustainable heating issues are often overlooked by Governments due partly to the fact that they are not addressed as part of the SDG 7 goal. However, polluting heating practices are ubiquitous in cold weather countries, and are co-contributors (together with unclean cooking and lighting) towards household air pollution and related health impacts. Not only that, polluting heating practices are inefficient, as they require a higher amount of fuel consumption. This also contributes towards gender inequality in the nation as women are more susceptible to consequences of household air pollution and enormous amount of time spent on collecting fuelwood.

Fuelwood heating made up about 59 per cent of Bhutan's residential energy consumption(135 ktoe) in 2017. Transitioning to advanced bukhari can be the immediate solution, which may reduce fuel consumption by half. This does not only contribute towards achieving the energy efficiency target, but also reduces deforestation. Even more importantly, it improves health and productivity, leading to gender empowerment. More can be done to raise community awareness of the benefits of advanced bukhari. Similar to promoting clean cooking technologies, a participatory approach with key stakeholders, together with frequent monitoring should be pursued to ensure a successful implementation of programmes. In addition, the sustainable heating issues should garner more attention and have a place in national policies and planning. In the long term, progressing towards electric heating should however be considered going forward, as the nation advances economically.

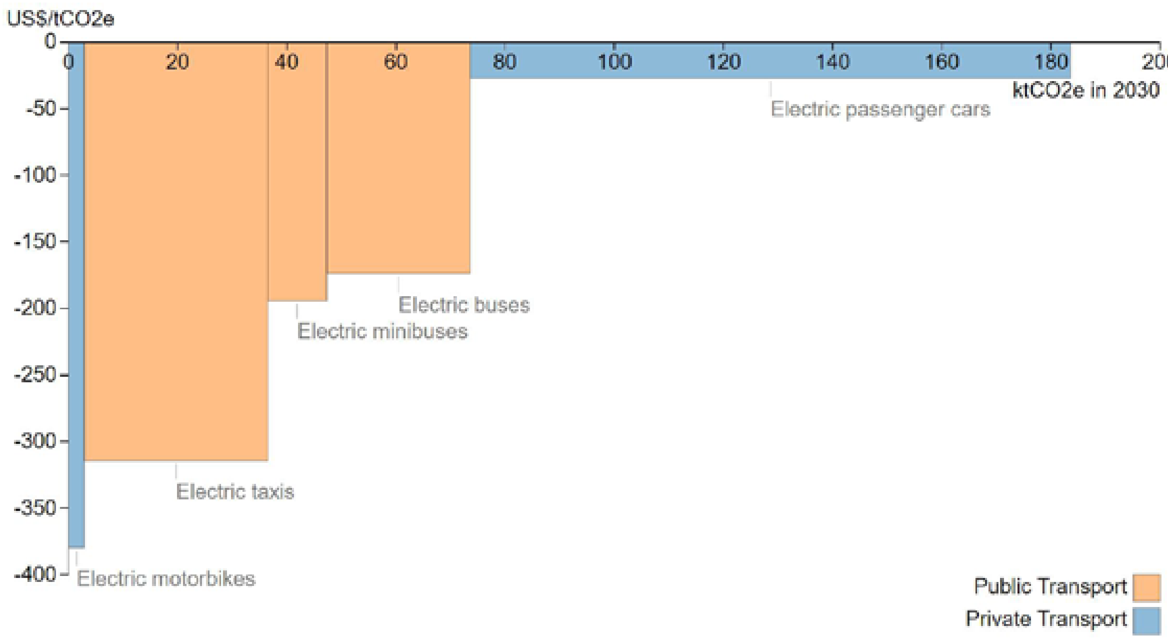
5.1.2 Transport electrification is a key to energy demand reduction and GHG emission reduction

Ambitious policy actions for the transport sector are critical for Bhutan to achieve the SDG 7 energy efficiency target, while contributing towards climate mitigation. Bhutan has recently developed its national EV roadmap. It projects a high transport activity growth, which is coupled with the stipulated annual sales targets, and may not allow Bhutan to meet its energy efficiency improvement target of 3 per cent per annum. Assuming a more conservative transport growth rate that is similar to the GDP growth, NEXSTEP analysis found that electric vehicle penetration of 40 to 50 per cent for passenger road transport and an electric vehicle share of 20 per cent for freight transport are required to meet the energy efficiency target. This, in turn, requires more ambitious annual sales targets than those stipulated in the national EV roadmap.

Electric vehicles have garnered great interest globally, growing exponentially during the past decade. Electric car sales passed 2 million globally in 2019, with a projected compound annual growth rate of 29 per cent through to 2030 (Deloitte, 2020). Various government 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 stated their ambition to phase out internal combustion engines before 2050, while the European Union's stringent CO_2 emissions standard has accelerated the adoption of electric vehicles (IEA,2020). With Bhutan's 100 per cent renewable power share, electric vehicles can help substantially to reduce overall GHG emissions. Other positive impacts include reducing local pollutant emissions due to their zero-tailpipe emissions.

Figure 18 shows the indicative marginal abatement cost (MAC) curve for the passenger transport sector. The MAC curve follows the measures proposed for the SDG scenario and uses the BAU scenario as the reference baseline.[37] Capital costs for more energy-efficient electric vehicles are generally higher than conventional internal combustion engines. Nonetheless, cost savings can be expected due to the reduced usage of expensive imported oil products. Annex VI provides the cost assumptions used in the MAC calculations.

Figure 18. Marginal abatement cost curve for the passenger transport sector



5.1.3 Energy demand savings in the commercial sector through green building code and sustainable cooking

The Bhutan Green Building Guidelines were introduced in 2013. As the country's first guidelines they are on a voluntary basis and take into account the limited technical capacity of the building professionals in the country. With the increasing pressure to decarbonize and increase energy efficiency, Bhutan should consider a hastened effort to encourage widespread uptake of sustainable designs in new and existing buildings.

The adoption of green building measures in the commercial sector (see box 6 for more information) can be encouraged through establishing a green building code that mandates a set of minimum building standards. This will ensure sustainable building designs for upcoming buildings. Moreover, this can be equally applied to existing buildings scheduled for retrofitting. The SDG scenario proposes applying a green building code to all new commercial buildings as well as aiming for a 50 per cent retrofitting rate for existing commercial buildings. This amounts to an estimated reduction of 14.1 ktoe.[38] Some groundwork has been done in investigating the energy savings potential and

37 Negative costs in figure 17 represent benefits.

38 This assumes a 30 per cent energy savings potential. However, energy savings potential is building-specific, depending on the baseline design, climate and energy efficiency measures.

interventions applicable for various building types in different climate zones in Bhutan (Department of Renewable Energy, 2015). In addition, the conversion from biomass cooking technology to electric cooking technology can provide a substantial reduction in energy demand and should therefore be encouraged. One possible in promoting sustainable measures in existing buildings is the high upfront cost to conduct energy audit and the subsequent implementation of measures. The Government of Bhutan should consider providing financial incentives while, at the same time, raising energy conservation awareness among the public.

Box6. Policy options for a more sustainable building sector

The building sector contributes significantly to the global energy consumption and GHG emissions. This calls for adoption of green building measures and designs in new and existing buildings to allow energy savings and rapid GHG emissions reduction to meet the Paris Agreement. A 'green' building can be defined as "a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment" (WorldGBC, 2021). Green building adoption can be made obligatory through the implementation of building codes or by promoting with certification/rating systems.

A building code is a comprehensive set of mandatory minimum building standards. One example is the 2018 International Green Construction Code (IgCC), developed to aid government jurisdictions in administering minimum requirements covering the design, construction and operation of buildings (ICC, 2021). Another implemented green building code by state jurisdiction is the California Green Building Standards Code (CALGreen) (State of California, 2021). Certification systems or rating tools, which provide third-party assessment and confirmation that a building meets certain green requirements or standards, are also widely used. Examples are ,the LEED (Leadership in Energy and Environmental Design) rating system and Australia's Green Star Buildings rating tool. For example, the Green Star certification has been given to almost 3,000 buildings with an average reduction of 56 per cent (Green Building Council of Australia, 2020).

5.1.4 Moving towards a greener industrial economy

Bhutan's industrial sector is the largest energy-consuming sector and, at the same time, accounts for more than 70 per cent of the GHG emissions from the energy sector and IPPU. NEXSTEP analysis shows that much can be reduced, particularly GHG emissions, through material substitution. In addition, energy efficiency can be realised from different subsectors.

Building on the recommendations provided in the LEDS for Industries and as analysed in this roadmap, the Government of Bhutan should take steps to encourage the implementation of the energy saving and GHG emission reducing measures. Energy audits should be promoted for all industries to identify and realise their energy savings potential. In addition, various policy measures can be considered for accelerating the green transformation through a range of policy measures. These may include market instruments (i.e., subsidies or taxes), an emissions cap and trade systems or regulatory instruments. The Practitioner's Guide to Strategic Green Industrial Policy by Partnership for Action on Green Economy (PAGE)[39] provides industrial policymakers with tools and information for developing a strategic green industry policy (SGIP).

39 See https://www.unido.org/sites/default/files/2016-11/practitioners_guide_to_green_industrial_policy_1__0.pdf

6. Building back better in the recovery from COVID-19 with the SDG roadmap

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

The COVID-19 pandemic has caused social and economic devastation globally, including in Bhutan. Credit is due to the Government's effective COVID-19 health strategies, as Bhutan has the lowest case fatality rate at only 0.05 per cent and confirmed cases of 2,660 (as of 28 December 2021). Its vaccination rate has achieved more than 70 per cent (as of 20 December 2021). However, the country's GDP growth in 2020 was only 0.9 per cent, down from 4.3 per cent in 2019. It is also projected to contract by 3.4 per cent in 2021, due to stringent containment measures that slow the nation's economic activity (ADB, 2021). The biggest impact is on its tourism sector, as national borders have been closed to tourists. While grappling with the devastation caused by the pandemic, Bhutan should not lose sight of its progress and ambitions towards achieving the SDGs targets. Bhutan should build back better from this crisis, to become more resilient in facing future challenges such as climate change.

Thus, it has never been more important to design a well-planned energy transition pathway that enables the country's energy sector to shield itself from the likely impacts of the COVID-19 pandemic and helps in the recovery to build back better. The SDG 7 roadmap has identified several key areas that will assist policymakers in strengthening policy measures to help recover from the COVID-19 impact while maintaining the momentum to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement.

6.1. Accelerating access to clean and modern energy services

Access to clean and modern energy services is essential in helping rural populations to combat challenges related to COVID-19. Relying on traditional and hazardous technologies for cooking increases their susceptibility to the effects of the virus. It is important to consider how these major shifts in the energy sector due to COVID-19 affect the most vulnerable people.

Approximately 23 per cent of Bhutan's population lacked access to clean cooking fuel in 2017.[40] In addition, a substantial proportion of the population is relying on unclean heating solutions. One medium-term impact of COVID-19 could be decreased investment in energy access, as national budgets come under strain and priorities shift. In addition, access to clean cooking and heating technologies is a major development challenge that is often forgotten. WHO has warned about the severity of health impacts arising from the exposure to traditional use of biomass for cooking and space heating, and is encouraging policymakers to adopt measures to address this challenge.

The SDG 7 roadmap has analysed and identified technical options for connecting the remaining population to cleaner fuel for cooking and heating. The benefits resulting from this measure, in the form of reduced mortality and health impact, will exceed the needed investment to advance the clean cooking rate and clean heating rate to 100 per cent.

6.2. Savings from the energy sector will help to build other sectors

The NEXSTEP analysis shows that there are ample opportunities for Bhutan to save energy by improving energy efficiency beyond the current practices. Several of these measures also provide cost savings and strengthen the country's energy security, making it less susceptible to fuel supply and price shocks. Savings from this improvement can help investment in other sectors, such as health, social protection and stimulus, which are

40 The clean cooking access rate grew to 79 per cent in 2019 (ESCAP, 2022).

critical in responding to, and recovering from the COVID-19 pandemic.

The electrification of the transport sector provides multiple additional related benefits (in addition to energy saving), including the reduction of expenditure on importing petroleum products and reducing local air pollution. Increasing renewable power capacity as currently planned, with the aim of cross-border power trade, also provides additional revenue for the country. Such measures are very important in solidifying the pathway to recovery from COVID-19 and building back better.

6.3. Long-term recovery planning to build back better, while ensuring sustainable growth

The COVID-19 pandemic has caused unprecedented socio-economic impacts around the world. On the brighter side, many countries have taken this opportunity to "reset" their economies. For example, the World Economic Forum has launched the Great Reset initiative, to encourage economic transformation and building a better society as the world recovers from the global health-care crisis (World Economic Forum, 2020b), and the European Commission has placed the European Green Deal at the heart of its long-term sustainable recovery from the pandemic (European Commission, 2020b). The global crisis has caused Bhutan's economy to plunge, due to its economic reliance on the tourism industry. Nonetheless, this may be an opportunity for Bhutan to re-examine its economic structure and leverage the potential of climate-smart sectors.

7. Revisiting existing policies


8.10
3.93
7.10
9.03
3.93
0.66
0.31
4.80
8.21
9.03
0.66
7.80
6.40
1.89
0.21
2.10
6.38

Bhutan's current energy policies have been evaluated based on the outputs from the NEXSTEP analysis in order to highlight any inconsistencies or the revisions required to achieve the SDG 7 and NDC targets by 2030. These are as summarized below.

* Several roadmaps have been developed to guide the development of Bhutan's energy sector, which may contribute towards reduction of energy demand and GHG emissions as well as improving renewable energy share. However, as mentioned above, the strategies proposed are not considered in the CP scenario, if not already implemented by October 2021.

7.1. Universal access to electricity

Existing policy	NEXSTEP analysis – gaps and recommendations
Not applicable	Bhutan achieved universal access to electricity in 2018.

7.2. Universal access to clean cooking

Existing policy	NEXSTEP analysis – gaps and recommendations
Unavailable.	**Gap(s):** The NEXSTEP analysis projects that Bhutan may only reach a 90 per cent clean cooking access rate given the historical improvement trend. **SDG scenario:** In considering the comments from stakeholders, the NEXSTEP analysis suggests bridging the remaining gap with improved cooking stoves as the most appropriate clean cooking solution.

7.3. Renewable energy

Existing policy	NEXSTEP analysis – gaps and recommendations
Alternative Renewable Energy Policy 2013 stipulates several targets for electricity and energy generation by 2025: - Solar – 5 MW - Wind – 5 MW - Biomass – 5 MW - Biomass energy system – 3 MW equivalent - Solar thermal system – 3 MW equivalent - Substituting 1,000 kilolitres of oil equivalent - 20% of the state-owned and 10% of the private vehicle fleets will be encouraged to run on clean and green fuels by 2025	The renewable share in TFEC is projected to be 42.3 per cent in the CP scenario. The currently planned power capacities of both solar and wind are expected to reach 18.2 MW and 23.6 MW, respectively, by 2025, thereby achieving the target set forth in Alternative Renewable Energy Policy. **SDG scenario:** SDG 7 has no quantitative goal for renewable energy share in TFEC, hence the NEXSTEP analysis estimates the renewable energy share based on the fulfilment of both the SDG 7.1 and 7.3 targets. The renewable energy share in TFEC is projected to be 54.4 per cent in 2030. The increase in renewable energy share is mainly due to the overall reduction in energy demand from the proposed energy efficiency measures. EV targets of between 40 to 50 per cent are required by 2030 to allow meeting the energy efficiency target.

7.4. Energy efficiency

Existing policy	NEXSTEP Analysis – Gaps and recommendations
The National Energy Efficiency and Conservation Policy of Bhutan 2019 stipulates several strategies across demand sectors.	**Gap(s):** The NEXSTEP analysis proposes an annual energy efficiency improvement rate target of 3 per cent, in alignment with the global improvement rate required to meet the SDG 7.3 target. The CP scenario is projected to achieve an energy intensity of 3.18 MJ/US$$_{2017}$ in 2030, which is a 1.3 per cent improvement rate. **SDG scenario:** The energy intensity is further reduced to 2.54 MJ/US$$_{2017}$ in 2030, meeting the energy efficiency by all demand sectors to realise an energy demand reduction of 228.5 ktoe in 2030, compared with the CP/BAU scenarios.

8. Conclusion

The 2030 Agenda for Sustainable Development and Paris Agreement provide a common goal for all countries to achieve sustainability and climate objectives. Achieving the SDG 7 and NDC targets is not an easy feat, but it will help to create a more sustainable and resilient society. This roadmap outlines the energy system projections under the current policy scenario and proposes measures for achieving the SDG 7 targets. These measures are also opportunities to improve Bhutan's energy security and socio-economic development. As we enter the decade of action, hastened effort from all parts of society is imperative to ensure the achievement of the goals and targets within the short timeframe.

Bhutan already achieved 100 per cent electricity access rate in 2018, up from 98.3 per cent in the baseline year of 2017.[41] On the other hand, much needs to be done if Bhutan is to achieve universal access to clean cooking. In 2017, 23 per cent of the population lacked access to clean cooking technologies. This is expected to decrease to 10 per cent by 2030, considering the historical trend. Similarly, Bhutan lags in terms of clean heating, with about 44 per cent of the population lacking access to cleaner heating solutions. A coordinated approach is therefore much needed by the private and public sectors in advancing the clean cooking and heating gaps in order to provide clean technologies to the population. These are, for example, improved cooking stoves and advance *bukhari* that builds on current traditional practices, while reducing fuel consumption and household indoor pollution.

Ample opportunities exist in the residential, commercial and transport sectors to save a substantial amount of energy through the implementation of energy efficiency measures. The residential sector provides the biggest energy saving potential with phasing out of unclean cooking and heating technologies. Altogether, this is projected to amount to 96 ktoe in 2030. Efficiency measures can also be promoted to the commercial sector, particularly through mandating a green building code to encourage sustainable designs and appliance usage. This will effectively reduce heating demand from the sector. Furthermore, uptake of electric cooking can effectively reduce fuel consumption, in comparison to the current practice of biomass cooking. Ambitious targets are required for transport electrification to enable the energy efficiency target to be achieved. Although challenging, it will bring multiple benefits to Bhutan – energy demand reduction, GHG emission reduction and improved energy security by reducing the energy sector's reliance on imported petroleum fuel. Climate awareness among the public is a key factor, while a holistic approach and investment need to be established to encourage a widespread uptake of electric vehicles.

Bhutan is committed to maintaining its carbon neutral status, which is achievable under a BAU scenario. The pursuance of measures in achieving the energy efficiency target can simultaneously contribute towards GHG emission reduction. Nevertheless, more can be done to reduce emissions by the industrial process and product use (IPPU) sector through material and fuel substitution. GHG emissions will be most substantially reduced from the ferro alloy and silicon industry through the substitution of coal-based reductants with bio-based reductants, while reduction by the cement industry can also be significant. This calls for attention to transform the sector into a low-carbon and energy efficient industrial economy.

The energy transition pathway presented in this SDG 7 roadmap provides ample opportunities for holistic socio-economic development by addressing energy poverty and inefficiency. Together, relieving import dependency will reduce fuel consumption and cost, which will support rebuilding better after the COVID-19 pandemic. In addition, the Government's noteworthy efforts in hydropower expansion will bring in the much-needed revenue, while contributing towards global climate change mitigation. Improvement of health and gender empowerment due to the phasing out of unclean technologies will certainly cause a positive ripple effect in the nation's economy. Henceforth, sustainable energy transition should be part of the Government's priorities while addressing the aftermath of COVID-19 pandemic.

41 The electricity access rate grew to 100 per cent in 2019 (ESCAP, 2022).

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Annexes

I. National Expert SDG 7 tool for energy planning methodology

The analysis presented in this national roadmap is based on the results from the National Expert SDG 7 Tool for Energy Planning (NEXSTEP) project. NEXSTEP is an integrated tool for assisting policymakers make informed policy decisions that will help in achieving SDG 7 and NDC targets by 2030. The SDG 7 and NDC targets are integrated in the LEAP energy model and backcasted from 2030, since the targets for 2030 are already defined.

Table 9. Targets and indicators for SDG 7

Target	Indicators	2017	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.	98.4%	100%
	7.1.2. Proportion of population with primary reliance on clean fuels and technology for cooking.	77%	100%
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.	33% (excluding traditional biomass)	54.4%
7.3. By 2030, double the global rate of improvement in energy efficiency.	7.3.1. Energy intensity measured as a ratio of primary energy supply to gross domestic product.	3.75 MJ/US$ (2017) PPP	2.54 MJ/US$ (2017) PPP

SDG 7.3. Energy Efficiency.

"By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production, plus net imports minus international marine and aviation bunkers plus stock changes. For comparison purposes, GDP is measured in constant terms at 2017 PPP.

$$Primary\ energy\ intensity = \frac{Total\ Primary\ Energy\ Supply\ (MJ)}{GDP\ (USD\ 2017\ PPP)}$$

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

where EI_{t1} is energy intensity in year t1 and EI_{t2} is energy intensity in year t2.

SDG 7.3. improvement rate suggested for Bhutan (global energy efficiency target): 3 per cent.

SDG 7.2. Renewable Energy

The renewable energy share in total final energy consumption is constraint by meeting the SDG 7.1 and SDG 7.3 targets.

Methodology: Share of renewable energy in total final energy consumption, where TFEC is total final energy consumption, ELEC is gross electricity production and HEAT is gross heat production.

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

II. Key assumptions for NEXSTEP energy modelling

(a) General parameters

Table 10. GDP, PPP and growth rate

Parameter	Value
GDP (2017)	2.53 billion
PPP (2017, constant 2017 US dollar)[42]	8.31 billion
Growth rate	4.63%

Table 11. Population, population growth rate and household size

Parameter	Value
Population (2017)	728,706
Population growth rate	0.94%
Number of households (2017)	164,011
Household size (constant throughout the analysis period)	4.44

42 Based on data provided in (World Bank, 2022).

(b) Demand-side assumptions

(i) Industry

- The residential sector is further divided into urban and rural households. The electrification rate of rural households was estimated at 97.5 per cent in 2017 and all households have achieved a 100 per cent electricity access rate since 2018.

- The clean cooking access rate is estimated at 77 per cent in 2017. The cooking distribution and assumed energy intensities are as estimated below:

Table 12. Cooking distribution in the urban and rural households for 2017[43]

Stove type	Urban		Rural (electrified)	
	Distribution	Energy intensity (GJ/household)	Distribution	Energy intensity (GJ/household)
LPG stove	90%	2.85	58.22%	2.55
Electric stove	9.22%	2.86	5.94%	1.92
Biomass stove	0.65%	68.57	33.50%	68.57
Kerosene stove	0.07%	35.85	0.15%	33.96
Biogas digestor	0.06%	19.83	2.19%	19.83

- The energy intensities and heating technology distribution are as shown in the table below.

Table 13. Heating distribution in the urban and rural households for 2017[44]

Stove type	Urban		Rural (electrified)	
	Distribution	Energy intensity (GJ/household)	Distribution	Energy intensity (GJ/household)
Fuelwood heating	15.52	15.52	59.74	80.5
Electric heating	59.49	2.06	15.49	1.42
LPG heating	0.13	2.69	-	-
Kerosene heating	4.53	36.43	-0.47	33.96

43 The cooking distribution is as estimated by ESCAP's team based on different data sources and in constraint of the cooking access rate of 77 per cent in 2017. Energy intensities are estimated based on top-down fuel consumption data.

44 The heating distribution is as collected by the national consultant. Energy intensities are estimated based on top-down fuel consumption data.

- The residential appliance ownership data, and energy use intensities in the baseline year are provided by the local consultant. The appliance ownership is projected to grow at a rate similar to the growth in GDP per capita, until reaching a saturation of 100 per cent. The average electrical demand per owning household for the different appliances are assumed constant throughout the analysis period, unless further energy efficiency measures are implemented (i.e., as discussed in the SDG scenario).

Table 14. Residential appliance baseline assumptions for 2017

Appliance	Urban		Rural	
	Ownership	Electricity intensity (kWh/ HH/year)	Ownership	Electricity intensity (kWh/ HH/year)
Lighting	100%	290.1	100%	199.9
Air conditioner	0.9%	3346.4	0.27%	1263.7
Refrigerator	81.6%	921.4	43%	656.6
Television	92%	68.9	64%	48.1
Electric heater	59%	573.1	15%	394.0
Electric cooker (rice cooker, curry cooker etc.)	99%	793.7	94%	532.4
Electric fan	15%	29.2	15%	20.9
Washing machine	38%	28.74	10%	19.0
Iron	34%	957.7	7%	-

(ii).Transport

- Land transport sector consumption is estimated using the vehicle statistics, load factor, annual travel mileage and estimated fuel economy as shown in table 6. The factors are based on vehicle statistics compiled by the local consultant and assumptions made by ESCAP and the local consultant, as local-specific data is scarce.

- Transport activities in 2017 are estimated at 3.95 billion passenger-kilometres and 2.1 billion tonne-kilometres. The growth in both passenger transport and freight transport activities is assumed growing at the same rate as the GDP, i.e., 4.63 per cent per annum.

Table 15. Transport sector baseline assumptions for 2017

Passenger Transport	No. of vehicles	Annual mileage (km)	Load Factor (pass-km/veh-km)	Fuel consumption	%share of passenger-km
Passenger car	44,656 (gasoline)	10,000	2.5	12 km/l	46.3%
	28,302 (diesel)			12 km/l	
	33 (Hybrid)			20 km/l	
	92 (Electric)			5 km/kWh	

Motorcycle	7,906 (gasoline)	5,500	1.6	25 km/l	1.8%
	116 (diesel)			25 km/l	
	24 (electricity)			21.65 km/kWh	
Taxi	468 (gasoline)	32,500	2.6	12.00 km/l	12.5%
	5,353 (diesel)			20.00 km/l	
	5 (hybrid)			5 km/kWh	
Bus	1 (gasoline)	60,000	30	3.56 km/l	27.5%
	603 (diesel)			3.56 km/l	
Minibus	15 (gasoline) 526 (diesel)	60,000	15	7.70 km/l	11.9%
Freight transport	**No. of vehicles**	**Annual mileage (km)**	**Load Factor (tonne-km/veh-km)**	**Fuel consumption**	**% share of tonne-km**
Freight truck	56 (gasoline)	20,000	11	8.30 km/l	100%
	9,409 (diesel)			8.30 km/l	

- Other than the transport categories listed above, earth moving equipment is estimated to have a relatively significant fuel consumption per year. The fuel consumption is estimated at 62 ktoe in 2017, using the assumptions below.

Type	No. of vehicles	Estimated operating (hours/day)	Average fuel consumption (litre/hour)	Capacity factor	Total fuel consumption (ktoe/year)
Diesel	3,663	12	17	25%	61.4
Gasoline	46	12	17	25%	0.7

- Other transport categories include tractors and power tillers, which the energy consumption was estimated at 0.1 ktoe and 0.29 ktoe, respectively, in 2017.

(iii).Industry:

- The industry sector is further differentiated into seven sub-categories. The fuel consumption by industry sub-categories is as detailed in the table below. The fuel consumption data references (National Environment Commission, 2021), averaged values during 2016-2019, except for the electricity consumption data which is provided by the local consultant.

- The industrial activity is assumed to be growing at an annual rate of 4.63 per cent, similar to the national GDP growth rate, with the exception of the cement industry and the ferro alloy and silicon industry.

- As per the National Environment Commission report, the cement industry is assumed to grow by 10 per cent by 2020 and 20 per cent by 2025. The ferro alloy and silicon industry is assumed to double by 2025 and grow with a factor of 2.5 by 2030, compare to 2017 activities, with reference to the projections made in (National Environment Commission, 2021).

Table 16. Fuel consumption by industry sub-categories in 2017

	Fuel consumption (toe)					
Industry	**Coal**	**Furnace oil**	**Diesel**	**Biomass**	**LPG**	**Electricity**
Cement	109,253		158.70	-	-	20,877.20
Iron and steel	951	1,100.30	0.01	-	0.31	8,005.71
Chemicals and synthetic products	-		-	-	-	15,509.80
Food and beverage	106		535.09	-	0.24	1,711.21
Wood and other products	-		-	-	-	523.48
Other industry	10,656		165.23	-	1.62	1,261.48
Ferro alloy and silicon Industry	- [45]		5,730.44	6,686.73	24.83	93,531.61
Total	120,966.12	1,100.30	6,589.47	6,686.73	27.00	141,420.50

- Without other data sources for 2017, the process emissions reference the estimation made in (National Environment Commission, 2021) for the year 2020. These are as follows:

Table 17. Industrial process emissions

Industry	2017 emissions (ktCO2-eq)	Projection
Ferro alloy and silicon industry	666	Assumed to double by 2025 and grow with a factor of 2.5 by 2030, compare to 2017 activities
Cement (clinker production)	442	Assumed to grow by 25 per cent by 2025 and 30 per cent by 2030

45 A huge amount of coal/charcoal is being used as reductants only. The table shows the fuel consumed for energetic purposes only, while the emissions from the reducing process are captured in the process emissions.

(iv).Commercial:

- The total commercial floorspace in the commercial sector is estimated at 4.21 million square metres in 2017. It is projected to grow at an annual rate of 4.63 per cent, similar to the national GDP growth rate.

- The commercial sector is differentiated into two subsectors – institutional buildings and commercial buildings. The fuel intensities are as summarized in the following table. The fuel intensities are assumed to remain constant, unless there are energy efficiency interventions (as proposed in the SDG scenario).

Table 18. Commercial sector fuel intensities in 2017

Category	Floorspace (million m2)	Energy intensity for cooking (toe/million m^2)		Energy intensity for heating (toe/million m^2)		Electricity intensity (kWh/ m^2)
		Biomass	LPG	Biomass	Kerosene	Electricity
Institutional Buildings	2.19	6106.4	415.8	4671.4	149.5	59.7
Commercial Buildings	2.01	6106.4	415.8	4671.4	149.5	32.0

- The electricity consumption share is estimated as such – lighting 13%, heating & cooling 76%, cooking 7% and others 4%.

(v).Other sectors:

- The remaining demand sectors are (1) non-specified use and (2) agriculture. The estimated energy consumption in 2017 are as detailed in the following table. The consumption growth is projected to grow at an annual rate of 4.63 per cent, same as the national GDP growth rate.

Table 19. Consumption from other sectors in 2017

Sector	Electricity consumption (toe)
Non-specified use	196
Agriculture	2,591

III. Economic analysis data for clean cooking technologies

The NEXSTEP economic model utilizes the technological and cost parameters to estimate the. annualised cost of clean cooking technologies (table 16). The calculation assumes an annual cooking thermal energy requirement of 3,840 MJ per household (Putti and others, 2015). In addition, a discount rate of 5.37 per cent is assumed.

Table 20. Technology and cost data for clean cooking technologies

Technologies	Efficiency[46](%)	Lifetime[47](years)	Stove cost[48](US$)	Variable O&M[49](US$/year)	Fuel cost[50](US$)
ICS (BES 2015)	21.8	4	51	10	0.015 per kg
LPG stove	56	7	56	10	0.81 per kg
Biogas digester	50	20	950	50	-
Electric stove	84	15	40	10	0.035 per kWh

IV. Economic analysis data for clean heating technologies

The NEXSTEP economic model utilizes the technological and cost parameters to estimate the. annualised cost of clean cooking technologies (table 16). The calculation assumes an annual cooking thermal energy requirement of 13,600 per household.[51] In addition, a discount rate of 5.37 per cent is assumed.

Table 21. Technology and cost data for clean heating technologies

Technologies	Efficiency[52](%)	Lifetime[53](years)	Stove cost[54](US$)	Variable O&M[55](US$/year)	Fuel cost[56](US$)
Traditional *bukhari*	20	1	17	10	0.015 per kg
Advanced *bukhari*	40	6	135	10	0.015 per kg
Electric heating	100	20	119	50	0.035 per kWh

46 Sourced from: ICS – own estimation, LPG stove and biogas digester efficiency ranges - (World Bank, 2014), electric cookstove (induction stove) - (IEA, 2012)

47 Sourced from: ICS – own estimation, LPG stove – (Clean Cooking Alliance, 2021), biogas digester - (Wang & Zhang, 2012), electric stove - (IEA, 2012)

48 Sourced from: ICS – own estimation, LPG stove and biogas digester – (IRENA, 2017), electric cookstove cost range - (The Kyrgyz Republic, 2015)

49 Variable O&M is based on own assumptions, with the exception of biogas digester (IRENA, 2017).

50 Wood cost is based on the average price provided in https://www.nrdcl.bt/firewood-price/, LPG price is assumed to be Nu 862 (or US$ 11.5) per 14.2 kg (https://bhutantimes.bt/index.php/2021/07/05/a-substantial-hike-in-fuel-prices-in-july/), Electricity price is based on the low voltage Block-II tariff (1st July 2021 – 30th June 2022).

51 ESCAP's assumption based on baseline fuelwood heating intensity of 68 GJ/household-year and efficiency of 20 per cent.

52 Sourced from: traditional bukhari – own estimation, assuming 50 per cent reduction in fuel consumption compared to traditional bukhari (IndiaSpend, 2017) , electric heating - (EDF, 2021)

53 Sourced from: traditional bukhari – assuming lasting one season (IndiaSpend, 2017), advanced bukhari – own assumption, electric heating – own assumption, wide range of lifespan provided in (Conserve Energy Future, 2021)

54 Sourced from: traditional bukhari – (IndiaSpend, 2017), advanced bukhari – recommended selling price as provided in (Department of Renewable Energy, 2018), electric heating – estimated price for an oil-filled heater

55 Variable O&M is based on own assumptions

56 Wood cost is based on the average price provided in https://www.nrdcl.bt/firewood-price/, Electricity price is based on the low voltage Block-II tariff (1st July 2021 – 30th June 2022).

V. Power technologies cost and key assumptions

The cost parameters considered for the power technologies are as follows:

Table 22. Power technologies key assumptions

Technologies	Maximum availability	Investment cost (US$/kW)[57]	Fixed O&M (US$/kW-year)
Large hydro[58]	57.5%	1000	23
Mini hydro	16%	2210	66.3 (3% of CAPEX)
Micro hydro	20%	2210	66.3 (3% of CAPEX)
Wind	22%	2472	44.5
Solar	14%	883	9

VI. Assumptions used in MAC calculations for the transport sector

The following details the assumptions used in the marginal abatement cost for the transport sector. The price of gasoline and diesel are assumed to be 1.152 US$/litre and 1.108 US$/litre, respectively.

Measures/actions	Assumptions
Electric passenger cars	Incremental capital cost of US$6800, lifetime of 15 years
Electric taxis	Incremental capital cost of US$6800, lifetime of 15 years
Electric motorcycles	Incremental capital cost of US$425, lifetime of 15 years
Electric buses	Incremental capital cost of US$55,250, lifetime of 15 years
Electric minibuses	Incremental capital cost of US$22,100, lifetime of 15 years

57 The cost figures (except for large hydro) reference the capital cost compiled in (IRENA, 2021) as follows: 1) Mini and micro hydro - based on capacity weighted average total installed cost for small hydropower projects for other Asia 2016-2020 (pg 128), 2) wind – based on onshore wind cost for Other Asia in 2020 (pg. 57) and 3) solar – based on total installed PV system cost and weighted averages for utility-scale systems in 2020 (pg. 72)

58 Large hydro investment cost and fixed O&M are provided by Druk Green Power Corporation

VII. Summary results for the scenarios

	BAU scenario	CPS scenario	SDG scenario
Universal access to electricity in 2030	100%	100%	100%
Universal access to clean cooking in 2030	90%	90%	100%, via improved cooking stove
Energy efficiency in 2030	3.18 MJ/US$	3.18 MJ/US$	2.54 MJ/US$
Renewable energy share in TFEC in 2030	42.3%	42.3%	54.4%
GHG emissions in 2030	3.93 $MTCO_{2\text{-}e}$	3.93 $MTCO_{2\text{-}e}$	2.97 $MTCO_{2\text{-}e}$
Renewable energy share in power generation in 2030	100%	100%	100%
Net benefits from the electricity export	US$ 3.24 billion	US$ 3.24 billion	US$ 3.25 billion
Total investment for the power sector	US$ 3.72 billion	US$ 3.73 billion	US$ 3.73 billion