Energy Transition Pathways for the 2030 Agenda

SDG 7 Roadmap for Nepal

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

NEXSTEP
National Expert SDG Tool for Energy Planning

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

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SDG7 Roadmap for Nepal

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

UNITED NATIONS ESCAP
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Foreword: ESCAP

Energy is the key enabler for development in the Asia-Pacific region. The COVID-19 pandemic has reinforced the need to change our development trajectory and to build back better. In this endeavour, transitioning to a sustainable, secure and least-cost energy system can form a key part of the recovery and pave the way to achieve the Sustainable Development Goals.

As a land-locked country with few fossil fuel reserves, a reliable energy supply is of utmost importance for Nepal to enhance its energy security and reduce reliance on imported fossil fuels. Goal 7 provides an opportunity to diversify energy resources and reduce the country's dependence on imported petroleum fuels. Furthermore, Nepal's endowment of renewable energy resources – hydropower, solar and biomass in particular – means that the country is well-positioned to establish a sustainable, clean-energy future through the energy transition. Access to clean cooking fuels and technologies is the major bottleneck for Nepal in achieving Goal 7.

This Roadmap for achieving Goal 7 offers an important resource for the Government of Nepal as it strives to ensure the country can achieve these essential targets. It details a range of technical opportunities and policy options for achieving universal access to modern energy services, reducing fuel imports with the adoption of fuel-efficient vehicles, cutting emissions, saving energy and lowering the cost of power generation. The complex geographical terrain of Nepal poses a major challenge to rural electrification. Increased use of indigenous renewable energy potential such as hydro and solar offers an opportunity to scale up mini-grid electrification systems to reach the last mile for electrification. Electric cooking technologies are a prime solution in closing the remaining clean cooking gap, capitalizing on Nepal's cheap and carbon-free electricity from renewable energy resources.

The Roadmap offers an opportunity to leverage a least-cost sustainable energy development pathway and direct the investment savings to other critical sectors – such as healthcare – in building back better from the COVID-19 pandemic. The Roadmap also examines how Nepal can enhance its Nationally Determined Contribution targets to further contribute to the attainment of the Paris Agreement. Nepal's renewables-based electricity supply is a great opportunity to scale up electric mobility and pave the path towards net zero carbon by 2050.

I am very pleased to see the collaboration between ESCAP and the Ministry of Energy, Water Resources and Irrigation. The success of this cooperative effort is a testament to our shared ambition for Nepal to deliver on the vision for energy in the Sustainable Development Goals. It provides an example for other countries to understand how they can begin taking up sustainable energy development opportunities.

I look forward to Nepal's continuing leadership in delivering a secure, resilient and sustainable energy future as it builds back better from the COVID-19 pandemic.

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: Nepal

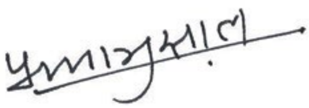
Nepal is committed to pursuing and achieving the Sustainable Development Goals (SDGs) by 2030. Global ambitions of SDG are broadly aligned with the social, economic and environmental aspirations that Nepal has set for itself in its constitution. SDGs deal with global and local development issues relating to poverty and social concern, natural resources and environment, technological and economic aspirations and finally global cooperation and access to knowledge. Among all 17 SDGs, this report deals with SDG 7 comprising three thematic goals i) universal access to affordable, reliable and modern energy services, ii) substantially increase the share of renewable energy in the global energy mix, and iii) double the global rate of improvement in energy efficiency. As energy is the prerequisite in achieving many of other SDG goals, timely meeting of the SDG 7 goals is of paramount importance.

I am pleased to see that a very important analysis on the Road Map to achieve SDG 7 goals has taken a final shape. The study has been made possible with technical support and guidance of the Energy Division of the Economic and social Commission for Asia and the Pacific (ESCAP). It has been prepared in collaboration with Murdoch University, Australia, and the Ministry of Energy, Water Resources and Irrigation (MOEWRI), Government of Nepal.

Nepal has already initiated and published the SDG roadmap back in 2016/17 through its National Planning Commission and set periodic targets of all three sub-goals. The roadmap sets targets that all of Nepal's populations will have access to electricity and means for clean cooking by 2030. The roadmap also seeks to achieve 50% share of renewable energy by 2030 with installation of hydropower over 15,000 MW. Similarly, it has also specified improvements in energy efficiency by reducing energy uses in production and consumption activities to achieve 50% of mobility based on electricity in Nepal. Similarly, the government of Nepal has further elaborated its aspirations through Nepal's second NDC document submitted to UNFCCC in 2020. Nepal's periodic plans and other policies and strategies have adopted these aspirations with further details.

The current document which is based on national data and rigorous model based exercise has critically analyzed the practicality and achievability of our aspirations. The findings of the study and recommendations will provide necessary additional insights for the update of energy planning in Nepal to achieve SDG7 goals.

The collaboration and technical support of UN ESCAP to accomplish this important endeavor is highly commendable. The Government of Nepal is thankful for the support and looking forward to continued support in materializing noble SDG7 goals. Officials of the Ministry of Energy, Water Resources and Irrigations unabated concerns and contributions of international and local experts are all praiseworthy for completing this very important study.



Hon. Pampha Bhusal

Minister

August 25, 2021

Abbreviations and acronyms

AEPC	Alternative Energy Promotion Centre
BAU	business-as-usual
CBA	cost benefit analysis
CO_2	carbon dioxide
CPS	current policy scenario
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
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
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
NEA	Nepal Electricity Authority
NEMO	Next Energy Modelling system for Optimization
NEXSTEP	National Expert SDG Tool for Energy Planning
OECD	Organisation for Economic Co-operation and Development
PP	power plant
RE	renewable energy
SDG	Sustainable Development Goal
TFEC	total final energy consumption
THL	Tanahu Hydropower Limited
TPES	total primary energy supply
US$	United States dollar
WECS	Water and Energy Commission Secretariat
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 Nepal 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 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 ision to develop and implement a set of policies to achieve SDG 7 by 2030, together with the NDC.

A. Highlights of the roadmap

Nepal has made significant progress in increasing access to electricity in recent years. Based on this progress, it is estimated that Nepal will achieve universal access to electricity by 2024,[3] earlier than the timeline mentioned in the Sustainable Development Goals Status and Roadmap 2016-2030. However, universal access to clean cooking technology and fuel has been, and remains, a challenge as more than half of the population is still relying on polluting cooking fuels and technology. Well-planned and concerted efforts will need to be made to achieve universal access to clean cooking by 2030. Energy efficiency improvement needs to be boosted across different sectors in order to achieve a 2.98 per cent annual improvement, reducing energy intensity to 3.5 megajoules per United States dollar by 2030.

Being a landlocked country with a mountainous topography and no proven fossil fuel reserve, Nepal is heavily reliant on imported energy resources (i.e., oil products); therefore, energy security is high on the national agenda. On the bright side, Nepal's abundant hydro resources supply two-thirds of the country's electricity demand. Small-scale renewable energy resources – mainly micro- and mini-hydro, and solar energy – are also used in meeting the electricity demand of remote and very remote areas. In addition, in its second NDC, Nepal has set out a plan for increasing its clean electricity exports to

1 The NEXSTEP tool has been specially designed to perform analyses of the energy sector in the context of SDG 7 and NDC, with an 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.

3 Linearly forecasted based on historical access rate between 2000 and 2019.

neighbouring countries. The NEXSTEP analysis has examined the usage of fossil fuel in the country e.g., in the transport sector and identified ways for Nepal to reduce its reliance on imported fuel to safeguard its energy sector from price and supply shocks.

B. Achieving Nepal's SDG7 and NDC targets by 2030

1. Universal access to electricity

As of 2019, Nepal's electrification rate is estimated to be 86 per cent. Of the portion of Nepal's population that lacks access to electricity, 90 per cent are in rural areas. Based on the historical improvement trend between 2000 and 2019, NEXSTEP analysis indicates that the remaining population will receive access by 2024, under the business-as-usual scenario.[4] In light of Nepal's complex terrain, providing last-mile connectivity may not be an easy feat, and achieving it will still require continued efforts from the Government, development partners and the private sector. NEXSTEP analysis indicates that providing off-grid/mini-grid electrification systems utilizing indigenous renewable resources may be the most appropriate solution, as micro- and mini-hydro systems provide the lowest cost per unit of electricity generated.

2. Universal access to clean cooking

As of 2019, more than half of the population in Nepal still relied on polluting cooking fuel and technology, thereby exposing themselves to negative health impacts. The Government of Nepal has disseminated more than 1 million clay and metallic improved cooking stoves; in 2019, the cooking stove distributions (estimated at 15) were made to 2.7 per cent of the total households in Nepal. It is expected that the clean cooking access rate will be raised to 72.3 per cent through the current policy settings, in accordance with the targets stipulated in the second NDC document. The targets include increasing the market penetration of electric cooking stoves to 25 per cent by 2030, and further dissemination of 500,000 Improved Cooking Stoves (ICS), 200,000 household biogas digesters and 500 large-scale biogas plants by 2025. Nevertheless, more needs to be done; NEXSTEP analysis suggests that electric cooking stoves may be the most suitable long-term solution in closing the remaining gap.

3. Renewable energy

The share of renewable energy in the total final energy consumption (TFEC) was 21.3 per cent in 2019.[4] Based on current policies, the share of renewable energy is projected to increase to 35.9 per cent by 2030. The increase is due to the projected increase both in renewable electricity and other renewable energy (excluding traditional use of biomass) consumption, while the TFEC increases at a slower rate. In the SDG scenario, the share of renewable energy is further improved to 39 per cent of TFEC in 2030. This improvement is solely due to the adoption of electric stoves while phasing out of traditional biomass usage, which also decreases the total final energy consumption.

4. Energy efficiency

Nepal's energy intensity in 2019 is estimated to have been 4.12 MJ/USD_{2011}. Energy intensity in Nepal has declined at an average annual rate of 1.49 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 2.98 per cent between 2018 and 2030. Correspondingly, the energy intensity in 2030 should be 2.96 MJ/USD_{2011} to achieve the SDG 7 target.

4 Excluding traditional biomass usage in residential cooking and space heating. In addition, electricity imported from India is treated as non-renewable.

Figure ES 1. Nepal's access to clean cooking under the BAU, CPS and SDG scenarios[5]

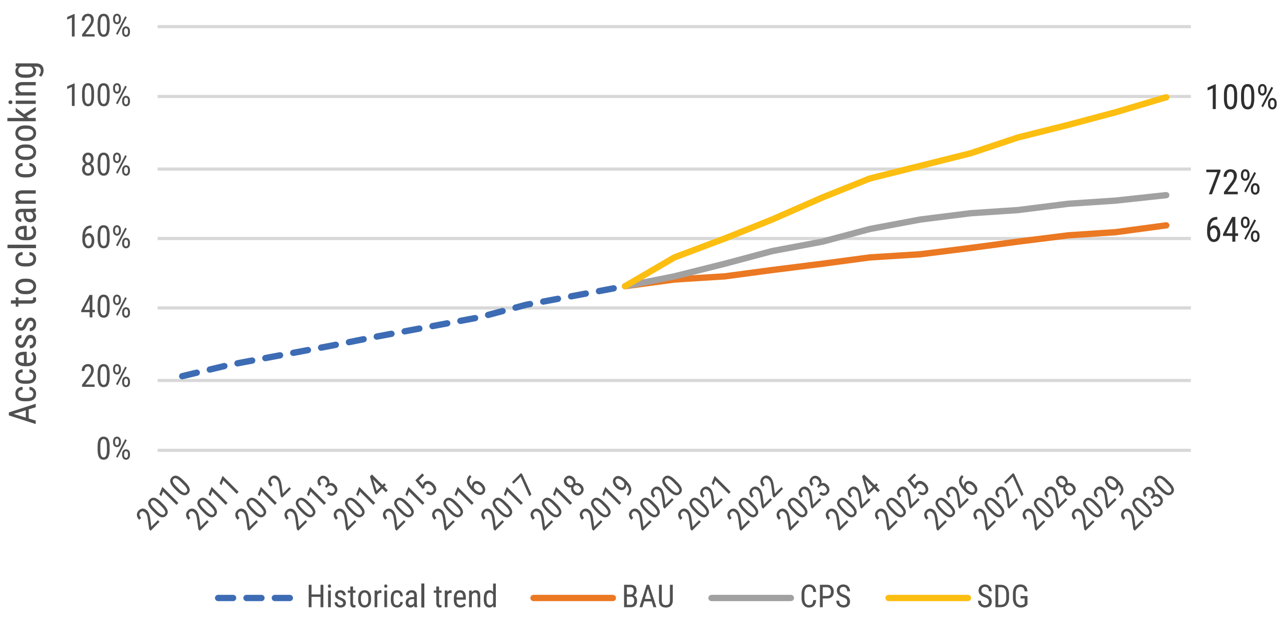
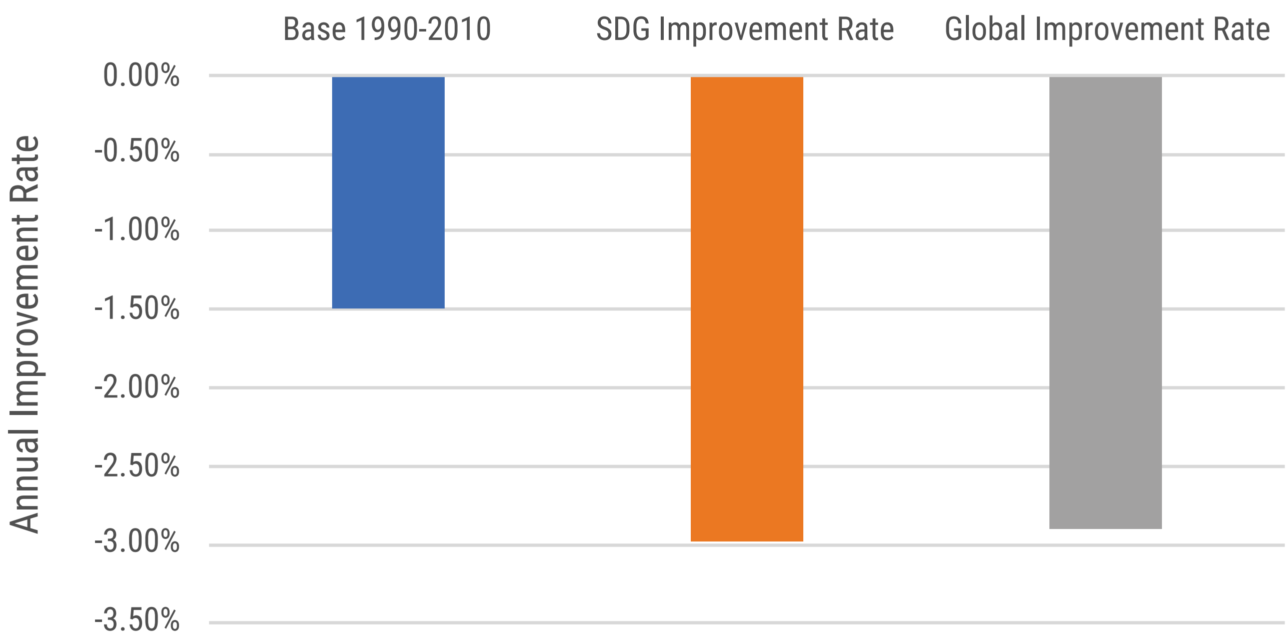


Figure ES 2. Nepal energy efficiency target[6]



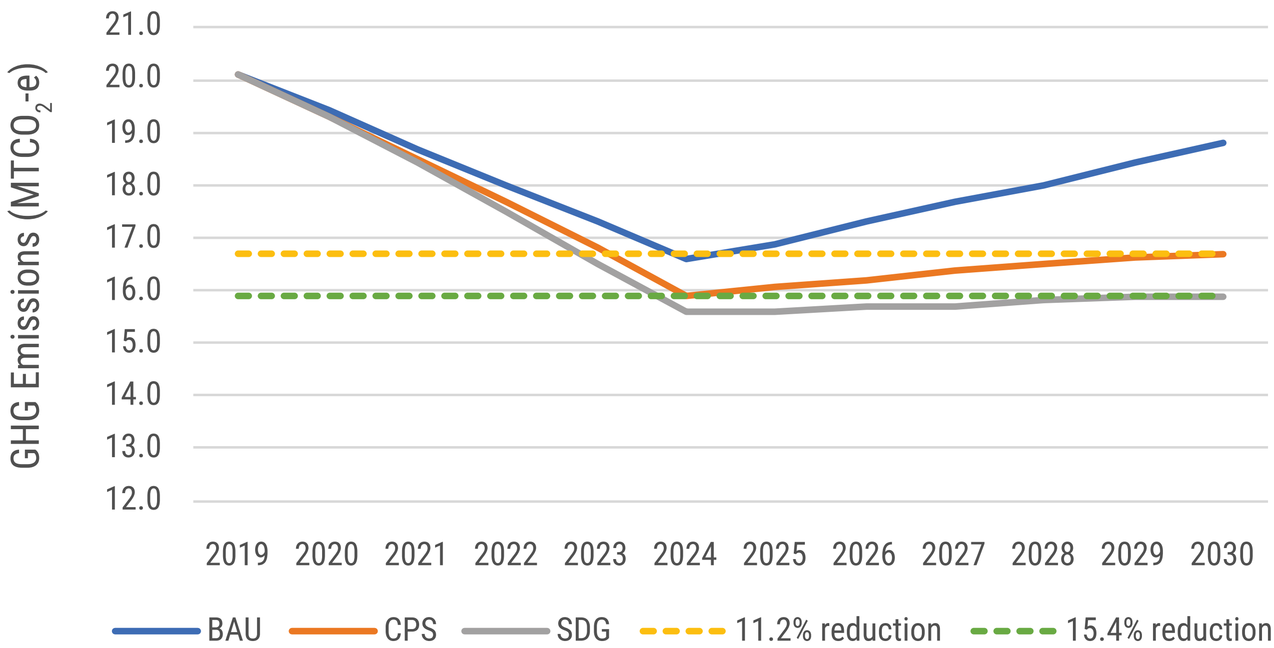
5 Historical trend projected based on 2000 access rate data provided in ESCAP, 2021a, and 2019 access rate provided by the national consultant.
6 Calculated based on data from the Asia Pacific Energy Portal.

Under the current policy settings, the energy intensity is projected to drop to 2.96 MJ//USD_{2011}. While the energy efficiency improvement target is achieved, more needs to be done to close the clean cooking gap. The energy efficiency target is exceeded in the SDG scenario with an energy intensity of 2.46 MJ//USD_{2011}, compared with the target of 2.96 MJ//USD_{2011}. This is achieved simultaneously with the clean cooking target through the phasing out of inefficient cooking technologies. There are ample energy savings opportunities for Nepal, as explored in the ambitious scenario. These opportunities are discussed in later sections of this report.

5. Nationally Determined Contribution

Nepal does not have an overarching GHG reduction target but has stipulated several sectoral strategies and measures in its second NDC document published at the end of 2020. As modelled, the stipulated measures may allow Nepal to reduce its GHG emissions by 11.2 per cent, with reference to the BAU scenario. In the SDG scenario, the GHG emission is projected to be 15.8 $MTCO_{2\text{-}e}$ in 2030, a 15.4 per cent reduction from the BAU scenario.

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



C. Important policy directions

The roadmap sets out four key policy recommendations to help Nepal achieve the SDG 7 targets as well as reduce reliance on imported energy sources:

(1) To ensure electricity access is on track to achieve the SDG 7 target by 2024, decentralised energy generation using indigenous resources such as wind and solar power should be utilized. Given Nepal's complex mountainous terrain and last-mile connectivity challenges, these approaches are needed to complement grid extensions;

(2) Electric cooking stoves should be the priority technology in improving clean cooking access. More effort is required from the Government to close the clean cooking gap. NEXSTEP analysis suggests that electric cooking stoves may be more appropriate technology, in terms of the health benefits, cost effectiveness, and little maintenance and follow-up requirements. However, comprehensive policies are required for promoting the uptake and long-term adoption of electric cooking stoves;

(3) Transport electrification strategies provide multi-fold benefits. Vigorous adoption of electric vehicles reduces the demand for oil products, hence reducing Nepal's reliance on imported energy resources. At the same time, it can contribute to climate mitigation by using Nepal's zero-carbon hydropower-based electricity;

(4) Energy efficiency measures should be encouraged with a whole-economy approach. Substantial energy savings can be achieved through sustainable heating technologies in the residential and commercial sectors, while utilization of efficient household appliances reduces electricity demand. Significant energy reduction can be similarly achieved through industry sector best practices.

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 (SDG7) and other SDGs. In this connection, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG7 targets as well as 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 has also garnered the support of the Committee on Energy in its second session, with recommendations to expand the number of countries being supported by this tool. The ministerial declaration advises ESCAP to support its member States, upon request, in developing national SDG 7 roadmaps.

1.2 SDG7 targets and indicators

SDG7 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 target 7.A – promote access, technology and investments in clean energy, and 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 a high priority. For example, the global energy sector was responsible for 76 per cent of the global GHG emissions in 2018 (Climate Watch, 2021). For Nepal, the contribution from the energy sector is estimated to have been 46 per cent in 2011 (Government of Nepal, 2020). Key approaches to reducing emissions from the energy sector include increasing renewable energy in the generation mix and improving energy efficiency. In its second NDC document published at the end of 2020, Nepal stipulated several emissions reduction measures to be implemented and achieved by 2030. It is noted that some of the measures stipulated in the NDC document are conditional, unless international financial contribution is provided. Nonetheless, based on the consensus achieved during the stakeholder consultation workshop held in March 2021, all measures will be considered fulfilled by 2030, and the NDC commitments are included in the current policy scenario.

2. NEXSTEP methodology

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

2.1. Key methodological steps

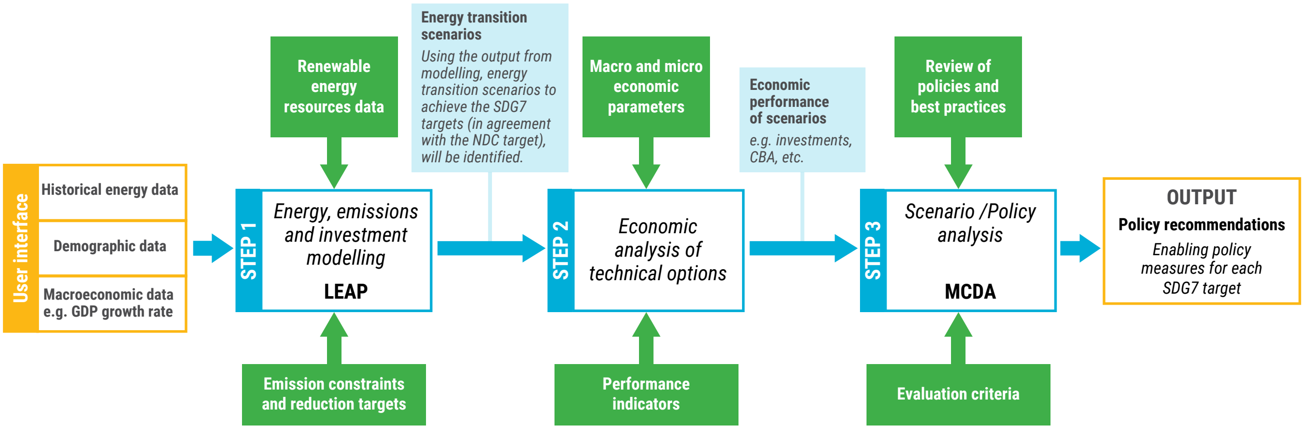
(a) Energy and emissions modelling

NEXSTEP begins with energy systems modelling to develop different scenarios for achieving SDG7 by identifying potential technical options for each scenario. Each scenario contains important information including the final energy (electricity and heat) requirement by 2030, possible generation/supply mix, emissions and the size of investment required. The energy and emissions modelling component uses the Long-range Energy Alternatives Planning (LEAP). It is a widely used tool for energy sector modelling as well as to create energy and emissions scenarios. Many countries have used LEAP to develop scenarios as a basis for their Intended INDCs. Figure1 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 present several economic parameters and indicators that would be useful for policymakers in making an informed policy decision.

Figure 1. Different components of the NEXSTEP methodology



(c) Scenario and policy analysis

Using Multi-Criteria Decision Analysis (MCDA) tool, this 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.

This tool is unique, in that no other tools look at developing policy measures to achieve SDG7. 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 SDG7 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.

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 Nepal, 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. In addition, (d) an ambitious scenario has been modelled, which looks to raise Nepal's ambition beyond the SDG and NDC targets.

(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 emission reduction measures and power capacity expansion plan stipulated in the second NDC document and the fifteenth National Plan.

(c) SDG scenario: This scenario aims to achieve the SDG 7 targets, including universal access to electricity and clean cooking fuel, substantially increasing 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.

(d) Ambitious scenario: Like the SDG scenario, the ambitious scenario aims to achieve the SDG 7 targets. In addition, this scenario also looks to increase the socio-economic and environmental benefits for the country from raising its ambition beyond just achieving the SDG 7 targets, such as by creating cost-effectiveness by further improving its energy efficiency beyond SDG 7.3 target or reducing GHG emissions beyond its NDC target.

The baseline year, 2019, has been chosen, as it is the most recent year with sufficient data information for modelling. Updated data (i.e., data as of 2020 or 2021) may be available for some indicators. However, only 2019 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, these are based on country-specific data to improve the analysis. They include land, building, machinery, equipment and civil works;

(b) Operation and maintenance cost 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 the Paris Agreement
- Fossil fuel subsidy phased out
- Price of 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 Nepal as a limited number of scenarios have been developed.

3. Overview of Nepal's energy sector

3.1. Current situation

Geography and climate: Located in the South Asia region, Nepal is a landlocked country bordering India and China. The country occupies a land area of 147,181 km^2, with an average stretch of 885 km in the East-West direction and 193 km in the North-South direction (Government of Nepal, 2014). Nepal has a diverse geography, including the fertile plain in the southern border area and some of the most challenging terrain in the world, i.e., the Himalayan mountain range. The country can be divided into five physio-graphic regions, characterized by an elevation ranging from 60 metres to 8,845 metres above sea level. While Nepal sits within the subtropical climatic zone, it exhibits a wide range of climatic conditions that vary from tropical in the south to alpine/arctic in the north due to topographic extremes. Its capital city, Kathmandu, sits in the Kathmandu Valley in central Nepal.

Population: The total population of Nepal was estimated at 29.6 million in 2019. The total population recorded in 2011 was 26.5 million (Government of Nepal, 2014), which translates into an annual growth rate of 1.4 per cent between 2011 and 2019. The recorded annual growth rate has slowed, compared to the growth rate between 1961 and 2001 (Government of Nepal, 2014). Nonetheless, the population has increased by more than threefold during the past 60 years, from just 9.6 million in 1961. The percentage of urban population ways estimated to be 23 per cent in 2019, a rapid increase from just 4 per cent in 1971 (Government of Nepal, 2014)

Economy: Nepal's GDP in 2019 was estimated as US$30.6 billion. Correspondingly, the GDP per capita stood at US$1,039. The growth in GDP per capita is remarkable, increasing at an average annual growth rate of 6.4 per cent during the past decade, from just US$592 in 2010 (World Bank, 2021a). According to the World Bank's country classification, Nepal is classified as a lower-middle income economy as of the 2021 fiscal year (World Bank, 2021b). The agricultural sector has been consistently the main contributing economic sector, accounting for about 27 per cent of the national GDP (Ministry of Finance, 2019). The Government of Nepal (2014) noted that the agricultural sector was the base of livelihood for around 80 per cent of its population and accounted for 60 per cent of the total employment.

Climate change risks: Nepal is highly vulnerable to climate change impacts as it is ranked fourth in terms of vulnerability towards climate change (UNDP, 2021b). As a nation that is highly dependent on its agricultural sector, probable changes in climatic conditions may cause adverse effect on Nepal's economy and its population's livelihood. Additionally, as the planet warms, the increased rate of glacier melting in the mountainous region towards the North will alter the dynamics of river flows in Nepal and across the region as well as increase the risk of glacier lake outburst flooding.

Energy: The Government's ambition towards a more sustainable energy transition is depicted in its second NDC, (Government of Nepal, 2020). For the energy sector, Nepal envisions increasing its clean power capacity by ten-fold, not only to meet the increasing electricity demand sufficiently but also to allow cross-border power trade. In addition, it plans to increase the market penetration of electric vehicles during the coming decade. Increased ambitions are also stipulated for the cooking sector to expand the share of clean cooking technologies (i.e., electric cooking stoves). Nepal is currently formulating a long-term low greenhouse gas emission development strategy, which aims to achieve carbon net-zero by 2050.

3.2. National energy profile

The electrification rate in Nepal was 86 per cent in 2019.[7] That has left around 887,000 households yet to be connected to any form of electricity supply. Nevertheless, Nepal's progress in electricity access improvement has been remarkable, rising by about 60 percentage points from 2001 to 2019 (ESCAP, 2021a). Among the unelectrified households, around 8 per cent are in urban areas, while the remaining are in rural areas.[7] The majority (approximately 89 per cent) of the current electrified population is connected to the main grid. A small percentage of households rely on off-grid systems, such as micro-hydro power and solar PV systems. The provision of off-grid systems not only provides essential electricity needs, but also brings in other indirect positive impacts, such as increasing local employment and women's empowerment.

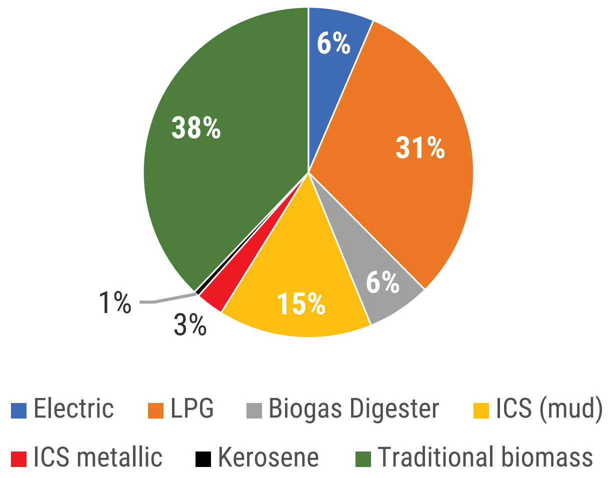
In 2019, only 46.5 per cent of the population had access to clean cooking fuel and technologies.[7] Liquefied petroleum gas (LPG) stoves are the dominant cooking technology used by the majority of Nepalese urban households, accounting for around a 31 per cent share of total stove usage distribution. This is followed by the traditional biomass stove, which has a share of 38 per cent and includes the use of wood, agricultural residue and animal dung as fuel mostly in rural areas. The Alternative Energy Promotion Centre (AEPC) of Nepal has disseminated more than 1 million improved cooking stoves, mostly mud stoves, since 2005. The cooking stove distribution of clay ICS and metallic ICS in 2019 was estimated at 15 per cent and 2.7 per cent, respectively. This analysis considers metallic ICS as a clean cooking technology (Tier 3+ Multi-Tier Framework – MTF) for cooking exposure attribute), while clay ICS is regarded as a non-clean cooking technology.[8] Other stove usage includes electric cooking stoves (6.4 per cent), biogas digesters (6.3 per cent) and kerosene (0.5 per cent).

Modern renewable energy delivered approximately 21.3 per cent of TFEC in 2019. This excludes traditional biomass usage in residential cooking and heating, which corresponds to an estimated 2,970 ktoe. On average in 2019, 37 per cent of Nepal's electricity demand was met by imported electricity from India, which is assumed non-renewable for the NEXSTEP analysis as electricity from India is mostly produced from fossil fuels. Most of the remainder (61.9 per cent) was locally produced in 2019 with large hydropower. Strategies to raise the renewable energy share are set out in the second NDC (Government of Nepal, 2020). These include increasing the renewable energy capacity to meet both local and external demand, and increasing the market penetration of electric vehicles that utilize renewable electricity.

While endowed with an abundance of hydropower potential, Nepal has a high reliance on imported fuels (i.e., coal and oil products) to meet its

7 National data compiled by the national consultant in consultation with the Ministry of Energy, Water Resources and Irrigation, Government of Nepal.
8 Metallic ICS is ranked Tier 4 for emissions (World Bank, 2019).

Figure 2. Cooking stove distribution in 2019



heating and transport fuel demands. Several strategies have been put forward to reduce its imported oil dependency in order to safeguard the energy sector from supply and prices shocks. For example, transport electrification ambitions set out in its second NDC does not only reduce GHG emissions, but also makes Nepal less susceptible to future supply and price shocks. In addition, the Government has set a maximum threshold for LPG stove penetration of 30 per cent.

The energy intensity in 2019 was calculated as 4.12 MJ/US$_{2011}$.[9]

3.3. National energy policies and targets

Nepal's energy sector development is guided by several national policies and frameworks. These policies have been used as guiding references for the NEXSTEP modelling, 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.[10] The policies or strategic documents consulted are detailed below.

Nepal's Second NDC (Government of Nepal, 2020) stipulates ambitions to:

(a) Raise the renewable capacity by another 15,000 MW by 2030,[11] of which 5-10 per cent of the capacity will be from renewable technologies exclusive of large hydropower;

(b) To produce 15 per cent of the total electricity demand from renewable sources (not including large hydropower);

(c) Raise the market sales of electric vehicles for private 2- and 4-wheelers and public 4-wheelers;

(d) Increase the share of electric stoves to 25 per cent and disseminate an additional of 500,000 ICS and 200,000 household-scale biogas plants.

Biomass Energy Strategy 2017 (Ministry of Population and Environment, 2017) aims to increase the access to biomass energy and hence contribute to environment conservation by transforming biomass energy use into modern, sustainable and clean energy.

National Energy Efficiency Strategy 2018 (MOEWRI, 2019) is to promote energy efficiency by effectively implementing energy efficiency programmes through establishing policy, legal and institutional frameworks. It also stipulates a goal of doubling the average improvement rate of energy efficiency from 0.84 per cent per year (between 2000-2015) to 1.68 per cent per year in 2030.

9 Author's calculation based on collected and assumed data for 2019.

10 Only policies with concrete measures are considered in the scenario modelling. Target-setting policy documents without concrete measures (i.e., energy intensity improvement target stipulated in the Energy Efficiency Strategy. 2075) are not considered, but are compared with scenario result findings in the "Revisiting Existing Policies" chapter.

11 It was noted during the stakeholder consultation workshop that 5,000 MW would be designated for cross-border power trade. In addition, 5,000 MW out of the total 15,000 MW is the unconditional target, while the remainder is subject to international funding. However, as agreed during the stakeholder workshop, both conditional and unconditional targets stipulated in the second NDC document will be considered in the modelling of the current policy scenario.

National Renewable Energy Framework (AEPC, 2017) was formulated in 2017 as an umbrella mechanism for AEPC to coalesce and coordinate policies and programmes in the renewable sector, covering four objectives (i.e., governance, demand, supply and financing) with activities in capacity-building, knowledge management, gender and social inclusion, and monitoring in a cross-cutting manner.

Renewable Energy Subsidy Policy 2016 (Ministry of Population and Environment, 2016) details the subsidy mechanism for various renewable energy technologies with a long-term goal of achieving universal access to clean, reliable and affordable renewable energy solutions by 2030.

Rural Energy Policy 2006 aims to contribute to rural poverty reduction and environmental conservation by ensuring access to clean, reliable and appropriate energy in the rural areas.

National Climate Change Policy 2019 (Ministry of Forests and Environment, 2020) provides policy guidance to various sectors and thematic areas (i.e., agriculture and food security, water resources and energy), in order to contribute to socio-economic prosperity of the nation by building a climate resilient society.

The Fifteenth Plan (National Planning Commission, 2020) was formulated with the aim of raising Nepal from a least developed country to a developing country by 2022, and achieving the SDGs by 2030. At the same time, it is aimed lifting Nepal to the level of a middle-income country through an increase in income level, development of quality human capital and the reduction of economic risks. Several energy sector targets and strategies are also outlined in the national development plan.

3.4. National energy resource assessment

Nepal depends on both indigenous renewable resources (i.e., hydro and solar) and imported electricity to meet its electricity demand. Other resources used in its energy system include petroleum products, coal and biomass. Nepal does not have its own petroleum reserve; the demand is met through importation via India. Coal deposits exist in Nepal; however, they are of low quality. The majority of its coal is imported from India and other countries (WECS, 2010). Nepal's theoretical hydropower potential has been estimated at about 83,000 MW, of which 45,000 and 42,000 MW is technically and economically feasible, respectively (WECS, 2010). Nepal has an abundant solar power potential; the average solar insolation intensity is about 4.7 kWh/m^2/day.

A study carried out by AEPC and UNEP in 2008 shows that potential of solar energy in grid connected areas was estimated as 2,100 MW based on free land availability (WECS, 2010). Wind potential is largely untapped in Nepal; the commercial potential of wind power is suggested at 3,000 MW (AEPC, 2021), a comparatively low level which is in part due to the lack of road and grid access to the regions with high wind speeds. Biomass is widely used in Nepal for cooking and heating purposes. Khatiwada, Purohit and Ackom (2019) estimated that the economic potential of biomass power using surplus agricultural residue is approximately 0.6 GW in 2030.

3.5. National energy balance 2019

The official national energy balance is unfortunately not available for 2019. The following describes the estimated national energy consumption, built up using data[12] collected with a bottom-up approach, based on data such as activity level and energy intensity.

In 2019, the total final energy consumption (TFEC) was 9,179 ktoe. Most of the demand came from the residential sector (51.7 per cent). Within the residential sector, 85.7 per cent of energy is consumed for cooking purposes. Such a high share is attributable to the widespread use of inefficient traditional biomass stoves. This is followed by the transport sector (20.5 per cent), industry sector (16.7 per cent), commercial (7.5 per cent) and others (3.6 per cent).

In terms of fuel usage in the TFEC, biomass is the dominant fuel, accounting for 47.3 per cent. Oil products, including LPG, diesel, kerosene and petroleum account for around 35 per cent of the TFEC. The transport sector, which operates predominantly with internal combustion engine vehicles, is the main consuming sector for oil products (58 per cent). Other uses of oil products include residential cooking and space heating

12 National data compiled by ESCAP's national consultant in consultation with the Ministry of Energy, Water Resources and Irrigation, Government of Nepal.

Figure 3. Total final energy consumption by sector, 2019

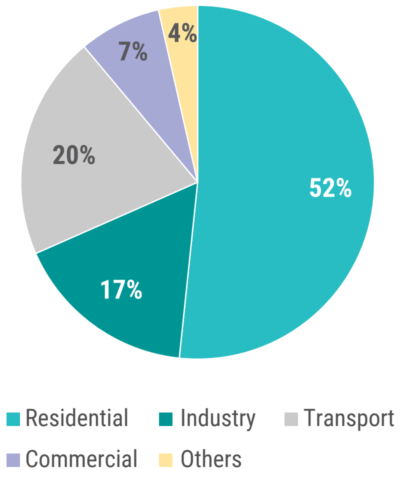


Figure 4. Total final energy consumption by fuel type, 2019

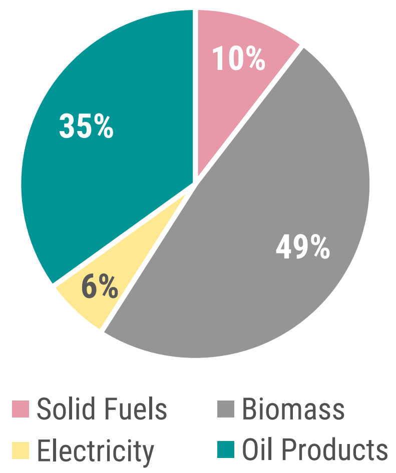
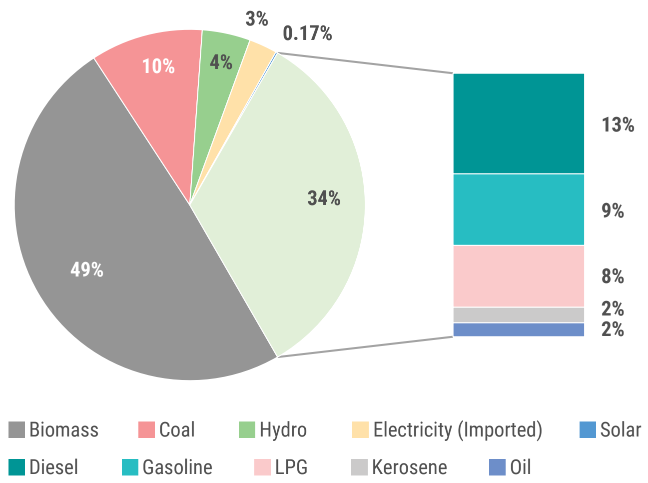


Figure 5. Total primary energy supply by fuel type, 2019



(21.4 per cent), process heating in the industry sector (5.12 per cent) and space heating in the commercial sector (4.83 per cent). Other fuel use includes coal (10.5 per cent) and electricity (6 per cent). Coal is mainly used in the industrial sector, with a small percentage (15 per cent) used in the commercial sector as a heating fuel. Figures 3 and 4 illustrate the total final energy consumption by consuming sector and fuel type.

The total primary energy supply (TPES) in 2019 was 9,279 ktoe. It generally shows a fuel usage distribution similar to the TFEC. Hydro and solar power contribute a total of 4.6 per cent and are used in power generation. Around 3 per cent of the primary energy is supplied in the form of electricity, imported from India. Imported electricity accounts for about 37 per cent of the electricity demand of Nepal.

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 1 provides a summary of the key modelling assumptions for the three main scenarios (i.e., BAU, CPS and SDG scenarios).

3.7. Energy demand outlook

Several measures have been outlined in the recently published NDC document in a bid to reduce GHG emissions. These include clean cooking strategies involving the dissemination of ICS and biogas digesters as well as increasing the market penetration of electric cooking stoves, as described in table 1. In addition, the Government is aiming to raise the usage of electric vehicles – an effective emission reduction strategy by phasing out the use of oil products with replacement by carbon-free electricity in the transport sector. The market sales of electric vehicles for private passenger 2- and 4-wheelers is expected to reach 25 per cent in 2025, and gradually rise to 90 per cent in 2030.The market sales of electric vehicles for public passenger 4-wheelers will be 20 per cent in 2025 and gradually increase to 60 per cent in 2030. These policy measures and targets, as included in the CP scenario, have substantial implications for the energy demand outlook in 2020-2030, relative to the BAU scenario.

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

Parameters	Business as usual scenario	Current policy scenario	Sustainable Development Goal (SDG) scenario
Economic growth	3.11% per annum		
Population growth	1.36% per annum		
Urbanization rate	23 per cent in 2019, gradually increasing to 28.6 per cent in 2030		
Commercial floor space	127.2 million m^2 in 2019, annual growth rate of 3.11 per cent		
Transport activity	Transport activities in 2019 were 125.6 billion passenger-kilometres and 23.1 billion tonne-kilometres, with assumed growth of 1.35 per cent annually		
Access to electricity	2024: 100%	2024: 100%	2024: 100%
Access to clean cooking fuels	Based on the historical penetration rate assumed for LPG and electric cookstove. Number of households utilizing biogas digester and ICS are assumed constant.	As per the ambitions stated in the NDC document: increase share of electric stoves to 25% by 2025 disseminate an additional of 500,000 ICS and 200,000 household-scale biogas plants by 2030 In addition, a maximum limit of 30 per cent LPG stove penetration by 2030 is applied	Building on the current policy scenario, NEXSTEP further recommends the use of electric stoves in reaching a 100% access rate.
Energy efficiency	Additional energy efficiency measures not applied	Improvement based on current policies (explained further in section 3.7)	2.98 per cent annual improvement in TPES target achieved
Power plant	Based on 2018 capacity share	New renewable energy capacity of 15,000 MW[13], and 15 per cent of total electricity demand will come from renewable energy (excluding large hydro), as stated in the second NDC	New renewable energy capacity of 15,000 MW[13], and 15 per cent of total electricity demand will come from renewable energy (excluding large hydro), as stipulated in the second NDC

13 As noted during the stakeholder consultation workshop held on1 March 2021, 5,000 MW of the stipulated target will be designated for cross-border power trade.

In the current policy settings, TFEC is projected to increase from 9,179 ktoe in 2019 to 9,223 ktoe in 2030. This corresponds to an average annual growth rate of 0.04 per cent, a number that is much lower than the projected growth in GDP (3.11 per cent) and population (1.34 per cent). As mentioned above, such low growth in energy demand is attributable to the Government's GHG emission reduction strategies in the residential sector (mainly by replacing biomass cooking stoves) and the transport sector.

In 2030, the residential sector will remain the main consuming sector, with an estimated TFEC of 3,847 ktoe (41.7 per cent), followed by the industrial sector at 2,153 ktoe (23.3 per cent), transport sector at 1,928 ktoe (20.9 per cent), commercial sector at 968 ktoe (10.5 per cent) and others at 327 ktoe (3.5 per cent). The sectoral overview of energy demand in the current policy scenario is discussed below and shown in figure 6.

(a) Residential

The residential sector will continue to dominate Nepal's TFEC, with a 41.7 per cent share in 2030. Nevertheless, demand is projected to decrease to 3,847 ktoe by 2030, compared with 4,471 ktoe in 2019. The notable decrease in energy demand is attributable to the phasing out of unclean and inefficient cooking technologies, specifically traditional biomass stoves. The share of traditional biomass in the cooking stove distribution is projected to decrease to 14.7 per cent, as the uptake of electric cooking stoves, ICS and biogas digesters increases in accordance with the Government's plans stipulated in the second NDC and Fifteenth Plan. As projected in NEXSTEP, the energy demand for cooking decreases from 4,061 ktoe in 2019 to 3,191 ktoe in 2030 through the adoption of more efficient cooking stoves, and fuel switching from traditional biomass to electricity.

(b) Transport

Nepal's transport sector comprises passenger and freight road transport. The total energy demand is projected to be 1,928 ktoe in 2030, increasing from 1,882 ktoe in 2019. Such a slow average annual growth rate of 0.21 per cent is due to the increased market penetration of electric vehicles as envisaged in the NDC document, specifically in the passenger road transport sector. A decreasing trend in energy demand growth is also projected from 2026 onwards, as the share of electric vehicles grows exponentially, replacing the less efficient internal combustion engine vehicles.

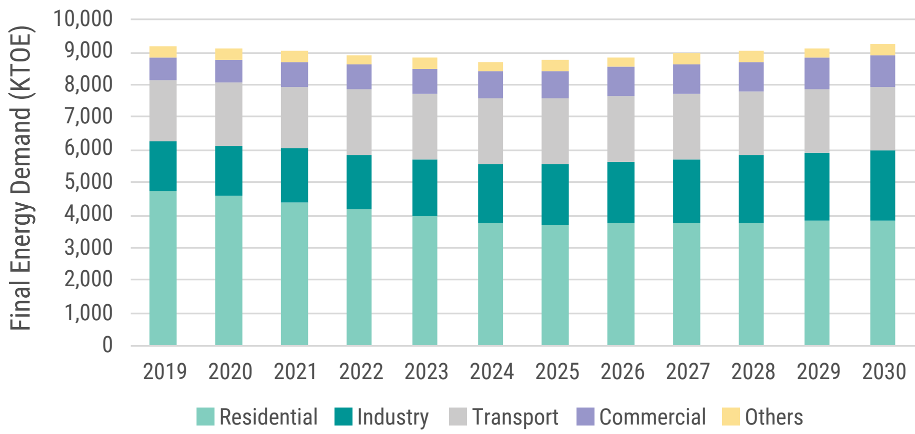
(c) Commercial

The commercial sector energy demand is projected to increase from 691 ktoe in 2019 to 968 ktoe in 2030. The sector is divided into seven subcategories, with each one projected to grow at an annual rate similar to the GDP growth rate (i.e., 3.11 per cent). The energy demand distribution is dominated by hotels at 467.2 ktoe (67.6 per cent), followed by government buildings at 97.2 ktoe (14.1 per cent). Other subcategories are shopping malls at 48 ktoe (6.9 per cent), universities at 31.4 ktoe (4.6 per cent), private offices at 20.8 ktoe (3 per cent), hospitals at 17.7 ktoe (2.6 per cent) and religious buildings at 9.2 ktoe (1.3 per cent).

(d) Industry sector

Energy demand by the industry sector is expected to grow from 1,537 ktoe in 2019 to 2,153 ktoe in 2030. The share of energy demand from the 10 different industrial sectors are detailed in Annex II. The energy intensity of the industrial sector is assumed to be constant, while the industrial sector GDP is projected to grow by 3.11 per cent annually.

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



3.8 Electricity generation outlook

The 2030 demand for electricity in the current policy scenario will be 12 Terawatt-hours (TWh), increasing from 6.4 TWh in 2019. The demand will be the highest in the residential sector at 6.8 TWh (56.8 per cent), followed by the industry sector (3.7 TWh, 30.6 per cent), the commercial sector (1.1 TWh, 9.6 per cent) and the transport sector (0.4 TWh, 3 per cent).

Nepal's installed electric power generation capacity in 2019 was 1,379 MW, of which 91.3 per cent was renewable generation capacity including large hydropower. As of 2019, the installed capacity available in Nepal was not sufficient to meet its local demand, particularly in the dry season, and 37 per cent of its electricity requirement was fulfilled by imported electricity from India. Nevertheless, it is expected that a total of 15,000 MW of new capacity will be installed by 2030, raising the total installed capacity to 16,378 MW. This includes 5,000 MW that will be designated for cross-border trade.

While the exact capacity shares of different power technologies are not available, the NEXSTEP analysis assumes that the export capacity will be fulfilled by large hydropower plants. Including the generation capacity for fulfilling local demand, the total installed capacity is assumed to be made up of large hydropower 90 per cent, mini-hydropower 3.5 per cent, micro-hydropower 3.5 per cent and solar PV 3 per cent. This conforms to the target set out in the NDC document, of which 5-10 per cent capacity will be mini- and micro-hydro power, solar, wind and bio-energy technologies. Figure 7 shows the expected installed capacity during the analysis period.

In terms of power output, it is expected that the export capacity of the 5,000 MW of large hydropower will allow an estimated export of 22 TWh, assuming running at a capacity factor of 51 per cent. In fulfilling the domestic electricity demand, the NDC document stipulates a generation target of 15 per cent from small-scale renewables by 2030, not including large hydropower. The projected generation by technology type is as illustrated in figure 8, whereby the total percentage of renewable energy share in electricity generation is 100 per cent.

3.9. Energy supply outlook

In the current policy scenario, TPES is forecast to increase from 9,279 ktoe in 2019 to 9,318 ktoe in 2030. The fuel shares in 2030 are projected to be oil products 3,303 ktoe, biomass 3,527 ktoe, hydro 2,987 ktoe, coal 1,345 ktoe and solar 62 ktoe. The substantial decrease in the biomass usage is due to the reduced consumption in the residential cooking sector. The primary supply of hydropower has ramped up steeply from just 412 ktoe. The steep increase is due to the projected electricity export of 1,907 ktoe. The share of imported fuels, such as oil products and coal, will still make up about 50 per cent of the TPES in 2030, posing a threat to Nepal's energy security and exposing it to future price and supply shocks.

3.10 Energy sector emissions outlook

The energy sector emissions, from the combustion of fossil fuel, 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 are accounted in the agriculture, forest and land use change (AFOLU) [14] 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.

In the second NDC document submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2020, Nepal did not stipulate an overarching quantitative GHG emissions target for 2030. It has instead specified several quantified targets for several key sectors. These include ambitions in increasing access to clean and efficient cooking technologies, renewable power capacity and generation as well as transport electrification, as already described in the previous sections.

In the current policy scenario, the total GHG emissions from the energy sector decrease from 20.1 $MTCO_{2-e}$ to 16.7 $MTCO_{2-e}$. The substantial decrease is again due to the reduced combustion of traditional biomass. The transformation sector

14 AFOLU sector is not within the scope of NEXSTEP.

is emission-free, as all electricity is generated from hydro and solar only. In the demand sector, the largest contributor of GHG emissions in 2030 will be the transport sector (34.2 per cent), followed by the industry sector (31.3 per cent), residential sector (17.9 per cent), commercial sector (9.7 per cent) and others (6.9 per cent).

Figure 7. Installed power capacity, CPS scenario

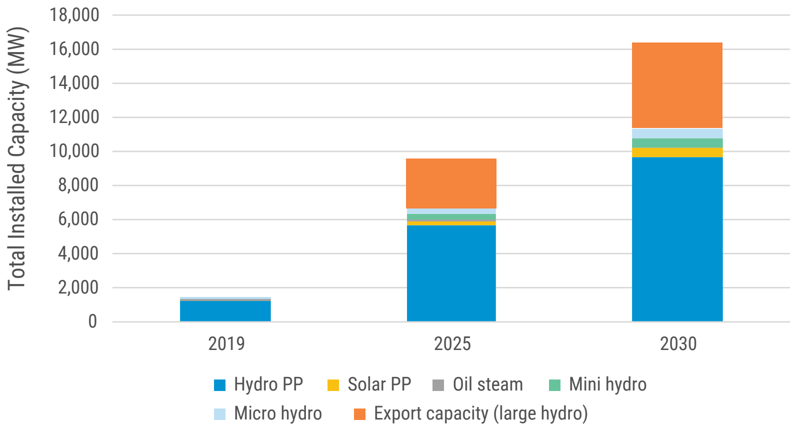


Figure 8. Electricity output by technology type, CPS scenario

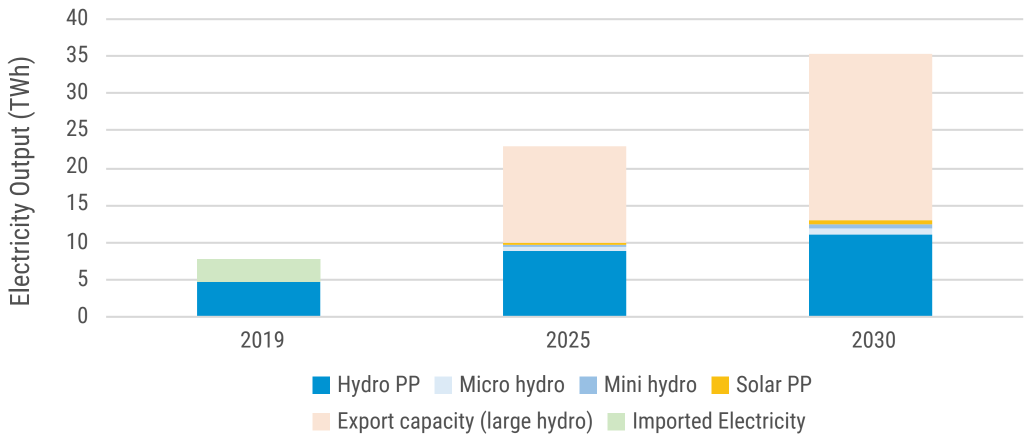
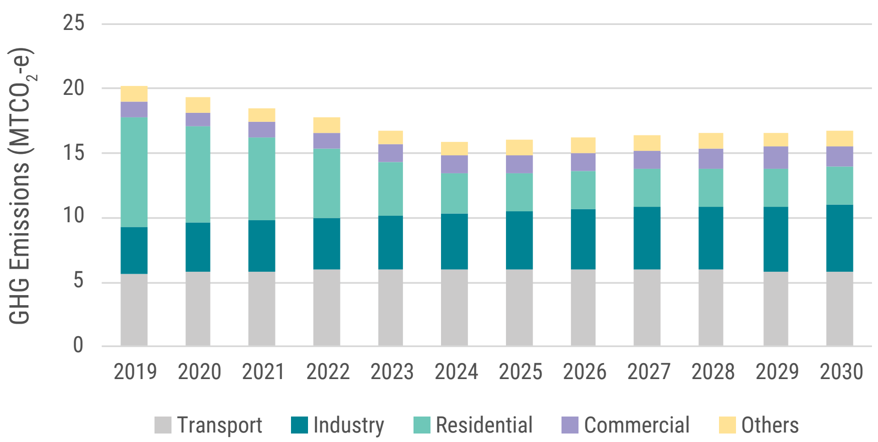


Figure 9. Nepal energy sector emissions outlook in the current policy scenario



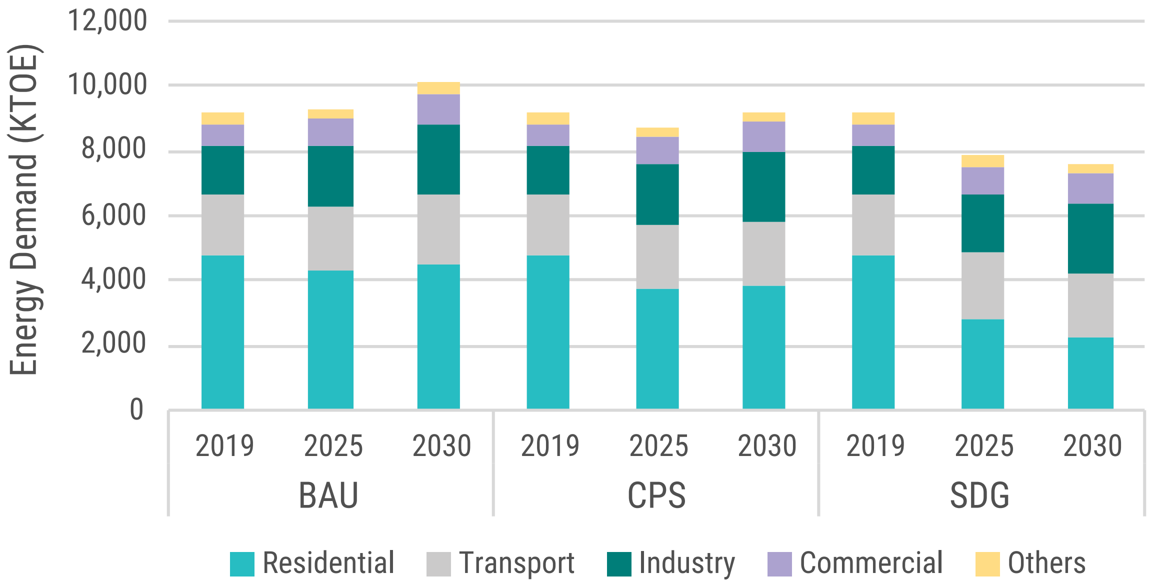
4. SDG scenario – achieving SDG7 by 2030

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. Nepal has made remarkable progress in providing universal access to electricity. The Government's recently announced targets in the second NDC document are expected to substantially increase the country's clean cooking access rate, while at the same time expediting energy intensity and GHG emissions reduction. Nonetheless, small gaps still need to be closed in order to allow the achievement of SDG 7 targets, with measures recommended in the SDG scenario. This chapter further details 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 decreases from 9,179 ktoe in 2019 to 7,624 ktoe in 2030. This is due to a substantial decrease in demand from the residential sector (about 50 per cent reduction from 2019) as efficient electric cooking stoves are taken up to replace low-efficiency traditional biomass and clay ICS. In 2030, the residential sector will have the largest share of TFEC at 2,249 ktoe (29.5 per cent), followed by the industrial sector (2,153 ktoe, 28.2 per cent), the transport sector (1,928 ktoe, 25.3 per cent), the commercial sector (967.9 ktoe, 12.7 per cent), and others (327 ktoe, 4.3 per cent). Figure 10 shows the projected TFEC by sector under the SDG scenario. Raising the clean cooking rate from 72.3 per cent in the CP scenario to meet the 100 per cent target allows a further reduction of 1,598 ktoe in TFEC.

Figure 10. Projection of TFEC by sector in different scenarios



4.2. SDG7 targets

4.2.1. SDG 7.1.1 – access to electricity

Nepal is on track to achieve the electricity access target within the timeline stipulated in the 2030 Agenda for Sustainable Development. Based on the historical improvement rate since 2000, it is expected that universal access to electricity will be achieved by 2024. [15] Nevertheless, continued efforts by the Government are still required in the "last mile" to provide the electrification solution to rural, remote settlements. In view of Nepal's challenging terrain and the fact that the majority of the unelectrified population are in remote rural areas, NEXSTEP analysis suggests that decentralised grid generation may be the appropriate way forward. This includes the utilization of mini- and micro-hydro-based electricity mini-grids in areas where there are substantial water resources. Solar PV mini-grids or a solar-wind hybrid system could also be considered for rural communities, where mini/micro-hydro implementation is not feasible and grid extension is too expensive. Last, solar home systems (SHS) could be considered wherever the above-mentioned technologies are not suitable (i.e., for highly dispersed households).

Notwithstanding this view, universal access to electricity may go beyond the provision of connection. Other aspects should also be considered, i.e., reliability, power capacity, availability, affordability (Bhatia & Angelou, 2015). The Government of Nepal cold aim to improve the quality of services, such as ensuring a sufficient supply for Tier 3 level of electricity demand and improving availability. Equally important is the affordability of electricity services for the financially deprived households.

As of 2019, 890,000 households had yet to be connected to electricity. Based on the first estimation using cost data provided on 19 March 2021 by AEPC, the total investment cost (system capital cost only) required to electrify the remaining 890,000 households ranges between US$760 million and US$1,100 million. The lower limit refers to the use of a solar power home system, which has a system cost of NRs. 10 million per 100 households, while the upper limit refers to the use of a solar mini-grid, which has a system cost of NRs.30 million NPR per 100 households. Further discussion on the electrification technologies is provided in subsection 4.4.1.

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

Under the current policy setting, particularly in adherence to the clean cooking targets stipulated in the NDC document, it is assumed that the clean cooking access rate will increase from 46.5 per cent in 2019 to 72.3 per cent by 2030. The current

15 The Sustainable Development Goals Status and Roadmap 2016-2030 stipulates a target to reach 85.7 per cent access rate by 2022, 90.7 per cent by 2025 and 99 per cent by 2030.

dominant clean cooking technology is the LPG stove, which had a share of 31 per cent in 2019. While being a clean and convenient solution, the popularity of LPG stoves presents a risk to the country due to potential price and supply shocks including energy security. Henceforth, the Government aims to reduce the market penetration of LPG stoves to 30 per cent, and at the same time encourage the uptake of electric cooking as well as other modern and efficient stoves as the more sustainable alternative. As stipulated in the NDC target, the Government plans to increase the market penetration of electric cooking stoves from 6.4 per cent in 2019 to 25 per cent by 2030. In addition, it is expected that 50,000 ICS and 200,000 household biogas digesters will be disseminated and installed by 2025.

This still leaves a gap of 28 per cent to be closed, notwithstanding the above-mentioned plans for the residential cooking sector. Based both on qualitative and quantitative analyses, NEXSTEP results indicate the use of electric cooking stoves as the most appropriate technology in filling in the gap due to the following reasons:

(a) Zero air pollution;

(b) Minimal follow-up required (as opposed to ICS, which requires an ongoing programme of maintenance support); and

(c) Cost-effective, considering a low electricity tariff.

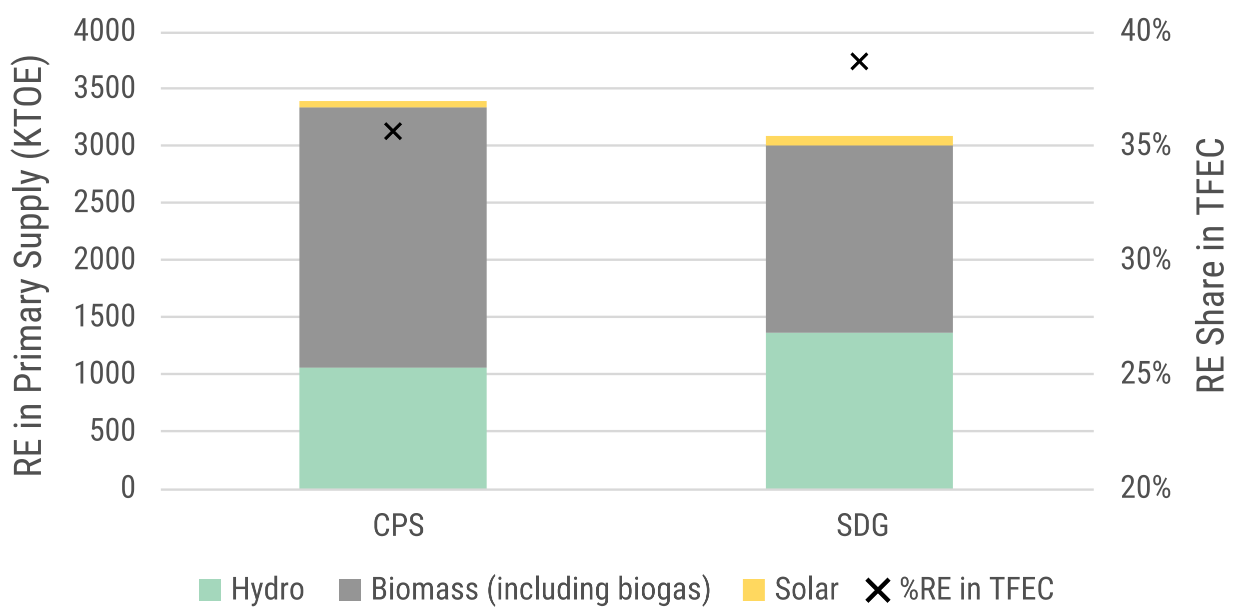
However, electric cooking stoves may not be suitable for households using off-grid electricity systems, as the appliance requires substantial power supply capacity. The better options would be the other modern and efficient technologies, such as improved cooking stoves, biogas digesters and LPG stoves. Such limitation should be considered while promoting clean cooking to ensure technological suitability. ICS and biogas digesters, to be disseminated as part of Nepal's NDC commitment, can be reserved for households utilizing off-grid electricity systems.

Section 4.4.2. details the evaluation of the various clean cooking technologies considered in the analysis.

4.2.3. SDG 7.2 – renewable energy

SDG7.2 does not have a quantitative target but 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 (figure 11).

Figure 11. Renewable energy in TPES and TFEC, 2030



In the context of Nepal, there is no overarching NDC reduction target stipulated in the second NDC document published in December 2020. As such, the renewable energy share in the SDG scenario reflects the share that is projected based on the targets and ambitions stipulated in the NDC document, while at the same time raising the access to clean cooking to 100 per cent.

The share of renewable energy in TFEC in 2030 will be 35.9 per cent in the current policy scenario (figure 11). This increase is largely driven by the increased use of (non-traditional) renewable energy and renewable electricity sourced locally, while TFEC grows at a comparatively slow rate. In the SDG scenario, renewable energy share in TFEC is increased to 38.8 per cent. This is a result of decreased energy demand, as the use of polluting cooking technologies (i.e., clay ICS and traditional biomass stoves) are phased out.

4.2.4. SDG 7.3 – energy efficiency

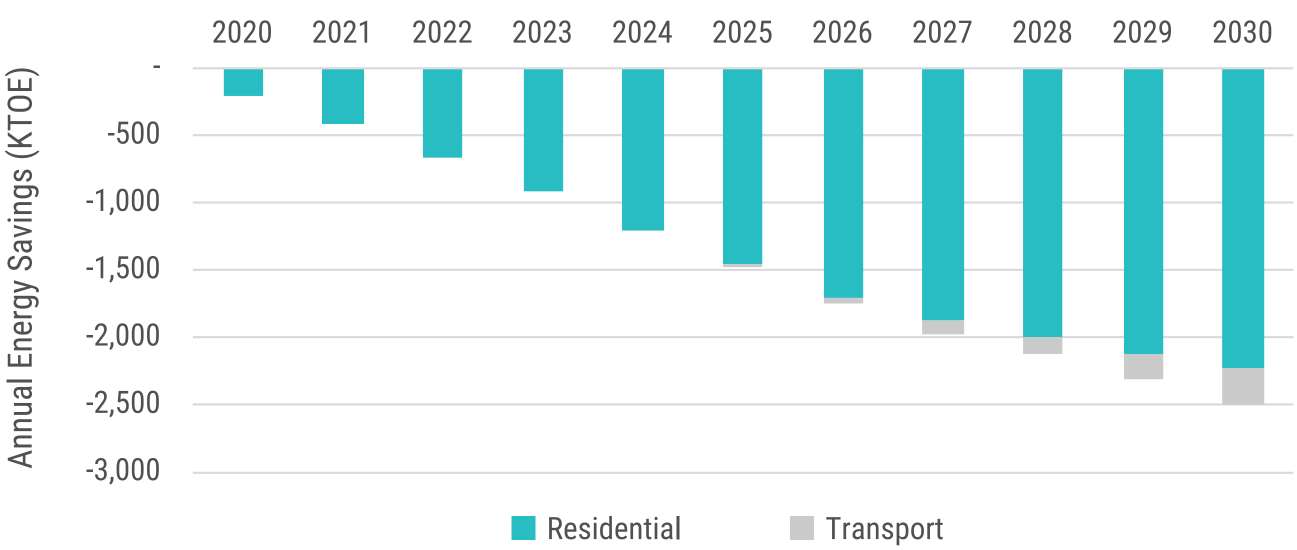
The primary energy intensity, a proxy for the measurement of energy efficiency improvement, is calculated as 3.26 MJ/US$_{2011}$ in the CP scenario. This corresponds to an improvement rate of 2.98 per cent, meeting the SDG 7.3 energy efficiency target (box 1). Such reduction is due to various factors, including a high rate of GDP growth relative to the population growth, a substantial reduction of inefficient traditional biomass usage as well as increased use of more efficient electric vehicles.

The energy intensity in 2030 is expected to become even lower in the SDG scenario – 2.46 MJ/US$_{2011}$. This is solely due to the phase-out of inefficient traditional biomass and clay ICS that do not meet the clean cooking criteria. Instead, they are replaced with more efficient electric cooking stoves.

Box 1. Nepal's energy efficiency target explained

The calculation of the energy efficiency target for Nepal is explained below. The base period rate for calculating energy efficiency improvements is 1990-2010. The ESCAP Asia-Pacific Energy Portal data for primary energy intensity are used to analyse improvements in the base period. In 1990, the primary energy intensity for Nepal was 10.8 MJ/US$_{2011,}$ which improved to 8 MJ/ US$_{2011}$ by 2010. The compounded annual growth rate (CAGR) for primary energy intensity improvements in the base period is 1.49 per cent. The SDG target for energy efficiency requires a doubling of improvement in primary energy intensity, which is 2.98 per cent per year. As the energy intensity in 2019 was 4.12 MJ/US$_{2011}$, this corresponds to an energy intensity target of 2.96 MJ/US$_{2011}$ in 2030.

Figure 12. Energy savings by sectors in the SDG scenario, compared with the BAU scenario



While not required to meet the energy efficiency improvement target, Nepal has ample energy savings opportunities across the different sectors, as are further explored in the ambitious scenario (see chapter 5).

4.2.5. GHG emissions

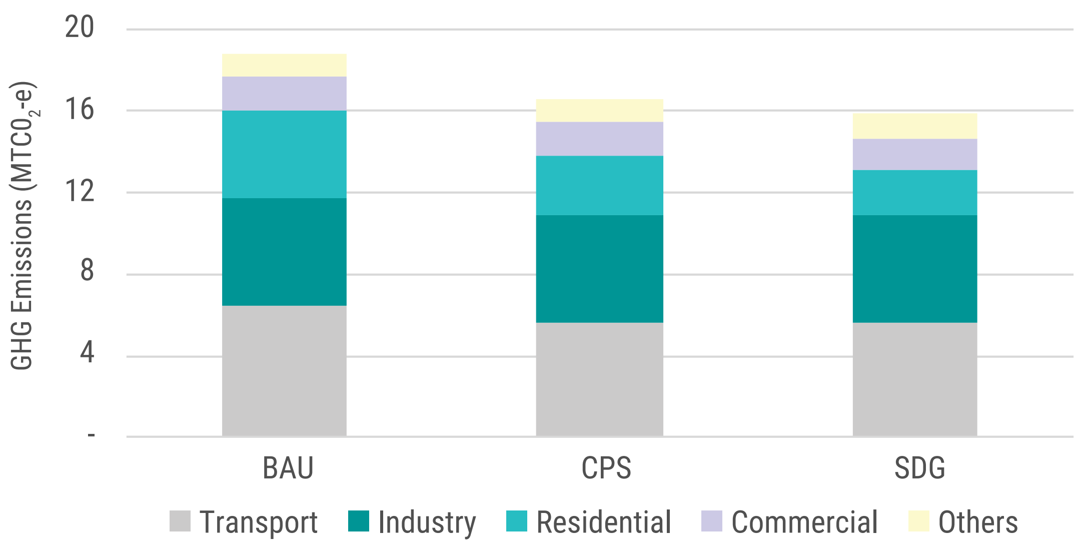
The emissions from the BAU and CP scenarios are projected to reach 18.8 $MTCO_{2\text{-}e}$ and 16.7 MTCO2-ein 2030, respectively. The emission from the SDG scenario is projected to be 15.9 $MTCO_{2\text{-}e}$ in 2030, a 0.8 $MTCO_{2\text{-}e}$ reduction compared with the CP scenario. This also corresponds to a 15.4 per cent reduction in the BAU scenario.[16] As noted above, the sole improvement suggested in the SDG scenario with regard to the CP scenario is the phasing out of unclean biomass stoves. While the combustion of biomass is considered to be CO_2 free as per the accounting methodology suggested by the IPCC, the GHG emissions reduction stems from the reduced emissions of methane and nitrous oxide from the biomass combustion. Figure 13 shows the emissions in different scenarios.

4.3. Power generation in the context of SDG7

The electricity demand in the SDG scenario is projected to increase from 6.5 TWh in 2019 to 15.2 TWh in 2030. The electricity consumption per capita is estimated at 443 kWh per capita.[17]This considers the assumed growth in different economic sectors as well as the increased demand due to the higher rate of adoption of electric cooking stoves. The sectoral split as projected is: the residential sector (10 TWh, 66 per cent); the industry sector (3.7 TWh, 24.1 per cent); the commercial sector (1.1 TWh, 7.6 per cent) and the transport sector (0.4 TWh, 2.4 per cent).

In the SDG scenario, the power capacity expansion plan is as per the CP scenario, which is guided by the capacity target stipulated in the second NDC document. The total installed capacity is as illustrated in figure 7, of which 5,000 MW large hydro is designated for cross-border power trade. The projected generation mix in meeting local demand in 2030 is shown in figure 14. As observed from figure 14, Nepal can be expected to be self-sufficient in meeting its local electricity demand, following its vigorous expansion plan. The generation share of large hydro is limited to 85 per cent, as per the NDC target.

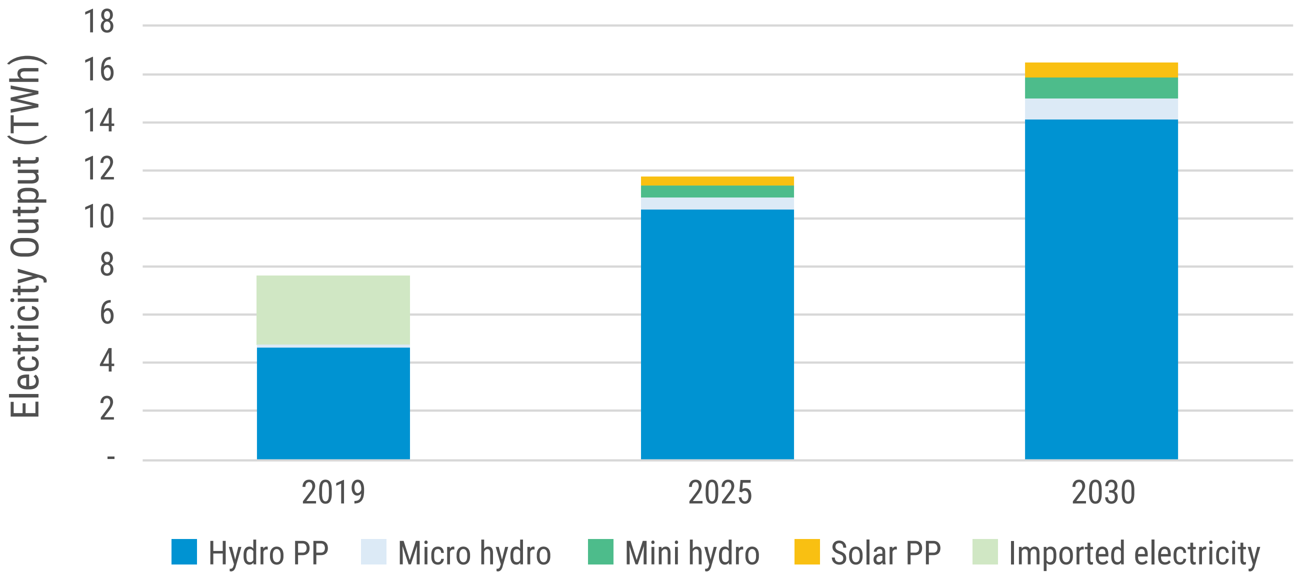
Figure 13. Sectoral emissions by scenario, 2030



16 Considering only the energy sector. Several emission reduction targets are similarly stipulated for the AFOLU and waste sector in the NDC document.

17 The fifteenth National Plan is aimed at increasing the electricity consumption per capita to 700kWh/capita by fiscal year 2023/2024. However, the electricity consumption per capita in 2030 will be 443 kWh/capita, considering the growth projections in the demand sector as well as increased uptake of electric vehicles and electric stoves.

Figure 14. Electricity output by technology type, SDG scenario



The projected total investment for the planned power capacities is $37.1 billion (capital cost for power plants only), of which 33 per cent is for the 5,000 MW hydropower plants designated for electricity export. The total net benefit (or "total net cost" as it returns a negative value) over the 12-year analysis period is expected to be -$4.2 billion. This is due to the relatively low sales tariff of electricity in the country (see box 2). When optimized for least-cost and demand, the model suggests that the planned power capacity expansion outpaces the electricity demand forecasted in NEXSTEP,[18] whereby, an estimated 54 per cent (5.2 GW) of the total expected large hydropower capacity may be able to fulfil the electricity demand in 2030. Therefore, the current expansion plan is likely to lead to a substantial amount of curtailed energy – for example, the curtailed energy production from large hydropower plants is expected to increase to 28.9 TWh in 2030. Notwithstanding this, curtailed energy production of 9.4 TWh can be expected from the optimized model, due to a supply-demand mismatch related to the seasonal variation of rainfall. There are two possible solutions to avoid curtailment, as discussed below.

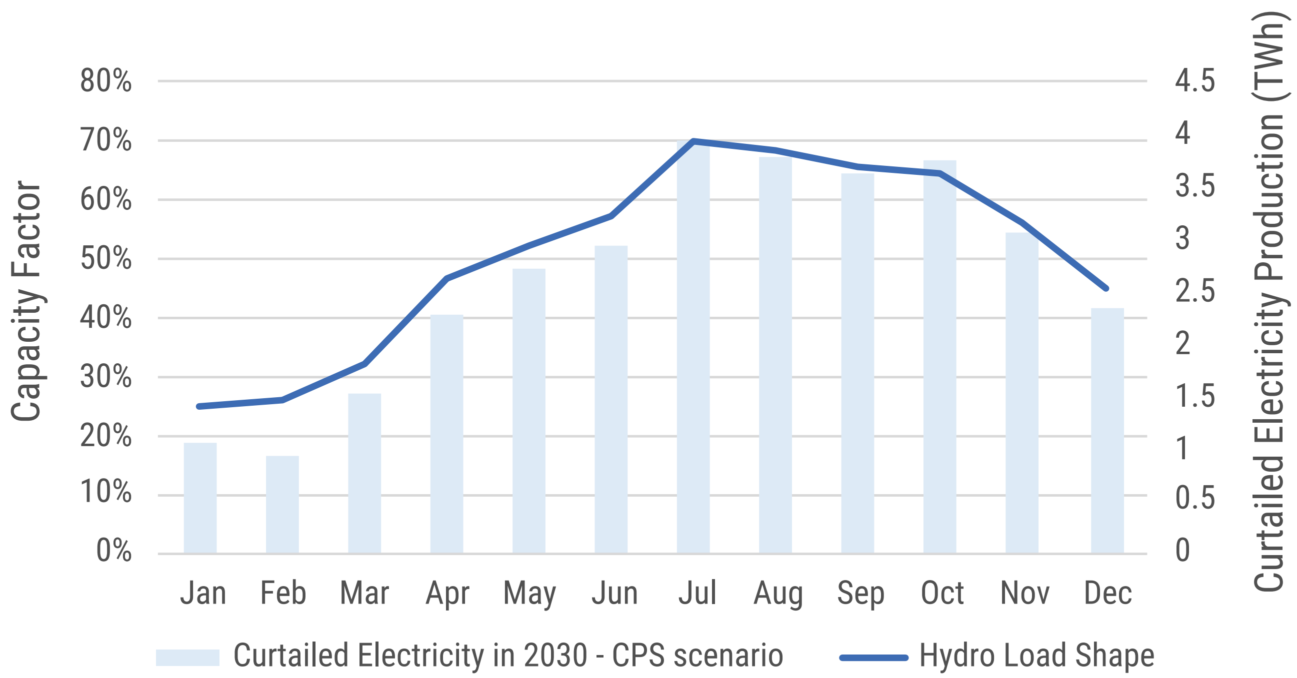
4.3.1. Increasing electricity exports to prevent curtailment

The additional capacity provides an opportunity for Nepal to increase its electricity exports beyond the designated 5GW. Full utilization of its large hydropower plants in meeting the local demand with the remainder being exported (e.g., to India) would prevent curtailment of energy and generate more revenue for the country.[19] For example, this additional electricity export could increase the total revenue by another US$9.4 billion throughout the analysis period. However, it is understood that the possibility of exporting this entire amount, particularly in view of seasonal availability, may be difficult. The Government of Nepal may examine such opportunities and revisit the expansion plan in order to maximise the net benefit.

18 Next Energy Modelling system for Optimization (NEMO) least-cost optimisation approach is used to estimate the optimum large hydropower capacity required to meet the demand. Capacities for all other technologies are provided exogenously (as in figure 7).

19 The hydropower plants are assumed to have an annual averaged capacity factor of 51 per cent.

Figure 15. Hydropower load shape and curtailed electricity production, by month



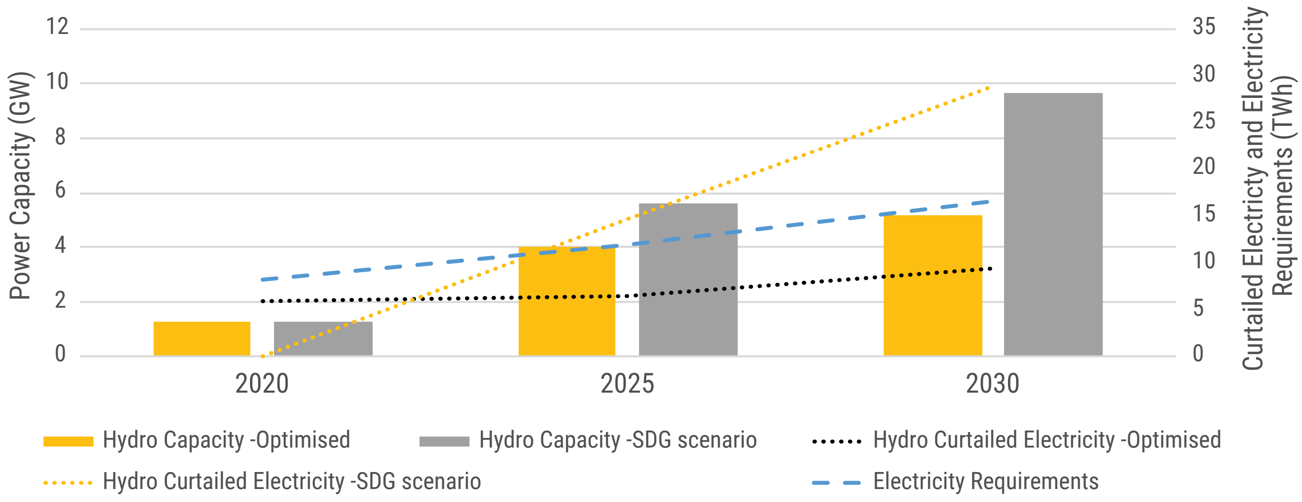
4.3.2. Building storage type hydropower to address seasonal variation

One of the key reasons that Nepal needs to maintain surplus capacity is the response to the seasonal variation, i.e., to offset the low hydropower resources availability in the dry season. The country's annual mean rainfall is estimated to be around 1,530 millimetres. Nonetheless, temporal and spatial variations exist due to the country's extreme topography and weather system. Notably, 80 per cent of the rainfall occurs during the monsoon season between June to September, and the remainder in winter (Government of Nepal, 2014). This has, in turn, influenced the availability of hydro-powered electricity generation in Nepal, which is mainly based on a run-of-river hydropower system with little to no storage capacity.[20] Hydropower in Nepal has an estimated annual average capacity factor of 51 per cent; however, it varies between 25 per cent and 70 per cent throughout the year.[21]

The seasonal variation of hydropower availability is a main consideration factor in hydropower capacity expansion. A capacity factor as low as 25 per cent during the dry season requires greater hydropower capacity in order to meet the electricity demand of the country. Notwithstanding this factor, the surplus capacity during the monsoon season with a capacity factor as high as 70 per cent will lead to a high level of curtailment of electricity production. Possible solutions for addressing the curtailment issue include setting up hydro storage dams to better regulate the water resources availability, and helping to balance supply and demand. Nepal plans to increase the number of storage-type hydropower plants such as the 140 MW Tanahu project situated about 15 km west of Kathmandu on the Seti River (THL, 2021), and a few others now in the planning stage (i.e., Dudhkoshi storage hydropower) (NEA, 2020). A nation-wide feasibility study of possible storage-type hydropower sites would be the appropriate approach to deciding on the capacity expansion.

20 As of 2019, the only existing storage-type hydropower station was the Kulekhani hydropower station. However, a few storage-type hydropower projects are in the pipeline (NEA, 2020).
21 Estimated based on 2019 measured data provided by NEA (2019 and 2020) and a total large hydropower installed capacity of 1,259 MW.

Figure 16. Comparison of capacity and energy availability in SDG vs. optimization[22]



Box 2. Power sector net benefits

The total net benefit (or "total net cost" as it returns a negative value) in the SDG scenario, throughout the 12-year analysis period, is projected to be -US$4.2 billion. The further breakdown of the net benefits by technology type are as listed below:

Technology	Total net benefits (Billion US dollars)
Large hydro	-2.13
Micro hydro	-1.10
Mini hydro	-1.14
Solar	0.15
Large hydro (export)	0.02
Total	-4.2

The low net benefits of the power sector are due to two main reasons: (a) a low electricity tariff and (b) over-expansion of power capacity. Micro-hydro and mini-hydro have negative net benefits at an assumed electricity tariff of US$0.09/kWh. Cost analysis provided by AEPC indicates that the LCOE of mini- and micro-hydro systems are approximately US$0.32/kWh. Such a huge difference in the electricity tariff and the LCOE is the main contributing factor to the negative net benefits.

As noted above, the possible over-expansion of the power sector has led to reduced net benefits for the large hydropower plants. The capacity expansion suggested by LEAP's least-cost optimization approach could instead lead to a total net benefit of US$1.1 billion.

22 This refers to large hydropower plants only.

4.4. Policy actions for achieving SDG7

4.4.1. Achieving last-mile connectivity with localized renewable resources

Nepal is on-track to achieve universal access to electricity by 2030. While complex terrains and poverty pose a major challenge to rural electrification, indigenous renewable potential (i.e., hydro and solar) brings opportunity to scale up self-sufficient mini-grid electrification systems.

Achieving last-mile connectivity is a major challenge in developing countries due to the remoteness of communities and villages, complex terrains, low population densities, and levels of willingness and ability of low-income households to pay. More than 90 per cent of the unelectrified households in Nepal are rural households and most are in remote areas among the complex terrains. With this regard, NEXSTEP suggests the use of mini-grid hydropower systems for settlements far from the central grid, where grid extension is technically and economically infeasible.

Considering the abundance of hydropower potential in Nepal, small-scale micro-hydro powered systems may be the priority technology, especially in rural and remote areas where extension of grid is too expensive including huge power loss. This is further supported by the cost data provided by AEPC. It is noted that the levelized cost of electricity (LCOE) generated from mini-hydro system is the lowest, estimated at NRs 37.2/kWh (US$0.32/kWh). Solar mini-grid systems have an LCOE estimated at NRs.71.23/kWh (US$0.61/kWh). Solar home systems (SHS), which have an LCOE estimated at NRs.52.23/kWh (US$0.44/kWh), may be a solution for standalone households where community grid system is not an option due to sparse rural settlement with low power demand. Nevertheless, SHS are unlikely to provide an at minimum Tier 3 daily consumption level of 1 kWh.[23] For example, a minimum capacity of 200W will be required to meet the daily demand of 1kWh, assuming an average capacity factor of 20 per cent. Future off-grid projects should be carefully planned, making sure that decentralised electrification projects do not overlap with any future NEA grid projects. Duplication should be avoided to ensure proper utilization of funds.

The choice of technology will be based on various aspects, including cost-effectiveness and resource availability. In addition, seasonal variation of rainfall may possibly have an effect at times on the availability of hydro-based power generation. Careful investigation should be conducted to assess the non-availability issue in proposing the most suitable technology. For example, hybrid combination of hydro plus solar mini-grid or solar power plus wind mini-grid or a combination of all three may be a possible choice in addressing the non-availability issue during the dry season, including being the most efficient and least cost option.

4.4.2. Electric cooking stove is a sustainable long-term solution with multi-fold benefits

Electric cooking stoves are a prime solution in closing the remaining clean cooking gap, capitalising on cheap and carbon-free electricity. It serves as a long-term solution with no added burden on fuel imports.

Building on the Government's planned efforts to close the clean cooking gap by increasing the uptake of electric cooking stoves, and through the dissemination of ICS and biogas digesters, NEXSTEP analysis suggests the remaining gap be closed with the promotion of electric cooking stoves based on the quantitative and qualitative analyses provided below.

(a) 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 electromagnetic energy to directly heat pots and pans, and can be up to 90 per cent efficient.

23 As classified in Bhatia and Angelou, 2015.

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. For example, the clay ICS disseminated under the AEPC programme is placed below Tier 3 of the MTF cooking exposure attribute; hence it is regarded as an unclean technology.[24] However, Tier 3+ ICS, which meet the WHO clean cooking guidelines, has the potential to reduce GHG emissions and provide socio-economic and health benefits, when it is promoted in carefully planned programmes. It can also play an intermediary role until cleaner options become more affordable.

Biogas digester

Biogas digesters have high upfront capital costs (about US$1,000 for a standard size that is suitable for a four-member family) and require a substantial subsidy due to their longer payback period. 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, as evidenced in Nepal.

LPG cooking stove

LPG in Nepal 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)[25] for cooking exposure and reduce indoor air pollution by 90 per cent compared to traditional cooking stoves.

Table 2 summarizes the estimated annualized cost of different cooking technologies in the context of Nepal. Annex IV summarizes the cost and technical assumptions used in the economic analysis.

As analysed, the expected installed capacity is more than sufficient to accommodate the additional demand due to the uptake of electric cooking stoves, as suggested in the SDG scenario. The use of electric cooking stoves not only reduces overall energy consumption, but also results in zero GHG emissions. This is of particular benefit for Nepal, where 100 per cent of its electricity is projected to be produced from renewables including large hydropower. As opposed to the LPG stoves, currently the dominant clean cooking solution, electric cooking stoves do not add an additional burden on fuel imports.

Table 2. Annualized cost of cooking technologies

Technology	Annualized cost
ICS	US$41
Electric stove	US$108
Biogas digester	US$131
LPG stove	US$154

24 As suggested by the World Bank, 2019, open fire stoves, traditional stoves and improved cooking stoves fall under Tier 0 to 2 for cooking exposure.
25 See http://documents.worldbank.org/curated/en/937711468320944879/pdf/88699-REVISED-LW16-Fin-Logo-OKR.pdf

While ICS is estimated to have a lower annualized cost than electric cooking stoves, concerns have been raised by various studies regarding their suitability as a long-term clean cooking solution for the general population. Nevertheless, the use of electric cooking stoves is also limited to households with sufficient power capacity, i.e., households connected to the main grid or to larger mini- grids. With that, NEXSTEP analysis suggests that ICS and biogas digester dissemination as stipulated in the NDC document be targeted at households relying on mini-grid/off-grid systems, while the remaining gap is closed with a more sustainable solution – electric cooking stoves. The economic status of the households/communities should also be taken into consideration in the clean cooking programmes, whereby lower cost technologies (i.e., ICS and biogas digesters) may be promoted in the most deprived communities.

However, comprehensive policies are imperative for ensuring the widespread and continuous use of electric stoves. For example, the Fifteenth Plan has targeted the development of standards for electric cooking stoves as well as providing an appropriate electricity tariff for cooking purposes (National Planning Commission, 2020).

5. Energy transition pathway with increased ambitions

The SDG scenario builds on the current policy settings to provide recommendations for achieving the SDG 7 targets. Further analysis shows that there are ample opportunities for Nepal to raise its ambition beyond just achieving the SDG7 targets. For example, additional energy efficiency measures can substantially increase energy savings and reduce fuel imports.

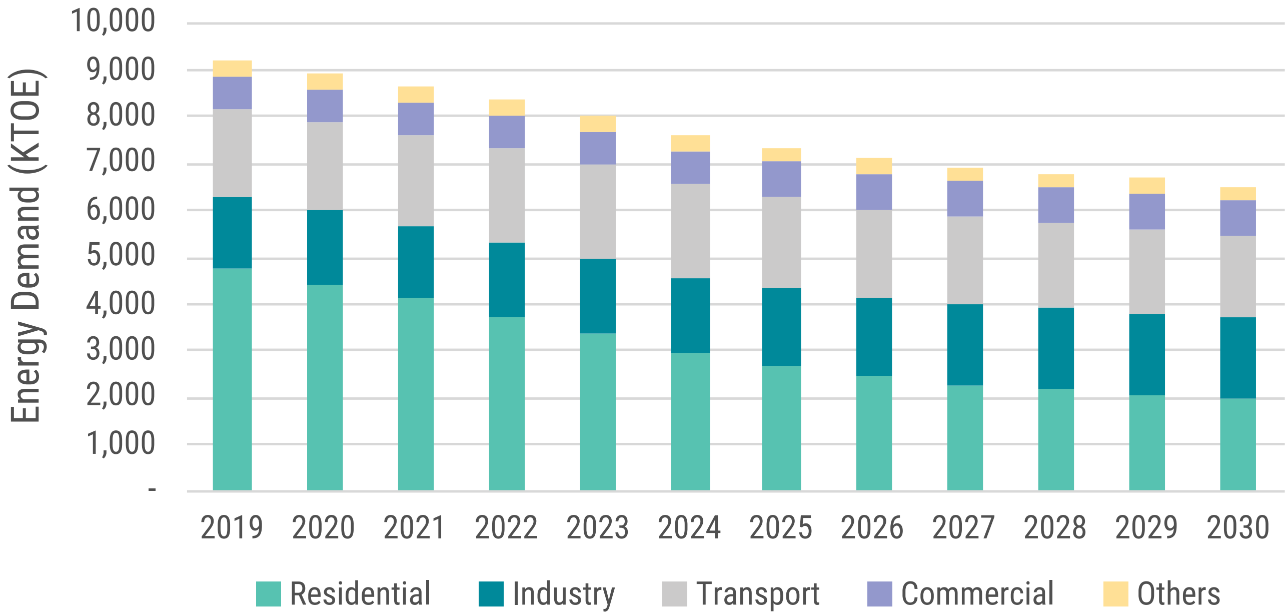
5.1. Increasing ambitions with enhancing energy efficiency (EE) scenario

This ambitious scenario looks at raising Nepal's ambition beyond the SDG 7 and NDC targets. Energy access targets are achieved as in the SDG scenario, while the power sector expansion and supply mix follow the CP and the SDG scenarios. In addition to the measures already applied in the SDG and CP scenarios, there is ample energy savings potential in the residential, transport, commercial and industry sectors, as explored in this scenario.

5.1.1. Energy demand outlook

With the implementation of further energy efficiency measures (discussed later in this section) the demand for total final energy is expected to decrease from 9,179 ktoe in 2019 to 6,533 ktoe in 2030. The largest sector remains the residential sector (1,962 ktoe, 30 per cent); followed by: the industrial sector (1760 ktoe, 27.0 per cent); the transport sector (1,708 ktoe, 26.2 per cent); the commercial sector (775 ktoe, 11.9 per cent); and others (327 ktoe, 5 per cent). Figure 17 shows the TFEC forecast by sector under the EE scenario.

Figure 17. Forecast of TFEC by sector in the EE scenario



5.1.2. Substantial energy savings can be achieved with a whole-economy approach

The EE scenario explores various energy efficiency strategies across the residential, industry, transport and commercial sectors. It is noted that the proposed measures have an estimated accumulated potential to reduce the final energy demand by 1,091 ktoe in 2030, compared with the SDG scenario. These sectoral energy efficiency measures are further described below.

(a) Residential sector – total estimated savings of 286.7 ktoe

The Minimum Energy Performance Standard (MEPS) has yet to be established in Nepal, which has the potential to improve the overall efficiency of household appliances. The EE scenario explores the possible savings gained from setting up MEPS for common household appliances,[26] while at the same time mandating the use of efficient LED light bulbs. In addition, increasing the penetration of electric space heating is expected to have a huge impact on energy demand. The measures and estimated savings based on NEXSTEP modelling are detailed in table 3.

(b) Transport sector – total estimated savings of 219.5 ktoe

The Government of Nepal aims to step up on transport electrification by increasing the market share for electric private and public four wheelers as well as private four-wheelers. Such ambition is laudable as it contributes positively to energy savings and GHG emission reduction. In addition, it improves Nepal's energy security by lessening the dependency on imported petroleum products. The EE scenario further explores the possibility of having more ambitious transport electrification strategies.[27] The estimated potential is relative to the CP and the SDG scenarios. The measures and estimated savings are detailed in table 4.

(c) Commercial sector – total estimated savings of 193 ktoe

The current space heating practices are dominated by conventional fuel combustion, such as coal, LPG and biomass. These make up about 87 per cent of the energy consumption in the commercial sector. Substantial savings can be expected from increased use of solar thermal heating system and heat pump system by Increasing the penetration of solar thermal heating systems and heat pump

26 A stock turnover analysis was performed to estimate the penetration of efficient appliances by 2030 due to the introduction of MEPS from 2024 onwards. It is assumed that all the existing appliances in 2019 were non-efficient appliances. The estimated savings from efficient appliances refer to 3-star rated appliances according to the rating system of either the Bureau of Energy Efficiency, India or the Government of Australia, where applicable.

27 The penetration of electric vehicles has been estimated based on a stock-turnover analysis.

Table 3. Energy efficiency measures and estimated savings in the residential sector

Actions	Timeframe	Estimated savings in 2030 (ktoe)
Phasing out of inefficient light bulbs with efficient LED light bulbs	By 2030	51.8
Introducing MEPS		
All new refrigerators and freezers	From 2024 onwards	8.65
All new televisions	From 2024 onwards	12.5
All new water pumps	From 2024 onwards	3.4
All electric fans	From 2024 onwards	1.0
All washing machines	From 2024 onwards	6.2
All air conditioners	From 2024 onwards	3.0
Double the penetration of electric space heating (with heat pumps) in the urban residential sector, from 39 per cent share to an 80 per cent share	By 2030	200.1
Total		**286. 7**

Table 4. Energy efficiency measures and estimated savings in the transport sector

Actions	Timeframe	Estimated saving in 2030 (ktoe)
Increase market sales of electric vehicles for private passenger two-wheelers	50 per cent in 2024 Gradually increase to 100 per cent in 2030	74.4
Increase market sales of electric vehicles for private passenger four-wheelers	50 per cent in 2024 Gradually increase to 100 per cent in 2030	25.2
Increase market sales of electric vehicles for public passenger four-wheelers	50 per cent in 2024 Gradually increase to 100 per cent in 2030	27.8
Increase market sales of electric rickshaws	50 per cent in 2024 Gradually increase to 100 per cent in 2030	42.9
Increase market sales of electric buses	50 per cent in 2024 Gradually increase to 100 per cent in 2030	17.5
Increase market sales of electric minibuses	50 per cent in 2024 Gradually increase to 100 per cent in 2030	31.7
Total		**219.5**

systems to 25 per cent by 2030, respectively, in all commercial subsectors,[28] creating an estimated reduction of 193 ktoe in 2030.

(d) Industry sector – total estimated savings of 392 ktoe

The energy consumption by the industry sector is expected to increase from 1,532 ktoe in 2019 to 2,152 ktoe in 2030, assuming a constant energy intensity and no energy efficiency intervention applied, as modelled in the CP and SDG scenarios. A baseline study conducted in 2012 on a selected number of industries showed that there is potential for the industry sector in Nepal to be more efficient in its energy usage(PACE Nepal, 2012). The findings by the study have been incorporated in the EE scenario, with estimated savings detailed as follows:

I. Adoption of energy efficiency measures in the glass, cement and non-metal industry,[29] with thermal energy saving potential of 41.7 per cent and electrical energy saving potential of 41.3 per cent – an estimated reduction of 288.3 ktoe;
II. Adoption of energy efficiency measures in the food and beverages industry, with thermal energy saving potential of 13 per cent and electrical energy saving potential of 9 per cent – an estimated reduction of 80.6 ktoe;
III. Adoption of energy efficiency measures in the iron and steel industry, with thermal energy saving potential of 28 per cent and electrical energy saving potential of 6.2 per cent – an estimated reduction of 23.1 ktoe.

5.1.3. Primary energy supply and fuel imports

The total primary energy supply is estimated to decrease to 6,660 ktoe by 2030, a 2,619 ktoe reduction compared to 2019. In comparison with the SDG scenario, this corresponds to a 1,086 ktoe reduction. With regard to the SDG 7.3 energy efficiency indicator, the energy intensity in 2030 is estimated to be 2.62 $MJ/US\$_{2011}$, which corresponds to an average annual energy efficiency improvement rate of 5.51 per cent from 2019 to 2030.

The substantial decrease in primary energy supply not only reduces Nepal's energy intensity but also enhances its energy security by reducing the need for fuel imports. With greater transport electrification ambition, the use of oil products in the transport sector is estimated to be reduced by another 340 ktoe. The adoption of more efficient space heating systems in the residential and commercial sectors will also reduce the use of oil products and coal by 135 ktoe and 98.5 ktoe, respectively. Energy efficiency measures applied in the industry sector could also lower coal usage by 203 ktoe.

5.1.4. GHG emissions

The transport and the industry sectors are expected to be the two largest GHG emitting sectors in 2030, contributing around 32.8 per cent and 35.9 per cent, respectively, of GHG emissions in the SDG scenario. This generally stems from the fuel combustion in the internal combustion engine vehicles and industrial boilers for process heating purposes. It is expected that the GHG emissions will be reduced by a significant margin with the above-mentioned measures (figure 18). The emissions of the EE scenario is projected to be 13 $MTCO_{2\text{-}e}$, a 31 per cent reduction from the BAU scenario.

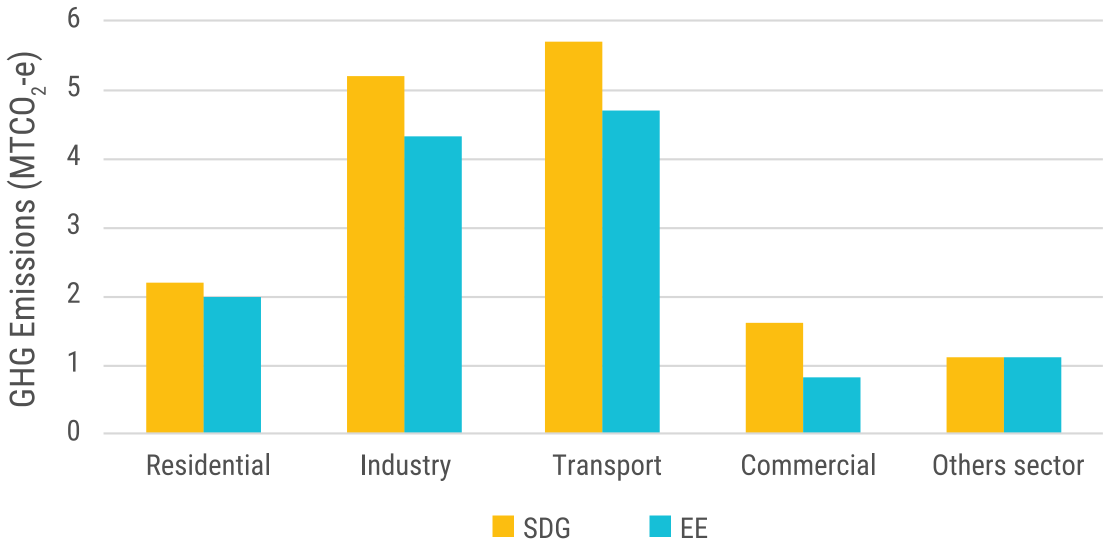
5.2. Policy recommendations to raise ambitions beyond SDG and NDC targets

5.2.1. Raising the efficiency standards of household appliances to save long-running costs

The Minimum Energy Performance Standard (MEPS) is a widely used policy instrument for promoting energy efficiency by removing poor-performing appliances from the market, thereby forcing manufacturers to introduce innovation and consumers to adopt energy efficient appliances. For example, in 1988 the Government of Japan launched the "Top Runner programme" for energy efficiency standards across 21 products. As a result, energy efficiency standards were met or exceeded across all 21 products, with benefits such as cost savings and GHG reduction due to reduced

28 The modelling assumes that the other fuel usage is displaced in a proportion similar to the existing share of final useful energy intensity.
29 The baseline study suggested potential savings for the cement industry only. In NEXSTEP, the industry classification refers to the glass, cement and non-metal industry. It is assumed that the industry is predominantly a cement industry, hence the reference to the potential savings suggested for cement industry in the baseline study.

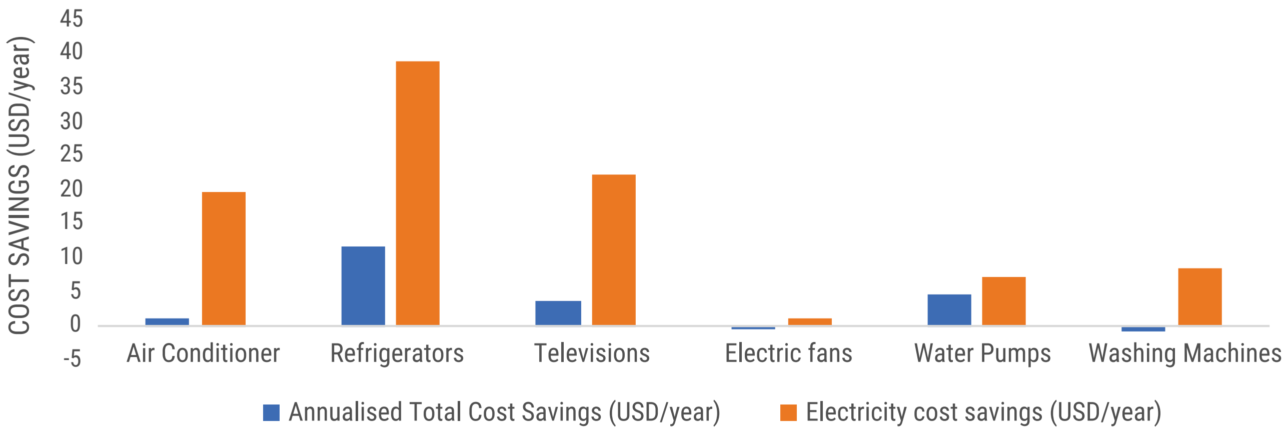
Figure 18. GHG emissions by sector, SDG and EE scenarios



energy consumption. Such schemes have also been introduced in Australia, India and Malaysia, among other countries. In India, MEPS was first rolled out in 2006 and now covers 28 products, as part of either the mandatory or the voluntary schemes (BEE, 2019). These include household appliances such as air conditioners, refrigerators and colour televisions. Complementing the roll out of MEPS, the Government of Nepal may consider having appliance replacement programmes, such as providing subsidies to promote early retirement of existing inefficient appliances. This will allow a more rapid adoption of efficient appliances.

Figure 19 shows the indicative[30] annualized total savings and electricity cost savings per appliance that may be gained from using efficient appliances. Annex IV provides the assumptions used in the calculations.

Figure 19. Indicative annualised and electricity cost savings from efficient appliances



30 The actual savings depend on user-specific factors such as the comparative capital cost between existing and efficient appliances as well as the capacity of the appliances and operating hours.

5.2.2. Adoption of sustainable heating systems helps to save fuel and reduce GHG emissions

About 90 per cent of the energy usage in the commercial sector is used for space heating purposes. In 2019, the heating requirement for the commercial sector was mainly provided by conventional fuel-burning practices – through the combustion of biomass (50 per cent), LPG (25 per cent) and coal (23 per cent). In view of the high share of imported fuels for space heating, fuel-switching should be a priority to reduce fuel dependency. In addition, adoption of sustainable heating systems such as solar heating systems and heat pumps also contribute significantly towards GHG reduction.

Two main types of sustainable heating systems have been proposed and modelled in the EE scenario – solar thermal heating systems and electric heat pumps. Solar thermal heating systems, specifically active solar heating systems, collect solar energy and circulate the heat energy throughout the interior space using pumps. The renewable-based heating system has a zero-fuel cost and is GHG emission-free. In addition, solar thermal can be applied for water heating purposes. Electric heat pumps are also viable alternatives that have coefficients of performance (or energy efficiency ratio) of between 2 and 4.5. These utilize a refrigerant cycle to source heat from the outside atmosphere to heat the interior space, whereby electricity is used to circulate the heat throughout the interior space. With Nepal's electricity being emission-free, electric heat pumps provide a zero-carbon heating solution and take advantage of the low local electricity tariff. More importantly, both systems free up the need for imported fuels (i.e., coal and LPG).

5.2.3. Transport electrification is a major step towards net zero 2050

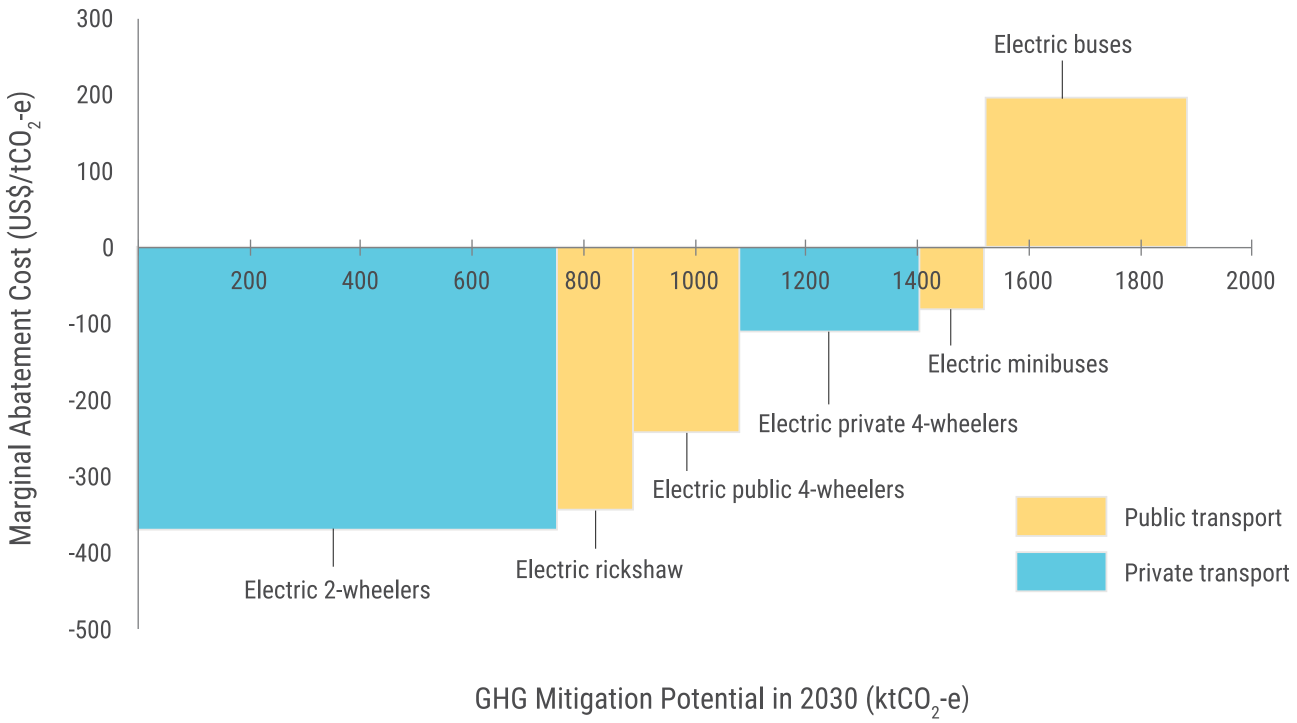
Ambitious policy actions for the land transport sector are critical for Nepal to achieve the SDG 7 energy efficiency target and contribute towards climate mitigation. For example, the proposed transport electrification target in the NDC document reduces energy supply needs by 254 ktoe of oil products (12 per cent) compared to the BAU scenario in 2030. However, a more vigorous approach can be considered, widening the scope to cover other transport vehicle categories (i.e., buses, trucks and auto rickshaws). With the transport sector projected to be the largest GHG emitting sector, early action is required to pave the way towards a net zero 2050.

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 Nepal'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. However, the uptake of electric vehicles needs to be promoted with complementing government initiatives, i.e., financial incentives and awareness programme. For example, the recently announced budget has revised down the duties on electric vehicles. At the same time, renewal and road taxes will be waived for five years should a conventional vehicle switch to electric vehicles (*Nepali Times, 2021*).

Figure 20 shows the indicative marginal abatement cost (MAC) curve for the transport sector. The MAC curve follows the measures proposed for the EE scenario and uses the BAU scenario as the reference baseline. It should be noted that the transport sector has a high GHG mitigation potential, with which most scenarios are cost-effective in the long term. 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 V provides the cost assumptions used in the MAC calculations.

Figure 20. Marginal Abatement Cost curve for the transport sector



5.2.4. Incentivize industrial energy efficiency measures for a more competitive industry sector

Based on PACE Nepal (2012), Nepal's industry sector has ample opportunities to run its operations with greater energy efficiency. This will save costs and improve the competitiveness of the sector. In particular, thermal energy saving measures reduce the use of coal and oil products. The measures suggested in the baseline study are detailed in box 3.

NEXSTEP results align with the recommendations provided by PACE Nepal (2012} and the strategy set out in the National Energy Efficiency Strategy 2075, whereby energy audits should be promoted to all industries to identify and realise the 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), emissions caps and trade systems (e.g., the European Union Emission Trading Scheme) or regulatory instruments. *The Practitioner's Guide to Strategic Green Industrial Policy* by Partnership for Action on Green Economy (PAGE)[31] provides industrial policymakers with tools and information for developing a strategic green industry policy (SGIP).

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

Box 3. Energy efficiency measures in the industry sector

PACE Nepal (2012) has identified several energy efficiency measures for a selected number of industries. The areas of potential savings that are present in the different subsector include (but are not limited to):

- Improvement in motor loading;
- Replacement of old and rewound motors;
- Installation of capacitor banks and increasing efficiency of existing capacitor banks;
- Improvement of combustion efficiency of boilers;
- Regular cleaning and maintenance of boiler equipment (i.e., condenser pipes);
- Installation of more efficient electric motors;
- Improvement of the steam distribution system including leakage control and insulation improvement;
- Electricity load management;
- Minimization of energy losses by partition of cooling areas, installation and effective use of air curtains;
- Minimization of heat losses from the boiler (or kilns for the cement sector).
- Condensate and waste heat recovery.

The specific measures for each industry subsector can be found in PACE Nepal (2012).

5.2.5. Green financing

Sustainable, green transition in the energy sector often offers financial benefits in the long term. For example, increasing renewable power capacity, particularly for power trade, provides additional revenue to the country, while also contributing towards global climate mitigation efforts. However, high capital expenditure is generally required for new renewable power capacities. For the other sectors, this could entail financial incentives to promote efficient vehicles or efficient household appliances. Hence, accelerating green financing is critical to achieving the sustainable energy transition. Policymakers need to work with central banks, regulatory authorities and investors to examine the possibility of developing a green finance policy and establishing a green finance bank or fund to help close the investment gap.

Green bonds mobilize resources from domestic and international capital markets to finance climate solutions. In Nepal, financing of programme and projects on climate change mitigation and adaptation from international climate financing funds, such as the Green Climate Fund (GCF), is expected to gradually increase with the national entities being accredited to the fund. Hitherto, AEPC and the National Trust for Natural Conservation are two of the GCF's accredited entities (AEs) in Nepal, enabling the AEs to prepare climate projects and programme and fund flows from the GCF. Targeting financing towards the green sectors will allow Nepal to achieve its NDC goals, while creating new job opportunities amid the economic downturn due to the COVID-19 crisis. The International Finance Corporation (IFC) announced in July 2020 that it will provide a green loan totalling up to US$25 million to help boost Nepal's green financing projects as well as small and medium enterprises (SMEs). This is expected to expand the SME portfolio to US$1 billion and at the same time creating around 50,000 jobs over the next five years (Parikh, 2020).

Renewable energy technologies have relatively high financing costs in developing countries, which reflects their unattractive risk/return profile. This is because of their long-term horizon, high initial capital costs (including high infrastructure cost), unfavourable policy for grid access, illiquid equipment and project risks. Policymakers can reduce high financing costs using two methods – de-risking and direct incentives. De-risking has two basic forms – policy de-risking instruments that reduce risk, and financial de-risking instruments that transfer risk. Direct incentives are direct finance transfers or subsidies to low carbon investments. The United Nations Development Programme's (2021) *De-risking Renewable Energy Investment*[32] is an important guide for policymakers in developing strategies to reduce risks in renewable energy investment.

32 See https://www.undp.org/content/undp/en/home/librarypage/environment-energy/low_emission_climateresilientdevelopment/derisking-renewable-energy-investment.html

6. Building back better in the recovery from COVID-19 with the SDG7 roadmap

Energy plays a key role in rebuilding better in the recovery from the COVID-19 pandemic. Energy services are essential to supporting health-care facilities, supplying clean water for essential hygiene, enabling communication and IT, and 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 Nepal. Nepal's economy has contracted for the first time in four decades, whereby Nepal's GDP has shrunk by 1.99 per cent in the 2020 fiscal year ending on July 15th (Reuters, 2021). In a bid to curb the spread of the coronavirus, Nepal was put under a strict lockdown for four months, shutting down nearly all its economic activities. In addition, such economic contraction also stemmed from its reliance on remittances (25 per cent) and the tourism industry (8 per cent) (UNDP, 2021a). The tourism industry has been hit hard as national borders have been closed to tourists. Not only that, the lockdown in other countries has also meant that Nepali migrant workers have lost employment, hence the flow of remittance back to Nepal has decreased substantially (World Economic Forum, 2020a). While grappling with the devastation caused by pandemic, Nepal should not lose sight of its progress and ambitions towards achieving the SDGs and NDC targets. Nepal should build back better from this crisis, to become more resilient to face 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 seismic shifts in the energy sector from COVID-19 affect the most vulnerable people.

Nepal has about 4 million people living without electricity and 16 million people without access to clean cooking fuel. One medium-term impact of COVID-19 could be decreased investment in energy access, as national budgets come under strain and priorities shift. Under-investment in this area would have a severe impact on the capacity of rural health centres to support front-line health workers and provide essential services to COVID-19 patients. For vaccines the need for cold storage and refrigerated transportation has become very important. The value of decentralised technologies such as solar power will therefore be enormous for large-scale immunisation efforts in rural areas of Nepal.

Access to clean cooking 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. Moreover, scientists are already investigating links between air pollution and higher levels of coronavirus mortality, with preliminary results showing a probable correlation between the two(Aarhus University, 2020)).

The SDG 7 roadmap has analysed and identified technical options for connecting the remaining population to cleaner fuel for cooking and has estimated the cost of the measure. The benefits resulting from this measure, in the form of reduced mortality and health impact, will exceed the needed investment to advance the clean cooking 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 Nepal 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 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 with the aim of cross-border power trade also provides new sources of income for the country. Such measures are very important to 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 their long-term sustainable recovery from the pandemic (European Commission, 2020b).

The global crisis has caused Nepal's economy to plunge for the first time in four decades. The nation has been hit hard, particularly due to its economic dependency on remittances and the tourism industry. Nonetheless, this may be an opportunity for Nepal to re-examine its economic structure and leverage the potential of climate-smart sectors. IFC estimates the country has climate-smart investment opportunities of US$46 billion[33] by 2030 (World Bank, 2017). Well formulated government policies will be able to unlock opportunities for private investment, while creating more job opportunities. For instance, several countries have shown that the two main challenges faced by Nepal, climate change and unemployment, can be addressed simultaneously (World Economic Forum, 2014).

1.28 MWp Solar Plant developed under 25 MWp Grid Tied SolarFarm Project (Location_ nearby Devighat Hydropower Forebay Area) Commissionin Feb 2021

33 Based on Nepal's first NDC document.

7. Revisiting existing policies

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

7.1. Universal access to electricity

Existing policy	NEXSTEP analysis – gaps and recommendations
Renewable Energy Subsidy Policy details the subsidy programmes available for the different types electrification systems (i.e., micro-hydro, solar mini-grid, solar home systems and solar wind hybrid system).	Nepal is on track to reach a 100 per cent electrification rate by 2024, as per the historical improvement trend. However, this will require continued government support in electrifying the remaining 900,000 households. The NEXSTEP analysis concurs with the choice of the technologies considered in the renewable energy subsidy policy, where off-grid systems would play a substantial role in electrifying rural and remote households.

7.2. Universal access to clean cooking

Existing policy	NEXSTEP analysis – gaps and recommendations
Nationally Determined Contribution (NDC) stipulates the following: - By 2030, ensure 25 per cent of households use electric stoves as their primary mode of cooking; - By 2025, install 500,000 ICS, specifically in rural areas; - By 2025, install an additional 200,000 household biogas plants.	**Gap(s):** The NEXSTEP analysis projects that Nepal may only reach a 72.3 per cent clean cooking access rate as per its current commitments. **SDG scenario:** The NEXSTEP analysis suggests bridging the remaining gap with electric cooking stoves as the most sustainable clean cooking solution.

7.3. Renewable energy

Existing policy	NEXSTEP analysis – gaps and recommendations
Nationally Determined Contribution (NDC) stipulates the following ambitions: - By 2030, expand clean energy generation from approximately 1,400 MW to 15,000 MW, of which 5-10 per cent will be from mini- and micro-hydropower, solar, wind and bioenergy. - By 2030, ensure 15 per cent of the total energy demand is supplied through clean energy sources (excluding large hydropower).	The renewable share in TFEC is projected to be 35.9 per cent in the CP scenario. **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 and NDC targets. The renewable energy share in TFEC is projected to be 39 per cent in 2030. The increase in renewable energy share is mainly attributable to the increase in energy efficiency in the SDG scenario, specifically through the uptake of electric vehicles and more efficient residential cooking stoves.

7.4. Energy efficiency

Existing policy	NEXSTEP Analysis – Gaps and recommendations
National Energy Efficiency Strategy 2018 stipulates a goal of doubling the average improvement rate of energy efficiency from 0.84 per cent, per year (between 2000-2015) to 1.68 per cent, per year in 2030. Ambitions and targets stipulated in the **NDC document** also contribute towards energy intensity reduction.	**Gap(s):** NEXSTEP analysis proposes an annual energy efficiency improvement rate target of 2.98 per cent, which is double the annual improvement rate for the 1990-2010 period. NEXSTEP recommends that the target stipulated in the national energy efficiency strategy to be revised, raising the target in adherence to the SDG target. The CP scenario is projected to achieve the energy efficiency target, with an energy intensity of 2.96 MJ/USD_{2011} in 2030. **SDG scenario:** Building on the CP scenario, the energy intensity is further reduced to 2.46 MJ/USD_{2011} in 2030, as the clean cooking access rate being raised to 100 per cent, through the adoption of electric cooking stoves. The projected annual improvement rate of the SDG scenario is 4.2 per cent. **EE Scenario:** There are ample of opportunities for Nepal to raise its ambition. Measures proposed in the EE scenario have the potential to reduce its energy intensity by an average annual rate of 5.9 per cent.

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 has presented a number of different scenarios together with their technical feasibility, investments, benefits, challenges and opportunities to inform policymakers of different pathways to energy transition. Some scenarios have looked beyond just achieving SDG 7 targets, and have explored the full potential of the country in relation to improving energy security by shielding the energy sector from supply and price shocks as well as to enhance the climate resilience of the energy sector.

Nepal is expected to achieve universal access to electricity by 2024. However, although several plans have been outlined by the Government, achieving universal access to clean cooking fuel is far off the target. If fully implemented, the Government's plan to offer improved cooking stoves and biogas digesters will increase the access rate to 72.3 per cent in 2030, leaving 2 million households cooking with unclean technologies. It is recommended that Nepal takes advantage of its clean electricity to roll out electric cooking stoves to connect the remaining population with clean cooking technologies. Several demonstration and research projects are currently ongoing to test the feasibility of electric cooking stoves, e.g., under the umbrella of AEPC, which will provide sufficient data to roll out an efficient and successful programme.

The major concern of the energy sector of Nepal is the heavy reliance on imported fossil fuel, particularly oil products. 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 and should be the main focus, as this sector represents 52 per cent of Nepal's energy consumption, particularly via the adoption of clean cooking technologies. Nepal has the potential to increase its ambition beyond what is needed for the SDG 7 energy efficiency target and to further reduce energy consumption in all sectors, with the key focus on the residential and transport sectors. For example, the introduction of MEPS for household appliances and increasing the penetration of electric space heating are key policy areas to consider, whereas in the transport sector the promotion of electric vehicles will result in substantial energy savings. These measures will eventually reduce the energy sector's reliance on imported petroleum fuel.

The Second Nationally Determined Contribution has set an ambitious target for the power sector that, if achieved, will see Nepal progress strongly on the sustainable and low-carbon energy transition path. Although most of the targets mentioned are conditional, and to be implemented with international financial contributions, it has stipulated several emission reduction measures to be implemented and achieved by 2030. The NDC target of increasing electric cooking stove use to 25 per cent is in line with the recommendation of this roadmap; however, it suggests increasing this target further to 52.7 per cent. Remote areas can be served with improved cooking stoves and biogas digesters.

The power capacity expansion plan that has been outlined in the NDC document is achievable with the renewable energy resources available in the country. However, once installed, the generation capacity is expected to be higher than the required capacity for meeting the demand in 2030. The NDC document also suggests an additional 5GW of capacity be installed for electricity exporting, in addition to the surplus generation mentioned above. Export of electricity will bring in foreign income, which is good for the economy; however, the Government may wish to carefully examine the cross-border power trade potential, and implement capacity expansion accordingly to avoid losses from energy curtailment.

Finally, the energy transition pathway presented in this SDG 7 roadmap will support rebuilding better after the COVID-19 pandemic. The proposed energy transition presents opportunities to reduce economic risks, both for public and private investment, and identifies areas for financial savings in the energy sector that can support the recovery of other critical sectors, such as the health sector.

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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 5. Targets and indicators for SDG 7

Target	Indicators	2019	2030
7.1. By 2030, ensure universal access to affordable, reliable, and modern energy services.	7.1.1. Proportion of population with access to electricity.	86%	100%
	7.1.2. Proportion of population with primary reliance on clean fuels and technology for cooking.	46.5%	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.	21.3% (excluding traditional biomass)	38.8%
7.3. By 2030, double the global rate of improvement in energy efficiency.	7.3.1. Energy intensity measured as a ratio of primary energy supply to gross domestic product.	4.12 MJ/US$ (2011) PPP	2.46 MJ/US$ (2011) 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 2011 PPP.

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

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

where is energy intensity in year t1 and is energy intensity in year t2.

Base period improvement rate for Nepal (1990 – 2010): 1.49 per cent.

SDG 7.3. improvement rate for Nepal (doubling of base period improvement rate): 2.98 per cent.

SDG 7.2. Renewable Energy

The renewable energy share in total final energy consumption is increased to meet NDC emission requirements by 2030.

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 6. GDP, PPP and growth rate

Parameter	Value
GDP (2019)	30.64 billion
PPP (2019, constant 2011 US dollar)[34]	94.2 billion
Growth rate	3.11%

Table 7. Population, population growth rate and household size

Parameter	Value
Population (2019)	29.6 million
Population growth rate	1.355%
Number of households (2018)	6.34 million
Household size (constant throughout the analysis period)	4.67

(b) Demand-side assumptions

(i) Industry

The industrial GDP is estimated to be 17.67 per cent of the total GDP in 2019. It is assumed that the industry sector will grow at an annual growth rate of 3.11 per cent, similar to the GDP growth rate. The industrial sector is further split into 10 different subsectors with an estimated baseline energy consumption as provided in table 8. The energy intensity is projected to remain constant, unless energy savings interventions have been taken (i.e., as modelled in the EE scenario).

34 2019 is extrapolated based on 2018 data provided at https://wits.worldbank.org/countryprofile/en/country/NPL/startyear/2014/endyear/2018/indicator/NY-GDP-MKTP-PP-KD (accessed on 2 July 2021), assuming an annual growth of 3.11 per cent.

Table 8. Consumption in 2019

Subsector	Share of total industrial demand (%)	Consumption in 2019 (ktoe)			
		Electricity	Oil	Coal	Biomass
Food and Beverages	40.3	244.6	57.4	243.8	141.9
Chemical and synthetic products	4.9	15.6	11.6	37.8	18.8
Glass, cement and non-metals	34.7	111.1	82.6	268.8	133.3
Iron and steel	4.8	8.7	3.6	49.2	20.4
Pulp and paper	0.6	0.8	8.0	1.2	0.3
Textile and leather	3.1	8.9	5.8	33.7	4.3
Machinery and transportation equipment	9.64	0.9	0.6	3.5	0.5
Wood and other products	1.61	0.6	0.5	154.2	9.5
Other processing industry	0.02	0.1	0.1	25.7	1.6

(ii) Transportation

Table 9 shows the estimated 2019 land transport activity for the different vehicle types, in absolute values and in percentage shares. The transport activity is assumed to grow at a rate of 1.355 per cent, similar to population growth rate.

Table 9. Land transport

Passenger transport	Billion passenger-kilometres, 2019	Share of vehicle activity in 2019 (%)
Cars	9.1	7.2
Motorbikes	18.9	15.1
Taxis	3.5	2.7
Buses	80.6	64.2
Auto rickshaw	3.4	2.7
Minibuses	7.5	5.9
Tractors	3.5	2.0
Freight transport	**Billion tonne-kilometres in 2019**	**Share of vehicle activity in 2019**
Trucks	21.0	90.8
Freight vans	2.1	9.2

(iii) Commercial sector

The total floorspace and estimated baseline energy consumption of the commercial sector is as provided in table 10. The energy intensity is projected to remain constant, unless energy savings interventions have been taken (i.e., as modelled in the EE scenario). The total floorspace is projected to grow at an annual rate of 3.11 per cent (table 10).

Table 10. Total floor space and energy consumption in 2019

Subsector	Floor space (million m^2)	Consumption in 2019 (ktoe)				
		Electricity	LPG	Coal	Biomass	Others
Private office	27.38	6.9	8	1	5	0.2
Government building	29.18	7.96	13	4	72	0.3
Shopping mall	41.30	25.05	15	0	0	8.0
Hotel	2.64	17.26	101	136	205	6.0
Hospital	5.20	2.37	7	1	7	0.2
University	19.56	3.81	8	1	17	1.0
Religious temple	1.93	6.91	0.1	0	2	0.2

(iv) Other sectors

The fuel usage in the other sectors are shown in tables 11 and 12.

Table 11. Energy consumption in the other sectors, 2019

Fuel type	Consumption in 2019 (ktoe)
Diesel	164
Kerosene	164

Table 12. Power sector assumptions[35]

Technology	Capital cost (million US$/MW)	Fixed O&M (million US$/MW-year)	Capacity factor
Solar (utility scale)	0.66	0.038	20%
Large hydro	2.45	0.015	51% (average)
Micro-hydro	3.57	0.072	25%
Mini-hydro	3.57	0.072	25%

35 The cost figures reference cost data provided by AEPC, except for large hydro. The capital cost for large hydro references the cost data provided for India in IEA and ECD/NEA, 2020..

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 (tables 13 and 14). 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 13. Technology and cost data for clean cooking technologies

Technologies	Efficiency[36] (%)	Lifetime[37] (years)	Stove Cost[38] (US$)	Variable O&M[39] (US$/year)	Fuel Cost[40] (US$)
ICS	35	4	35	10	0.03 per kg
LPG stove	56	7	56	10	0.85 per kg
Biogas Digester	50	20	950	50	-
Electric stove	84	15	40	10	1.07 per kWh

IV. Assumptions used in appliance annualised cost and electricity cost savings calculations

Table 14. Assumptions used in appliance annualised cost and electricity cost savings calculation

Appliance	Incremental Capital Cost (USD)	Annual Electricity Savings (kWh/year)	Comments
Air conditioner	170	219	Lifetime of 12 years, running 3 hours, 365 days; 1 ton capacity
Refrigerators	255	434	Lifetime of 12 years; 200-250L storage capacity
Televisions	170	246	Lifetime of 12 years, running 5 hours, 365 days; 40-inch colour TV
Electric fans	12.75	7.2	Lifetime of 12 years, running 6 hours, 120 days; 1200mm sweep
Water pumps	25.5	80.3	Lifetime of 12 years, running 2 hours, 365 days; 1 horsepower
Washing machines	85	94	Lifetime of 12 years, 2 washes each week
Lighting	1.3175	76.65	Lifetime of 2 years (incandescent) and 3 years (LED); 450 lumens

36 Sourced from: ICS – own estimation, LPG stove and biogas digester efficiency ranges (World Bank, 2014), electric cookstove (induction stove) (IEA, 2012).
37 Sourced from: ICS – own estimation, LPG stove (Clean Cooking Alliance, 2021), biogas digester (Wang and Zhang, 2012) and electric stove (IEA, 2012).
38 Sourced from: ICS – own estimation, LPG stove and biogas digester – (IRENA, 2017), electric cookstove cost range (Putti and others, 2015).
39 Variable O&M is based on own assumptions, with the exception of biogas digester (IRENA, 2017).
40 Wood cost is assumed opportunity cost related to wood collecting activities, LPG price is quoted as 1400 Rs per 14.2 kg(https://www.ktm2day.com/petrol-diesel-lpg-gas-aviation-fuel-price-in-nepal/), Electricity price is quoted as US$ 0.069/kWh. Available at https://www.globalpetrolprices.com/Nepal/electricity_prices/

V. Assumptions used in MAC calculations for the transport sector

Table 15. Assumptions used in MAC calculations for the transport sector

Measures/actions	Comments
Electric private 4-wheelers	Incremental capital cost of US$6800, lifetime of 12 years
Electric public 4-wheelers	Incremental capital cost of US$6800, lifetime of 12 years
Electric 2-wheelers	Incremental capital cost of US$425, lifetime of 14 years
Electric buses	Incremental capital cost of US$55,250, lifetime of 15 years
Electric rickshaw	Incremental capital cost of US$425, lifetime of 15 years
Electric minibuses	Incremental capital cost of US$22,100, lifetime of 15 years

VI. Summary results for the scenarios

	CPS scenario	SDG scenario	High Energy Efficiency scenario
Universal access to electricity in 2030	100%	100%	100%
Universal access to clean cooking in 2030	72.3%	100%, via electric cooking stove	100%, via electric cooking stove
Energy efficiency in 2030	2.96 MJ/US$	2.46 MJ/US$	2.11 MJ/US$
Renewable energy share in TFEC in 2030	35.9%	39.0%	41.2%
GHG emissions in 2030	16.7 $MTCO_{2-e}$	15.9$MTCO_{2-e}$	13.0 MTCO2-e
Power generation optimization	Expansion plan stipulated in the NDC	Expansion plan stipulated in the NDC	Expansion plan stipulated in the NDC
Renewable energy share in power generation in 2030	100%	100%	100%
Net benefits from the power sector	US$ - 5.97 billion	US$ - 4.20 billion	US$ - 4.05 billion
Total investment for the power sector	US$ 37.1 billion	US$ 37.1 billion	US$ 37.1 billion