Energy Transition Pathways for the 2030 Agenda

SDG 7 Roadmap for Tonga

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

NEXSTEP
National Expert SDG Tool for Energy Planning

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

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

The Kingdom of Tonga has been working to develop its energy sector in line with the targets set out in SDG7. As an island nation, energy is a critical input to the wellbeing and economy of the country, underpinning its trade, transport and services.

Tonga's Sustainable Development Goal 7 Road Map highlights that good progress has been made on many of the targets of SDG7. It underscores that continued progress will be assisted by an integrated policy framework. The Road Map is intended to play this role in helping Tonga achieve its SDG and NDC targets by providing a matrix of technological options and enabling policy measures. Its scenarios have been developed using national data and take into account existing energy policies and strategies, together with the NDC. It offers recommended technology solutions and policy options for reducing emissions, saving energy, lowering costs and improving access for all.

It is hoped that the analysis in the Road Map will help the Government of Tonga to make an informed decision to develop and implement a set of policies to achieve SDG 7 by 2030 and deliver on its NDC.

Tonga is among the first countries in the region to develop an SDG7 road map. This experience will help other countries in the region looking to understand how they can realize increased ambition on sustainable energy.

ESCAP is committed to continue to support Tonga and all its member States in delivering a secure, resilient and sustainable energy future as it builds back better from COVID-19.

Hongpeng Liu

Director, Energy Division, ESCAP

Foreword: Tonga

It is my pleasure to provide the foreword for this, the first Report on the Tonga Energy Roadmap 2010-2020. This Roadmap for achieving Sustainable Development Goal 7 (SDG 7) presents a detailed assessment aimed at helping the country to reach a clean and green energy future and in particular achieve its national energy targets under NDC and TERM Plus. It details a range of technical opportunities and policy options for reducing emissions, saving energy and lowering costs. The Roadmap offers an opportunity to leverage a least-cost sustainable energy development pathway, and to direct the investment savings to other critical sectors. The National Expert SDG Tool for Energy Planning (NEXSTEP) will enable policymakers to make informed policy decisions to support the achievement of the SDG7 targets as well as emission reduction targets (NDCs).

From the Government of Tonga's perspective, the development of the Roadmap has required unprecedented access to government ministries and one of the state-owned enterprises (Tonga Power Limited) by the country's development partners to enable them to clearly identify the underlying problems and, therefore, identify optimum and targeted solutions. This has not always been an easy process, as it has stretched the resources and capacity of some of the government entities. Hard questions have also had to be asked in relation to the adequacy of government processes in areas of governance, effectiveness, transparency and accountability.

Energy is a fundamental building block for the Kingdom in its social and economic development, and in enhancing the livelihood and wellbeing of all Tongans. It affects all businesses and every household. Accessible, affordable and sustainable electricity that is environmentally responsible and commercially viable is a high priority. My Government recognizes the importance of having dependable, accessible and reasonably-priced power as a key catalyst for sustainable economic growth. Achievement of these goals is crucial to achieving the Government's primary target of "poverty alleviation", including100% accessibility to electricity.

I commend this Roadmap and the information it contains and hope that its impacts will benefit all.

'Ofa atu

Mr. Paula Ma'u

CEO for Ministry of MEIDECC

January, 2021

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Abbreviations and acronyms

BAU	business-as-usual
BESS	battery energy storage system
CBA	cost benefit analysis
CFL	compact fluorescent light
CNO	coconut oil
CO2	carbon dioxide
CPS	current policy scenario
CTCN	Climate Technology Centre and Network
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
GEF	Global Environment Facility
GHG	greenhouse gas
ICS	improved cooking stove
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
JNAP2	Joint National Action Plan on Climate Change and Disaster Risk Management
ktCO2-e	thousand tonnes of carbon dioxide equivalent
kTOE	thousand tonnes of oil equivalent
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LEAP	Long-range Energy Alternatives Planning
LED	light-emitting diode
LPG	liquified petroleum gas
MCDA	Multi-Criteria Decision Analysis
MEIDECC	Ministry of Meteorology, Energy Information, Disaster management, Environment, Climate Change and Communications
MEPS	minimum energy performance standard
MJ	megajoule
MTF	Multi-Tier Framework
MW	megawatt
MWh	megawatt-hour
NDC	nationally determined contributions
NEXSTEP	National Expert SDG Tool for Energy Planning
NREL	National Renewable Energy Laboratory
OIREP	Outer Island Renewable Energy Project
PCREEE	Pacific Centre for Renewable Energy and Energy Efficiency
PIREP	Pacific Islands Renewable Energy Project
PP	power plant
PV	photovoltaic
RE	renewable energy
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
SPC	Pacific Community
TERM	Tonga Energy Roadmap
TFEC	total final energy consumption
TPL	Tonga Power Limited
TPES	total primary energy supply
TSDFII	Tonga Strategic Development Framework 2015-2025
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, more importantly, consider and capitalize on the interlinkages between Sustainable Development Goal 7 (SDG 7) and other SDGs. In this connection, ESCAP has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as emission reduction targets – 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 is to assist the Government of Tonga to develop enabling policy measures for achieving the SDG 7 targets. It 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 of Tonga to make an informed decision to develop and implement a set of policies to achieve SDG 7 by 2030, together with the NDC.

A. Highlights of the Roadmap

Tonga has been making good progress towards achieving the SDG 7 targets, but more needs to be done to achieve all SDG 7 targets by 2030 through a concerted effort and the establishment of an enabling policy framework. Tonga is on track to achieve the universal access to electricity by 2021, which contributes to bringing the Government a step closer to alleviating poverty.

Currently, close to 35 per cent of the Tonga's population still relies on unclean cooking technologies and fuels. A remarkable progress in clean cooking access is projected under no policy interventions, yet more governmental commitment and targeted measures are required to bring the access rate to a 100 per cent. The energy efficiency target, in accordance with an annual improvement rate of 0.07 per cent, can be readily achieved under the current policy settings through the gradual transition from low efficient to more efficient cooking technologies as well as the projected ramp-up in renewable energy generation. Nevertheless, Tonga may not achieve its NDC target without increasing its planned renewable power capacity.

There are ample of opportunities for Tonga to raise its ambitions beyond achieving the SDG and NDC targets, while offering multiple benefits. Energy savings in the residential and commercial sectors through phasing-out of inefficient appliances allows reduction of electricity demand which, in turn, reduces the need for power sector investment. Sustainable transport strategies – such as encouraging the electrification of vehicle fleets – will not only reduce GHG emissions but also enhance Tonga's energy security by reducing the reliance on imported fuels. Diversification of fuel for power generation that focuses on exploiting the full potential of indigenous sources should also be Tonga's key priority. The levelized cost of electricity from renewable power technologies has experienced a steep decline, becoming economically more competitive than the conventional fossil-fuel-based technologies. A low carbon power sector is not only economically feasible, it may also be the optimal way forward considering its imperativeness in climate change mitigation and energy security enhancement.

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

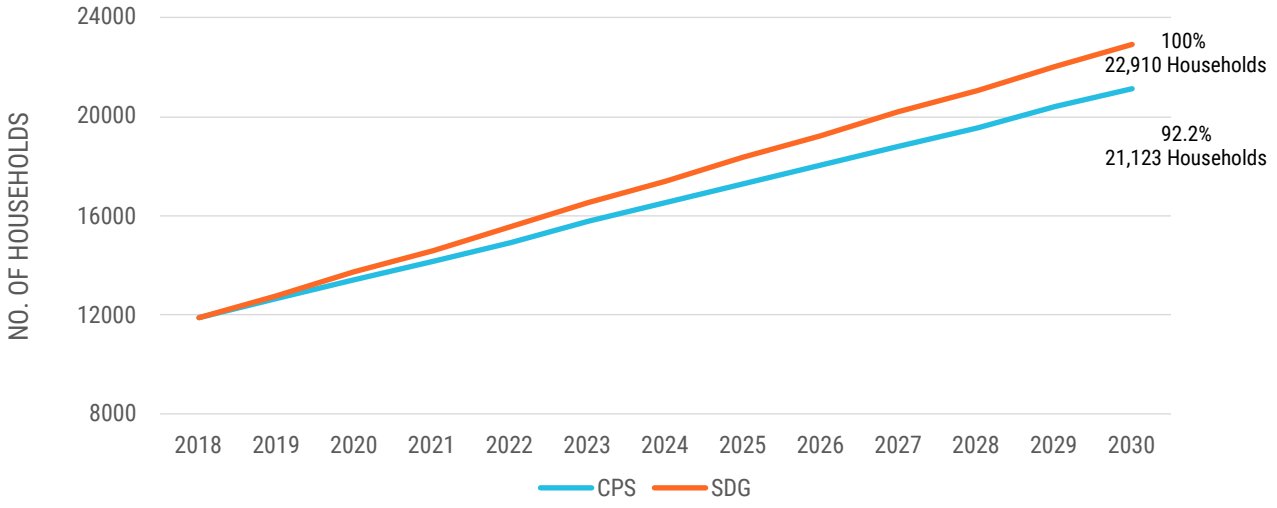
Universal access to electricity

Tonga is on-track to achieve universal access to electricity by 2021. Achieving universal access to electricity is a priority for the Government of Tonga, The Tonga Energy Roadmap (TERM) states that Tonga should achieve 100 per cent access to electricity by 2020 (Government of Tonga, 2010). Achievement of this target is crucial to meet the Government's primary target of "poverty alleviation". Based on geographic location of the households that have yet to be connected, NEXSTEP suggests that off-grid PV mini-grid technology would be more cost-effective and would enable faster implementation.

Universal access to clean cooking

Tonga does not have a specific policy for achieving universal access to clean cooking. NEXSTEP analysis shows that the current rate of improvement is not enough to achieve universal access to clean cooking (figure ES 1). In the current policy settings, access to clean cooking will increase from 65.3 per cent in 2018 to 92.2 per cent in 2030, which leaves about 8,000 people (1,787 households) relying on inefficient and hazardous cooking fuels and technologies. Tonga needs to increase its efforts to achieve universal access to clean cooking fuels. NEXSTEP analysis indicates that LPG cooking stoves is the recommended option, based on affordability, high efficiency and reduced indoor air pollution for the remaining 8,000 people by 2030.

Figure ES 1. Tonga access to clean cooking



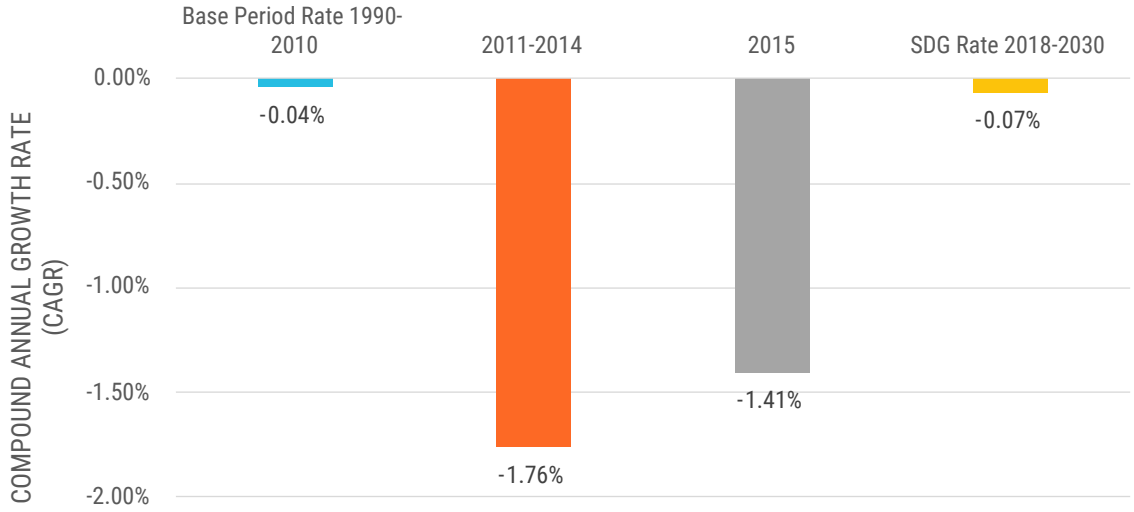
Renewable energy

The share of renewable energy in total final energy consumption (TFEC) was 25.2 per cent (including traditional biomass) in 2018. Based on current policies, the share of renewable energy will decrease to 15.2 per cent by 2030, mainly due to the substitution of traditional biomass cooking stoves by LPG cooking stoves. In the SDG scenario the share of renewable energy in TFEC will be 17.7 per cent by 2030. The increase will require a high penetration of renewable energy in the power sector, with a renewable energy capacity addition of 26 MW of solar PP and 8 MW of wind PP by 2030, compared with current plans of 18 MW of solar PP and 6 MW of wind PP in the Tonga Power Limited Business Plan. Looking further, diesel-fired power plants beyond 2020 are seen to be an uneconomic option as the lifecycle cost of renewable-based power generation is substantially cheaper than the fossil fuel counterpart.

Energy efficiency

The current trend of energy intensity reduction indicates that Tonga will achieve its energy efficiency target by 2030. The SDG rate requires annual improvement of 0.07 per cent of primary energy intensity (figure ES 2) to achieve the SDG 7 target of 2.94 MJ/$ by 2030, a slight drop from 2.97 MJ/$ in 2018.

Figure ES 2. Tonga energy efficiency target



There are ample opportunities for Tonga to achieve this target as well as even implement a higher rate of improvement. These include, for example, introducing minimum energy efficiency standard (MEPS), rapidly deploying electric vehicles and improving energy efficiency in new commercial buildings. These opportunities are discussed in later sections of this report.

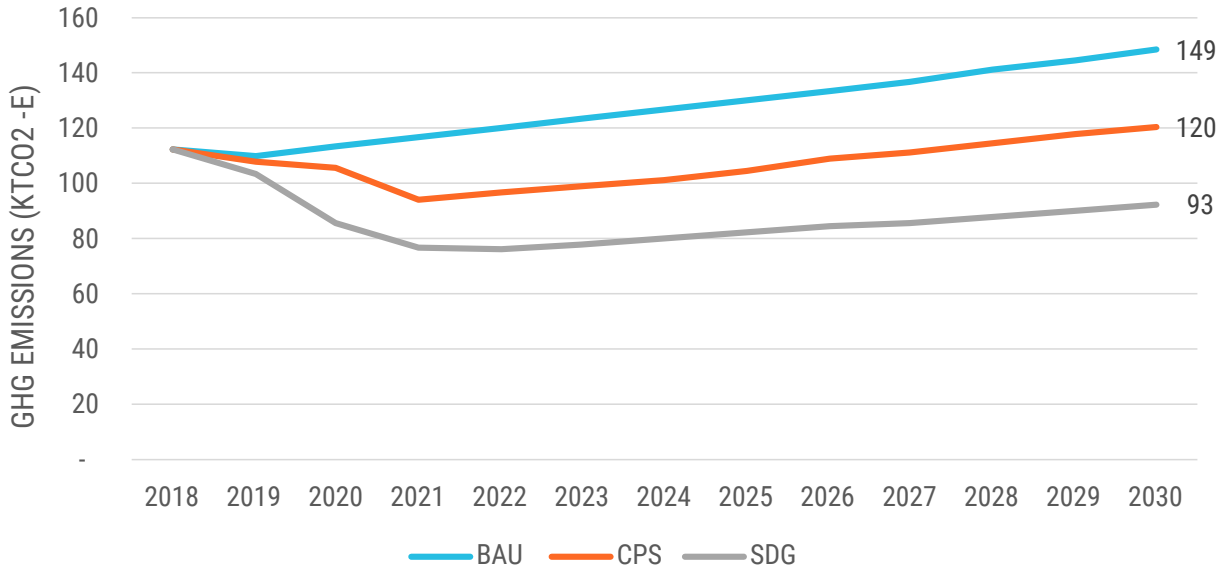
Nationally determined contributions

Tonga makes negligible contribution to global greenhouse gas emissions and is not obliged to have any emission target as per the NDC document. Tonga's intended national contribution targets cascaded at the energy sector level are (Kingdom of Tonga, 2015):

- Fifty per cent renewable energy in electric power generation by 2020 will be achieved in the 2020-2021 fiscal year, based on current policies. The share of renewable energy in electric power generation is projected to be 24 per cent in 2020, increasing to 55 per cent in 2021, as per the TPL plan. The target will be achieved a year late due to implementation delays caused by COVID-19.
- The second target of 70 per cent renewable energy in electric power generation by 2030 may not be achieved, based on current policies, and additional investment is required. The share of renewable energy in power generation, as per the TPL plan, will range between 52 per cent and 55 per cent during 2021-2030.
- Improved energy efficiency through reduction of electricity line losses to 9 per cent by 2020 (from a baseline of 18 per cent in 2010).

Emissions in the current policy scenario will reach 120,000 tCO_2-e (ktCO2-e) by 2030, about a 20 per cent drop from the baseline. Emissions in the SDG scenario will be 93 $ktCO_2$-e in 2030 which is set to achieve the NDC targets for renewable energy the power sector (figure ES 3).

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



C. Important policy directions

The key policy recommendations to help Tonga achieve SDG 7 and NDC targets as well as enhance energy security and build back better from the COVID-19 pandemic, include:

- **Improving energy efficiency beyond the SDG 7 target is economically feasible and will help to reduce fuel import dependency.** Negative and low-cost measures, including efficient lighting, Minimum Energy Performance Standards (MEPS), switching to electric transport and improving fuel economy standards, have a solid business case with a quick return on investment.
- **Tonga has the potential to achieve its NDC target of renewable electric power generation by increasing its ambition.** The SDG scenario recommends investments in solar and wind energy in line with the Tonga Power Limited Business Plan 2020-2025. However, the current plan of 52 per cent by 2030 can be increased to 70 per cent, in line with TERM 2010-2020, by using an integrated approach of energy efficiency, energy storage to increase the capacity factor and prioritizing renewables with zero additional investments.
- **Diesel-fired power generation is no longer cost-effective compared with renewables, and new deployment of this technology should be avoided.** Least-cost optimization analysis suggests that lifecycle costs of renewables are cheaper than diesel-fired technologies. The results from optimization indicate early investments in renewables will generate greater benefits compared to late interventions.
- **Efforts to achieve universal access to clean cooking need to increase.** LPG cooking stoves are the recommended technology option to achieve this target for Tonga. Implementation of this programme will cost the Government of Tonga US$ 100,000, considering a full subsidization on the upfront stove costs for the households, to achieve universal access to clean fuels and technologies for cooking by 2030.

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1. Introduction

1.1 Background

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

1.2 SDG 7 targets and indicators

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

- **Target 7.1**: "By 2030, ensure universal access to affordable, reliable and modern energy services." Two indicators are used to measure this target: (a) the proportion of the population with access to electricity; and (b) the proportion of the population with primary reliance on clean cooking fuels and technology.
- **Target 7.2**: "By 2030, increase substantially the share of renewable energy in the global energy mix". This is measured by the renewable energy share in total final energy consumption (TFEC). It is calculated by dividing the consumption of energy from all renewable sources by total energy consumption. Renewable energy consumption includes consumption of energy derived from hydropower, solid biofuels (including traditional use), wind, solar, liquid biofuels, biogas, geothermal, marine and waste. Due to the inherent complexity of accurately estimating traditional use of biomass, NEXSTEP focuses entirely on modern renewables (excluding traditional use of biomass) for this target.
- **Target 7.3**: "By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production plus net imports, minus international marine and aviation bunkers, plus stock changes. For comparison purposes, GDP is measured in constant terms at 2011 PPP.

1.3 Nationally Determined Contribution

Nationally Determined Contributions (NDCs) represent pledges by each country to reduce national emissions and are the steppingstones 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. Key approaches to reducing emissions from the energy sector include increasing renewable energy in the generation mix and improving energy efficiency.

As a non-Annex I member country, Tonga is not obliged to encounter any greenhouse gas reduction or any constraining goals in terms of commitments under the Kyoto Protocol. In its NDC document Tonga intended national contributions cascaded at the energy sector level are:

- Fifty per cent of electricity generation from renewable energy sources by 2020.
- Seventy per cent of electricity generation from renewable energy sources by 2030.
- Improve energy efficiency through the reduction of electricity line losses to 9 per cent by 2020 (from a baseline of 18 per cent in 2010). This target has been achieved.

2. NEXSTEP methodology

The main purpose of NEXSTEP is to help design the type and mix of policies that would enable the achievement of the SDG 7 targets and the emission reduction targets (under NDCs) through policy analysis. However, policy analysis cannot be done without modelling energy systems to forecast/backcast energy and emissions, and economic analysis to assess which policies or options would be economically suitable. Based on this, a three-step approach has been proposed. Each step is discussed in the following sections.

2.1. Key methodological steps

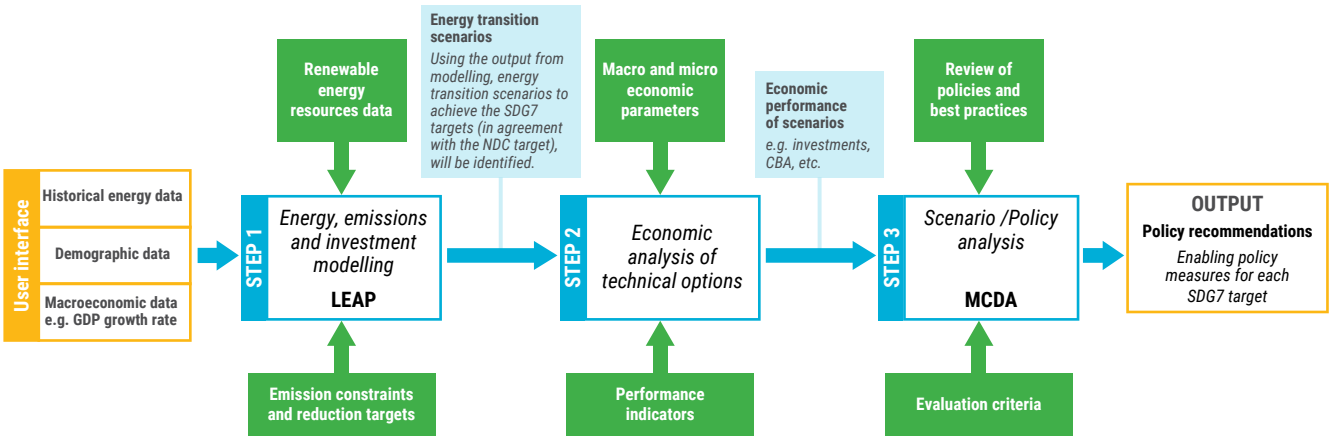
(a) Energy and emissions modelling

NEXSTEP begins with the energy systems modelling to develop different scenarios to achieve SDG 7 by identifying potential technical options for each scenario. Each scenario contains important information including the final energy (electricity and heat) requirement by 2030, possible generation/supply mix, emissions and the size of investment required. The energy and emissions modelling component use the Long-range Energy Alternatives Planning (LEAP). It is a widely used tool for energy sector modelling and to create energy and emissions scenarios. Many countries have used LEAP to develop scenarios as a basis for their Intended Nationally Determined Contributions (INDCs). The Least Cost Optimisation method is used to calculate the optimal expansion and dispatch of the electric power system. Figure 1 shows different steps of the methodology.

(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

Figure 1. Different components of the NEXSTEP methodology



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

selected technologies will help policymakers to identify and select economically effective projects for better allocation of resources. The economic analysis helps to present several economic parameters and indicators that would be useful for policymakers in making an informed policy decision.

(c) Scenario and policy analysis

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

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 Tonga, four main scenarios have been modelled – (a) a business-as-usual (BAU) scenario; (b) current policy scenario (CPS); (c) Sustainable Development Goal (SDG) scenario, and (d) ambitious scenario:

(a) The BAU scenario: This scenario follows historical demand trends, based on simple projections, by using GDP and population growth. It does not consider emission limits or renewable energy targets. For each sector, the final energy demand is met by a fuel mix reflecting the current shares in TFEC, 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 and modified from the BAU scenario, this scenario considers all policies and plans currently in place. These are, for example, the Tonga Energy Roadmap 2010-2020 and the Tonga Strategic Development Framework 2015-2025 (TSDFII);

(c) SDG 7 scenario: This scenario aims to achieve the SDG 7 targets, including universal access to electricity and clean cooking fuel, substantially increasing the renewable energy share and doubling the rate of energy efficiency improvement. For clean cooking, different technologies (electric cooking stove, LPG cooking stove and improved cooking stove) have been assessed, with the subsequent recommendation of the most appropriate technology. Energy intensity has been modelled to help achieve the SDG 7 target. Finally, the NDC target has been used to estimate the optimum share of renewable energy in TFEC;

(d) Ambitious SDG scenarios: Similar to the SDG scenario, these ambitious scenarios are aimed at achieving the SDG 7 targets. In addition, these scenarios also look to increase the socio-economic and environmental benefits

for the country from raising its ambition beyond just achieving the SDG 7 targets – such as creating cost-effectiveness by further improving its energy efficiency beyond SDG 7.3 target, or reducing GHG emissions beyond its NDC targets through decarbonising the power sector.

2.3. Economic analysis

This 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 to facilitate an efficient distribution of resources in public sector investment.

2.3.1. Basics of economic analysis

The economic analysis of public sector investment differs from a financial analysis. A financial analysis considers the profitability of an investment project from the investor's perspective. In an economic analysis the profitability of the investment considers 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 include 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 to the economic analysis. The overall project cost is calculated using:

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

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

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

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

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

(f) GHG abatement – avoided cost of CO_2 generation is calculated in monetary value based on carbon price. The 2016 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories are followed in the calculation of GHG emissions 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 MCDA tool, with a set of criteria and weights assigned to each criterion. Ideally, the weights assigned to each criterion should be decided in a stakeholder consultation. If deemed necessary, this step can be repeated using the NEXSTEP tool in consultation with stakeholders, where the participants may wish to change weights of each criterion, where the total weight needs to be 100 per cent. Although the criteria considered in the MCDA tool can include the following, stakeholders may wish to add/remove criteria to suit the local context:

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

3. Overview of Tonga's energy sector

3.1. Current situation

Country profile: The Kingdom of Tonga (Tonga) is a constitutional monarchy and a parliamentary democracy with a unicameral legislative assembly. Tonga is a Small Island Developing State (SID). It has integrated the implementation of 2030 Agenda for Sustainable Development, including the internationally-agreed blueprint for the sustainable development of small-island developing States and the SIDS Accelerated Modalities of Action Pathway (SAMOA Pathway) (United Nations General Assembly, 2014), in its national planning processes.

Geography: Tonga lies in the central south-west Pacific, between latitudes 15 to 23.5 south and longitudes 173 to 177 west. Tonga comprises an archipelago of 176 islands, covering a land area of 718 square kilometres and a sea area of 30 square kilometres (Kingdom of Tonga, 2019). The main island groups are Tongatapu, Ha'apai, Vava'u, 'Eua and Niuas.

Population: The population of Tonga declined from 101,352 people in 2011 to 100,651 people in 2018. During 2011-2018, the population decline averaged 0.1 per cent annually, which can be partially explained by emigration (Kingdom of Tonga, 2019). The Tonga National Census 2016 (Tonga Statistics Department, 2017) recorded 18,198 households with an average of 5.53 persons per household.

Economy: Tonga's gross domestic product (GDP) nominal was reported as US$ 514.1 million.[1] The services sector accounts for 62.4 per cent of GDP, with the primary supply coming from agriculture, forestry and fishing (19.4 per cent) and the industrial sector (18.2 per cent). The economy is dependent on remittances which totalled 27.4 per cent of GDP in 2017 (ADB, 2019). According to the World Bank, Tonga is classified as an upper-middle income country, with a GDP per capita US$ 4,364 (current US dollar) in 2018 (World Bank, 2020). During 2008-2018, Tonga experienced strong economic growth with an annual GDP per capita increase of 2.6 per cent.

Climate change risks: Tonga faces challenges similar to other Pacific island countries and is vulnerable to external shocks, high costs of climate change impacts and natural disasters, such as Cyclone Winston in February 2016 and Cyclone Gita in February 2018. According to the International Monetary Fund (IMF), Tonga suffered the highest loss from natural disasters (as a percent of GDP) in 2018, equivalent of 38 per cent of annual GDP from the Tropical Cyclone Gita (IMF, 2020).

Energy: The country's main energy policy is the Tonga Energy Roadmap 2010-2020 (TERM) – "A 10-year roadmap to reduce Tonga's vulnerability to oil price shocks and achieve an increase in quality access to modern energy services in an environmentally sustainable manner" (GoT, 2010). The TSDFII 2015-2025 and Climate Change Policy 2016 play a critical role for the energy sector.

3.2. National energy profile

Universal access to electricity in Tonga was reported as 96 per cent in 2018, based on data from Ministry of Meteorology, Energy Information, Disaster management, Environment, Climate Change and Communications (MEIDECC), leaving 4,026 people without electricity access. Tonga planned to achieve universal access to electricity by 2020, ensuring access to clean, secure, safe and sustainable grid and off-grid energy.

Universal access to clean cooking fuels is measured at 65.3 per cent, based on data from MEIDECC. Liquefied petroleum gas (LPG) is the main fuel used for cooking in Tong, with a share of 63.8 per cent of total households using the fuel for cooking in 2018, an increase from 52.3 per cent in 2010. Despite the progress in universal access to clean and modern cooking systems, traditional

1 Data from the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications.

biomass cooking stoves are used by 34.3 per cent of total households in Tonga, posing risks to health, environment and climate.

The renewable energy share in TFEC was calculated as 25.17 per cent in 2018. Figure 2 shows Tonga's electricity generation after losses. The planned installed capacity addition is based on data from the Tonga Power Limited (TPL) Business Plan 2020-2025 (TPL, 2020). The planned installed capacity was to meet the strategic objective of 50 per cent electricity generation from renewable energy sources by 2020. This includes 6 MW Sunergise Solar IPP, China Wind 2.2 MW, Wind IPP 3.8 MW, 6 MW GET Solar IPP and 6 MW Solar Farm Extension.

Current policy focus encompasses end-use energy efficiency and generation efficiency measures to reduce diesel fuel usage, and to promote financially and environmentally sustainable energy access. Under TERM, the goal is to improve system-wide energy efficiency by 18 per cent against a BAU scenario. This includes the reduction of diesel use by 50 per cent in power generation and the decrease in losses of power distribution. The NDC document stipulated a target for reducing the electricity line losses to 9 per cent, which was achieved in 2017.

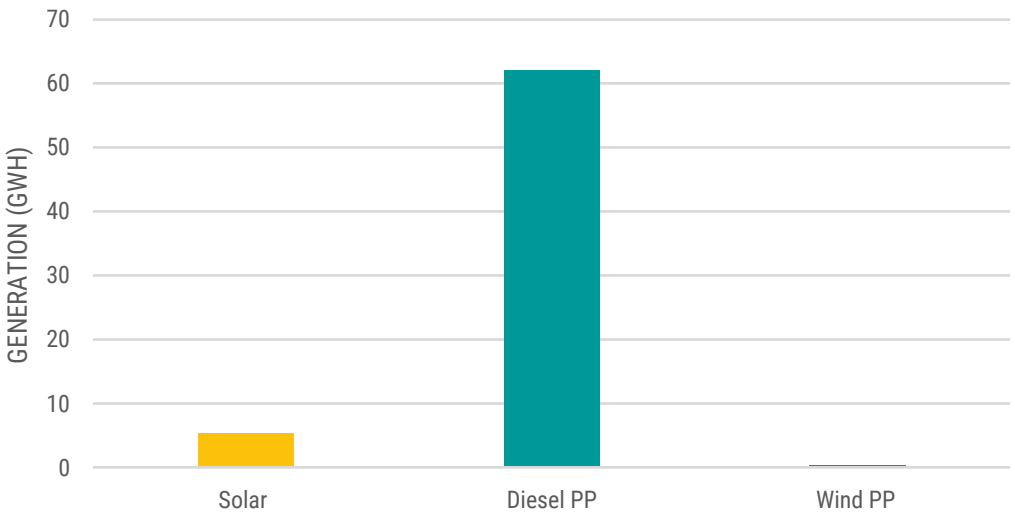
In addition, Tonga Power Limited is targeting about 5 per cent reduction in diesel use. TERM prioritizes demand-side management measures, particularly lighting, such as the use of LED or dimming for streetlights, and compact fluorescent lights (CFLs) in government, residential, commercial and religious sectors.

3.3. National energy policies and targets

Scenario development has been based on energy policies and assumptions, as summarized in table 1 as well as taking into consideration relevant policies (listed below) that are already in place (ESCAP, 2020).

- **Tonga Energy Roadmap 2010-2020** (GoT, 2010): The objective of TERM is to lay out a least-cost approach and implementation plan to reduce Tonga's vulnerability to oil price shocks, and to achieve an increase in quality access to modern energy services in a financially and environmentally sustainable manner. The recommendations include:
  - » Improvements in the petroleum supply chain to reduce the price and price fluctuations of imported petroleum products;
  - » Efficiency of conversion of petroleum to electricity (i.e., increases in efficiency and reduced transmission and distribution losses);
  - » Efficiency of conversion of electricity into consumer electricity services (i.e., end-use efficiency measures); and
  - » Replacing a portion of current or future grid-based generation with renewable energy.
- **TSDFII 2015-2025** – A more progressive Tonga: Enhancing our inheritance**.** The SDFII prioritizes universal access to modern energy sources, including decreased dependence on fossil fuels, increased utilization of renewable energy resources and improving energy

Figure 2. Tonga electricity generation after losses, 2018



efficiency is critical to the vision. The TSDFII targeted 48% of renewable energy usage by 2018, increasing to 50 per cent by 2025 (GoT, 2015).

- **Tonga Climate Change Policy –** A resilient Tonga by 2035. The policy is focused towards building a resilient Tonga by 2035 to encompass an integrated approach to adaptation, disaster risk reduction and mitigation. A target for 100 per cent renewable energy by 2035 is outlined (MEIDECC, 2016).
- **Renewable Energy Act 2008 –** The Act regulates the use of renewable energy in Tonga. It promotes the development of the renewable energy industry, establishes the Renewable Energy Authority and its functions and powers, and regulates renewable energy agreements. The primary purpose of this Act is to provide a legal framework to promote the utilization of renewable energy in Tonga, through the creation of a conducive and an enabling market environment (GoT, 2008).
- **Outer Islands Renewable Project –** The Tonga Outer Island Renewable Energy Project (OIREP) will construct Solar Photovoltaic (PV) power plants on eight outer islands, with a total installed capacity of 1.25 MWp (GEF, 2016).
- **Tonga Renewable Energy Project –** The Tonga Renewable Energy Project is a US$ 53.2 million that will construct a battery energy storage system (BESS) on the main island and the outer island and five solar mini-grids on five outer islands.
- **Tonga's Nationally Determined Contribution (NDC) –** Tonga's NDC outlines clear targets for reducing the Kingdom's contribution to climate change (Kingdom of Tonga, 2015):
  - » Fifty per cent of electricity generation from renewable energy sources by 2020;
  - » Seventy per cent of electricity generation from renewable energy sources by 2030;
  - » Improved energy efficiency through the reduction of electricity line losses to 9 per cent by 2020 (from a baseline of 18 per cent in 2010)

3.4. National energy resource assessment

Tonga has abundant renewable energy resource potential in solar, wind and biomass energy resources. The Pacific Islands Renewable Energy Project (PIREP) assessed the potential of renewable energy resources in Tonga. Solar energy has high potential in Tonga; satellite imagery indicates average insolation of up to 5.8 kWh/m2/day. According the National Renewable Energy Laboratory (NREL, 2010) the estimated solar energy potential is 767,297 MWh/per year. Wind energy resource data are limited in Tonga. A wind energy resource assessment on the main island of Tongatapu indicates annual mean wind speeds of 6.8 m/s (Palmer-Wilson, 2012). Biomass energy is limited to a small quantity of sawmill wastes associated with milling operations. Agricultural and forest wastes are not considered as exploitable energy resources in Tonga. Coconut oil (CNO) is a potential biofuel for substituting up to 50 per cent of imported diesel oil in existing engines. The resource assessment is based on estimates, and an in-depth study is required to ensure adequate supply for energy generation.

3.5. National energy balance

The national energy balance of Tonga, 2018, from MEIDECC is the starting point of the NEXSTEP analysis. Tonga is dependent on petroleum imports to meet energy demand requirements. The dependency is highlighted in TERM, which states that petroleum fuel accounts for 25 per cent of all imports and almost 10 per cent of GDP. Biomass, domestically sourced, is mainly used in the residential sector by households as a source of cooking fuel. The solar and wind power share in the Total Primary Energy Supply (TPES) is planned to increase due to investments in the renewable power project. Figure 3 shows that TPES of Tonga is 48,000 tonnes of oil equivalent (kTOE) by fuel share. Fuel shares in TPES are oil products (39 kTOE – 81 per cent) and biomass (9 kTOE – 19 per cent).

Total Final Energy Consumption (TFEC) in 2018 was reported as 37 kTOE (figure 4). Tonga's TFEC in 2018, by fuel, is led by oil products (23 kTOE – 62.7 per cent), biomass (9 kTOE – 24.7 per cent) and electricity (5 kTOE – p 12.6 per cent).

3.6. Energy modelling projections

The energy demand is calculated using the activity level and energy intensity in the LEAP model. Tonga's energy outlook for 2020-2030 is influenced by population growth of 0.2 per cent per annum, GDP growth of 0.7 per cent annually and energy elasticity for each sector. The methodology and assumptions are explained below for each

Figure 3. Total primary energy supply

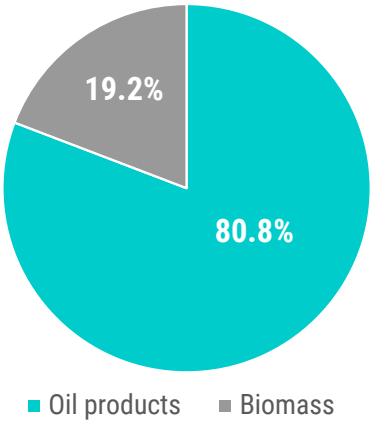
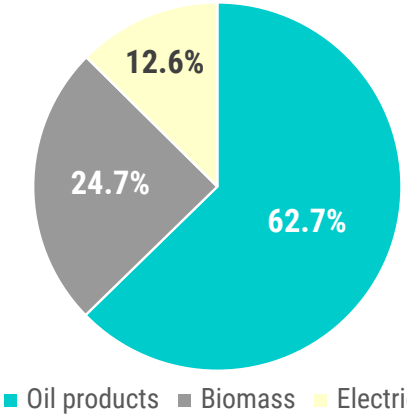


Figure 4. Total final energy consumption



demand sector and a summary is presented in table 1:

- Residential sector population growth is modelled at 0.2 per cent per year, household size decreases from 5.53 in 2018 to 4.5 by 2030 (SPC, 2016) and urbanization remains the same. Ownership of appliances is projected to increase over the period (NREL, 2018);
- The transport sector is influenced by the population growth rate of 0.2 per cent per year and an increase in passenger-km due to an increase in per capita GDP of 2.4 per cent per year (estimate). Freight-km is similar with a projected increase of 2.4 per cent per year over the period of analysis;
- The industry sector in Tonga is very small; however, it is projected to increase by 3 per cent annually;
- The commercial sector forecast is based on historical growth in commercial floor space during 2008-2018, which is extrapolated to 2035, while energy intensity remains constant;
- The agriculture sector is projected to increase at the same rate as the GDP growth rate of 0.7 per cent per year.

3.7. Energy demand outlook

3.7.1. Business as usual scenario

In the business-as-usual scenario, TFEC is expected to increase from 37 kTOE in 2020 to 40 kTOE in 2030. The current fuel mix in the energy system is expected to continue to 2030 in the absence of any major intervention. In 2030, the transport sector will have the largest share of TFEC at 25 kTOE (63 per cent), followed by the residential sector at 9 kTOE (23 per cent), commercial sector at 4 kTOE (10 per cent), industrial sector at 1 kTOE (3 per cent) and agricultural sector at 1 kTOE (3 per cent).

3.7.2. Current policy scenario

In the current policy scenario, TFEC is projected to show a similar growth rate from 37 kTOE in 2020 to 40 kTOE in 2030 (figure 5). The current fuel mix in the energy system is expected to continue to 2030 in the absence of any major intervention. In 2030, the transport sector will have the largest share of TFEC at 25 kTOE (63 per cent), followed by the residential sector at 9 kTOE (23 per cent), commercial sector at 4 kTOE (10 per cent), industrial sector at 1 kTOE (3 per cent) and agricultural sector at 1 kTOE (3 per cent). The sectoral overview of energy demand in the current policy scenario is discussed below.

(a) Transport sector

The transport sector's energy demand will continue to dominate Tonga's TFEC, and is projected to increase to 24.6 kTOE by 2030, compared with 18.5 kTOE in 2018. In 2030, the subsector share of transport energy demand will be passenger transport at 11.5 kTOE (47 per cent), freight at 11.6 kTOE (47 per cent) and aviation at 1.5 kTOE (6 per cent).

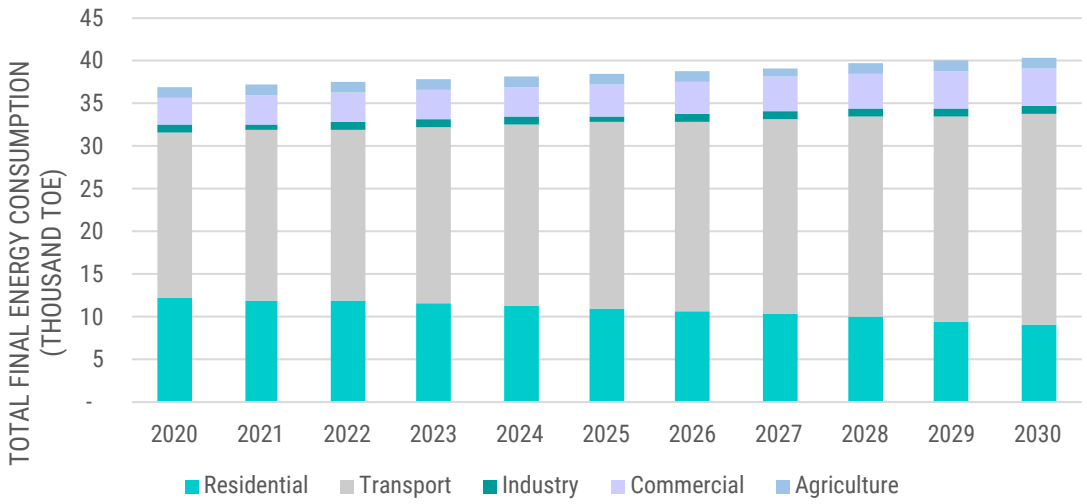
(b) Residential

The residential sector's demand in Tonga is projected to decrease to 9.2 kTOE by 2030, compared with 13 kTOE in 2018. In 2030, the subsector share of residential energy demand will be urban at 2.1 kTOE (23 per cent), and rural at 7.1 kTOE (77 per cent). The residential sector energy demand outlook is influenced by the replacement of traditional biomass cooking stoves (10-20 per cent efficiency) by energy efficient LPG cooking stoves (56 per cent efficiency).

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

Parameters	Business as usual	Current policy scenario	Sustainable Development Goal
Economic growth	0.7 per cent		
Population growth	0.2 per cent		
Population	100,651		
Household	18,198		
Household size	5.53 persons /household		
Commercial floor space	8,274,905.19 m^2 (MEIDECC data)		
Transport activity	Transport sector is influenced by population growth rate of 0.2% per year and an increase in passenger-km due to increase in per capita GDP of 2.4% per year (estimate).		
Access to electricity	2021: 100%	2021: 100%	2021: 100%
Access to clean cooking fuels	Based on historical rate of improvement	Based on historical rate of improvement and current policies	100 per cent access to clean cooking fuels and technologies by 2030
Energy efficiency	Remains constant	Improvement based on current policy	0.07 per cent annual improvement in TPES target achieved
Power plant	Based on 2018 share	TPL Business Plan 2020-2025	Based on least-cost optimization

Figure 5. Tonga's energy demand outlook, 2020-2030



(c) Commercial

The commercial sector's energy demand is projected to increase from 3 kTOE in 2018 to 4.3 kTOE in 2030. The sector is divided into existing buildings and new buildings. In 2030, the subsector share of commercial energy demand will be existing buildings at 3.1 kTOE (72 per cent) and new buildings at 1.2 kTOE (28 per cent). The commercial sector analysis is based on floor space occupied by the sector and the energy intensity per square metre.

(d) Industrial sector

Energy demand in the industrial sector was reported to be only 0.7 kTOE in 2018, since Tonga's manufacturing sector is very small and is projected to increase to 1.0 kTOE by 2030.

4. SDG scenario: Achieving SDG 7 by 2030

Access to affordable, reliable, sustainable and modern energy is essential to achieving the 2030 agenda for SDGs and the Paris Agreement on climate change. This chapter provides details of the SDG scenario. It starts with the energy demand forecast and then discusses the energy sector in relation to SDG goals and targets. It also examines the potential for Tonga in achieving the NDC unconditional target.

4.1. SDG energy demand outlook

In the SDG scenario, TFEC increases from 36 kTOE in 2020 to 38 kTOE in 2030. The reduction of 2 kTOE in TFEC in this scenario, compared to the other scenarios, is due to the improvement in energy efficiency as per the SDG 7 targets. In 2030, the transport sector will have the largest share of TFEC at 25 kTOE (66 per cent), followed by the residential sector at 7 kTOE (14 per cent), commercial sector at 4 kTOE (11 per cent), industrial sector at 1 kTOE (3 per cent) and agricultural sector at 1 kTOE (3 per cent). Figure 6 shows TFEC by scenarios in 2030.

4.2. SDG 7 targets

4.2.1. SDG 7.1.1. Access to electricity

Based on the historical improvement rate, Tonga is on track to achieve the universal access to electricity by 2021. The electricity demand in the SDG scenario will increase from 58 GWh in 2020 to 81 GWh in 2030.

4.2.2. SDG 7.1.2. Access to clean fuels and technologies for cooking

Under current policies, Tonga's population with access to clean fuels and technologies for cooking is projected to increase from 65.3 per cent in 2018 to 92.2 per cent in 2030. Despite this progress, Tonga will fall short of the target of universal access to clean fuels and technologies for cooking, with 8,041 people (1,787 households) relying on inefficient and hazardous cooking fuels and technologies.

In the SDG scenario, various technologies and options have been analysed and compared with the baseline technology to identify the most appropriate avenue to achieving this target. These include LPG cooking stoves, electric cooking stoves, improved cooking stoves and biogas cooking stoves.

4.2.3. Clean cooking technologies evaluated

(a) Electric cooking stoves

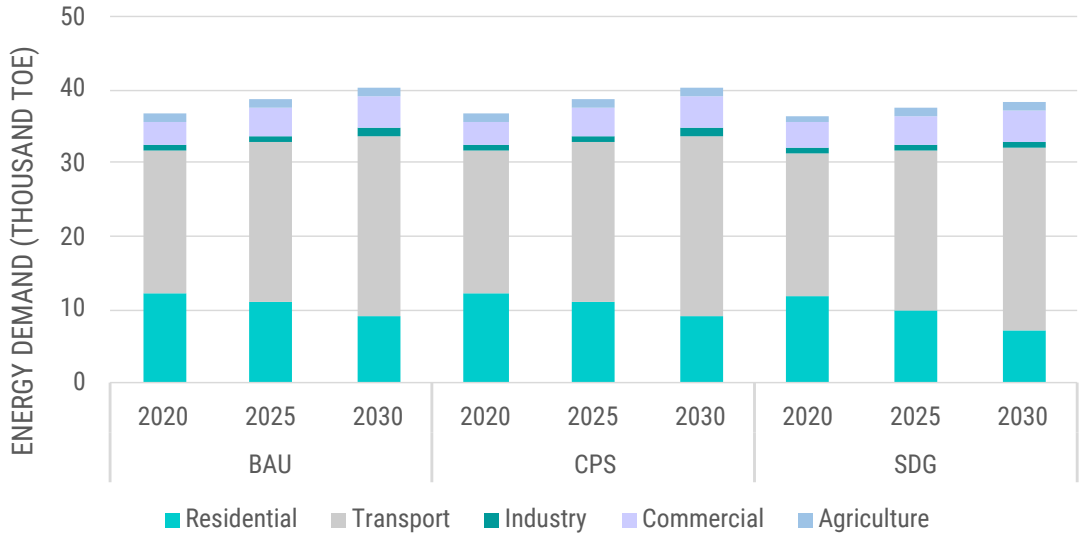
Tonga has renewable electricity generation potential and can use this generation to promote electric cooking stoves. The technology is classed as Level 5 in the World Bank MTF for Indoor Air Quality Measurement. Electric cooking stoves are more efficient than other types of cooking stoves, including gas stoves. Electric cooking stoves can be generally divided into two types – solid plate and induction plate. While solid plate uses a heating element to pass radiant energy onto the food and reaches about 70 per cent efficiency, induction plate cooking stoves use electromagnetic energy to directly heat pots and pans, and can be up to 90 per cent efficient.

However, feedback from the stakeholder consultation workshop suggests that the high electricity tariff of Tonga would be a challenge for the adoption of electric cooking stoves, as the rural households would not be able to afford the running cost of the technology.

(b) Improved cooking stoves

Studies suggest that ICS programmes often have low adoption rates due to inconvenience of use, preference for traditional cooking stoves, the need for frequent maintenance and repairs etc. ICS programmes initially require strong advocacy to promote adoption, after which they require ongoing follow-up, monitoring, training, maintenance and repairs in order to ensure continuing usage. Based on WHO guidelines for emission rates for clean

Figure 6. Projection of TFEC by sector, 2030, SDG scenario



cooking, only certain types of ICS technology comply, particularly when considering that cooking stove emissions in the field are often higher than they are in the laboratory settings used for testing. Based on the need for ongoing follow-up, ICS serves better as a temporary option, but is not best-suited as a long-term solution.

(c) Biogas digester

Biogas digesters have high upfront capital costs (about US$ 1,000 for a standard size that is suited for a four-member family) and require substantial subsidy due to their longer payback period. The technology is not favoured in rural areas due to the cultural aspects of using animal or human waste to use for cooking. In addition, a standard size biogas digester requires 2-4 cows, depending on the size of the cow, to produce enough feedstock for daily gas demand for a household.

(d) Natural gas stove

Clean cooking with natural gas is not a viable solution for rural households as it would require building agas distribution infrastructure, which is extremely difficult in remote locations. Table 2 summarizes annualized costs of different cooking technologies in the context of Tonga.

(e) LPG cooking stove

LPG in Tonga is constrained due to fuel import dependency and supply chain challenges. An LPG cooking stove creates less indoor air pollution compared with ICS. It is classified as Level 4 in the World Bank Multi-Tier Framework (MTF)[2] for cooking exposure, and reduces indoor air pollution by 90 per cent compared to traditional cooking stoves.

The feedback from the stakeholder consultation workshop suggests that cooking with LPG has two-fold advantages. First, it is very much culturally accepted and well-established in the community. Second, the running cost of LPG cooking stoves would be cheaper compared to electric cooking stoves; therefore, LPG cooking stoves would be more affordable than electric cooking stoves.

The NEXSTEP analysis estimates that achieving universal access to clean cooking with LPG will increase LPG imports in Tonga by about 20 per cent in 2030 when compared to a non-LPG approach, e.g., electric cooking stoves. However, based on other multiple benefits that LPG-based cooking will offer for Tonga, LPG cooking stoves are recommended for achieving universal access to clean cooking.

Table 2. Annualized cost of cooking technologies[3]

Technology	Annualized cost
ICS	US$ 24
LPG stove	US$ 104
Biogas digester	US$ 131
Electric stove	US$ 172

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

3 Cost and technological assumptions in calculating the annualised costs are listed in Annex III, table 14.

4.2.4. SDG 7.2. Renewable energy

SDG 7.2 does not have a quantitative target; however, an increase in renewable energy is required to meet the NDC target. 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 NDC target for the energy sector to estimate the renewable energy share in TFEC.

The share of renewable energy in TFEC in 2030 will be 15.3 per cent in the current policy scenario (figure 7). This increase is largely driven by an increase in the renewable energy share in power generation. In the SDG scenario, the renewable energy (RE) share in TFEC will need to increase to 17.6 per cent in order to reduce emissions and meet the NDC unconditional target, i.e., 50 per cent renewables share in power generation. As indicated above in the NEXSTEP methodology this is the optimum share of RE that considers the reduction of TFEC due to the improvement in energy efficiency as well as switching from biomass-based cooking stoves to LPG cooking stoves.

4.2.5. SDG 7.3. Energy efficiency

The primary energy intensity, a proxy for the measurement of energy efficiency improvement, is calculated as 2.82 MJ/$ in the current policy scenario and is projected to achieve the SDG rate of 2.94 MJ/$ in 2030. The rate of improvement in primary energy intensity is expected to increase by 0.4 per cent in the current policy scenario. The required improvement in primary energy intensity is 0.07 per cent and is achieved in the SDG scenario and all ambitious scenarios (figure 8).

Figure 7. Renewable energy in TFEC, 2030

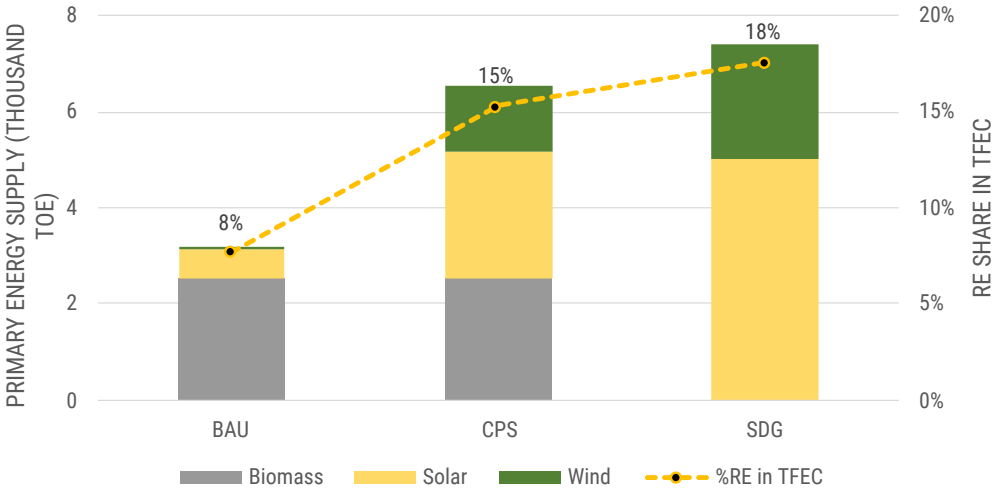
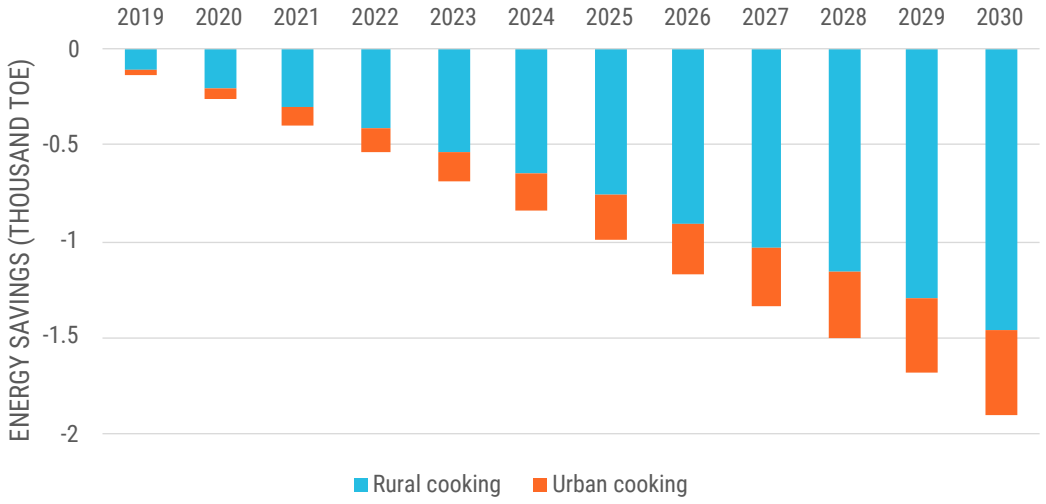


Figure 8. Energy efficiency savings in the SDG scenario



The calculation of the energy efficiency target for Tonga (0.07 per cent annual improvement in primary energy intensity) is explained below. The base period rate for calculating energy efficiency improvements is 1990-2010. World Bank data for primary energy intensity are used to analyse improvements in the base period. In 1990, the primary energy intensity for Tonga was 3.26 MJ/$, which only improved to 3.24 MJ/$ by 2010. The compounded annual growth rate (CAGR) for primary energy intensity improvements in the base period is 0.035 per cent. The SDG target for energy efficiency requires a doubling of the improvement in primary energy intensity, which is 0.07 per cent per year.

Tonga's required improvement in energy efficiency target is reached in the SDG scenario by achieving the universal access to clean cooking fuels and technologies by 2030. This is because the recommended technology option of LPG cooking stoves has higher energy efficiency (50-60 per cent) compared to traditional biomass cooking stoves' energy efficiency (10-20 per cent) – thereby leading to energy saving of about 2,000 TOE in 2030 compared to the current policy scenario. The NEXSTEP analysis is not limited to achieving the SDG target, and measures to achieve gains beyond are discussed in later sections of this report.

4.2.6. NDC unconditional target

Tonga does not have an emission reduction target as per the NDC document; the NDC target relates to the increase in renewable energy share in power generation. In the business-as-usual scenario, emissions are projected to reach 149,000 tonnes CO_2-e ($ktCO_2$-e). Emissions in the current policy and SDG scenarios will be 120 $ktCO_2$-e and 93 $ktCO_2$-e in 2030, respectively, which is set to achieve the NDC targets for the energy sector. Figure 9 shows emissions by sector in different scenarios. It also presents emissions from electricity generation. Sectoral emissions in figure 9 are demand-side emissions, where the emissions in the industry and residential sectors are primarily linked to heat production.

4.3. Power generation in the context of SDG 7

The demand for electricity in 2030 will be 81 gigawatt-hours (GWh) in the current policy scenario. The electricity demand in the commercial sector will be 43.3 GWh (53 per cent) and in the residential sector it will be 37.7 GWh (47 per cent). In the SDG scenario, the demand is expected to increase to 81 GWh, similar to the previous scenarios.

In terms of fuel mix in power generation, diesel-fired power will be the dominating source (42 per cent) of power generation in the business-as-usual and current policy scenarios. In the SDG scenario, high penetration of renewable energy will be needed to achieve the NDC target and to substantially increase the share of renewable energy in TFEC. Figure 10 shows shares of different renewable energy sources in different scenarios in 2030.

4.4. Policy actions for achieving SDG 7

4.4.1. Achieving universal access to electricity and enhancing climate resilience using off-grid renewable energy systems

Tonga is on track to achieve universal access to electricity by 2021. The rural electrification programme in Tonga should be based on renewable off-grid generation. The NEXSTEP analysis recommends off-grid renewable energy systems, e.g., RE-based mini-grid or solar home systems to improve climate resilience

Grid electrification is executed by the state-owned enterprise Tonga Power Limited. As of 2018, Tonga access to electricity was reported as 96 per cent, leaving 4,026 people (727 households) without access. In areas without access, households rely on candles, kerosene lamps or batteries for their needs. Achieving last-mile connectivity is a major challenge in developing countries due to remote communities and villages, complex terrain, low population densities, and levels of willingness and ability to pay in low-income households.

Tonga is particularly vulnerable to external climate shocks. In 2018, Tropical Cyclone Gita destroyed or caused severe damage to almost 2,000 homes, which led to the evacuation of more than 4,500 people and left 80 per cent of homes in Tonga without power (ReliefWeb, 2018).

According to the World Bank, off-grid solar home systems are a smart solution to address climate vulnerability and build resilience. For example, when Tropical Cyclone Pam caused damage in Vanuatu to 65 km of power lines, leaving 12,000

Figure 9. Emissions by scenario, 2030

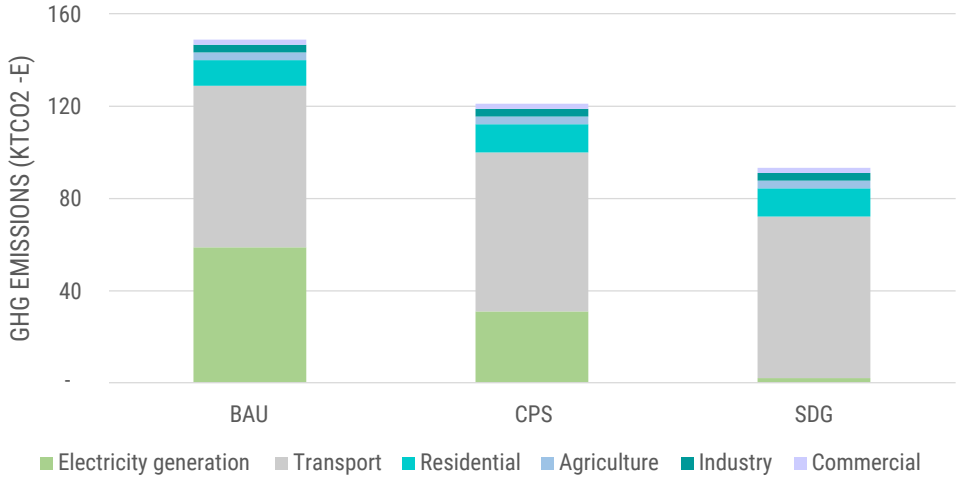
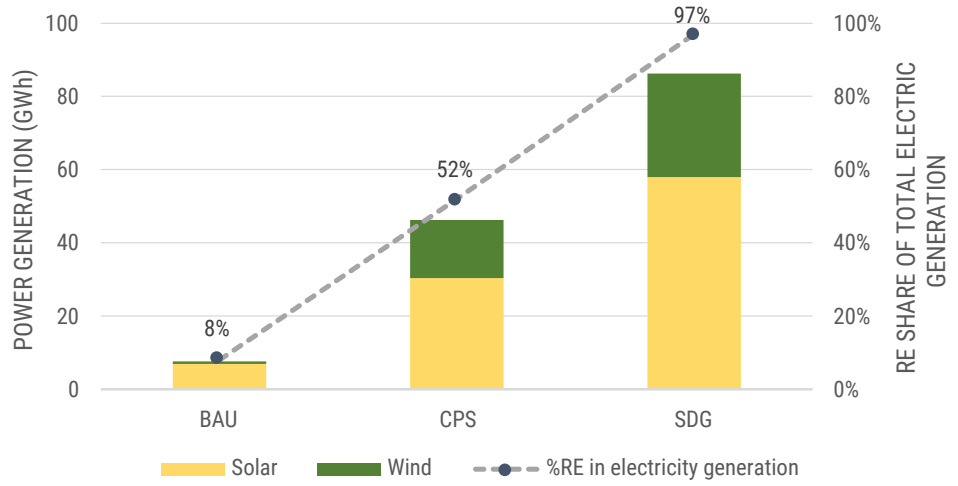


Figure 10. Renewable power generation, 2030



customers without power, residents with solar home systems prepared early for the storm by storing equipment inside homes.

Similarly, Bangladesh is also a good example with the implementation of solar home systems for 3.95 million customers to provide access to electricity and build resilience against storm surges (World Bank, 2017). Prioritizing awareness and building resilience to extreme weather events and climate change is crucial for Tonga. From an energy security perspective, increasing off-grid renewable energy generation will reduce dependency on fuel imports and increase self-sufficiency

4.4.2. Decarbonizing power generation with 100 per cent renewable energy is a long-term solution for Tonga

The SDG 7 target for renewable energy does not specify any quantitative target – it suggests substantially increasing the share of renewable energy in TFEC by 2030. The NEXSTEP methodology employs an integrated and logical approach to estimating a target that will not only help to achieve the SDG7 targets but also support the achievement of Tonga's NDCs. Based on this approach, NEXSTEP estimates that the share of renewable energy in TFEC will need to be 17.7 per cent in 2030.

The current trend suggests that Tonga will fall short of this target and will reach only 15.2 per cent in TFEC under the current policy scenario; therefore, taking a significant step up is necessary to bridge the gap. The major increase will need to be in the power sector. In terms of technology mix for electric power generation, the share of electricity generation will come from solar (65.2 per cent), wind (31.7 per cent) and diesel (3.1 per cent) in 2030.

5. Energy transition pathways with increased ambition

Several ambitious scenarios have been further analysed to identify the best way forward for Tonga to transition its energy sector to 2030. This analysis explains that there are socio-economic and environmental benefits for Tonga in raising its ambition beyond just achieving the SDG7 targets, such as the fact that it will be cost-effective to further improve its energy efficiency as well as there are economic benefits to enhance its NDC target beyond the unconditional and conditional NDC targets.

The SDG scenario is further expanded with different ambitious scenarios for analysing and comparing costs and benefits, and for identifying a scenario that is most suited to Tonga. Similar to the SDG scenario, these ambitious scenarios, at a minimum, aim to achieve the SDG 7 targets. A Next Energy Modelling system for Optimization-based least cost optimization has been applied to electricity generation. The scenarios are:

- Enhanced energy efficiency scenario. Tonga has the potential to raise its ambition in reducing the primary energy intensity further, compared to the 0.07 per cent reduction target. Ample opportunities can be found in the residential, commercial and transport sectors, through the implementation of MEPS standards for electrical appliances and fuel economy standards;
- Transport electrification strategies scenario. This scenario is the same as the enhanced energy efficiency scenario, with an additional focus on the transport sector. It further explores the possibility of electrifying part of the transport fleet. This not only reduces primary energy intensity further, but also allows Tonga to be less dependent on fuel imports;
- Decarbonisation of Tonga's power sector scenario. This scenario is the most ambitious scenario where the power sector is completely decarbonized by phasing out all fossil fuel-based power generation by 2030. Energy efficiency and transport measures applied in the transport electrification strategies scenario are similarly considered in this scenario.

The following section presents details of the key results of the ambitious scenarios. In addition, a summary of the results is given in Annex VI.

5.1. Ambitious scenario 1: Enhanced energy efficiency

As previously explained in section 4.2.4, achieving the SDG 7.3 target requires doubling improvement in primary energy intensity compared with the base period, which is 0.035 per cent. Correspondingly, improvement in primary energy intensity from 2018 to 2030 is 0.07 per cent, a very small and highly-achievable target, through increasing clean cooking access.

Nevertheless, there are ample of opportunities for Tonga to raise its ambition beyond the SDG 7.3 target, specifically in the residential, commercial and the transport sectors. The following summarizes energy efficiency measures applied in the residential and the transport sectors and the corresponding energy savings (figure 11).

(a) Residential sector[4] – total savings in 2030: 697.3 TOE
   - » MEPS Lighting - Replacement of inefficient incandescent bulbs and CFL bulbs from 2022 onwards by LEDs. The market share of LEDs is expected to reach a 100 per cent by 2030 – 354.6 TOE;
   - » MEPS television – share of efficient television to reach 80 per cent by 2030 – 163.4 TOE;
   - » MEPSL refrigeration – share of efficient refrigeration to reach 80 per cent by 2030 – 137.7 TOE;
   - » MEPS washing machine – share of efficient washing machine to reach 80 per cent by 2030 – 41.6 TOE.

4 Further explanations or assumptions made on the applied residential measures are provided in Annex IV.

(b) Transport sector – total savings in 2030: 437.2 TOE
   - » Heavy-Duty Vehicles Fuel Economy Standards: Fuel economy for new heavy-duty vehicles improves from 30 l/100km to 20 l/100km (Mauritius HDV Fuel Economy) – 251.4 TOE;
   - » Light-Duty Vehicles Fuel Economy Standards: Fuel economy for new light-duty vehicles improves from 10 l/100km to 7 l/100km by 2030. Measure from Tonga National Energy Efficiency Master Plan (CTCN,2018) – 96.9 TOE;
   - » Passenger car fuel economy standards and labelling: Fuel economy for new passenger cars improves from 7.5 l/100km to 4.4 l/100km by replacing with hybrid vehicles by 2030 – 88.9 TOE.

(c) Commercial sector – total savings in 2030: 772.5 TOE
   - » New commercial buildings lighting consumption improves from 3.75 kWh/m^2 to 1 kWh/m^2 by adopting efficient LED bulbs (73 per cent reduction in energy intensity) – 772.5 kTOE.

5.1.1. Electricity demand and power capacity

The additional energy efficiency measures applied, particularly in the residential and commercial sectors, allows a reduction in electricity demand of 1.47 kTOE. Consequently, such reduced demand reduces the need for power infrastructure by 9.8 MW (solar, 9.3 MW and wind, 0.5 MW). This is a substantial decrease of 15 per cent compared with the SDG scenario.

5.1.2. Import fuel dependency

Tonga's reliance on imported fuel is high, whereby 81 per cent of its primary energy supply in 2018 came from externally sourced oil products. The majority of petroleum products are used for power generation purposes (39 per cent) as well as in the transport sector (50 per cent). Improved

Figure 11. Energy savings by measures, 2020-2030

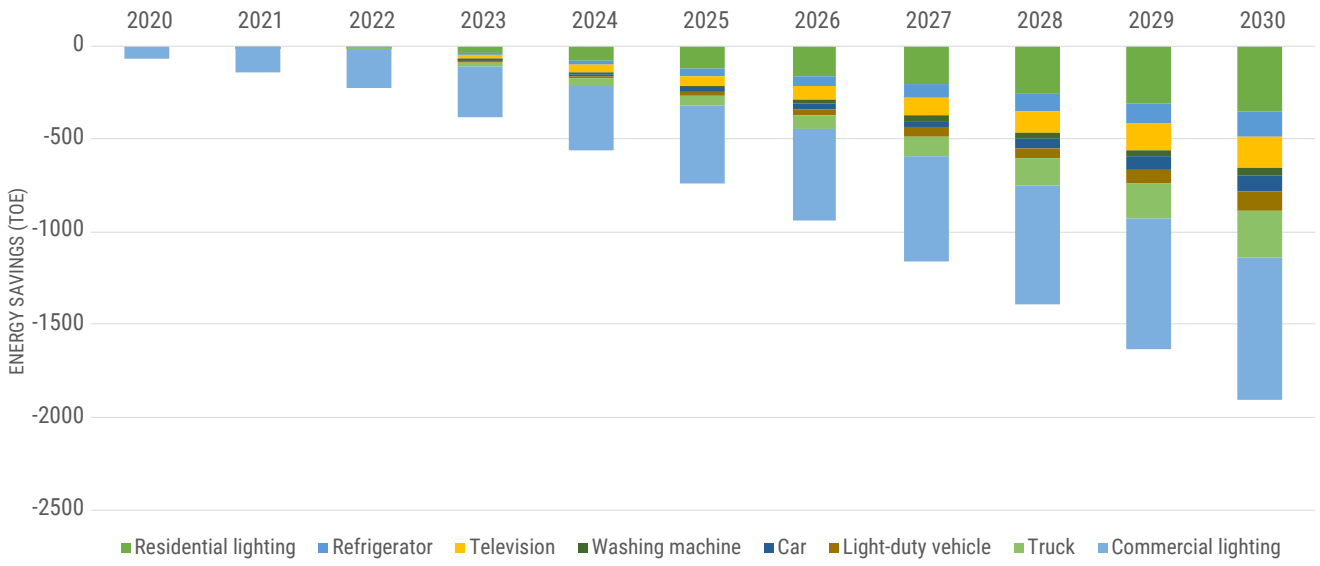
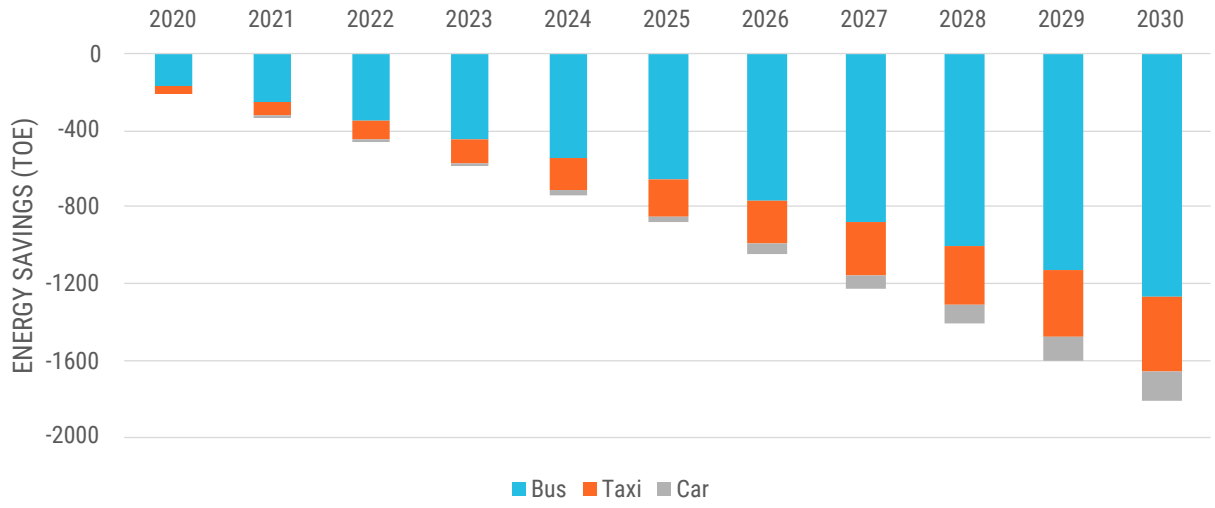


Figure 12. Energy savings via transport electrification measures



fuel economy in the transport fleet will allow a usage reduction of 437 TOE, compared to the SDG scenario.

5.2. Ambitious scenario 2: Transport electrification strategies

The biggest final energy demand comes from the petroleum fuel-reliant transport sector. It is also the sector (considering both power and demand-side subsectors) with the highest GHG emissions. This will be even more so when substantial decarbonisation has been achieved in the power sector by 2030, whereby 75.2 per cent of the GHG emissions in the SDG scenario comes from the transport sector.

This scenario further explores the possibility of electrifying part of the transport fleet. Multi-fold benefits can be gained, reducing the GHG emissions while enhancing Tonga's energy security by reducing its reliance on imported fuels. These are further explained quantitatively. The following measures are modelled:

- Electrification of 100 per cent of new passenger cars sold in Tonga by 2030;
- Electrification of 100 per cent of the bus fleet by 2030;
- Electrification of 100 per cent of the taxi fleet by 2030.

The total energy saving of the transport electrification measures in 2030, relative to the SDG scenario, is 1,815 TOE.

5.2.1. Electricity demand and power capacity

The electrification of part of the transport fleet raises the electricity demand by 555 TOE, relative to both the SDG scenario and the enhanced energy efficiency scenario. On the other hand, energy savings of nearly four-fold at can be achieved (relative to the SDG scenario) due to greater efficiency of the electric fleet.

With the added electricity demand, additional power capacity of around 3.8 MW is expected, compared to the enhanced energy efficiency scenario. In comparison to the SDG scenario, however, there is a net reduction of capacity of around 6 MW, attributable to the energy savings in the other sectors.

5.2.2. Import fuel dependency

Transport electrification strategies further enhances Tonga's energy security. The total reduced use of oil products is 2.28 kTOE. The biggest contributor is through the 100 per cent electrification of the bus fleet by 2030, allowing a petroleum savings of 1.6 kTOE in 2030.

5.3. Ambitious scenario 3: Decarbonization of Tonga's power sector

In the SDG scenario and ambitious scenarios discussed above, the least cost optimisation approach has suggested a renewable power generation between 97% and 98% by 2030. This indicates that, from the cost-effectiveness perspective, Tonga is able to raise its ambition to 70% renewable power generation stipulated in its NDC contribution. Going a little further, this scenario looks at completely decarbonizing Tonga's power generation by 2030, as discussed below. To do so, LEAP's least-cost optimization approach is utilized, with the only constraint being that diesel PP is gradually phased out by 2030.

5.3.1. Power capacity and electricity output by fuel type

Figure 13 shows the power capacity installed over the analysis period. Diesel PP capacity is modelled as gradual phasing out by 2030, allowing 100 per cent decarbonization of the power sector by 2030. LEAP's least-cost optimization approach suggests a ramping up of solar capacity to 29.7 MW by 2030. The wind power expansion is relatively modest, reaching a capacity of 9.6 MW by 2030, up from just 1.3 MW in 2018. Decarbonization of the power sector requires slightly more renewable capacity to be developed – specifically, 3.9 MW extra solar capacity compared to the transport electrification strategies scenario.

The primary fuel types for electricity generation in Tonga are diesel, solar and wind. In this scenario, electricity output from diesel-based power generation is gradually phased out by 2030 and replaced by solar generation, which increases from 5.3 GWh in 2018 to 53.5 GWh in 2030. On the other hand, wind power generation increases from 0.02 GWh in 2018 to 23.8 GWh in 2030.

Figure 13. Renewable power capacity, 2018-2030: Decarbonization of Tonga's power sector scenario

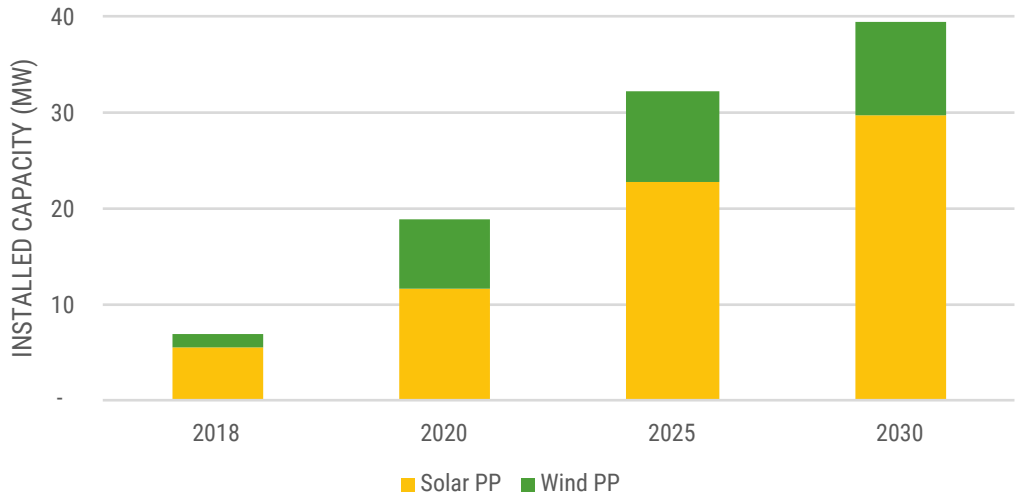
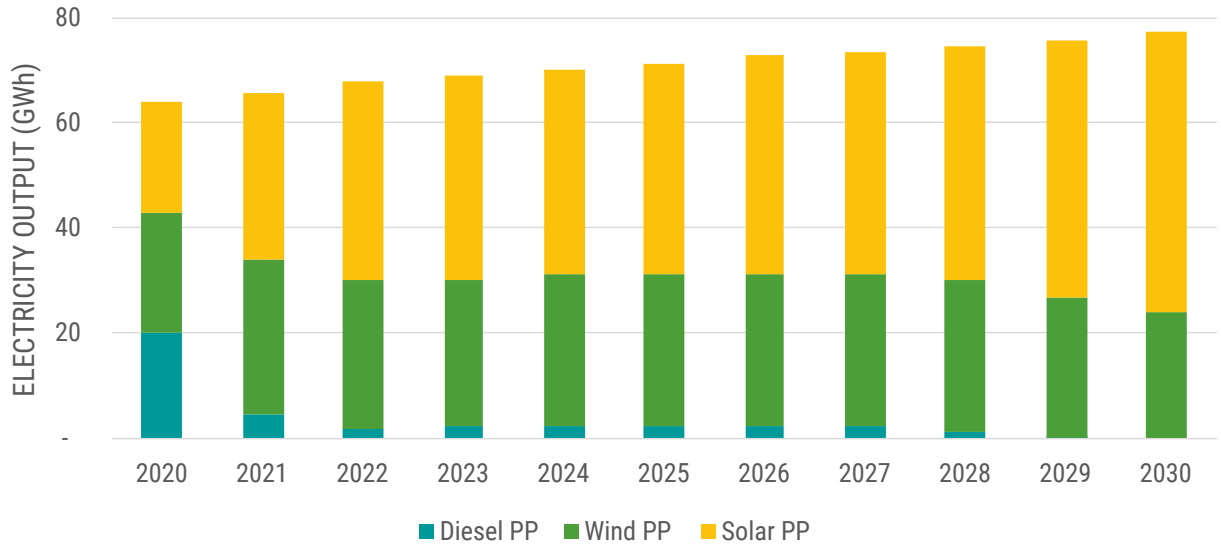


Figure 14. Electricity output by fuel type: Decarbonization of Tonga's power sector scenario



6. Policy recommendations to raise ambitions

6.1. Scenario ranking

The current policy, SDG and the ambitious scenarios have been evaluated and ranked, using the MCDA tool, with a set of 11 criteria and weights assigned to each criterion (table 3). The weightage for each criterion has been decided based on consolidated stakeholders' feedback gathered during the consultation workshop via an online polling platform. If deemed necessary, this step can be repeated using the NEXSTEP tool. The following factors have been considered to assume comparative weights across the set of criteria, where the total weight needs to be 100 per cent:

- Universal access to electricity to be achieved;
- Universal access to clean cooking fuel to be achieved;
- Renewable energy share in the total final energy consumption to increase;
- Energy efficiency improvement should be doubled, and where there is an economic benefit it should be further enhanced;
- The unconditional NDC target should be achieved. Where possible, the conditional target should be achieved if it is economically viable.
- Total investment should be kept low, but the net benefit should be high;
- When applicable, carbon pricing should be introduced to encourage investments in clean energy.

Table 4 shows the summary of results obtained through this evaluation process. The scenario recommendation suggests that the ambitious decarbonization of Tonga's power sector scenario is the highest-ranked energy transition pathway for Tonga.

The following presents several policy recommendations to aid Tonga in raising its ambitions beyond the SDG and NDC targets. The policy recommendations are not only valid for the decarbonization of Tonga's power sector scenario, but also offer cross-cutting suggestions for the other ambitious scenarios.

Table 3. Criteria with assigned weights for MCDA

Criterion	Weight (%)
Access to clean cooking fuel	8
Energy efficiency	13
Share of renewable energy	12
Emissions in 2030	12
Alignment with PA	10
Price on carbon	6
Fossil fuel phase-out	6
Cost of access to electricity	12
Cost of access to clean cooking fuel	5
Investment cost (power sector)	12
Net benefit from the power sector	4

Table 4. Scenario ranking based on MCDA

Scenarios	Weighted scores	Rank
Decarbonization of Tonga's power sector	65.6	1
Transport electrification strategies	65.4	2
Enhanced energy efficiency	62.4	3
Sustainable Development Goal	58.7	4
Current policy scenario	39.3	5

6.2. Enhance energy savings measures for multi-fold benefits

There are ample of opportunities for Tonga to raise its ambition beyond the SDG 7 energy efficiency target. The benefits of increasing energy efficiency gains are multi-fold. Substantial electrical energy savings reduce the need for investment in power infrastructure. More importantly, the fuel savings from the transport sector reduce fuel cost and reliance on fuel imports, making Tonga less vulnerable to supply and price shocks.

Energy savings opportunities can be found in the residential, transport and commercial sectors, as noted in section 5.1. In the residential sector, energy savings are gained through the introduction of Minimum Energy Performance Standards (MEPS) for various household appliances, which in total may yield annual savings of 697 TOE in 2030. MEPS is a policy instrument used to promote energy efficiency by banning the poor-performing appliances from the market, thereby forcing manufacturers to introduce innovation and consumers to adopt energy efficient appliances. In 1998, 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 energy consumption. Similarly, in the commercial sector, encouragement to adopt efficient light bulbs in commercial buildings may yield up to 73 per cent savings compared with the baseline.

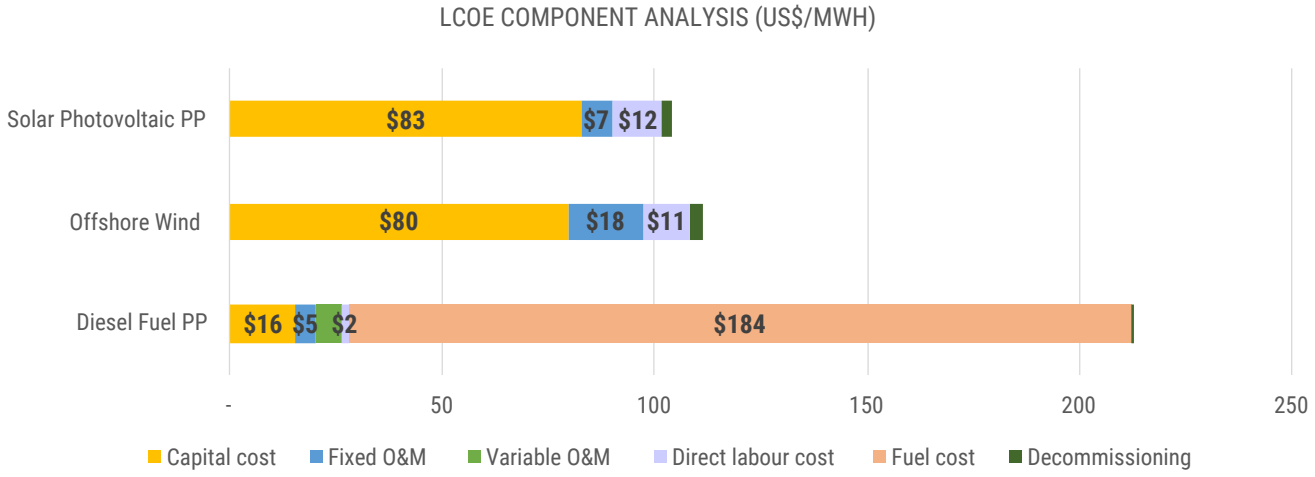
Multiple strategies can be adopted in the transport sector, including both an electrification strategy for part of the transport fleet and the introduction of vehicle fuel economy standards (VFES). Vehicles in Tonga are mainly imported, hence, implementing VFES on vehicle imports could be considered to improve the average fuel economy of the transport fleet. Various countries have successfully rolled out such standards in the past, including Japan through its "Top Runner Programme". In the European Union's bid to become climate neutral by 2050, the European Commission has also further strengthened its mandatory emission targets for new cars and vans, calling for a 37.5 per cent and 31 per cent reduction from 2030 onwards, respectively, using 2021 as the starting point (European Commission, 2020).

6.3. Renewable power generation is cost-effective

The cost of renewable power generation has decreased drastically over recent years, reaching levels lower than the fossil fuel-based power technologies. Figure 15 shows the Levelized Cost of Electricity (LCOE) for the power technologies applicable for Tonga. The LCOE is a widely-used metric in the energy industry for comparing the cost competitiveness of different electricity generation technologies. It calculates the unit cost of electricity ($/MWh) over the lifetime of the project, including capital, operating and financing costs.

Tonga is endowed with abundant renewable energy potential, with its solar potential estimated to be 767,297 MWh/year (NREL, 2010). With the cost of solar power generation reaching a level that is much lower than diesel power generation, Tonga may consider ramping up its solar power capacity towards 2030. LEAP's least-cost optimisation approach has considered the cost of production from different power generation technologies and has suggested a quick ramping up of both renewable power capacity and power generation, reaching a 93 per cent renewable generation in 2021 and a 97 per cent in 2030. Nonetheless, this implies an early retirement of the existing diesel power capacity.

Figure 15. LCOE of different power plant technologies in Tonga



6.4. Reducing petroleum product dependency via transport efficiency strategies and power sector decarbonization

Tonga's reliance on imported fuel is high, whereby 81 per cent of its primary energy supply in 2018 came from externally sourced oil products. The majority of petroleum products are used for power generation purposes (39 per cent) as well as in the transport sector (50 per cent). Being a Pacific Island State, all of Tonga's petroleum products are imported. Hence, such high reliance on petroleum products makes Tonga susceptible to future supply and price shocks.

Rapid ramping up of renewable power generation allows a substantial decrease of petroleum product usage in the power sector. For example, a decrease in diesel usage ranging up to 14.6 kTOE can be achieved if the power sector is fully decarbonized, compared to the usage in 2018. Notwithstanding this, Tonga's energy security can be further enhanced through transport efficiency measures. These are, for example, by introducing vehicle fuel economy standards and by electrifying part of the transport fleet.

6.5. Green financing

Accelerating green financing is critical to achieving the sustainable energy transition. Large capital investments in renewables will be required, but at the same time it will lead to even greater savings compared to fossil fuel-based generation. 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. Setting an example for the Pacific Island States, in 2017 Fiji successfully raised US$ 40 million through issuing its first green bonds. The proceeds are expected to be used to fund climate resilience projects, with the focus area including the transport sector (PCREEE, 2017).

Renewable energy technologies have relatively high financing costs in developing countries, which reflects their unattractive risk/return profile. This is because of their long-time horizon, high initial capital costs, 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 for low carbon investments. The United Nations Development Programme's (UNDP) "De-risking Renewable Energy Investment"[5] is an important guide for policymakers in developing strategies to reduce risks in renewable energy investment.

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

7. Tonga Energy Roadmap 2035 – Tonga's energy future

The Tonga Energy Roadmap 2035 (TERM Plus 2035) scenario envisages a future for Tonga's energy sector in which the Government achieves the NDC renewable electricity generation targets of 50 per cent by 2021[6] and 70 per cent by 2030. The timeframe for analysis is extended until 2035 to include a renewable electricity generation target of 100 per cent by 2035, as stipulated in the Climate Change Policy and Joint National Action Plan on Climate Change and Disaster Risk Management (JNAP 2).

The TERM 2035 scenario is based on Tonga achieving SDG 7 and NDC targets by 2030. In the scenario, universal access to electricity is achieved by 2020, based on current plans. Universal access to clean cooking fuels and technologies is achieved by 2030, by implementing an LPG cooking stove programme in Tonga. Renewable energy targets of 50 per cent by 2021 and 70 per cent by 2030 in electric power generation are achieved. The SDG energy efficiency target of 2.94 MJ/$ is easily achieved in 2030, whereby the primary energy intensity in this scenario is of 2.31 MJ/$ in 2030. The annual improvement in primary energy intensity is 2.1 per cent, compared to the required target of 0.07 per cent.

7.1. Energy demand outlook

The TERM 2035 scenario inherits the energy efficiency measures applied in the transport electrification strategies scenario and the decarbonisation of Tonga's power sector scenario. Consequently, in TERM 2035 various measures are applied in the residential sector through the introduction of MEPS for lighting, televisions, washing machines and refrigerators. In the transport sector, new fuel economy standards are introduced for light-duty and heavy-duty vehicles, whereas 100 per cent of the bus fleet and 100 per cent of the new passenger car fleet are electrified. Electricity demand for lighting is reduced by 73 per cent in new commercial buildings, on a per-square metre basis.

6 It should be noted that the 50 per cent renewable electricity generation target was to be achieved by 2020. Nevertheless, the target will be achieved a year late due to implementation delays caused by COVID-19.

In the TERM 2035 scenario, TFEC is reduced from 36 kTOE in 2020 to 35 kTOE in 2030, and then increases to 38 kTOE in 2035. All sectors, except for the residential sector, show gradual growth during the analysis period. In 2035, the transport sector will have the largest share of TFEC 25 kTOE (66 per cent), followed by the residential sector with 7 kTOE (14 per cent), commercial sector with 4 kTOE (11 per cent), industrial sector with1 kTOE (3 per cent) and the agricultural sector with 1 kTOE (3 per cent). In the residential sector, a decrease in energy demand is observed up to 2030, due to the phasing out of traditional biomass stoves and replacement with LPG stoves. After 2030, a net increase in energy demand is observed, due to the use of household appliances. Figure 16 shows the energy demand trajectories up to 2035.

7.2. Power sector outlook

The power sector is modelled to achieve Tonga's NDC renewable electricity generation targets of 50 per cent by 2021 and 70 per cent by 2030. It is then extrapolated to reach a 100 per cent renewable share in 2035. The power capacity for the different power technologies is exogenously applied, whereby diesel PP is gradually phased out by 2035. Figure 17 shows the power capacity installed during the 2018-2030 analysis period, at five-year intervals. Nevertheless, NEXSTEP has not analysed the impact of a 100 per cent renewable share on the grid management due to the lack of data. For example, daily load curve data are required to enable storage modelling. Further in-depth analysis will be performed to better

Figure 16. Energy demand by sector, 2020-2035, TERM 2035 scenario

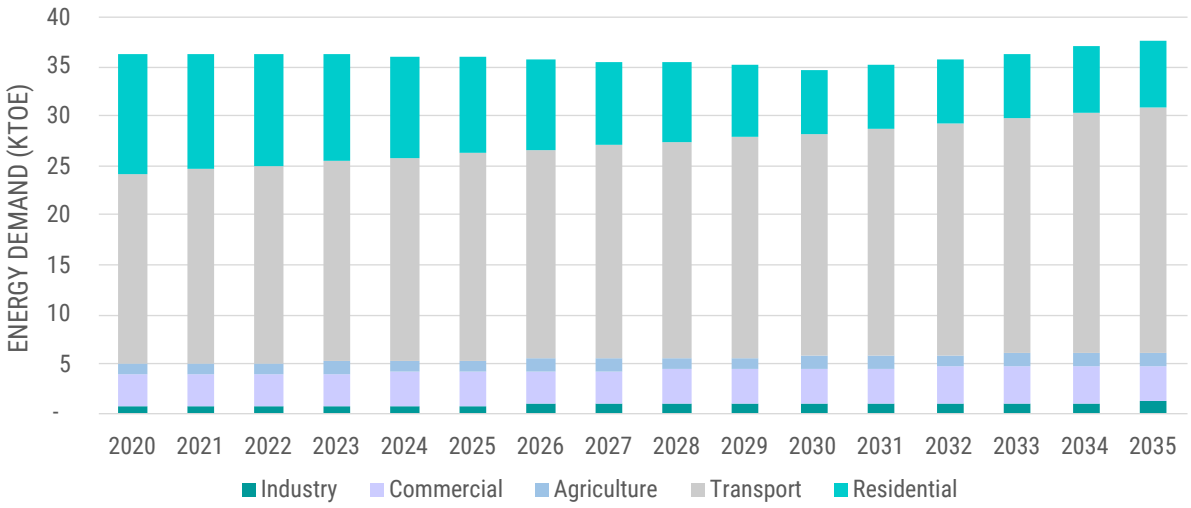
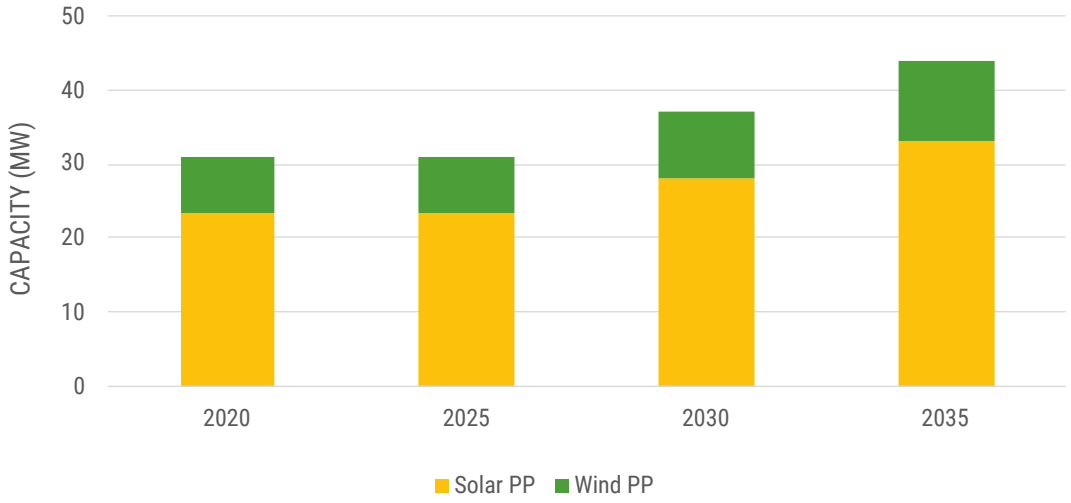


Figure 17. Renewable power capacity installed, 2018-2030, TERM 2035 scenario



understand the potential for storage and demand-side management to improve grid flexibility.

The electric output share by power technologies, which is shown in figure 18, achieves the NDC targets and reaches a 100 per cent renewable power in 2035.

The total investment costs incurred during 2018-2035 is US$ 107.3 million, while the total net benefit is US$ 250.2 million.

7.3. Emission trajectory

A gradual decrease in GHG emissions is expected in TERM 2035 scenario, down from 112.3 $ktCO_2$-e to 90 $ktCO_2$-e. In comparison to the BAU scenario, this corresponds to a 73.4 $ktCO_2$-e reduction in 2035. This stems from the energy savings measures applied as well as the 100 per cent decarbonized power sector. Figure 19 shows the emission trajectories from 2018 to 2035, for BAU, CPS and the TERM 2035 scenarios.

Figure 18. Electricity output share by power technologies, TERM 2035 scenario

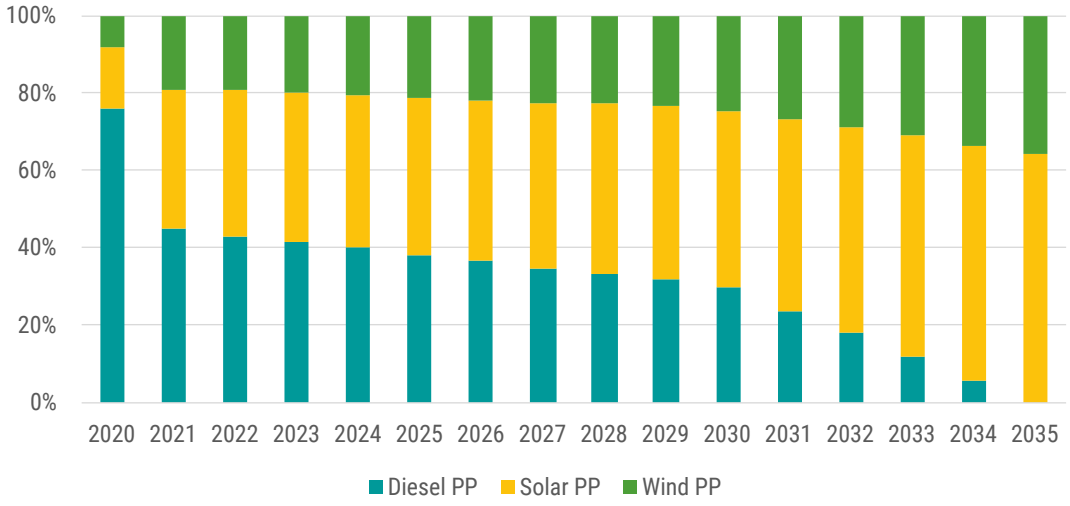
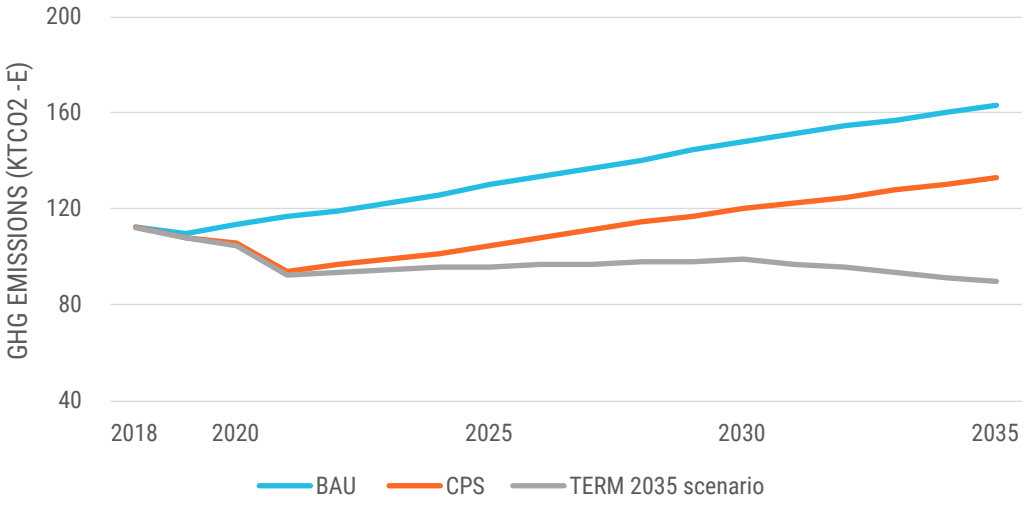
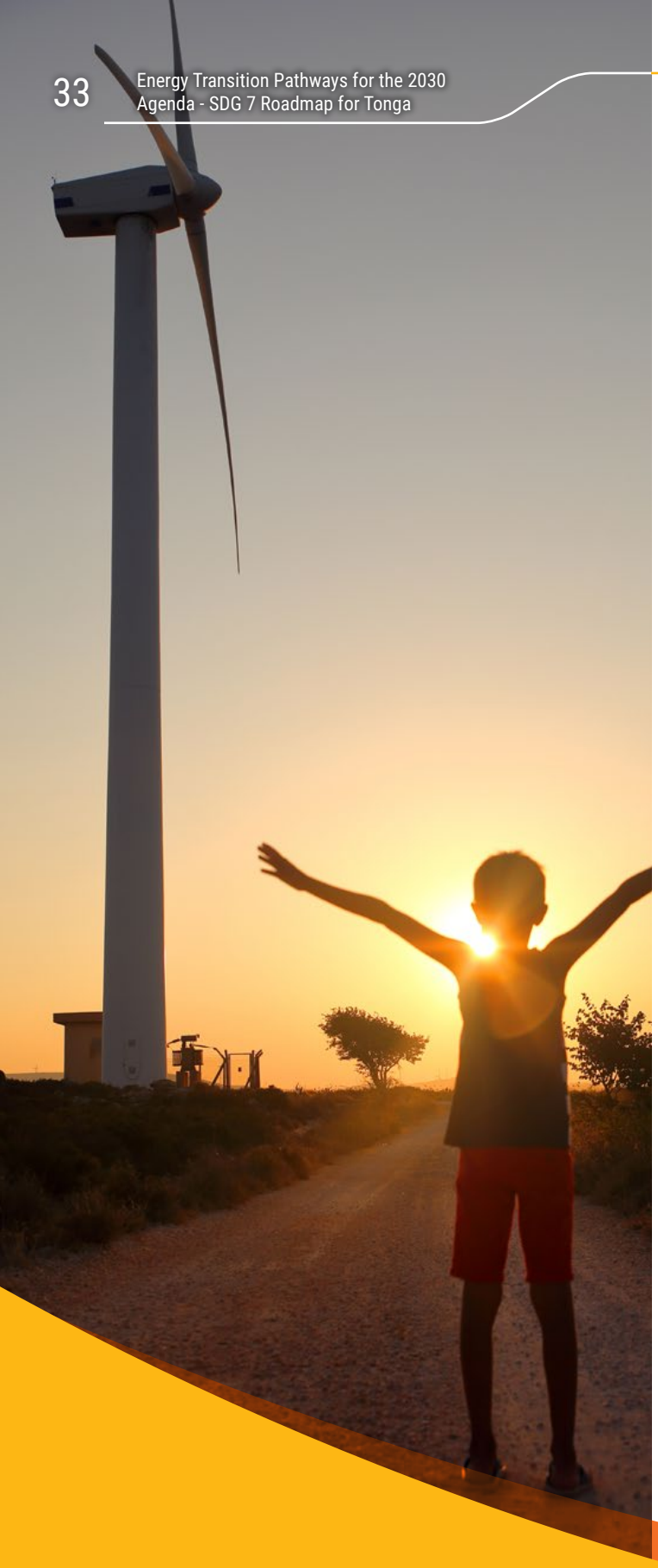


Figure 19. Emission trajectories, 2018-2035





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 in renewable energy and energy efficiency, and eventually, impeding national economic growth.

The COVID-19 pandemic has hit the Pacific Island States hard. Tonga has responded quickly to the global pandemic by closing its borders and has successfully kept the virus away from its shore. Yet, the pandemic has had an impact on the economy, especially the tourism industry which accounts for around 25 per cent of Tonga's GDP and 22 per cent of the total employment (International Monetary Fund, 2020). While grappling with the devastation caused by this global health crisis, Tonga should not lose sight of its progress and ambitions towards achieving the SDG and NDC targets.

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 the recovery from the COVID-19 impacts, while maintaining the momentum to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement.

8. Building-back-better in recovery from COVID-19 with the SDG 7 Roadmap

8.1. Accelerating access to clean and modern energy services

Access to clean and modern energy services is essential for 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.

In 2018, Tonga had about 35,000 people without access to clean cooking fuel. Access to clean cooking technologies is a development challenge that is often forgotten. One medium-term impact of COVID-19 could be decreased investment in energy access, as national budgets come under strain and priorities shift. WHO has warned about the severity of health impacts arising from the exposure to traditional use of biofuel for cooking, and is encouraging policymakers to adopt measures to address this challenge. Moreover, scientists are already investigating links between air pollution and higher levels of coronavirus mortality, with preliminary results showing a probable correlation between the two.

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 of US$ 100,000 to advance the clean cooking rate to 100 per cent.

8.2. Savings from the energy sector will help in building other sectors

The NEXSTEP analysis shows that there are ample opportunities in Tonga to save energy by improving energy efficiency beyond the current practices as well as further strengthening the national target of energy-intensity reduction. As highlighted in the previous chapters of this report, several cost-effective energy efficiency measures can be implemented in the residential, transport and commercial sectors that will result in net financial gain. Savings from this improvement can help to increase investment in other sectors, such as health, social protection and stimulus, which are critical in responding to, and recovering from the COVID-19 pandemic.

An example of low- to no-cost measures is the introduction of minimum energy efficiency standards (MEPS) in producing appliances, e.g., air conditioners, televisions and lights, all of which have zero or negative costs. There is also potential for implementing energy efficiency in the transport sector, for example by introducing vehicle fuel economy standards and by promoting electric vehicles. This has multiple additional related benefits (in addition to energy saving), including the reduction of expenditure on importing petroleum products and reducing local air pollution. At the same time, other options for sustainable transport also need to be explored. These options include: (a) avoiding the need to travel through integrated land-use planning and transport demand management; (b) shifting travel to the most efficient or clean mode, e.g., non-motorised or public transport; and (c) improving the environmental performance of transport through technological improvements that make vehicles more energy-efficient and less carbon-intensive. Such measures are very important to solidifying the pathway to recovery from COVID-19 and rebuilding better.

9. Revisiting existing policies

Tonga's current energy policies have been evaluated based on the outputs from the LEAP model, in order to highlight any inconsistencies or revisions required in order to achieve the SDG 7 and NDC targets by 2030. These are as summarised below by topic.

9.1. Universal access to electricity

Existing policy	NEXSTEP analysis – gaps and recommendations
Tonga Energy Roadmap (TERM) 2010 – 2020 TERM 2010-2020 stipulates the Government's goal of electrifying 100 per cent of Tonga's population by 2020. Access to electricity is crucial in meeting the Government's primary target of "poverty alleviation".	**SDG target is expected to be achieved by 2021** **Achieving SDG and ambitious scenarios:** NEXSTEP suggests that off-grid PV mini-grid technology would be more cost-effective and will enable faster implementation.

9.2. Universal access to clean cooking

Existing policy	NEXSTEP Analysis – Gaps and recommendations
Not available	**Gaps:** Tonga will fall short of achieving the SDG target, reaching only 92.2% population with clean cooking fuel by 2030. **Achieving SDG and ambitious scenarios:** Considering the stakeholder's feedback, NEXSTEP recognises that promoting LPG cooking stoves may be the most appropriate measure. The feedback from the stakeholder consultation workshop suggests that cooking with LPG is very much culturally accepted and well-established in the community. In addition, the running cost of LPG cooking stoves would be cheaper compared to electric cooking stoves; therefore, LPG cooking stoves would be more affordable than electric cooking stoves.

9.3. Renewable energy

Existing policy	NEXSTEP Analysis – Gaps and recommendations
Tonga's nationally determined contributions stipulates the following targets: • Fifty per cent of electricity generation from renewable energy sources by 2020 • Seventy per cent of electricity generation from renewable energy sources by 2030.	**Gaps**: Due to the COVID-19 pandemic, Tonga is set to achieve the 50 per cent renewable power generation target in 2021. Nevertheless, Tonga will fall short of achieving the 2030 target in the CPS scenario. The projected renewable power share by TPL in 2030 is 52 per cent. The electricity line losses have been reduced to 9 per cent as ambitioned. **Achieving SDG scenario and ambitious scenarios:** LEAP's least-cost optimisation approach has suggested a rapid ramping up of renewable power generation (specifically solar PV), reaching a 97 per cent renewable power generation share in 2030. In terms of renewable energy share in TFEC, the SDG scenario projects a 17.7 per cent share in 2030. **TERM 2035 scenario:** NEXSTEP also explores a 2018-2035 pathway, reaching the 70 per cent and 100 per cent renewable power generation share in 2025 and 2030, respectively. Diesel generation is gradually phased out, with the majority replacement coming from solar PV. In terms of the renewable energy share in TFEC, this scenario projects a 12.1 per cent share in 2030.

9.4. Energy efficiency

Existing policy	NEXSTEP Analysis – Gaps and recommendations
Tonga's nationally determined contributions stipulates the following target: • Improve energy efficiency through reduction of electricity line losses to 9 percent by 2020 (from a baseline of 18 percent in 2010). **Tonga Energy Roadmap (TERM) 2010-2020** stipulates that the goal is to improve system-wide energy efficiency by 18 per cent against a business-as-usual scenario.	**SDG energy intensity target of 2.94 MJ/US$ is expected to be achieved in the CPS scenario** Energy intensity target is expected to be achieved in the CPS scenario via a multi-sectoral approach. The energy efficiency target stipulated in the NDC has been realised. In addition, the expected increase in clean cooking access rate, which sees a transition from low efficient to more efficient cooking stoves, and the increase in renewable power generation allows the SDG target to be reached. **Achieving SDG and ambitious scenarios:** 100% clean cooking access rate in the SDG scenario reduces further the energy intensity in 2030. The energy efficiency through increased use of renewable energy further enhances energy savings, reaching the 18 per cent goal stipulated in TERM. Nevertheless, NEXSTEP analysis suggests that there are ample energy savings opportunities in the residential, transport and the commercial sector.

10. Conclusion

Tonga is progressing satisfactorily towards SDG 7, and is on track to achieve the 100 per cent electrification target and the energy efficiency target. Nevertheless, more effort is needed to achieve the full suite of SDG 7 targets, particularly providing clean cooking access to its population. On the other hand, Tonga is likely to miss its 2030 NDC target, despite making a huge stride towards its intermediate target in 2021. The SDG 7 roadmap offers an integrated multisectoral plan to build on the existing plans and policies of Tonga in achieving SDG 7 and NDC targets. The NEXSTEP analysis suggests several areas where efforts are needed to achieve these targets and has proposed several feasible pathways for Tonga to go above and beyond the existing targets.

Without well-designed and targeted policy measures, Tonga will still have a population of around 1,800 households cooking with harmful fuels and technologies in 2030 and beyond. Such a gap can be closed by actively promoting clean cooking options. For example, LPG cooking stoves may be the most-appropriate technological option, considering cultural acceptance and fuel costs. Tonga is on track to reach a 100 per cent electrification rate in the very near future, whereby solar home systems may aid the rapid uptake of electricity while being climate resilient. Tonga has made great effort in increasing its renewable power energy share. From just 8 per cent in 2018, it is projected that the renewable power generation share will reach 55 per cent in 2021. Nonetheless, more effort in required to achieve a 70 per cent share, as stipulated in Tonga's NDCs. As analysed, it may be cost-effective to quickly ramp up the renewable power generation share due to the high cost of diesel imports, while reducing reliance on imported diesel fuel.

Going beyond the stipulated targets, there are ample opportunities for Tonga to improve its energy intensity. The reduced use of electricity in the residential and commercial sectors will require less power infrastructure to be built. Furthermore, efficiency measures in the transport sector can further enhance Tonga's energy security by reducing the reliance on imported fuels. As a country endowed with huge solar potential, reaching a 100 per cent renewable energy share is also highly feasible.

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 health care.

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Annexes

Annex I. National Expert SDG 7 Tool for Energy Planning Methodology

The analysis presented in the 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 reach informed policy decisions that will help achieve 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	2018	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.	96%	100%
	7.1.2. Proportion of population with primary reliance on clean fuels and technology for cooking.	65.3%	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.	25.2% (including traditional biomass)	17.7%
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.	2.97 MJ/US$ (2011) PPP	2.94 MJ/US$ (2011) PPP
7. A. By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced and cleaner fossil fuel technology, and promote investment in energy infrastructure and clean energy technology.	7.A.1. International financial flows to developing countries in support of clean energy research, and development and renewable energy production, including in hybrid systems.	US$ 19.9 million, 2017 PPP (2017 data)	n.a.

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 EI_{t1} is Energy intensity in year t1 and EI_{t2} is energy intensity in year t2

Base period improvement rate for Tonga (1990 – 2010): 0.035 per cent

SDG 7.3 improvement rate for Tonga (doubling of base period improvement rate): 0.07 per cent

SDG 7.2. Renewable Energy

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.

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

Annex II. Key assumptions for NEXSTEP energy modelling

(a) General parameters

Table 6. GDP and GDP growth rate

Parameter	Value
GDP (2018)	514.1 million
PPP (2018, constant 2011 US dollars)	646.7 million[7]
Growth rate	0.7%

Table 7. Population, population growth rate and household size

Parameter	Value
Population (2018)	100,700
Population growth rate	0.2%
Household size	5.53 (2018) 4.5 (2030)[8]

(b) Demand-side assumptions

(i) Industry

Table 8. Productivity by industry type

Parameter	Productivity in 2018
Industrial GDP	31.9 million
Industrial GDP growth rate	3%

7 Sourced from http://data.un.org/Data.aspx?q=gdp+ppp&d=WDI&f=Indicator_Code%3aNY.GDP.MKTP.PP.KD

8 Sourced from SPC, 2016.

(ii) Transportation

Table 9. Transport

	2018	2025	2030
Passenger transport (million passenger/km)			
Passenger car	97.8	117.1	133.1
Light-duty vehicle	115.1	137.8	156.7
Motorcycle	2.4	2.8	3.2
Bus	109.4	131.0	148.9
Taxi	16.1	19.7	21.9
Tractor	4.2	5.2	5.8
Freight transport (million tonne/km)			
Truck	346.0	414.2	471.1
Aviation transport (thousand people)			
Aviation	100.7	102.1	103.1

(iii) Residential

Table 10. Residential urbanization, percentage

Area	Throughout the analysis period
Rural	23
Urban	77

(iv) Commercial

Table 11. Commercial floor space

Parameter	2018	2025	2030
Commercial floor space (m^2)	8,274.9	10,053.9	11,536.4

Annex III. Economic analysis data for power plant technologies

The NEXSTEP Economic model analyses the power plant technologies based on technical and economic parameters to estimate levelized cost of electricity.

Table 12. Economic analysis parameters

Economic parameters	
Nominal discount rate	8.00%
Inflation rate	2.50%
Standard Conversion Factor (SCF)	0.90
Carbon price	0.00 US$/Ton CO_2e
Electricity tariff	0.38 US$/kWh
Skilled workforce	80%
Shadow Wage Rate Factor (SWRF)	0.75

Table 13. Fuel price for power plant technologies

Fuel Price	
Diesel	800 US$/ton

Table 14. Tonga technology capacity factor/efficiency and cost data

Technologies	Capacity factor/ efficiency (%)	CAPEX/MW (US$/MW)	Fixed O&M (US$/ MW)	Variable O&M (US$/MWH)
Diesel PP	36.62	1,800,000	37,700	6.4
Solar photovoltaic PP	21	2,500,000	15,000	0.0
Offshore wind	35	4,000,000	60,000	0.0

Annex IV. 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. The calculation assumes an annual cooking thermal energy requirement of 1,132 MJ per household. In addition, a discount rate of 5.37 per cent is assumed.

Table 15. Technology and cost data for clean cooking technologies

Technology	Efficiency (%)	Lifetime (years)	Stove cost (US$)	Variable O&M (US$/year)	Fuel cost (US$)
ICS	30	4	25	10	0.03 per kg
LPG stove	56	7	56	10	1.80[9] per kg
Biogas digester	50	20	950	50	-
Electric stove	84	15	40	10	0.40 per kWh

Annex V. Energy efficiency measures in the residential sector

The following details provide further explanation on the energy efficiency measures applied across the ambitious scenarios in the residential sector.

MEPS lighting

Households in Tonga own 6.9 lightbulbs on average; they rely on inefficient incandescent bulbs (28.76 per cent), CFL (20.89 per cent) and T8 fluorescent bulbs (50.05 per cent). The lifetime of incandescent bulbs is typically one year, while CFL bulbs have a five-year lifetime. Minimum Energy Performance Standards (MEPS) implementation from 2022 onwards in lighting will promote a LED lighting market share to 100% by 2030.

MEPS refrigeration

Household ownership of refrigerators in Tonga is 50 per cent and is projected to increase to 78 per cent by 2030 (CTCN, 2018). The household share of inefficient refrigerators is 84 per cent, while for efficient refrigerators it is16 per cent. Modelling assumption is 20 per cent (for practical reasons based on experiences in other countries – for example, the Georgia National Energy Efficiency Action Plan and World Bank analysis) of inefficient appliances will not be replaced, and efficient refrigerators will have a market share of 80 per cent by 2030 (World Bank, 2016).

MEPS washing machines

Ownership of washing machines in households in Tonga is 77 per cent and is projected to increase to 80 per cent by 2030 (NREL, 2018). The share of Inefficient washing machines is 100 per cent and efficient washing machines zero per cent (estimate, as data are not available). Modelling assumption is that 20 per cent of inefficient appliances will not be replaced and efficient washing machines will have a market share of 80 per cent by 2030 (World Bank, 2016).

MEPS televisions

Ownership of televisions in Tonga households is 73 per cent and is projected to increase to 85 per cent by 2030 (CTCN, 2018). The share of inefficient televisions 85 per cent and efficient televisions 15 per cent in households. Modelling assumption is 20 per cent of inefficient appliances will not be replaced and efficient refrigerators will have a market share of 80 per cent by 2030 (World Bank, 2016).

9 Sourced from the Pacific Community (SPC, 2019).

Annex VI Summary result for the scenarios

	SDG Scenario	Enhanced energy efficiency	Transport electrification strategies	Decarbonisation of Tonga's power sector	TERM 2035
Universal access to electricity in 2030	100%	100%	100%	100%	100%
Universal access to clean cooking in 2030	100%, via LPG stove	100%, via LPG stove	100%, via LPG stove	100%, via LPG stove	100%, via LPG stove
Energy efficiency in 2030	2.35 MJ/US$	2.23 MJ/US$	2.13 MJ/US$	2.11 MJ/US$	2.31 MJ/US$
Renewable energy share in TFEC in 2030	17.7%	14.6%	16.7%	17.2%	12.1%
Emission reduction/NDC target	92.8 ktCO2-e	91.0 ktCO2-e	84.3 ktCO2-e	82.6 ktCO2-e	99.2 ktCO2-e
Power generation optimization	Least-cost	Least-cost	Least-cost	Fossil fuel phaseout	In accordance with Tonga's RE target in the power sector 2021[10] – 50% 2030 – 70% 2035 – 100%
RE share in power generation in 2030	96.9%	96.9%	96.9%	100%	30%
Total investment for the power sector	US$ 99.4 million	US$ 74.1 million	US$ 83.6 million	US$ 93.4 million	US$ 86.8 million
Net benefits from the power sector	US$ 239.4 million	US$ 215.9 million	US$ 225.7 million	US$ 225.5 million	US$ 158.4 million

10 The 50 per cent target was set for 2020. Nevertheless, due to the unfortunate COVID-19 circumstances, the target is now projected to be reached in 2021.