GOVERNMENT OF TONGA

TERM PLUS

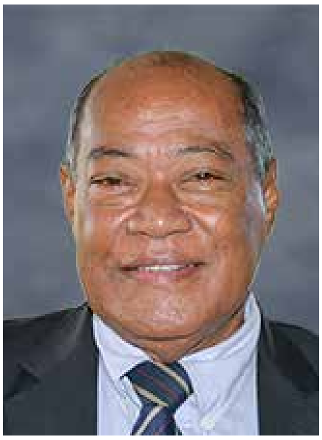
TONGA ENERGY ROAD MAP

2021-2035

© Popua Solar Farm (on-grid)

GOVERNMENT OF TONGA

FOREWORD



Tonga is proud of its 10-year journey that has provided an example of renewable energy transformation to the world. The Tonga Energy Road Map (TERM) launched in 2010 prepared a way forward to protect the Tongan economy from the volatility of oil prices, increase access to energy services and set a future renewable platform. Specifically, from 2010–2020, the TERM policies delivered a least-cost approach and implementation plan to reduce Tonga's vulnerability to oil price shocks, achieve an increase in quality access to modern energy services in a financially and environmentally sustainable manner, and set a target of 50% renewable electricity. Tonga has proven through the past decade of implementation that it is determined to transform its energy system as some accomplishments from this period include:

- Achievement of 96% energy access for all of Tonga under phase 0.
- Energy efficiency through reduction of electricity line losses from 18% to 9% under phase 0.
- GoT restructuring and elevating energy programme as Department of Energy under phase 0.
- On track to reach renewable electricity of 50% under phase 1 and 2.

Fortunately, by implementing the TERM, the Government of Tonga and Tonga Power Limited have been working closely together to meet these challenges. Together, with the significant support of our development partners, we have implemented multiple renewable electricity projects and made substantial improvements to the network´s infrastructure. Today, all four island systems operate with significant renewable energy and reliability.

Since late 2020 and 2021, Tonga has been intensively collaborating on the TERM-PLUS Framework (Framework) that set the foundation for this TERMPLUS. The Framework was the living document that allowed all our stakeholders´ inputs, to ensure we are all coordinated and based on solid ground. Now, the TERMPLUS becomes the central document to help guide Tonga towards its ambitious energy goals. We enter the next decade and a half with even more purposeful objectives to increase Tonga's goals not only in renewable electricity, but also transportation, energy security, resiliency, gender-inclusion and data management.

To materialise such ambitions, we need everyone's support, Government Ministries, state-owned enterprises, development partners, civil society organisations, and the private sector. In the end, it will take a grand alliance of these stakeholders to continue our successful Tongan march. This TERMPLUS builds upon and mobilises these veteran forces to commence the journey ahead towards 2035.

Our transition now has great clarity as the TERMPLUS will raise-the-bar again to 70% renewable electricity by 2025. An ultimate goal of 100% renewable electricity by 2035, will build on the projects that have been and will be designed, planned, and implemented up to that target date. The TERMPLUS dives deeper into the elements that will make these goals possible.

With monumental transformations in energy generation and distribution, as well as energy policy underway through the Energy Bill, Tonga's electric system will perform with far greater complexity in the future. Operating and maintaining this future renewable system will require technology upgrades in almost every area. Similarly, capacity building will be needed to develop the skills of those who control and maintain, as well as regulate this increasingly dynamic network. In tandem, we begin advancing the transportation sector to be powered by a clean energy ecosystem using technology, advanced grid infrastructure and public policy to make the most of our country's renewable resources. There is no energy area that remains untouched by the magnitude of this roadmap.

For this reason, as we continue into the second half of 2022, an Investment Plan will be developed using the experience from the previous decade and the direction given by the TERMPLUS to deliver fully on its goals for an affordable, accessible, inclusive, resilient, sustainable and secure Tonga energy sector. The upcoming TERMPLUS Investment Plan will set up the right projects in the correct sequence, attracting private sector and development partner funding to achieve Tonga's TERMPLUS goals.

Please join me in kicking off the next 15 years of a Tongan journey that we take with great resolve and pride.

Malo 'aupito,

Hon. Samiu Kuita Vaipulu
Acting Prime Minister

ACKNOWLEDGEMENTS

The Government of Tonga would like to acknowledge and thank the New Zealand Ministry of Foreign Affairs and Trade (MFAT), for their kind and generous financial support for the development of our TERMPLUS under the Low Emissions Climate Resilient Development (LECRD) programme. The development of this TERMPLUS has been led by the Department of Energy (DoE) under the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC) with technical assistance provided by Global Green Growth Institute (GGGI) and on the ground support from the many invaluable energy stakeholders, including the Ministry of Infrastructure, Electricity Commission, Oil Companies and Tonga Power Limited (TPL). The entire DoE Staff and GGGI extend their warm and heartfelt gratitude to Dr. Tevita Tukunga, Nik Fonua, Kakau Foliaki, Simon Wilson, Seti Chen, Sela Bloomfield and all the workshop participants and stakeholders consulted throughout the process. *Malo 'aupito.*

GGGI

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Manatū Aorere

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AFOLU	Agriculture, Forestry and Other Land Use
BAU	Business as usual
BEV	Battery electric vehicle
BESS	Battery Energy Storage System
BTB	Business to be
CBD	Central business district
COVID-19	Corona virus disease 2019
DoE	Department of Energy
EIA	Environmental Impact Assessment
EOI	Expression of Interest
EV	Electric Vehicle
Framework	TERM-PLUS Framework
GCF	Green Climate Fund
GoC	Government of the People's Republic of China
GGGI	Global Green Growth Institute
GoT	Government of the Kingdom of Tonga
GWh	Gigawatt-hour
ICE	Internal Combustion Engine
IPCC	Intergovernmental Panel for Climate Change
IPP	Independent power producer
JICA	Japan International Cooperation Agency
JNAP 2	Joint National Action Plan 2 on Climate Change and Disaster Risk Management
kW	Kilowatt
kWh	Kilowatt-hour
LPG	Liquefied petroleum gas
LT-LEDS	Long-term low emissions development strategy
MEIDECC	Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications
MEPSL	Minimum energy performance standard and labelling
MFAT	New Zealand Ministry of Foreign Affairs and Trade and Tourism
MW	Megawatt
MWh	Megawatt-hour
NDC	Nationally Determined Contribution
NNUP	Nuku'alofa Network Upgrade Project
NSDF	National Strategic Development Framework
OIREP	Outer Island Renewable Energy Project
PALS	Pacific Appliance Labelling and Standards
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaic
PPA	Power Purchase Agreement
RFT	Request for Tender
TEEMP	Tonga Energy Efficiency Master Plan
TERM	Tonga Energy Road Map 2010-2020
TERMPLUS	Tonga Energy Road Map 2021-2035
TPES	Total primary energy supply
TPL	Tonga Power Limited
TREP	Tonga Renewable Energy Project

EXECUTIVE SUMMARY

Following the completion of the Tonga Energy Road Map (TERM) 2010–2020 the TERMPLUS 2021-2035 lays out the key targets, approaches and prioritised **actions needed to decrease Tonga's dependence on fossil fuels and deliver an energy system, that by 2035 is affordable, accessible, inclusive, resilient, sustainable, secure and enhances the livelihood and wellbeing of all Tongans.**

This 'energy roadmap' serves to consolidate and rationalise the energy sector development policies set forth by His Majesty during the opening of the Legislative Assembly 2022 and the Government of Tonga (GoT) in the Tonga Strategic Development Framework (TSDF II), Joint National Action Plan (JNAP 2), Sustainable Development Goal 7 (SDG 7), Tonga Energy Efficiency Master Plan (TEEMP), and Low Emission Development Strategy 2021–2050 (LT-LEDS) as well as the Energy Bill 2020. The TERMPLUS also provides Tonga's energy strategy to exceed its 2020 Nationally Determined Contributions (NDC) of 13 $GgCO_2e$ by 2030, with the potential to deliver cumulative GHG reductions of approximately 580 $GgCO_2e$ by 2030 if all initiatives are implemented.

To achieve this, the TERMPLUS follows three principal approaches:

- First, increase the share of electricity generated from renewable sources using a least-cost approach.
- Second, reduce oil consumption, with a focus on the transport sector for the first time.
- Third, improve the policy and regulatory environment to support the achievement of Tonga's national energy objectives.

The TERMPLUS reflects these approaches in its targets for energy supply, energy consumption and electricity generation.

TABLE 1.
TERMPLUS Targets

	Target	Baseline 2021	2035
Security	Reduction in net oil Imports	2,158 TJ[1]	1,942 TJ Reduced by 10% vs 2018
	Strengthen Energy Security by improving storage	36-day supply[2]	45-day supply
Electricity	Electricity generated from renewable energy	12.27%[3]	100%
	Improve Demand Side Energy Efficiency	65 GWh total consumption[4]	Reduction of 40 GWh versus BAU[5]
	Maintain line losses under 8%	7.4%[6]	<8%
Transport	Limit growth in oil consumption for road transport (an average of 1.4% per year)	2% per year[7]	<25% increase

The TERMPLUS document will ensure Tonga delivers fully on its energy sector goals in an affordable, accessible, inclusive, resilient, sustainable and secure manner.

1 Baseline data from Department of Energy's Energy Balance calculations 2021.
2 2018 storage capacity for diesel Source: DoE 2021; Twoney and Labett 2010; Total 2021
3 Tonga Power Limited (TPL) presentation at TERMPLUS Energy Stakeholder Meeting 24-August-2021 'TERM and TERM Plus – Our Journey thus far'.
4 TPL Annual Report 2020, pg. 20.
5 Government of Tonga Energy Efficiency Master Plan 2020–2030.
6 TPL Annual Report 2020.
7 GGGI BAU growth rate to 2035, see TERMPLUS Transportation Section.

TABLE 2.
TERMPLUS indicative Project Pipeline

Opportunity	Accumulated[8] Renewable Electricity %	Project Status	Pipeline priority rank	Annual GHG emissions reduction in 2030 ($GgCO_2e$)	Cumulative GHG emissions reduction by 2030 ($GgCO_2e$)
Sunergise 6 MW Solar PV IPP	23.4%	Underway	1	7	42
GET 6 MW Solar PV IPP	34.8%	PPA Signed	1	7	42
2.25 MW China Wind Farm	41.5%	Underway	2	5	30
3.8 MW of Wind IPP[9]	~50%	Re-Tender or RFT	3	8.5	51
TPL-RFT (34-50 GWh, technology agnostic)	~50-70%	Design	4	~32	126
Nuku'alofa Network Upgrade		Underway and Ongoing	5	0.4	2.4
Improving Intake Quality of Vehicles		Concept	1	9.9	99
Non-motorised Transport		Concept	2	2.2	22
Low Emission Vehicles		Concept	3	17	165

Source: TPL Presentation – 24 August, 2021 – TERM Pipeline Renewable Energy Projects, TPL – 2022, GGGI Transportation Analysis

While a number of TERM projects are underway in the Electricity Sector and key interventions have been identified in the Transport Sector (see Table 2 above) there is a need to develop a TERMPLUS Investment Plan using experience from the previous decade and the priorities of the MEIDECC's DoE. The TERMPLUS Investment Plan will be based on this TERMPLUS document to set up the right projects in the correct sequence attracting private sector and development partner funding to achieve Tonga's ambitious 15-year goals, while prioritising three underlying principles.

Least Cost Implementation—a key approach under the TERM, remains a key focus for the TERMPLUS investment planning. This ensures that potential investments are ranked according to least-cost of implementation and on their impact on reducing the cost of accessing modern energy services.

Energy security is a key focus—understood as the energy system's capability to ensure uninterrupted availability of fuel by withstanding and recovering from disturbances and contingencies—is an important consideration for Tonga. The uninterrupted external supply of fossil fuels—in particular oil products—will remain critical for most of the period covered by the TERMPLUS, despite the target to reduce the importance of oil products in Tonga's total primary energy supply.

Resilience, reliability, data management and gender-inclusion are cross-cutting concerns given the need to maintain reliable generation and distribution of electricity will become more challenging given the aim to expand the share of electricity in primary energy supply while increasing reliance on variable renewable sources. Compounding resiliency and reliability challenges will be the effects of climate change which are expected to become increasingly severe in terms of their impact on Tonga.

In data management, robust granular data is required to identify cost-effective energy efficiency measures and determine the functionality of renewable technologies for each intervention. Finally, the need to address gendered impacts and bottlenecks to women's involvement, decision-making and leadership in the aspects of supply, consumption, electricity generation, renewable technology, energy efficiency, transport, energy security and resilience.

[8] TPL presentation at TERMPLUS Energy Stakeholder Meeting 24-August-2021 'TERM and TERM Plus – Our Journey thus far'.
[9] TPL June 2022 - An initial IPP bid was unsuccessful and TPL considering retendering or for inclusion in the TPL - 2021 RFT for 34-50 GWh.

REVIEW OF THE TERM 2010–2020

This section summarises the findings of a review of TERM 2010–2020 undertaken in 2020 and presented to Tonga at the October 2020 workshop. A range of options were considered and evaluated relative to one another based on the principle of the lowest lifecycle cost among the technically feasible alternatives, with a recommended three-phase implementation plan to deliver the TERM's four objectives:

- Petroleum Supply Chain: Improvements in Petroleum Supply chain to reduce the price and price volatility of imported petroleum products.
- Electricity Supply-Side Efficiency: Efficiency of conversion of petroleum to electricity (i.e. increases in efficiency and reduced losses at TPL).
- Electricity Demand Side Efficiency: Efficiency of conversion of electricity into consumer electricity services (demand side management).
- Renewable Energy: Replacing a portion of current or future grid-based generation with renewable energy.

Results of TERM

Specifically, from 2010-2020, the TERM policies provided a least-cost approach and implementation plan to reduce Tonga's vulnerability to oil price shocks and achieve an increase in quality access to modern energy services in a financially and environmentally sustainable manner. Tonga has proven through the past decade of TERM implementation that it is determined to create this future energy system as some of Tonga's impressive accomplishments from period include:

- Achievement of 96% Energy Access for all of Tonga.[10]
- Transition to Cleaner & Safer Cooking Fuels nearly on-track for 100% by 2030.[11]
- Energy Efficiency through reduction of electricity line losses from 18% to 9% by 2020.[12]
- On track to reach renewable electricity of 50%.[13]
- GoT elevated the energy programme to a focused Department of Energy and with the anticipated Energy Act set to become a Ministry of Energy.

Further, during the TERM period, Tonga has been proven successful in attracting and securing development partner funds as well as collaborating effectively with these diverse global partners. Additionally, TPL through major efforts, has become a trusted partner and implementing agency essential to reach TERM's 50% renewable electricity target with a series of designated pipeline projects.

Key indicators for the TERM

The TERM made excellent progress towards its renewable energy and energy efficiency objectives but was largely unsuccessful in implementing any activities to improve the petroleum supply-chain. Table 3 below shows the increase in the share of renewable energy and improvement in line losses achieved by the implementation of solar, wind and new electricity network technology over the period of the TERM.

10 MEIDECC – DoE - 2021.

11 SDG 7 Roadmap – UNESCAP- SDG 7 Roadmap– page 17 – 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%) compared to traditional biomass cooking stoves' energy efficiency (10–20%).

12 2015 INDC document stipulated a target for reducing the electricity line losses to 9%, which was achieved in 2017). The energy efficiency target stipulated in the NDC has been *realised*. The current trend of energy intensity reduction indicates that Tonga will achieve its energy efficiency target by 2030 – UNESCAP – SDG 7 Roadmap.

13 TPL Business Plan 2021–2026 and TPL Business Plan 2020–2025 - Delay in reaching TERM goal of 50% renewable electricity largely attributed to COVID-19.

TABLE 3.
Key indicators for TERM 2010–2020

	Indicator	2010	2015	2019
Dependence on fossil fuels	Total amount of fossil fuel supply[14]	1,513.8 TJ	1,712.9 TJ	1,565.7 TJ
	Share of fossil fuel supply in total TPES	73%	79%	77%
Share of electricity generated from renewable sources	Share of electricity generated from renewable sources (grid)	0.3%	5.7%	10.9%
Access to electricity	Access to electricity (grid and off-grid)	90%	-	95-97%
Conversion efficiency	Total electricity generated from fossil fuels (TJ/year)	189.3TJ	204.02TJ	241.84TJ
	Diesel consumption for electricity generation	488.92TJ	502.68TJ	588.64TJ
	Conversion efficiency	39%	40%	40%
Transmission and distribution losses	Line losses	15%	8.0%	7.6%

Source: GGGI, '*Review of the Tonga Energy Road Map 2010-2020 and Recommendations for the Tonga Energy Road Map 2021–2035*', September 2020

[14] Supply is defined as domestic production plus imports minus exports, stock changes and deliveries to international marine bunkers and international aviation.

TERMPLUS APPROACH

The TERMPLUS has been created as a result of the review of the TERM, interviews with over-100 key energy stakeholders, access to data sets from DoE, MOI and TPL, update of the TERM-PLUS interim Framework document (Framework), as well as a review of 200-plus national and sectoral policies, strategies, reports and studies. From these analyses a set of targets and corresponding measures for 2021–2035 were developed, presented and verified with key energy sector stakeholders at national workshops in October 2020, April, August and December 2021.

Now, building on the TERM successes, the Framework and in response to international commitments and national needs, the MEIDECC—DoE has prepared the TERMPLUS in consultation with energy stakeholders and development partners to comprehensively address the projected 15-year energy needs of Tonga conducted in an affordable, accessible, inclusive, resilient, sustainable and secure manner.

Targets and measures relating to transportation, energy efficiency, data management, resiliency and gender-inclusion were also discussed with a broader range of stakeholders at workshops designed for the development of Tonga's 2020 Nationally Determined Contribution (NDC) and the Long-Term Low-Emissions Development Strategy (LT-LEDS). The interim Framework document delivered in December 2020 was structured and aligned with Tonga's 2020 NDC to provide a solid foundation for the development of TERMPLUS. In early April 2021, a further-updated Framework was presented and reviewed at a 'Stakeholder and Joint Development Partners Meeting'. As a result of the meeting, improved targets including a new transportation section were discussed, recommended and adopted for this TERMPLUS.

TERMPLUS will carry on the work of the TERM while expanding implementation in the energy sector to include deep analyses on transportation and integrating resilience, gender-inclusion as well as energy efficiency measures. Evidence-based decision making, knowledge sharing, and institutional learning are fundamental components of the TERMPLUS, and recommendations on improved data management create an integrated energy roadmap. Continued collaboration on the TERMPLUS between the increasing energy stakeholders and ongoing support of development partners will facilitate coordinated actions and streamlined finance; ultimately increasing the momentum needed to accomplish Tonga's ambitious goals.

In the new normal, climate change will have an increasing impact on Tonga and its future energy needs. Additionally, the recent Hunga-Tonga-Hunga-Ha'apai disaster strengthens the Government of Tonga's resolve for even greater resilience. Consequently, it is necessary to identify, develop and implement resilient energy projects, infrastructure and sustainable transport measures to enhance the adaptive capacity of the overall system. For rural energy access, this requires active participation by local communities engaging in energy planning, ownership, operations and maintenance. During the next decade of further implementation, energy stakeholders and development partners will require a complete energy system perspective and an even closer coordination with national and sub-national government bodies.

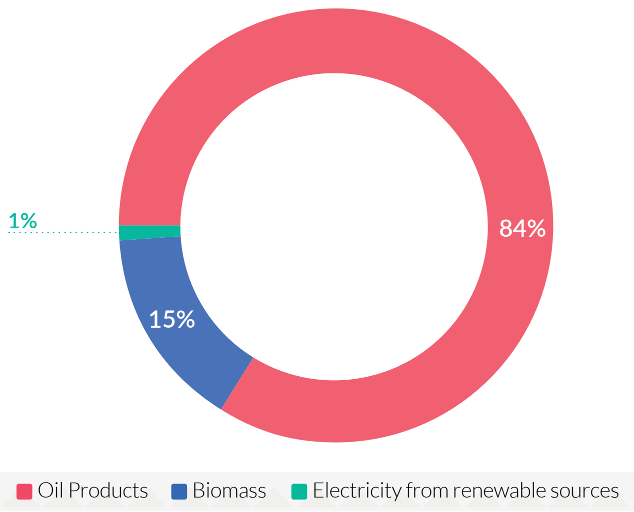
1 | ENERGY SUPPLY

1.1 OVERVIEW

The total primary energy supply in Tonga is dominated by the import of oil products.[15] In 2018, oil products accounted for 84% of TPES, followed by biomass with 15%. Biomass supply in Tonga consists mainly of fuel wood and wood waste (83%) and to a smaller extent of coconut residue (17%). Electricity generation from renewable sources (i.e. wind and solar) accounted for only 1% of TPES (Figure 1).

The share of fossil fuels in total primary energy supply increased in both absolute and relative terms between 2010 and 2018. Total amounts of fossil fuel supply increased by 38% during that period, from 1,561 TJ to 2,158 TJ. Since total primary energy supply during the same period only increased by 21%, the share of fossil fuels in TPES increased from 74% in 2010 to 84% in 2018 (DoE, 2021; Figure 2 and Figure 3).

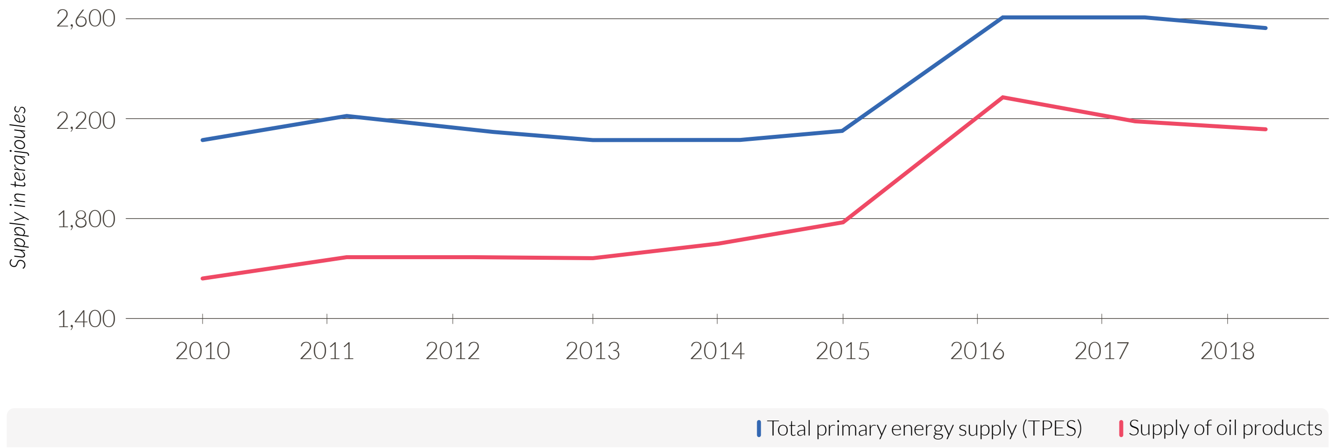
FIGURE 1.
Total primary energy supply by fuel (2018)



Source: DoE, 2021

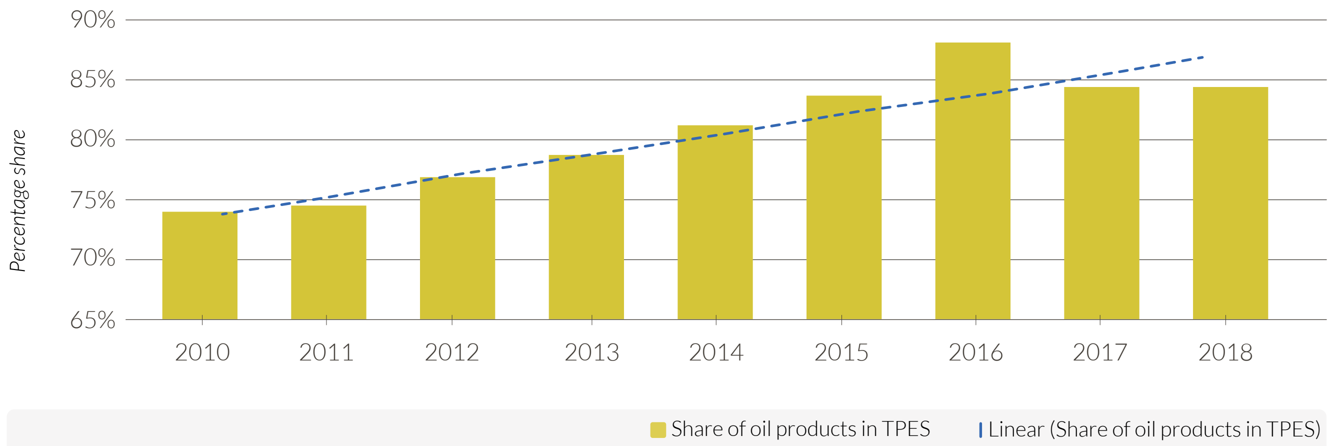
[15] Total primary energy supply (TPES) is defined as the sum of production and imports minus the sum of exports, stock changes and deliveries to international marine bunkers and international aviation of primary and secondary fuels, except electricity. For electricity, TPES only includes electricity generated from renewable sources, while electricity generated from fossil fuel is accounted for under electricity generation.

FIGURE 2.
Tonga total primary energy supply and supply of oil product 2010–2018



Source: DoE, 2021

FIGURE 3.
Share of oil products in total primary energy supply



Source: DoE, 2021

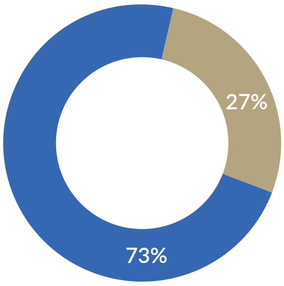
Fossil fuel supply consists entirely of oil products, with diesel (52%), motor gasoline (37%), LPG (5%), and kerosene (2%) accounting for 96% of supply. The remainder consists largely of lubricants that are used for non-energy purposes.

Over one quarter (27%) of fossil fuel supply is used for electricity generation (transformation), while nearly three quarters (73%) are used for direct final consumption (DoE, 2021; Figure 4). The transport sector accounts for close to 90% of total final oil consumption, dominated by road transport, representing about 80% of total final oil consumption. Households (6%); agriculture, forestry and fishing (3%); manufacturing and construction (2%), and commerce and public services (1%) account for the remainder (DoE, 2021; Figure 5).

As a result, in order to decrease the country's dependence on fossil fuels, the Government of Tonga (GoT) follows two principal approaches. First, the share of electricity generated from renewable sources is to be increased. Second, oil consumption in the transport sector is to be reduced. The TERMPLUS reflects these approaches in its targets for energy supply, energy consumption, and electricity generation.

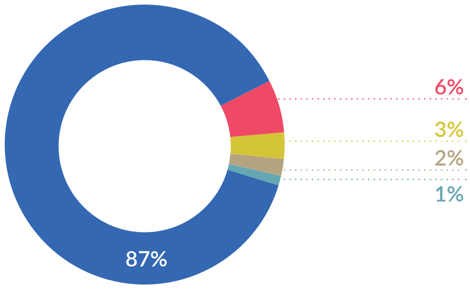
However, the TERMPLUS also recognises that oil products will remain an important component of Tonga's total primary energy supply in the short- to medium-term. This is principally a result of the lack of cost-effective alternatives to effectively replace oil products in some sectors. The targets set for energy supply in Tonga reflect this reality.

FIGURE 4.
Fossil fuel use for electricity generation and total final consumption



Source: DoE, 2021

FIGURE 5.
Use of fossil fuel by sector



Source: DoE, 2021

1.2 SUPPLY TARGETS

The TERMPLUS identifies two principal targets for energy supply. Those targets are (Table 4):

- Reduce the total amount of net oil product imports in 2035 by 10% compared to 2018, and
- Strengthen energy security.

First, the TERMPLUS sets the target of reducing the total amount of net oil product imports in 2035 by 10% compared to 2018. This supply target is closely linked to the targets for electricity generation (displacement of oil products by renewables), final consumption (introduction of energy efficiency measures for buildings and appliances), and transport (limitation of oil consumption growth in land transport). The relevant targets, the corresponding measures, and related requirements are discussed in more detail in the chapters: 2. Energy Consumption, 3. Electricity Generation and Distribution, and 4. Transport, respectively.

TABLE 4.
Targets, measures, and requirements for supply

Target	Measures	Requirement
Reduce the total amount of net oil product imports in 2035 by 10% compared to 2018	• Displacement of diesel by renewable sources for electricity generation • Limitation of oil product consumption growth in road transport through increased fuel efficiency, encouragement of non-motorised transport, and electrification of transport	• Alignment of consumer incentives • Public acceptance • Financing • Upgrade of electric network • Upgrade of transport infrastructure
Strengthen energy security	• Increase days coverage of motor gasoline and diesel stocks to the equivalent of 45 days of net imports • Establish direct shipments of oil products (e.g. Singapore)	• Agreement on required infrastructure • Agreement on stock holding arrangements, ownership, and management of assets • Agreement on investment and financing model for infrastructure to accommodate medium-range tankers • Establishment of legislation on decision-making procedures and on modalities of stock release and replenishment

Source: GGGI

Second, the TERMPLUS aims to strengthening energy security. Given that oil products are going to continue to account for a considerable share of Tonga's total primary energy supply for the foreseeable future, they will also continue to play a dominant role for energy security. Therefore, this target is not regarded as contradictory to the GoT long-term ambition of reducing the role of fossil fuels and lowering greenhouse emissions. Instead, it is regarded as a complementary measure, making the unavoidable consumption of fossil fuels more resilient to physical disruptions. This provision sharpens the GoT's view on security of supply, with a focus of preventing physical supply disruptions and moving away from earlier endeavours to hedge against oil price fluctuations.

1.3 SUPPLY MEASURES

While it is challenging to establish a numerical target for measuring improvements in energy security, the related measures to achieve the target are quantifiable and can be objectively measured. In order to strengthen energy security the following measures will be undertaken:

- Expansion of existing storage facilities for motor gasoline and diesel stocks to holding volumes equivalent to 45 days of net imports, and
- Establishment of direct shipments of oil products from Singapore.

First, as one measure to strengthen energy security, the TERMPLUS identifies increasing days coverage of motor gasoline and diesel stocks to the equivalent of 45 days of net imports.[16] The GoT has determined stock coverage of 45 days of net imports as desirable based on past assessments.[17] Holding oil stocks is an effective measure to respond to physical supply disruptions and help reduce the associated price spikes. Drawing down emergency stocks is regarded as the most effective option to respond to a short-term supply disruption. It allows for providing additional oil to an undersupplied market and can be complemented by other measures during an emergency.

In Tonga, two oil companies are responsible for all imports of petroleum products. For their operations, these companies require storage facilities for oil products. Their total existing storage capacity amounts to net volumes of approximately 1,088 m^3 of motor gasoline, 3,500 m^3 of diesel, and 464 m^3 of jet kerosene.[18]

The maximum coverage provided by stocks—if storage tanks were fully filled—has decreased in the period from 2010 to 2018. As the result of increasing consumption having led to higher net imports, coverage decreased from 36 days in 2010 to 17 days of net imports in 2018 for motor gasoline and from 42 days in 2010 to 36 days of net imports in 2018 for diesel.

Coverage provided by stocks of motor gasoline is projected to remain at a low level of approximately 17 days by 2035, if consumption growth can be limited by successful interventions in the transport sector. Coverage provided by diesel stocks is projected to increase over the longer term to 53 days of net imports, if diesel is largely replaced by renewable sources for electricity generation and final consumption growth is reduced by interventions in the transport sector (Table 5).

TABLE 5.

Net imports and maximum coverage of stocks for motor gasoline and diesel

Oil product	Net storage capacity (m^3)	Net imports (m^3)			Days of coverage (days)		
		2010	2018	2035	2010	2018	2035
Motor gasoline	1,088	9,964	23,572	23,278	36	17	17
Diesel	3,496	30,091	35,481	23,959	42	36	53

Source: DoE, 2021; Twoney and Labett, 2010; Total, 2021

16 Net imports are defined as imports minus stock changes, minus the sum of exports and deliveries to international aviation and marine bunkers. Net imports are adjusted for stock changes such that increases in stocks each year are deducted from the amount of imports, while stock draws each year are added to the import figure.

17 Past assessments suggest that desirable stock levels should be somewhere between 30-days (World Bank, 2010) and 45-days (Twoney and Labett, 2010).

18 Jet kerosene stocks in Tonga are primarily held for the supply of international aviation and are, therefore, not addressed as part of the TERMPLUS.

Second, the second measure to strengthen energy security consists of establishing direct oil product shipments from Singapore to Tonga via medium-range tankers, bypassing Fiji and making the supply chain more robust. The current supply chain via local coastal tankers delivering oil products to Tonga is tight and prone to interruption of deliveries due to bad weather conditions. As a result of limited oil product storage within Tonga, delays in oil product shipments can quickly cause physical fuel shortages.

Switching from supply via local coastal tankers to medium-range tankers will require the construction of new or upgrading of existing marine facilities to accommodate medium range tankers—including the wharf or anchorage for discharging tankers, pipelines, pumps, and terminal—and an expansion of storage infrastructure. It would be complementary to the envisioned expansion of storage and eliminate the need to hold oil stocks for Tonga in Fiji. Finally, past assessments have shown that the establishment of direct shipments from Singapore could reduce retail prices for motor gasoline and diesel in Tonga (see Appendix A for full analysis).

The measures related to achieving the target of reducing the total amount of net oil product imports in 2035 by 10% compared to 2018 are closely linked to the measures for electricity generation (displacement of oil products by renewables), final consumption (introduction of energy efficiency measures for buildings and appliances), and transport (increased fuel efficiency, encouragement of non-motorised transport, electrification of transport). The relevant measures are discussed in detail in the chapters: 2. Energy Consumption, 3. Electricity Generation and Distribution, and 4. Transport, respectively.

1.4 REQUIREMENTS AND ENABLING ENVIRONMENT

There are several major requirements to expand storage facilities for motor gasoline and diesel stocks and successfully establish direct shipments of oil products from Singapore to Tonga. Most of these requirements revolve around the physical set-up, the financing, and the legal modalities of both measures.

First, in order to expand existing storage facilities for motor gasoline and diesel stocks to holding volumes equivalent to 45 days of net imports, the GoT, in close consultation with the industry, will decide whether to introduce a minimum stockholding requirement for oil products. In its decision, the GoT will weigh the aims of improving supply security and of minimising the costs associated with increased stockholding.

Tonga could rely solely on operational stocks held by suppliers, in particular, if these stocks were to be expanded as part of putting in place the infrastructure to accommodate medium-range tankers supplying oil products directly from Singapore. Alternatively, the GoT will consider establishing a system of holding emergency stocks. If a decision was made to introduce a minimum stockholding requirement, the GoT will determine stockholding arrangements from among three different approaches to ensure compliance (Appendix B):

- Government-controlled stocks financed through the central government budget and held exclusively for emergency purposes,
- Stocks held by a separate agency whose structure and arrangements will be clearly defined by legislation, or
- A minimum stockholding obligation for oil importers and/or distributors in proportion to each company's oil import share or its share of sales in the Tongan market.

The decision on whether to introduce a stockholding requirement will determine the amount of the stocks available during a supply disruption, the decision-making process to release stocks, and the modalities of how these stocks will be made available if needed and replenished afterwards. It will also have an influence on oil prices in Tonga, as holding stocks beyond operational requirements comes at a cost. This cost will ultimately be borne by consumers and/or taxpayers.

If a decision is made in favour of introducing a stockholding requirement, GoT—again in close consultation with the relevant companies—will need to agree on the required infrastructure. To a considerable extent, infrastructure requirements will depend on which stockholding option is ultimately chosen (Appendix B). Infrastructure requirements include the following:

1. Given past and projected trends in oil product consumption, storage expansion will likely focus on the accommodation of additional motor gasoline stocks at existing facilities.
2. The size of the storage facilities to provide stock coverage for an equivalent of 45 days of net imports as well as piping and pump capacity to achieve the required draw down rates will need to be determined.
3. The possibility of repurposing diesel tanks to hold motor gasoline, if the projected reduction in diesel consumption occurs.

Investment costs and the financing mechanisms will also largely dependent on the stockholding option chosen. While some options require considerable public investment, which would be borne by all taxpayers, others rely primarily on private sector investment, with the costs being ultimately passed on to consumers (Appendix B).

If the GoT decides in favour of introducing a minimum stockholding obligation, it will need to decide on the design of that system, weighing several aspects such as monitoring compliance with the obligation, the timely availability of stocks, the institutional burden of maintaining a reliable stockholding system, and who will bear the costs associated with holding stocks beyond operational requirements. For that purpose, the GoT will establish the necessary legislation regarding the decision-making procedure on whether to make stocks available to the market, on the modalities of a stock release, and the process of replenishment of stocks after a release.

Second, in order to establish direct shipments of oil products from Singapore, the infrastructure to accommodate medium-range tankers will have to be set up. For that purpose, the GoT, in close consultation with the industry, will decide on what infrastructure to build, and how to finance and operate that infrastructure. Past assessments concluded that a privately-owned medium-range tanker terminal with regulated open access represents the most beneficial option for the GoT. Under that option, a private investor would own the facility and grant access to all interested fuel suppliers on the same terms. This arrangement was considered to efficiently manage key risks and maintain competition for fuel supply into Tonga. Alternatively, the GoT could invest in the additional infrastructure required for accommodating medium-range tankers, while agreeing on terms to use the existing assets.

Before committing to either option, the GoT requires further evaluation to understand which of the options is most likely to achieve the targets of increasing oil supply security and reducing oil product prices, while ensuring financial viability. Therefore, during the initial implementation of the TERMPLUS, both options will be developed in more detail, before the GoT makes a final decision on the supply model. Based on that decision, the necessary legal, regulatory, and operational arrangements will be put in place, including agreements with existing suppliers on the use of their infrastructure, and possibly running tenders for fuel supply, construction, terminal operations, and distribution (Appendix A).

© Boat carrying Solar Home System batteries to the small islands (off-grid)

1.5 ENERGY SUPPLY ROADMAP

The overall targets for each intervention are sub-divided into short-, medium-, and long-term targets as shown in table below.

Interventions/ Policy Alignment	Short-Term Target 2025	Medium-Term Target 2030	Long-Term Target 2035	Key Stakeholders
Direct Shipments of Oil products from other countries Policy: TERM, NIIP2	Study and Analysis on Singapore direct supply, Decision on Singapore direct supply	Shipment arrangements from other countries or more resilient and cost-effective logistics designed and deployed	Tonga Biofuels/ Green Fuels Export / Import	Sector Lead: PMO, AG, MTED Partners: MEIDECC–DoE, Oil Co.s, TPL Finance: Private & Development Partners, GoT, Oil Co.s
Developing Standards on energy security and Enforce Policy: Energy Bill / Act	Review Resource Adequacy, Adjust Market Design, Set Standards for operational requirements to meet energy security parameters	Enforce Standards on Oil Co.s and renewable IPPs	Enforce Standards on Oil Co.s and renewable IPPs	Sector Lead: Energy Comm., TPL, MEIDECC – DoE, Oil Co.s Partners: IPPs Finance: GoT
Increase days coverage of motor gasoline and diesel stocks to the equivalent of 45 days of net imports Policy: JNAP2, HTHH-DRRP	Upgrade Bulk Fuel Facilities (Tank Farm, Bunkering) to support improved supply chain logistics	Maintain 45-day Supply	Maintain 45-day Supply	Sector Lead: PMO, AG, NEMO Partners: MEIDECC–DoE, TPL Finance: Oil Co.s, Development Partners, GoT

KEY			
HTHH-DRRP	Hunga-Tonga-Hunga-Ha'apai Volcanic Eruption and Tonga Tsunami (HTHH Disaster) Recovery and Resilience Building Plan 2022–2025	TSDFII	Tonga Strategic Development Framework 2015–2025
TEEMP	Tonga Energy Efficiency Master Plan 2020–2030	NIIP2	National Infrastructure and Investment Plan 2013–2023
JNAP2	Joint National Action Plan 2018–2028	NIIP3	National Infrastructure and Investment Plan 2020–2030
TCCP	Tonga Climate Change Policy 2015	LT-LEDS	Long-Term Low-Emissions Development Strategy 2021–2050

2 ENERGY CONSUMPTION

2.1 OVERVIEW

Final energy consumption is defined as all fuels supplied to final consumers for all energy uses in all sectors. It does not include any amount of fuel used for electricity generation to avoid double the counting of energy. Electricity consumption is included for residential, commercial and public services.[19]

Tonga's total final energy consumption was 1,772 terajoules in 2010 and increased by 17% to 2,080 terajoules in 2018. Table 6 shows the sectoral breakdown of energy consumption between 2010–2018.

TABLE 6.
Total final energy consumption by sector

	2010	2018	2018
Sector	TJ	TJ	Share (%)
Transport	935	1,290	62.0%
Residential (incl. electricity)	681	575	27.7%
Commercial and public services (incl. electricity)	111	138	6.6%
Agriculture, forestry, and fishing	28	47	2.3%
Manufacturing	17	30	1.4%
Total	**1,772**	**2,080**	**-**

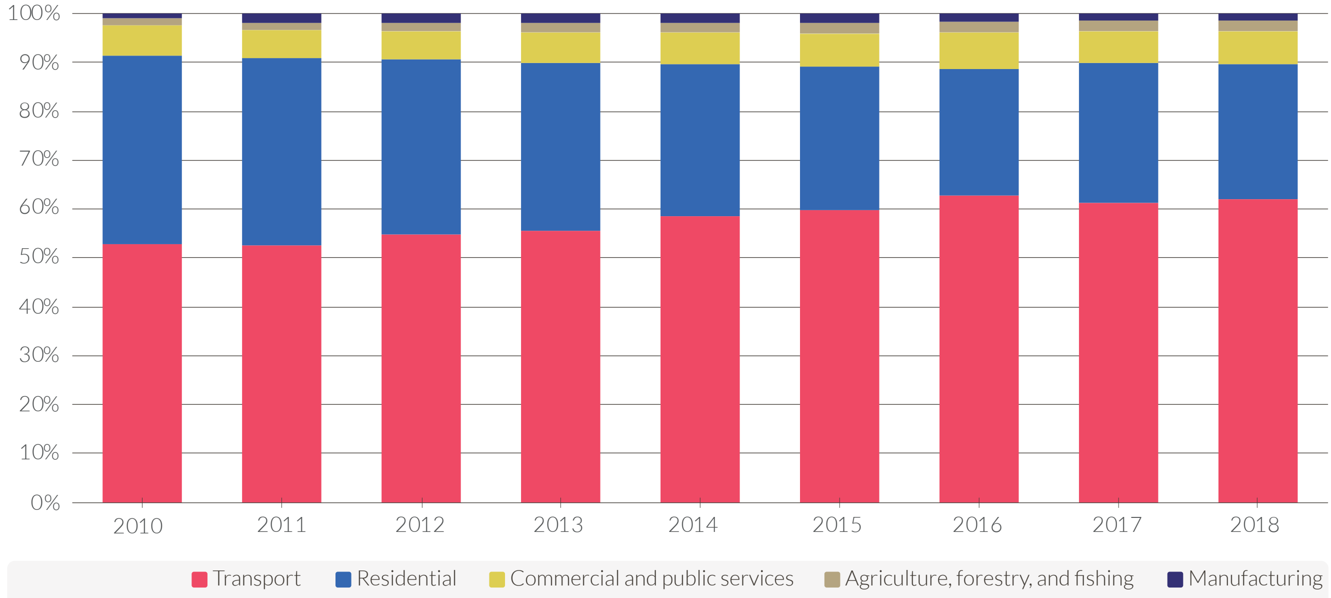
Source: DoE, 2021

19 Residential sector accounted for 44% of electricity consumption according to the Tonga Energy Efficiency Master Plan. Commercial, religious, government, and public services make up the remaining 56%.

Energy consumption by sector

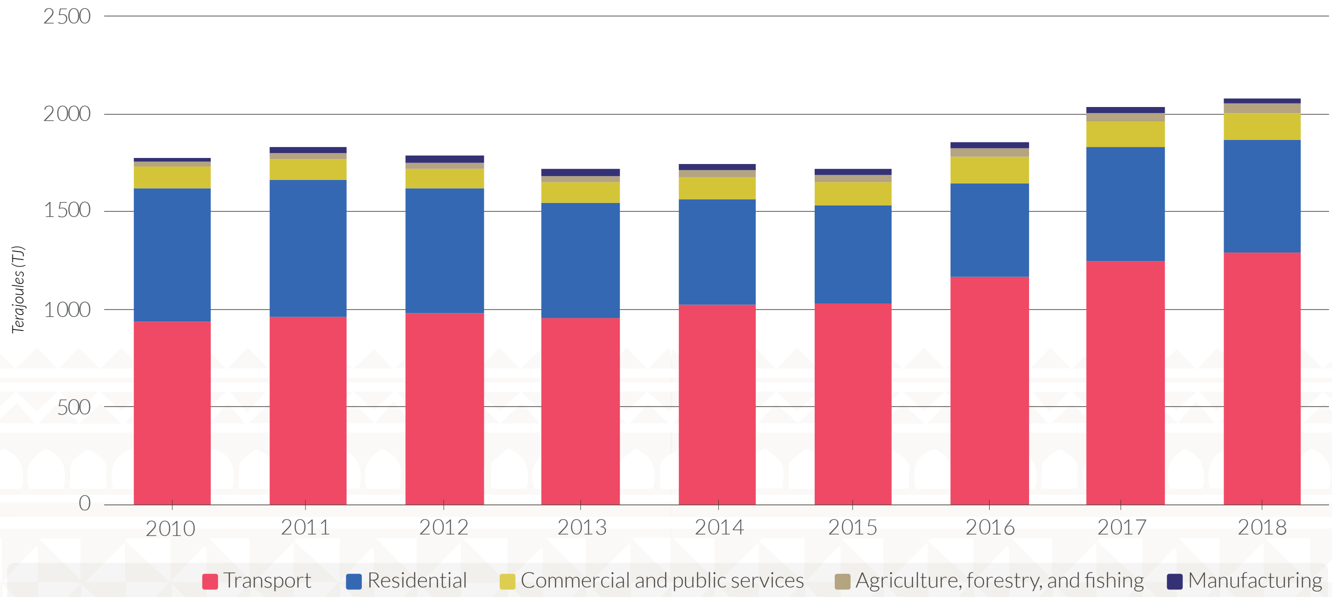
The key end-use sectors in Tonga comprise i) transport, ii) residential, iii) commercial and public services, iv) agriculture, forestry, fishing, v) manufacturing. Figure 6 and Figure 7 represent the historical trend of sectoral energy consumption between 2010–2018. During that period, energy consumption in the transport sector increased by 38% whereas the residential sector decreased by 16%. In 2018, energy consumption in transport sector is 1,290 TJ which accounts for 62.0% of total final consumption, followed by residential sector for 27.7% (575 TJ), commercial and public services for 6.6% (138 TJ), agriculture, forestry, fishing for 2.3% (47 TJ), manufacturing for 1.4% (30 TJ).

FIGURE 6.
Energy consumption share by sector



Source: DoE, 2021

FIGURE 7.
Energy consumption amount by sector



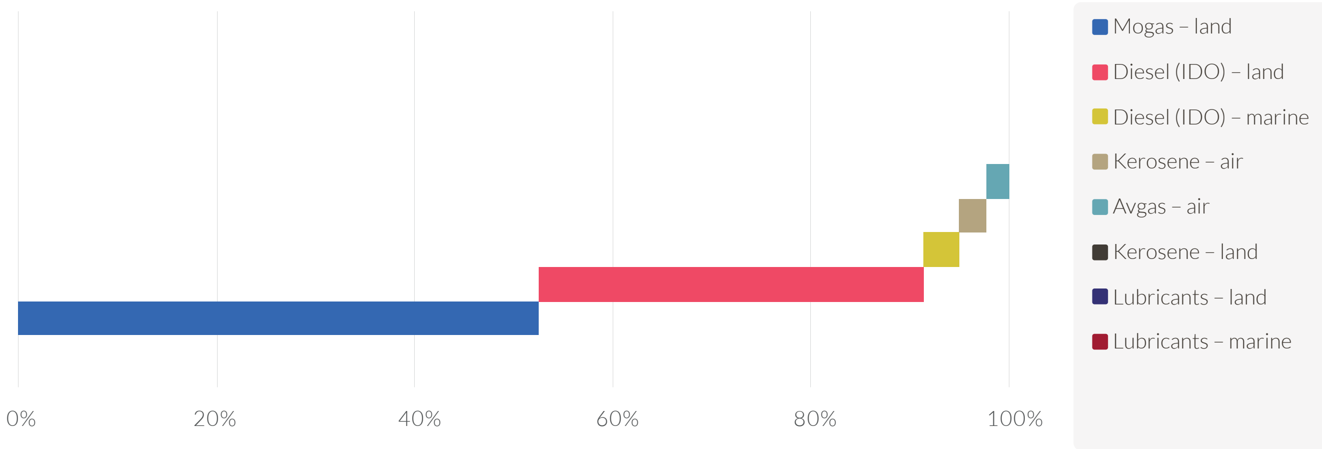
Source: DoE, 2021

Energy consumption by fuel source in Transport Sector

The transport sector is the major energy consumer sector in Tonga with 62% of the total annual energy consumption (Figure 6 and Figure 7). Fossil fuels are the only energy source for the transport sector (land, maritime, and aviation) and except for a few plug-in hybrid and pure electric vehicles, there is no electrification in the transport sector. Motor gasoline and diesel fuel for land and marine transportation contribute to 91% of all energy consumption in transport. The use of fossil fuels such as aviation gas, kerosene and lubricants are relatively marginal. Figure 8 shows the share of fuel source in terms of contribution to energy consumption in the transport sector.

FIGURE 8.

Fuel share in total energy consumption in Transport Sector



Source: DoE, 2021

Energy consumption by fuel source in Residential Sector

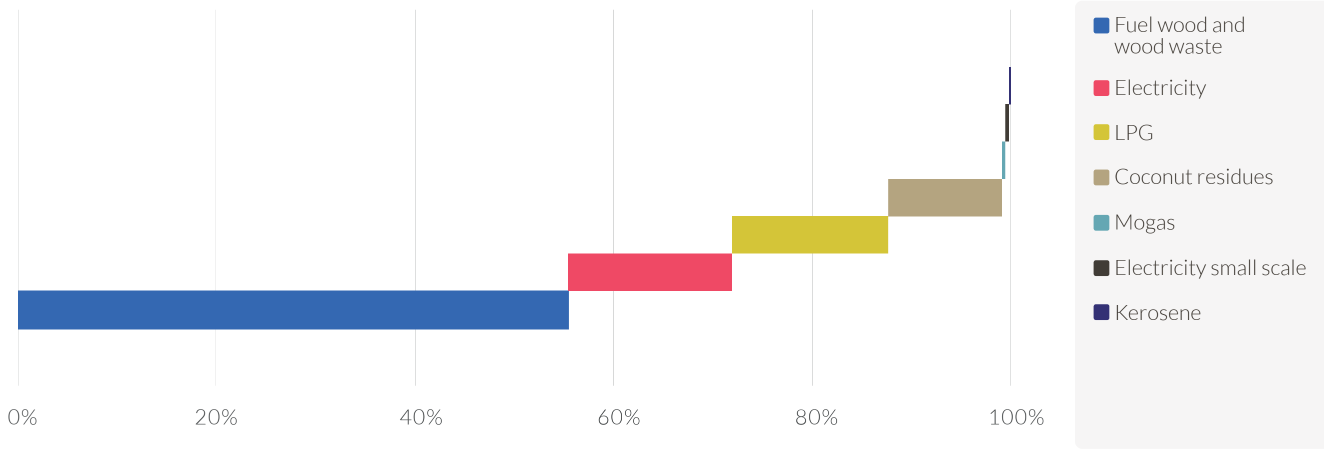
The residential sector is the second largest energy consumer with 27.7% of the total annual energy consumption (Figure 6 and Figure 7). The residential energy consumption is mostly from biomass in the form of fuel wood and wood waste (55%) and coconut residues (11%). On-grid electricity consumption[20] (16%) and renewable energy generated small scale off-grid electricity (<1%) have a significant share in total energy consumption in the residential sector. Other fossil fuels such as LPG, kerosene and motor gasoline contribute for the remaining energy consumption. The combined energy consumption from biomass and fossil fuel types is higher than the electricity consumption for residential. This indicates the majority of household energy consumption may be due to high reliance on LPG, kerosene, and biomass for cooking. Figure 9 shows the share of fuel source in terms of contribution to energy consumption in the residential sector.

The consumption of fuel wood and wood waste and coconut residues within the residential sector have both decreased by 30% between 2010–2018 whereas LPG consumption increased 77% during the same period (Figure 10). This can be attributed to the increase in LPG demand for cooking which has become the preferred choice compared to the traditional fuelwood stove and electric stove. Anecdotal evidence indicates that the major use of fuelwood is for traditional underground ovens (umus) although there remains some use of fuelwood stoves.This transition to LPG cooking is one of the contributing factors to the decrease in biomass consumption over the years in the same period. Electric stove adoption on the other hand, has not been successful due to the high electricity tariff for households. It is anticipated that the LPG demand will continue to increase to 92% by 2030 as this cleaner source of energy fuel becomes cheaper and readily available in the market.[21]

[20] GGGI is unable to identify the electricity consumption from the residential sector due to the limitation in TPL consumer categorizations. Electricity consumption in the residential sector is calculated as 44% of total electricity consumption according to TEEMP.

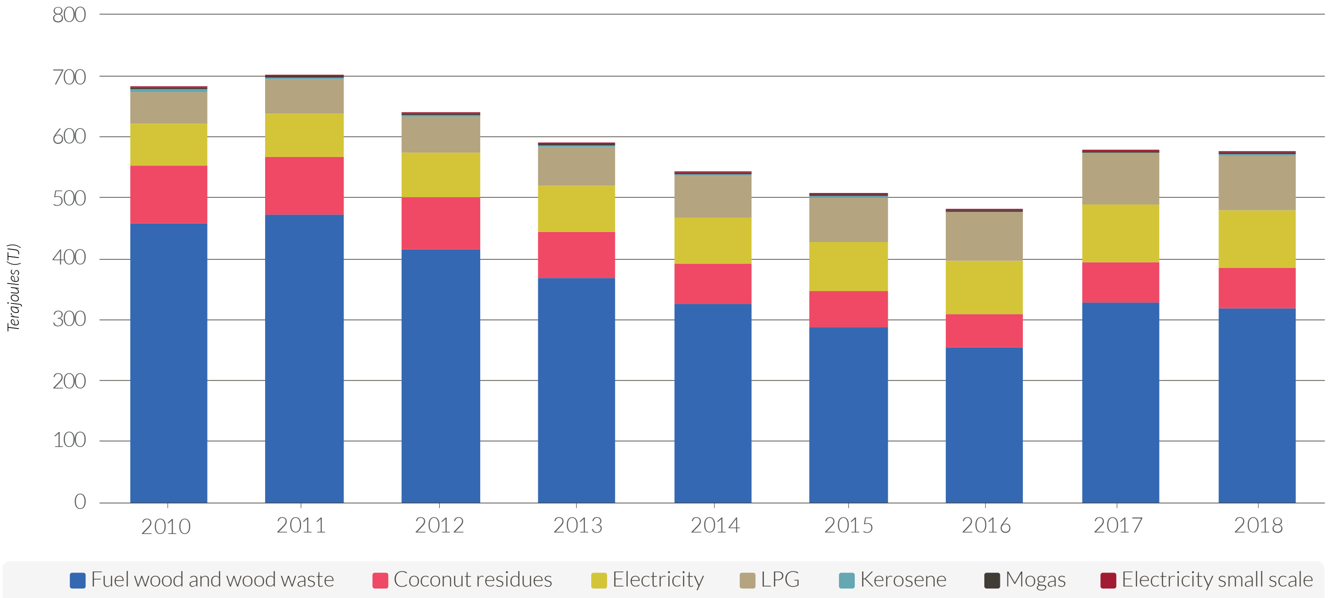
[21] 2021 United Nations Publication: Energy Transition Pathways for the 2030 Agenda – SDG 7 Roadmap for Tonga Executive Summary page VI: Tonga does not have a specific policy for achieving universal access to clean cooking. NEXSTEP analysis shows that the current rate of improvement is not enough to achieve universal access to clean cooking. In the current policy settings, access to clean cooking will increase from 65.3% in 2018 to 92.2% 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 as well as stakeholder discussions for the remaining 8,000 people by 2030.

FIGURE 9.
Fuel share in total energy consumption in Residential Sector



Source: DoE, 2021

FIGURE 10.
Energy consumption by fuel in Residential Sector



Source: DoE, 2021

2.2 CONSUMPTION TARGETS

The TERMPLUS identifies two major targets for consumption. Those targets are listed below and shown in detail in Table 7.

- Limit growth in oil consumption for road transport to 25% for the period 2019–2035 (an average of 1.4% per year).[22]
- Limit growth in grid-connected residential electricity end-use to 1% per year on average for the period 2019–2035.

Total final energy consumption is defined as the sum of energy consumption in all sectors. Overall electricity consumption is reported separately and the breakdown for each sector is not listed in the collected data. Electricity consumption for the residential sector is taken to be 44% of total electricity consumption while commercial and public services correspond to the remaining 56%.[23] The transport sector has almost no share of the overall electricity consumption and except for four electric vehicles and some plug-in hybrid vehicles, it fully relies on fossil fuel.

TERMPLUS sets two targets for limiting energy consumption. The first target is to limit growth in oil consumption for road transport to 25% for the period 2019–2035. The related targets and corresponding measures as well as requirements are discussed in more detail in Section: 4. Transport.

TABLE 7.
Targets, measures, and requirements for consumption

Target	Measures	Requirements

Limit growth in oil consumption for road transport to 25% for the period 2019–2035 (an average of 1.4% per year)	• Improving Intake Quality of Vehicle; Fuel efficiency; End-of-life
	  ◦ Motor industry quality assurance programme
	  ◦ Stricter emission standards for new/existing vehicles and fuel
	  ◦ Shared Mobility
	• Non-Motorised Transport
	  ◦ Walkway and bicycling lanes expansion
	  ◦ Pedestrianisation
	  ◦ Public Bicycle Sharing (PBS)
	• Low Emission Vehicles
	  ◦ Electric Private Passenger Vehicles[24]
	  ◦ Electric Public Transportation
	  ◦ Electric Commercial Taxis
	  ◦ Electric Vehicles in Government fleet
	  ◦ Electric Freight Vehicle
	  ◦ Maritime Electrification
		• Investment requirements (private and public finance options)
		• Institutional requirements (policy and planning requirements, execution, monitoring, and evaluation)
		• Policy and regulatory requirements

Limit growth in residential electricity end-use to 1% per year on average for the period 2019–2035	1. Adoption and enforcement of minimum energy performance standards 2. Curtailment of import of non-LED bulbs 3. Installation of solar water heating systems 4. Energy efficiency standards for buildings introduced and enforced	1. Policy and legislative requirements 2. Financial incentives and subsidies 3. Funding requirements 4. Research on energy perception and values

Source: GGGI

22 This target is the result of limiting growth of motor gasoline consumption in road transport to 9% and growth of diesel consumption in road transport to 50% for the period 2019–2035 (an average of 0.5% and 2.3% per year, respectively).

23 According to TEEMP, in 2017, the residential sector accounted for 44% of electricity consumption, with commercial, religious, government and public service accounts making up the remaining 56%.

24 Electric Vehicle references include Plug-in Hybrid Electric Vehicles.

Second, TERMPLUS aims to limit growth in residential electricity end-use to 1% per year on average for the period 2019–2035. This target is linked to i) adoption and enforcement of minimum energy performance standards for appliances, ii) curtailment of import of non-LED bulbs as lighting requires significant electricity demand together with other appliances used in homes, iii) installment of solar water heating systems to reduce the use of electric water heaters and utilise available solar resource, and iv) introduction and enforcement of building standards for energy efficiency.

TERMPLUS targets are consistent with national policies such as TEEMP and Tonga's NDC and the identified measures are the most impactful means to contribute to reaching the set target. However, more detailed analysis is required to make more accurate quantitative estimation for each measure and the breakdown of savings contribution to limit the residential electricity end-use. The conclusions of the previous studies conducted by DoE are summarised in Appendix C.

2.3 CONSUMPTION MEASURES

In order to limit energy consumption growth and achieve the targets set out in the TERMPLUS, the following measures for residential electricity end-use, which are in-line with the measures in TEEMP, will be undertaken. The target set for limiting the oil consumption, corresponding measures, requirements and enabling environment are discussed in detail in Section 4. Transportation.

Target: Limit growth in grid-connected residential electricity end-use to 1% per year on average for the period 2019-2035. In order to limit the growth in residential electricity end-use, the following measures will be undertaken.

- Adoption and enforcement of minimum energy performance standards.
- Curtailment of import of non-LED bulbs.
- Installation of solar water heating systems.
- Energy efficiency standards for buildings introduced and enforced.

These measures are identified as the most impactful means in terms of high energy savings and GHG emission reduction potential, and low upfront cost for implementation. 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. The early study[25] funded by Australian Aid estimated that implementing MEPS will achieve a 10 GWh savings in 2030 with cumulative projected savings of 117 GWh in between 2015–2030. The TEEMP analysis anticipates upwards of 12.7 GWh could be saved through rigorous MEPS implementation in 2030. The difference can be attributed to different BAU consumption figures, less selective MEPS, and applicability of fewer appliances.[26]

In Tonga, a high proportion of households use appliances such as a stove, washing machine, television, fridge and freezers especially in Tongatapu compared to all other regions. This would be the indication of both higher household access to grid electricity and higher income. Almost 90% of households use mobile phones in all regions except Ongo Niua with a usage rate of 78%, making mobile phones the most common household goods in Tonga. With the increased access to technology, the ownership of laptops, tablets, and personal computers has also increased. According to a survey conducted in 2016, 38% of private households in Tonga have a laptop, 18% a tablet and 9% a desktop computer. As more households access the internet and adopt smart appliances, Information and Control Technology (ICT) will be able to monitor their equipment and appliances to increase energy efficiency and decrease energy usage.

Only 2% of all private households have air-conditioning (Tonga Census, 2016). Among others, electrical appliances such as refrigerators, washing machines, electric water heaters, air-conditioning and lighting comprise most of residential electricity consumption which are not always highly efficient. LED lighting and high efficiency whiteware are available in Tonga, however, the cost of these technologies and appliances is relatively high compared to non-efficient appliances. The adoption and implementation of minimum energy performance standards for electric appliances is of the utmost importance to limit the residential end-use electricity consumption. Draft MEPSL regulations for Tonga covering refrigerators and

25 Energy Labelling and Minimum Energy Performance Standards for Appliances and Lighting: Impacts in Cook Islands, Fiji, Kiribati, Samoa, Tonga, and Vanuatu (Australian Aid, 2016), http://prdrse4all.spc.int/sites/default/files/energy_labelling_and_minimum_energy_performance_standards_for_appliances_and_lighting-impacts_in_ci.fj_.ki_.sa_.to_.va_.pdf.

26 Australian Aid's study energy savings projections include electricity use by each sector including residential, commercial, government and industrial—and derived from the reports of the various Pacific Island Country electric utilities. The specific quantitative impact of each measure to achieve the set target for residential electricity end-use requires more analysis with appropriate data.

freezers, air conditioners and lighting were developed in 2017 under the Pacific Appliances Labelling and Standards (PALS) project and is still in progress for implementation. This regulation is crucial to standardise and enforce the import of appliances that are highly efficient. The regulation is aligned with Tonga's anticipated Energy Act which is expected to become law in 2022 (with royal ascent). The MEPSL will also intend to prevent the import of products below the minimum acceptable level of efficiency. This will include curtailment of import of non-LED bulbs. The goods that are non-compliant with MEPSL regulation will be confiscated by the Ministry responsible for energy according to the upcoming Energy Act.

The use of properly sized solar water heating (SWH) systems will reduce residential electricity consumption as they will replace the electric water heaters which are common in Tonga. SWH systems may involve a higher initial cost but typically have a pay-back period of 3–5 years. Therefore, incentives must be developed to advance the uptake of these appliances which can support behavioural change and avoid rebound effects.

Energy efficiency standards for buildings are designed to provide a significant reduction in residential electricity consumption. Building codes were first introduced in Tonga in 2017. Currently, a complete review, strengthening, update and enforcement of building code is needed. There have been discussions between the DoE and the Ministry of Infrastructure to incorporate and specifically include energy efficiency designs in Tonga's building codes. However, this is still a work in progress and has yet to be completed. The new energy efficiency standards for new or retrofitted buildings must address passive techniques mainly on passive ventilation, cooling and daylighting to reduce the energy consumption. Building stock in Tonga varies from designs adopted from the United States, New Zealand and Australia, who have distinct types of design that suit their natural environments. Tongan traditional architecture should be also investigated as it would already be adapted to the environment. The existing building type and operations must determine which strategies, applications and standards will provide the best impact on energy performance of the building including house-orientation, water conservation, green infrastructure, etc. and these standards must be introduced and enforced accordingly.

Another major household appliance that needs regulation are LPG cooking stoves, which have increased considerably over the several decades. LPG is one the preferred fuel resources for cooking in the residential sector in Tonga (Tonga Census, 2016). LPG stoves are preferred over electric stoves due to the currently high electricity tariff. However, LPG stoves are not very energy efficient. An alternative cooking method that is more energy efficient is the induction cooking stove. Unlike LPG stove which has 30% efficiency and the conventional electric stove which has 42% efficiency, induction stoves reduce the energy lost through direct heating making them more energy efficient by 76% (Dols, Sweeney and Sharp 2014). Hence, induction cooking stove would be extremely useful in Tonga. To enhance the adoption of induction cooking stove, the government will need to create an enabling environment for the induction stove market especially when electricity tariff is high and there is still significant reliance on fossil fuel for its generation.

2.4 REQUIREMENTS AND ENABLING ENVIRONMENT

Energy efficiency plans must be aligned with existing national policies and planning practices such as TSDF, National Spatial Planning Framework Act, National Infrastructure Investment Plan II, NDC, SDG 7 Roadmap, and JNAP 2. This includes understanding transportation demand management in high level planning to address the emissions from the transport sector as well as the current energy efficiency considerations from appliances and building standards to inform the low-emissions strategy. Coordination between levels of government, private sector and communities is critical to ensure goals and investment decisions are aligned not only to national targets but to global targets under the United Nations – Sustainable Development Goals (SDG) including:

- SDG 3 (good health and well-being).
- SDG 7 (affordable and clean energy).
- SDG 13 (climate action by 2030).

The adoption and implementation of minimum energy performance standards for electric appliances will be instrumental to limit the residential end-use electricity consumption. MEPSL requirements and standards will be continuously reviewed, updated and monitored for efficient and effective implementation. The enforcement of the MEPSL will require financial support from the GoT to all key stakeholders. The draft MEPSL regulation for Tonga only applies to refrigerators and freezers, air conditioners and lighting. The following actions will be taken for the expansion of the current MESPL regulations to include (but not limited to) the following:

1. Expand MEPSL appliances including cooking appliances such as induction stoves.
2. Include appliances with motors such as water pumps.
3. Include washing machines, electric water heaters and other household appliances.

4. Provide financial incentive for demographic of income.
5. Establish a MEPSL laboratory as part of a renewable energy lab to test appliances in Tonga.
6. Initiate energy behaviour programme to influence behavioural change and increase public awareness.

The energy efficiency standards for buildings will be introduced and enforced to reduce residential electricity consumption. Upgrading the existing Tonga building code is a priority and will be in parallel with the promotion of transforming the building stocks into energy efficient buildings.

The capital costs of new and improved retrofits for building envelopes, windows, doors are currently high due to an immature market with high fragmentation and transaction costs. Energy efficiency standards of a buildings' envelope and equipment yield different outcomes when not designed properly. There is a need to update research to understand appropriate building envelope and design required for Tonga's tropical and cyclone prone environment. These should also be reflected in the Tonga National Infrastructure Investment Plan update (NIIP 3) to occur in 2023. The policy will include but not be limited to:

- Investment in energy efficient materials that are locally sourced for retrofit or new buildings.
- Incorporation of biomimicry and regenerative design into building codes.
- Financial incentives for the demographic of income.
- Adoption of energy efficiency standards and labels for buildings.

Adoption of standards from other countries may not yield the expected outcome due to many factors that need to be considered. Some factors to consider include supply, availability, affordability, demand and, more importantly, practicality and applicability. Such codes and standards will determine the success of achieving desired outcomes. The following requirements are necessary to limit growth in residential electricity end-use:

- Policies and legislative requirements - Innovative energy efficient equipment and appliances are often scarce and difficult to procure in Tonga. On the other hand, cheaper but poor-quality technologies tend to flood the Tongan market. Due to lack of energy efficiency building codes, buildings and their construction are usually designed based on technology stock within a country. Therefore, there is a need for robust policy and legislations that enables the private sector to invest in expanding the energy efficient design market in Tonga.
- Financial incentives and subsidies - Household appliances will continue to dominate energy consumption in homes. To ensure the success of limiting energy consumption in homes, enforcement and policing of MEPSL is imperative. The government will enforce the MEPSL regulations within the next two years. This will require a period of transition where the government needs to be actively engaged in and work together with the private sector for marketing, capacity building and training on these MEPSL appliances. The cost for these appliances will initially be higher, hence, various financial incentives through green loan or subsidies will be considered to promote the uptake and use of these appliances. In addition, the uptake of LPG stoves is poised to grow in upcoming years unless government coordinates with the TPL and private sector to promote the more energy efficient induction stove. However, the transition to the more expensive induction stove will require exploring sustainable financing mechanisms and incentives to facilitate the shift.
- Funding requirements - Funding is vital and must be sustainable to ensure that interventions are supported. These funding opportunities must be revenue generating rather than fully relying on donor funding. The government will work closely with donor agencies and key stakeholders, especially the private sector, to design good business models that will help fund low emission interventions.
- Research on energy perception and values - Consumer's value of technologies in buildings are generally based on individual preference factors such as affordability rather than energy efficiency. Most families in Tonga have other priorities such as church obligations, bills, family that are usually prioritised and met first. There is a need for updated research to better understand consumers and their behaviours. This information is critical for policies that are designed to boost the energy efficiency market.

2.5 ENERGY CONSUMPTION ROADMAP

The overall targets for each intervention are sub-divided into short-, medium-, and long-term targets as shown in table below.

Interventions/ Policy Alignment	Short-Term Target 2025	Medium Term Target 2030	Long Term Target 2035	Key Stakeholders
Complete LED Street Lamp Retrofit Policy: TERM, TEEMP	Tongatapu	Vava`u, Ha`apai, `Eua	Outer Islands	Sector Lead: MEIDECC – DoE, TPL Partners: PCREEE, Private Sector Finance: Development Partners
Complete Interior LED Retrofits Policy: TERM, TEEMP	Tongatapu	Vava`u, Ha`apai, `Eua	Outer Islands	Sector Lead: MEIDECC – DoE Partners: PCREEE, Private Sector, MEIDECC – DCC Finance: Development Partners
Expand Minimum Energy Performance Standards and Labelling (MEPSL) with Act Adopted Policy: TEEMP	Include appliances with motors such as water pumps, washing machines, electric water heaters and other household appliances, Provide financial incentives for demographic of income	Establish a MEPSL laboratory as part of a renewable energy lab to test appliances in Tonga, Initiate energy behaviour programme to influence behavioural change and increase awareness, Enforce Standards	Enforce Standards	Sector Lead: MEIDECC – DoE Partners: PCREEE, MEIDECC – DCC Finance: GoT
Solar Water Heaters Policy: TEEMP	25% Residential	50% Residential	100% Residential	Sector Lead: MEIDECC – DoE Partners: PCREEE, Private Sector Finance: GoT
Commercial and Residential Air Conditioner retrofits Policy: TEEMP	25% Commercial and Residential	50% Commercial and Residential	100% Commercial and Residential	Sector Lead: MEIDECC – DoE Partners: PCREEE, Private Sector Finance: GoT
Increased deployment of high-efficiency water pumps where applicable	25% Pumping Facilities	50% Pumping Facilities	100% Pumping Facilities	Sector Lead: MEIDECC – DoE Partners: PCREEE, Private Sector Finance:GoT
Information and Communications Technologies (ICT) interventions in households and businesses to decrease electricity usage and improve energy efficiency	25% Commercial and Residential	50% Commercial and Residential	100% Commercial and Residential	Sector Lead: MEIDECC – DoE, TPL Partners: PCREEE, Private Sector Finance: GoT

Interventions/ Policy Alignment	Short-Term Target 2025	Medium Term Target 2030	Long Term Target 2035	Key Stakeholders
Green Entrepreneurs Energy Efficiency Program for Tonga Policy: TEEMP	Innovative energy efficiency devices and technologies, energy efficient and locally produced umu-biomass cooking	Innovative energy efficiency devices and technologies, energy efficient and locally produced solar water heaters	Energy efficient designs for residences and businesses	Sector Lead: MEIDECC–DoE, TPL Partners: GGGI, PCREEE and Private Sector Finance: GoT, TPL, Private Sector
Consideration of a Public-Private-Partnership in Energy Efficiency (EE) Business to reduce Consumer Demand and decrease unnecessary Power Generation capacity additions Policy: TEEMP, TCCP, JNAP2, SDG7.3	Establish Program and Set Target for 2025, Achieve 2025 Target and Set Target for 2030	Achieve Target for 2030 and Set Target for 2035	Achieve Target for 2035 and Set Targets for the future	Sector Lead: MEIDECC–DoE, TPL Partners: GoT, Private Sector, PCREEE, GGGI Finance: GoT, Private Sector
GoT energy efficiency requirements for new procurement/purchases for the government Policy: TEEMP	Amend and Develop GoT High-Efficiency Procurement Policy	Implement and Refine GoT High-Efficiency Procurement Policy	Incentivize and Facilitate Implementation in Private Sector	Sector Lead: MEIDECC–DoE Partners: TPL, Private Sector Finance: GoT, TPL
Building Codes Policy: TEEMP	A complete review, strengthening, update, upgrade and enforcement of building code, and be reflected in the NIIP	New Buildings or Retrofits of Buildings requires investment in energy efficient and resilient materials that are locally sourced, Financial incentives for the demographic of income investing in Residential Retrofits, Adoption of energy efficiency standards and labels for buildings	Incorporation of biomimicry and regenerative design into building codes, Financial incentives for the demographic of income, Review and update Building Codes and Enforce	Sector Lead: MOI, MEIDECC–DoE Partners: World Bank, ADB, Private Sector Finance: Development Partners, GoT
More Efficient and Clean Cooking Access Policy: TEEMP, SDG 7.1, UNESCAP SDG7 Roadmap	Incentivize the transition from Biomass to LPG cooking by 2030	Achieve universal access to clean cooking fuels with LPG cooking stoves	Enhance the adoption of the electric induction cooking, Create an enabling environment for induction stove market when electricity tariff is high	Sector Lead: MEIDECC–DoE, TPL Partners: Private Sector Finance: GoT, TPL
Solar Street Lights Policy: TEEMP	Tongatapu	Vava`u, Ha`apai, Eua, Outer Islands	Maintain, repair, replace and upgrade as necessary	Sector Lead: MEIDECC–DoE, TPL Partners: Private Sector, PRC Finance: Private Sector, TPL, GoT

Interventions/ Policy Alignment	Short-Term Target 2025	Medium Term Target 2030	Long Term Target 2035	Key Stakeholders
Solar Freezer Systems Policy: TEEMP	Vava`u, Ha`apai	Outer Islands	Maintain and repair as necessary	Sector Lead: MEIDECC–DoE Partners: JICA, NGOs, Private Sector Finance: Development Partners, GoT
Conducting energy audit trainings Policy: TEEMP	Develop energy audit training courses/ programs, Start energy audits for largest energy-use buildings and facilities	Implement energy audits for government, commercial and residential buildings according to updated high-energy-efficiency Building Codes	Energy audits for new buildings according to high-energy-efficiency Building Codes	Sector Lead: MOI, MEIDECC–DoE Partners: Private Sector, Development Partners Finance: GoT, Development Partners
Conducting studies on consumer behaviour/ usage of electricity Policy: TEEMP	Tongatapu	Vava`u, Ha`apai, `Eua	Outer Islands	Sector Lead: MEIDECC–DoE, TPL Partners: Development Partners, Private Sector Finance: Development Partners, GoT

3 ELECTRICITY GENERATION AND DISTRIBUTION

3.1 OVERVIEW

Electricity is generated by power systems capable of converting primary sources into electrical energy. These primary sources may be non-renewable fossil fuels (oil, natural gas, diesel, coal, etc.) or renewable (wind, solar, geothermal, hydro, ocean, tidal, etc.). Renewable power systems are designed to run on the unlimited supply of a country's renewable resources. The goal of transforming a nation's electricity supply through renewable energy systems is fundamental for a low-emission and climate-resilient sustainable-growth strategy.

While today, Tonga relies significantly on non-renewable diesel generation, over the past decade, its electricity sector has been undergoing a transformation with the integration of renewable systems at an increasing rate. In 2008, to address the challenges of energy security, climate-change and energy access, Tonga's progress began with bold policies of the 2008 Renewable Energy Act. In 2009, the GoT approved the goal of 50% of electricity to be generated from renewable energy sources by 2020 which became the centrepiece of the ground-breaking Tonga Energy Road Map 2010–2020 (TERM). Subsequently, Tonga followed TERM strategies from 2010 to 2020 resulting in a series of renewable generation and network upgrade projects moving from total dependence on fossil-fuels to an increasing share of renewable electricity.

Through this TERMPLUS and TPL's Renewable Acceleration Power IndepenDence (RAPID) Project, Tonga will raise-the-bar again to 70% renewable electricity by 2025 along with goals of sustainable transportation, improved data management, energy security and a greater emphasis on climate-resilient energy systems. The ultimate goal of 100% renewable electricity by 2035, will build upon the projects that will be planned, funded and implemented in the next decade. TERMPLUS strengthens the Framework foundation to support Tonga's progressive march towards higher penetrations of renewable electricity. This TERMPLUS, provides a roadmap of the elements that make these goals possible.

In August 2021, Tonga's energy transition gained acceleration with the GoT's Energy Bill passed by Parliament and anticipated to become Act in 2022. This comprehensive Bill provides policies to establish coherent institutional and regulatory frameworks for coordination of the energy sector. It establishes clear national objectives as well as promotes private sector incentives and research initiatives. The anticipated Energy Act will begin the development and adoption of Tonga's National Energy Policy to be reviewed, updated and adopted every five years. The National Energy Policy will include all existing energy-related regulations and legislations including the MEPSL.

Electricity transmission and distribution systems, known as networks, enable the transfer of electricity from generation sources to the end-user. Historically, losses in Tonga's four electricity networks have been reported as high as 18% in the last decade (2010–2020). However, due to the strong efforts of Tonga Power Limited (TPL) and considerable development partner investments, network losses have been reduced significantly from a baseline of 18% to below 9%.[27] Enhanced TERMPLUS targets further drive those losses down to under 8% through 2035.

With massive transformations underway in renewable energy generation, distribution and policy, Tonga's electric system will perform with ever-increasing complexity in the future. Operating and maintaining this renewable electricity system of the future will require technology upgrades in almost every area and significant capacity-building will be needed to develop the skills of those who control, operate, maintain and regulate Tonga's increasingly dynamic network.

Fortunately, the GoT and TPL have worked closely over the past decade to meet many of the challenges of this transformation. TPL's core business as Tonga's sole electric utility is the generation, distribution and retailing of electricity across the four main island systems in Tonga consisting of more than 25,000 customers.[28] Since the TERM began in 2010, TPL, with the help of MEIDECC – DoE and development partners has implemented multiple renewable electricity projects and made substantial improvements to their network infrastructure. Today, all four island systems operate with significant renewable energy both as a percentage of installed capacity and as a percentage of peak electricity demand (Table 8).

TABLE 8.
Installed Renewable Capacity on TPL Island Networks

Tongatapu	Type	% Renewable
14.9 MW	Diesel	-
5.7 MW	Renewable	28%
9.3 MW	Peak Load	61%

Vava'u	Type	% Renewable
1.9 MW	Diesel	-
420 kW	Renewable	18%
1.1 MW	Peak Load	38%

`Eua	Type	% Renewable
670 kW	Diesel	-
200 kW	Renewable	23%
300 kW	Peak Load	67%

Ha'apai	Type	% Renewable
670 kW	Diesel	-
560 kW	Renewable	45%
330 kW	Peak Load	170%

Source: TPL Business Plan 2021-2026

However, those renewable systems generate according to nature at approximately 4 hours per day (17%) for solar and approximately 7 hours a day for wind (30%).[29] Remarkably, maximum renewable electricity generated during each day of the year (hours, minutes, seconds), from Tonga's installed renewable generation is theoretically capable of providing 38% to 67% of the peak electric load for Tongatapu, Vava`u, `Eua and 100% in Ha'apai.

That is exactly the goal of Tonga's Government and TPL, to enable through advanced energy storage (i.e. load-shifting BESS), new technologies and controls, a future electricity system that can fully-harness those renewable energy potentials when they are needed. Thus, moving from a system based on fossil-fuels with its associated economic volatility and destructive environmental consequences to a sustainable system that provides the basis for green economic growth.

27 GGGI TERM Review – Table 1 – October 2020 Workshop.
28 Electricity Concessions are awarded on a five-year basis. TPL was awarded their most recent concession in 2021.
29 Capacity Factors derived from Green Climate Fund – Funding Proposal 28 November 2018 FP090: Tonga Renewable Energy Project under the Pacific Islands Renewable Energy Investment Programme, page 21 of 72. The above performance metrics are typical of Pacific Islands (middle latitudes, with regular cloud cover). TONGA RENEWABLE ENERGY PROJECT - Final Feasibility Report – 30 May, 2020 – page 44 – Prepared by Hydro-Electric Corporation ABN48 072 377 158 Solar Capacity factors in the range of 15–19% are common.

Since the introduction of the TERM, the following renewable energy projects have been accomplished (Table 9):

TABLE 9.
TERM Projects Completed 2010–2020

Projects	Tech.	MW	Additional Technology	Installation
Tongatapu				
Maama Mai	Solar	1.332	BESS – Grid Stability and Power Smoothing	October 2015
Mata 'o e La'a	Solar	1.0	BESS - Grid Stability and Power Smoothing	October 2015
Matatoa Solar	Solar	2.0	Microgrid Controller	September 2017
Manumataongo	Wind	1.3	Curtail Controller	June 2019
Vava'u				
La'a Lahi	Solar	.42	.60 MWh BESS	August 2013
Ha'apai				
Ha'apai	Wind	.011	-	April 2015
Ha Masani	Solar	.55	.33 MWh BESS	October 2017
\`Eua				
Huelo Koula'o e Fungafonua	Solar	.20	-	September 2017
Other				
Third-party	Solar	.51	-	2015–2020
TPL-rooftop	Solar	.065	-	2015–2020
Off-Grid Rural				
JICA SHS Vava'u and Tongatapu	Solar SHS	.103	BESS 512x130AH	2010–2013
Japanese PALM 5 Solar Freezer and Solar Pump	Solar Pump/Solar Freezer	.363	Pump and Freezers with BESS	2015–2017
IUCN Enhancing Livelihood SHS and Solar Pump	Solar SHS/ Solar Pump	.033	Water Pump with SHS BESS 58x130AH	2010–2020
China Solar Street Lights	Solar	.350	BESS 1750x130AH with LED	2016–2020

Source: GGGI, DoE 2022

For the TERM period of 2010–2020, Tonga's renewable projects and network upgrades have been assisted with funding from a diverse set of countries and development partners (Table 10).

TABLE 10.
Recent Grant Funded Projects

Project	Development Partner Funding ($USD)
TREP	53.20 M
OIREP	28.11 M
NNUP, TVNUP, TCGRP, TCIRCRP	13.93 M
GoC WIND FARM	12.31 M
JICA SHS Vava'u and Tongatapu	5.9 M
Japanese PALM 5 Solar Freezer and Solar Pump	4.0 M
IUCN Enhancing Livelihood through SHS and Solar Pump – Austria / Italy	0.34 M
China Solar Street Lights	3.5 M
Total	121.29 M

Source: TPL Business Plan, 2020–2025, DoE, 2022

TREP

Tonga Renewable Energy Project (TREP) is the most diverse and largest grant-funded project aimed at expanding access to clean, resilient and affordable energy. The TREP approved in March 2019 (finalised with three grants signed September 2019) is a suite of renewable energy projects targeting the energy needs of eight separate islands in the Kingdom of Tonga. TREP is estimated to enable, through Independent Power Producers (IPP), contribution of around 28% toward the TERM target of 50% renewable electricity.[30] It comprises the following subprojects:

- TREP 1 BESS – Grid stability BESS at Popua Power station, Tongatapu (5.1 MW / 2.5 MWh)
- TREP 2 BESS – Load shifting BESS at the Villa, Tongatapu (5 MW / 17.4 MWh)
- TREP 3 – Vava'u and 'Eua PV +BESS:
    - 350 kW solar PV facility and 1003 kW/ 1,856 kWh BESS at 'Eua
    - 300 kW solar PV facility and 1003 kW/ 2,007 kWh BESS at Vava'u
- TREP 3 – Ha'apai group and Niuafo'ou microgrids:
    - Solar PV – BESS micro-grid, including low voltage distribution system, for the following islands in the Ha'apai group: 'O'ua, Tungua, Kotu, Mo'unga'one
    - Solar PV – BESS micro-grid, including medium / low voltage distribution system, at Niuafo'ou

TREP 1 BESS and TREP 2 BESS[31]

Battery Energy Storage Systems (BESS) are able to stabilise the grid and store renewable energy generated at Tonga's existing solar and wind generation sites as well as distribute it to the electric grid when demanded. TREP 1 BESS will perform grid stabilisation services and is located next to the 1.3 MW solar PV at Popua power station. TREP 1 BESS has the capability to charge and discharge at 5.0 MW and has a usable storage capacity of 2.5 MWh.[32]

TREP 2 BESS will function as a load shifting battery to facilitate increasing capacity of renewable generation by storing solar generation during the day for use during evening peak and at night. The TREP 2 BESS will have capability to charge and discharge at 5.0 MW and have a usable storage capacity of 17.4 MWh. It is installed at Matatoa (May 2022) next to the existing 2 MW solar PV.

The impact of TREP is a transformational shift away from the traditional reliance on fossil fuels toward a greater emphasis on climate-resilient renewable energy systems and reduced GHG emissions as well as the promotion of private sector investments into renewable energy development. To achieve this, TREP will make a major contribution to Tonga's NDC target of generating 50% of electricity from renewables; laying the technology foundation for and increasing the momentum to reach the 70% target.

The two Tongatapu BESS installed under TREP will enable an increase in renewable energy generation by at least 7.8 MW (4 MW solar PV and 3.8 MW wind power to be funded by the private sector), which will enable Tonga to increase their renewable energy penetration by 27% without negatively affecting the grid. Moreover, the BESS on Tongatapu will assist TPL in enhancing the GoT's NDC target of reducing electricity line losses to 8% by 2035 (from a baseline of 18% in 2010).[33] TREP financed generation technologies in the outer islands will directly generate about 3% of additional clean electricity.

OIREP

The Outer Island Renewable Energy Project (OIREP) is the second largest grant-funded project. OIREP is aimed at helping to construct solar power plants on outer islands. OIREP will install a total capacity of 1.25 MW of mini-grid and grid-connected solar systems on nine outer islands: Vava'u, 'Eua, Lifuka, Ha'ano, Ha'afeva, Niuatoputapu, Niuafo'ou, 'Uiha, and Nomauka. Some of these outer islands will gain 100% coverage with a reliable and climate-resilient energy network. The benefits of such resilience and coverage were demonstrated in 2018 when Tropical Cyclone Gita and more recently Tropical Cyclone Harold tore through the region. The cyclone resistant network on `Eua suffered minimal damage and was able to supply much-needed power to communities as Tonga sought to rebuild.[34]

30 Green Climate Fund – Funding Proposal (28 November 2018) FP090: Tonga Renewable Energy Project under the Pacific Islands Renewable Energy Investment Programme, page 41 of 72.

31 The BESS complex consists of the Tonga 1 and 2 facilities, which Akuo installed on behalf of the islands' grid operator Tonga Power Ltd. the 9.3 MW/5.3 MWh Tonga 1 will help improve the grid's stability, while Tonga 2 the larger facility, of 7.2 MW/23.9 MWh, is designed for load-shifting. BESS Tonga 1&2 allow for more renewable electricity on the grid.

32 Entura – TONGA RENEWABLE ENERGY PROJECT – Final Feasibility Report – 30 May, 2020 – page 10: Prepared by Hydro-Electric Corporation ABN48 072 377

33 Green Climate Fund – Funding Proposal (28 November, 2018) FP090: Tonga Renewable Energy Project under the Pacific Islands Renewable Energy Investment Programme, page 5 of 72.158. The purpose of this BESS is to provide: spinning reserve, smooth variations in load on diesel generators, manage short term power imbalance in the system (active and reactive power), and to potentially allow diesel off operation (ZDO) of the system by setting grid frequency and voltage.

34 *Source :* https://www.pv-magazine-australia.com/2020/06/02/australia-tops-up-solar-funding-to-tonga

GoC Wind Farm

The Government of China is funding a wind farm to be located at the eastern side of Tongatapu.[35] The project is planned to install a total capacity of 2.25 MW using three 750 kW wind turbines. Successful signing of construction contract occurred in September 2020.[36]

NNUP, TVNUP, TCGRP, TCIRCRP

Nuku'alofa Network Upgrade Project (NNUP) is the upgrade and modernisation of the electricity network in the Nuku'alofa Area, in 5 phases which encompasses the 5 areas of Nuku'alofa. NNUP approved May 2018, will help to reduce network losses, increase access to electricity, provide safe and reliable electricity supply to approximately 8,472 households and businesses in the greater Nuku'alofa area, and improve TPL's operating and maintenance capability.[37]

NNUP is a necessary technology upgrade to reduce transmission losses as well as a network resilience programme. that adds to the already completed Tonga Village Network Upgrade Project (TVNUP). The project deliverables include upgrading 64 km of high voltage lines, upgrading 283 km of low voltage lines, and replacing 11,645 power poles. NNUP started in late 2018 and has secured funding for 3 out of the 5 areas with 1 area now in the process of due diligence. Funding support for the last area under NNUP is expected but remains outstanding.[38]

Tonga Village Network Upgrade Project (TVNUP) reduced line losses from 18% to 12% in 20 villages and is working to expand to more villages.[39] Tonga Cyclone Gita Recovery Project (TCGRP) had a total financing (ADB) of $6.8 million The Cyclone Gita Recovery Project is reconstructing and upgrading priority sections of the electricity network in Nuku'alofa damaged by Tropical Cyclone Gita in February 2018.[40] World Bank provided assistance on a reconstruction project called the Tonga Cyclone Ian Reconstruction and Climate Resilience Project (TCIRCRP) which was designed and implemented in response to the severe damage caused in Ha'apai as a result of Tropical Cyclone Ian (TC Ian).[41]

3.2 ELECTRIC GENERATION AND DISTRIBUTION TARGETS

In collaboration and for over a decade, the GoT and TPL have been steadily marching toward the same target of 50% renewable electricity generation. While the 50% objective is highly ambitious for any country, Tonga has made great strides. Today, the target date has been delayed due to external factors beyond the GoT and TPL's control; namely COVID-19.42 Of necessity, remaining projects have newly scheduled completion dates.[43] The following TERM projects are currently funded, in the pipeline, ready to achieve the 50% objective (Table 11).[44]

35 TPL Expression of Interest – April 2021.
36 Source : https://www.pcreee.org/article/tonga-raised-pacifics-priority-re-and-ee-inauguration-belt-and-road-energy-partnership
37 Source: Tonga Power Limited website http://www.tongapower.to
38 Source: Tonga Combined Utilities Business Plan, 2018–2022, TPL (October 2021), Update from OIREP Project Manager.
39 Tonga Village Network Upgrade Project – Reduces Line Loss and Elevates Power Distribution, Tonga Power Limited, 12 March, 2018, http://www.tongapower.to/NewsRoom/tvnup_update_dec2012.aspx
40 ADB 2020 Report – The assistance package leverages ADB's comparative advantage supporting power sector improvements and reconstruction activities in Tonga, and will deliver a safer, more reliable power network for the capital.
41 Government of Tonga - Ministry of Finance - Budget Statement for year ending 30 June, 2020.
42 Source: TPL Business Plan, 2020–2025, page 31 – COVID-19 has had a large impact on timelines of all the projects under TERM. As an example, the TPL portion of the TREP was expected to be completed by the end of 2021. Specifically, the 50% target was to be met by the end of 2020 but this was dependent on the introduction of batteries under the TREP project. The delays occurred from delayed equipment procurement and manufacture in foreign countries. Construction activities also were impacted by travel restrictions imposed on engineering and construction personnel. Significant implications to the broader TPL projects due to their reliance on completion timing of the BESS projects on Tongatapu.
43 TPL Business Plan, 2021–2026.
44 TPL Business Plan, 2021–2026, page 18. TPL Business Plan, 2020–2025, page 22.

TABLE 11.
Pipeline projects toward TERM – 50% renewable electricity goal

Projects	MW	BESS	RE%	Status
Sunergise Solar IPP	6.0	-	23%	Signed 25-year PPA – March 2019
GET Solar IPP	6.0	-	34%	Signed 25-year PPA – November 2019
GoC Wind	2.2	-	41%	Construction Contract – Sept. 2020
Wind IPP[45]	3.8	-	~50%	Re-Tender Wind IPP or use TPL-RFT for 34-50 GWh
TREP BESS #1	-	5.1 MW/2.5 MWh	-	Installed 4th Quarter, 2021
TREP BESS #2	-	5.0 MW/17.4 MWh	-	Installed 2nd Quarter, 2022
Total Tongatapu	18.0		-	
TREP 3 Solar Vava`u[45]	0.3	2 MWh BESS	-	Funding Approved – March 2019
TREP 3 Solar `Eua[46]	0.35	1.85 MWh BESS	-	Funding Approved – March 2019

Source: TPL Presentation – 24 August, 2021 – TERM Pipeline Renewable Energy Projects, TPL – 2022

It has been noted by the Green Climate Fund (GCF), Asian Development Bank (ADB) and TPL that the installation of TREP (final phase) including pipeline and BESS projects will actually result in 57% renewable electricity for Tongatapu and 54% for the entire system including outer islands (Table 12). This places Tonga well on its way to achieve the 70% renewable electricity goal.

TABLE 12.
Analysis – Projected kWhs / year of TREP Phase 3 and IPP RE Projects

TPL Grid or Non-TPL Grid	TPL Grid	TPL Grid	TPL Grid	TPL Grid	Non-TPL Grid	Total
Island	Tongatapu	‘Eua	Vava`u	Ha`apai	Outer Islands	Total System
Projected Total RE + BESS + IPPs (kWh)	30,666,400	812,800	1,149,000	853,650	2,040,047	35,521,897
Total System (kWh)	54,215,438	1,791,133	6,148,000	1,553,085	2,292,344	66,000,000
Projected Renewable (%) per Island	57%	45%	19%	55%	89%	54%

Source: GGGI Analysis on Green Climate Fund Consideration of funding proposals – Addendum II Funding proposal

Three targets on electricity generation and distribution were advanced for Framework and TERMPLUS workshops that are carried into the TERMPLUS (Table 13). All three targets address the concerns regarding Tonga’s dependence on imported fossil fuels which threaten national security and economic stability. These targets, when achieved, will dramatically reduce the country’s greenhouse gas emissions as a result of implementing a sustainable low-carbon green growth plan.

45 TPL June 2022 – An initial IPP bid was unsuccessful and TPL considering retendering or for inclusion in the TPL – 2021 RFT for 34-50 GWh.
46 Entura - TONGA RENEWABLE ENERGY PROJECT - Final Feasibility Report - 30 May, 2020 – page 11: Prepared by Hydro-Electric Corporation ABN48 072 377 158 TREP Project: The proposed addition of 300 kW PV (from TREP) is expected to increase Vava`u to about 16% renewable energy.
47 Entura – TONGA RENEWABLE ENERGY PROJECT – Final Feasibility Report – 30 May, 2020 – page 11: Prepared by Hydro-Electric Corporation ABN48 072 377 158 TREP Project: The proposed additional solar PV (from TREP) is expected to increase `Eua renewable energy to about 37% (in 2020).

TABLE 13.
Targets, measures, and requirements for electricity generation and distribution

Target	Measures	Requirement	Alignment with existing targets
70% of electricity[48] generated from renewable sources by 2025	Combination of solar, wind, and battery storage (70 GWh[48])	• Financing • Upgrade of network infrastructure	• 2022 TPL Renewable Accelerated Power IndepenDence (RAPID) Project • 2018 Joint National Action Plan (JNAP 2), • 2015 Nationally Determined Contribution (NDC) • Second NDC 2020 • Long-Term Low-Emissions Development Strategy (LT-LEDS)
100% of electricity generated from renewable sources by 2035	Combination of solar, wind, battery storage, firm-renewable generation, advanced controls, microgrids, and electric transportation (buses, vehicles, etc.)	• Financing • Upgrade of network infrastructure	• 2018 Joint National Action Plan (JNAP 2) • Second NDC 2020 • Tonga Climate Change Policy (TCCP) • Long-Term Low-Emissions Development Strategy (LT-LEDS)
Maintain line losses at under 8%	Upgrade of electricity networks to accommodate larger share of variable renewable sources	• Financing • Upgrade of network infrastructure	• 2015 NDC Target - 9% • 2010 Tonga Energy Road Map (TERM) - 9% • Second NDC 2020 - 8%

3.3 MEASURES BY SECTOR TO ACHIEVE TARGETS

The GoT supported by the Green Climate Fund (GCF), Asian Development Bank (ADB), TPL and associated energy consultants (ARUP, Entura) confirmed with modelling that Tonga's can achieve 54–58% renewable electricity with 17.5–20.1 MWs of renewable system capacity.[49] Coupled with those renewable electricity systems are the necessary short-term grid-integration BESS of 5.1 MW / 2.5 MWh and the long-term load-shifting BESS of 5 MW / 17.5 MWh (both recently installed). As renewable electricity percentages move to that 54–58% range, the TERMPLUS targets comes closer to fruition.

First, the target of 70% of electricity from renewable sources by 2025 aims at increasingly substituting a total of 70 GWh/year of electricity generation from imported fossil fuels to locally available renewable sources. This 70% target is considered achievable with today's technology of solar and wind power systems in combination with additional sizeable, long-duration, short-duration and stabilising battery storage.[50]

This level of renewable electricity absorption will require further upgrading of network infrastructure including switching-protection and reactive power support. Also, centralised control with communication systems and automation features will need to be incorporated. Advanced forecasting tools for wind and solar are required to be input into the controls.[51] Inertia will be required in the grid for fault clearing and this could be accomplished by fast acting capacitors. Additional external sources of finance (grants and loans) can help facilitate the transition.

Second, the target of 100% of electricity from renewable sources by 2035 aims at removing fossil fuels completely as a source of electricity generation. The 100% target will likely need both a new primary source of firm renewable energy

48 TPL Expression of Interest – July 2021.

49 Green Climate Fund – Meeting of the Board 1–4 July 2018 Songdo, Incheon, Republic of Korea – Provisional agenda item – GCF/B.20/10/Add.02–8 June 2018 Consideration of funding proposals – Addendum II – Funding proposal package for FP083, pages 14–15. TPL-Tonga-Renewable-Energy-Road-Map-Presentation-Setitaia-Chen.

50 Entura TONGA RENEWABLE ENERGY PROJECT Final Feasibility Report, 30 May ,2020. Prepared by Hydro-Electric Corporation ABN48 072 377 158: For Tongatapu, the power station BESS (noting the above network strengthening requirements) is critical to further progress towards the Tonga renewable energy policy goals. This TREP BESS provides substantial benefits through enabling connection of new generation. The load shifting TREP BESS provides additional benefits by utilizing excess energy that would otherwise be spilled and is especially important in achieving higher levels of renewable energy, including the ability to reach the 70% renewable energy target.

51 Arup – May 2018 – Phase II Workshop Presentation for TPL from Arup 20180507.

(i.e., biofuels, biomass, geothermal, ocean, etc.) as well as more advanced storage technologies (i.e. flywheels, synchronous condensers, advanced-BESS, etc.) not yet fully developed or deployed commercially. Additionally, new network enhancing technologies will be incorporated such as modular 'smart-grids' and advanced-microgrids, as well as vehicle-to-grid systems where EVs, Hybrids and/or hydrogen fuel cell vehicles (HFCV) can communicate to sell demand-response services by either returning electricity to the grid or by throttling their charging rate. For 100% renewable electrification, detailed load curves are required to help model the entire system with increased demand-side options and energy storage needs.

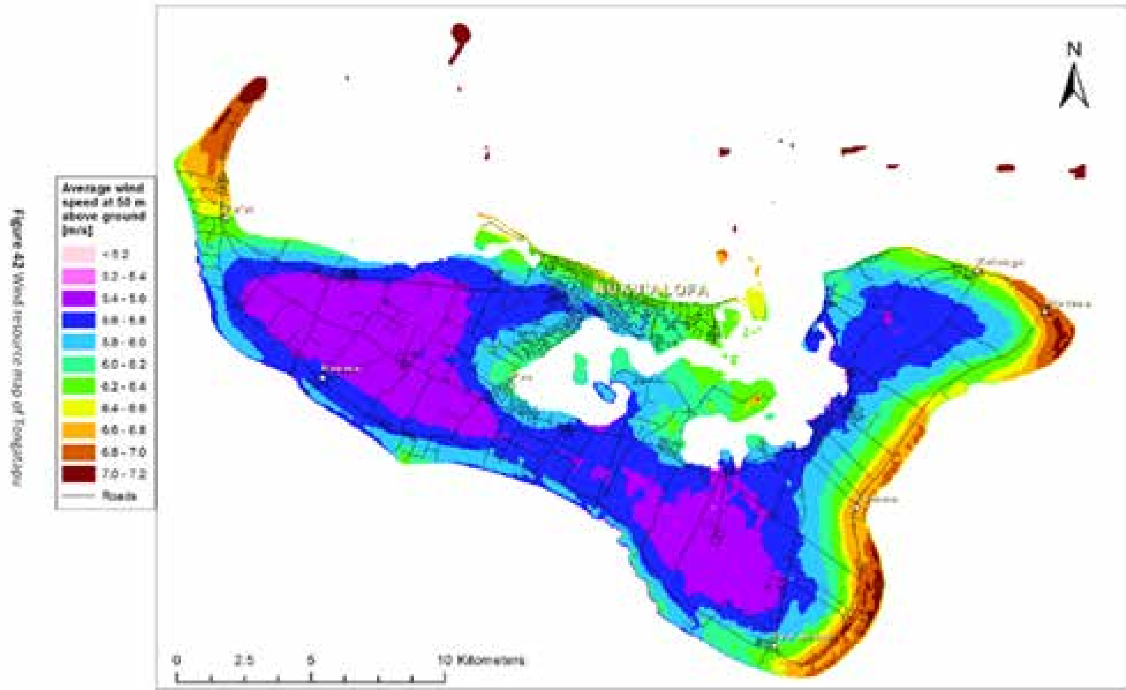
Third, the updated TERMPLUS target of keeping line losses under 8% with 70% to 100% renewable electricity will require continued transmission & distribution investments as well as upskilling workers in control, operations and maintenance of Tonga's complex network-infrastructures.

These critical measures are discussed in more detail below:

Renewable Resources

Tonga has abundant potential for renewable energy, most notably from solar, wind and biomass.[52] As the cost of wind and solar generation has continued to decline, these projects are now more cost-effective than diesel generation and on Tongatapu, a combination of solar and wind power (with battery storage) is optimal.[53] It is noted that wind monitoring conducted on Tongatapu indicated some complementarity with solar PV, specifically at night-time, when the solar output is zero, wind provides generation potential.

FIGURE 11.
Wind Resources – Tongatapu



Source: GIZ, SPC, German Cooperation – Pre-Feasibility Study on Wind Energy – October 2012

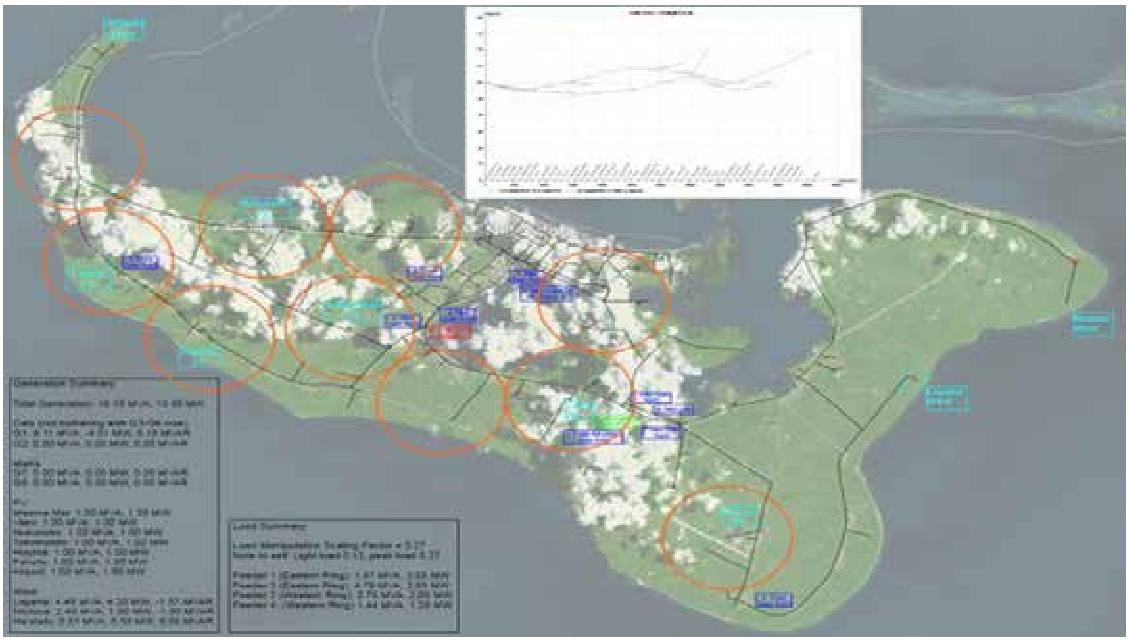
[52] Initial Environmental Examination Project No. 49450-012, March 2018 TON: Renewable Energy Project Prepared by Tonga Power Limited & Ministry for Meteorology, Energy, Information, Disaster Management, Environment, and Climate Change for Ministry of Finance and National Planning & Asian Development Bank, page 4.

[53] Green Climate Fund – Funding Proposal, 28 November, 2018, FP090: Tonga Renewable Energy Project under the Pacific Islands Renewable Energy Investment Programme, page 21 of 72.

One of the key advantages of wind energy is its availability at night throughout most of the year, due to the relatively reliable trade winds. This is of interest in Pacific Island nations like Tonga with ambitious renewable energy targets. In 2015, to meet the 50% renewable electricity target, AECOM recommend that TPL pursue development of approximately 6 MW of wind generation and 6 MW of solar generation and delay decisions on how to achieve higher levels of wind and solar penetration than this. At that time, due to falling costs of solar and energy storage it was not clear whether it was optimal to implement additional solar or alternatively large battery storage to achieve higher levels of renewable electricity penetration. This guidance has been updated and validated to require both the implementation of solar and large battery storage to reach 50%.

It was also recommended that if more than 2 MW of wind generation was developed, then it should be separated into multiple locations (Figure 11) to avoid fast generation changes due to wind fluctuations resulting in island-wide black outs. With these guidelines and standards adopted, AECOM and Entura found that relatively high levels of renewable electricity up to 50% could be developed without particularly onerous investment. The largest risk to the system once these become adopted rules would not be the fluctuation of the variable renewable generation output but the instantaneous loss of the largest generator which in most cases will be a wind farm. In 2020, it was further recommended that solar plant size should also be limited to 2 MW (Figure 12) to ensure good spatial distribution of solar generation, allowing spatial averaging to minimise the potential impact of ramping due to cloud effects on the network.[54] Additionally, biofuel generation was proposed as an economical addition to the renewable energy fleet.[55]

FIGURE 12.
Solar sites potential in multiple locations – Tongatapu



Source: AECOM Stage 2 Report, 2015 – Many Solar Plants Can be Developed Even with 4 km Minimum Separations – October 2012

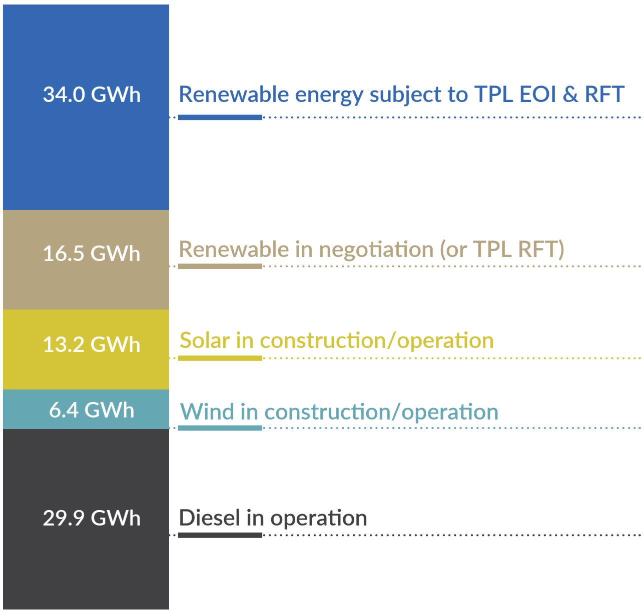
[54] Entura – TONGA RENEWABLE ENERGY PROJECT – Final Feasibility Report – 30. Prepared by Hydro-Electric Corporation ABN48 072 377 158 – page 43.
[55] Source: AECOM Stage 2 Report, 2015 – page IV.

TPL Expression of Interest - 70% Renewable Electricity

To achieve the renewable energy target of 70% renewable electricity in a single procurement, TPL released an Expression of Interest (EOI) in July 2021 aimed at procuring renewable generation projects from Independent Power Producers (IPP). To forecast and reach 70% renewable electricity by 2025, TPL performed numerous modelling scenarios using Hybrid Optimization of Multiple Energy Resources (HOMER) and other tools.[56] TPL has tested, verified and improved their modeling by cross-referencing development partners' energy consultant models to form the basis of the EOI. This enabled TPL to confidently seek and receive bids from numerous vendors to procure a minimum of 34 GWh on a technology-agnostic basis. Also stated in TPL's EOI, 'a further 16.5 GWh can be bid on which are reflected the pipeline of projects currently under negotiation and on which necessarily depends the eventual outcome of each of the projects in negotiation.'[57]

The range of 34–50 GWh per year (for Tongatapu) of renewable energy generation was bid upon by numerous entities where 5–7 contenders have been short-listed for the upcoming Request for Tender (RFT). These bids have all comprised percentages of solar, wind, and battery projects which will allow for the retirement of older and less-efficient diesel generators. Evaluation criteria included: cost-effective pricing, high reliability and favourable power purchase agreement terms. With the GoT approval, this short list of qualified contenders from the EOI will move on to the RFT expected to be released mid-2022.

FIGURE 13.
2025-2030 Projected Generation to 70% Renewable Electricity



Source: TPL Expression of Interest – July 2021

Timing of Implementation

Tonga's 70% renewable electricity goal can be achieved as early as 2025. That is if the TPL awards a successful bidder from the RFT the option to have all generation installed in the earliest stages of the agreement.[58] In tandem, this approach should allow optimisation of a cost-effective electricity tariff. A major reason for electricity tariff optimization is that most power purchase agreements (PPA) of this small size (relative to international standards) are all 'take-or-pay'; in other words, you pay for all energy that could be produced, not only what you can use. This occurs even if you must limit or curtail renewable generation due to oversupply (i.e., more generation is available than demand) and your storage capacity is full.[59]

The target generation called for in the upcoming TPL procurement is based on the 2025-2030 forecast loads (Figure 13) of approximately 100 GWhs, hence if you install early and forecasts are correct, there is a lot more spilled energy.[60] Another option is to sign PPAs now for full amount of generation needed but with a staged implementation strategy and mechanisms for adjusting tariff changes with the market. This may be done in a 2-phase approach with solar plus battery installed in phase-1 and wind plus battery installed in phase-2.

With each project proposed for the RFT, a TPL grid study will most likely be needed to determine if the network distribution lines and associated equipment must be upgraded or modified for each renewable system. The cost of power generation (not including network upgrades) for these projects to reach 70% renewable electricity are estimated to be in the range of USD 60–80 million with a power purchase agreement of 20–25-years to deliver a kWh price that will be less than diesel generation is today.[61]

56 https://www.homerenergy.com Hybrid Optimization of Multiple Energy Resources (HOMER) originally developed at National Renewable Energy Laboratory (NREL).
57 Tonga Power Limited – Expression of Interest – April 2021. The 4.5 MW Wind Project is no longer being negotiated due to pricing concerns for consumers (TPL – CEO – Nik Fonua, December 2021). The 4.5 MW Project may now become part of the TPL RFT or be sent out for Re-Bidding.
58 In November 2021, procurement documents are currently being finalised along with the modelling of the solutions presented by the interested bidders. This modelling will input into the final solution which will likely be a set capacity of solar, storage and wind. At this point the documents will be circulated around the GoT and TPL for approval to proceed. Timing issues will be important as Tonga must decide to commit to moving towards 70% in the near term and sign up to 25-year PPA agreements as opposed to a long-term approach like TERM (2010–2020) where Development Partners greatly assisted the last phases of implementation
59 The upcoming RFT that allows bidders to provide tiers of minimum and maximum GWhs with pricing successively lower for each GWh tier over the minimum (ADB Project Manager).
60 Total generation (diesel plus renewables) in all four islands groups for year ending June 2020 was about 73.2 GWh, an increase from 70.6 GWh in the year 2018/19. Total renewable energy generation for the FY 2019/20 year was 9,363 MWh, which was a 38.2% increase from the previous year 2018/2019 figure of 6,775 MWh (TPL Annual Report 2020).
61 ADB Tonga consultants

100% Renewable Electricity

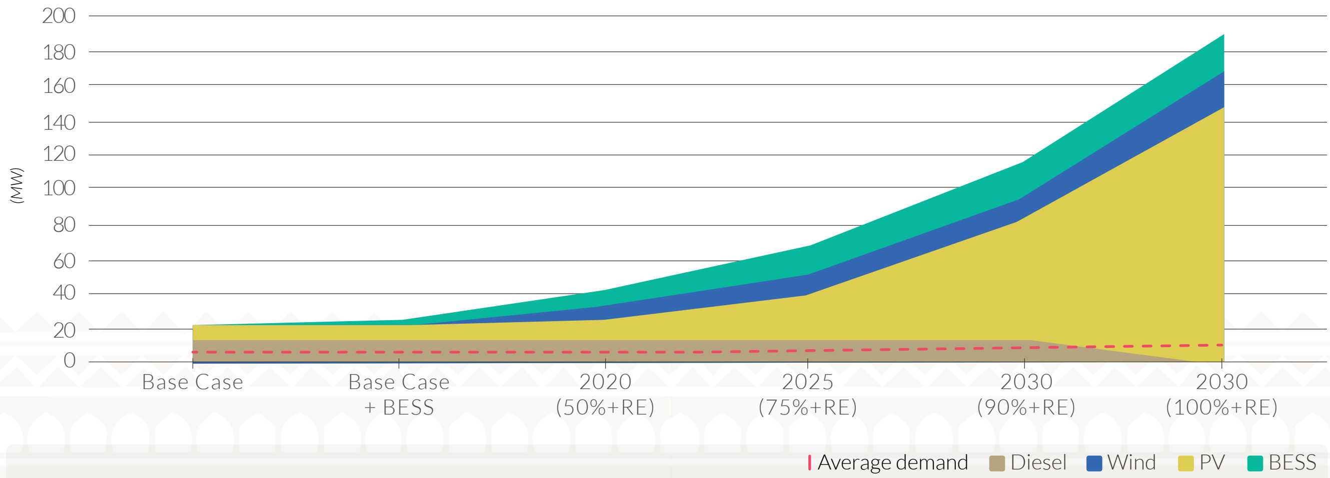
For 100 percent renewable electricity the engineering modelling and cost-benefit analysis remains a work-in-progress. Importantly, this modelling and analysis can be regularly updated with proven technology developments as well as the expected solar, wind and BESS declining costs. Current models, appear to agree that 'a diversified mix of low-CO_2 generation resources' add up to a more cost-effective path to deep decarbonisation than 100% renewables. This is particularly true above 60–80% decarbonisation, when the costs of the renewables-only option rise sharply.[62]

In 2018, high-penetration renewable electricity scenarios from 50% up to 100% were modelled (Arup and Entura) which yielded a range of solar, wind and BESS capacity numbers as well as costs. For the Arup model (Figure 14 and Table 14), cost-effective renewable penetrations were shown in the range of 58.8% to 90.9%. This model assumes that associated BESS technologies were donated for the solar and wind project additions.

FIGURE 14.
Energy Consultant Arup Model

System configurations results							
Demand Models	**Unit**	**Base Case**	**Base Case + Bess**	**2020 (>50%RE)**	**2025 (>75%RE)**	**2030 (>90%RE)**	**2030 (100%RE)**
Diesel Generation	MW	14	14	14	14	14	-
PV #1 Grant	MW	23	23	23	23	23	23
PV #2 $0.15/kWh	MW	2	2	2	2	2	2
PV #3 $0.12/kWh	MW	4	4	4	4	4	4
Additional PV @ $0.12/kWh	MW	-	-	4	18	60	140
Wind Farm #1 JICA Grant	MW	-	-	1.4	1.4	1.4	1.4
Wind Farm #2 GoC Grant	MW	-	-	22	22	22	22
Additional wind @ $0.15/kWh	MW	-	-	4.4	8.8	8.8	17.6
ESS – Peak Power	MW	-	3	8	15	20	20
ESS – Energy Capacity	MW	-	8.4	26.3	73.5	147	273
Average demand	MW	6.56	6.56	6.56	8.36	10.72	10.72

Installed generation capacity versus average demand



Source: Arup – Presentation for TPL Phase 1. Detailed Workshop, May 8, 2018

[62] https://www.vox.com/energy-and-environment/2017/4/7/15159034/100-renewable-energy-studies

Arup (Table 14) determined that 100% renewable electricity required installed capacity of 148.3 MW solar and 21.6 MW wind along with 20 MW / 273 MWh of BESS.[63] This modelling indicated that even with development partner funding that can completely donate additional BESS needed, the resulting electricity tariff from 100% renewable electricity goal (2030) would necessarily get much higher for Tonga's electricity consumers. These are truly large numbers for an electrical system that may only require 15 - 20 MWs of traditional generation between 2030–2035 to support Tongatapu's projected average demand.

TABLE 14.
Arup analysis – total installed capacities towards 100% renewable electricity goal

Solar	Wind	BESS	RE%	Cost of Generation	Excess Spilled Power (per year)
12.3 MW	8 MW	8 MW/26.3 MWh	58.8%	$0.229 USD / kWh	5,505 MWh
26.3 MW	12.4 MW	15 MW/73.5 MWh	76.5%	$0.238 USD / kWh	14,639 MWh
68.3 MW	12.4 MW	20 MW/273 MWh	90.9%	$0.252 USD / kWh	44,672 MWh
148.3 MW	21.6 MW	20 MW/273 MWh	100%	$0.438 USD / kWh	176,681 MWh

In 2021, UNESCAP using their NEXSTEP model advanced a 'Decarbonisation of Tonga's power sector' scenario where 29.7 MW of solar and 9.6 MW of wind were required to get to the 100% goal (Tongatapu 2030) at a cost of USD 93.4 million.[64] In the NEXSTEP analysis, grid storage was not modelled due to lack of available data such as daily load curves and future potentials for demand-side management.

Recently in 2022, the United States Trade and Development Agency (USTDA) awarded Tonga (MEIDECC and TPL) with a grant of approximately USD 1.5 million to work with energy analyst firm, GridMarket on decarbonising the TPL grids. This feasibility study, expected to be complete in August 2023, "is intended to accelerate the critical technical, regulatory and financial development work that lays the foundation for optimised renewable energy installations across Tonga's four main islands. The work will identify the exact mix of renewable energy technologies to be deployed and the viable financial mechanisms that will optimise value for the utility, the local government, and the people of Tonga."[65]

Importantly, the GridMarket feasibility study implementation plans will be developed according to five (5) methodologies:

- Greatest benefit (reliability, energy access, etc.) to largest number of consumers.
- Lowest levelized cost of electricity (LCOE) in shortest timeframe.
- Fastest decarbonization (displacing fossil fuel in shortest timeframe).
- Ease of implementation.
- Cost of implementation.

Fortunately, the goal of 100% renewable electricity by 2035 allows more than a decade of technology developments with associated declining costs that can beneficially change the current analyses. Therefore, it remains sensible to model the TPL grids at appropriate intervals of renewable energy integration with updated technology inputs and configurations. The need for energy storage in all scenarios and the disproportionate impact of the cost of BESS projects on electricity tariffs in the high-penetration scenarios makes it a key area of focus for developing grant funded assistance. This is currently being reviewed by the Climate Finance Access Network (CFAN) Advisor for Tonga given the BESS requirements for all high renewable penetration scenarios.

Today, when approaching high-penetrations of renewable electricity with declining support of diesel-generation (firm power), current technological limitations must be addressed. Consider the case of the power station BESS, which will now be required to have grid forming capability (forming the grid voltage, providing inertia, uninterrupted power supply and black start). This allows it to set the frequency and voltage of the grid and operate the grid with all diesel generators off ('zero-diesel' operation). While this has advantages in further reducing fuel consumption and increasing renewable energy contribution, it is an immature and unproven technology in a grid of this scale.

The main limitation of BESS grid forming mode is its ability to support the grid under fault scenarios, which may occur frequently with an overhead distribution system of this scale, and multiple distributed generators. Any trip or fault on a part of a feeder could result in an outage of the entire island. One way to provide significant support for the BESS is to add a synchronous condenser, which provides inertia and

63 Tonga Energy Storage Roadmap Phase 1. Detailed Workshop, May 8, 2018 – Presentation for TPL Arup using HOMER modelling.
64 UNESCAP Energy Transition Pathways for the 2030 Agenda SDG7 Roadmap for Tonga, April 2021, pages 23-24 & 46.
65 https://www.globenewswire.com/news-release/2022/05/11/2441013/0/en/GridMarket-Announces-Funding-From-the-United-States-Trade-and-Development-Agency-to-Transition-the-Kingdom-of-Tonga-to-Renewable-Generation.html

fault current for minimal energy consumption. This should be considered as a future addition to the TPL power system.

Alternatively, BESS capabilities are improving rapidly, and it is conceivable that in the future, the capabilities of the installed BESS technology will be able to reliably address all operating conditions. If desired, this may be ascertained through progressive and cautious testing and operational experience in the network, at non-critical times, working closely with the BESS manufacturer. At this time, it is not recommended (Entura) for the operation of the Tongatapu grid without either at least one diesel generator or a synchronous condenser online to provide inertia.

To realistically approach Tonga's 100% renewable electricity target, at a minimum the following must be fully deployed:

- Relentless research development and deployment of renewable firm – dispatchable resources.
- Daily electricity load curves from every major load are required to optimise storage needs.
- Increasing the role of deploying demand-side management (DSM) to maximise grid flexibility.
- Using a holistic approach between the grid and transport systems including electrification of transportation (EVs and e-Buses) to be integrated as BESS and DSM systems.

Electricity Grid Upgrades

When a high proportion of electricity generation comes from variable renewables like solar and wind; other grid technologies are required to strike the correct balance between energy generated and energy demanded. With diesel generators currently providing the only firm energy and projected to be retired over time, other technologies are required to be coupled with solar, wind and BESS systems to integrate more renewable electricity. Some of these technologies include:

- Advanced Supervisory Control and Data Acquisition (SCADA) systems.
- Meshed-ring communication systems.
- Upgraded Control Centre for Generation and Distribution.
- Smart Meters for Load Management.
- Distributed Energy Resource Management System.
- EV Charging Stations & Controls.

Certainly, Tonga's electricity grids (Figure 15) in the TERMPLUS period up to 2035 are going to be distinctly different from its electricity grid of the last decade. Electricity grids like Tonga's, were designed for one-way electricity flow from generator to user. As Tonga integrates more renewable electricity from a variety of power sources and geographically dispersed locations; the coordination becomes ever more complex and more advanced technologies are needed.

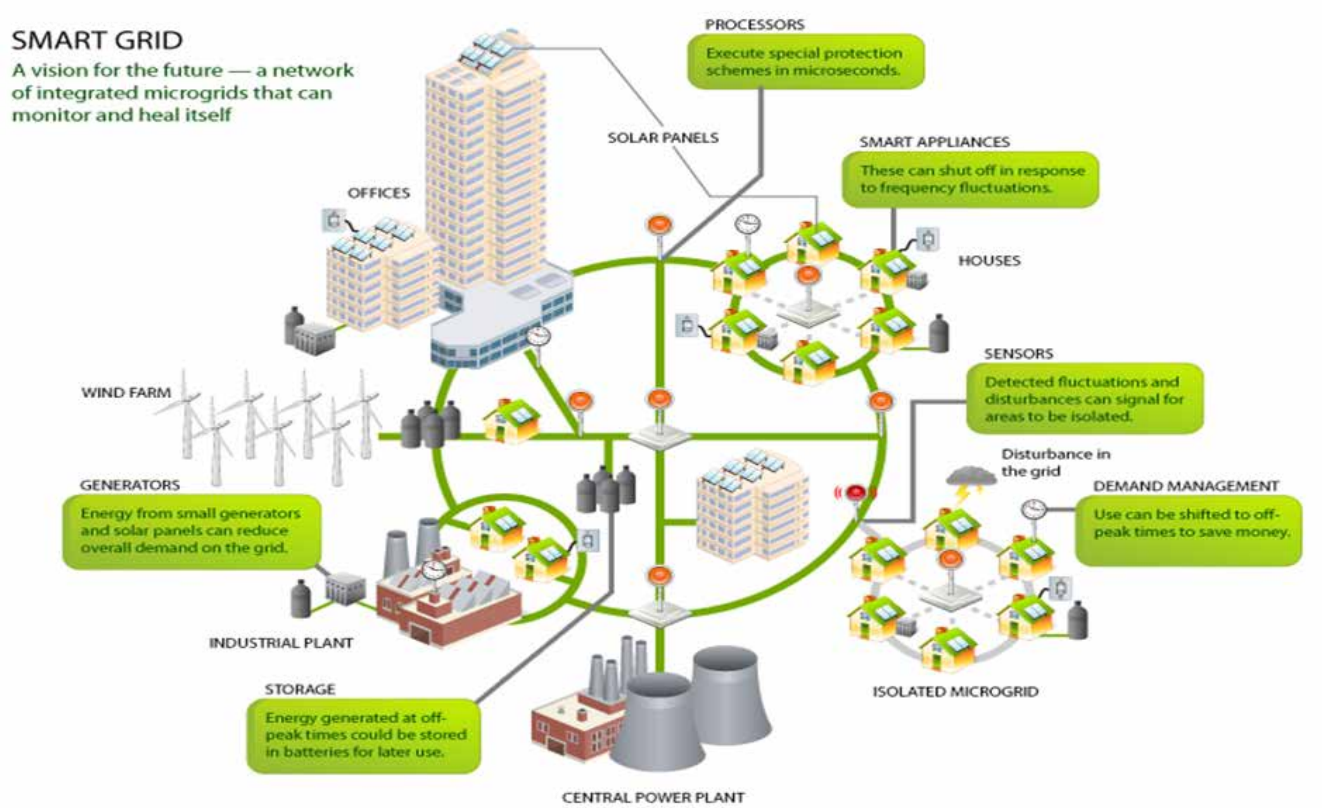
FIGURE 15.
Electricity Grid – Tongatapu

Source: JICA, 2017

Adding to that complexity, will be the many homes and businesses that will install and use their own solar panels, batteries and other innovative technologies to generate, consume and store electricity. Further integration needs arise as Tonga transitions its transportation fossil fuels to cleaner renewable electricity to charge a growing number of EVs from the renewable grid. To coordinate moment-to-moment fluctuations in supply and demand, the future power grid will depend on technologies that allow two-way digitised communications with advanced computer control systems that can retrieve and synthesise data instantaneously from thousands of sensors.

This network of connected sensors, communications and computers providing real-time visibility and control of the electricity grid will continue to evolve in the future and has been labelled the 'Smart-Grid' (Figure 16). The Smart Grid is intended in part to help the power system operator more efficiently utilise variable renewable sources. Therefore, smart grid applications will allow for more fine-turned control over both supply and demand of electricity, making it easier for the system operator to integrate more variable sources onto the grid.

FIGURE 16.
Smart Grid Concept



Source: Smart Grid, iTeres, Inc (2012): Filling the Gap for New Technology.[66]

Tonga has been both skilled and fortunate in securing external financial support to upgrade and rebuild its networks with NNUP, TVNUP, TCGRP, and TCIRCRP projects, so far. These projects have been essential in achieving the efficiency of supply, reliability, resiliency, safety and accessibility of electricity for Tonga. Further improvements of TPL networks to the next level will require smart grid technologies capable of handling the challenges of increasing two-way-flowing renewable electricity. Although there will also be challenges associated with securing the significant amount of funding needed to transition to a complete Smart Grid, additional support may be found with partners interested advancing Tonga to the highest renewable energy potentials. As mentioned previously, grid-modernisation will be required to interconnect each renewable project in a sequence that enables higher levels of renewable energy penetration.

[66] Smart Grid, iTeres, Inc (2012). 'iTeres Smart Grid: Filling the Gap for New Technology'. from http://www.iteresgroup.com/services/smart-grid.

'Negawatt' Projects – Energy Efficiency

Substantial electrical energy savings reduce the need for investment in power infrastructure. Aggregated energy efficiency programmes can be characterised as 'negawatt' renewable energy projects.[67] Each programme's aggregate kWh, MWh and GWh savings can be equated to 'not building unnecessary power generation'.[68] For example, by using an integrated approach of energy efficiency and energy storage Tonga can increase each renewable project's capacity factor with zero additional investments. For example, just from doubling the Business as Usual (BAU) case of Tonga currently at 0.035% energy efficiency per year to 0.07% (thru 2035); reduces the need for power infrastructure by 9.8 MW (solar, 9.3 MW and wind, 0.5 MW).[69]

Electricity rates and fuel costs have important implications for incentivising energy efficiency investment; high rates act to discourage energy usage. Despite differences in generation cost, the TPL tariff rates are standardised across the four main islands.[70] The TEEMP lists the potential to reduce energy consumption by multiple measures in electricity and transportation. A public-private-partnership with MEIDECC – DoE targeting energy efficiency goals based on the TEEMP can be a favourable path to focus on those attainable goals.

As one of the largest and most influential single employers, the GoT is in a prime position to adopt a policy that establishes energy efficiency requirements for new procurement/purchases for the government. The policy should also apply to all purchases that are directly procured or let out to bid and specify that procurement or the bidders are required to comply with the energy efficiency specifications and provide acceptable documentation at no cost to the GoT. This policy could be implemented by the Ministry of MEIDECC and the Ministry of Finance as well as be considered by other Ministries and departments with energy-consuming product needs (new vehicles, information technologies, meteorological forecasting systems, etc.) and deployed when those departments are specifying purchasing requests.

© Network Upgrade by TPL

67 https://www.renewableenergyworld.com/energy-efficiency/whats-a-negawatt/#gref.

68 In an assessment funded by Australian Aid, scenarios were formulated around the business as usual (BAU) activities in Tonga and implementing minimum performance standards for lights and appliances. Scenarios were used to compare the energy savings in GWh consumed through 2030. In Australian Aid's study, implementing MEPS early on will achieve a 10 GWh savings by 2030. The TEEMP analysis anticipates upwards of 12.7 GWh could be saved through rigorous MEPS implementation by 2030; the difference between this figure and Australian Aid's can be attributed to different BAU consumption figures, less selective MEPS, and applicability to fewer appliances.

69 SDG 7 Roadmap – UNESCAP – April 2021 – page 21.

70 TEEMP – Executive Summary – page IV – June 2020.

Decentralised Rooftop Solar Programme (grid-connected)

Private companies can provide residential and commercial grid-connected solar and small-scale wind power systems along with battery storage systems that effectively increase the Tonga's renewable electricity percentages and make the overall grid more flexible and resilient. Private power generation would require few amendments of the energy legislation to accommodate the feeding of electricity into the grid, including appropriate feed-in tariffs and metering arrangements.[71]

Advantages of decentralised, small-scale, roof mounted generation with solar PV are the following:

- Straight-forward business opportunity for local businesses.
- No additional land required.
- Potentially increased reliability of local power supply (e.g. in case of diesel generator failure) when combined with batteries, smart-inverter and grid technology.
- Potential reduction of grid load, especially at locations with coinciding, strong daytime demand.
- Solar energy resources match well with air-conditioning load during the day, which is projected to increase in Tonga.
- Reduced fluctuations of power generation and improved grid stability from the wider geographic distribution of solar.
- Up and downward scaling of standardised modular designs possible.
- Private financing, avoiding the need for scarce public finance.
- Possibility of concessional loan finance through Tonga Development Bank and/or development partners.
- Operation in off-grid mode possible, ideally in combination with energy storage

Disadvantages are:

- Greater management and administration costs.
- Bi-directional metering required.
- Feed-in tariffs and net-metering tariffs are required initially.
- High up-front costs may limit private financing and may not be affordable for all.
- Potential cost of roof reinforcement.
- Safety training needed for property owners and fire department.
- More difficult access to solar system and its performance monitored by TPL.
- Poor power quality due to no fault ride through capability and lower quality standards.

3.4 REQUIREMENTS

To reach the TERMPLUS goals of 70% renewable electricity by 2025 and 100% by 2035 will require increasingly focused efforts on designing and implementing the next phases of projects in a well-planned sequence. This will involve using experience from the previous decade of project design, development and implementation, hiring experts, providing capacity building in renewable technologies as well as training in advanced grid operations.

The following requirements are necessary to achieve the 70% and 100% renewable electricity goals:

Public-Private-Partnerships, Power Purchase Agreements and Contract Management

Public-private partnerships utilising private sector funds are an important financing source. Worldwide, the private sector's enthusiasm for investing in energy-related projects provides an indication of their general profitability. Private sector funding can be available for renewable energy and energy efficiency projects using innovative financing mechanisms such as Power Purchase Agreements and Energy Performance Contracts.

The private sector is the engine of growth for the economy, and this is no different when it comes to the energy sector in the transformation to renewable electricity. Funding must

[71] AECOM 2015 Feasibility Study – page 10 – Private Power – proposes a model of 70% Electric Utility plus 30% Private Power.

encourage the private sector to invest in renewable energy and this requires an enabling business environment. This can be developed through various measures, but fundamentally requires the right market signals through proper government regulation. The private sector contributions to infrastructure development also needs facilitation by easier access to finance and incentives with more suitable regulations and laws.

Power Purchase Agreements (PPA) are the contractual agreements between two parties, one which generates electricity and the other to purchase the electricity. The PPA defines all the commercial terms for the sale of electricity between the two parties, including when the project will begin commercial operation, schedule for delivery of electricity, penalties for under-delivery, with payment terms and termination of the project.

Developing successful PPAs requires significant legal skills as well as technical knowledge. In the past, TPL has had to incur significant legal expenses associated with developing their PPAs. TPL as party to upcoming RFT for 70% renewable electricity and the associated complex PPAs will need to further increase its skill on these contracts. TPL must ensure that the best arrangements are obtained for the benefit of their customers. TPL must also ensure balance is achieved between the financial viability of the project and the fair and affordable price to the consumer.

Long term agreement or contract management skills within the electric utility is a vital part of ensuring that the PPAs contribute to overall objectives of TPL and facilitate Tonga›s ambitious goals of 70% and 100% renewable electricity. Capacity-building in this area is fundamental and should find needed support from development partners.

Independent Power Producers

Independent Power Producers (IPPs) will play a leading role in taking Tonga towards its ambitious renewable electricity goals. Substantial investments will be needed to continue to transform the electricity sector and engaging private sector investment is essential. Reaching Tonga's ambitious renewable electricity 70% and 100% targets offers opportunities for the private sector to deliver their latest-proven technical solutions with opportunities to engage mutually beneficial financing models working with development partners.

Some obstacles of the past to attract IPPs include smaller project size, lower financial returns on investments, perceived high-risk as well as incomplete data from Tonga. The Foreign Exchange Control Act also inhibits foreign IPPs from investing in projects. These issues need to be addressed in the upcoming years to allow the full flow of IPP developed projects in reaching the 70% and higher renewable electricity goals. Continued work with development partners that can support Tonga's IPP transactions is an area that needs to be prioritised.

Fortunately, Tonga has experience working with IPPs, creating a more enabling environment for private sector investment in renewable energy projects with transaction advice from ADB's Private Sector Development Initiative (PSDI).

Some examples of successful IPP projects include the 2 MW solar facility in Matatoa, sourced, structured, negotiated and completed in 2017, currently in operation as the first IPP to be established in Tonga. Additional IPP projects in the pipeline include: (i) option for additional 6 MW (3 lots of 2 MW) of IPP solar through a current power purchase agreement; and (ii) the Government of New Zealand (MFAT) has committed grant funds to support a 2.2 MW wind IPP project, for which MFAT and TPL have started identifying the IPP.

Derisking Renewable Energy Investment[72]

Tonga's key challenge for private sector funding the transition towards a low carbon energy system is to address existing risks that affect the financing costs and competitiveness of renewable energy projects. High financing costs reflects perceived or actual informational, technical, regulatory and administrative barriers of the associated renewable technology investment risk. These compound the baseline factors of renewable energy projects long-time horizon, high initial capital costs, illiquid equipment, and inherent project risks.

Policymakers can reduce these high financing costs using two methods: derisking and direct incentives. Derisking has two basic forms – policy de-risking instruments that reduce risk, and financial derisking instruments that transfer risk. Where policy and financial de-risking is insufficient, direct incentives provide direct finance transfers or subsidies for low carbon investments.

- Policy derisking instruments seek to remove the underlying barriers that are the root causes of risks. These instruments include, for example, support for renewable energy policy design, institutional capacity-building, resource assessments, grid connection and management, and skills development for local operations and maintenance (O&M).

[72] https://www.undp.org/content/undp/en/home/librarypage/environment-energy/low_emission_climateresilientdevelopment/derisking-renewable-energy-investment.html.

- Financial derisking instruments do not seek to directly address the underlying barriers but, instead, transfer the risks that investors face to public actors, such as development banks. These instruments can include, for example, loan guarantees, political risk insurance and public equity co-investments.
- Direct financial incentives recognise that not all risks can be eliminated or transferred through policy or financial derisking. Carbon offsets, price premiums, and tax breaks can provide compensation for residual incremental costs and thereby increase returns. The overall aim is to achieve a risk/return profile that can attract private sector investment.

Green Bond Funding

Green bonds mobilise resources from domestic and international capital markets to finance climate solutions. Green bonds help accelerate the market and open investments for private sector projects that support renewable energy and energy efficiency. Setting an example that can be deployed in Tonga, Fiji successfully raised USD 20 million through issuing its first green bonds which was oversubscribed by more than double that amount (USD 40 million in 2017). Fiji will use bond proceeds for projects supporting its renewable energy and carbon emissions reduction commitments.

Development Partner Funding Support

Although development partner funding has not been explicitly sought in the TPL EOI and soon to be released RFT, as discussed above, there are projects that development partners are interested in or would consider funding such as distinct project elements like BESS devices, grid studies, grid upgrades, capacity-development & technical assistance. Long-time development partners (ADB, GCF, World Bank) and others have recently indicated interest in supporting projects by derisking the IPP investments with guarantees of credits and payments.[73]

3.5 ENABLING ENVIRONMENT

The 100% renewable electricity target will benefit from all the activities along the path to 70% renewable electricity and the downward sloping cost curves for the Tonga's main technologies of solar, wind, storage with the possibility of future cost-effective firm renewable generation sources (i.e. biofuels, biogas, waste to energy, etc.). Based on analytical models, it is agreed by development partners – energy consultants (ARUP and Entura) that the 70% target can be reached by 2025 and the 100% target can be reached as early as 2030, however further detailed financial analysis is needed as the earlier dates tend to lock-in higher costs, which may lessen the GoT's goal of seeking the most cost-effective renewable electricity pathway.

To approach Tonga's ambitious goals of 70–100% renewable electricity by 2025 and 2035 will require concentrated efforts and an enabling environment that can facilitate these objectives. This will involve using the experience gained and lesson-learned from the previous decade and upcoming years of project design, development and implementation, hiring experts, coordinating EOIs & RFTs, capacity building in renewable technologies and training in advanced grid operations. The following enabling elements will guide the path to achieve toward 70–100% renewable electricity goals.

Energy Bill

A key outcome of TERM was the Tonga Energy Bill which provides a fundamental policy shift from Tonga's current energy structure. Tonga's Energy Bill has passed Parliament in 2021 and is now in its final phase anticipated to become an Act. The purpose of the Energy Bill is to:

- provide an institutional and regulatory framework for the energy sector.
- establish clear national objectives for energy and ensure those objectives are achieved.
- establish a Ministry centralised for all energy matters.
- establish an Energy Commission, ensuring energy security and enforcing regulations.
- promote private sector incentives and research initiatives.

[73] Initial Environmental Examination Project No. 49450-012, March 2018, TON: Renewable Energy Project. Prepared by Tonga Power Limited & Ministry for Meteorology, Energy, Information, Disaster Management, Environment, and Climate Change for Ministry of Finance and National Planning & Asian Development Bank, page 2. New Zealand MFAT is also providing funding for partial risk guarantee (LC) to support TPL.

The Energy Bill designates a Ministry for all aspects of energy policy including a comprehensive energy sector database. It will also facilitate private sector investment to achieve Tonga's renewable electricity goals and alleviate many of the challenges IPPs face today. Additionally, within 12 months of commencement of the anticipated Energy Act, a national energy policy will be developed as the successor to the TERM policies (2010–2020). It is anticipated, that by adopting coherent and comprehensive energy authorities and policies included in the Bill, Tonga will clear the path to their renewable electricity goals and national energy objectives.

Regulatory Capacity Development

Utility regulation in the Pacific region remains in its infancy. In most instances, electricity services are provided by state owned, vertically integrated natural monopolies, with sector regulatory decisions driven by political imperatives, often on an ad hoc and unpredictable basis. Regulatory and governance regimes of this nature, especially in capital-constrained environments, do not provide for efficient management of scarce resources, and can significantly limit investor confidence.[74]

Robust, predictable, and effective regulations are essential to attracting private sector investment into energy sectors across the Pacific including Tonga.

With the anticipated Energy Act, establishing the Energy Commission, its functions will include:

- ensuring the safety, affordability and security of supply of energy.
- monitoring and enforcing standards and regulations.
- regulating price and quality.
- administration and maintenance of energy assets.
- recommending the establishment of new or revised standards or regulations.

Traditionally, regulatory proceedings referred to as dockets are where interested Interveners and Parties can participate and substantially improve the case. Recommended dockets for Tonga to consider should include:

- Renewable Energy Definitions – Defining what is a renewable energy (as well as 'what is not') for Tonga is fundamental to monitoring the amount of renewable energy on the grid. This will also define what is acceptable for Tonga from a renewable energy system.
- Renewable Portfolio Standards – Tonga's Renewable Portfolio Standard (RPS) is a key driver of energy policy and activities by other stakeholders. The RPS requires the electric utility to obtain 70% of its electricity sales from renewable sources by 2025[75] and 100% by 2035. Tonga is permitted to aggregate renewable electricity across its service territories. Failure to meet the RPS allows the electricity regulators to adjust targets and deadlines if the failure was 'due to reasons beyond the reasonable control of an electric utility'.
- Energy Efficiency Portfolio Standards – Tonga's Energy Efficiency Portfolio Standard (EEPS) requires electricity regulators to establish standards to maximise cost-effective energy-efficiency programmes and technologies, achieving a targeted number of gigawatt-hours (GWh) of electricity use reductions country-wide by 2030 and 2035.
- Public Benefit Fee – The Public Benefits Fee (PBF) is intended to subsidise energy efficiency measures through a minimal surcharge (1%) on electric utility bills. Money collected through this minimal surcharge is deposited in the Public Benefits Fund. The electricity regulators are authorised to transfer the proceeds of the PBF to the electric utility or a private-sector third-party administrator to support energy efficiency and demand-side management programmes and services, subject to the review and approval of the electricity regulators.
- Net-Energy-Metering – This legislation establishes a framework for net energy metering to encourage additional distributed renewable electricity generation. To encourage private-side investment in renewable technologies, this has proven to be one of the most successful renewable energy programmes developed.[76]
- Feed-in Tariff – The Feed-in-Tariff (FIT) establishes a new method for interconnection of distributed generation into Tonga's TPL grid. FIT is a mechanism intended to reduce the Tonga's fossil

[74] ADB Pacific Energy Update, 2020, p. 11 – Development of the Pacific Energy Regulators Alliance Status: Active ADB financing: $0.225 million. ADB is working with regulators across the region to build a community of best practices, which will help strengthen sector policy and regulation, improve utility management performance, and improve the private sector investment climate. The Development of the Pacific Energy Regulators Alliance Technical Assistance will promote modern regulation of energy utilities in the region by developing a regional platform to deliver capacity building, enable the exchange of knowledge and skills, and help the Pacific DMCs to pool limited resources to address common challenges. The alliance will leverage a regional approach to strengthen individual power markets in the affiliated Pacific DMCs.

[75] TPL Business Plan, 2021-2026 and TPL Renewable Accelerated Power IndepenDence (RAPID) Project.

[76] Hawaii – Net-Energy Metering: https://openei.org/wiki/Net_Metering_(Hawaii).

fuel dependence and accelerate the acquisition of renewable energy. The FIT is designed to simplify the process of integrating new renewable sources by providing more certainty as to the procedure and substantive requirements for interconnection, and by guaranteeing pre-established payment rates for energy delivered to the grid.

- Integrated Resource Planning – A five-year Integrated Resource Plan (IRP) will guide the future of the electric utility's electrical supply and grid investment decision-making. The utility will develop short- and long-term plans for electrical energy supplies in Tonga. Decisions made in the IRP docket will affect the electricity supply situation in Tonga for decades. The IRP docket is one of the most all-encompassing dockets in which a Country can advance its citizens' electrical energy goals.
- Additional dockets to consider are:
    - Interconnection standards for private distributed generation.
    - Electric utility business model.
    - Electricity tariff cases.
    - Demand-side programmes.
    - Reliability and safety standards.

Electric Utility Business Model

There are two fundamental utility business model characteristics, they are the profit motivation and profit achievement methods. A critical decision for the policy makers in Tonga is how to re-balance the utility between electricity sales orientation (profit achievement) and becoming more value- and service-based (profit motivation).

The profit motivation for TPL is going from asset based to value based. The pursuit of the 50%, 70%, and 100% renewable electricity targets is not only economically driven but is also a commitment to a change in values and commitment to a greener more sustainable future as we fight against climate change. The question becomes whether the pursuit of profit should be based on the value TPL provides to consumers instead of the size of the assets the company owns.

This aligns with the renewable energy goals of TERMPLUS because it removes the threat of lost revenue or stranded assets if consumers invest in their own generation assets. If this threat is solved, then investment by the public in renewable energy can go ahead uninhibited. If TPL's motivation is value then the best value would be provided by transitioning from centralised electricity generation for electric ratepayers to encouraging consumers to have their own green electricity generation assets such as roof-top solar, batteries and EVs. Where power generation reliability is most critical, TPL could provide multiple support services to consumers through a bundled utility package providing backup power.

The future profit achievement methods would then be no longer commodity based they would become services based. Again, aligning with the renewable energy goals would mean achieving profits from services instead of the number of units of electricity sold. For example, charging for the service of maintaining and operating the assets of a consumer who has renewable energy system. This could make sense in Tonga as the electrical expertise already exists within TPL. This conservative nature of profit achievement based on services aligns well with the disruptive drivers and challenges that the electricity utility services industry is currently facing.

Solar Standards

A key step to support development of roof-top (and other) solar in Tonga is establishing a national solar design, installation and maintenance standards. This will not only help local businesses achieve the quality necessary, but it will also support customer satisfaction and safety and control requirements by TPL (whose grid the roof-top solar systems would connect to). The national standard could be based on the Sustainable Energy Industry Association of the Pacific Islands (SEIAPI) regional standards which were developed with support from the Pacific Power Association and the World Bank.

Future Solar Development

Tonga is endowed with abundant renewable energy with its solar potential estimated to be 767,297 MWh/year (NREL, 2010). However, land availability and the land transfer process are viewed as one of the biggest issues in developing solar power generation projects in Tonga. Although getting to 70% renewable electricity may be accomplished in Tongatapu with all on-ground systems, the 100% goal may include some necessary offshore alternatives. In this regard, ADB is currently undertaking technical assistance project for floating solar (FPV) on Tongatapu's Laguna starting with a 100-kW pilot project with stated goals of preparing a 5-MW FPV for IPP implementation.

Future Wind Development

Wind generation at Niutoua has been studied in detail by TPL and its consultants.[77] Niutoua is a coastal village in the north-east of the island of Tongatapu, 1.5 km south-east of the village where the JICA-financed wind farm is located. The expansion proposed for financing through an IPP arrangement will extend the wind farm along the same service road and continue the arc of wind turbines along the coast, progressing towards the village of Haveluliku. The project will finance a BESS to provide storage capacity for energy produced by the wind farm.[78] It is expected as Tonga pursues its 100% renewable electricity goals that wind generation sites financed through various IPP will comprise at least an additional 20 turbines requiring approximately 12 hectare (10,000 square metres) of land.

The proposed future wind farms resulting in those estimated 20 turbines will be added to the already installed turbines in the Niutoua area. This significantly increases the scale of the development, extending it in a line following the coastline in a south westerly direction. The feasibility and environmental investigation undertaken to date concur that the cumulative impacts will not outweigh the benefits of the development.[79]

Wind performance metrics are good for Tonga sites with good wind exposure. Capacity factors in the range of 24–30% are common in such locations. Availability of such sites with good wind exposure presents a real benefit for Tonga. However, wind projects may be limited from going offshore into Tonga's best wind regimes due to the projected cyclone risk.

Future wind development will need the following derisking elements:

- Actual data of wind resources in site-specific locations,
- Guaranteed procurement of wind turbines of 300 kW to 1 MW that are cyclone-proof which are of a very limited supply with very long leadtimes, uncertain maintenance schedules, spare parts and repair costs,
- Better methods of determining land availability and streamlining land procurement.

Technical Capacity Development

As more renewable electricity is generated and deployed in Tonga, highly skilled employees trained in solar, wind, BESS, smart-grid, microgrid and EV-charger systems will be needed. Alongside those workers, existing skilled diesel-generation operators and maintenance personnel will need upskilling to learn to operate in new fast-start and cycling-modes. If Tonga wants to develop and retain these valuable employees, then the GoT and TPL must make this a high priority including proper compensation consideration with incentives to stay in country.

The highest penetrations of variable solar and wind systems up to 100% like those projected for Tonga are relatively new in the world of power generation. Increasing the capacity of existing workers and attracting new candidates will require a programme of development and on-going training. Without these skilled workers the transition to higher levels of renewables is not sustainable.

To facilitate the building of technical capacity development programmes, the GoT has already initiated a National Strategic Development Framework (NSDF). The NSDF aims to improve electricity generation and distribution systems and its safe operation in order to improve the living standards of all Tongans. The framework highlights a desire to improve services, accountability, and revenue collection, as well as the coordination of development partners, in line with the NSDF vision of 'a more progressive Tonga supporting a higher quality of life for all'.[80]

Diversification of Renewable Fuels

77 Tongatapu Wind Generation Study Phase 2b Detailed Design – Draft A Report (1 of 2 - Main Body) Aurecon & Infratec for Ministry of Foreign Affairs and Trade, 15 December, 2015, Revision: A, Reference: 240867 Tongatapu Wind Generation Study Phase 2c Construction Briefing Paper Ministry of Foreign Affairs and Trade Aurecon for Ministry of Foreign Affairs and Trade, 13 October, 2016, Revision: 0.3, Reference: 240867.

78 ADB – Entura – TONGA RENEWABLE ENERGY PROJECT – Final Feasibility Report – 30 May ,2020 page ii and iii: Prepared by Hydro-Electric Corporation ABN48 072 377 158: For Tongatapu, some additional network support to ensure the grid remains within its operating parameters for voltage and stability, Progressive upgrade of the control system to provide automated curtailment control of distributed generation, and generator scheduling, in coordination with the BESS, Completion of a ring feeder to the Niutoua wind farm site, Upgrade of the distribution line capacity to the Niutoua wind farm site to limit voltage rise in the network and enable full export, Changing settings on existing generators, and require voltage support and fixed reactive power absorption at each of the new generator sites. To support these changes, European Union Technical Assistance is being used to draft a grid code for Tonga. The grid code will include regulated Distribution and Generation Expansion plans, an update of TPL's internal Distribution and Generation Asset Management Plans, which will identify how and when generator and distribution settings and additional asset investments will be made. A draft of this grid code is now available but has not been formally endorsed. Recommendation to provide additional reactive power at the power station, by way of installing a synchronous condenser or capacitor bank when additional wind and solar is installed to allow maximum power output from these subprojects.

79 Initial Environmental Examination Project No. 49450-012, March 2018, TON: Renewable Energy Project. Prepared by Tonga Power Limited & Ministry for Meteorology, Energy, Information, Disaster Management, Environment, and Climate Change for Ministry of Finance and National Planning & Asian Development Bank, page 14 and page 48.

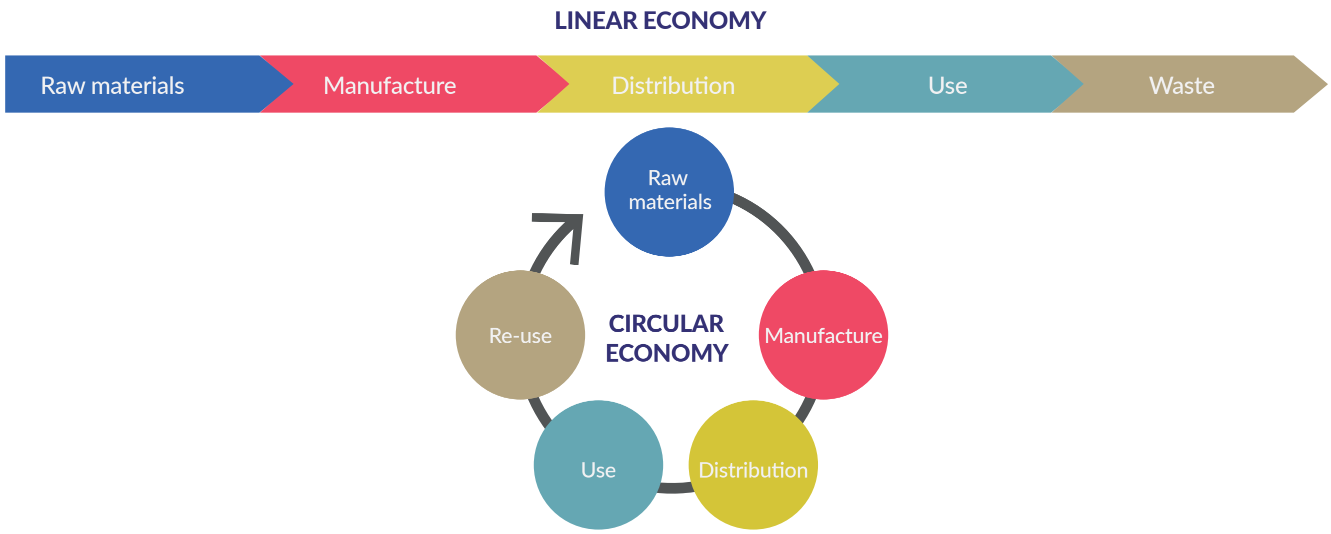
80 Government of Tonga (GoT): National Strategic Development Framework.

Biogas Plant – Circular Economy[81]

Biogas from anaerobic digestion is not merely a concept of production of renewable energy; it cannot be compared to a wind turbine or a photovoltaic array. Nor can anaerobic digestion be bracketed as just a means of waste treatment or as a tool to reduce greenhouse gases in agriculture and in energy. It cannot be pigeonholed as a means of producing biofertilizer through mineralisation of the nutrients in slurry to optimise availability, or as a means of protecting water quality in streams and aquifers. It is all these and more. The multifunctionality of this concept is its clearest strength (Figure 17). Sustainable biogas systems include processes for treatment of waste, for protection of environment, for conversion of low-value material to higher-value material, to produce electricity, heat and of advanced gaseous biofuel. Biogas and anaerobic digestion systems are dispatchable and as such can facilitate variable renewable electricity.

There are no modern, commercial biogas plants serving the people of the Pacific Islands. The specific biogas project that is proposed for Tonga is a 3 MW biomethane biogas plant. One of the main benefits is that it will enable the development of a new, crop-based agricultural subsector and provide participating farmers with a substantial and highly secure source of income not affected by fluctuating commodity price. Another key benefit is that the system is modular and can be built in 500 kW increments with testing and verification at each stage. Tonga's inexhaustible ability to grow prolific amounts of biomass in support of food, feed, fibre, energy, organic fertiliser and bio-products underpins the ability to transition to an equitable, prosperous, sustainable and largely self-determined circular economy.

FIGURE 17.
Circular versus Linear Economy



Source: IEA Bioenergy – The role of Anaerobic Digestion and Biogas in the Circular Economy – 2018

Biofuels

[81] United Nations Industrial Development Organization (UNIDO) Project: Tonga Circular Economy Project – Biogas Feasibility Study – Reference Number: 7000003978 – April 30, 2021.

The TEEMP goal of blending 10% biodiesel into all diesel fuel is recommended by 2030. This quantity of biodiesel would be supplied by available waste grease and coconut oil. 10% biodiesel is compatible with nearly all diesel vehicles in a warm climate and provides lubricity and cetane benefits. To take full advantage of its waste grease resources, Tonga would need to build biodiesel production facilities with a total of about 1-million litres per year capacity, likely divided between a few islands. The economics of such small-scale waste-grease-to-biodiesel production facilities can be favourable, depending on numerous factors and there is a need for some detailed studies of the proposal to provide clearer guidance to the way forward.[82]

Tonga Renewable Energy Lab and Pacific Partnerships

Sustainable Development Goal, SDG 7.a., states: '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'. It further states 'International financial flows to developing countries in support of clean energy research, development and renewable energy production, including in hybrid systems'.

Although Tonga has abundant renewable solar and wind energies, it is lacking a firm renewable energy source that may be needed for higher percentages of renewable electricity beyond 70%. Although currently not cost-effective, a promising firm resource may be found in biofuels which can be used for both power generation and transportation. Tonga's primary area of focus for the next 10 years of research and development should consider biofuels that can 'drop-in' to the existing diesel generation fleet and be used for transportation. Hydrogen technologies may also become more cost-effective and have a niche for the future of energy storage, transportation and shipyard/airport utility vehicles.

Waste-to-energy can take many forms, including digester and incineration technology options. For Tonga, the main challenge is ensuring enough waste to make the waste-to-energy facility economically viable. Waste-to-energy could also be included as a research project that can be used for power generation either as fuel or biogas.[83]

Ocean energy technologies are just becoming commercially available, but there is interest in developing renewable energy from ocean thermal, wave, and tidal. Ocean energy from waves and Ocean Thermal Energy Conversion (OTEC) should be considered as possible for Tonga's energy future.

As called for in the Energy Bill, Tonga should be pursuing these research areas for renewable energy. Through the Tonga Renewable Energy Lab, partnerships in research, development and deployment can be pursued in the Asia-Pacific region to gain knowledge and practical solutions with a focus on the renewable biofuels, biogas, hydrogen and ocean arenas.

Environmental Impact of Future Projects

As Tonga develops future solar, wind and BESS projects it will further pressure the limited land-availability. Many of these projects will necessarily be subject to Environmental Impact Statements. For the power sector, Tonga will necessarily become well-versed in wind and solar and BESS technologies, but also biomass, biofuels, waste-to-energy and possibly hydrogen and ocean technologies which will be needed to approach 100% renewable energy.[84]

Preliminary environmental analysis will include a review of the potential impacts that each project may have on the environment. It also needs to address any special conditions put forth by the GoT as well as the financiers.

Initial environmental assessments should include:

- existing environmental guidelines,
- evaluation of water needs and discharge requirements,
- land cover and air emissions,
- regulatory compliance issues,
- forest resources and coral impacts,
- resilience and climate change assessments.

[82] TEEMP – 2020 page 37 .
[83] Carbon Black Global (https://www.carbonblackglobal.com) is working with TPL, Waste Authority and MEIDECC – DoE.
[84] See: Mitigating biodiversity impacts associated with solar and wind energy development by IUCN here: https://portals.iucn.org/library/node/49283.

3.6 ELECTRICITY GENERATION AND DISTRIBUTION ROADMAP

The overall targets for each intervention are sub-divided into short-, medium-, and long-term targets as shown in table below.

Interventions/ Policy Alignment	Short-Term Target 2025	Medium-Term Target 2030	Long Term Target 2035	Key Stakeholders
Tonga 50%, 70% and 100% Renewable Electricity (RE) Goals Policy: TERM, NDC, SDG 7.2, JNAP2, NIIP2, LT-LEDS, TPL's RAPID Project	Complete TERM Pipeline Projects to **50% RE** Award & Implement TPL RFT Winning Bid Projects for 70% RE, Implement Grid Modernization and BESS Procurement for 70% RE System	TPL **100% RE** EOI and RFT, Award Bidders, Design Grid Modernization and BESS Procurement Options for 100% RE System	Implement TPL RFT Winning Bid Projects to 100% and Implement Grid Modernization and BESS Procurement for 100% RE System	Sector Lead: TPL, IPPs Partners: MEIDECC – DoE , MPE, MNFP, GridMarket Finance: Development Partners
Energy Bill / Act Policy: TERM	Anticipated Royal Ascent of Energy Bill, Implementation, Establish Ministry of Energy, Adopt National Energy Policy	5-year review of National Energy Policy and Update	5-year review of National Energy Policy and Update	Sector Lead: MEIDECC – DoE Partners: EU, Tonga Consultants Finance: EU
Technical Assistance to implement Energy Act and TERMPLUS Policy: Energy Bill / Act	Strengthen the institutional capacity of the Ministry responsible for Energy, the Department of Energy, the Energy Commission, the Energy Advisory Committee, TPL and relevant authorities			Sector Lead: MEIDECC-DoE Partners: EU Finance: EU
Monitoring and Evaluation of TERMPLUS	Progress on TERMPLUS Goals	Progress on TERMPLUS Goals	Progress on TERMPLUS Goals	Sector Lead: MEIDECC – DoE Partners: EU Finance: EU
Green Bond Funding	Model work done in Fiji, Tonga's first bond goal = USD 20 million	USD 40 million	USD 100 million	Sector Lead: PMO, MFNP Partners: MOI, MEIDECC Finance: World Bank
Carbon Credit Potentials (Article 6) for Renewable Electricity Interventions Policy: NDC, LT-LEDS, TCCP, JNAP2	GGGI Analysis done for TPL and MEIDECC Projects, MEIDECC and TPL Implementation for 70% RE	Implementation for 70%-100% RE	Implementation for 100% RE	Sector Lead: TPL, MEIDECC – DoE Partners: GGGI Finance: Development Partners

Interventions/ Policy Alignment	Short-Term Target 2025	Medium-Term Target 2030	Long-Term Target 2035	Key Stakeholders
Grid Modernisation and Renewable Electricity Feasibility Studies to 70-100% Policy: NDC, LT-LEDS, TCCP, JNAP2	Tongatapu, Vava`u, Ha`apai, `Eua 5-year Phased Implementation Plan, Develop procurement plan, Develop Grid Modernisation RFT, Award and Implement Grid Modernization for 70% RE	Updated Feasibility Study based on Load Projections, Load Curves and Demand-side Management Potentials Updated Grid Modernisation Studies for 70-100% RE, Develop Grid Modernisation RFT for 100% RE, Award and Implement Grid Modernization for 100% RE	Updated Grid Modernisation Studies for 100% RE	Sector Lead: TPL, MEIDECC-DoE Partners: GridMarket Finance: USTDA
Smart Grids Policy: NDC, LT-LEDS, NIIP2	Grid Modernization Plan, Implement Smart Grid Components for 70% RE. Maintain Line Losses less than 8%	Implement Smart Grid Components for 70-100% Renewable Electricity, Maintain Line Losses to less than 8%	Complete Smart Grid 100% RE, Maintain Line Losses to less than 8%	Sector Lead: TPL Partners: MEIDECC–DoE Finance: Development Partners
Complete Smart Meter Installations Policy: TEEMP	Tongatapu	Vava`u, Ha`apai, `Eua		Sector Lead: TPL Partners: MEIDECC–DoE Finance: TPL
Advanced Weather Forecast System	Weather instrumentation deployed for existing and planned renewable electricity sites for Tongatapu, Vava`u, Ha`apai, `Eua	Improved weather forecasts utilised for battery management, Projected renewable energy generation accommodated in system dispatch planning,	Integrate with SmartGrid, Renewable energy generation periods planned during which the batteries can be charged again using the lowest cost renewable energy	Sector Lead: TPL, MEIDECC – DoE Partners: MLNR Finance: Development Partners
Demand/Load-Curve Study on Existing Major Grid Loads, Forecasted & Probable New Load Additions (i.e. Resorts, Water Pumps, New Wharf, Businesses, etc.) Policy: NIIP2	DSM in Tongatapu	DSM in Vava`u, Ha`apai, `Eua	DSM in Outer Islands	Sector Lead: TPL, MEIDECC-DoE Partners: MFNP GridMarket Finance: USTDA
Residential Load Studies for Aggregated Community Solar PV and Residential PV Projects Policy: JNAP2	Tongatapu	Vava`u, Ha`apai, `Eua	DSM in Outer Islands	Sector Lead: TPL Partners: MEIDECC–DoE Finance: Development Partners

Interventions/ Policy Alignment	Short-Term Target 2025	Medium-Term Target 2030	Long-Term Target 2035	Key Stakeholders
Outer Islands Renewable Electricity (RE) Feasibility Studies and Implementation Policy: TERM; TCCP, JNAP2	Implement OIREP to 70% RE	Implement OIREP to 70-100% RE	Implement OIREP to 100% RE	Sector Lead: OIREP Team Partners: MEIDECC-DoE, GGGI, GridMarket Finance: ADB, GCF, DFAT
Regulatory Studies Policy: Energy Bill / Act, TEEMP	RE Definitions, RE Portfolio, EE Portfolio Standards	Public Benefit Fee, Net Energy Metering, Feed-in Tariff	Integrated Resource Planning, Tariffs, Business Models	Sector Lead: Electricity Commission Partners: TPL, MEIDECC-DoE Finance: Development Partners
National Solar Standard Policy: Energy Bill / Act, TEEMP	Solar design, installation and maintenance standards based on the Sustainable Energy Industry Association of the Pacific Islands (SEIAPI) regional standards, Safety and Control Requirements, Update based upon 70% RE	Safety and Control Requirements, Update Standard based on 70-100% RE	Update Standard based on 100% RE	Sector Lead: TPL, MEIDECC-DoE Partners: Pacific Power Association Finance: World Bank
Decentralised Solar + Battery Rooftops Programme Policy: SDG 7.a	Tongatapu	Vava`u, Ha`apai, `Eua	Outer Islands	Sector Lead: MEIDECC –DoE, OIREP Team Partners: Private Partner Finance: Private Finance
Floating solar (FPV) Pilot starting with a 100-kW pilot project Policy: SDG 7.a	Tongatapu Laguna	Prepare 5-MW FPV for IPP implementation	Deploy in appropriate Tonga Outer Islands	Sector Lead: TPL, MEIDECC–DoE Partners: Private Partner Finance: ADB
Tonga Renewable Energy Lab – Feasibility Studies Policy: Energy Bill / Act, NIIP2, SDG 7.a	Research and Demonstration on Biofuels, Biogas, Waste to Energy, Micro-/Nano-grids	Research and Demonstration on Geothermal and Ocean Energy (OTEC, Tidal, Wave)	Research and Demonstrations Hydrogen, Synthetic Methane and other renewable-derived fuels	Sector Lead: MEIDECC–DoE Partners: TPL Finance: International Energy Labs, Private and Development Partners
Biogas Plant - Circular Economy Policy: SDG 7.2, NIIP2, HTHH-DRRP	Tongatapu	Vava`u, Ha`apai, `Eua		Sector Lead: MEIDECC–DoE Partners: TPL, Dept. of Environment, WAL Finance: Private Finance
Waste to Energy Policy: SDG 7.2, NIIP2, HTHH-DRRP	Tongatapu	Vava`u, Ha`apai, `Eua		Sector Lead: MEIDECC–DoE Partners: TPL, Dept. of Environment, WAL Finance: Private Finance

Interventions/ Policy Alignment	Short-Term Target 2025	Medium-Term Target 2030	Long-Term Target 2035	Key Stakeholders
High-Skilled Technical Workers Capacity Building Policy: NSDF	Develop Training Programmes for Renewable Energy Workers with specializations in Solar, Wind, BESS, Smart-grid, Microgrid and EV-charger systems	Develop higher-skilled workers from existing skilled diesel-generation operators and maintenance personnel will need upskilling to learn to operate in new fast-start and cycling-modes	Training Programmes for Grid Control Personnel that operate the Renewable System	Sector Lead: TPL, MEIDECC-DoE Partners: Tonga Institutes Finance: TPL, Development Partners
Solar Water Pumps Policy: SDG 7.1, 7.2, HTHH-DRRP	Vava`u, Ha`apai			Sector Lead: MEIDECC-DoE Partners: Community Finance: IUCN, JICA
Solar Home Systems Policy: SDG 7.1, 7.2, HTHH-DRRP	Vava`u, Ha`apai			Sector Lead: MEIDECC-DoE Partners: Community Finance: IUCN, JICA
Solar Home Systems Policy: SDG 7.2	Vava`u, Ha`apai	-	-	Sector Lead: MEIDECC-DoE Partners: Community Finance: EU, Japan, IUCN
St. Andrew Solar Farm Policy: SDG 7.2	Tongatapu	-	-	Sector Lead: MEIDECC-DoE Partners: TPL Finance: St. Andrews
Tonga High School Solar System Policy: SDG 7.2	Tongatapu	-	-	Sector Lead: MEIDECC-DoE Partners: TPL Finance: Tonga HS
Police Training HQ - Longolongo Solar Farm Policy: SDG 7.2, HTHH-DRRP	Tongatapu	-	-	Sector Lead: MEIDECC-DoE Partners: TPL Finance: Police
Solar System for Niuafo'ou Hospital Policy: SDG 7.1, 7.2, TSDFII, JNAP2, HTHH-DRRP	Niuafo`ou	-	-	Sector Lead: MEIDECC-DoE Partners: Community Finance: ADB, DFA, EU

4 TRANSPORTATION

4.1 OVERVIEW

Economic growth in Tonga driven by its growing fisheries exports, industrial development, and tourism amongst others, is having an increasing impact on the energy needs of land and maritime transport. The transport sector remains entirely dependent on oil products and comprises over 62% of Tonga's total energy consumption.

The transport sector is the main user of imported petroleum products (Government of Tonga, 2015) and accounts for approximately 90% of end-use petroleum oil demand in Tonga (excluding oil used in electricity generation). Land transport is the dominant mode of transport, while maritime (domestic shipping for transportation of people and goods and fishing) is also important. Domestic aviation industry plays a very limited role. International maritime and aviation are not considered in the TERMPLUS.

There are approximately 18,200 households in the country, owning a total of 16,000 vehicles for land transport and 129 maritime small (less than 15 m size) vessels (Tonga Statistics Department, 2017). Based on vehicle stock figures, the country has an estimated motorisation rate of approximately 160-170 vehicles per 1,000 people (GoT and United Nation's Climate Technology Centre and Network 2018; Tonga Statistics Department 2017) which is relatively high compared to other countries in the Asia-Pacific region. However, the vehicles are not evenly distributed across all regions but ~85% of land transport vehicles are concentrated in the region of Tongatapu, as shown in Figure 18.

One of the primary concerns for Tonga is the dominance of private vehicles in its transportation system. As of 2021, approximately 95% of registered vehicles in Tonga are owned by individuals or private organisations. The market is dominated by four-wheeler personal and light pick-up trucks that account for approximately 75% of the total registered vehicles, while heavy and medium buses together constitute less than 1%, highlighting the need and scope to strengthen public transport. Figure 19 shows the share of different types of vehicles within the land transport sector.

FIGURE 18.
% Share of registered vehicles for different regions in Tonga (2020)

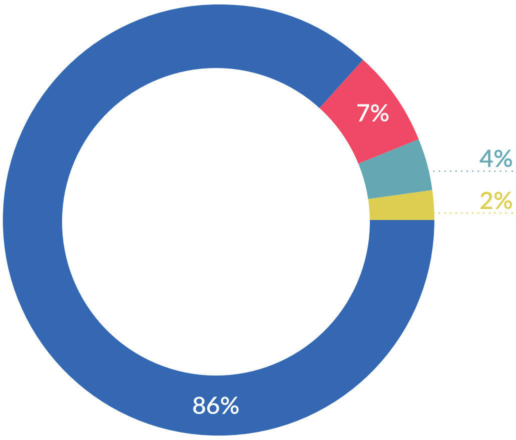
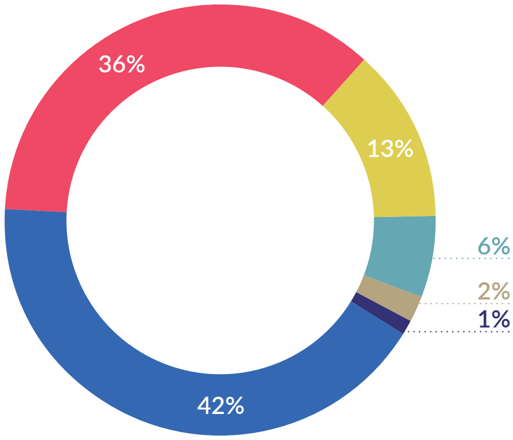


FIGURE 19.
Modal Share of Land Transport in Tonga (2021)



Maritime constitutes less than 2% of total vehicle stock. As per the Marine & Ports Division, there are 129 vessels currently operating (less than 15m in size). Out of which, 90 vessels have outboard engines, and 39 vessels have inboard engines. The majority of vessels with outboard engines are tourist vessels, and the vessels with inboard engines are fishing vessels.

All transport sector related responsibilities that include land, maritime and aviation sub-sectors come under the Ministry of Infrastructure (MOI).[85] The main actor in land transport is the Land Transport Division (LTD). Similarly, the main actors in the maritime sector are Marine and Ports Division (MPD), Port Authority of Tonga (PAT), Ministry of Education, Tonga Maritime Polytechnic Institute (TMPI). Tonga Airports Limited share responsibilities for the aviation sector with the Civil Aviation Division under MOI.

The World Bank estimates that the total population of Tonga will grow at a CAGR of 0.2% (2022–2035) and reach 108,913 people by 2035. Figure 20 shows the population growth trend for Tonga till 2035.

Vehicle registration has been rising and declining over the past 10 years, which makes it difficult to comment on future trends. A segment based vehicular growth rate has been taken based on stakeholder consultations for TERMPLUS. Overall vehicle numbers are estimated to grow at a rate of 1.3% (Figure 21), which implies an increase of 342 total vehicles per 1,000 population by 2035.

[85] For electrification of transportation scenarios that are part of this chapter, additional transport-related responsibilities will include other Ministries and Departments such as MEIDECC – Department of Energy. It will also involve Tonga state-owned-enterprise Tonga Power Limited (Tonga's electric utility).

FIGURE 20.
Population trend of Tonga (2011–2035)

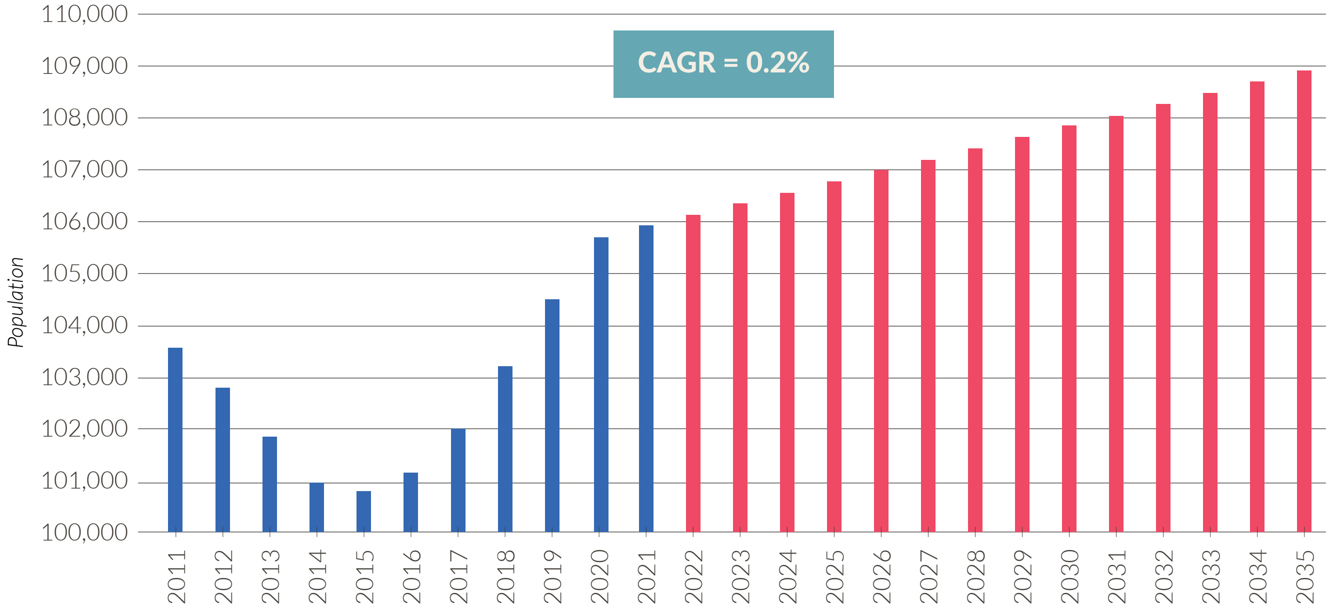


FIGURE 21.
Vehicle growth estimates till 2035 for different vehicle categories

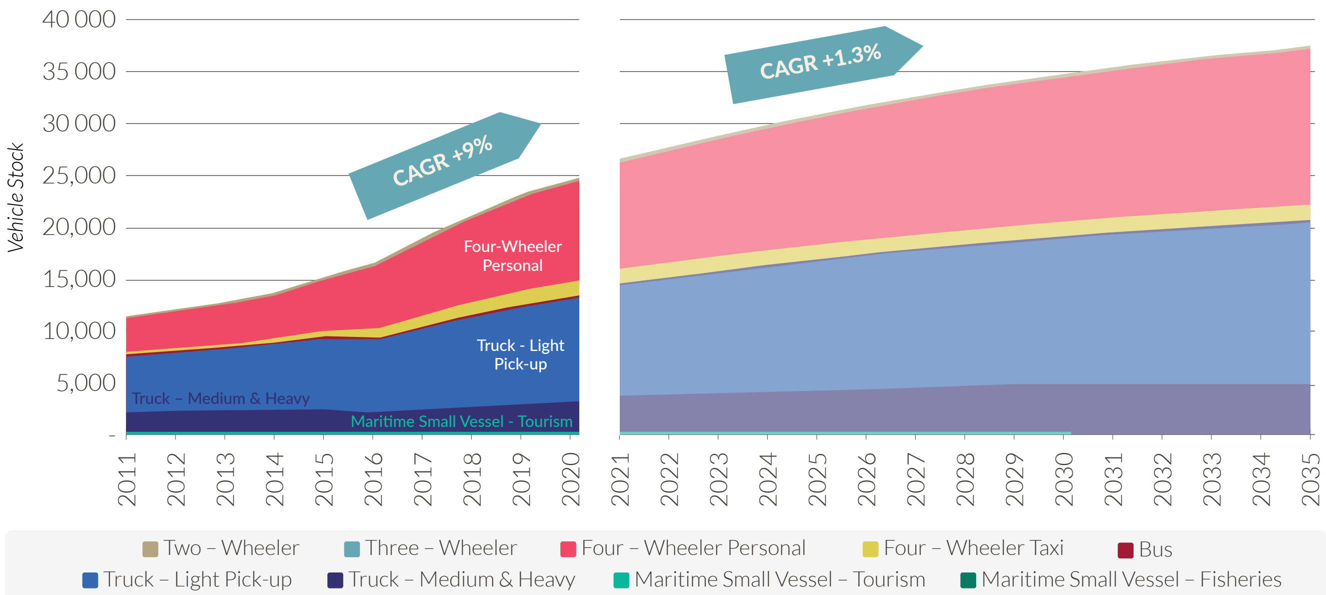


Figure 22 shows GHG emissions projection (2022–2035) in a BAU scenario for different vehicle categories, (see also Appendix D: Methodology note for calculating GHG and Air Pollutant Emissions)

Figure 23 shows that in 2021, transport related GHG emissions are estimated to be 130,449 metric tons CO_2e, inclusive of emissions from petrol and diesel fuel supply chains.

Primary contributors to emissions are truck (medium and heavy vehicles with 37%, followed by light pick-up trucks with (36%), four-wheel personal cars (15%), four-wheel taxi and government fleet (7.2%), and maritime small vessels of less than 15 m (2.7%).

Emissions from the transport sector are expected to rise to 170,175 metric tons CO_2e by 2035, i.e. 1.3x times of emissions in 15 years at an average year-on-year growth rate of 2%.

Figure 23 indicates the trend of per-capita GHG emissions in Tonga for the period 2021-2035. Per-capita GHG emission includes all vehicle segments and are estimated to increase at a CAGR of 3% in the mentioned period. This is due to expectations of higher vehicle growth rate (>1%) and lower population growth rate (approx. 0.2%).

FIGURE 22.

GHG Emissions Projection (2022–2035) – Tonga BAU Scenario

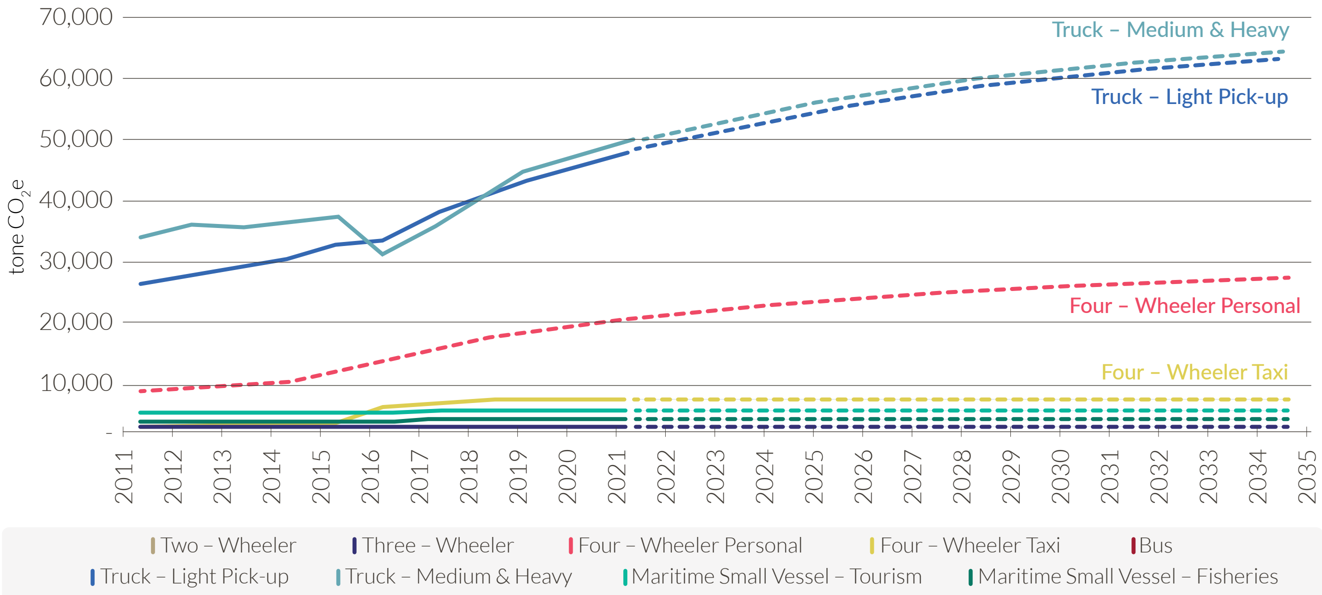
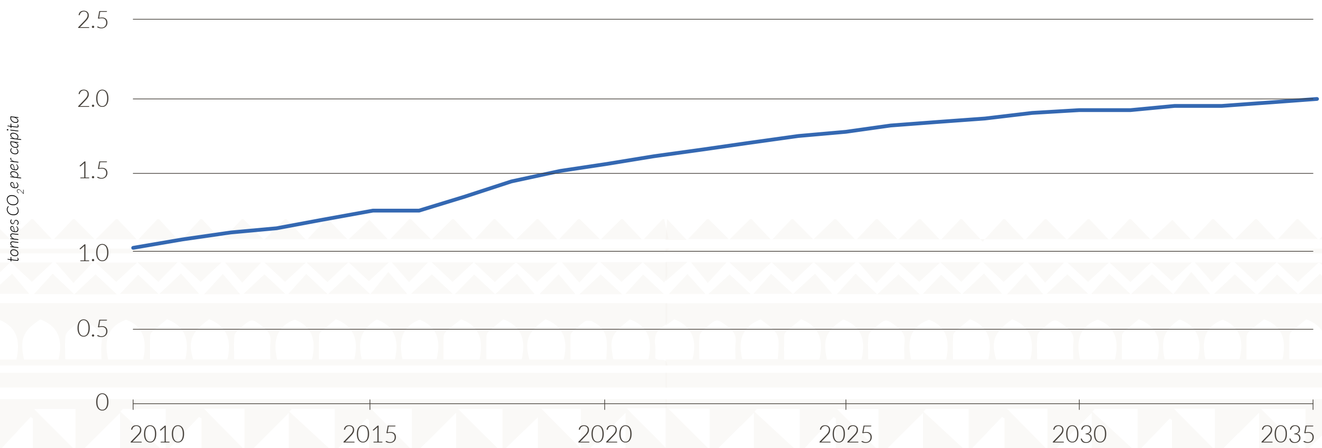


FIGURE 23.

Estimated trend of per-capita GHG emission in Tonga (2021–2035)



Relevant Policies, Legislations, and Regulations

As transport sector development in Tonga is largely governed by the policies, legislations, and regulations, this section sets the context for existing legislative instruments and policies that are most relevant for the low emission land and maritime transport infrastructure in Tonga.

Policies

- **Tonga Climate Change Policy, 2016** reinstates Tonga's commitment towards resilience to the impacts of climate change and climate-related disaster risks. Outlined in the policy are Tonga's 20 targets on climate change including the targets of 'a transport system that is not reliant on fossil fuels' and '100 % renewable energy' (GoT, 2016).
- **Tonga's Second NDC, 2020** states the target of reducing GHG emissions from the combustion of fossil fuels by 13% (16 Gg) by 2030 compared to 2006 (GoT, 2020). It also specifies a transport sector measure of 2% efficiency gain per year for newly purchased light duty vehicles to contribute to the NDC emission reduction target.
- **Tonga Strategic Development Framework (2015–2025)** highlights priority issues for the overall development of Tonga. In terms of transport**,** TSDF prioritises the goal to provide more reliable, safe, and affordable transport infrastructure and services on each island, connecting islands and connecting the Kingdom with the rest of the world by sea and air, to improve the movement of people and goods.
- **Tonga Budget Statements (TBS 2021-2022)** provides the policy direction for the annual recurrent and development budget. According to TBS, Government has approved a policy to commence establishment of a Land Transport Authority (LTA) to manage (RMF) all road infrastructure maintenance and development in Tonga.
- **National Infrastructure Investment Plan (NIIP) 2013–2023** outlines Tonga's priorities and plans for major initiatives in economic infrastructure including transportation over the 5–10 years. It recognises the need to improve road infrastructures, build Fanga'uta Bridge to improve journey times and facilitate relocation of communities from low lying areas. And for the maritime space, the need to: (i) reduce the cost of services to reduce transport costs and improve Tonga's international competitiveness; (ii) improve the sustainability of maritime infrastructure by ensuring adequate maintenance, so as to minimises long-term costs and maximises availability; (iii) enhance inter-island shipping services to help improve socio-economic conditions; (iv) increase the safety of the transport system, and its resilience to climate change and natural disasters, to minimises disruptions; (v) strengthen and reform the institutional framework that governs the management, maintenance, and financing of maritime infrastructure and services; and (vi) promote and better use a competitive private sector.
- **The Pacific Blue Shipping Partnership, 2021** targets to achieve 40% GHG emissions reduction across fleets of member countries, from targeted deployment of current on-market technology by 2030. This includes upgrades to: propulsion, ship design, main machinery and engine, energy management and recovery, speed / voyage optimisation, trim, just-in-time berthage.
- **Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management 2** (JNAP 2) aligns with the Tonga Climate Change Policy and covers both climate change adaptation and disaster risk management including transportation sector focus aspects

Legislations and Regulations

- **Traffic Act 2020** provides legislative provision regarding registration of vehicle, control of vehicles through permits, provision relating to use and user of vehicles and special provisions relating to transport undertakings like traffic regulation, insurance, liability, offences and penalties, etc.
- **Tonga Shipping Act 2016** makes provision with respect to registration of ships in Tonga, provides rules for navigation by ships registered in Tonga and any ship in Tongan waters and for matters related to navigation.
- **Road Act 2020** covers the building, maintenance, and protection of public roads as a Government Asset and highlights the need for better management and maintenance of public roads. The Act gives authority for Government to set up separate Roads Maintenance Funds (RMF) where money from vehicle registrations and grants for road work go directly towards routine maintenance.

- **Tonga Energy Bill 2020** is imperative to the development and future of the energy sector. It will set up the key governance structures to formalise the functions of the Department of Energy and will authorise the establishment of an Energy Commission to regulate petroleum, electricity, and renewable energy. It will repeal three existing Acts: Petroleum Act, Electricity and Renewable Energy Act.
- **Public Enterprise Act 2002** details the incorporation of all public enterprises under the Ministry of Enterprises, including Ports Authority Tonga and Tonga Airports Limited.
- **National Spatial Planning and Management Act 2012** covers a range of issues that impact significantly on improving infrastructure planning and implementation.

Challenges of Transport Sector in Tonga

The challenges in the transport sector include high private vehicle demand, increasing dependence on fossil fuel, poor quality of traffic management and road infrastructure system, limited public transport and gaps in transport policies. These are compounded by lack of sector resources and coordination. The key issues are discussed below:

- High private vehicle demand
  - Currently, four-wheeler personal and light pick-up trucks account for more than 75% of the total registered vehicles, while heavy and medium buses together constitute less than 1%.
  - Overall, total vehicles registered will continue to grow driven by an increase in private vehicle ownership.
  - This large disparity is not only resulting in traffic congestion, but also is a major contributing factor to deteriorating air quality, increasing GHG emission, and increasing road crash fatalities.
- Increased dependence on fossil fuel
  - Transport sector remains entirely dependent on oil products and comprises over 62% of Tonga's total energy consumption.
- Poor Quality of Traffic Management and Road Infrastructure System
  - Traffic congestion due to poor traffic management and relative lax enforcement of vehicle testing and assessments.
  - High cost of vehicle operation and maintenance.
  - Poor design and construction of roads including pavements and facilities.
  - Lack of climate proofing (poor drainage, etc.).
  - Limited road signs and safety measures installed and regulated.
  - Inadequate pedestrian walkways and road surface markings.
  - Lack of maintenance of road surfaces and road infrastructure.
  - Limited evacuation access roads in case of emergencies and natural disasters.
- Poor public transport services
  - Limited public transport operation with inconsistent public transport services.
  - Lack of terminals for all public transport modes, bus-stops and other facilities.
- Gaps in transport policies
  - Absence of guidelines and difficulties in enforcement of traffic regulations to carryout efficient and safe traffic management services for both passengers and cargos.
  - Absence of integrated transport and land use planning.
  - Gaps in transport policies and guidelines to ensure multi-modal transport safety.
  - Gaps in transport policies relating to emissions reductions and sustainable transport measures.

4.2 TRANSPORTATION TARGETS

Targets Definition

The TERM 2021–2035 targets to limit growth in oil consumption for road transport to 25% for the period 2019–2035 (an average of 1.4% per year).

As one of the prime causes of increasing oil consumption is the rising number of vehicles, measures specifically targeting vehicles will be needed to meet this target.

In a business-as-usual (BAU) scenario, it is expected that increasing fossil fuel consumption will continue and will pose a significant threat to the environment and economy. Increasing global fuel prices, in addition to the increasing fuel demand, would create pressure on the balance of trade by widening the trade deficit. Thus, appropriate, and timely measures are required to control the increasing demand of private vehicles and to also replace the existing conventional fossil fuel vehicles with cleaner technologies like electric vehicles (EVs) and with non-motorised transport (walking and cycling).

4.3 MEASURES

The LT-LEDS transport sector vision for Tonga is to achieve low emissions in the transport sector, through sustainable maintenance, knowledge production, enforced regulation and decentralisation of services. The TERMPLUS is aligned with this objective alongside its target as stated above.

In order to decrease oil consumption in the land transport sector and move towards a low-emission development path aligned with the LT-LEDS, mitigation interventions for the transport sector need to be identified to move away from the BAU scenario. Based on a combination of stakeholder consultations and a literature review of the national and regional policies of Tonga, three broad potential intervention areas have been identified, under which 12 sub-activities are proposed. These interventions are listed in the Table 15 below:

TABLE 15.
Transport Sector Intervention Areas

Sr. No.	Interventions	Sr. No.	Activities
1	Improving Intake Quality of Vehicle; Fuel efficiency; End-of-life	1.1	Motor industry quality assurance programme
		1.2	Stricter emission standards for new/existing vehicles & fuel
		1.3	Shared Mobility
2	Non-Motorised Transport	2.1	Walkway and bicycling lanes expansion
		2.2	Pedestrianisation
		2.3	Public Bicycle Sharing (PBS)
3	Low-Emission Vehicles	3.1	Electric Private Passenger Vehicles (2W, 4W, light pick-up truck)
		3.2	Electric Public Transportation (Bus)
		3.3	Electric Commercial Taxis (4W)
		3.4	Electric Vehicles in Government fleet (4W)
		3.5	Electric Freight Vehicle (Medium & Heavy-Duty Trucks)
		3.6	Maritime Electrification (small vessels primarily used in tourism & fisheries)

1. Improving Intake Quality of Vehicle; Fuel efficiency; End-of-life

Improving Intake Quality of Vehicle, adopting high fuel efficiency standards, periodic review of vehicle emissions standard, capacity building on vehicle maintenance practises and awareness can improve fuel economy and reduce the vehicular emissions level. Some of the identified interventions are:

Sub-interventions & their respective measures	**1.1 Motor industry quality assurance programme:** By considering the vehicle performance, different standards of emission rate, fuel economy, and other regulations; Several improvements and developments could be made to meet those standards. These include adding additional mechanical components such as the variable valve timing, changing engine structure, and creating a new technology to reduce tailpipe emission. Fuel efficiency improvement through motor industry quality assurance programmes include (a) electronic throttle control, (b) variable valve timing, (c) turbo charging, (d) low displacement engine, etc. Some of the mechanical parts that could be improved are focused on the timing of the opening and closing of the inlet and exhaust valve. By installing technology relating to valve timing, the vehicle's thermal efficiency and fuel economy can be improved. Almost every company has its valve timing system installed in their vehicle. Similarly, several engine structures could be created to improve stability, vibration, and horsepower (hp). For e.g., designs, including the inlet engine, V engine, and the boxer engine, all have unique benefits that improve engine performance. **1.2 Stricter emission standards for new/existing vehicles & fuel:** Implementation of vehicle and fuel standard will automatically ensure implementation of other intervention options like cleaner Sulphur fuels, and instalment of diesel particle filters (DPF), etc. Measures relevant for stricter emission standards are stricter Euro standards, banning import of light diesel vehicles, installing DPF in HDVs, age limit of vehicles for importation and scrappage, improved inspection & maintenance, cleaner sulphur fuel, etc. **1.3 Shared Mobility:** This concept has a potential to improve the average vehicle occupancy (fleet utilisation) by allowing more passengers and goods to travel in the same vehicle. This also makes the transportation more affordable as cost is shared among users/goods. Measures relevant for shared mobility are ride sharing services (e.g. Uber), ride hailing services (e.g. OLA pool, Uber pool), rental bike/cycle, scooter services, micro transit services (e.g. Shuttle), etc.
Applicability for Tonga	1.1 and 1.2 are applicable in all of Tonga. These measures are highly aligned to education and well aligned to environment, inclusivity, culture and traditional knowledge (GoT, 2021). Whereas for shared mobility, 1.3, this is a new concept and can promote new ventures and new business opportunities. It can be supported by growing smartphone penetration and internet connectivity. Enabling factors that make shared mobility activities favourable are seen primarily in Tongatapu.
Status of implementation & target setting	

Sub-Interventions	As-Is	Target Setting
Motor industry quality assurance programme	No motor industry quality assurance programme	Increase in fuel efficiency over years to 2.4%
Stricter emission standards for new/existing vehicle, fuel	Euro III standard is applicable all over Tonga and Euro III fuel is imported	Implement Euro V by 2035 (Real-life Drive Emissions (RDE) and Monitoring Systems)
Shared Mobility	No initiatives for shared mobility	Improve vehicle occupancy in 4W Taxi and 3W by 1.5%

GHG estimations	Inspection equipment and building or specific areas for tests and inspections, policy, regulations and/or incentives to increase the uptake of more energy efficient, lower emissions conventional vehicle technologies, promulgating stringent fuel-efficiency standards for all new ICE vehicles import have an overwhelming impact on GHG mitigation. Furthermore, this intervention does not require any significant capital investment for new vehicles/ technologies or infrastructure creation expenditure. This is therefore an imminent 'low-hanging fruit' opportunity available for the Government to implement.

Activities	CO_2e mitigated per year per person	Total mitigation (by 2035)
Motor industry quality assurance programme	0.173 tons CO_2e	91,566 tons CO_2e
Stricter emission standards for new/existing vehicle, fuel	0.710 tons of air pollutant	3,848 tons of air pollutant
Shared Mobility	0.005 tons CO_2e	3,550 tons CO_2e

Key enabling actions	Incentives and taxation like high import tariffs on inefficient vehicles and lower tariffs for efficient vehicles and a maximum age of imported vehicles of 5 years. Accompanied by awareness raising, enforcement with penalties. An awareness raising campaign will support behavioural change and promote the benefits of this approach as well as raise awareness on enforcement and penalties. Capacity measures will need to involve a broad range of stakeholders. General awareness raising to the public in the short and medium-term to provide everyone with good access to information, particularly on enforcement and penalties. There will also need to be short courses for government officials, technicians and mechanics, customs officers, transport civil servants, owners of large commercial fleets and other private sector professionals. These capacity building measures will need to continue periodically for the medium-term to embed the change in behaviour. Strict enforcement of vehicle emission and roadworthiness testing. Setting up of central facility for vehicle disposal of old and inefficient vehicles. Mandating provision of employees commuting buses for commercial enterprises larger than a threshold size. Limiting the number of car parking spaces available in public and commercial areas of cities for single-occupancy cars, and freezing all efforts to increase these capacities which implicitly and explicitly encourage personal automobile use. Improving the availability and quality of public transport services offers an opportunity to change the trend of rapid vehicle growth and meet increased demands for mobility more sustainably. The suggested improvements in existing public bus operation include route optimisation, more bus stops, GPS systems installation. Additionally, focus should also be on comprehensive route coverage, reducing overcrowding at peak times, improving off peak frequencies, extending service hours in the evening to improve service reliability, and public bus service performance.

2. Non-motorised Transport

Non-motorised transport (NMT) is being pursued as an alternative and sustainable mode of transport in urban and major settlement areas around the world. The benefits of the NMT includes (a) reduction in fuel use and vehicular emissions, (b) reduction in lifestyle diseases, (c) reduce nuisance related to traffic congestion and noise pollution, and (d) lower road maintenance cost, etc.

NMT can be classified as a) footpath (walkway, pavement, pedestrian pathway) and b) bicycling. Also, it is estimated that more than 75% of trips below 3–4 km in Tonga are performed either through walking or other non-motorised options so this is already a widely used transport modality. Given that the travel distances are usually short within cities, NMT is a significant option for reducing fossil fuel use and increasing low or no-emission transportation in urban areas. Common ways to support increased non-motorised transport include the following:

Sub-interventions & their respective measures

2.1 Walkway and bicycling lanes expansion: Currently, Tonga has around 50 kms of footpaths and almost negligible bicycling lanes. Around 15% of the major roads in the Tongatapu have a footpath. However, footpaths in general are not continuous, universally accessible, user friendly, or are often in poor condition. Despite of limited and lack of safe infrastructure for non-motorised transport, most of daily trips are made on foot, which indicates that Tonga has huge potential to promote walking.

Infrastructure-adapting Road layouts & creating safe separation between different modes of transport, adding cycle lanes and infrastructure for parking bikes safely, adding pavements/sidewalks and creating new dedicated paths for cycles and pedestrians. Creating green spaces and pathways which make it pleasant to cycle or walk in pedestrianised or exclusively cycling areas are the measures to promote walking and bicycling.

2.2 Pedestrianisation: At the moment, the development of infrastructures of vehicular movements are prioritised over pedestrians. Therefore, urgent steps are needed to ensure there is more equitable allocation of road space by focusing on walking and cycling in planning, design, construction, and management of transport systems. This action includes the development of an integrated urban planning programme (homes, employment, transport) and pedestrians-only city centre area. Behavioural change and community and individual participation will be important for driving this change. Behavioural change can be kick-started by initiating and sustaining a car free day initiative like Raahgiri day (Appendix E: Case Study on Raahgiri Day-Car free Sunday); with support from a green cities programme and awareness raising campaign on health benefits of cycling and walking, etc.

Globally used technological options for NMT measures are A) Fence, curb ramp, bollard, lighting, street furniture for footpath infrastructure, B) Pelican button, flashing beacon, marking symbol for crosswalk infrastructure, C) Chicane, curb extension, raised crossing, speed treatment as traffic calming elements, D) CCTVs or other surveillance methods in high-risk areas/locations for safety of NMT users.

Key Element	Footpath/bicycling infrastructure	Crosswalk infrastructure	Traffic calming measures
Options	Includes fence, curb ramp, bollard, lighting, street furniture etc. 	Includes pelican button, beacon, marking symbol etc. 	Chicane, curb extension, raised crossing, speed treatment etc. 

2.3 Public Bicycle Sharing: Public Bicycle Sharing (PBS) can play a vital role in promoting bicycling in the country. This concept allows the users to pick up a cycle from any station and return it to any other station, thereby encouraging the use of cycles for short distances, need-based, point-to-point, and one-way trips. It can also serve as an alternative transport mode to address the challenges related to 'last mile' connectivity. PBS has the potential to prove attractive to students as well as tourists.

Similarly, there are several elements involved in entire PBS system which include cycles, docking stations, control stations, redistribution centres, ITS integration, revenue stream, promotional programmes, etc. Out of all elements, cycles and docking stations are the key elements. The technological options that are available for docking stations are a) automatic, b) semi-automatic, and c) manual. Similarly, the technological options available for bicycles are a) geared, b) non-geared, and c) e-Bicycle. For the country like Tonga, which is mostly flat terrain, semi-automatic dock station along with non-geared bicycles is best suited for implementatio.n

Applicability	Introduction of NMT interventions in Tongatapu, as 75% of the population resides in this main island, Tongatapu and Central business districts (CBD) of other major islands. e.g. Nuku'alofa: The traffic has built up over the years in and around Nuku'alofa with the main approach roads to the town centre from the south, Taufa'ahau and Vaha'akolo. Congestion is especially severe in the urban centre particularly around the public market, and elsewhere at peak office and school arrival and departure times. This action focuses on the expansion and creation of new cycling and pedestrian pathways/sidewalks both within and outside CBD of Nuku'alofa have huge potential of modal shift from private vehicles towards walking and cycling.
Status of implementation & target setting	Global benchmark: • Footpath: More than 75% of urban roads should be covered with dedicated footpaths • Bicycle lane: More than 50% of urban roads should be covered with dedicated footpaths • PBS: 10–12 bicycles for every 1,000 population and 1.5 docks per cycle is recommended Baseline: • Footpath: 25% of urban road (50 km) is covered with footpath • Bicycle lane: Absence of bicycle lane • PBS: No PBS system in Tonga Target setting: • Footpath: Annual construction speed of 5 kms/year in short term (2021-2025), 10 kms/year in medium term (2026–2030) and 15 km/year in long term (2031-35) which will results to 200kms (75 % of urban road) covered with footpath by 2035 • Bicycle lane: Annual construction speed of 3 kms/year in short term (2021-2025), 4 kms/year in medium term (2026–2030) and 5 km/year in long term (2031-2035) which will results to 60kms (50 % of urban road) covered with bicycle lane by 2035 • PBS: 2 public bicycles per 1,000 urban population in short term (2021-2025), 5 public bicycles per 1,000 urban population in medium term (2026-2030) and 10 public bicycles per 1,000 urban population in long term (2031–2035)
GHG estimations	(see table below)

Activities	CO_2e mitigated per year per person	Total mitigation (by 2035)
Walkway and bicycling lanes expansion	0.0095 tons CO_2e	8,256 tons CO_2e
Pedestrianisation	0.0073 tons CO_2e	6,116 tons CO_2e
Public Bicycle Sharing	0.012 tons CO_2e	7,367 tons CO_2e

Key enablers	Mere persuasive measures and campaigns to persuade the public to start using non-motorised transport, isn't effective to bring a ural change with respect to opting greener means for mobility. The success of this intervention would depend on the following policy interventions: Walking is becoming a socially and culturally normalised mode of commuter transport and not merely seeing it as a recreational activity which does not mitigate any climate harm from fossil-fuel based personal transport Government and other public officials conspicuously and deliberately walk for short commuting trips including designation of no car days. A direct reduction of motorised vehicles on roads, not just by campaigns but also by implementing actionable measures, to systemically ensure safer streets with a lower average vehicle velocity Gradual phasing out and annual vehicle capping system for import/sales of ICE personal automobiles from 2025 onwards. Limiting the number of car parking spaces available in public and commercial areas of cities and freezing all efforts to increase these capacities which implicitly and explicitly encourage personal automobile use Road reserve or lack thereof needs to be solved so that footpaths and bicycle lanes can be located well so that power poles and telecom poles are not in the way

3. Low–Emission Vehicles

Globally, EVs are being envisaged as a high potential intervention to reduce dependence on fossil fuels and mitigate GHG emissions from the transport sector. Tonga's NDC and LT-LEDS are clear on the need to move away from fossil fuel-based vehicles. The biggest challenge with EVs is that the entire value chain has to be established right from the ground-zero level. This task is more difficult for island countries like Tonga that are dependent on vehicle imports from other countries. The set of challenges include technology cost, technology options, capacity building, infrastructure, financial requirements, etc. Despite these challenges, EVs are identified as one of the key low emission technology approaches to implement the NDC and LT-LEDS. A successful transition to the EV scenario will create greater resilience to fuel supply shocks can contribute to better management of foreign exchange reserves and improve air quality.

Sub-interventions & their respective measures	**Electric Private Passenger Vehicles (2W, 4W, light pick-up truck):** Electric-powered passenger vehicles are less polluting transport alternative and possible intervention to reduce GHG emissions and local air pollution stemming from the anticipated increase in imports and use of fossil-fuel powered passenger vehicles. On a per-passenger-km basis, the climate pollution from a conventional petrol or diesel 4 W in 2035 is estimated to be 141 grams CO_2e/passenger-km. Conversely, the emissions for the same person travelling in an electrically powered 4 W are significantly lower at 52 grams CO_2e/passenger-km, indicating electric powered is 170% more cleaner than ICE. Similarly, conventional Light pick-up trucks emission estimates are 90 grams CO_2e/passenger-km against 13 grams CO_2e/passenger-km in electrically powered and 2 W has 69 grams CO_2e/passenger-km against 16 grams. **Electric Public Transportation (Bus):** Public transport systems, such as a bus, provide a compelling and direct means to drastically reduce GHG emission per passenger transported for the same distance travelled relative to personal transport vehicles. On a per-passenger-km basis, the GHG emission from Four-Wheelers in 2035 is estimated to be 141 grams CO_2e/passenger-km. In contrast, the emissions for the same person travelling in a public electric-powered bus are significantly lower at 29 grams CO_2e/passenger-km. Therefore, in effect, an electric public bus is approximately 7 times more efficient than a petrol- or diesel-powered private car and creates 25% lesser climate and air pollution than ICE bus. **Electric Commercial Taxis (4W):** More than even the reduced GHG emission impact from switching passenger vehicles from fossil power to renewable-electricity powered Electric Vehicles, switching taxis across this same fuel-pair provides considerably greater GHG mitigation opportunities on a per-vehicle basis. This can be attributed to the fact that taxis in Tonga travel approximately 3 times more distance per year relative to private vehicles. Thus, switching one commercial taxi to EV yields approximately 1.27 metric tons CO_2e mitigation per taxi switched and creates 170% lesser climate and air pollution than ICE. **Electric Vehicles in Government fleet (4W):** Electric powered is 170% more cleaner than ICE. Hence, government should set an example by replacing its fleet with electric, so that private should be encouraged. This action would follow-on from the piloting of EVs within the government municipal fleet and would expand adoption of EVs to the public, including different types of light duty EVs (cars, bikes, minivans, etc.). **Electric Freight Vehicle (Medium & Heavy-duty Trucks):** More than even the reduced climate pollution impact from switching taxis or private vehicles to renewable-electricity powered Electric Vehicles, switching heavy and medium commercial trucks provides considerably greater GHG mitigation opportunities on a per-vehicle basis. This can be attributed to the fact that trucks are designed with large engine capacities with low fuel efficiency owing to the need to generate high quantities of horsepower imperative for carrying heavy payloads. Thus, while switching one fossil-powered taxi to EV yields approximately 1.27 metric tons CO_2e mitigation opportunity per year, switching heavy and medium commercial trucks to low-carbon electric power yields a mitigation of 12 metric tons CO_2e per truck switched. Electric Trucks provide a compelling and direct means to drastically reduce climate pollution per ton of freight transported for the same distance travelled relative to fossil-fuel powered trucks. **Maritime Electrification (small vessels used in tourism & fisheries):** Similarly, Maritime electrification has a more powerful impact than any other segment. As switching one fossil-powered Bus or truck to EV yields approximately 8 and 12 metric tons CO_2e mitigation opportunity per year respectively, whereas switching diesel based maritime small vessels to low-carbon electric power yields a mitigation of 45 metric tons CO_2e.

Technology options and feasibility	MOI acknowledges the opportunity in transition to clean transport economy and aspires to make a technology leap and pilot Low-Emission Vehicles (LEVs) in the country. Consequently, a number of studies have been commissioned to understand EV market landscape, charging technology options, and user preferences. The technology options that are recommended for Tonga are: Promote Battery Electric Vehicles (BEVs) over Plug-In Hybrid EVs (PHEVs). BEVs and PHEVs are a viable mitigation alternative to conventional petrol and diesel-powered vehicles because they are more efficient, more environmentally friendly and cost less than conventional vehicles to operate. Although PHEVs are considered more convenient and reliable than BEVs because of the flexibility they provide in allowing users to switch between different types of fuel (i.e. battery vs. petrol/diesel). PHEVs run on petrol/diesel, and therefore, they emit more GHG emissions and air pollutants than BEVs. It is expected that Tonga will follow the best practices adopted in other countries. **Fixed charging technology:** Type 2 (AC) and Combo CCS 2 charging standards can be made mandatory for public charging stations. The other charging standards like CHAdeMO can be kept optional. **Battery swapping (particularly in case of 2W and light vehicles):** should be recognised and appropriate capital subsidies for swapping batteries and bulk chargers extended. **Retrofitting technologies:** Explore pilot opportunities and amend motor rules and regulations to recognise retrofitting technologies.
Applicability	Tongatapu is a very well-suited location for EVs, as it has 70% of Tonga's population, it is flat, only 60km and 30km in each direction. TPL is engaged in the discussion on EVs and PHEVs and has started research to investigate a transition to EVs and what this means for electricity generation.
Status of implementation & target setting	**As-Is:** Hardly any EVs on-road **Target setting:** ~30% of total new vehicle sales to be EV by 2035 • 35% of Private Passenger Vehicles sales to be EVs by 2035 • 30% of Public Transportation (Bus) sales to be EVs by 2035 • 70% of Commercial Taxis (4W) sales to be EVs by 2035 • 100% of Government fleet (4W) to be EVs by 2035. • 5% of Freight Vehicle (Medium & Heavy-duty) sales to be EVs by 2035 • 20% of Maritime Electrification (small vessels used in tourism & fisheries) sales to be EVs by 2035
GHG estimations	(see table below)

GHG estimations

Activities	Emission/pax-km for ICE (gms/Pax-km)	Emission/pax-km for EV (gms/Pax-km)	CO_2e mitigation / pax-km (gms/Pax-km)	Total mitigation (by 2035)
Electric Private Passenger Vehicles	2W: 69	2W:16	2W: 53	129,541 tons CO_2e
	4W Personal:141	4W Personal: 52	4W Personal: 89	
	Truck – Light pick-up: 132	Truck –Light pick-up: 90	Truck – Light pick-up: 42	
Electric Public Transportation	29	19	10	1,704 tons CO_2e
Electric Commercial Taxis (4W)	141	52	89	13,534 tons CO_2e
Electric Vehicles in Government fleet (4W)	141	52	89	9,663 tons CO_2e
Electric Freight Vehicle	342	125	217	8,409 tons CO_2e
Maritime Electrification	385	97	288	2,051 tons CO_2e

Key enablers	The success of this intervention would depend on the following policy interventions:
	• Gradual phasing out ICE personal automobiles from 2025 onwards
	• Implementing annual vehicle capping system for import/sales of personal automobiles (irrespective of power train technology – ICE, EV, etc.) from 2025 onwards
	• Tax and other soft incentives to promote the uptake of electric vehicles. These are:
	  • Import duty and sales tax exemption
	  • Capital subsidy (purchase subsidy)
	  • Vehicle financing up to 70% available with term period of 7 years
	  • Introduction of green number plates for EVs
	  • Free EV charging at public charging stations
	  • Waiving off parking fees (if any)
	Government, in addition to exploring domestic resources should actively seek for bilateral and multilateral support for a range of actions to further encourage uptake of electric vehicles, including funding for subsidies, charging infrastructure, policy support and capacity building including regulatory efforts.
	Piloting of EVs within government municipal fleet and would expand later to the public, including different types of light duty EVs (cars, bikes, trucks, maritime, etc.).
	Capacity building (awareness raising, on-the-job training, short courses, tertiary, and vocational training).
	Provision of dedicated charging points in all new buildings.
	Introduction of national EV regulations and standards to ensure safety and good quality.
	Introduction of regulations and standards for battery management and disposal.
	Creation of no-ICE vehicle traffic zones in the vicinity of schools, hospitals, parks/gardens and other public spaces to protect the wellbeing of citizens through maintaining clean air quality.
	Further, policy measures to encourage small-scale assembly of electric vehicles and energy storage in the country.

Multi-Criteria Analysis (MCA)

The previous section presented numerous opportunities identified for low emission development. The next step is to prioritise those interventions through Multi-Criteria Analysis (MCA) and adopt a sustainable transport development plan for their implementation. Given limited availability of resources, access to technology and implementation capacity; prioritising interventions will help policymakers to make an informed decision for right phase-wise transport development.

MCA Framework

Indicated in Table 16 are different criteria that were used to prioritise 12 sub-activities. After consultations with the stakeholders on development priorities, it was decided that the following Level 1 (L1) evaluation criteria need to be included:

- Scale and scale up potential,
- Costs; Benefits,
- Strategic alignment, and
- Implementation needs.

These were then further broken down into sub-criteria. The full list of sub-criteria is available in Appendix F. Each criterion was given weight for relative importance to consolidate final priority scores for each activity. The weights were estimated based on consultation with transport specialists and interactions with different Tongan stakeholders (see also Appendix F: Stakeholders List for Transportation TERMPLUS Workshop and Appendix G: Weightages and Scoring Criteria for MCA). The activities with the highest scores are identified as the most preferable options. A consolidated MCA across all 29 criteria for 12 identified activities along with details of calculations are provided in Appendix H: Normalised Score for MCA.

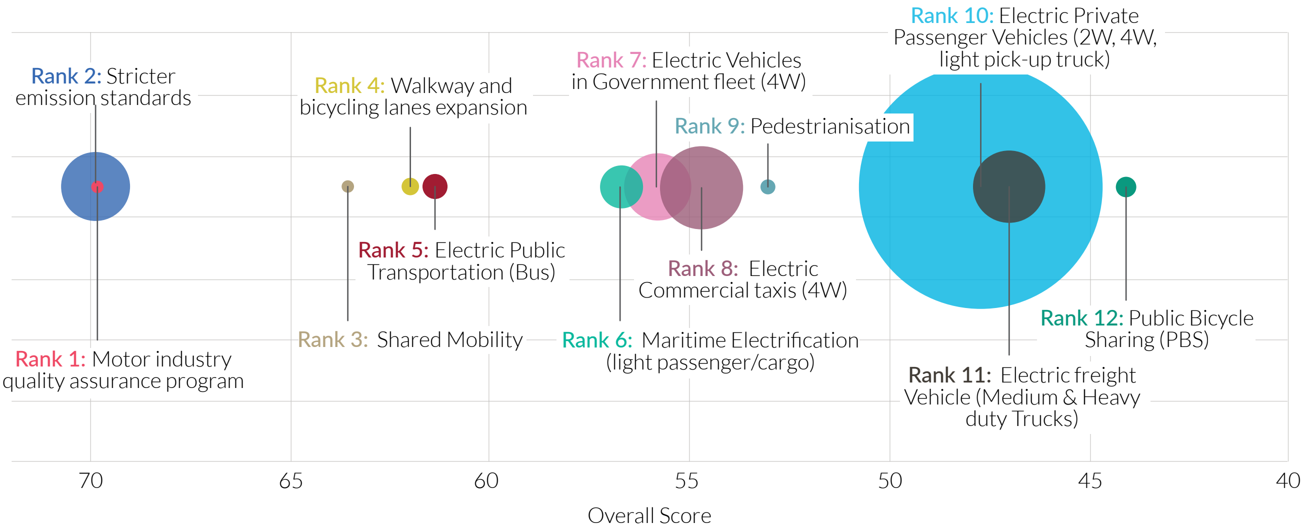
TABLE 16.
Identified criterion to prioritise identified sub-intervention using MCA

Sr	Level 1 (L1)	Level 2 (L2)	Level 3 (L3)	Measurement
1	Scale and scale up potential	Project /system scale	Population served	Whole population (universal), some communities only
2		User impact	User frequency	Daily by users or occasional/ as needed
3		Scale up potential	Domestic Replicability	Replicability in other regions/parts of Tonga
4			International replicability	Replicable in other jurisdictions
5	Cost	CAPEX	CAPEX Investment requirement	Capital Expenditure to government (till 2035)
6			Timing of capital costs	Upfront cost requirement
7		OPEX	OPEX Investment requirement	Operational Expenditure to government (till 2035)
8	Benefits	Economic	Revenue potential	Potential income stream, like user charges and advertising space
9			Cost Savings	Non-fuel cost reductions per year, compared to BAU
10			Fuel cost savings	Fuel costs saved per year, compared to BAU
11		Social	Job creation/ Employment	Number of jobs, welfare impacts on existing jobs
12			Social inclusion	Ease of movement, connection opportunities, accessibility to disabled users
13			Gender Equality	Women's accessibility and welfare impacts
14		Environmental & Climate	Air pollution reduction potential	PM reduction compared to BAU (till 2035)
15			GHG reduction potential	GHG reduction (till 2035)
16	Strategic alignment	Policy alignment	Government's alignment with budget priorities	Alignment with budget priorities or national development priorities
17			Government's alignment with sectoral policies	Alignment with sectoral policies
18			Existing Planning and Feasibility studies	Ability to build on existing /planned feasibility studies
19			Legal framework	Supportive legal framework, including vehicle regulations and standards
20	Implementation needs	Complementary Infrastructure needs	Roads and transport	Investment or action required
21			Energy	Investment or action required
22		Local industry capability	Capacity of local skills to support	Skills needs and their local availability
23			Local availability of equipment	Availability of existing infrastructure
24			Local post sales services & spare parts availability	Existing local ecosystem availability for Repair & Maintenance
25		Local population support needed	People/citizen behavioural change	Degree of behaviour change required

Sr	Level 1 (L1)	Level 2 (L2)	Level 3 (L3)	Measurement
26		Implementation funding	Ownership structure identified	Ownership or corporate structure identified
27			Domestic funding sources	Funding available or committed by government or private sector
28			International funding sources	Funding source/s identified, including donor and private sector
29		Implementation Management	Planning and Execution Capacity	Available R&D, Planning, and execution capacity

The final ranking of identified interventions along with their relative estimated GHG mitigation potential (as size of bubble) is shown in Figure 24.The results show highest priority for motor industry quality assurance programme and stricter emission standards and lowest priority for public bicycle sharing.

FIGURE 24.
Results of MCA across identified interventions



Note: Bubble size represents GHG mitigation potential

4.4 REQUIREMENTS AND ENABLING ENVIRONMENT

Investment Requirements

The growing economy, increasing purchasing power, and high rate of urbanisation has fuelled the demand for innovative mobility solutions and infrastructure requirement in Tonga. Generally, these projects are capital intensive in nature and are dependent on project financing from various sources. Policy support, project attractiveness and long-term viability are critical aspects to attract private investments. Therefore, it is recommended to undertake detailed feasibility study and prepare action plans to identify the most suitable sources of financing options. Some of the options are discussed below in detail:

- **Private Investment Option:** Among the key organisational outcomes sought in the TSDF 2015-2025 are closer and more effective public/private partnerships, and a strengthened enabling environment for business. According to the IMF notes, growing Tonga's private sector is the reform needed to unlock private sector potential and that the most durable solution to addressing Tonga's fiscal development and growth challenges. The Ministry of Public Enterprises (MPE) is developing a policy framework for public/private partnership (PPP). It may mean for the government to encourage private investors to undertake or fund the projects on PPP model. The project capital and operational expenditure is managed by the private investor and investments are recovered through right to revenue stream (e.g. user charges) or annuity payments by the government as per agreed performance milestones.

- **Public Finance Option:** The reality for financing opportunities is that reliance on grants from Development Partners will continue, and this reliance will most likely increase as a result of the economic consequences of the pandemic, recent volcanic eruption and the increasing risks associated with extreme weather events. It is therefore anticipated that the most viable financing option will be sourced through grants from development partners and high concessional international financing funding mechanisms. Having said this, contributions can be expected from:

  Government, which funds some capital expenditure each year and could direct a portion of this to transport infrastructure investment. For this to happen, there needs to be some improvement in the Government's fiscal position and the current restrictive policy in relation to external borrowing, which is likely to continue in place for some time. The planned Road Maintenance fund under the new Roads Act 2020 will provide a dedicated funding stream for road maintenance.

  This option is more suitable for those projects which may be commercially not viable and difficult to attract private investments. For example, providing subsidies to fund electric vehicle programmes. In such projects, direct investment is made by the government. If programme budget is higher and public finances are limited, the government may explore funds from different channels as summarised in Table 17.

TABLE 17.
Sources of funds and instruments available for financing transport intervention

Source of funds	Details
Development assistance and financial institutions	Government may explore grants or loans provided on concessional rates by: • Multilateral agencies • Financial institution • Commercial bank
Bond market	Issuance of Bonds
Internally generated fund (user charges, taxation, etc.)	To enhance public finance to fund transport related projects, the government can also consider increasing user charges such as tax on sale of vehicles, tax on fuel sales, parking charges, etc.

Conclusion

Two major sources of financing options have been discussed above. However, there are international funds available for public and private financing to support projects that enhance sustainable transport development. Table 18 outlines potential sources of climate finance that could potentially be used by Tonga.

TABLE 18.
Climate Finance Options[86]

	Nature of support			Type of intervention supported					Transport modes supported		
	Grants	Loans	Technical	Concepts and Plans	Infrastructure	Operations and Management	Technology Transfer	Capacity Building	Road	Urban public transport	Non-motorised transport
Global Environment Facility (GEF)	■	-	■	■	■	■	■	■	■	■	■
Clean Technology Fund (CTF)	■	■	-	■	■	■	■	■	■	■	■
Global Climate Change Alliance (GCCA)	■	-	■	■	Not applicable			■	■	■	■
IDB Sustainable Energy and Climate Change Initiative	■	■	■	■	■	■	■	■	■	■	-
ADB Climate Change Fund	■	-	■	-	■	-	■	■	■	■	■
ADB Clean Energy Fund	■	-	■	-	-	-	-	■	■	■	■
Clean Development Mechanism (UNFCCC)	■	-	■		■	■	■	-	-	■	■
Nationally Appropriate Mitigation Action (NAMA) Facility	■	■	-	-	■	-	-	■	■	■	■
Green Climate Fund (GCF)	■	■	■	-	■	-	■	■	■	■	■
European Bank for Reconstruction and Development (EBRD)	■	-	-	-	-	-	-	-	■	■	■
European Investment Bank (EIB)	■	-	-	-	-	-	-	-	■	■	■
World Bank Group (WGB)	■	■	■	-	■	-	■	-	■	■	■
ADB Renewable Energy, Energy Efficiency, and Climate Change (REACH)	■	-	■	-	-	-	-	■	■	■	■

Institutional Requirements

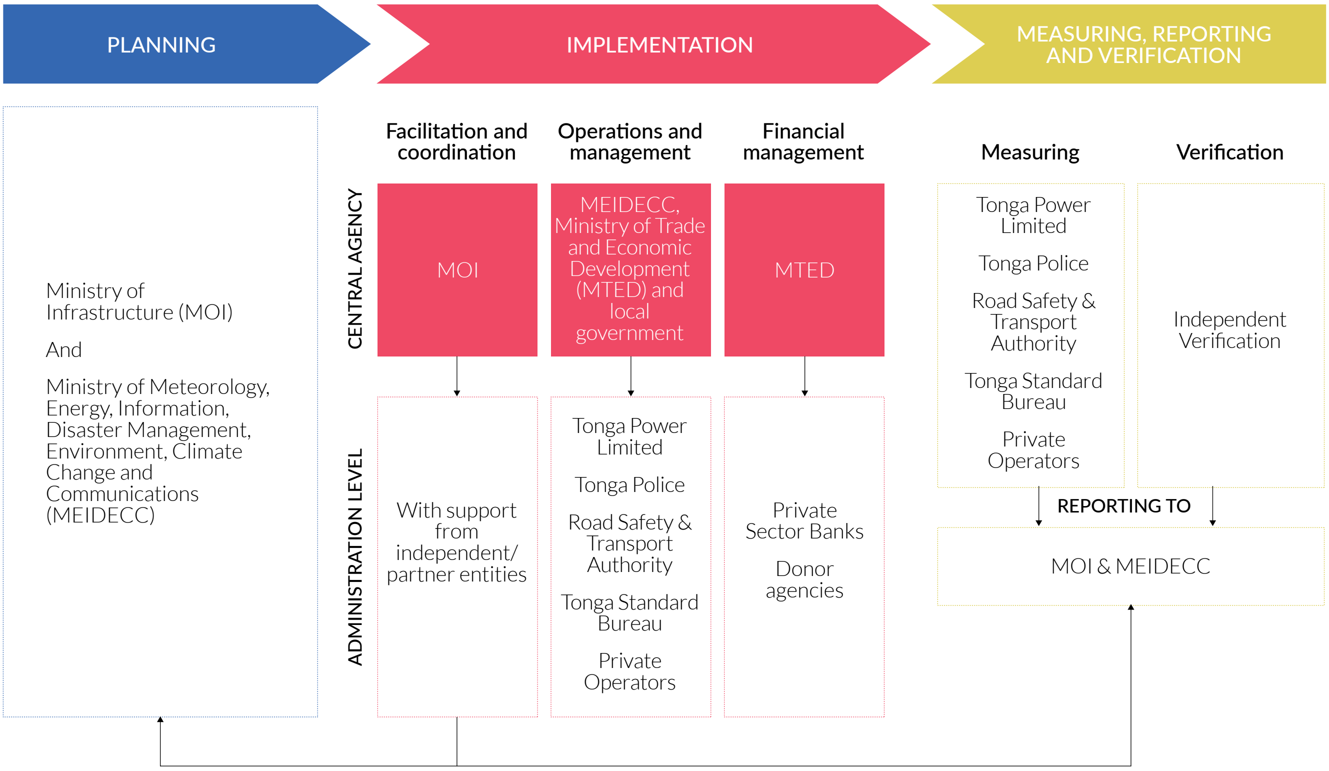
All the required steps in implementation of interventions have been grouped into three categories, namely a) Policy and Planning Regulation, b) Execution, and c) Monitoring and Evaluation.

1. **Policy and Planning Regulation** includes initial decision making on targets, ensuring broader policy support for intervention, technical planning, and identification of finance sourcing.
2. **Execution** deals with ground level execution of the suggested intervention, including setup and O&M.
3. The final step in implementation is **Monitoring & Evaluation,** which also includes reporting the progress and quality of implementation of intervention to review against original set targets and timelines. Monitoring and Evaluation is exhibited at various levels going from the bottom-to-top.

Figure 25 outlines a broad structure for the institutional arrangements that are necessary to support implementation of the Transport Intervention. This structure would in principle be suitable for any or all the proposed interventions.

[86] This is an indicative list from secondary research and was updated based on stakeholder consultation.

FIGURE 25.
Proposed institutional structure for the implementation of Transport Intervention



Policy & Regulations

This section outlines a range of direct actions that can be undertaken for the transport sector. It is based on a series of collaborative actions following consultations among different stakeholders to deliver integrated transport outcomes. It has been observed from the global experience that adoption of a single policy, strategy, or plan will not create the desired impact; the benefits accruing from it would be diffused by the complexities and inefficiencies in the system. Therefore, a multi-pronged approach is required, combining several measures, and only then would it be possible to provide an effective transport system. The following actions and related policies have been grouped by the intervention which they primarily relate to:

a. **Improving Intake Quality of Vehicle; Fuel efficiency; End-of-life**

i. **Motor industry quality assurance programme**

- Inspection equipment and building or specific areas for tests and inspections for imported vehicles.
- Bans on certain types of vehicles, regulations on imported vehicles to meet QA norms.

ii. **Stricter emission standards for new/existing vehicles & fuel**

- Enforce and monitor vehicle emissions standards.
- High import tariffs on inefficient vehicles and lower tariffs for efficient vehicles.
- Limit age of imported vehicles.
- Annual vehicle capping system, Gradual phase out of ICE vehicles, odd/even etc. has huge GHG mitigation potential but its success depends on complimentary policy/economic support from relevant government/ public institutions to provide alternatives for low-carbon transport, public transport, etc.

iii. **Shared Mobility**

- Define shared mobility policy/guidelines. Review and revise guidelines periodically to accommodate new business model and support ecosystem. Provide and increase access to different public shared mobility solutions.
- Support pilots to validate new technology. Evaluate performance and its impacts.

- Work with the taxi industry, mobility groups and other stakeholders to review the locations and availability of taxi parking zones and to understand better the role that taxis play in major island of Tonga.
- Make the transport data publicly available on an open data basis to encourage research, innovation and applications (apps) in its use and interpretation.
- Establish and enforce carpool lanes along major highways and main city streets.
- Limit the number of car parking spaces available in public and commercial areas of cities for single-occupancy cars.

b. Non-Motorised Transport

- Close coordination between Road transport authority and local government to provide easy pedestrian access to all public transport stops, stations, and interchanges.
- Develop a pedestrian and bicycle master plan. Both pedestrian and cycling tracks to be planned as an independent/dedicated network.
- Government and other public officials, conspicuously using e-bicycle for short commuting trips.
- Corporate bike programme – bike to work can be encouraged to incentivise use of NMT.

c. Low-emission vehicles

- Advocate regulatory/legislative and policy changes to support new transport technology.
- Support electric vehicles by allocating an annual budget for EVs. This budget to be utilised to support purchase incentives, installation of charging infrastructure and public awareness campaigns.
- Prioritise the transition of commercial (passenger and freight) vehicles to low-emissions technology in close consultation with taxi, bus and freight operators.

4.5 TRANSPORTATION ROADMAP

The overall targets for each intervention are sub-divided into short-, medium-, and long-term targets as shown in table below:

Interventions/ Policy Alignment	Short-Term Target 2025	Medium-Term Target 2030	Long-Term Target 2035	Key Stakeholders
Motor industry quality assurance programme establishment	Increase in fuel efficiency over years by 0.8%	Increase in fuel efficiency over years by 1.4%	Increase in fuel efficiency over years by 2.4%	Sector Lead: MOI Partners: MEIDECC Finance: GoT
Stricter emission standards for new/ existing vehicles & fuel	Implement **Euro IV**	Enforce **Euro IV**	Implement **Euro V** and Enforce	Sector Lead: MOI Partners: MEIDECC Finance: GoT
Shared Mobility Policy: TEEMP	Improve vehicle occupancy in 4W Taxi and 3W by **0.5%**	Improve vehicle occupancy in 4W Taxi and 3W by **1%**	Improve vehicle occupancy in 4W Taxi and 3W by **1.5%**	Sector Lead: MOI Partners: MEIDECC Finance: GoT
Walkway and bicycling lanes expansion Policy: TEEMP	**4 km/year and 3 km/year** construction speed of walkway and bicycle lane Footpath: 75 km Bicycle Lane: 15 km	**10 km/year and 4 km/year** construction speed of walkway and bicycle lane Footpath: 125 km Bicycle Lane: 35 km	**15 km/year and 5 km/year** construction speed of walkway and bicycle lane Footpath: 200 km by 2035 Bicycle Lane: 60 km by 2035	Sector Lead: MOI, MoT Partners: MEIDECC Finance: GoT
Pedestrianisation Policy: TEEMP	**5 km/year** construction speed of pedestrianised street Pedestrianised street-**25 km**	**10 km/year** construction speed of pedestrianised street Pedestrianised street-**75 km**	**15 km/year** construction speed of pedestrianised street Pedestrianised street-**150 km**	Sector Lead: MOI, MoT Partners: MEIDECC Finance: GoT
Public Bicycle Sharing (PBS) Policy: TEEMP	**2 Public bicycle** per 1,000 urban population Public Bicycle (Nos) **50**	**5 Public bicycle** per 1,000 urban population Public Bicycle (Nos) **150**	**10 Public bicycle** per 1,000 urban population Public Bicycle (Nos) **350**	Sector Lead: MOI, MoT Partners: MEIDECC Finance: GoT
Electric Private Passenger Vehicles (2W, 4W, light pick-up truck)	**10%** of private passenger vehicles imports to be EVs	**25%** of private passenger vehicles imports to be EVs	**35%** of private passenger vehicles imports to be EVs	Sector Lead: MOI, MEIDECC-DoE Partners: MOI Finance: Private Partners
Electric Public Transportation (Bus)	**10%** of public transportation imports to be EVs, Build a strategic parking lot and bus stop at intersection of Taufa'ahau and Loto Roads	**20%** of public transportation imports to be EVs	**30%** of public transportation imports to be EVs	Sector Lead: MOI, MEIDECC-DoE, Chamber of Commerce, Tonga Bus Association Partners: Private Partners Finance: Private/ Development Partners

Interventions/ Policy Alignment	Short–Term Target 2025	Medium–Term Target 2030	Long–Term Target 2035	Key Stakeholders
Electric Commercial Taxis (4W)	20% of commercial taxis imports to be EVs	50% of commercial taxis imports to be EVs	70% of commercial taxis imports to be EVs	Sector Lead: MOI, MEIDECC-DoE Partners: Chamber of Commerce Finance: Private/ Development Partners
Electrification of Transportation (EoT) Road Map	• Identify gaps in policy and standards • Identify TPL - EV Charging Backbone for DSM • Assess technologies of appropriate e-mobility solutions • Economic analysis of necessary charging infrastructure • Analysis of the impact on electricity grid of LDV uptake of 30–35% LDVs by 2030–2035 • Start implementation of EoT roadmap strategies • Incentivize charging behaviour through electricity tariffs that supports Tonga's goal of 70% RE	Identify TPL - EV Charging Station Network Backbone for demand-side-management (DSM). Incentivise charging behaviour through electricity tariffs that supports Tonga's goal of 70-100% RE	Incentivise charging behaviour through electricity tariffs and DSM programs that supports Tonga's goal of 100% RE	Sector Lead: MOI, MEIDECC-DoE, TPL Partners: Electricity Commission, MFNP Finance: PCREEE, NREL, GGGI, Development Partners
Electric Vehicles in Government fleet (4W)	20% of government fleet imports to be EVs	50% of government fleet imports to be EVs	100% of government fleet imports to be EVs	Sector Lead: MOI, MEIDECC-DoE Partners: MFNP Finance: PCREEE, Development Partners
Electric Freight Vehicle (Medium & Heavy-duty Trucks)	0% of freight vehicle imports to be EVs	3% of freight vehicle imports to be EVs	5% of freight vehicle imports to be EVs	Sector Lead: MOI, MEIDECC-DoE Partners: MOI Finance: Development Partners
Maritime Electrification (light passenger/cargo)	3% of maritime imports to be EVs	10% of maritime imports to be EVs	20% of maritime imports to be EVs	Sector Lead: MOI Partners: MEIDECC-DoE Finance: Development Partners
EV Charger Network	EV Chargers Installed at Government Buildings	EV Charger Network across Tongatapu, EV Charger Strategic Locations for Vava`u and Ha`apai	EV Chargers for Outer Islands	Sector Lead: MEIDECC-DoE, TPL Partners: PCREEE, GGGI Finance: Development Partners

Interventions/ Policy Alignment	Short-Term Target 2025	Medium Term Target 2030	Long Term Target 2035	Key Stakeholders
Pilot Government Ministries EV Project	3–5 EVs w/ Chargers	15–25 EVs w/ Chargers	50–100 EVs w/ Chargers	Sector Lead: MEIDECC-DoE, MOI Partners: PCREEE, GGGI Finance: PCREEE, GGGI
Solar Tuk Tuk Policy: TEEMP	Tongatapu	Vava`u, Ha`apai, `Eua	Outer Islands	Sector Lead: MEIDECC-DoE Partners: MOI Finance: Germany - Private Partner
Tonga Government Declaration on Electrification of Transportation Goals by 2030 and 2035	Tongatapu	Vava`u, Ha`apai, `Eua	Outer Islands	Sector Lead: PMO Partners: MOI, MEIDECC-DoE, TPL Finance: Development Partners
Adopt appropriate fiscal and financial incentives to promote HEVs, EVs and fuel economic vehicles, tuks-tuks, etc. Policy: TEEMP	Tongatapu	Vava`u, Ha`apai, `Eua	Outer Islands	Sector Lead: MFNP, MOI, MEIDECC-DoE Partners: TPL Finance: Development Partners

5 ENERGY SECURITY AND RESILIENCE

Energy security and resiliency can be implemented in Tongatapu in-parallel with other populated islands with each proposed and developed project. Three areas are examined regarding energy security and resiliency: 1) oil supply; 2) electricity system and 3) transportation.

Energy security—understood as the energy system's capability to ensure uninterrupted availability of fuel by withstanding and recovering from disturbances and contingencies—is an important consideration for Tonga. Concerns about energy security will continue to involve two aspects. First, the uninterrupted external supply of fossil fuels—in particular oil products—will remain critical for the period covered by the TERMPLUS, despite the target to reduce the importance of oil products in Tonga's total primary energy supply. Second, the need to maintain reliable generation, transmission, and distribution of electricity will become more challenging given the aim to expand the share of electricity in primary energy supply while increasing reliance on variable sources. Compounding these two aspects will be the effects of climate change which are expected to become increasingly severe in terms of their impact on Tonga.

5.1 OIL SUPPLY SECURITY

Oil products are going to continue to play a dominant role for security of supply as they are going to continue to account for a large share of Tonga's total primary energy supply for the period covered by the TERMPLUS. While the share of oil in total primary energy supply will diminish, the importance of ensuring adequate supply, oil will remain, since the impact of a sudden shortfall in supply will continue to have severe repercussions. Therefore, strengthening oil supply security is not regarded as contradictory to the GoT's long-term ambition to reduce the role of fossil fuels and to lower greenhouse emissions. Instead, it is regarded as a complementary measure, making the unavoidable supply of fossil fuels more resilient to physical disruptions.

In order to strengthen oil supply security, the TERMPLUS identifies two measures:

1. Expansion of existing storage facilities for motor gasoline and diesel stocks to holding volumes equivalent to 45 days of net imports
2. Establishment of direct shipments of oil products from Singapore.

These measures sharpen the GoT's view on energy security, with a focus of preventing physical supply disruptions and moving away from earlier endeavours to hedge against oil price fluctuations.

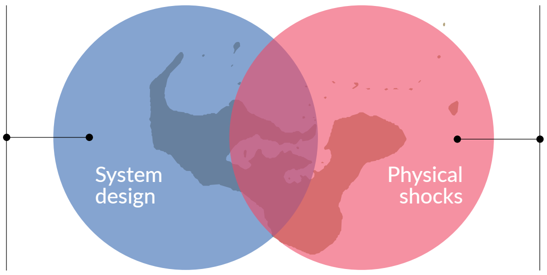
5.2 ELECTRICITY SECURITY

The increasing share of electricity in total final consumption puts the generation, transmission, and distribution even more at the heart of energy security than it already is. Increased reliance on electricity in combination with a higher share of electricity being generated from variable renewables has both positive and negative implications for energy security. A higher share of electricity generated from domestic sources will reduce Tonga's dependence on fossil fuel imports and the kingdom's exposure to supply disruptions. However, the increased importance of electricity also means that any disruption of the electricity system will have larger impacts. For example, electricity infrastructure is often more vulnerable to physical shocks, such as extreme weather events, than infrastructure associated with oil products, such as oil terminals, petrol stations, and diesel generators. At the same time, a higher share of variable renewables makes the electricity system more prone to fluctuations in output, requiring increased system flexibility, backups, and redundancies.

To maintain electricity security, the risk of system failure will need be mitigated. This involves ensuring adequacy and operational security. For the purpose of the TERMPLUS, adequacy refers to the medium- to long-term ability of the electricity system to meet the aggregate electricity demand within its area at all times under normal operating conditions. The definition of what qualifies as 'normal conditions' is crucial to determining system design and make long-term investment decisions. Operational security refers to the short-term ability of the electricity system to maintain system stability and avoid electrical outages, in the event of any disturbance, independent of whether this disturbance is the result of the system design itself or any external shock (Figure 26).

FIGURE 26.
Conceptual breakdown of electricity security

Increasing share of variable renewable
Need for increased flexibility
Higher uncertainty of output
Loss of inertia
Legal arrangements with independent power producers
Decentralised generation



Hazardous events related to climate change or extreme weather conditions
Increase in temperature
Rise in sea level
Changes in precipitation
Extreme weather events (cyclones)

Source: GGGI 2021

The operation of the electricity system involves a diverse set of actors. To maintain electricity security, clear roles need to be assigned and co-ordination among participants is required:

1. Government: Legislators put in the place the basic principles of electricity security, define the necessary parameters by law, and assign responsibilities to regulators, system operators and industry. The executive implements the policy within the boundaries set by the legislation and exercises oversight over the electricity sector.
2. Regulator: While government sets the policy for ensuring electricity security, the task of developing standards and enforcing them is delegated to the regulator. In this capacity, the regulatory authority is tasked with reviewing resource adequacy, adjusting market design, and setting standards and operational requirements to meet security parameters.
3. Tonga Power Limited: The utility is responsible for ensuring sufficient electricity supply to meet load. As such, TPL fulfils the role of transmission and distribution system operator. TPL maintains its own generation infrastructure or can purchase electricity through contracts with other suppliers. Given its role, TPL is in a privileged position to undertake regular system-wide analyses to identify risks, respond to outages and record the lessons learned, and identify changes in market design and specifications to improve reliability. This will require close coordination between the utility and the regulator, as any such changes typically need to be proposed to the regulator and require approval before implementation.
4. Independent power producers (IPP): Generation assets under the control of IPPs will play an increasingly important role in Tonga's electricity

system. As a result, they will be essential to support adequacy and operational security. Their timely response to the system operator's instructions will be required to maintain secure operation. This includes responding to calls to ramp up or down generation to meet load needs, offering ancillary services or taking responsibility themselves for adhering to a projected infeed profile.

5. Consumers: Historically, load was regarded as inflexible and seen as a passive element in electricity systems. In modern systems, end users can shape the load profile and adjust consumption, if provided with suitable incentives. Distributed generation—such as distributed solar PV—can blur the line between consumer and generation. Embedded generation is not an entirely new trend, as many facilities have had emergency generators for decades, which can support reliability of the individual facility and also the resilience of the wider system. However, the variable nature of solar systems adds to the complexity of balancing the network. Other developments, such as behind-the-meter storage and electric vehicle charging, can make consumption patterns less passive than in the past.

System design

The lower share of dispatchable electricity generation from diesel (replaced by variable electricity) and the increase in electricity consumption (despite energy efficiency measures) poses a large array of new challenges for maintaining system stability (Table 19):

- There is a need for increase in flexibility, including storage, dispatchable electricity generation from renewable sources, expansion of transmission and distribution networks, technologies for fast frequency response, demand side responses enabled by digitalisation. The effectiveness of different options to increase flexibility varies according to the time intervals that they are needed for ranging from short-term (seconds to hours) to medium- and long term (days to seasons and years).
- The higher share of variable sources increases uncertainty of electricity generation, requiring more elaborate forecasting of output from these sources, with the help of more accurate meteorological forecasts for short-term projections (hours to days) and using probabilistic analysis for medium- to long-term projections (weeks to years).
- Wind and solar are non-synchronous generators and do not provide inertia in the system, making it necessary to add rotating elements to create the inertia formerly provided by diesel generators.
- IPPs operating in the electricity market will require careful assessment of and legally binding arrangements concerning curtailment of generation in times of oversupply or emergency situations.
- The challenge for real-time system balancing would increase further if electricity generation were to become more decentralised in the future, such as a considerable number of distributed solar PV systems being connected to the larger networks in Tonga. During periods with strong solar irradiation, distributed solar PV could provide a large share of electricity generated and its responses during stress situations would affect the entire system. While distributed wind and solar PV can improve electricity security by mitigating risks arising from physical supply disruptions and have the potential to facilitate recovery from large-scale blackouts during the restoration process, they also require a considerably more flexible network than the current centralised electricity generation from diesel.
- If a considerable share of the vehicle fleet becomes electric, this will increase electricity consumption. Depending on behavioural choices, peak consumption could increase considerably.

TABLE 19.
Anticipated impacts of changes in system design on electricity security

	Generation	Transmission and distribution	Consumption
Higher share of variable renewables	• Increase in flexibility • More elaborate forecasting • Compensation for lost inertia from diesel generators	• Expansion of distribution network • Options to quickly respond to frequency fluctuations	• More flexible tariff system to incentivise demand responses
Entry of independent power producers	• Curtailment of generation in times of oversupply and emergencies	• No overall impact expected; specific T&D needs will be project dependent	• No impact expected
Decentralisation	• Increase in flexibility • More elaborate forecasting • Curtailment of generation in times of oversupply	• Expansion of distribution network • Options to quickly respond to frequency fluctuations	• Less clear distinction between producers and consumers of electricity

Source: GGGI 2021

5.3 RESILIENCE

Tonga has ranked second and third place on the World Risk Report since its first publication in 2011. Tonga has seen increase in tropical cyclones in the past 30 years and it is increasing not only in numbers but in force. The Intergovernmental Panel for Climate Change (IPCC) latest assessment clearly indicates that SIDS like Tonga will be severely impacted by climate change, including but not limited to sea level rise, coastal inundation and severe weather. Tongatapu has seen many tropical cyclones but has not seen the likes of a major category 5 since TC Isaac in 1982 until TC Ian in 2014, TC Gita in 2018 and then again with TC Harold (2020) showing how severity of cyclones has intensified.[87]

Recently in January 2022 the Hunga Tonga Hunga Ha'apai (HTHH) volcanic eruption and resulting tsunamis took away four (4) lives, damaged infrastructure, agriculture, destroyed homes and properties, and displaced residents primarily in Tongatapu, 'Eua, and Ha'apai. The severity and unexpectedness of the event, the scale of the damage and the emotional toll, provided an opportunity for families and communities to unite in solidarity to restore Tonga to a more resilient community.

The GoT collaborated with development partners to produce the Hunga-Tonga-Hunga-Ha'apai Volcanic Eruption and Tonga Tsunami (HTHH Disaster) Recovery and Resilience Building Plan 2022-2025. This Plan's vision is to 'Recovery with Greater Resilience'. Its goal focuses on providing long-term recovery and reconstruction assistance that is fully inclusive, sustainable, and contributes to disaster risk reduction. The 'Recovery and Resilience Building Plan' currently reports a needed investment of TOP $55 million for the essential services of renewable energy, water, generators and power networks.[88]

While renewable electricity and its efficient distribution are very important goals for Tonga's energy systems, resilient development has become equally important. It has been strategic from an energy security and overall economic perspective to have the main island of Tongatapu as a resilient electricity network with capabilities to recover quickly after natural disasters. For the future safety, health and welfare of Tongan people in the entire island chain of Tonga, it is important to make sure with each infrastructure project that Tongatapu and all inhabited islands are made even more resilient to respond effectively to an entire island-nation with dispersed population. Importantly, Tongatapu should continue as the primary Disaster Management hub for the entire country of Tonga and its energy systems resiliency to climate change and disasters should be a priority.

Physical shocks

Electricity infrastructure is often more vulnerable to external physical shocks than infrastructure associated with oil products, such as oil terminals, petrol stations, and diesel generators. The increasing share of electricity in total final consumption makes strengthening the resilience of the power

87 [1] Source: https://www.gov.to/press-release/resilience-building-in-tonga-transitional-hybrid-fale/ 23 October 2020. TC Ian 2014 was also category 5 and affected the Ha'apai islands tremendously (TPL, 2021).
88 Hunga-Tonga-Hunga-Ha'apai Volcanic Eruption and Tonga Tsunami (HTHH Disaster) Recovery and Building Back Better Plan, 2022–2025.

system even more pertinent than it has been in the past. In this context, resilience refers to the ability to anticipate, absorb, accommodate, and recover from the effects of a potentially hazardous event related to climate change, natural disaster or extreme weather conditions. For the TERMPLUS, resilience is assessed considering the electricity sector's exposure, sensitivity, and adaptive capacity to climate change, natural disaster and extreme weather events (Appendix I).

First, Tonga's electricity sector is exposed to a range of physical shocks that can affect the generation, transmission, and distribution of electricity. In the context of the TERMPLUS, physical shocks refer to long-term effects related to climate change—i.e. rise in temperature, rise in sea level, ocean acidification, and changes in precipitation patterns—and to short-term extreme weather and natural disaster events (independent of whether these events are the result of climate change, such as alterations to the intensity or frequency of tropical cyclones and droughts).

Among the long-term trends, there is clear evidence for a rise in temperature, a rise in sea level, and an increase in ocean acidity as the result of climate change. Of these three trends, only rise in temperature and rise in sea level are considered to have an impact on Tonga's electricity system. There is considerable uncertainty if and to what extent precipitation patterns might change in the future. If changes in precipitation patterns were to occur, long-term alterations are considered to have less of an impact than extreme rainfall or drought events.

Short-term extreme weather events include tropical cyclones, which are accompanied by intense winds and heavy rain, as well as the occurrence of droughts. It is uncertain if and what extent the frequency and intensity of both kinds of events might be altered by climate change. However, independent of whether these events are subject to climate change, Tonga's electricity system is particularly exposed to tropical cyclones, while it is considered to be less susceptive to droughts.

Second, the extent to which Tonga's electricity infrastructure is sensitive to these different trends and events differs (Table 20).

1. Increase in temperature: A long-term increase in temperature might lead to higher electricity consumption due to increased use of air conditioning. Higher temperatures might also have an impact on biomass and liquid biofuel production. The potential impact on current biomass supply—mainly for cooking—is uncertain. Any future impact is highly dependent on the specific fuel used, for example, if liquid biofuels were produced in Tonga. Finally, higher temperatures might reduce electricity generation efficiency and increase line losses, though these are likely marginal effects.
2. Rise in sea level: A long-term increase in sea level might be a threat to assets located in low-lying areas that are prone to inundation.
3. Changes in precipitation patterns: It is highly uncertain if and to what extent rainfall patterns will change in Tonga as a result of climate change. If climate change was to increase cloud cover, electricity generation from solar PV would likely be affected. This could severely affect the electricity system, given the anticipated prominence of solar PV in power generation. Conversely, any future reduction in cloud cover might have a positive effect on electricity generation from solar PV.
4. Globally, extreme weather events such as heatwaves, wildfires, cyclones, and floods are prominent causes of large-scale electricity outages. In Tonga, the electricity system is regarded as particularly sensitive to the impact of tropical cyclones, with above-ground transmission and distribution lines being particularly susceptible to high winds and heavy rainfall.

TABLE 20.
Anticipated impacts of physical shocks on electricity security

	Generation	Transmission and distribution	Consumption
Increase in temperature	No impact expected on current or future generation mix	Low impact on efficiency	Moderate increase in consumption
Rise in sea level	Physical risk to assets in low-lying locations	Physical risk to assets in low-lying locations	No impact expected
Changes in precipitation patterns	Potential impact on output from solar PV	No impact expected	No impact expected
Occurrence of extreme weather and natural disaster events	Physical risks to all generation assets	Physical risk to above-ground lines	No impact expected

Source: GGGI 2021

Third, adaptation refers to the ability of Tonga's electricity infrastructure to cope with the adverse impacts of climate change and extreme weather events. Adapting infrastructure to the adverse impacts of climate change and extreme weather events can follow two broad approaches:

- Infrastructure can be hardened with the aim to withstand potential physical shocks. Examples include locating new generation and distribution infrastructure outside areas subject to future sea-level rise or flooding; building sea walls to protect assets; and changing from above-ground distribution lines to underground cables, which are less vulnerable to cyclones. While such changes often require a higher upfront investment, they can considerably reduce potential damage and reduce recovery costs.
- Infrastructure can be made more flexible by including redundancies and backups that are used in case a certain element within the system is compromised. This includes expanding the transmission and distribution system, keeping backup generation capacity and storage available, geographically distributing generation assets and installing microgrids with onsite renewable energy technologies in strategic locations. It can also include preparations for quickly repairing expected damages, by having in place the necessary spare parts and contingency plans.

It is important to note that diesel generation will still be needed for contingency planning to provide the immediate future-needs of the TPL grids. Therefore, diesel generation investments will need to continue in the next 5 to 10 years for the Tongatapu, 'Eua, Vava`u, Ha`apai Grids. This is especially important with the future promise of a biodiesel 'drop-in' fuel for both power generation and transport. With load growth estimated to increase 50% from 2020 to 2030, modelling will be required to determine just how much and where diesel generation is needed, especially in the outer islands where the maintenance and dispatchability of the renewable generation will not be as robust.

Another element of improving resilience, particularly in the outer islands, is to improve maintenance of diesel generators. To date there have been challenges integrating renewables with the current generators and controllers which are older. Therefore, as well as strengthened maintenance regimes, some diesel generators will need to be replaced with newer models which integrate technologies needed for integration with renewables, especially at higher penetration of renewables on the small outer island grids. This will include increasing BESS in stages on the outer islands.

In terms of resilience, especially during disaster response, it would be worthwhile exploring a diesel generation replacement strategy. Development partners can the necessary transition in this area, especially if biodiesel becomes more viable. However, despite the considerable cost of maintaining the diesel fleet, it could have a very real benefit to the resilience of the electricity supply in Tonga.

Transportation Resiliency

Transportation Resiliency is just beginning to be discussed in Tonga's energy planning. Among the key interventions that have been discussed in '4. Transportation' and immediately increase resiliency for Tonga include:

- Electrification of transportation including new EVs, e-Buses, and e-bikes;
- Fuel diversification through renewable electricity, biofuels and renewable gas (from waste treatment, landfills, and agricultural waste);
- Newly designed alternate road infrastructure such as the bridge planned for the northern side of the Laguna;
- A water transport system for the Laguna that can be used when roadways are unpassable.

5.4 REQUIREMENTS AND ENABLING ENVIRONMENT

Energy Security and Resilience are cross-cutting themes that are necessarily dependent on the requirements and enabling environment of Energy Supply, Consumption, Electricity Generation and Distribution and Transportation depending on the specific intervention. Energy Security and Resilience interventions must be in alignment with Joint Nation Action Plan 2 (JNAP 2), National Infrastructure and Investment Plan (NIIP 2 & 3) and the recent Hunga-Tonga-Hunga-Ha'apai Volcanic Eruption and Tonga Tsunami Disaster Recovery and Resilience Building Plan, 2022–2025.

5.5 ENERGY SECURITY ROADMAP

The overall targets for each intervention are sub-divided into short-, medium-, and long-term targets as shown in table below.

Interventions/ Policy Alignment	Short-Term Target 2025	Medium Term Target 2030	Long Term Target 2035	Key Stakeholders
Demand-Response System Tariffs for Grid Flexibility Policy: LT-LEDS, NIIP2	Create flexible tariff system to incentivise demand responses for 70% RE	Implement flexible tariff system to incentivise demand responses for 70-100% RE	Implement flexible tariff system to incentivise demand responses for 100% RE	Sector Lead: Energy Commission Partners: TPL, DR-System Owners Finance: Private
EV Charging Off-Peak Schedule and Vehicle to Grid Power Policy: LT-LEDS, NIIP2	Create tariffs to encourage Off-Peak EV Charging	Implement tariffs to encourage EV to Power Grid and Residences	Implement tariffs for all of Tonga EVs including e-buses capable of providing power to Grid, Disaster Response Systems and Emergency Shelters	Sector Lead: Electricity Commission, Energy Commission, TPL Partners: EV Owners Finance: Private
Diesel Generators Fleet Strategy and Contingency Standby System Implementation Policy: NIIP2	Implement Diesel Fleet Strategy for 70% RE	Implement Diesel Fleet Strategy for 70-100% RE	Implement Diesel Fleet Strategy for 100% RE	Sector Lead: TPL Partners: MEIDECC-DoE Finance: Development Partners
Wind and Solar Forecast Systems Policy: NIIP2	MEIDECC-Meteorology	TPL-Control room	MEIDECC-Meteorology and TPL Collaboration	Sector Lead: TPL, MEIDECC-Meteorology Partners: MEIDECC-DoE Finance: Development Partners
Smart Grid Enhancements to control Decentralised Solar Policy:NIIP2	Tongatapu	Vava`u, Ha`apai, `Eua	Outer Islands	Sector Lead: TPL Partners: Energy Commission Finance: Development Partners
Disaster Risk Management Assessments Policy: JNAP2, TEEMP	Tongatapu - 1,200 km of Roads, 26,000 Power Assets	Vava`u, Ha`apai, `Eua	Outer Islands	Sector Lead: GoT Partners: TPL, MEIDECC Finance: ADB, Development Partners

5.6 ENERGY RESILIENCE ROADMAP

The overall targets for each intervention are sub-divided into short-, medium-, and long-term targets as shown in table below.

Interventions/ Policy Alignment	Short-Term Target 2025	Medium Term Target 2030	Long Term Target 2035	Key Stakeholders
Ensure new generation and distribution infrastructure is resilient to future sea-level rise Policy: JNAP2, TEEMP, NIIP2, HTHH-DRRP	Tongatapu, Vava`u, Ha`apai, `Eua	Outer Islands	All new generation and distribution infrastructure resilient to sea-level rise	Sector Lead: TPL, OIREP Partners: Energy Commission, MEIDECC – DoE & DCC Finance: Development Partners
Continuing to harden Transmission and Distribution network by burying strategic lines Policy: JNAP2, TEEMP	Tongatapu, Vava`u, Ha`apai, `Eua	Outer Islands	-	Sector Lead: TPL, OIREP Partners: Energy Commission, MEIDECC – DoE & DCC Finance: Development Partners
Incorporating resilience into building codes to enable buildings and structures to better withstand storms Policy: JNAP2, TEEMP	All Tonga	Enforce Standards	Enforce Standards	Sector Lead: MOI Partners: MEIDECC – DoE & DCC Finance: Development Partners
Microgrids - Tongatapu, Vava`u, Ha`apai, `Eua Policy: JNAP2, HTHH–DRRP	Design and Deploy Islanding-capable, 70% Renewable Electricity Microgrids comprised of Solar, BESS, Appropriate Mix of Biodiesel	Design and Deploy Islanding-capable, 70%-100% Renewable Electricity Microgrids comprised of Solar, BESS, EVs, Appropriate Mix of Biodiesel	Design and Deploy Islanding-capable, 100% Renewable Electricity Microgrids comprised of Solar, BESS, EVs, Appropriate Mix of Biodiesel	Sector Lead: TPL, Energy Commission, MEIDECC – DoE Partners: NEMO Finance: Development Partners
Minigrids - Outer Islands Policy: SDG 7.1, JNAP2, NIIP2, HTHH-DRRP	Increased Deployment of Solar Water Mini-Grid Pumping Stations Design and Deployment of Off-Grid 70% Renewable Electricity Minigrids comprised of Solar, Battery, appropriate Mix of Biodiesel	Design and Deployment of Off-Grid 70-100% Renewable Electricity Minigrids comprised of Solar, Battery, appropriate Mix of Biodiesel	Design and Deployment of Off-Grid 100% Renewable Electricity Miniogrid comprised of Solar, Battery, appropriate Mix of Biodiesel	Sector Lead: MEIDECC – DoE, OIREP Partners: Island Communities, TPL Finance: USTDA, Development Partners
Diesel Generation Fleet Deployment/Replacement Study Policy: JNAP2, TEEMP	Study for 70% RE	Study for 70%-100% RE	Study for 100% RE	Sector Lead: TPL Partners: MEIDECC–DoE Finance: Development Partners
Deploy Biodiesel Mix for Electricity and Transport Systems Policy: JNAP2, TEEMP	10% Mix	25% Mix	50% Mix	Sector Lead: TPL, MOI, MTED Partners: MEIDECC–DoE Finance: Oil Co.s

Interventions/ Policy Alignment	Short Term Target 2025	Medium-Term Target 2030	Long-Term Target 2035	Key Stakeholders
Reducing dependence on roads, which may become damaged in a disaster shortcutting large sections of road with a bridge Policy: JNAP2, TEEMP	Tongatapu	-	-	Sector Lead: MOI Partners: MEIDECC- DoE Finance: Development Partners
Emergency Water Transport system for the Laguna Policy: TEEMP, HTHH-DRRP	Tongatapu	-	-	Sector Lead: MOI Partners: MEIDECC- DoE Finance: Development Partners

© Solar Street Light at Vai ko Niutoua (off-grid)

6 GENDER

6.1 OVERVIEW

Tonga has a goal of Gender Equity by 2025 (GoT, SPC, 2019) and the GoT recognises that sustainable development can only be achieved if gender considerations (i.e., the respective issues, concerns, and priorities of women and men) are factored into the work of the government. This approach is espoused in the *Tonga Strategic Development Framework 2015–2025 (TSDF II)*, of which the third National Outcome envisions 'a more inclusive, sustainable and empowering human development with gender equality'. It is critical that women and men, girls and boys be equally represented and engaged for development and planning to be effective. This is equally true for the energy sector where women and men play different gender-defined roles in relation to energy production, distribution and use at the household, community, professional, and policy levels. There are numerous barriers for women involvement in the energy sector in Tonga that are sensitive and challenging to overcome, such as, the perception of gender roles, cultural and social norms, prevailing hiring practices, self-perception, lack of awareness of opportunities, lack of women in leadership roles in the sector and lack of support for women in technical roles. In order to address women's inclusion in the TERMPLUS, interventions and strategies must be applied at every level from the individual to the working and home environment and through to the structures and organisations where national policy and government implementation converge.

There is a strong business case for gender equality and a wide body of international literature shows that countries with greater gender equality have higher Gross Domestic Product (GDP) or better performing economies (GoT, SPC, 2019). Ensuring the equal access and participation of women, thus, makes economic sense. More specifically for the energy sector, benefits of equal gender participation can be improved project success rate as some projects fail due to a lack of inclusiveness in the approach (UNDP, 2016), bringing new or different perspectives to the workplace, improving collaboration and yielding better performance overall (IRENA, 2019; UNDP, 2013) and engaging women as active agents in deploying renewable energy solutions is known to improve sustainability, maximise socio-economic benefits and increase energy access (IRENA, 2019). Some of the benefits of equal gender participation in the energy sector are summarised in Table 21 below.

TABLE 21.
Benefits of equal gender participation in the energy sector

Economic	Social	Project-level
Higher GDP and/or better performing economy	• Improved sustainability	• Improved project success rate
Larger workforce to provide needed skills	• Maximisation of socio-economic benefits	• Bringing new or different perspectives and/or solutions
Ensure Women and Men can equally benefit in economic outcomes and opportunities	• Increased energy access • Increased safety • Better health and education outcomes	• Improvement in collaboration and yielding better performance overall

Energy improvements to enhance access of the poor to modern and affordable energy services in both rural and urban provides prospects for economic development, especially for women collecting and managing energy, fuel in households and small-scale enterprises. On the other hand, lack of access to energy has been found to have a disproportionately negative impact on women and girls. Any lack of access to modern, sustainable energy services withholds support to reduce women's time and labour burden in tasks such as collecting biomass for cooking, washing clothes by hand and restricts women's activities such as weaving, sewing and other activities to daylight hours.

Energy access also leads to improve in women's health and provide women with the opportunities for enterprise and capacity building. Time and physical exertion involved with supporting household energy needs can reduce the time women have available for education and employment and contributes to overall inequality. As a result, access to affordable, reliable, and clean energy can play a significant role in empowering and supporting the lives and livelihoods of women and girls, as well as protecting them. Women and children are 14 times more likely than men to die during a disaster[89] and are disproportionately vulnerable to the impacts of climate change. A non-exhaustive list of potential specific interactions between energy and gender issues in Tonga is presented in Table 22.

TABLE 22.
Specific interactions between energy and gender issues in Tonga

Household Energy Management	In rural and urban settings women and girls are often closely involved with energy provision activities whether it be via the collection of firewood or the collection of water (in absence of pumping facilities), women's mat weaving and handicrafts-making groups at night, etc. At the same time, men often make decisions that affect the way energy is used and managed. The priorities of men and women can be different and the needs of each may not be equally met.
Biomass Burning and Health	As women are often the most directly involved with cooking and biomass burning activities in rural and peri-urban areas they are also at the frontline of the health impacts from unclean cooking activities and the first to benefit from the transition to cleaner cooking practices. Modern energy provides capacity to use electronic home appliances and provision of lighting provides options for flexible working hours thereby increasing the time available for the family and other activities.
Lack of access to energy	Female heads of households are more likely to face poverty than single men or male heads of households thus increasing the impact and likelihood of energy poverty. Energy poverty can limit productivity and scope to improve safety, livelihoods, and access to education. Energy poverty or a complete lack of access to electricity has various implications which can increase the workload, reduce opportunities, and increase the vulnerability of women and girls to financial hardships and domestic violence.

89 Gender and Disaster Risk Reduction Asia and Pacific Policy Brief, UNDP, 2013.

Education and Energy	Access to adequate lighting is important to enable students to study in the evenings. While a lack of access to electricity can have a negative impact on both male and female students, this factor can further compound inequity and inherent barriers to education further limiting women and girls capacity to develop key skills and hindering their ability to access future employment. There's a need to invest early in the next generation to increase energy knowledge and skills of both men and women.
Employment and Training in the energy and transport sectors	There is limited employment of women in the energy and transport sectors, particularly in technical and non-administration roles. Women are affected differently from men, and women needs to be well represented in the workforce to drive transition measures that will benefit all citizens of Tonga. Female enrolment in energy and transport sector related training and higher education courses and across the region is low.
Women leadership and policy decision-making in the energy and transport sector	Women's leadership has the potential to accelerate an inclusive transition to a clean economy. Women access to data and finance and women representation on the boards and executive committees of energy and transport related agencies and organisations are very low, suggesting that the strategic direction of the sector is primarily decided by men. Initiatives to promote gender inclusivity have progressed, however the gender disparities are still very high at both corporate and field level positions. Increased women's participation in the sectors could accelerate the energy transition more inclusively and will ensure maximum participation and the will for behavioural change in all the measures for TERMPLUS.
Energy Project Design	Although action has been taken to improve involvement of women in project consultations at the community level, there is still room for improvement both at the policy level and grassroots level. Women have often had limited involvement in the design of new energy projects and interventions. New standards introduced by government and requirements by donors, and multilateral funds have increasingly helped to change this, and an increasing number of projects have a gender action plan and indicators to increase gender equality and equity in the project consultation, design and implementation phases.[90]

6.2 MAINSTREAMING GENDER THROUGH THE TERMPLUS

Effective gender mainstreaming to address issues such as those above, including through the TERMPLUS, may require changing some practices in the way government business, as it requires a more equitable and people-centred approach to development, but ultimately it will support achievement of the vision of the TSDF, the TERMPLUS and other government policies. The National Women's Empowerment and Gender Equality Tonga Policy and Strategic Plan of Action (WEGET) 2019–2025 Policy includes specific national priorities to address gender issues that the GoT and national stakeholders have agreed require urgent attention. Two of these priorities are particularly relevant in the context of TERMPLUS:

- Enabling environment for mainstreaming gender across government policies, programmes, services, corporate budgeting and monitoring and evaluation.
- Equitable access to economic assets and employment.

There is an opportunity to address both of these priorities in the implementation of the TERMPLUS. Table 23 below lays out a possible conceptual framework for the links between the development of the energy sector as laid out in the TERMPLUS and how applying gender considerations at each step can lead to multiple benefits.

Some of these opportunities in the value chain are already being realised. Women are an indispensable part of the workforce, but they still face barriers to working in the energy sector routed in societal and cultural norms. This has started to change in Tonga with the DoE[91] and TPL taking the lead, with support through development partners, providing training and creating opportunities for women in the Tonga to engage in the energy workforce. Energy sector projects in Tonga are contributing to a higher participation rate of women in non-traditional jobs, including technical roles such as installing and maintaining solar and carrying out electrical work. Technical assistance is providing targeted training to mainstream gender considerations into government and TPL. Over the years, TPL has engaged more female technical staff, who now account for about 10% of the workforce.

90 An example of this is the Renewable Energy Project (FFP TON 49450-012) funded by ADB.
91 For example, the 'Incorporation of Gender Issues in Renewable Energy Projects Workshop' held by the Tonga Department of Energy in March 2018.

TABLE 23.
Conceptual framework linking clean energy sector value chain and gender

Sectoral action	Objective	Multiple Benefits
• Address gendered impacts in each sector of the TERMPLUS: • Supply, consumption, electricity generation, renewables, energy efficiency, transport, energy security, and resilience.	• Gender-responsive value chain across all sectors • Enabling Policy • Planning and procurement • Public and private sector investment • Siting of infrastructure • Generation • Transmission and Distribution • Deliver/supply to end users • Energy access and affordability • Transport access, use and mobility • O&M and decommissioning	• Improved energy security • Reduced GHG emissions • Inclusive Energy transition with equal benefits to all citizens
• Address bottlenecks to women's involvement, decision-making, and leadership in each sector of the TERMPLUS: • Supply, consumption, electricity generation, renewables, energy efficiency, transport, energy security, and resilience.		Enhanced development outcomes, economic growth and climate resilience. • Contribution towards Gender Equality • Empowerment of women, better participation and improved support for women in the energy workforce

Source: Adapted from Pearl-Martinez, R., 2014. Women at the Forefront of the Clean Energy Future. White Paper. IUCN-USAID.

However, the energy and transport sector will remain a male dominated field in the short- to medium-term, and in order to maintain the current progress, it is critical to train and support men in the workforce to accept and normalise working with women in technical roles and to understand the benefits for both men and women when traditional perceptions and restrictions with regard to types of jobs are broken down and eventually removed. The relevant authorities need to ensure that women are well supported within the organisation with policies to ensure a safe and fair working environment free from all forms of discrimination and abuse. TPL is creating long-term employment opportunities for women in keeping its commitment to invest in a healthy, well-trained, and gender-diverse workforce (ADB 2020). Requirements laid out in gender action plans for renewable energy projects aim to carry out procurement in a way that that tendering and civil works contracts provide equal opportunities for men and women, and that they receive equal compensation for work. For example, the OIREP project is increasing gender equity in the energy sector by training and employing female line technicians.

In addition, as energy delivery objectives of the TERMPLUS are met, consideration should also be given to how energy will be used by men and women at the point of consumption and how productive use of energy can enhance socio-economic outcomes. Consideration should be given in project planning and design for the different role of men and women in different productive sectors, so that the energy delivered responds to all needs and both men and women can take advantage of enhanced employment and/or livelihood opportunities. Possible downstream productive uses of energy are shown in Table 24.

TABLE 24.
Downstream productive uses of energy

Agriculture, Fisheries, and Livestock	Services	Manufacturing
Increase in jobs due to water pumping for farming; ability to freeze and store produce, fish and meat, including post-harvest storage and transport.	Commercial employment thanks to improved lighting, heating, cooling options for commercial and residential purposes.	Improved output and products from access to power tools, sewing machines, etc.

Source: Pacific Energy and Gender Network Strategic Action Plan, December 2020 (SPC).

6.3 PRINCIPLES

The Government of Tonga has developed a Gender Mainstreaming Handbook (GoT, SPC, 2019) which can serve as a tool to accompany gender mainstreaming training and as a reference document with guidance to help relevant actors ensure the concerns of all women and men, girls and boys are considered in policy, project and programme planning, implementation, and monitoring and evaluation.

As an island country with limited resources, Tonga's comparative advantage is its people. Contributing to achieving the WEGET in the energy sector and realising the benefits for the implementation of the TERMPLUS and the wider socio-economic benefits, will require direct investment in women and girls to narrow disparities in participation in decision-making and planning, vocational and technical skills training, access to productive assets, employment, entrepreneurship and income-earning opportunities, alongside mechanisms for gender mainstreaming to which the Tongan government has already stated its commitment. This will enhance Tonga's ability to reach its energy sector targets, for example, by providing the additional skilled workforce required, amongst other benefits.

The TERMPLUS will therefore apply the following principles for gender mainstreaming in its implementation:

1. Establishment of gender as a pillar of energy and transport strategies
2. Access to information about TERMPLUS and its implementation to all stakeholders
3. Reform of the labour market and workplace to encourage women to join the energy and transport workforce with associated support mechanisms provided
4. Invest in the next generation
5. Participation of women in the formulation of energy and transport policies, strategies, plans, standards and regulations
6. Involvement of women in consultations and decision-making at all levels
7. Equal access to low carbon electricity, transport, water, and other infrastructure services
8. Equal access to training opportunities and new green job opportunities
9. Awareness of and equal access to leadership positions
10. Involvement in data collection, analysis, and research
11. Equal access to data, resources, finance, incentives, and tax cuts; and
12. Consultation as part of changes in land use and equal access to compensation,

Entry points to mainstream gender through the TERMPLUS are as follows:

- Each measure proposed for the TERMPLUS should be analysed through a gender lens in the planning and design stage and a gender action plan developed and implemented where appropriate. Women should not be regarded as just a vulnerable group, or beneficiaries, but as active participants, decision-makers and potential agents of change, who can support a project to be more successful.

The following are broad questions to guide gender analysis for the TERMPLUS measures and help identify specific gender issues:

- What are the gender roles and divisions of labor in relation to energy generation and use?
- How do these issues impact the differing workloads and divisions of labor for women and men?
- What are the respective knowledge and skills of women and men that could be used to address the issues?
- Do the measures proposed contribute to addressing the respective needs of women and men?
- Are the goals in line with the TSDF goals on gender equality?
- Do the measures proposed contribute to equitable benefits of the programmes and services for women and men?
- Do activities involve women and men? Do they address the respective needs of women and men? Do they take into consideration the current roles women and men play and seek to reduce disadvantages women may face due to differential treatment?
- Energy access affects women and men differently; is this considered?
- How consultative has TERMPLUS been in involving communities in both rural and urban areas?
- What are the varying impacts of different proposed energy measures on the different demographics of society or on populations in different locations (Tongatapu vs Outer islands)?

These questions and others can be used to apply a gender lens while planning and designing the implementation of the TERMPLUS.

- Including gender analysis in the corporate planning process to implement the TERMPLUS: applying a gender lens is critical and must be done systematically and consistently. The right gender questions need to be asked and answered first (i.e. the gender analysis) before knowing which activities / projects/programmes can be undertaken (i.e. gender-sensitive activities /projects/ programmes).
- Collecting sex-disaggregated data and gender statistics for more informed planning: Gender statistics, in the simplest sense, sex-disaggregating statistics about people, ensure accurate data on the status and roles of women and men, girls and boys in society and in this case for the energy sector, are produced and used to develop policy and improve service delivery. Gender statistics are essential for gender mainstreaming and, ultimately, for national development.
- Gender assessment is also a requirement for many multi-lateral and bilateral funding agencies, e.g. the Green Climate Fund and therefore needs to be conducted as part of major new renewable energy projects.[92] A project Gender action plans seek to operationalise the constraints and opportunities for women and men identified during the gender analysis towards fully integrating them into the project design and ultimately implementation.
- Value chain weaknesses can impede the transition to renewable energy and greater energy efficiency. Some barriers impeding the clean energy transition in Tonga have been identified in the past as the need for a qualified technical workforce with new skills and a more involved and more qualified private sector. The need for a qualified technical workforce and strong and qualified private sector, with new skills as technologies evolve, represents opportunities to increase the engagement of women in the clean energy value chain through education, training and professional development.

6.4 REQUIREMENTS AND ENABLING ENVIRONMENT

Gender is a cross-cutting theme that is necessarily dependent on the previous requirements and enabling environment of Energy Supply, Energy Consumption, Electricity Generation and Distribution and Transportation.

For the policies and partnerships in below Roadmap to be effective and for women and men to benefit equitably, Tonga must commit to make resources available for the below initiatives to be implemented. The participation and representation of women and men, girls and boys, is critical to maintain relationships and to foster effective development and planning. Therefore, the GoT will seek development partners' support to mobilise the necessary human and financial resources to mainstream gender into all TERMPLUS actions and into the energy sector in general.

In conclusion, women's economic opportunities can be expanded through employment and entrepreneurship in the energy sector thus contributing to WEGET and TSDF goals as well as the TERMPLUS targets. Engaging women at every segment of the clean energy value chain would not only economically empower women, but also create a more inclusive business model to achieve the TERMPLUS goals. As the energy sector in Tonga transforms to meet renewable energy and energy efficiency targets, it is important that national authorities ensure that both women and men have equal access to the new opportunities created. From an energy access perspective, it is also important to ensure that both men and women are benefitting from energy that is affordable and accessible for all.

[92] For example, a Gender Action Plan was developed as part of the recently approved Tonga-Green Climate Fund Project – FP090: Tonga Renewable Energy Project under the Pacific Islands Renewable Energy Investment Programme.

6.5 GENDER ROADMAP

The overall targets for each intervention are sub-divided into short-, medium-, and long-term targets as shown in table below.

Interventions/ Policy Alignment	Short-Term Target 2025	Medium-Term Target 2030	Long-Term Target 2035	Key Stakeholders
Employment, education, training and professional development Policy: TSDFII	Identify baseline for women's participation in energy sector, by subsector and through Interventions above, the TERMPLUS aims to achieve increase in women's participation in energy sector workforce	Identify and create pathways for women and youth through technical and vocational education, training and internships to develop technical skills for the energy sector.	Establish mentoring and networking programs for women and youth employed and graduates in the energy sector,	Sector Lead: MEIDECC – DoE Partners: TPL, NGO Finance: GoT
Energy policy, monitoring and evaluation Policy: TSDFII	Develop Gender assessment tools, set indicators to monitor gender aspects and collect gender disaggregated data Assess gender mainstreaming w/in DoE, energy sector, TPL and the energy sector, Develop action plan to address gaps Development of a gender monitoring programme for gender balance in utilities and ministries, in employment and entrepreneurship	Promote development of gender monitoring programme w/in DoE similar to TPL. Develop action plan Apply a gender approach to clean energy investment tools: feed-in-tariffs, renewable energy auctions and competitive bidding techniques, power purchase agreements, performance metrics, private sector subsidies and other economic incentives	Mandate collection of gender-disaggregated data in clean energy. Create and implement a gender scorecard for ministries and utilities	Sector Lead: MEIDECC–DoE Partners:TPL, NGO Finance: GoT
Partnerships, advocacy and awareness raising Policy: TSDFII	Support enhancement of the capacity of gender experts, women's organisations, and multilateral gender focal points on renewable energy and climate change mitigation, in order to encourage engaged participation in policy and large-scale project development	Build awareness of women's role in clean energy, including stories of women and girls in the energy sector, side events at major energy meetings, communication campaigns, identifying high level champions, and replicating successful models for women's advancement	Develop publicly accessible case studies, data, webinars, and other tools on gender in clean energy infrastructure Host Pacific Island Countries, leadership exchange on women's advancement in the energy sector.	Sector Lead: MEIDECC – DoE Partners:TPL, NGO, Ministry of Internal Affairs and the Dept. of Women Finance: GoT
Projects and procurement Policy: TSDFII	Research avenues for addressing gender as a way of reducing risk and increasing returns on clean energy investments	Adapt project documents and assessments to be gender-responsive throughout the project cycle	Explore a requirement of gender-responsiveness in all contracts and agreements.	Sector Lead: MEIDECC-DoE, TPL Partners: NGO Finance: GoT

7 DATA MANAGEMENT

7.1 COVERAGE AND COLLECTION REQUIREMENTS

Data collection, sharing and dissemination are essential for any reliable analysis and to make informed policy decisions regarding supply, consumption, and electricity generation. The DoE has established a data collection system and the relevant procedures. However, while data on supply is comparatively robust (with the notable exception for data on stocks levels), data for electricity generation, transmission and distribution as well as final consumption show considerable gaps. Among others, there is a paucity in end-use data, with no sectoral breakdown for electricity consumption being available. In addition, data on final consumption for some sectors is estimated, including agriculture, forestry, and fishing. Furthermore, daily load profiles for electricity are only available for Tongatapu.

These gaps in essential data propagate through much of the analysis of the energy sector and put the results of many assessments on weak foundations. The lack of timely and reliable data undermines the assessment of trends, the development and evaluation of specific policies, interventions, and projects and makes investments less attractive. For example, key questions such as how to achieve a higher share of electricity generation from renewable sources, how to reduce consumption of petroleum products, and what are relevant energy efficiency measures can only be answered when the necessary data is available.

At a minimum, the GoT wants to ensure that the information necessary to build an energy balance for Tonga is collected. An energy balance is essential to observe major trends such as changes in consumption patterns over time, assess energy security, determine the share of renewables in the electricity mix, assess energy intensity, and calculate greenhouse gas emissions from the combustion of fossil fuels, among others. For that purpose, data must be collected for relevant fuels and flows covering supply, consumption, and electricity generation. Relevant fuels in Tonga include oil products, biomass, and electricity. The principal flows for supply include indigenous production, imports and exports, stock changes, and deliveries to international aviation and marine bunkers. For final consumption, data is required by sector, distinguishing between all major activities of fuel use. For electricity generation, essential flows include generation and battery capacity, the amount of electricity generated by fuel, power plants' electricity own use, and transmission and distribution losses.

In addition, more granular data—often collected at the household level—is required to identify cost-effective energy efficiency measures for transport, buildings and appliances; the feasibility of distributed electricity generation from renewable sources; and appropriate interventions to support clean cooking fuels and technologies. Detailed information is also required to determine the layout of Tonga's electricity networks to accommodate a higher share of electricity from variable renewables.

The Energy Bill provides the legal foundation for introducing mandatory data collection. It stipulates that the Ministry of Energy shall 'establish and maintain a comprehensive energy sector database'. The Energy Bill does not explicitly provide the Minister of Energy with the power to establish regulations and standards for data collection. However, it stipulates that the Minister may 'require a person to supply information to the Ministry in relation to the provision of an energy product or service in the Kingdom'. Prior to the Energy Bill / Energy Act (anticipated), there has been no regulation for mandatory data reporting. With regulation missing on what data is collected, how it is collected, and how frequently it is collected, information collected by the DoE has not been compiled, managed, and disseminated in a standardised way.

Relevant data is and will continue to be collected by different entities, including the DoE,[93] the Department of Statistics, TPL, the Revenue and Customs Authority, and oil companies operating in Tonga. The different entities will continue collecting different information in different formats. However, institutional roles need to be clarified, establishing reporting requirements. These requirements should detail which information each entity should report to a centralised authority—possibly the Ministry of Energy—and the frequency by which information has to be reported. Depending on the nature of the information collected and the entity collecting the data, reporting formats can vary between standardised questionnaires, sample surveys, census data, etc. Similarly, the frequency of data collection and reporting depends on the nature of the information and the purpose it is needed for, and ranges from hourly and daily information to monthly and yearly. The highest priorities to improve data collection are described in the following sections. Further details can be found in Appendix J.

To ensure the collection, management, and dissemination of robust and reliable information about the energy sector, the necessary financial and staff resources need to be allocated. Data collection should be formalised and follow standardised procedures. Given the small market size of the Kingdom of Tonga, with a limited number of suppliers and consumers, data collection systems can be comparatively simple. Using standardised templates, data collection can rely on widely available, low-cost, and user-friendly software that allows easy input from providers and easy extraction from the collecting agency. In addition, data collection should follow a fixed schedule that is known and agreed on by information providers and the collecting agency. Similarly, standardised procedures for data management and dissemination must be agreed on with the relevant government departments and—possibly—external stakeholder. Both, management and dissemination can rely on the cost-effective and user-friendly software solutions. Standardised procedures also require that staff in the collecting agency must be assigned clear roles and tasks for data collection. Drafting an internal handbook on collection, management and dissemination schedules and procedures is regarded as a useful tool to ensure standardisation and efficiency, particularly in times of staff changes.

7.2 SUPPLY

In Tonga, supply information covers two principal fuels, i.e. oil products and biomass. Generally, electricity generated from renewable sources is considered as part of supply, as those amounts of electricity are not the result of transforming a primary fuel into electricity. However, for the purpose of data collection, electricity generation from renewable sources is addressed as part of 'Section 3. Electricity Generation and Distribution'. The principal flows, for which data needs to be collected, include indigenous production, imports and exports, stock changes, and deliveries to international aviation and marine bunkers.

Oil products

For the petroleum sector, relevant flows include imports and exports, deliveries to international aviation and marine bunkers, and stock changes. While trade data and deliveries to international bunkers are considered to be comparatively reliable, information on stock levels and stock changes is often incomplete and incorrect. Data reporting should be ensured either by importers and retailers entering into voluntary data sharing agreements with the GoT or by subjecting them to mandatory data reporting to the Ministry of Energy. Reporting from importers and retailers should occur in addition to or coordinated with data collected by customs and tax authorities. This would allow improved data quality. For example, in combination with sales data from oil companies, available information on trade and bunkering could help to verify and improve the quality of oil stocks data.

Stock data should distinguish between the amount of stocks held in Tonga, stocks on incoming vessels, and stocks held in Fiji for Tonga.[94] A decision will have to be made whether stock levels on national territory will only include primary stocks (i.e., stocks held by companies supplying the domestic

93 The Energy Bill envisions the creation of a 'Ministry responsible for energy'. which will likely replace the Department of Energy.

94 From these three stock categories, only the stocks held in Tonga should be counted towards compliance with a potential stockholding obligation, as only these stocks are immediately available in case of an emergency, e.g. a typhoon affecting the country.

market) or if stock information will also include secondary and tertiary stocks (e.g. stocks held by electricity plants). Issues concerning confidentiality of companies' stock data will have to be addressed, since only two oil companies (owning all major storage facilities) are operating in Tonga.

Biomass

In Tonga, biomass represents a major local supply source for energy, in the form of coconut residues, fuel wood, and wood waste. Data reliability for the supply of biomass is subject to considerable uncertainty as wood and waste are to a considerable extent informally collected by households and not obtained through formal markets. As a result, data is—at least partially—obtained through household surveys, where the reliability of the information is subject to the accuracy of household responses.

As part of the 5-year census, information is collected on the number of households using wood and coconut husk as the main cooking fuel. However, quantities of biomass used are not available. While amounts of biomass can be estimated based on population growth, urbanisation rate, and other variables, these estimates are subject to considerable uncertainty. Therefore, future censuses or sample surveys should ask for information on the amount of biomass consumed. Information on the supply of biomass will likely have to rely on consumption data as a proxy, with production being considered equal to consumption—since there is no transformation of wood into charcoal or other residues into liquid biofuels.

7.3 ELECTRICITY GENERATION

In Tonga, electricity generation refers to the transformation or conversion of fossil fuels into electricity and the generation of electricity from renewable sources.[95] In Tonga, data for electricity generation should be collected distinguishing between three fuels or sources, i.e. diesel, solar, and wind. Given the distinct characteristics of electricity generation from solar and wind, these two renewable sources should be accounted for separately. Similarly, if further renewable sources for electricity generation become available in the future (e.g. biomass), data collection procedures should also allow for tracking them separately.

Essential data covering the electricity sector include generation capacity and the amount of electricity generated by fuel, generation plants' own use of electricity and their conversion efficiency, transmission and distribution losses, and the available battery storage capacity. This data is mostly collected by TPL and shared with the DoE for the Kingdom of Tonga's four main networks. It is considered to be comparatively reliable information. In addition, information on generation capacity and electricity generated from off-grid systems is collected by the DoE. This information will continue to be collected either through voluntary data sharing agreements between the new Ministry of Energy and TPL—and in the future possibly independent power producers—or by establishing regulation subjecting power producers to mandatory reporting.

More detailed information will be required to reduce the share of dispatchable electricity generation from diesel and replace it by variable electricity from wind and solar, while electricity consumption continues to increase. However, currently, only a fraction of the required information is available. Essential data to successfully address these challenges includes:

1. Daily load profiles for all four networks, distinguishing consumption by consumer type and distinguishing supply by generation source,
2. Detailed network layouts,
3. Appliance ownership and floor area at household level, and
4. Information on solar irradiation and wind speeds both to observe existing installations and identify sites and configurations for additional infrastructure.

While some of that information can be collected by the utility—and possibly independent power producers—some challenges will require systematic data collection through household surveys—possibly as part of the census—or demand external expertise.

95 Electricity generated from renewable sources is generally considered as part of supply, as those amounts of electricity are not the result of transforming a primary fuel into electricity. However, for the purpose of data collection, electricity generation from renewable sources is addressed as part of '3 Electricity generation'.

7.4 FINAL CONSUMPTION

Final consumption covers fuel use for final energy consumption and for non-energy purposes. For final consumption, data is required by sector, distinguishing between all major activities of fuel use. Amounts of fuels used for electricity generation are excluded from final consumption and covered as part of '3. Electricity Generation and Distribution'.

Consumers are classified by principal economic activity, based on the International Standard Industrial Classification (ISIC rev. 4). For final energy consumption, the main sectors are industry; transport; residential; commercial; social and government services; agriculture and forestry; and fishing. Each sector contains further subsectors. Ideally, information should be collected for each subsector. In addition, amounts of fuel for non-energy use have to be distinguished but no breakdown by sector is required for those.

Information on final consumption should ideally rely on sales data, deliveries data, and household surveys. It should not be inferred from data on supply and electricity generation. Collecting consumption data separately provides a general measure for the accuracy of energy data and allows to detect possible inconsistencies between information on supply, transformation, and consumption. [96]

Industry

In Tonga, energy consumption in the industry sector amounts to a fraction of total final energy consumption, including oil products and (presumably) electricity. Given the small size of Tonga's industry sector, it should be comparatively simple to collect relevant data from a limited number of companies. Economic activities considered as industry should be aligned with ISIC rev. 4. Amounts of fuel included in consumption data for the industry sector should exclude any quantities used to generate electricity and heat for sale as well as any quantities consumed for transport on public roads. Amounts of fuel used for electricity and heat generation for sale should be included in electricity generation, while amounts of fuel consumed for transport on public roads should be included as part of transportation.

Information on electricity consumption in the industry sector is currently not available. However, data on how much electricity is consumed by which type of consumer is essential to evaluate options for energy efficiency measures and integrating higher shares of electricity generation from renewable sources into the network, among others.

Transport

In Tonga, energy consumption in the transport sector consists entirely of oil products. Reporting should distinguish between road transport, domestic shipping, and domestic aviation. To the extent possible, information should be based on sales or deliveries data.

There is likely some inaccuracy in diesel consumption for road and domestic maritime transport due to the difficulty of distinguishing between diesel sales for land and small-scale maritime transport. Many consumers likely purchase fuel at retailers, with the retailer having no information on how the fuel is going to be used. Similarly, while efforts are made to distinguish oil products consumed by fishing vessels from fuel consumed by maritime transport, the amounts are currently estimated. The existing data collection system distinguishes comparatively reliable between deliveries to domestic and international aviation and maritime transport.

In addition, introducing and evaluating the impact of fuel efficiency standards, fuel switching, and other measures in the transport sector will require a comprehensive set of data, including detailed information on the development of the vehicle stock over time, vehicle efficiencies, and average passenger and freight kilometres by vehicle category. While some of the data can be collected as part of standardised procedures (e.g. vehicle stock), other information will require considerable resources and dedicated collection procedures (e.g. passenger and freight kilometres). Data collection efforts in this area will likely have to be led by the Revenue and Customs Authority and the Land Transport Division.

Residential, commercial, social and government services, agriculture, forestry, and fishing

Energy consumption for residential, commercial, social and government services, agriculture, forestry, and fishing consists of biomass, oil products, and electricity.

According to existing information, biomass—in the form of coconut residues, fuel wood, and wood waste —is exclusively consumed in the residential sector. Data reliability for the consumption of biomass is subject to considerable uncertainty as wood and waste are to a considerable extent collected informally by households and not obtained through formal markets. As a result, data is—at least partially—obtained through household surveys, where the reliability of the information is subject to the accuracy of household responses.

[96] The main challenge for MEIDECC – DoE is getting the sector breakdown of oil products consumption (demand side data). The data is with the two existing oil companies in which they currently do not release due to confidentiality issues. The DoE then resolves to estimation based on other available data (fishing boats, maritime consumption, etc.). Currently, TPL only identifies its customers into two categories – Residential & Commercial, hence why Agriculture, forestry, and the fishing sector are missing from the electricity consumption sector breakdown.

Oil products consumption includes mainly LPG and kerosene for cooking and lighting, motor gasoline for fishing boats, and diesel for agriculture and forestry. Data for residential consumption of LPG is currently estimated, applying a fixed growth rate per year. Similarly, data for diesel consumption in agriculture and forestry as well as motor gasoline consumption for fishing is currently estimated, applying fixed yearly growth rates. Particularly for household consumption of LPG, sales data should be used instead of estimates. Obtaining actual data for diesel consumption for agriculture and forestry as well as motor gasoline consumption for fishing will be a challenge.

Many consumers likely purchase both fuels at retailers, with the retailer having no information on the fuels end-use.

Currently, a sectoral breakdown for total electricity consumption is not available. It is of utmost importance to distinguish electricity consumption between different consumer categories via metering of end-users. The absence of such a sectoral breakdown prevents forecasting consumption, evaluating possible energy efficiency measures, and assessing the potential for distributed electricity generation from renewable sources, among numerous others.

7.5 REQUIREMENTS AND ENABLING ENVIRONMENT

Data Management is a cross-cutting theme that is necessarily dependent on the requirements and enabling environment of Energy Supply, Consumption, Electricity Generation and Distribution, Transportation and the anticipated Energy Act.

In addition, more granular data—often collected at the household level—is required to identify cost-effective energy efficiency measures for transport, buildings and appliances; the feasibility of distributed electricity generation from renewable sources; and appropriate interventions to support clean cooking fuels and technologies.

To some extent, the policy goals set in the TERMPLUS will determine data collection requirements. For example, successfully increasing the share of electricity generated from renewable sources will require the collection of information on the daily load profile, frequency fluctuations, etc. for all four networks. An assessment of energy efficiency measures for buildings and appliances requires household level data on floor area and appliance ownership, in addition to collecting data on end-use electricity consumption at a household level. Similarly, an assessment of the energy saving potential in transport requires detailed data on passenger and freight kilometres, vehicle ownership by vehicle model, traffic patterns, etc.

© Solar Street Light at Lofanga after the Volcanic eruption and Tsunami (off-grid)

7.6 DATA MANAGEMENT ROADMAP

The overall targets for each intervention are sub-divided into short-, medium-, and long-term targets as shown in table below.

Interventions/ Policy Alignment	Short-Term Target 2025	Medium-Term Target 2030	Long Term Target 2035	Key Stakeholders
Implement GoT Energy Sector Data Management Systems Policy: Energy Bill / Act, JNAP2	Comprehensive Energy Sector Database established; Standardised templates developed for GoT; Establish record of generation capacity of off-grid systems; produce Tonga energy balance Update Database for 70% renewable electricity and electrification of transportation	Government Ministries data responsibilities and reporting requirements; publish GoT Internal handbook on data collection, management and reporting; establish remote monitoring of electricity generated from off-grid systems Update Database for 70%-100% renewable electricity and electrification of transportation	Update Database for 100% renewable electricity and electrification of transportation	Sector Lead: MEIDECC – DoE Partners: TPL, PSC, MRC, Department of Statistics, MOI Land, Marine, Air Divisions and Oil companies Finance: Development Partners, ESCAP
Improve GoT Energy Data Collection Policy: Energy Bill / Act, NDC	Energy questions added to 2025 Household Census: Appliance ownership, floor area, source and amount of biomass consumed. LPG consumption	Additional electricity and transportation questions added to 2030 Household Census	Additional electricity and transportation questions added to 2035 Household Census	Sector Lead: Department of Statistics Partners: MEIDECC – DoE Finance: GoT
Improve TPL Electricity Data Collection Policy: Energy Bill / Act, JNAP2	Daily load profiles for all four networks. Distinguishing consumption by consumer type and distinguishing supply by generation source. TPL automated data collection from IPPs and Smart-Meter Loads for 70% renewable electricity	Detailed network layouts Tongatapu, Vava`u, Ha`apai, `Eua, Information on solar irradiation and wind speeds to observe existing installations TPL automated data collection from IPPs and Smart-Meter Loads for70%–100% renewable electricity	TPL automated data collection from IPPs and Smart-Meter Loads for 100% renewable electricity	Sector Lead:TPL, Partners: IPPs, Finance:TPL, Development Partners
Improve access to Electricity Performance Metrics Policy: Energy Bill / Act, JNAP2	TPL Web portal launched with: Wind – GWh per quarter, Solar – GWh per quarter, Diesel – GWh per quarter TPL Web portal utilized as source of data for 70% renewable electricity	TPL Web portal enhanced to include: • Detailed quarterly price per kWh. • Total installed battery capacity. • Detailed quarterly generation mix. • Detailed quarterly network losses. • TPL Web portal utilized as source of data for 70%–100% renewable electricity	TPL Web portal utilized as source of data for 100% renewable electricity.	Sector Lead:TPL, MEIDECC – DoE Partners: MEIDECC – DoE Finance: Development Partners

Interventions/ Policy Alignment	Short-Term Target 2025	Medium-Term Target 2030	Long Term Target 2035	Key Stakeholders
Improve Energy Balance Data Collection Policy: Energy Bill / Act, NDC, SDG7	Develop and distribute DoE 'Energy Statistics Yearbook' which provides significant benchmarks and references for the National Energy Balance on an annual basis. Establish energy sector GHG emission MRV protocol; develop and include assessment of security of supply Update Database for 70% renewable electricity and Electrification of transportation	Develop and include assessment energy consumption per sector; assess amount of fossil fuel stocks held in Tonga; detailed information on vehicle stock over time. Update Database for 70%-100% renewable electricity and Electrification of transportation	Update Database for 100% renewable electricity and Electrification of transportation	Sector Lead:MEIDECC – DoE Partners: Oil Companies, TPL, IPP, Households Finance: IRENA, GoT/ Development partners
Establish M&E system of the implementation of the TERMPLUS Policy: JNAP2	2022–2025 M&E Report of TERMPLUS	2025–2030 M&E Report of TERMPLUS	2030-2035 M&E Report of TERMPLUS	Sector Lead:MEIDECC – DoE Partners: EU, TERMPLUS Stakeholders Finance: EU

© Solar Freezer System (off-grid)

APPENDICES

APPENDIX A. CONSIDERATIONS FOR DIRECT SHIPMENTS OF OIL PRODUCTS FROM SINGAPORE

Recent Analysis on direct shipments of oil from Singapore

The establishment of direct shipments of oil products from Singapore to Tonga has been under consideration since almost two decades.[97] The Tongan cabinet decided on 28 September 2018 to proceed with negotiations with oil companies to ship petroleum products from Singapore directly to Tonga (GoT,2018). However, direct shipments have not materialised and no changes to the supply chain have been implemented.

A study conducted in 2015 concluded that Tonga has a range of options for how to build, finance, and operate the infrastructure required to accommodate medium-range tankers:

1. Option 1: Privately-owned, restricted access medium-range tanker terminal,
2. Option 2: Privately-owned, regulated open access medium-range tanker terminal,
3. Option 3: Publicly owned incremental medium-range tanker terminal infrastructure, with fuel supply tendered (and fuel distribution within Tonga and ownership of existing fuel terminal assets remaining unchanged), and
4. Option 4: Publicly owned medium-range tanker terminal infrastructure (existing and new), with fuel supply and distribution regularly tendered (the Tonga Competitive Fuels Model).

These options are associated with different advantages, risks, and costs.[98] Depending on the supply option, the study estimated that wholesale prices of motor gasoline and diesel would reduce by 8.11 seniti per litre (option 4) to 8.91 seniti per litre (option 2), not including any potential savings from improvements to the pricing template or from competitive tendering (Table 25).

These cost reductions are based on two premises:

- Switching from oil supply via local coastal tankers to medium-range tankers would allow to bypass Fiji and avoid associated costs (landing, storage, holding, and freight). It would also allow for economies of scale as a result of larger shipments. The estimated savings amounted to 13.56 seniti per litre. These savings do not include the costs of constructing and operating the infrastructure required for Tonga to be able to receive medium-range tankers.
- Switching from supply via local coastal tankers to medium-range tankers will require the construction and operation of the infrastructure to accommodate medium-range tankers. This is associated with a range of different costs, including project costs, transaction costs, a competitive neutrality adjustment and a quantification of delay costs for options 3 and 4, and an estimate for major risks that are transferred to the private sector under options 1 and 2. The estimated costs range from 4.65 seniti per litre (option 2) to 5.45 seniti per litre (option 4).[99]

The analysis excludes some costs. Therefore, total costs might be higher and net benefits lower. However, the authors were confident that costs for establishing direct shipments of oil from Singapore will be lower than the expected cost savings of 13.56 seniti per litre.

97 Singapore is the closest major refining hub with considerable oil product exports. The next closest possible origins for oil product imports other than Singapore are China, Taiwan, and Korea. Travel distances from these three points of origin to Tonga are considerably longer than the route from Singapore. Australia, Indonesia, and New Zealand are net importers of oil products. Therefore, for the foreseeable future, the only viable origin for direct shipments of oil products is considered to be Singapore.

98 For a detailed discussion of each option, please refer to Castalia Advisory Group et al. (2015).

99 Using Public Sector Comparators (PSC) five different cost components were estimated for each option:
- The costs of implementing each option, including return on capital, depreciation, and operating and maintenance costs),
- A competitive neutrality adjustment that reflects the government foregoing tax revenue on the profits of a private sector owner, if medium-range tanker facilities are owned by the government and not by a private sector entity;
- An adjustment reflecting the value of risks transferred to the private sector;
- An estimate of the opportunity cost of differences in timing between the options; and
- An estimate of transaction costs under each option.

The purpose of the PSC was to compare costs across the four oil supply options, rather than to provide an accurate estimate of the cost of implementing each option. The attempt was not to quantify all possible costs and risks associated with each option, and the results of the analysis should not be considered accurate estimates of the total cost. Rather, the analysis focused on the costs that are likely to differ between options.

TABLE 25.
Estimated costs and savings from using medium-ranger tankers (in seniti per litre)

		Option 1 (restricted access)	Option 2 (regulated open access)	Option 3 (public incremental investment)	Option 4 (Tonga Competitive Fuels Model)
A	Cost saving from using medium-range tanker	13.56	13.56	13.56	13.56
B	Total cost	4.84	4.65	4.94	5.45
	Project costs	4.59	4.38	3.35	3.72
	Competitive neutrality adjustment	-	-	0.275	0.3875
	Risk transfer adjustment	-	-	0.335	0.4
	Opportunity cost	-	-	0.55	0.55
	Transaction cost	0.25	0.275	0.425	0.4
A-B	Net saving from using medium-range tanker	8.72	8.91	8.62	8.11

Source: Castalia Advisory Group et al. (2015)

The study concluded that option 2 represents the most beneficial option for a privately-owned medium-range tanker facility, while providing efficient ways to manage key risks and maintain competition for fuel supply into Tonga. Under that option, a private investor would recover a weighted average cost of capital and grant access to the facility to all interested fuel suppliers (existing and new) on the same terms. Option 3 represents the most cost-effective option for a publicly owned medium-range tanker facility, with the GoT investing in the additional infrastructure required for accommodating medium-range tankers, while agreeing on terms to use Pacific Energy and Total's existing assets.[100]

Before committing to either option, the GoT requires further evaluation to understand which of them is most likely to achieve the targets of increasing oil supply security and reducing oil product prices. The 2015 report advised to investigate options 2 and 3 in more detail to ensure financial viability. Echoing this recommendation, during the initial implementation of the TERMPLUS, both options will be developed further—providing advocates of either option an opportunity to prove the practical feasibility of their preference—before Cabinet making a final decision on the supply model. Given the complexity of establishing direct shipments of oil products from Singapore to Tonga, key issues that should be investigated include questions related to infrastructure and logistics as well as legal and financial considerations.[101]

The price reduction to be expected from direct shipments is comparatively minor. The estimated reduction in oil product prices of 8 to 9 seniti per litre as a result of direct shipments from Singapore to Tonga is comparatively minor. Fuel costs on the international market (40%) and taxes and duties levied in Tonga (35%) account by far for the largest shares of wholesale product prices in the country. Estimates suggest that transport, distribution, and retail only account for approximately 20% of the wholesale diesel and motor gasoline prices.[102] Fluctuations in benchmark diesel and motor gasoline prices in Singapore are considerably larger than any price reductions from introducing direct shipments.

[100] However, the report highlighted that option 3 faces considerable upside risks to the point that it might not be feasible, in particular that Pacific Energy or Total might not be interested in such an arrangement, as it would require them to give up control over the supply chain into Tonga (which would be subject to a public tender) and control over the operation of their existing storage infrastructure. The two companies would also have to share information on their current stocks, their forecast sales and storage requirements, which may present concerns around commercial sensitivity and competition. If no agreement on using the existing infrastructure was reached, in the worst-case scenario, the GoT might have to pay as much as 16.7 million TOP to purchase the existing assets (similar to option 4).

[101] This annex only highlights some of the key aspects that will need to be addressed. These items are discussed in more detail in Castalia Advisory Group et al. (2015).

[102] Oil product prices in Tonga are regulated and determined by the Tonga Competent Authority (TCA). The TCA determines maximum oil product prices for Tonga, reflecting the actual costs of buying fuels on the international market, of delivering those fuels to Tonga, of distributing them across the country, and providing a return on capital for the companies involved. The TCA uses a pricing template that calculates prices for four oil products considering the following components of the supply cost:

- Singapore product price and shipping cost, based on international benchmarks Platts and Worldscale (adjusted monthly);
- Storage fees and oil company operating cost, based on ex-post reviews of reasonableness (adjusted annually),
- Wholesale and retail mark-ups (adjusted monthly with changes in underlying fuel price); and
- Government duty, wharfage, and taxes (adjusted on an ad hoc basis as necessary).

The investment costs for putting in place the infrastructure to accommodate medium-range tankers is high. Direct shipments of oil products from Singapore would require the construction of new or upgrading of existing marine facilities to accommodate medium range tankers—including the wharf or anchorage for discharging tankers, pipelines, pumps, and terminal—and an expansion of storage infrastructure. Depending on whether current suppliers agree to use their existing infrastructure and the expected return on investment, in 2015, total investment costs were estimated to amount to 15 to 26 million TOP. The actual cost of financing this project, and whether and how these costs will change in the future (e.g., when loans are refinanced), are uncertain. Securing a loan at favourable conditions might be a challenge and depends on whether suitable external or domestic finance (e.g., Tonga pension fund) can be found.

There is considerable uncertainty regarding the infrastructure required to accommodate medium range tankers. For example, it is not clear to what extent the existing wharf can be extended, whether new facilities will have to be constructed (new wharf or multiple buoys mooring facility), or whether the planned upgrade of the Queen Salote International Wharf and other port infrastructure in Nuku'alofa Port could be modified to allow for the discharge of medium-range tankers.[103] This has direct implications for the investment required. Similarly, the storage requirements for oil products depend on the size and frequency of shipments arriving in Tonga. There is a trade-off between the frequency of deliveries and the size of the necessary storage. The higher the frequency of deliveries, the lower the storage required. However, a higher frequency of discharges translates into higher port charges. Conversely, a lower frequency of deliveries reduces port charges, but increases the size of storage needed, which is also associated with a financial cost. In that context, Twomey and Labett (2010) estimated that an average cycle time of 45 days in combination with an additional net tankage of 5 million litres represents the most cost-efficient alternative.

Two key questions in enabling the supply of oil products to Tonga via medium-range tankers are who finances the investment to build the necessary infrastructure and how are the costs recovered. The four options assessed by Castalia Advisory Group et al. (2015) reflect different answers to those questions. Option 1 would see one of the existing suppliers financing the infrastructure and recovering the related costs based on the existing oil price template.[104] Similarly, option 2 involves a single, dedicated company owning and operating the medium-range tanker terminal but adds some complexity because it would require open access regulation to ensure competition. Options 3 and 4 would be the most complex to implement. Option 3 involves a network of arrangements, with multiple infrastructure owners and operators. It would also involve agreeing, coordinating, and supervising several private sector contracts, for fuel supply, terminal construction, and terminal operations. Option 4 also involves multiple private sector contracts for fuel supply, construction, terminal operations, and distribution. In addition, it requires the GoT to own all the related infrastructure, which would include the nationalisation of existing assets.

The aspiration of reducing supply costs through tendering (in combination with a medium-range tanker port) might not be achieved. Currently, the GoT regulates fuel prices based on the actual costs of buying fuels on the international market, of delivering those fuels to Tonga, of distributing them across the country, and providing a return on capital for the companies involved. Several of the proposed options would include moving away from fuel price regulation and introducing competitive tenders for supply. Options 3 and 4 involve competitive tenders for fuel supply, while option 2 allows for the possibility of competitive tenders.

Available data is insufficient to assess whether or not there is a correlation between tendering oil supply (and vessel size) and fuel prices. There are only two countries that rely on competitive tenders in combination with shipping via medium-range tankers. Both countries show lower pre-tax retail prices for motor gasoline and diesel. However, the sample size is too small to derive any statistically robust conclusions.

Historical oil product prices in the Pacific Islands suggest that regulation (such as in Tonga and Fiji) is as effective as tendering to keep costs to fuel consumers as low as possible. Although countries that tender for fuel supply tended to have prices around or below the Pacific Island average pre-tax retail price, examples exist of countries that do not tender supply yet obtain prices below the average through regulated pricing. Fuel prices in Tonga have historically been at the lower end of the regional range. Therefore, while medium-range tankers can reduce costs by changing supply chain economics, further price reductions from tendering out supply (or improvements to price regulation) are questionable.

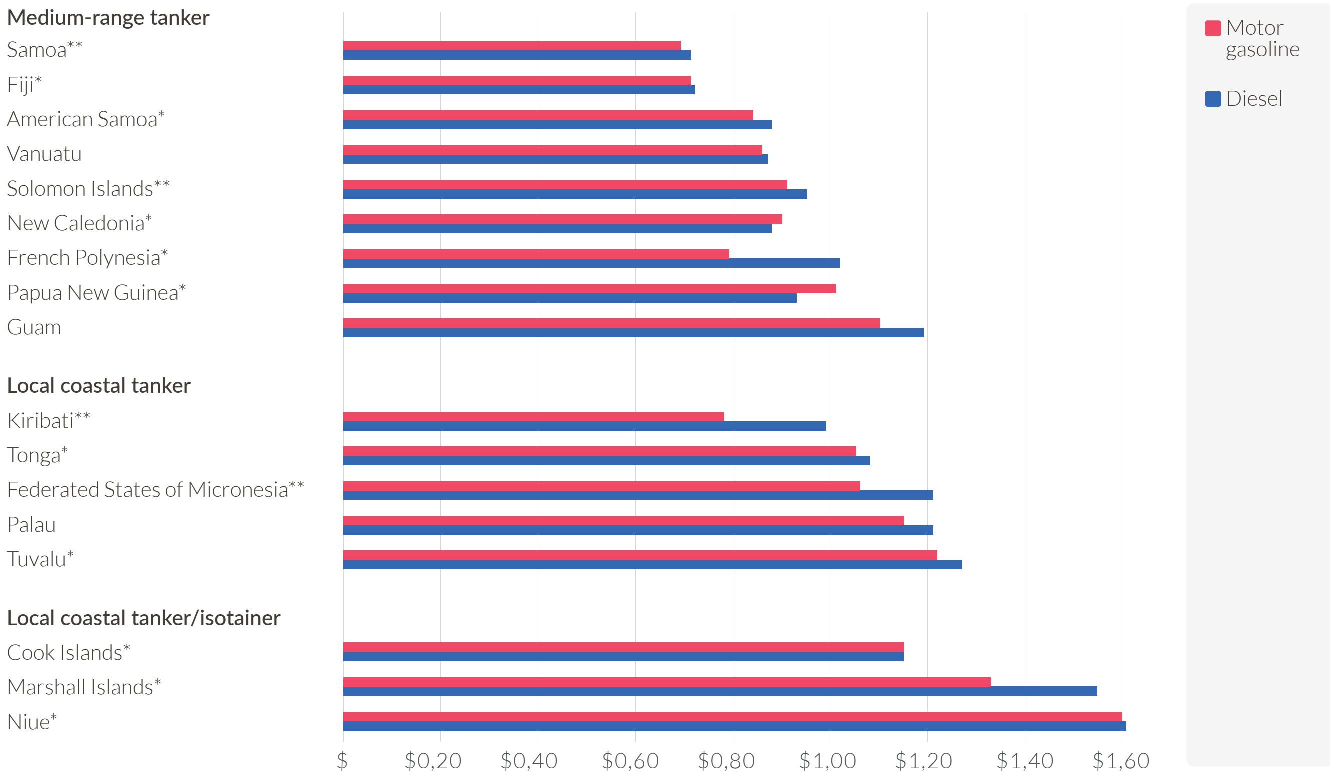
103 The upgrading of the port infrastructure is limited to extending capacity (i.e. rehabilitation of existing port infrastructure, extension of international cargo wharves, and improvement of supporting infrastructure) and increasing operational efficiency for the handling of cargo ships. While the upgrade does allow for an increase in liquid bulk vessel calls, no increase in parcel size is considered. As a result, it is unclear if and to what extent the planned expansions includes any upgrading that would be needed to allow for the discharge of medium-range tankers (ADB, 2020).

104 However, option 1 carries the risk that a single company would have a monopoly on Tonga's oil supply. Even if other parties have access to fuel supplies (upstream market) or fuel consumers (downstream market), they may be unable to compete effectively without access to the medium-range tanker facility on the same terms as the owner of that facility.

In addition, for a competitive tender to be successful, it would require adequate capacity to design and monitor the tender, to vet the companies that apply for the tender and their bids, and reasonable confidence that more than one company is interested in supplying the market. Running competitive tenders to secure oil product supply is a complex venture, with which the GoT has no experience and will likely have to rely on considerable external support (that the GoT will have to pay for).

FIGURE 27.

Pre-tax retail price for motor gasoline in Pacific Islands



hale & twomey

Tonga Petroleum Supply Optimisation Next Steps

Prepared for Ministry of Trade and Economic Development

9 September 2021

thinking energy.

Hale & Twomey Limited is an energy consultancy specialising in strategic issues affecting the energy sector. With a comprehensive knowledge of local and international energy markets, we provide strategic advice, comprehensive analysis and services across the entire sector.

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1.0 Introduction

The Government of Tonga is assessing how to progress the implementation of petroleum supply optimisation. The ultimate aim of petroleum supply chain optimisation is to provide consumers with lower cost fuel through reducing the costs involved in getting fuel to, and distributing fuel within Tonga. At the same time supply optimisation provides the opportunity to improve Tonga's petroleum supply security. This is expected to involve investment in storage and marine facilities to enable direct supply to Tonga with Medium Range (MR) tanker deliveries rather than the current supply route which uses smaller tankers to bring fuel from Fiji. [1]

The Ministry of Trade and Economic Development (the Ministry) asked Hale & Twomey Limited (H&T) to assess the position of the current suppliers to supply chain optimisation opportunities during the 2021 Annual/Triennial Petroleum Review and then lay out steps on how the project could be progressed.

2.0 Background

2.1 H&T Involvement

H&T has been working for the Government of Tonga since 2009, providing technical advisory support for petroleum fuels and liquified petroleum gas (LPG). In addition to H&T's annual obligations under its current contract with the Ministry, we have been engaged on the following petroleum supply chain projects by various government and regional organisations:

1. *Tonga MR Tanker Port Feasibility Study*. January 2010. Report for the Ministry of Labour, Commerce & Industries. Hale & Twomey Limited
2. *Tonga Fuel Supply Options Review*, December 2012. Report for Ministry of Finance Tonga. Hale & Twomey Limited
3. *Evaluation of Possible Models for Medium-Range Tanker Supply of Petroleum Products to Tonga*, Report to Government of Tonga, June 2015. Castalia Strategic Advisors, Anthony Harper, Chapman Tripp and Hale & Twomey (2015 Report).
4. *Review and Update of Medium Range Tanker Costs for Tonga Fuel Delivery,* March 2019. Report for the Ministry of Trade and Economic Development.
5. *Review of Pacific Energy/Petrocean Medium Range Tanker Delivery Proposal for Tonga Fuel Delivery 2020,* April 2020. Report for the Ministry of Trade and Economic Development.

H&T's recommendation on being approached about progressing the MR project earlier this year, was, rather than producing another report, to use the Annual Review Process to talk to each of the current suppliers (Pacific Energy and Total), and with that feedback lay out a process the Government could follow to progress the work. This paper summarises the feedback from the companies and suggested next steps.

[1] MR tankers are the tankers used to bring petroleum products to the region from Asia.

In addition, following the recent annual/triennial review, H&T has recalculated the likely savings to the Tonga consumer for the change in supply route (Section 3). In recent years this saving has increased due to the rising costs of bringing fuel through Fiji and escalating freight rate of the Local Coastal Tankers (LCT), together with higher overall Tonga consumption which improves the investment economics for the new supply chain.

2.2 TERM-PLUS Framework

The recently released Tonga Energy Road Map Plus Framework 2021-2035 (TERM-PLUS) sets the investment projects to reach 70% renewable electricity target by 2030 and 100% by 2035. This follows the first Tonga Energy Road Map issued in 2010.

As part of the energy transition, the TERM-PLUS framework highlights the importance of reliable and cost-effective supply of petroleum over the period and outlines plans for the optimisation of the petroleum supply as shown in Table 1. This includes direct supply of oil products from the major Asian trading centres (Singapore) which is aligned with the MR project being covered in this paper.

Table 1: Targets, means, and requirements for supply

Target	Means	Requirement
Increase security of supply	Establish direct shipments of oil products via Singapore Expand oil product storage	Agreement on required infrastructure Agreement on investment and financing mechanism Agreement on ownership and management of assets Establishment of decision-making procedure and legislation on modalities of stock release and replenishment
Reduce total amount of diesel imports in 2035 by 10% compared to 2015	Mandatory vehicle standards and/or incentives through tax, fees, import tariffs Displacement of diesel by renewable sources for electricity generation	Alignment of price signals for consumers with targets Public acceptance Financing Upgrade of network infrastructure

Source: Tonga Energy Road Map Plus Framework 2021-2035 (TERM-PLUS)

3.0 Savings from MR Project

We have recalculated the savings from direct MR supply to Tonga based on 2021 July prices (excluding COVID adjustments). The Tonga price template has been updated following the 2021 Annual Review which increased Fiji related costs. We are using 2019 volumes for the analysis as we expect the jet/kerosene volume to recover post-Covid. All other products have recovered to levels seen pre-Covid.

Because each proposal has been different over the years, it is difficult to compare the savings calculated each time with previous proposals, particularly as the investment may be different with different return levels proposed. As a base we have updated the savings in comparison to the

2020 Pacific Energy (PE) proposal, which had savings of around 13 seniti/litre only marginally higher than the savings calculated in the 2011/2012 proposals (~12 seniti per litre pre-tax)

Table 2: Summary of saving (July 2021 prices)

	Current Template	2021 update using PE 2020 proposal costs
Singapore MOPS (US$/bbl) (average across product mix)	81.86	81.86
Delivered price in Fiji (seniti per litre)	129.6	137.0
Delivered price into Tonga (seniti per litre)	198.5	183.5
Wholesale price (including taxes) (seniti per litre)[2]	250.6	234.2
Saving verses current (seniti per litre)	n.a	16.4
Saving verses current excluding consumption tax (seniti per litre)	n.a	14.2

In total we estimate savings of around 14.2 seniti/litre excluding the consumption tax impact (the consumer would see a more than 16 seniti/litre reduction due to the reduced tax). This is more savings than previous studies as the Fiji storage and handling cost has increased combined with higher LCT transport between Fiji and Tonga. Therefore there is more to gain from removing these costs.

We note that the savings are based on the most recent proposal (2020) from PE, although once into detailed design and assessment the cost of the investment required may change. This could impact the overall prize. Based on current volumes an MR supply could reduce the fuel costs to Tonga by over $9 million seniti (again consumption tax impact removed). This confirms that there is a lot of value in working on how such a supply route can be implemented.

4.0 Position of current suppliers

This section covers the feedback from each supplier during the annual review together with some background on the suppliers' previous positions on MR investment in Tonga.

4.1 Pacific Energy

Pacific Energy (PE) stated they remain interested in pursuing direct MR supply to Tonga as long as the investment makes sense for the company. They were interested in understanding the government's position given this has changed over time.

PE mentioned to the review team that during the 2015 Annual/Triennial Review, TCA rejected PE's work in progress for Touliki tank upgrade connected to enabling MR delivery (TOP 442,657). At

[2] Note the apparent saving for the delivered price into Tonga and greater than the wholesale price saving as the delivered price into Tonga contains all the savings, whereas the new costs (new investment) are in the build-up of the wholesale price from that figure.

the time the TCA rejected the claim noting that the MR investment had not been approved by Government of Tonga. PE has kept the assets purchased for the MR project at the Touliki Terminal and would like to seek reimbursement once the project is approved. In principle, PE would like to have the MR project endorsed by Government of Tonga before committing to any future investment.

Summary of Pacific Energy MR proposals

PE has put forward a number of proposals for developing MR supply over the past decade. They have also shown willingness to make these types of investments in other countries with similar demand levels such as Vanuatu. The proposals for Tonga supply have varied over time with the initial 2011 proposal probably providing the best opportunity, likely in response to the proposal developed internally and supported by the Government at that time (the Tonga Competitive Fuels Model - TCFM). The proposals have typically been in association with their related shipping company (Petrocean), although we are unsure if that relationship is still in place.

The most recent MR proposal from PE came in early 2020 through a local agent (John Paul Chapman). Any progress on that proposal got overtaken by COVID.

The key issue with most of the PE proposals is that they would lead to market domination by PE. The Government of Tonga is interested in an optimised supply chain while retaining in-country competition between suppliers.

4.2 Total

Total also stated they are interested in direct MR supply to Tonga during the Annual Review and they could see the savings that might be made.

This is an interesting position as previously (particularly during the work done in 2015/16) Total were unwilling to engage as its management did not think MR supply made sense. This position appears to have changed with new management.

Since Total became the supplier to Tonga Power in 2015 , they have also been a more significant supplier to Tonga with around 40-45% market share[3]. They have also invested more capital in Tonga during the last five years than PE, so have more to lose should they not have a stake in any future supply.

Total has expressed its concern about MR tanker supply in three main areas.

- The Government should ensure there is competition in the downstream sector. Total will have difficulty competing with an MR supplier if the project was awarded to PE.
- Total has done significant investment in terminal assets over the last 6 years which has improved the overall energy security of Tonga.
- Total's largest client is Tonga Power (TPL) who awarded Total a supply contract through a tender process. In their view TPL will need to be part of the MR consultation process.

As with PE, Total are keen to understand the Tongan Government's position on direct MR supply.

[3] Total's market share was a little higher in 2020 due to the low jet volumes for Pacific Energy.

5.0 Next Steps

The feedback from the companies is positive and gives the Tongan Government something to work with. It is also positive in that it is consistent with the direction recently outlined in the TERM-PLUS framework.

While it is in theory possible to develop an MR supply chain without engaging with the current suppliers, this has proven to be unsuccessful in the past. This includes:

- The TCFM developed in 2011. While the development of the concept was sound, it relied on the Tongan Government investing and forcing the existing suppliers to sell their assets. The proposal stalled when the Government said it would not have the funds to invest.
- 2015 Chapman Tripp/Castalia report. This development's preferred solution was purchasing existing terminals as part of a shared terminal development. Valuations prepared by the current suppliers for their assets were excessive and the project stopped when such valuations took away most of the prize.
- In 2018, the Government of Tonga setup a Task Force Committee (TCF) to oversee the construction of a new petroleum storage terminal in Nukualofa. The new terminal was expected to meet the growing needs of the Tongan consumers and Tonga Energy Road Map (TERM) objectives of safe, affordable, secure and sustainable supply. A tender was advertised by TFC to build, operate and transfer (ownership) an oil terminal in Nukualofa with the objective to rationalize the amount of petroleum storage volume available to ensure viability of this option. H&T is not aware whether the oil companies submitted their proposals to the government but to our knowledge this process was abandoned at some stage in late 2019.

Hale & Twomey's view is it is likely to be more feasible, while still providing a large portion of the savings to the Tongan consumer, to work with the companies to implement the MR supply chain. This is particularly true of the marine investment as the suppliers need to ensure the ships they charter can safely come into port and discharge. It is better to leverage off the suppliers' expertise in this area.

With that understanding H&T's suggestions for the next steps are as follows:

1. Prepare documents for each of the suppliers in preparation for follow up meetings on the MR project covering:

    a. Objective of the Tongan Government (using the TERM-PLUS framework as the basis);

    b. Possible options for the physical development of assets (based on prior proposals);

    c. H&T estimate of likely savings from direct MR supply including how these may be impacted by increased renewable penetration over time; and

    d. Key issues that have been identified in previous proposals that would need to be worked through.

2. Meetings (virtual) held with each company to discuss the document and cover any questions.

3. Following the meeting having each supplier provide a formal response to the document, including their view on the savings, how they might address issues identified from previous proposals and suggestions for next project steps including things they would like to see in place before progressing those steps.

4. From this process a project plan could be developed in conjunction with the suppliers on how to move the project forward.

Our view at this stage is, that while companies are interested in pursuing the MR option, it may be difficult to progress while COVID impacts are still being felt, particularly in Fiji. It might be that companies are not in position to progress until 2022, although that should not stop the initial steps outlined above getting underway this year.

APPENDIX B. STOCKHOLDING OPTIONS

TABLE 26.
Overview of oil stockholding options

		Minimum stockholding requirement		
	No minimum stockholding requirement	Industry obligation	Agency	Government
Expansion of storage and amount of stocks	Expansion of storage and increase in stock levels only to the extent needed for operational requirements	• Expansion of storage and increase in stock levels to meet industry obligation • Stocks are held by importers, including operational stocks and stocks held exclusively to meet the obligation • Generally, the required amounts of oil are determined in proportion to a company's oil import share or its share of sales in the domestic market • Operational and obligated stocks are commingled	• Expansion of storage and increase in stock levels to cover the difference between operational stocks held by industry and stock levels mandated under the stockholding requirement Operational stocks are held by importers • Stocks to cover, at a minimum, the difference between operational stocks and stock levels mandated under the stockholding requirement are owned by a separate stockholding agency exclusively for emergency purposes, but might be comingled with operational stocks • Agency structure and arrangements are defined by national legislation, they are either government-administered or industry-owned entities	• Expansion of storage and increase in stock levels to cover the difference between operational stocks held by industry and stock levels mandated under the stockholding requirement operational stocks are held by importers • Stocks to cover, at a minimum, the difference between operational stocks and stock levels mandated under the stockholding requirement are owned by the GoT exclusively for emergency purposes, but might be comingled with operational stocks
Decision making process for stock release	No institutional decision-making process required	Institutionalised decision-making process is required	Institutionalised decision-making process is required	Institutionalised decision-making process is required
Modalities of stock release during an emergency and replenishment	Companies will utilise stocks as required	• Stock release consists of the GoT temporarily lowering the obligation by a certain percentage or by a specified number of days, allowing companies to bring additional amount of oil to the market, or the GoT instructing a physical release of stocks • Replenishment consists of reinstating the initial obligation	• During a stock release, the stockholding agency can bring stocks to the market either as loans to oil companies or by selling them via a tender bidding process • To replenish stocks, the stockholding agency either receives the loaned amounts of oil back from oil companies or purchases the required amounts	• During a stock release, the GoT can bring stocks to the market either as loans to oil companies or sell them via a tender bidding process • To replenish stocks, the GoT either receives the loaned amounts of oil back from oil companies or has to purchase the required amounts

		Minimum stockholding requirement		
	No minimum stockholding requirement	Industry obligation	Agency	Government
Costs	Stockholding as part of companies' operational costs and included in consumer prices	Additional costs due to expansion of infrastructure and storage levels costs borne by consumer as part of retail prices	• Additional costs due to expansion of infrastructure and storage levels • Initial capital costs for expanding storage facilities and purchasing additional stocks can be financed from central government budget, bank loans, or in through bonds issued by the stockholding agency • Operational costs can be financed through central government budget (ultimately borne by all taxpayers), through a levy paid by market operators or through a direct tax paid by final consumers (both ultimately borne by consumer as part of retail prices) which is passed on to the stockholding agency	• Additional costs due to expansion of infrastructure and storage levels • Expansion of storage and holding of emergency stocks is financed through the central government budget, with the costs being ultimately borne by all taxpayers

Source: OECD/IEA, 2014[105]

[105] Note: The options laid out in Table 26. assumes that (1) no stocks held by major consumers (such as Tonga Power Limited) are counted towards minimum stockholding requirement and (2) that a minimum stockholding requirement is only placed on importing companies, not on major consumers (such as TPL).

Holding oil stocks is an effective means to respond to physical supply disruptions and help reduce the associated price spikes. Drawing down emergency stocks is widely regarded as the most effective option to respond to a short-term supply disruption. It allows for providing additional oil to an undersupplied market and can be complemented by other measures during an emergency. Using emergency stocks is not a tool for price intervention or long-term supply management, both of which are more effectively addressed through other policies, such as reducing oil imports, increasing energy efficiency, and diversifying the energy supply mix.

Among the available options for a minimum stockholding requirement, the introduction of an industry obligation is regarded as the most viable alternative to a continued exclusive reliance on operating stocks. An industry obligation is considered the most suitable option for Tonga because it poses a lower institutional and administrative burden on the GoT, it likely incurs lower financial costs, and it ensures availability and fuel quality of stocks.

First, introducing an industry obligation means that ownership and operation of storage facilities and management of oil stocks would remain under the responsibility of importing companies. As a result, this option would pose a limited institutional and administrative burden on the public administration, whose role would principally consist of putting in the place the necessary legislation, verifying compliance, and decision-making during a supply disruption. Legislation would include the legal foundations for a stockholding obligation, including the necessary definitions, sanctions in the event of non-compliance, decision-making procedures for a stock release, and the modalities of a stock release and replenishment. Verification of compliance would require companies to regularly report stock levels, most likely on a monthly or quarterly basis. Setting up decision-making procedures would require identifying the institutional arrangements in the event of a supply disruption. It should also be considered whether to establish clear and binding parameters for a decision on whether to release stocks, as there is a risk of stock releases being used as a short-term political tool instead of being a measure in the event of an emergency.

A major advantage of an industry obligation is that physical handling of stocks would remain with oil importing companies, who possess the necessary technical expertise, can judge viable options for expanding storage and related infrastructure, and have a solid understanding of oil market dynamics. Other options would require considerably more commitment and resources from the GoT, including the establishment of stockholding entity (either as a separate agency or as part of an existing government department); for that entity to take over the tasks of establishing and maintaining the required infrastructure, organising and implementing a physical release in the event of an emergency, organising the replenishment of stocks, etc. In addition, given the limited experience on oil stockholding within the GoT, considerable external expertise and resources would be required in order to establish a stockholding agency or government-controlled stocks.

Second, introducing an industry obligation to expand oil stockholding likely incurs a lower financial cost than setting up a stockholding agency or government-controlled stocks. The latter require more administrative resources and potentially increase infrastructure costs, depending on the extent to which operational stocks and emergency stocks would be comingled. An industry obligation would also allow for a simpler financing mechanism, with costs for expanding storage and stockholding being recouped through retail prices paid by consumers, with no need to introduce a levy, separate tax, or mechanism to allocate government budget.

Third, under an industry obligation, the stocks held for emergency purposes are integrated into the regular supply chain. Their availability during an emergency and the quality of the stored oil products would be ensured, since emergency stocks would be comingled with operational stocks. However, due to their integration into the supply chain, it would not be possible to distinguish between operational and emergency stocks. As a result, while the overall stock level can be monitored to verify compliance, it would be impossible to determine the amount of stocks that is exclusively held for emergency purposes. In contrast, agency or government-controlled stocks held in segregated tanks would add visibility to emergency stocks and make them comparatively easy to monitor. However, such segregation of emergency stocks could make a stock draw logistically more challenging and increase the time needed for oil products to be released. Segregating emergency stocks would also require regularly refreshing the volumes in storage in order to maintain fuel quality specifications, adding to stockholding costs.

APPENDIX C.
RESULTS OF ENERGY SAVINGS STUDIES

Tonga Power Limited (TPL) has categorised its customers into only two main sectors, the residential sector (44%) and company sector (56%). The residential sector is the largest homogenous sector given that the company sector comprises many other key sectors including agriculture, fisheries, etc. From 2010–2019, the residential sector's average annual growth was 4.4% while the company sector was 3.3%. Accordingly, the residential sector is the fastest growing electricity consumer in Tonga.

The Department of Energy in Tonga conducted a study (funded by SPC[106] in 2011) and projected an estimated 55.9 GWh (201 TJ) savings for Tonga between 2015-2025, should the MEPSL regulations be implemented. As more data became available, this figure was later revised in 2015 to 117 GWh (421 TJ) savings for 2015–2030.[107] This is an average 7.8 GWh (28.1 TJ) savings per year with the assumption that Tonga's annual population growth remains at 1% per year.

106 Pacific Appliances and Labelling Standards Project (PALS).
107 Due to more updated data and information collected by the PALS projects.

APPENDIX D.
METHODOLOGY NOTE FOR CALCULATING GHG AND AIR POLLUTANT EMISSION

Based on the estimated vehicle growth, the GHG (or CO_2 emission) and air pollutant emission is calculated for the two scenarios, BAU and BTB (Business-to-be). The parameters considered in sequence for calculation of emissions are as follows:

TABLE 27.
Parameters for calculating Vehicle Emissions[108]

Parameter	Emission Modelling
Vehicle kilometres travelled (VKT) and Passenger kilometres travelled (PKT)[109]	**For both scenarios** • VKT (for each vehicle segment) = vehicle stock x annual distance travelled • PKT (for each vehicle segment) = VKT x Average occupancy of respective vehicle segment
Vehicle technology/ fuel mix (petrol, diesel, and electricity)[110]	Vehicle segment wise percentage distribution across fuel mix in base year
Vehicle fuel efficiency[111]	The efficiency of vehicle in each segment will see an improvement of 0.5% for ICEV and 0.2% for BEV across vehicle segments for every L/100km or kWh/100km
Well to wheel emission factor[112] by fuel type	To estimate the emissions caused by fuels (gasoline, diesel and electricity) for the base year (2021), the emissions ($KgCO_2$) per unit (L/ kWh) is determined using the calorific value[113] for the liquid fuel (Gasoline and Diesel) and grid emission factor[114] for electricity. All the fuel types are converted to a single unit ($KgCO_2$/Lge), to bring all the fuels types to an equivalent unit **For Gasoline and Diesel** • The emission factor for the gasoline and diesel ($KgCO_2$/Lge) remains constant across all the years **For electricity** • The emissions due to electricity will vary based on the renewable and non-renewable share in the country. • As it is mentioned in TERMPLUS that Tonga is emphasising to have 70% of electricity generated from renewable sources by 2025 and 100% by 2035, impact on grid emission has been calculated over year **Emission factor** • Fossil Fuel Emission Factors for Tonga are in accordance with methodology outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories • The emission factors are given below,

Tank to Wheel CO_2 emission factor

Fuel Type	Emission factor
Diesel	2.55 Kg CO_2e/Lge
Gasoline	2.35 Kg CO_2e/Lge
Electric – Tonga	-

Wheel to Tank CO_2 emission factor

Fuel Type	Emission factor
Diesel	0.26 Kg CO_2e/Lge
Gasoline	0.54 Kg CO_2e/Lge
Electric – Tonga	0.67 Kg CO_2e/kWh (2010)

108 All the data has been provided and validated by local experts.
109 VKT is the measure of the total annual distance travelled by the vehicle stock in a given year. PKT is the measure of total passenger kilometres travelled in a year. It is the product of the occupancy factor and the VKT of the vehicle segment.
110 Vehicle fuel mix is the distribution of vehicle across various fuel types.
111 Vehicle fuel efficiency is a measure of average unit consumption (L or kWh) of a vehicle segment for every kilometre run.
112 Well-to-wheel emission factor is a combination of well-to-tank and tank-to-wheel efficiencies. Well-to-tank efficiency is an efficiency from fuel extraction to transportation to supply to storing in a fuel tank of a vehicle Both are considered in same units (i.e. $KgCO_2$/Lge).
113 Calorific Value is the energy contained in a fuel, determined by measuring the heat produced by the complete combustion of a specified quantity of it. This is now usually expressed in joules per kilogram.
114 Grid emission factor refers to a CO_2 emission factor (tCO_2/MWh) which will be associated with each unit of electricity provided by an electricity system.

APPENDIX E.
CASE STUDY ON RAAHGIRI DAY-CAR FREE SUNDAY

Raahgiri Day which began in Gurugram, India, is a sustained community movement towards the provision of better and safer walking and cycling infrastructure. Raahgiri Day is organised every Sunday morning on sections of prominent public roads that are closed for motorised transport and thrown open to the people for walking, cycling, exercise, and other community activities. It has already had several successful seasons in Gurugram, and was expanded to the entire city of New Delhi and adopted in 36 other Indian cities under the same or similar names.

This movement has resulted in a big mind-set shift in people:

- Huge turnout at Raahgiri every week, has got the authorities thinking towards the importance of providing safe pedestrian and cycling infrastructure.
- It encourages people to buy their own cycles, a lot of whom have now started cycling to reach the Raahgiri zone, their workplaces and to nearby marketplaces.
- It gets people to ditch their cars at least on Sundays raising awareness around physical inactivity, pollution caused by vehicles, road safety, and sensitivity for cyclists and pedestrians.
- It has shown positive impact both socially and environmentally.

This campaign-based approaches have really worked in driving big messages and going into this paradigm shift, which made it possible to have a conversation that you can have a city without car. And this is what city without car feels and looks like.

Similarly, in the South American country of Colombia, data shows that Ciclovia (Bogota's car free Sundays) was one of the seeds planted in the Colombian city to prioritise people, not cars. It flourished with the construction of permanent bikeways (now a 320-km network), sidewalks and public transport (Trans Milenio BRTS system, now 104-km of busway and moving 2 million people a day).

APPENDIX F.
STAKEHOLDERS LIST FOR TRANSPORTATION TERMPLUS WORKSHOP

Key Stakeholders

All transport sector related responsibilities that include land, maritime and aviation sub-sectors come under the Ministry of Infrastructure (MOI). The main actor in land transport is the Land Transport Division (LTD). Similarly, the main actors in the maritime sector are Marine and Ports Division (MPD), Port Authority of Tonga (PAT), Ministry of Education, Tonga Maritime Polytechnic Institute (TMPI).

Table 27 highlights key agencies relevant for TERMPLUS Transportation and their responsibilities for Transport sector in Tonga.

TABLE 28.
Relevant Agencies and their responsibilities for Transport sector in Tonga

Sr. No	Stakeholder	Responsibility
1	Ministry of Infrastructure (MOI) • Land Transport Division (LTD) • Marine and Ports Division (MPD) • Civil Aviation Division (CAD)	1. Manages all transport including land, maritime, and aviation sub-sectors. 2. It also collects data on domestic shipping, including the number of ferries, the number of passengers, and the volume of cargo delivered to various wharves (Government of Tonga and United Nation's Climate Technology Centre and Network 2018).
2.	Ministry of Revenue and Customs	Responsible for effective and efficient collection of revenue, safeguarding the borders and facilitation of legal trade including motor vehicles, maritime vessels, and aircrafts.
3	Ministry of Trade and Economic Development	MTED along with MORC has a role to play in implementation, manage and enforcement of vehicle and fuel standards.
4	• Ministry for Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC) • MEIDECC – Climate Change Division (CCD) • MEIDECC – Department of Energy (DoE)	CCD – Facilitates and /or oversees the government's climate change programmes and the JNAP 2. DoE – Leading on the National low emissions programmes and the development and implementation of the Tonga Energy Road Map 2021–2035.
5	National Spatial Planning Authority Office	To make important contributions to improved infrastructure planning and implementation including promoting strategic planning/coordinated action in relation to sustainable land use.
6	Public Enterprises • Tonga Power Limited (TPL) • Ports Authority Tonga (PAT) • Tonga Airports Limited (TAL)	• TPL – Tonga's sole electricity provider- generate, distribute and sell electricity and are committed to explore and facilitate Tonga's transition to lower emission transportation through EV. • PAT – share responsibilities for the maritime sector with the Marine and Ports Division under MOI. • TAL – share responsibilities for the aviation sector with the Civil Aviation Division under MOI.

The Tonga Department of Energy in collaboration with the Land Transport Division under the Ministry of Infrastructure held a Government Transportation stakeholders' workshop, where identified low emission transportation measures were discussed as part of the development of the Tonga Energy Road Map 2021- 2035 (TERMPLUS). The forum was led by Global Green Growth Institute (GGGI) consultants with the objective to inform, engage, and gain input from relevant agencies on low emission interventions that could facilitate the transition to a low carbon transportation system as part of TERMPLUS.

Transportation Stakeholders' Workshop for TERMPLUS was held on 19 October, 2021, from 9.30 am – 1.30 pm, at the Ministry of Infrastructure Conference Room at Vaololoa. It was attended by over 25 participants from across the Transportation departments- Roads (Land), Maritime, Civil Aviation Division under MOI, other key relevant government agencies, relevant Public Enterprises, Civil Society Forum Tonga and representatives from the Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE) and Tonga Chamber of Commerce (TBEC).

The draft list of interventions was presented and feedback on them were gathered, however overall, all actions and interventions were received and discussed positively. It is clear to the stakeholders how a lot of barriers may challenge these, and that there's a lot of issues in the sector that seriously needs improvement and strengthening if Tonga is to implement these measures and to be of use to the transport users. A press release of the workshop can be found on Tonga Gov Portal.

TABLE 29.
Transportation Stakeholders for TERMPLUS Invitee List

Sr. No	Department	Name of stakeholder
1	Ministry of Infrastructure (MOI)	CEO MOI – Mr Lopeti Heimuli
2	• Land Transport Division (LTD) • Traffic Unit • Vehicle Inspection Unit	• Director LTD – Mr Tevita Lavemai • Ms Ana Fifita, Ms Hepi Oko
3	Maritime and Ports Division (MPD)	Director MPD – Ms Kelela Tonga
4	• Ministry of Trade and Economic Development • Consumer Division	CEO – Ms Distaquaine Tuihalamaka Director Consumer Division – Ms Sandra Fifita
5	Ministry of Revenue and Customs	CEO – Mr Kelemete Vahe
6	Ministry of Health	CEO – Mr Siale Akauola
7	National Spatial Planning Authority Office (NSPAO) – Ministry of Lands and Survey	Director NSPAO – Mr Tukua Tonga
8	Ministry of Public Enterprises	CEO – Mr Sione Akauola
9	Ministry of Finance	ACEO Ms Pisila Otunuku
10	Tonga Power Limited	CEO – Mr Nikolasi Fonua
11	Statistics Department	CEO – Mr Viliami Fifita
12	Department of Environment	Director – Ms Lupe Matoto
13	Department of Energy	Act.Director – Mr Ofa Sefana
14	Civil Aviation Division – MOI	Director – Mr Kilifi Havea
15	Lulutai Airline Limited	CEO – Mikaele Fa'asolo
16	Waste Authority Limited	CEO – Mr Malakai Sika
17	Tonga Airports Limited	Mr Viliami Maake
18	Ministry of Fisheries	CEO – Mr Tuikolongahau Halafihi
19	Department of Climate Change	Director – Ms Luisa Malolo
20	Civil Society Forum of Tonga	Director – Ms Keasi Pongi

APPENDIX G.
WEIGHTAGES AND SCORING CRITERIA FOR MCA

MCA Criteria						Weightage			
Sr. No	Level 1 (L1)	Level 2 (L2)	Level 3 (L3)	Quantitative/Qualitative	Definition	L1	L2	L3	Final
1	Scale and scale up potential	Project /system scale	Population served	Qualitative	Higher is better	10%	40%	100%	4%
2		User impact	User frequency	Qualitative	Higher is better		30%	100%	3%
3		Scale up potential	Domestic replicability	Qualitative	Higher is better		30%	70%	2%
4			International replicability	Qualitative	Higher is better			30%	1%
5	Cost	CAPEX	CAPEX Investment requirement to Govt.	Quantitative	Lower is better	25%	80%	60%	12%
6			Timing of capital costs	Quantitative	Lower is better			40%	8%
7		OPEX	OPEX Investment requirement to Govt.	Quantitative	Lower is better		20%	100%	5%
8	Benefits	Economic	Revenue potential	Qualitative	Higher is better	30%	40%	10%	1%
9			Cost savings	Quantitative	Higher is better			30%	4%
10			Fuel cost savings	Quantitative	Higher is better			60%	7%
11		Social	Job creation/ employment	Qualitative	Higher is better		25%	50%	4%
12			Social inclusion	Qualitative	Higher is better			25%	2%
13			Gender equality	Qualitative	Higher is better			25%	2%
14		Environmental and climate	Air pollution reduction potential	Quantitative	Higher is better		35%	20%	2%
15			GHG reduction potential	Quantitative	Higher is better			80%	8%
16	Strategic alignment	Policy alignment	Government's alignment with budget priorities	Qualitative	Higher is better	15%	100%	20%	3%
17			Government's alignment with sectoral policies	Qualitative	Higher is better			30%	5%
18			Existing planning and feasibility studies	Qualitative	Higher is better			30%	3%
19			Legal framework	Qualitative	Higher is better			20%	3%
20	Implementation needs	Complementary Infrastructure needs	Roads and transport	Quantitative	Lower is better	20%	30%	60%	4%
21			Energy	Quantitative	Lower is better			40%	2%
22		Local industry capability	Capacity of local skills to support	Qualitative	Higher is better		15%	33%	1%
23			Local availability of equipment	Qualitative	Higher is better			33%	1%
24			Local post sales services and spare parts availability	Qualitative	Higher is better			33%	1%
25		Local population support needed	People/citizen behavioural change	Qualitative	Lower is better		20%	100%	4%
26		Implementation funding	Ownership structure identified	Qualitative	Higher is better		20%	25%	1%
27			Domestic funding sources	Qualitative	Higher is better			25%	1%
28			International funding sources	Qualitative	Higher is better			50%	2%
29		Implementation management	Planning and execution capacity	Qualitative	Higher is better		15%	100%	3%

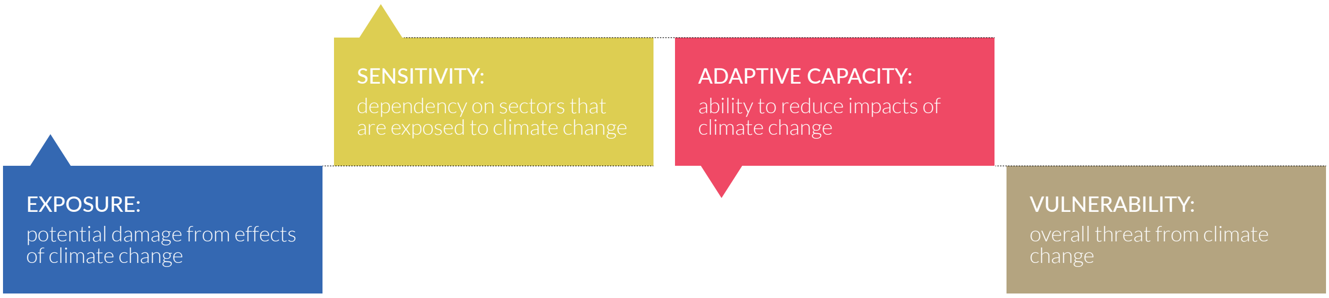
APPENDIX H.
NORMALISED SCORE FOR MCA

Criteria		1. Improving Intake Quality of Vehicle; Fuel efficiency; End-of-life			2. Non-Motorised Transport			3. Low-Emission Vehicles					
Sr. No	Level 3 (L3)	Motor industry quality assurance programme	Stricter emission standards	Shared Mobility	Walkway and bicycling lanes expansion	Pedestrianisation	Public Bicycle Sharing (PBS)	Electric Private Passenger Vehicles	Electric Public Transportation (Bus)	Electric Commercial Taxis (4W)	Electric Vehicles in Government fleet (4W)	Electric Freight Vehicle	Maritime Electrification
1	Population served	100	91	82	73	-	9	45	64	36	55	18	27
2	User frequency	100	91	82	73	-	9	45	64	36	55	18	27
3	Domestic replicability	73	100	91	82	9	27	36	55	45	64	18	-
4	International replicability	73	100	91	82	9	27	36	64	45	55	18	-
5	CAPEX Investment requirement	100	100	100	88	97	93	-	93	86	60	81	95
6	Timing of capital costs	100	100	100	90	97	97	-	95	87	60	100	99
7	OPEX Investment requirement	100	100	100	98	99	99	84	100	99	100	-	100
8	Revenue potential	73	73	100	73	73	91	73	82	73	73	73	73
9	Cost savings	1	1	-	0	0	0	26	0	1	1	29	100
10	Fuel cost savings	1	-	0	0	0	1	100	1	30	20	54	14
11	Job creation/ employment	100	73	91	73	73	73	82	82	82	82	82	82
12	Social inclusion	100	91	82	73	-	9	45	64	36	55	18	27
13	Gender equality	45	45	91	73	64	55	55	100	82	82	45	45
14	Air pollution reduction potential	-	0	0	0	0	0	100	2	2	1	40	1
15	GHG reduction potential	1	-	0	1	0	1	100	1	11	8	21	6
16	Government strategic and sector policy	91	100	45	55	45	45	45	64	45	73	45	82
17		91	100	45	55	45	45	45	64	45	73	45	82
18	Existing planning and feasibility studies	91	100	45	55	45	45	45	64	45	73	45	82
19	Legal framework	91	100	45	55	45	45	45	64	45	73	45	82
20	Roads and transport	100	100	100	100	100	-	75	100	100	81	97	100
21	Energy	100	100	100	100	100	100	-	98	96	98	45	100
22	Capacity of local skills to support	64	73	100	82	91	55	55	45	55	55	36	36
23	Local availability of equipment	73	91	100	82	82	64	64	64	64	82	64	64
24	Local post sales services and spare parts availability	73	91	100	82	82	64	64	64	64	82	64	64
25	People/citizen behavioural change	64	55	73	100	91	18	27	82	36	45	-	9
26	Ownership structure identified	91	100	45	82	64	36	27	55	18	73	-	9
27	Domestic funding sources	73	82	36	100	91	45	9	55	27	64	-	18
28	International funding sources	18	18	18	73	64	36	27	91	55	82	45	100
29	Planning and execution capacity	45	91	100	73	82	36	27	55	64	64	18	9
	Overall Score	68.1	69.7	63.5	62.1	53.1	44.1	46.3	61.4	54.1	55.4	45.9	58.1
	Rank	2	1	3	4	9	12	10	5	8	7	11	6

APPENDIX I.
FRAMEWORK TO ASSESS RESILIENCE TO CLIMATE CHANGE AND EXTREME WEATHER EVENTS

Climate change and extreme weather events is an inherently complex topic, manifesting itself in a wide spectrum of impacts and affecting multiple sectors (Arent et al., 2014; UNFCCC 2007). Therefore, systematically assessing the extent to which Tonga's electricity sector is affected by climate change and extreme weather events is a challenge. This challenge is exacerbated by the paucity of a universally agreed concept and definition of resilience (Lavell et al., 2018). For the TERMPLUS, resilience is assessed considering the electricity sector's exposure, sensitivity, and adaptive capacity to climate change and extreme weather events (Chen et al., 2015, Figure 28). The TERMPLUS deliberately distinguishes between long-term effects related to climate change—i.e. rise in temperature, rise in sea level, ocean acidification, and changes in precipitation patterns—and short-term extreme weather events that are not necessarily the result of climate change but still have a severe impact on electricity infrastructure, such as tropical cyclones. The theoretical framework behind this assessment is based on the IPCC assessment reports.

FIGURE 28.
Theoretical framework



Source: GGGI 2021

While the TERMPLUS refers to resilience, the IPCC generally speaks of vulnerability. Both terms largely describe the propensity or predisposition of an element to be adversely affected. However, while vulnerability directly refers to the predisposition of being negatively affected, resilience refers to the capacity to avoid such negative impact. Both measures are inversely correlated, i.e., the higher an element's vulnerability the lower its resilience, the lower an element's vulnerability the higher its resilience. For the purpose of simplicity in visually illustrating the theoretical framework, Figure 28 refers to vulnerability.

APPENDIX J. DATA COLLECTION

TABLE 30.
Data collection for supply

Fuel	Flow	Collected by whom	Suggested reporting mechanism to Ministry of Energy	Notes
Biomass (coconut residues, fuel wood, wood waste)	Indigenous production	Department of Statistics	Census data, household income and expenditure survey	As part of the 5-year census, information is collected on the number of households using wood and coconut husk as the main cooking fuel. As part of the household income and expenditure survey, data is collected on the expenditure on solid fuels. However, quantities of biomass used are not available. While amounts of biomass can be estimated based on population growth, urbanisation rate, expenditure, and other variables, these estimates are subject to considerable uncertainty. Therefore, future censuses or sample surveys should ask for information on the amount of biomass consumed. Information on the supply of biomass will likely have to rely on consumption data as a proxy, with production being considered equal to consumption—since there is no transformation of wood into charcoal or other residues into liquid biofuels.
Total primary energy supply				
Oil products (LPG, motor gasoline, aviation gasoline, diesel, jet kerosene, other kerosene)	Imports	Oil companies	Standardised quarterly/monthly Excel questionnaire	Currently, imports data is shared by the Revenue and Customs Authority with the Department of Energy. The data could also be directly collected from oil companies.
		Revenue and Customs Authority	Standardised quarterly/monthly Excel questionnaire	Data for LPG imports relies on a combination of information from the Revenue and Customs Authority and Tonga Gas.
	Deliveries to international marine and aviation bunkers	Oil companies	Standardised quarterly/monthly Excel questionnaire	-
		Port authority and/or Ministry of Infrastructure, Department of Transport, Maritime Transport Division	Standardised quarterly/monthly Excel questionnaire	-
		Revenue and Customs Authority Ministry of Infrastructure, Department of Transport, Civil aviation division	Standardised quarterly/monthly Excel questionnaire	Currently, data for deliveries to international aviation in based on imports information collected by the Revenue and Customs Authority and stocks changes. Going forwards, as part of Tonga's requirement as a member of the International Civil Aviation Organization (ICAO), the Civil Aviation Division was scheduled to start collecting data on fuel consumption for international flights, starting from the second half of 2020.

Fuel	Flow	Collected by whom	Suggested reporting mechanism to Ministry of Energy	Notes
Total primary energy supply				
Oil products (cont.) (LPG, motor gasoline, aviation gasoline, diesel, jet kerosene, other kerosene)	Stock levels and stock changes	Oil companies	Standardised yearly/ quarterly/monthly Excel questionnaire	Companies generally regard information on their stocks as sensitive business information. Since only two oil companies operate in Tonga, having information on total stocks in combination with the company's own stocks data allows to infer stock information of the competitor. Collecting stock data only once a year could possibly minimise concerns regarding confidentiality.

Source: GGGI
Note: Electricity generated from renewable sources is generally considered as part of supply, as those amounts of electricity are not the result of transforming a primary fuel into electricity. However, for the purpose of data collection, electricity generation from renewable sources is addressed as part of electricity generation.

TABLE 31.
Data collection for electricity generation, transmission, and distribution

Indicator	Scale	Collected by whom	Suggested reporting mechanism to Ministry of Energy	Notes
Electricity generation, transmission, and distribution				
Amount of electricity generated by fuel (diesel, solar, wind)	Grid	Tonga Power Limited, independent power producers	Standardised quarterly/monthly Excel questionnaire	The amount of electricity generated should include centralised and decentralised generation that is connected to the grid.
	Off-grid	Department of Energy	Census data or dedicated household survey	This information is currently directly collected by the Department of Energy.
Installed electricity generation capacity (diesel, solar, wind)	Grid	Tonga Power Limited, independent power producers	Standardised quarterly/monthly Excel questionnaire	-
	Off-grid	Department of Energy	Census data or dedicated household survey	This information is currently directly collected by the Department of Energy.
Installed battery storage capacity	Grid	Tonga Power Limited, independent power producers	Standardised quarterly/monthly Excel questionnaire	-
	Off-grid	Department of Energy	Census data or dedicated household survey	This information is currently directly collected by the Department of Energy.
Power plant own use	Grid	Tonga Power Limited, independent power producers	Standardised quarterly/monthly Excel questionnaire	-
Transmission and distribution losses	Grid	Tonga Power Limited	Standardised quarterly/monthly Excel questionnaire	-
Daily load curves	Grid	Tonga Power Limited	On request	-

Indicator	Scale	Collected by whom	Suggested reporting mechanism to Ministry of Energy	Notes
Electricity generation, transmission, and distribution				
Detailed network layouts	Grid	Tonga Power Limited	On request	This information will be required to reduce the share of dispatchable electricity generation from diesel and replace it by variable electricity from wind and solar, while maintaining network stability. Currently, this information is only available for the largest network in Tongatapu. This information does not have to be shared at regular intervals with the Ministry of Energy, but it should be available upon request.
Electricity consumption data at the household level	Grid	Tonga Power Limited	On request	This information will be required to design and evaluate energy efficiency measures in buildings and appliances. This information does not have to be shared at regular intervals with the Ministry of Energy, but it should be available upon request.
	Off-grid	Department of Energy	Census data or dedicated household survey	This information is currently directly collected by the Department of Energy.
Solar irradiation and wind speeds	Grid	Tonga Power Limited, independent power producers	On request	At existing solar and wind power sites, solar irradiation and windspeeds should be recorded to evaluate electricity generation efficiency. This information does not have to be shared at regular intervals with the Ministry of Energy, but it should be available upon request.
	-	Qualified service providers	External surveys	This information will have to be collected when identifying new sites and configurations for additional electricity generation capacity from solar and wind

Source: GGGI

Note: Electricity generated from renewable sources is generally considered as part of supply, as those amounts of electricity are not the result of transforming a primary fuel into electricity. However, for the purpose of data collection, electricity generation from renewable sources is addressed as part of electricity generation.

TABLE 32.
Data collection for final consumption

Sector	Fuel	Collected by whom	Suggested reporting mechanism to Ministry of Energy	Notes
		Total final energy consumption		
Industry	Oil products	Ministry of Infrastructure	Standardised yearly/ quarterly/monthly Excel questionnaire	Currently this information is estimated based on data from the Ministry of Infrastructure. Going forward, the Ministry of Infrastructure, a different agency, or an industry association (e.g. Chamber of Commerce and Industry) should collect this data through a dedicated industry survey.
	Electricity	Tonga Power Limited	Standardized yearly/ quarterly/monthly Excel questionnaire	This information will require end-use metering by Tonga Power Limited.
Road transport	Motor gasoline, diesel	Oil companies	Standardised yearly/ quarterly/monthly Excel questionnaire	Data for fuel consumption in land transport will likely have to rely on a combination of sources. While customs data allows for some distinction between product use as a result of different taxes being applied to different usages, it will likely have to be complemented by other sources.
		Revenue and Customs Authority	Standardised yearly/ quarterly/monthly Excel questionnaire	
		• Department of Transport, • Ministry of Infrastructure, • Land Transport Division	Standardised yearly/ quarterly/monthly Excel questionnaire	
	Electricity	Tonga Power Limited	Standardised yearly/ quarterly/monthly Excel questionnaire	This information should be collected if electric vehicles are introduced to Tonga and the related charging infrastructure is set up.
Domestic maritime transport	Diesel	Port authority and/or Ministry of Infrastructure, Department of Transport, Maritime Transport Division	Standardised yearly/ quarterly/monthly Excel questionnaire	There is likely some inaccuracy in diesel consumption for road and domestic maritime transport due to the difficulty to distinguish between diesel sales for land and small-scale maritime transport. Many consumers likely purchase the fuel at retailers, with the retailer having no information on how the fuel is going to be used.
Domestic aviation	Jet kerosene, aviation gasoline	Revenue and Customs Authority Ministry of Infrastructure, Department of Transport, Civil Aviation Division	Standardised quarterly/monthly Excel questionnaire	Currently, data for domestic aviation is based on imports information collected by the Revenue and Customs Authority and stock changes. Going forwards, as part of Tonga's requirement as a member of the International Civil Aviation Organization (ICAO), the Civil Aviation Division was scheduled to start collecting data on fuel consumption for international flights, starting from the second half of 2020. Together with data on imports and stock changes, fuel deliveries to domestic aviation can be inferred as the difference between total aviation fuel and deliveries to international aviation.

Sector	Fuel	Collected by whom	Suggested reporting mechanism to Ministry of Energy	Notes
Total final energy consumption				
Residential	Biomass	Department of Statistics	Census data, household income and expenditure survey	As part of the 5-year census, information is collected on the number of households using wood and coconut husk as the main cooking fuel. As part of the household income and expenditure survey, data is collected on the expenditure on solid fuels. However, quantities of biomass used are not available. While amounts of biomass can be estimated based on population growth, urbanisation rate, expenditure, and other variables, these estimates are subject to considerable uncertainty. Therefore, future censuses or sample surveys should ask for information on the amount of biomass consumed.
	Oil products other than LPG	Revenue and Customs Authority	Standardised yearly/ quarterly/monthly Excel questionnaire	Customs data should allow to capture kerosene for residential and commercial consumption as a result of product specifications. It is unclear to what extent it will also allow to capture other oil products for residential consumption. As a result, customs data might have to be complemented by other sources.
Residential	LPG	Tonga Gas	Standardised yearly/ quarterly/monthly Excel questionnaire	Currently data is estimated based on information is collected as part of the census, recording the number of households using LPG as the main cooking fuel, and information collected as part of the household income and expenditure survey, recording household expenditure on gas. Going forward, information on LPG consumption should rely on sales/deliveries reported by Tonga Gas, in combination with information from the household income and expenditure survey.
	Electricity	Tonga Power Limited	Standardised yearly/ quarterly/monthly Excel questionnaire	Information on consumption of grid-connected customers will require end-use metering by Tonga Power Limited.
		Off-grid	Census data or dedicated household survey	This information is currently directly collected by the Department of Energy.
Commercial	Oil products other than LPG	Revenue and Customs Authority	Standardised yearly/quarterly/ monthly Excel questionnaire	Customs data should allow to capture kerosene for residential and commercial consumption as a result of product specifications. It is unclear to what extent it will also allow to capture other oil products for residential consumption. As a result, customs data might have to be complemented by other sources.

Sector	Fuel	Collected by whom	Suggested reporting mechanism to Ministry of Energy	Notes
Total final energy consumption				
Commercial (cont.)	LPG	Tonga Gas	Standardized yearly/ quarterly/monthly Excel questionnaire	Currently data is estimated based on information is collected as part of the census, recording the number of households using LPG as the main cooking fuel, and information collected as part of the household income and expenditure survey, recording household expenditure on gas. Going forward, information on LPG consumption should rely on sales/deliveries reported by Tonga Gas, in combination with information from the household income and expenditure survey.
	Electricity	Tonga Power Limited	Standardised yearly/ quarterly/monthly Excel questionnaire	This information will require end-use metering by Tonga Power Limited.
Government services	Electricity	Tonga Power Limited	Standardised yearly/ quarterly/monthly Excel questionnaire	This information will require end-use metering by Tonga Power Limited.
Agriculture, forestry, and fishing	Oil products	Department of Statistics	Estimates based on census data or dedicated household survey	Data on oil product consumption in agriculture, forestry, and fishing is currently estimated, given the difficulty to distinguish between fuel sales for different uses. Many consumers likely purchase the fuel at retailers, with the retailer having no information on how the fuel is going to be used. In the future, estimates should rather rely on census data than applying a constant yearly growth rate.

Source: GGGI

Note: This table does not include the collection of information on the vehicle stock, vehicle efficiencies, average passenger and freight kilometres by vehicle type. Such data will be required when introducing and evaluating the impact of fuel efficiency standards, fuel switching, and other measures in the transport sector. While some of the data can be collected as part of standardised procedures (e.g. vehicle stock), other information will require considerable resources and dedicated collection procedures (e.g., passenger and freight kilometres). Any data collection in this area will likely have to be led by the Customs and Tax Authority and the Land Transport Division.

APPENDIX K.
METHODOLOGY NOTE FOR CALCULATING GHG AND AIR POLLUTANT EMISSIONS

Electricity Sector

TABLE 33.
Assumptions used in the calculation of electricity sector emissions

Description	Amount	Unit	Source
Operating Margin Grid Emission Factor, gCO_2/kWh (including for use in PCAF GHG accounting)	753	gCO_2/kWh	The IFI Dataset of Default Grid Factors v.3 2021
2018 Global weighted average Capacity factor for Wind Turbines	34%	-	IRENA 2019, FUTURE OF WIND Deployment, investment, technology, grid integration, and socio-economic aspects
Forecast output of the 1.375 MW Wind Farm at Niutoua, funded by Japan	3925	MWh/year	Environment Impact Assessment Proposed Wind Farm, Niutoua, Hahake Districts, Tongatapu Island, 2014
NNUP Project Area Consumption Baseline 2016	33.22	GWh	TA-8345 REG: Due Diligence of Tonga Nuku'alofa Distribution Network Upgrade Project Due Diligence Report
Tonga Load Growth Rate to 2030	5%	-	TPL Projections in Tonga Energy Efficiency Master Plan

Transport Sector

Transport sector has utilised the methodology from 'Tonga's NDC Implementation Roadmap and Investment Plan with Project Pipeline, 2022'. This is based on the estimated vehicle growth, the GHG (or CO_2 emission) and air pollutant emission is calculated for the two scenarios (i.e. BAU and BTB). The parameters considered in sequence for calculation of emissions are shown in Table 32.

TABLE 34.
Parameters considered for calculation of GHG emissions – transport sector

Parameter	Emission Modelling[115]
Vehicle kilometres travelled (VKT) and Passenger kilometres travelled (PKT)[116]	For both scenarios • VKT (for each vehicle segment) = vehicle stock x annual distance travelled • PKT (for each vehicle segment) = VKT x Average occupancy of respective vehicle segment
Vehicle technology/ fuel mix (petrol, diesel, and electricity)[117]	Vehicle segment wise percentage distribution across fuel mix in base year
Vehicle fuel efficiency[118]	The efficiency of vehicle in each segment will see an improvement of 0.5% for ICEV and 0.2% for BEV across vehicle segments for every L/100km or kWh/100km

115 The data has been provided and validated by local experts
116 VKT is the measure of the total annual distance travelled by the vehicle stock in a given year. PKT is the measure of total passenger kilometres travelled in a year. It is the product of the occupancy factor and the VKT of the vehicle segment.
117 Vehicle fuel mix is the distribution of vehicle across various fuel types
118 Vehicle fuel efficiency is a measure of average unit consumption (L or kWh) of a vehicle segment for every kilometre run

<table>
<tr><th>Parameter</th><th>Emission Modelling</th></tr>
<tr><td>Well to wheel emission factor[119] by fuel type</td><td>To estimate the emissions caused by fuels (gasoline, diesel and electricity) for the base year (2021), the emissions (KgCO_2) per unit (L/ kWh) is determined using the calorific value[121] for the liquid fuel (Gasoline and Diesel) and grid emission factor[120] for electricity. All the fuel types are converted to a single unit (KgCO_2/Lge), to bring all the fuels types to an equivalent unit.

For Gasoline and Diesel

• The emission factor for the gasoline and diesel (KgCO_2/Lge) remains constant across all the years.</td></tr>
<tr><td>Well to wheel emission factor[122] by fuel type</td><td>For electricity

• The emissions due to electricity will vary based on the renewable and non-renewable share in the country.
• As it is mentioned in TERMPLUS that Tonga is emphasising to have 70% of electricity generated from renewable sources by 2025 and 100% by 2035, impact on grid emission has been calculated over year.

Emission factor

• Fossil Fuel Emission Factors for Tonga are in accordance with methodology outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
• The emission factors are given below:

Tank to Wheel CO_2 emission factor

<table>
<tr><th>Fuel Type</th><th>Emission factor</th></tr>
<tr><td>Diesel</td><td>2.55 Kg CO_2e/Lge</td></tr>
<tr><td>Gasoline</td><td>2.35 Kg CO_2e/Lge</td></tr>
<tr><td>Electric - Tonga</td><td>-</td></tr>
</table>

Well to Tank CO_2 emission factor

<table>
<tr><th>Fuel Type</th><th>Emission factor</th></tr>
<tr><td>Diesel</td><td>0.26 Kg CO_2e/Lge</td></tr>
<tr><td>Gasoline</td><td>0.54 Kg CO_2e/Lge</td></tr>
<tr><td>Electric – Tonga</td><td>0.67 Kg CO_2e/kWh (2010)</td></tr>
</table>
</td></tr>
</table>

[119] Well-to-wheel emission factor is a combination of well-to-tank and tank-to-wheel efficiencies. Well-to-tank efficiency is an efficiency from fuel extraction to transportation to supply to storing in a fuel tank of a vehicle Both are considered in same units (i.e. KgCO_2/Lge)

[120] Calorific Value is the energy contained in a fuel, determined by measuring the heat produced by the complete combustion of a specified quantity of it. This is now usually expressed in joules per kilogram

[121] Grid emission factor refers to a CO_2 emission factor (tCO_2/MWh) which will be associated with each unit of electricity provided by an electricity system

[122] Well-to-wheel emission factor is a combination of well-to-tank and tank-to-wheel efficiencies. Well-to-tank efficiency is an efficiency from fuel extraction to transportation to supply to storing in a fuel tank of a vehicle Both are considered in same units (i.e., KgCO_2/Lge)

Intended

Intended

Intended

Intended

TERM PLUS

TONGA ENERGY ROAD MAP

2021-2035

DEPARTMENT OF ENERGY
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