# ZERO-ENERGY TRANSITION, TONGA

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# ZERO-ENERGY TRANSITION, TONGA

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# I. General background

The Kingdom of Tonga is an archipelago located in the Pacific of 176 islands comprising 36 inhabited islands with a land surface area is about 750 km$^2$ scattered over an Exclusive Economic Zone of about 700,000 km$^2$. Its population of over 100,000 inhabitants enjoys a middle-income standard of living. The country's GDP in 2020 was USD 488 million (in current USD) and USD 707 million in PPP parity (USD, 2020), or USD 4,625 and USD 6,700 per capita, respectively[1]. About 70% live on the largest island, Tongatapu, and about one-quarter in the capital Nuku'alofa.

Tonga has a narrow export base in agricultural goods (agricultural exports make up two-thirds of total exports). The country remains dependent on external aid and remittances (USD 205 million, 2021) from overseas[2] Tongans to offset its trade deficit. Tonga shares several characteristics with other small Pacific Island economies such as remoteness, limited diversification, small domestic market, narrow resource base, scarcity of skilled labour and high exposure to natural disasters. Tonga is especially vulnerable to climate change and natural disasters and is. In recent years, Tonga was particularly hit by large cyclones (Ian in 2014 and Gita in 2018) and the eruption of the Hunga-Tonga-Hunga-Ha'apai volcano[3]. According to the World Risk Report 2021 (BEH, 2021) Tonga was ranked the third highest disaster risk country globally[4],

The government of Tonga has successfully quarantined its population from COVID-19, although there have been about 16,182 cases and 12 deaths in the period 03 January 2020 – 28 September 2022[5]. Tourism had been the second-largest source of hard currency earnings (about 15% of GDP before the pandemic) and has been protracted considerably as a consequence of the COVID-19 border closures.

**Macroeconomic and public financial management framework**

When the ESRC was designed, Tonga's annual budget process was considered relatively strong and credible on an aggregate level with expenditure and revenue outturns broadly matching budget plans. In addition, a medium-term budget framework (MTBF) for some priority sectors was expected to be developed in FY 2012-2013, with ADB support, thus helping ensure fiscal discipline and enabling strategic allocation of resources.

In terms of funding to the energy sector, the implementation of TERM priorities had been largely dependent on donor financing (NZ, Japan, UAE, WB), implemented in the context of on-budget projects (amounting to some USD 40M). The fiscal space in the Government's budget to spend in the energy sector has remained very shallow, following the 2008/9 financial crisis.

Growth was expected to remain modest at 1.2% in FY 2012/13 taking into account projected record grants from donors at 11.6% of GDP in FY12/13. Inflation had been on a downward trend from 6.1% in FY10/11 to 4.6 % in FY2011/12 and was expected to remain at 4.5% during FY 2012/13 as a result of the stabilisation of import prices and exchange rate appreciation. Foreign reserves, thanks to donor inflows, had been maintained at 5.9 months of import cover.

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1 Population size was 100,209 according to the 2021 Census. Source data: Evaluation Terms of Reference; *Report for Selected Countries and Subjects,*. 2020 (www.imf.org); *World Indicators* (data.worldbank.org)

2 More than double the population of about 100,000 lives abroad

3 The eruption of the Hunga-Tonga-Hunga-Ha'apai volcano on 15 January 2022 was the largest recorded since the eruption of Krakatoa in 1883. The eruption triggered tsunami waves of up to 15m which struck the west coast of Tongatapu, 'Eua and Ha'apai. Ashfall covered an area of at least five km$^2$. Source: https://reliefweb.int/disaster/vo-2022-000005-ton

4 Impacts mentioned include seismic activity with earthquakes and tsunamis; frequent tropical cyclones with damaging winds (often between 22-65 knots), rain and storm surges; droughts, and sea level rise.

5 https://covid19.who.int/region/wpro/country/to

Overall, the macroeconomic conditions were expected to marginally improve over the short term. The Government had reduced its expenditures and, while acknowledging fiscal vulnerabilities in June 2012, the IMF noted earlier that the authorities continued to show expenditure restraint. The government's medium-term fiscal framework expected substantial reductions in recurrent spending of 3.5% of GDP by FY2016/17. The World Bank was considering that the country's macroeconomic policy stance was satisfactory and sustainable over the medium term, though requiring continued support from development partners.

With regards to public finance management (PFM), progress was noted since 2008, with the Government undertaking measures to support domestic resource mobilisation and expenditure control. The 2010 PEFA report captured this progress, with 12 indicators showing an improvement. Other areas showing progress included payroll, budget preparation, and accounting. While the annual budget preparation process was perceived as relatively strong, budget execution and reporting were perceived as more challenging areas, with in particular a limited coverage of in-year budget reports, excessive use of the contingency fund and the lack of access to key budget information. A related challenge was the lack of scrutiny of the budget by the auditor general and by Parliament. Nevertheless, the structural capacity to implement PFM reforms was considered adequate. In 2012, progress towards the implementation of a Treasury Single account for all government-funded operations, a better alignment of government expenditure with mid-term policy objectives and priority sectors as well as some policy works to improve revenue effort (e.g., presumptive tax for small and medium-sized enterprises) was noted.

**Development and environmental policy**

The **Tonga Strategic Development Frameworks (TDSF**) 2011-2014 provide the overarching frameworks for the long-term development of the Kingdom of Tonga. These entail guiding principles and directions for the formulation of sector plans, ministerial corporate plans and the medium-term budgetary framework, facilitating more consistent and integrated planning. The 2011-2014 TSDF had nine Objectives, with infrastructure referred to in Objective no. 3 “Appropriate, well planned and maintained infrastructure that improves the everyday lives of the people and lowers the cost of business, by the adequate funding and implementation of the National Infrastructure Investment Plan”, in which the topic of energy specifically referred to in Strategy 11 “Maintaining and where possible expanding the provision of reliable and cost-efficient power supplies, using traditional and renewable options, to all communities”.

The **TSDF II (2015-2025**) has the vision of achieving “a more progressive Tonga supporting a higher quality of life for all”, translated into seven National Outcomes to be achieved via a set of 29 Organizational Outcomes that are grouped into five Pillars. Relevant to the topic of sustainable energy is Pillar 4, Organizational Outcome 4.1 “More reliable, safe and affordable energy services” which is significantly linked with the National Outcome E “A more inclusive, sustainable and successful provision and maintenance of infrastructure and technology”. Energy-specific targets under this Outcome are a) 13% or below total system losses, b) reduction in average total duration of power interruption per customer by more than 50%, and c) 50% renewable energy usage by 2025[6].

Tonga’s first **Nationally Determined Contribution (NDC)** of 2015 states the following climate change mitigation targets a) 50% of electricity generation by renewable energy sources in 2020 and 70% in 2030 (from a baseline of 9% in 2015), and b) Improved energy efficiency through reduction of electricity line losses to 9% by 2020 (from a baseline of 18% in 2010), c) 100% electricity access by 2020. The updated Second NDC was submitted to UNFCCC in 2020 (see *Figure 4* for a summary of energy-relevant facts and targets). **Tonga Climate Change Policy (TCCP)** of 2016 intends to make Tonga climate-resilient by 2035 and enhance mitigation efforts. Its vision is for ‘A Tonga that is resilient to the impacts of climate change and climate-related disaster risks and is able to protect and safeguard its present and future citizens.’ The **Joint National Action Plan II Climate Change and Disaster Risk Management** (JNAP II) 2018-2028 provides the strategic action plan for both the TSDF II and TCCP. Its guiding principles were replicated in the Tonga Low-Emission Development Strategy (LT-LEDS 2021-2050, see Figure 4).

[6] And moderately linked with the National Outcomes A (A more inclusive, sustainable and dynamic knowledge-based economy knowledge-based economy), B (A more inclusive, sustainable and balanced urban and rural development across island groups), and F (A more inclusive, sustainable and effective land administration and environment management, with resilience to climate change and risk)

Shaped by the TSDFs, the **Tonga National Infrastructure Investment Plan (NIIP**) outlines priorities and plans for major infrastructure initiatives for the period 2013 – 2023 in energy (electricity, fuel), telecommunications (telephone, internet, broadcasting), water and waste-related services (water supply, wastewater, drainage, solid waste), and transport (airports, roads, seaports). Reliable and affordable energy is one important theme and the strategy espoused under the NIIP entrenches the intentions of the Tonga Energy Roadmap (TERM 2010). NIPP II will be superseded the NIIP III (2020-2030).

# II. Energy and power

**Energy situation *before* TERM**

Given Tonga's isolation, smallness, and lack of resources (petroleum, gas or hydro), Tonga relies heavily on fossil fuels to meet the energy needs of its economic and social developments. The cost of petroleum is high, and its use causes negative environmental impacts.

Before TERM was initiated, the total primary energy supply (TPES) was 2074 TJ of which 75% was provided by imported fossil fuels (diesel, motor gasoline and LPG) with the remainder coming from biomass (2010 figures). About one-third of fossil fuels were used in the form of diesel (489 TJ) for power generation. Only 0.3% of electricity was provided by renewable energy. Electricity was supplied through the national grid, with 89% of all households being connected to the grid. The fuel import bill was tremendous, accounting for about 25% of all imports and about 10% of GDP. The volatility of prices of oil and oil products continues to have a significant impact on Tonga's balance-of-payments situation. Also, high prices of diesel lead to the highest electricity tariffs and negatively affect the economic activity and quality of life of Tongans. Electricity tariffs are high in Tonga compared with those in other countries that import fossil fuel for power generation, because of its remote location and the high cost of transport.

***Figure 1: OPEC oil price development***


Source: https://www.statista.com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/

The state-owned Tonga Power Limited (TPL) has concessions to operate four independent grids; the largest, which is on the main island of Tongatapu, and three smaller grids on the main islands of the 'Eua, Ha'apai, and Vava'u island groups. The combined peak demand in the four grids was about 9.5 MW and 11.3 MW in 2010 and 2021 respectively. Energy generation was 50.89 gigawatt-hour (GWh) and 73.6 GWh for same period. The billed energy was 42.92 GWh, implying system losses of 15.7% in 2010[7]. Electricity generation was forecasted in TERM to grow to about 66.3 GWh, which would imply the need for new diesel generation capacity to meet the 2020 peak demand of 12.8 MW and diesel fuel requirements growing from 13.3 million litres in 2010 to 18.85 million litres in 2020.

[7] Based on data in TERM 2010-2020

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The 'Outer Islands' (OI's) of Tonga are a group of 26 islands scattered throughout the three primary island groups of Tonga and are outside TPL's concession area. With a population of about 6,000 people, these had been provided with solar energy and small diesel generation projects with varying levels of success. The cost of electricity in the OI's (an estimated average of USD 0.75 per kilowatt-hour, 2016) has been much higher than in the TPL concession islands (an average USD 0.33 per kWh in 2016) [8]

**Tonga Energy Road Map (TERM)**

During 2009 and 2010, a number of studies focusing on Tonga's renewable energy options, energy demand, energy conservation options and donor and institutional requirements were produced forming the basis of the "Tonga Energy Road Map 2010 - 2020" (TERM). In 2009, the GoT approved the goal of 50% of electricity to be generated from renewable energy sources which would become the centrepiece of TERM. Different policy documents did provide different target years; the NDC mentions the 50% goal to be reached by 2020, while the TSDF II revisited the original TERM goal of 50% renewable power from 2012 to 2025.

TERM sets out a ten-year road map to reduce Tonga's vulnerability to oil price shocks and achieve an increase in quality access to modern energy services in an environmentally sustainable manner. The TERM itself did not provide operational guidelines, milestones and performance benchmarks. It is more of a guiding document for GoT actions and development partner support to the energy sector. The TERM contemplates significant improvements in the two energy major subsectors, power and petroleum, considering a range of possible interventions and provides:

- Technical assessment, cost estimates and recommendations of the least cost approach to reducing the cost of petroleum, reducing Tonga's dependence on petroleum for power generation and increasing accessibility as fast as possible;
- Actions in the policy, legal, regulatory and institutional areas necessary to implement the plan;
- Sources of funding and financing strategy; and
- indicative implementation plans.

The least-cost interventions include:

Improvements in the supply chain to reduce the price and price fluctuation of imported petroleum products;
- Efficiency of conversion of petroleum to electricity (including reduced losses at Tonga Power Ltd. (TPL);
- Efficiency of conversion of electricity into consumer electricity services (demand-side management);
- Replacing a portion of current or future grid-based generation with renewable energy.

The implementation of the TERM has been expected to contribute to better energy security; greater tariff stability; improved affordability; and greater accessibility to electricity for the people of Tonga. It has been expected to address the need to reduce dependence on imported oil for electricity generation and to reduce the vulnerability of electricity consumers to oil price shocks. It foresees that improved efficiency in supply and demand would play a major role, together with renewable energy options.

## Other energy policy documents

The *Renewable Energy and Energy Efficiency Plan II (2016 – 2020) (REEEP II)* defines strategic priorities in energy supply efficiency, energy demand efficiency, renewable energy share in electricity production, and access to remote rural communities in Tonga. In 2016, REEP II was integrated into the revised TERM. A monitoring and evaluation framework was also incorporated.

The Government launched the *Tonga Energy Efficiency Master Plan (TEEMP)* in 2018, which complements TERM and builds on the greenhouse gas emission baseline assessments of the NDC, focusing on energy efficiency improvement interventions in the power sector and transportation. Regarding electricity, proposed interventions are:

- Adoption of minimum energy performance standards (following Australian and New Zealand standards for all fridges, freezers, air conditioners, water heaters, televisions, computers, clothes washing machines, dryers, and cooking appliances);

[8] TERM 2010-2020; ADB Outer Island Renewable Energy Project (RRP TON 43452-024), Sector Assessment

- Curtailment of import of non-LED bulbs,
- 50% electricity generation from renewable sources,
- Incentives for the adoption of TPL's existing net-metering program,
- Reduction of line losses to the lowest feasible amount by 2030.
- Implementation of building standards covering energy efficiency and performance of energy audits for all large customers by 2025,
- Reducing the uptake of electric water heaters, particularly those with tanks, by incentivizing the purchase of solar water heaters,
- Complete retrofitting of streetlights with LED bulbs,
- Establishment of a Green Hotel Accreditation program and leverage the Ministry of Tourism's existing accommodation guide to review hotels based on these standards.
- Implementation of a revolving loan program through the Tonga Development Bank to assist private entities in financing energy efficiency and net-metering projects,
- Establishment of an integrated resource planning process with TPL to identify how energy efficiency and renewable targets will be met in specific detail. Use this planning process to identify the cost-effectiveness of other potential options, such as refurbishing or replacing diesel generators to increase efficiency.

**Institutional setup**

In Tonga, two oil companies, Total and Pacific Energy SWP Ltd , are responsible for all imports of petroleum products. For their operations, these companies require storage facilities for oil products. Wholesale and retail fuel prices across Tonga vary, reflecting the higher transport costs to provinces distant from the main island, Tongatapu. However, in each province, a single price is set regardless of the supplier. Direct shipments from Singapore have been under discussion since 2010, but these have not materialized and no changes to the supply chain have been implemented during the period 2010-2020[9].

**Tonga Power Limited (TPL)** is solely responsible for providing grid-connected electricity services in Tonga. TPL is a vertically integrated public enterprise wholly owned by the government; TPL generates, distributes, and retails electricity, and provides operation and maintenance services. TPL undertakes the expansion and investment planning for the four grids under its concession contract in the 'Eua, Ha'apai, Tongatapu, and Vava'u islands. Tariff setting is regulated by the Electricity Commission on the four main islands covered by TPL's concession.

Tonga's electricity sector was re-structured in 2008 when the Government established the Electricity Commission (EC) through the Electricity Act 2007 and purchased the electricity assets from a privately owned entity. The functions of the EC include the regulation of tariffs, establishing consumer service standards, managing electrical safety, as well as licensing electricians, and creating regulations for major electrical works. Tonga Power Limited (TPL) operates under a strict regulatory framework through the Electricity Concession Contract (ECC) in which tariffs, operational efficiency benchmarks, consumer service standards and penalties are specified between the EC, the Government and TPL.

TPL has its own Company Constitution and also operates under the Public Enterprises Act 2010 which provides greater commercialization incentives for state-owned corporate entities. TPL is entrusted with enforcing the Electricity Act and regulations. Furthermore, TPL has been established with an independent Board of Directors drawn from the commercial sector of Tonga, appointed by the Government.

The **energy sector** had been under the dispersed responsibility of seven separate ministries until the 2012 government's structural reform, which made four ministries and the Prime Minister's office responsible for the Tongan energy sector:

- TPL is the state-owned power utility under the Ministry of Public Enterprises;
- Overall responsibility for electricity sector policy and planning is shared by the Prime Minister's Office and the Ministry of Finance and National Planning (MFNP), renamed Ministry of Finance in the 2019 cabinet and thereafter
- A Department of Energy (DoE) was set up under the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change, and Communications (MEIDECC) with responsibility for energy policy, planning, monitoring and regulation of the sector.

[9] TERM 2010-2020; GGGI (2020)

- All transport-related responsibilities that include land, maritime and aviation sub-sectors come under the Ministry of Infrastructure (MOI).
- TERM was initially managed by TERM-A as a government agency (under the Prime Minister's Office) and overseen by a TERM Committee (TERM-C) but these functions were merged with the newly created DoE in 2014.

Relevant other donor interventions and coordination

At the time of designing the first ESRC, the fiscal space in the Government's budget to spend on the energy sector was very shallow, following the 2008/9 financial crisis, and this remained. In terms of funding to the energy sector, the implementation of TERM -priorities had been largely dependent on donor financing (NZ, Japan, UAE, WB), implemented in the context of on-budget projects (amounting to some USD 40 million).

The ESRC was expected to complement parallel on-budget project funding in the energy sector by other development partners (Japan, UAE, NZ, WB) and thus enhance the discretionary spending space for Government to implement the TERM[10]. The budget support operation was also intended to further promote the pursuit of a credible stability-oriented macroeconomic policy, satisfactory progress in the implementation of the Tonga PFM Reform Programme as well as public availability of timely, comprehensive and sound budgetary information.

The ESRC was to be accompanied by an EU-funded Technical Cooperation Facility (FED/2013/024766) of EUR 0.472 million) to support the National Authorising Officer (NAO), promote good governance and to increase the capacity of non-state actors. In 2013, the GoT developed a costed renewable energy and energy efficiency sector plan. It was expected that these investments would continue to be financed by development partners. When the ESRC II has been formulated, the pipeline of investments entailed projects that were: under implementation (ex: Micro-Wind Project, Ha'apai Cyclone Ian Reconstruction, Tonga Village Network Upgrading Project), committed (OIREP), under development or in the feasibility stage (e.g., Tongatapu Windfarm, tidal power) or seeking funding (ex: Nuku'alofa Grid Upgrading Project, 'Eua Biomass). The current status of projects is discussed in the next section. The "Outer Island Renewable Energy & Energy Efficiency Programme in Tonga" (OIREEP) has been implemented by ADB (total investment of USD 23.64 million) with an of EUR 3 million from the regional 10th EDF[11].

**Activities undertaken and support received during TERM**

The Term 2010-2020 included an indicative implementation plan that was divided into three phases. The first phase (phase 0) focused mainly on institutional strengthening and legal framework; the second phase (phase 1) includes investments in energy efficiency and renewable energy (proof of concept); the third phase is expected to promote private sector participation (independent power producers, IPPs), further investments in energy efficiency and renewable energy and their institutionalization and regulatory reform (see *Table 1*)

TPL electricity networks

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% (16% actually in 2011) to below a targeted 9%[12] (11% in 2020)[13] with the help of the NNUP project in Nuku'alofa and OIREEP project in Vava'u. A total of 15,000 smart meters have been installed in Tongatapu (covering 91% of customers in 2020).

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10 The ESRC had been built upon the VFLEX budget support programme which was disbursed in FY2011/12 (EUR 5.5M) and was aligned with the Asian Development Bank (ADB) budget support programme. AusAID, New Zealand (NZ) and the World Bank (WB) also disbursed budget support in the FY2011/2012 following progress in achieving the budget support matrix's indicators.

11 In addition, the regional 10th EDF programme entailed a TVET component implemented by SPC which supported the delivery of a certificate in Resilience in partnership with the Tongan Training Institutes and Industry as well as an" Adaptation to Climate Change and Sustainable Energy" component implemented by GIZ. The latest was supporting some costal protection activities

12 Based on TERM Plus document

13 Line losses down from 13.2% in 2011 to 8.1% in 2020 (TPL, 2020)

Of the 18,005 households, 16,662 were connected as TPL customers, while about 800 households (in the outer islands) are off-grid power or small diesel systems, according to the 2016 Census implying electrification access of 93-97% (without or with isolated systems). TPL had 23,607 customers in June 2020[14].

Renewable energy

TPL, with the help of MEIDECC, DoE and development partners has implemented multiple renewable electricity projects and made substantial improvements to its 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 (see *Figure 2*). Over the period 2010-2020 the installed renewable energy capacity in the TPL-managed networks and installed by third parties and individual solar PV on the four islands increased from negligible to about 6.9 MW, 28% of the total generation capacity of 25 MW in 2020, through a number of solar and wind energy projects, summarized at the bottom of *Table 1.*

The TREP project will form the biggest contributing factor that will bring up the RE penetration to achieve the 50%. The project covers four areas: 1) an increase in the number of solar plants installed through private sector investment; 2) an increase in wind power capacity (aside from the JICA and China-supported wind power projects); 3) increasing battery energy storage (BESS)[15], and 4) mini-grids for outer islands to increase access to a modern electricity supply. The ADB-supported OIREP project has also supported small distributed generation (with a target of 1.25 MW).

Energy Bill

A key outcome of TERM has been the Tonga Energy Bill which provides a fundamental policy shift from Tonga's current institutional-legal energy structure. Tonga's Energy Bill 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 as the focal point for all energy matters.
- Establish an Energy Commission, ensuring energy security and enforcing regulations[16].
- Promote private sector incentives and alleviate many of the challenges IPPs face today within 12 months of the commencement of the anticipated Energy Act, a national energy policy will be developed as the successor to the TERM policies (2010–2020).

Energy efficiency

For the period from 2010 to 2020, there have been several initiatives to increase energy efficiency in specific areas. Examples[17] include:

- Replacement of 109 HPS street lights with LED lights along the Vuna Road under the PEEP-1 pilot project (ADB 2011),8 replacement of 161 HPS street lights with LED lights in the Outer Islands, replacement of 135 HPS street lights with LED lights in Tongatapu, and replacement of T8 fluorescent lamps with more efficient T5 florescent lamps in residential, commercial and public sector in Tongatapu and the Outer Islands under PEEP-2 project
- Distribution of energy-saving light bulbs to 15,000 consumers
- Conducting comprehensive energy audit training and practical on-site training, developing standards,
- Conducting studies on consumer behaviour/usage of electricity (in-country interviews).

[14] Population was 100,651 people in 2016, and 100,209 people in 2021 (preliminary results 2021 Census) TPL had 23,607 customers in June 2020

[15] This will enable a large share of variable renewable energy sources, solar and wind, to supply to the TPL grid

[16] Its functions will include a) ensuring the safety, affordability, and security of supply of energy, b) monitoring and enforcing standards and regulations, c) regulating price and quality, d) administration and maintenance of energy assets, e) recommending the establishment of new or revised standards or regulations.

[17] Taken from GGGI (2020)

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***Table 1: Main projects and activities during TERM 2010-2020***

| | Phase I (2014-2019) | Phase II (2017-2019) | Phase III (2018-2020) |
|---|---|---|---|
| **Projects and funding** | | | |
| Renewable energy – 50% electricity generation by 2030 | • Outer island Energy project (OIREP) – USD 29.18 M<br>o ADB loan (USD 2.5 M)<br>o ADB grant (USD 11.44 M)<br>o GEF (USD 2.64 M)<br>o Australia (USD 6.72 M)<br>o Denmark (USD 0.75 M)<br>o EU (USD 3.57 M)<br>o GoT (USD 1.57 M) | • IPPs (solar) – USD 5 M<br>• Wind farms (JICA, China) – USD 10-15 M | • Tonga Renewable Energy Project (TREP) – USD 53.2 M<br>o ADB grant (USD 12.2 M)<br>o GCF (USD 29.9 M)<br>o Australia (USD 2.5 M)<br>• GoChina wind farm (Tonga |
| Energy efficiency: 9% power grid losses by 2020 | • Cyclone Ian recovery project (rehabilitation Ha'apai grid) – USD 2.5 M<br>o ADB (USD 2 M)<br>o TPL (USD 0.5 M)<br>• Tongatapu-Tonga Village Network project<br>o New Zealand (USD 37.5 M) | • Tongatapu Smart Metering (USD 5.6 M)<br>o New Zealand (USD 0.6 M)<br>o TPL (USD 3 M) | • Nuku'alofa Network Upgrade project (NNUP; USD 14.8 M)<br>o ADB grant (USD 6.8 M)<br>o New Zealand (USD 8 M)<br>• Tonga Cyclone Gita Recovery Project (TCGRP; ADB, USD 6.M) (repair damage Nuku'alofa grid) |
| **ESRC** | **ESRC I (2013-2016, extended 2017-2019** | | |
| | • Budget: EUR 7,488,000<br>o Budget support: € 7.05 M, evaluation: € 0.088 M, technical assistance: € 0.35 M)<br>o 2013: EUR 6.488 M; topped up in 2014 with € 1 M) | | |
| | Achievements:<br>• RE in electricity. Target: 8%, realized: 8% (2015)<br>• EE (grid losses). Target: 11%, realized: 12% (2015)<br>• Rebuilding of lines in Ha'apai | | |
| | | **ESRC II (2016-2019, extended 2020-2022)** | |
| | | • Budget: EUR 11,990,000<br>o Budget support: € 11.89 M; evaluation: EUR 0.1 M<br>o 2016 : EUR 9.9 M ; 2018 : top up with € 1.99 M for TC Gita recovery efforts | |
| | | Achievements:<br>• RE in electricity. Target: 20%, realized: 10.8% (2019)<br>• EE (fuel efficiency generation). Target: 4.12 kWh/litre, realized: 4.41 kWh/litre (2019) | |

**Results and projects** (as reported by TPL and in TERM Plus documents)

| | 2010 | 2015 | 2019/2020 |
|---|---|---|---|
| Fossil fuel consumption | 1513.8 TJ | 1712.9 TJ | 1565.7 TJ |
| Share of fossil fuels in TEPS | 73% | 79% | 77% |
| Access to electricity | 90-93%% | 93-96% | 95-98% |
| Total electricity installed (TPL) | 9.5 MW | 18 MW | 25 MW |
| - share of renewable energy | 0.5% | 3 MW (16%) | 6.9 MW (26%) |
| Total electricity generated (TPL) | 50.89 GWh | 56.84 GWh | 77.98 GWh |
| '- share of renewable energy | 0.3% | 8% | 9.36 GWh (12%) |
| Electricity consumed | 42.92 | 50,739 MWh | 69,815 MWh |
| Losses | 15.7% | 10.8% | 10.5% |
| '- Line losses | 15% | 8% | 7.6% |
| '- diesel (litre per kWh) | 4.15 | 4.35 | 4.41 |
| Tariff (TOPc/kWh) | | 69.9 | 61.0 |

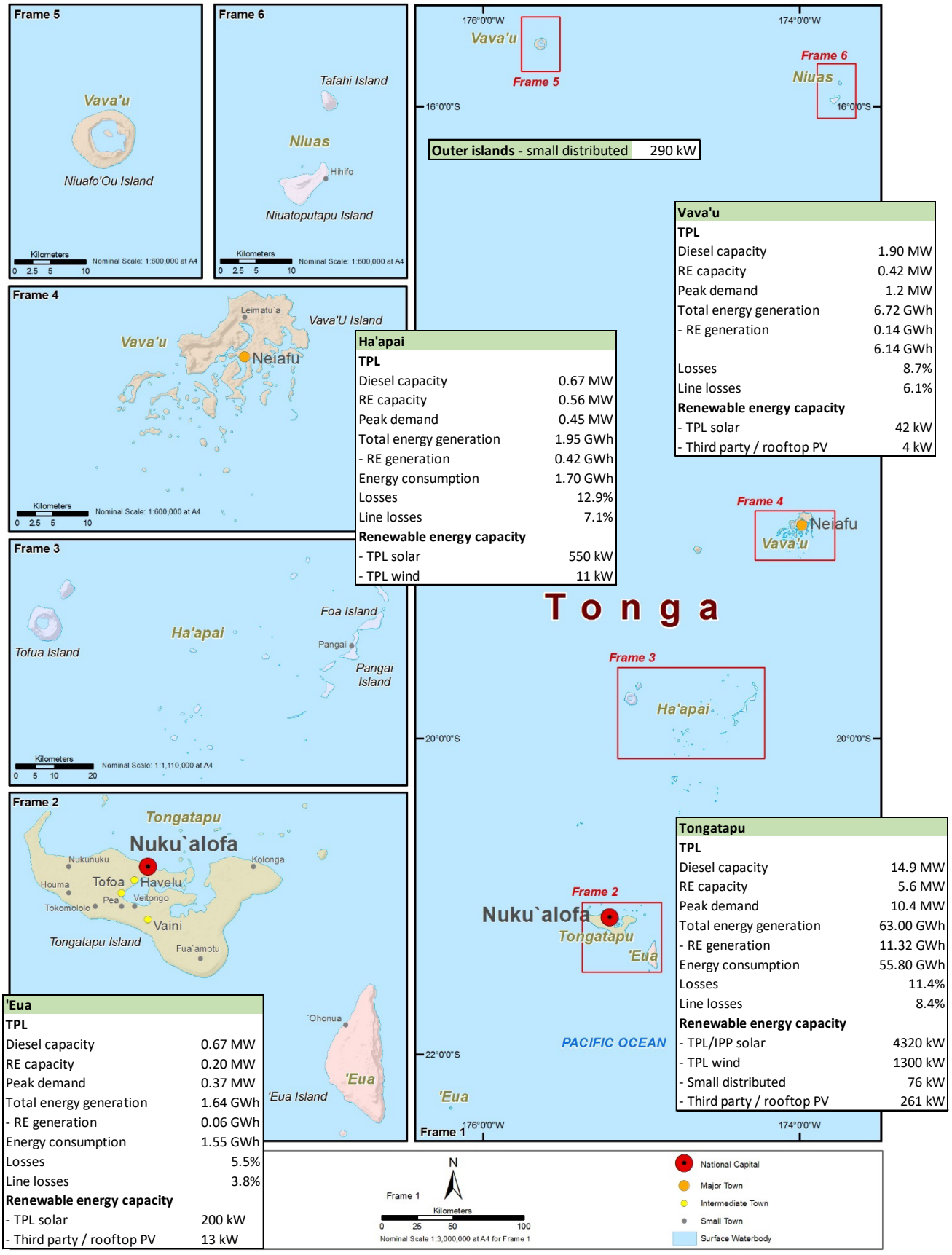
**Realized renewable energy projects**

| | 2013-2016 | 2017-2021 |
|---|---|---|
| Tongatapu TPL | Maama Mai solar (1320 kW), 2015<br>Mata 'o e La'a solar (1000 kW), 2015 | Matatoa solar (Singyes IPP – 2000 kW), 2017<br>Ii 'o Manumataongo wind (1300 kW), 2019 |
| Ha'apai TPL | Ha'apai wind (11 kW), 2015 | Ha Mai solar (550 kW), 2017 |
| Vava'u TPL | La'a Lahi solar (420 kW), 2013 | |
| 'Eua TPL | Huelo 'o e Funga Fonua solar (200 kW) | |
| Other | Small distributed generation (Tongatapu, 76 kW; Outer Islands, 290 kW)<br>Third-party and rooftop PV (Tongatapu, 261 kW; Vavaú 4 kW; 'Eua 13 kW) | |

Sources: data compiled from TPL (2020), GGGI (2020), TEAM 2021-2030

***Figure 2: Electricity supply and demand in Tongan island groups 2019/2020***

Based on data provided in TPL (2020), GGGI (2020), TEAM 2021-2030, TPL website




| Vava'u | |
|---|---|
| **TPL** | |
| Diesel capacity | 1.90 MW |
| RE capacity | 0.42 MW |
| Peak demand | 1.2 MW |
| Total energy generation | 6.72 GWh |
| - RE generation | 0.14 GWh |
| | 6.14 GWh |
| Losses | 8.7% |
| Line losses | 6.1% |
| **Renewable energy capacity** | |
| - TPL solar | 42 kW |
| - Third party / rooftop PV | 4 kW |

| Ha'apai | |
|---|---|
| **TPL** | |
| Diesel capacity | 0.67 MW |
| RE capacity | 0.56 MW |
| Peak demand | 0.45 MW |
| Total energy generation | 1.95 GWh |
| - RE generation | 0.42 GWh |
| Energy consumption | 1.70 GWh |
| Losses | 12.9% |
| Line losses | 7.1% |
| **Renewable energy capacity** | |
| - TPL solar | 550 kW |
| - TPL wind | 11 kW |

| Tongatapu | |
|---|---|
| **TPL** | |
| Diesel capacity | 14.9 MW |
| RE capacity | 5.6 MW |
| Peak demand | 10.4 MW |
| Total energy generation | 63.00 GWh |
| - RE generation | 11.32 GWh |
| Energy consumption | 55.80 GWh |
| Losses | 11.4% |
| Line losses | 8.4% |
| **Renewable energy capacity** | |
| - TPL/IPP solar | 4320 kW |
| - TPL wind | 1300 kW |
| - Small distributed | 76 kW |
| - Third party / rooftop PV | 261 kW |

| 'Eua | |
|---|---|
| **TPL** | |
| Diesel capacity | 0.67 MW |
| RE capacity | 0.20 MW |
| Peak demand | 0.37 MW |
| Total energy generation | 1.64 GWh |
| - RE generation | 0.06 GWh |
| Energy consumption | 1.55 GWh |
| Losses | 5.5% |
| Line losses | 3.8% |
| **Renewable energy capacity** | |
| - TPL solar | 200 kW |
| - Third party / rooftop PV | 13 kW |

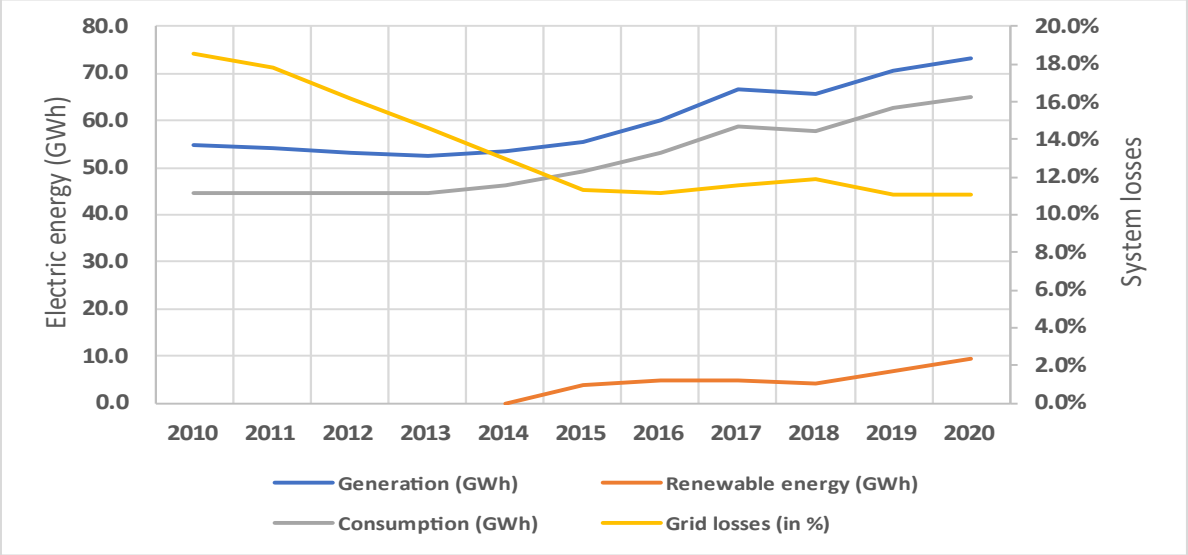
# ZERO-ENERGY TRANSITION, TONGA

Summary assessment of TERM progress

The dependence on fossil fuels increased in both absolute and relative terms between 2010 and 2020. Fossil fuel supply consists entirely of oil products, with diesel (70%), motor gasoline (16%), and LPG (7%) accounting for more than 90%. Approximately a third of the fossil fuel supply is used for electricity generation (transformation), while two-thirds are used for direct final consumption. The transport sector accounts for approximately 80%. In order to decrease dependence on fossil fuels, a higher share of electricity would have to be generated from renewable sources and oil consumption in transport would have to be reduced, either by using alternative fuels (biodiesel, ethanol, electricity). It should be noted that TERM 2010-20 did not include any provisions for the transport sector.

In the power sector, the goal of 50% electricity generation from renewables has not been reached. The conversion efficiency for electricity generation from diesel has not increased over the past decade, remaining at approximately 40%[18]. Electricity losses have been reduced considerably. According to data shared by TPL, over the last decade, line losses have been successfully reduced to below 9% of electricity generated for all four networks.

***Figure 3: Electricity production and consumption in the TPL grid systems***




Compiled from TPL annual reports 2010-2020. The year indicate fiscal year, thus "2020" is fiscal year July 2019-June 2020

Despite the introduction of various demand-side measures, there is no overarching policy covering energy efficiency and linking it to other areas. Adoption of the proposed Energy Bill would be a prerequisite for the introduction of appliance standards and labelling (by applying the Pacific Appliance Labelling and Standards, PALS, in Tonga).

## TERM Plus

With technical assistance being provided by the Global Green Growth Institute (GGGI), the GoT has developed a new roadmap for the period 2021-2035, known as TERM Plus, based on the GGGI/GoT assessment of the progress made in the implementation of TERM 2010-2020.

[18] Increasing share of electricity generated from renewable sources requires diesel generators to be used for backup generation. This necessitates running diesel generators at load factors below their optimal capacity, which reduces their efficiency. As a result, diesel consumption per unit of electricity generated from fossil fuels increases. Conversion efficiency is actually assumed to decrease further with higher shares of electricity generation from renewables in Tonga, particularly intermittent solar power. In order to increase conversion efficiency, the role of diesel generators to provide back-up generation would need to be, at least partially, taken over by battery storage (source: GGGI, 2020)

***Table 2: Main elements of TERM Plus (2021-2035)***

| Target | Main actions | Alignment with existing targets |
|---|---|---|
| Electricity from renewable energy:<br>50% RE in 2025<br>70% RE in 2030<br>100% RE in 2035 | • Combination of solar, wind and battery storage displacing diesel (incl. completion of planned RE projects (see *Table 3*), floating solar, decentralized solar, outer island minigrids, and rooftop PV programmes; diesel stand-by strategy)<br>• Financing (incl. green bond funding)<br>• Upgrade of network structure and adoption of electricity networks to accommodate larger share of intermittent/variable output of electricity from renewable sources (feasibility assessments; implement smart grid components, complete smart meter installations; demand/supply load curve studies)<br>• National solar design, installation and maintenance standards<br>• Promotion of biogas and waste-to-energy | Second NDC (8%)<br>LEDS<br>TPL (RAPID project)<br>TCCP |
| Maintain line losses under 8% | | Second NDC (8%)<br>TEEMP |
| Limit growth in oil product consumption in transport to 25% in 2019-2035 (average 1.4% a year) | • Mandatory vehicle standards (emission standards)<br>• Promotion of non-motorised transport (walkways, bicycles)<br>• Low-emission vehicles (electric/hybrid passenger vehicles, incl. taxis and government vehicles; public transportation; maritime electrification; solar tuk-tuks)<br>• Alternative fuel assessments (e.g. biodiesel in transport)<br>• Transport electrification road map<br>• Adoption of minimum energy performance standards and enforcement<br>• Curtailment of import of non-LED bulbs<br>• Increased deployment of solar water heaters and air conditioner retrofits and LED street lamp retrofits<br>• Energy efficiency standards for buildings introduced and enforced<br>• Alignment of price signals for consumers with targets<br>• Public acceptance (research on perception and values) and promotion (e.g., energy audit trainings, green entrepreneurs' programmes and PPPs in energy efficiency)<br>• Financing (private and public)<br>• Financial incentives through tax, fees, import tariffs<br>• Demand-responsive electricity tariffs and off-peak electric vehicle charging | TEEMP |
| Limit growth in residential electricity end-use to 1% per year on average for the period 2021-2035 | | TEEMP<br>TCCP |
| Increase security of supply | • Establish direct shipments of oil products via Singapore<br>• Expand petroleum storage (equivalent to 45 days of net imports)<br>• Develop standards on energy security,<br>• Stock holding requirements and permission to build necessary infrastructure<br>• Financing<br>• Ensure energy infrastructure (T&D) is resilient to sea-level rise; incorporation of resilience in building codes | TERM<br>NIIP2<br>JNAP2<br>Energy Bill |

| TERM and TERM Plus baseline and targets | 2010 | 2020 (target) | 2021 (baseline) | 2035 (target) |
|---|---|---|---|---|
| Fossil fuel imports (TJ) | 1,514 | 1,566 | 2,158 | 1,942 |
| - share of fossil fuel imports in TPES (%) | 73% | 77% | - | - |
| Improved storage (days of supply) | - | - | 36 days | 45 days |
| Electricity generation (RE and fossil fuels) , GWh<br>- share of RE (%) | 54.7 *<br>0.3% | 73.2 *<br>50% | 73.2 *<br>12.3% | 100 **<br>70%**, 100% *** |
| Electricity consumption | 44.5 | 65.1 | 65 | 40 |
| Conversion efficiency diesel-electricity | 39% | 40% | - | - |
| Line demand losses | 15% | 7.6% | 7.4% | < 8% |
| Limit growth in fossil fuel consumption for transport | - | - | 2% a year | < 25% increase |

* Not a target as such mentioned in the TERM; ** in 2030

*** The 100% renewable electricity will require installed capacity of 148.3 MW solar and 21.6 MW wind, along with 20 MW / 273 MWh of BESS. There is a price tag attached to it to the 100% RE (which otherwise would require 15-20 MW of diesel capacity, as cost of generation of 100% RE would be USD 0.438/kWh as compared to the cost at 60% RE generation at USD 0.30/kWh

# ZERO-ENERGY TRANSITION, TONGA

This 'energy roadmap' serves to consolidate and rationalize the energy sector development policies outlined 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. TERM Plus also provides Tonga's energy strategy to exceed its 2020 Nationally Determined Contributions (NDC) of 13 kilotons of $CO_2e$ by 2030, with the potential to deliver cumulative GHG reductions of approximately 580 kilotons of $CO_2e$ by 2030 if all initiatives are implemented.

To achieve this, the TERM Plus follows three principal approaches: a) increase the share of electricity generated from renewable sources using a least-cost approach, b) reduce oil consumption, with a focus on the transport sector for the first time, and c) improve the policy and regulatory environment to support the achievement of Tonga's national energy objectives.

***Figure 4: NDC and LEDS***

The World Risk Report has ranked Tonga as one of the world most at-risk country for natural hazards, and sea level rising. Thus, climate change impacts in the from of loss and damage from extreme weather events (destructive tropical cyclones) and coastal erosions are affecting Tonga's development with damages costing 20% of GDP, according to Tonga's **Nationally Determined Contribution** (NDC, 2015). Tonga makes a negligible contribution to global greenhouse gas emissions, with total emissions in 2006 of 310 kilotons of $CO_2e$ and low per capita emissions of 2.95 $tCO_2e$ (39% from energy use and generation; agriculture and land-use change 61%, waste 0.3%)* , Nonetheless, as a country with much at stake in regard to climate change and variability and natural hazards, Tonga has been strongly committed to climate change mitigation. but the first NDC mentions the following greenhouse gas mitigation targets: a) 50% of electricity generation from renewable sources by 2020 and 70% by 2030; b) improve energy efficiency through reduction of electricity line losses to 9% by 2020 (from a baseline of 18 % in 2010). The adaptation side covers boosting climate resilience (public infrastructures, foreshore protection, buildings and houses) and doubling marine protected areas by 2030. The **second NDC** (2020) reconfirms the 70% RE generation target by 2030 as well as energy efficiency measures** (resulting in a 16 kiloton $CO_2e$ reduction by 2030 in comparison from the 120 $tCO_{2e}$ emissions from energy in 2006) as well as measures in forestry (doing an inventory and planting a million trees by 2023) and expanding formal waste collection.

Aligned to the TSDF II and NDC, **Long-Term Low-Emissions Development Strategy 2021-2050** (LT-LEDS) provides low-emission pathways in the energy, waste, AFOLU (agriculture, forestry and land use), waste and human settlements sectors. The LT-LEDS mentions a number of actions to achieve the energy sector emission reduction goals:

Implement standards and regulations for renewable energy and energy efficiency technologies imported into the country;

- Draft regulation and policy paper for infrastructure developed using green infrastructure standard;
- Renewable energy and energy efficiency to become part of standard education curriculum.
- Draft regulation and policy paper to support roll out of light emitting diode (LED) street lamps and interior LED lamps
- Increase access to finance for the private sector to fund demand-side, renewable energy projects and green initiatives
- Technologies like battery storage to upgrade, maintain and operate a renewable energy network;
- Government to provide a loan program to private sector for low energy buildings;
- Improved transport data collection and waste management;
- Mandatory vehicle standards and incentives for more efficient vehicles through tax, fees and import tariffs;
- Strengthening road maintenance;
- Decentralization of services from urban to rural areas to decrease traffic congestion;
- Introducing electric vehicles (EVs) in the municipal government fleet;
- Low-emission vehicles;
- Strengthen sustainable maintenance of all vehicles
- Implementation of non-motorised and cycling transport options;
- Public adoption of 50% electric vehicles (EVs).

*) When land use and forestry is taken into account, Tonga is a net carbon sink of about 1,682 kiloton $CO_2e$, with its forests absorbing substantially more greenhouse gas emissions than is emitted (NDC, 2015; emission recalculated in 2nd NDC)

**) 2% efficiency gains for new light-duty vejciles, and limiting electricity demand growth to 1% per year

Source: NDC (2015), Second NDC (2020) and LT-LEDS (2021)

# ZERO-ENERGY TRANSITION, TONGA

Based on the finalization of the TREP project and the current baseline of RE IPP and BESS projects (see *Table 3* ), Tonga is able to achieve 54–58% renewable electricity with 17.5–20 MW of renewable system capacity (generating about 35.5 GWh out of out a total of 66 GWh). Coupled with those renewable electricity systems are the necessary short-term grid-integration of battery energy storage systems (BESS) of 5.1 MW / 2.5 MWh and the long-term load-shifting BESS of 5 MW / 17.5 MWh (both recently installed; see *Table 3* )[19].

***Table 3: Planned RE projects 2021 and beyond, contributing to 50% RE goal in 2025***

| | | MW | Battery storage | RE% in generation | Status |
|---|---|---|---|---|---|
| Baseline (RE) | | 6.9 | 0.33 MWh | 12.3% | . |
| Tongatapu | | | | | |
| Sunenergise solar IPP | | 6.0 | | 23% | PPA signed 2019 |
| GET solar IPP | | 6.0 | | | PPA signed 2019 |
| GoChina wind | | 2.2 | | | Contract construction 2020 |
| Wind IPP | | 3.8 | | | To be retendered by TPL |
| TREP BESS 1 | | | 5.1 MW/2.5 MWh | | Installed 2021 |
| TREP BESS 2 | | | 5.0 MW/17.4 MWh | | Installed 2022 |
| TREP 3 solar Vava'u | | | 2 MWh BESS | | Funding approved 2019 |
| TREP 3 solar 'Eua | | | 1.85 MWh BESS | | Funding approved 2019 |

Compiled from TPL Annual Report 2020, TERM Plus (2021-2035, GoT)

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. 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.

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) with a minimum of 34 GWh[20]. 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 is 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

Public-private partnerships utilising private sector funds are an important financing source. Obstacles to attracting independent power producers include the relatively small size of the IPP projects, lower financial returns on investments, perceived high financing and other risks as well as incomplete data from Tonga. These can be addressed by policy de-risking instruments (for example, institutional capacity-building, resource assessments, grid connection and management, and skills development for local operations and maintenance, as well as by financial (e.g., loan guarantees, political risk insurance and public equity co-investments provided by development banks).

[19] Source: TERM Plus 2021-2035 (GGGI,

[20] 30 GWh would be generated by diesel and 70 GWh by renewable energy (of which 19.6 MW of solar and wind capacity in construction or operation, 16.5 GWh in negotiation and 34 GWh subject to TPL's recent for tender.

# ZERO-ENERGY TRANSITION, TONGA

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 (bioenergy, or ocean energy) and 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 electric vehicle-to-grid systems.

***Table 4: Installed capacity and cost of energy towards a 100% RE goal***

| Diesel | Solar | Wind | BESS | RE share | Cost of generation (USD/kWh) |
|---|---|---|---|---|---|
| 14 | 12.3 | 8 | 8 MW / 26.3 MWh | 58.8% | 0.229 |
| 14 | 26.3 | 12.4 | 15 MW / 73.5 MWh | 76.5% | 0.238 |
| 14 | 68.3 | 12.4 | 20 MW / 273 MWh | 90.9% | 0.252 |
| 14 | 148.3 | 21.6 | 20 MW / 273 MWh | 100% | 0.438 |

Source: TERM Plus 2021-2035 (GoT), based on consultant's Arup modelling

Not surprisingly, the cost of generation will be substantially higher and lead to higher tariffs even if all BESS storage would be donated by development partners. The 100% renewable electricity target in engineering modelling and cost-benefit analysis remains a work-in-progress. The modelling and analysis will need to be regularly updated with proven technology developments as well as to reflect the decline in costs of expected solar, wind and BESS. A first start is a feasibility study planned for 2023, which will look at the a) benefit (reliability, energy access, etc.) to consumers, b) levelized cost of electricity (LCOE), c) cost of implementation, d) ease of implementation and decarbonization timeframe.

**Capacity building and role of development partners**

In addition to the private sector investments, development partners' funding will be needed for distinct project elements like BESS devices, grid studies, grid upgrades, capacity development and technical assistance.

Capacity-building in this area is fundamental and should find needed support from development partners. For example, developing successful PPAs (power purchase agreements) with IPPs requires significant legal skills as well as technical knowledge. For TPL to enter successfully in the phase of 70% renewable electricity (and its associated complex PPAs) will need to further increase its negotiation and technical skill so that it can ensure that the best arrangements for the benefit of its customers, i.e., TPL must also ensure a balance is achieved between the financial viability of the project and the fair and affordable price to the consumers.

As part of the grid modernization and upgrading projects supported by ADB and New Zealand, Tonga has now skilled and experienced experts in power transmissions and distribution line maintenance. 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 as well. 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. Increasing the capacity of existing workers and attracting new candidates will require a programme of development and ongoing training. Without these skilled workers, the transition to higher levels of renewables is not sustainable.

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 so skilled people will be in high demand. If Tonga wants to develop and retain these valuable employees, then the Government and TPL must make this a high priority including proper compensation consideration with incentives to stay in the country to avoid them looking for greener fields abroad.

### Other renewable energy sources and sectors

The biomass resources in Tonga (and in similar smaller Pacific Island nations) have not been explored fully for utility-scale energy production, except Vanuatu UNELCO is using CNO (coconut oil) for power generation alongside diesel and wind sources. Samoa recently installed a 750 kW biomass gasifier[21]. Another route is biogas from anaerobic digestion. There are no commercially utility-scale biogas facilities but the use of 0.3 – 3 MW plants in countries such as Tonga could be possible that use municipal or silvoagricultural residues and waste to generate power.

The TERM PLUS identifies two major targets for consumption:
a) Limit growth in oil consumption for road transport to 25% for the period 2019–2035 (an average of 1.4% per year) and
b) Limit growth in grid-connected residential electricity end-use to 1% per year on average for the period 2019–2035.

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[22].

In transport, three main areas of intervention are considered. The first is improving the intake quality of the vehicle, adopting higher fuel efficiency standards, periodic review of vehicle emissions standards together with capacity building on vehicle maintenance practises and awareness can improve fuel economy and reduce the vehicular emissions level. Non-motorised transport (NMT) is being pursued as an alternative and sustainable mode of transport in urban areas (walkways and bicycle lane expansion, pedestrianisation). A third measure is moving away from fossil fuel vehicles towards private electric vehicles and promoting of electric public transportation.

TEEMP presented a goal of blending 10% biodiesel into all diesel fuel by 2030. This quantity of biodiesel would be supplied by available waste grease and coconut oil. The 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. This also offers opportunities for regional trade in biodiesel between Pacific nations that have less biomass resource availability than others according to the needs in each of the countries.

To limit the growth in residential electricity end-use, the following measures will be undertaken a) adoption and enforcement of minimum energy performance standards, b) curtailment of import of non-LED bulbs, c) installation of solar water heating systems, and d) energy efficiency standards for buildings introduced and enforced.

[21] Using *Gliricidia* and other invasive species that are choking the plantation area in which the plant is situated and reduce coconut growing and livestock-raising activities. Additionally, fast-growing regenerative trees species can be used as well as coconuts shells as biomass feedstock. Through biomass gasification, the plant generates and sells power at a feed-in tariff of around USD 0.20/kWh to the grid. Source: Van den Akker (2020)

[22] TERM Plus 2021-2035