ENVIRONMENTAL IMPACT ASSESSMENT

Tonga Power Limited Proposed Wind Farm

Niutoua, Hahake Districts, Tongatapu Island

July 2014
Environment Impact Assessment

Proposed Wind Farm, Niutoua, Hahake Districts, Tongatapu Island

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EXECUTIVE SUMMARY

This is an Environmental Impact Assessment report at Niutoua, Hahake District Area, with consideration of the Tonga Power Limited’s proposed wind farm. This is the eastern coast of Tongatapu Island, the capital island of the Kingdom of Tonga. The principal objective is to improve energy supply with an increasing use of renewable energy.

Tonga has been recognised as a Small Island Developing States (SIDS); and SIDS are a grouping of 52 similar countries, 14 of these self governing states¹ are located in the Pacific and are commonly referred to as Pacific SIDS (PSIDS). In effect, Tonga, like other Pacific island countries, is accorded a ‘special case’ stemming from global recognition in Rio 1992² of the unique characteristics, challenges and vulnerabilities of SIDS and their ability to achieve sustainable development. This special case is defined largely by its small size, extreme isolation, limited and narrow resource bases, geographic dispersion and isolation from markets, diseconomies of scale, capacity limitations, susceptibility to climate change and natural disasters and global crises.

The Tonga Energy Road Map (TERM) provides a detailed pathway towards a low carbon, cost-effective, technically sound, equitable transformation of the entire energy sector in the Kingdom of Tonga. The Government of Tonga launched the plan in 2010 to address the challenge of energy security combined with the substantial reduction of the Kingdom’s contribution to Green House Gas (GHG) emissions.

The Kingdom is highly dependent on imported fuel to meet its energy requirements. In effect, the total fuel import accounts for about twenty percent of the total import value in 2011³. Tonga Power Limited is the sole electricity production and distribution SOE in Tonga. The grid-supplied electricity accounts for about 98% of electricity and it is based on diesel generation. In 2013, TPL used 12,941,465 litres of diesel for power generation. The total cost of diesel to TPL in 2013 was around $US19, 500,000. Under the current electricity regulatory structure the cost of fuel is essentially

¹ 14 Pacific SIDS include - Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Nauru, Niue, Palau, Papua New Guinea, Republic of the Marshall Islands, Samoa, Solomon Islands, Tonga, Tuvalu & Vanuatu
² In 1992, the UN Conference on Environment and Development in Rio acknowledged the “special case” of Small Island Development States (SIDS), which led to the development of a Global Programme of Action for the Sustainable Development of Small Island Developing States (BPoA) in 1994, Barbados. This has been supported and reiterated in subsequent global agreements such as the MDGs, Rio agreements, UNFCCC, CBD, HLF4, amongst others.
³ SPC, 2012
passed through to electricity consumers. Electricity consumers are fully exposed to oil price rises and fluctuations.

TPL, within the framework of TERM 2010-2020, is proposing a wind farm in the Hahake District (Niutoua-Lavengatonga). The proposed wind farm to be established in Niutoua, will be another step forward in addressing the energy issues in Tonga.
1.0 Background

Figure 1: Kingdom of Tonga

(Source: Halatuituia, 2002)
The Kingdom of Tonga comprises a population of 103,000 persons inhabiting 36 islands. In total there are 170 islands of volcanic and coral origin. The Kingdom has four main groups namely, Tongatapu and ‘Eua, Vava’u, Ha’apai and the remote Niuas.

Like other Pacific island countries, the Kingdom of Tonga is experiencing a number of rapid socio-economic and environmental challenges. The growth in urbanization, being the result of migrations from rural to urban (Tongatapu Island), and also from outer islands to Tongatapu. Consequently, there is unevenly high pressure on the land, in particular around the capital Nuku’alofa where almost 40% of the country’s total population is concentrated. In recent years, the greater Nuku’alofa expanded up to the northern, western, and eastern coastal areas; and as far south as Tofoa. Further, townships continues to expand in the rural areas. This means that many former food producing farmers are now rapidly becoming net consumers, and this has a direct effect on the country’s trade balance. At present, the total value of imports surpasses almost 20 times the import.

Tonga is one of the most vulnerable countries in the Pacific. This is due to its geographical position and its low topographic which mean that Tonga’s islands are prone to natural hazards like sea-level rise, cyclones, volcanic activity, seismic and tsunami hazards. In parallel, increasing population with limited land area, and increasing social and economic developments, usher in issues such as land degradation.

Increasing urbanization not only means an expansion of built areas but also an increasing usage of environmentally sensitive areas. Expansion of commercial farming since the mid-1980s has increased the use of agrochemicals, fertilisers and pesticides in particular. This is accompanied by a demand for oil-based energy which has risen considerably.

1.2 Tonga Power Limited: a state owned enterprise

The Kingdom of Tonga has produced electricity by means of diesel generators for over six decades, and had been managed by four different management institutions. During these times, Tonga’s economy has become monetised; land use has become commercialised; population increase has put on an increasing pressure on its land resources; limited land supply pushed developments into vulnerable areas with great impacts on the environment. Overall, the demand for energy continues to rise in volume and expand into new areas.
The expansion development proposed combines the aspiration of Tonga Power Limited to meet its obligations under the Tonga Strategic Development Framework (TSDF) and Tonga Energy Road Map (TERM). Central to its operations, TPL endeavours to be more fuel efficient and to meet an increasing public demand for energy with special consideration to the environment.

TPL is government owned and is responsible for generating and reticulating electricity across 4 island groups in Tonga, largest of which is Tongatapu, accounting for 85% of the customers, assets and sales. Approximately, TPL has 21,000 customers and produces 53 GWh of electricity annually.

1.4 The proposed Wind Farm Location: Area of Interest

The proposed site for the installation of the new wind farm facility is along the Hahake coastal area, spanning from Niutoua to Hamula.

This is a satellite image of the area of interest as specified by the Wind Map.

Figure 2: Area of Interest for TPL Wind Farm; Niutoua Site (yellow circle)
The area of interest covers all tax allotments between Liku Road and eastern coastline. It runs from Niutoua village to Nakolo village. The statuses of these tax allotments have been attained from the Ministry of Lands and Natural Resources. However, according to the wind map (Figure 2), Niutoua is potentially the best location.
Figure 3: Hahake District Area
1.4.1 Area of Interest Land Status

In total, there are 231 allotments on the allocation map; only 174 allotments were able to be verified as registered, leased, reverted, applied for, or have an executive decision on (Cabinet or Court Decision). There were 57 allotments were not verified from the Land Registration and also the Land Application record.

Table 1: Results of Preliminary land title search.

<table>
<thead>
<tr>
<th>Years</th>
<th>1920s</th>
<th>1930s</th>
<th>1940s</th>
<th>1950s</th>
<th>1960s</th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
<th>2000 -</th>
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<tr>
<td>Registered</td>
<td>13</td>
<td>1</td>
<td>52</td>
<td>16</td>
<td>27</td>
<td>24</td>
<td>10</td>
<td>3</td>
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</tr>
<tr>
<td>Sub total</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>159</td>
</tr>
<tr>
<td>Revert &amp; Annulment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>New Applications; Itemised Applications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Leases</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Allocated but no registration/application record found</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>57</td>
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<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>231</td>
</tr>
</tbody>
</table>

It must be noted that it is not uncommon for an allotment to be allocated and either not registered or applied for but the registration process is not completed. However, the users are descendants or relatives of the original landowners. Without current registration or land application; the allotment is usually reverted to the estate-holder. This does not mean that the land allotment is “free for all” to claim. The estate-holder will consider or allocate the land to the rightful heir in accordance with the rule of succession in the Land Act. It is safe to assume that despite the fact that a land allotment is laying in idol, it does not mean it is “free”.

1.4.3 Site Location

The location for the site has been identified by JICA as shown on the following map:
Aerial map of Niutoua (red: preferred location)

The preferred site is adjacent to a secondary road, and that the surrounding area is predominantly tax or farming land allotments. It is expected that the 5 tower wind farm will spread along the side of the road. This will cover two to three registered tax allotments.
1.4.2 Site location due considerations

There are matters for considerations when exploring the specific sites within the areas of interest.

a) Land access

Physically accessing land allotment needs to be done as most of the access roads are not in good condition and may need upgrading. In addition, rights of access to potential sites within land allotments should be secured from the proper land owners. This will be done through formal leasing agreements.
b) Aviation Restrictions

Obstacle Limitation Surfaces (OLS)

Obstacle Limitation Surfaces (OLS) are a series of surfaces that define the limits to which objects may project into the airspace.

The OLS comprises the following;

i.) Transitional surface;

It is a complex surface sloping upwards and outwards up to the inner horizontal surface from the edge of the approach surface and from a line originating at the end of the inner edge of each approach area, drawn parallel to the runway centre line in the direction of landing.

ii.) Approach surface / Take-off climb surface;

The approach and take-off climb area shall be established from the smaller ends of the runway strip for each runway direction intended to be used for the landing and take-off of aeroplanes.

iii.) Inner horizontal surface;

The inner horizontal surface will be a composite pattern, consisting of two circular areas centred at the two runway ends with a radius of 4000 m. These areas will be joined tangentially to form an elliptical shape.

iv.) Conical surface;

The conical surface shall be projected upwards and outwards from the periphery of the Inner Horizontal Surface (HIS). The slope of the conical surface measured above the HIS in a vertical plane will be 5% (1:20).

v.) Outer Horizontal surface;

The Outer Horizontal Surface (OHS) will extend to 4,000 m from the median point at the end of the runway.

vi.) Inner approach surface;

vii.) Inner transitional surface;

viii.) Balked landing surface.

The inner approach, inner transitional and balked landing surfaces together define a volume of airspace in the immediate vicinity of a precision approach runway Cat-II & III, which is known as the obstacle-free zone. This zone will be kept free from fixed objects, other than lightweight frangible mounted aids to air navigation which must be near the runway to perform their function, and from transient objects such as aircraft and vehicles when the runway is being used for precision approaches Cat II/III.

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4 Result of consultation with Captain Vili Cocker, Director of Civil Aviation, MOI; and Captain Samuela Folaumoetu’I, Pilot, Real Tonga Airlines.
For the purpose of this report, it is noted here that, F), G), and H) are obstacle free zones, and are not considered as wind turbine sites. Therefore, A) – E) are requirements that should be considered in this project.

The Outer Horizontal Surface (OHS) with a radius of 4,000m originates from the median tip of the runway. The maximum height allowed within this radius is 45m. It is noted here that point of origin is approximately 34.8m above sea level. Thus, the possible height allowance within the OSH arc is about 79m above sea level.

Beyond the OSH, is the Approach and Take-off Surface, commonly known as the ‘approach fan’, with a height restriction of about 120 m. This is not a concern for this project; given the towers are only about 50m.
The Nakolo area, which is east of the Fua’amotu International Airport, is the higher part of Tongatapu Island. Unfortunately, most of this area is within the OSH 45m restriction. The 4,000m origination from the ARP at the end of Runway 29, defines the OSH 45m restricted area. As shown by the map below, Nakolo, Ha’asini/Hamula, and Lavengatonga are under the same restriction.

The proposed Niutoua site is just outside this restriction; and also at safe distance from the Airport.

Figure 4: Restricted Area (45m height).

**ix.) 8.3 Surrounding vegetation**

It is noted here that most of the vegetation cover in the area of interests are coconut and guinea grass, except the coastal areas. There are some patches of trees (mango trees, Leucaena (sialemohe) mainly) among the land allotments. The coastline on the other hand, is covered by natural coastal forest that includes pandanus plants. It is evident that the patches of secondary forest are a mixture of many native and introduced plants.

**x.) 8.4 Proximity to inhabited areas**

It is noted that the areas of interests are rural areas and not within the Township areas. However, public awareness is necessary to avoid negative reactions to this project.
8.5 Proximity to electricity network.

The TPL technicians will deliberate on the distance of any selected sites to the main electricity network. It is also noted that all tax allotments either fronts a road or have access easement to the main public road.

8.6 Potential Sites (priority Areas)

In identifying the specific sites, it will mean that part of the selected tax allotment will need to be secured and accessed by TPL. It is noted here that in addition to the minimum area for erecting the wind tower, an area will be needed for lowering the tower for maintenance purposes or during time of natural disaster (cyclone).

However, quantifying the area of a wind power farm is challenging given the discontinuous nature of its configuration. The area concerned includes not only land directly impacted by installation of the turbines, but includes the surrounding area that potentially may be impacted. It is noted that there are two general types of areas:

a) The direct land area impacted due to wind turbine construction and infrastructure (specific area part of the tax allotments – permanent clearing). This is the area occupied by turbine pads, access roads or easements, sub-stations, service buildings, and other infrastructure which physically occupy the land.

b) The immediate area associated with the total area of the wind farm as a whole (eastern coastal area – wind turbine spread). This is the area of a wind power farm consists of the area within the perimeter surrounding the entire turbines in the project. The perimeter is highly dependent on terrain, turbine size, current land use, and relevant regulations such as set back.

At this stage, the total area required for the proposed TPL project can vary considerably, and is particularly dependent on two key factors: the desired size of the wind farm (either defined by installed capacity or the number of turbines); and the characteristics of the local terrain. Generally, the wind turbine spacing is determined by the rotor diameter and local wind conditions. In Tongatapu Island, the prevailing winds are generally from one direction; turbines may be installed 3 or 4 rotor diameters apart (in the direction perpendicular to the prevailing wind). Under multidirectional wind conditions, spacing may be between 5 and 7 rotor diameters. However, the
technical and feasibility study will provide information and recommendation on specific sites, turbines specifications and spacing.

1.5 Cultural and Social Consideration

TPL is conscious of the fact that this project is utilising farming areas in Niutoua. Hence the TPL preferred to spread the wind turbines in a row not only to use only part of certain tax allotments, but also catch the trade winds. In this regard, people may still be bale to farm much of their tax allotments.

Preliminary study of the area revealed that farming activity within the locality, identified as preferred sites, is low compared to areas further inland. Further, medicinal vegetation is also rare in this area due to previous land clearances.

On the other hand, having the project installed, it will extend the electricity line to the locality (rural) and also there will be some road upgrades. These will definitely benefit people in terms of access to their tax allotments, and also access electricity. Overall, increasing the potential for people to engage in activities that may have been impossible otherwise.

1.6 Environment Consideration

It is important at this point that changing in the land use will have potential risks to the environment. This is dealing with adverse impacts of the project but equally important; attention be availed to the greening of the Tonga’s economy.

It is noted that, stakeholders include all sectors of the economy, relevant government ministries, other state-owned enterprises, and the eastern Tongatapu communities at large. Electricity is underpinning pillar of development for the Kingdom. Interests in power generation and distribution vary from its purely monetary value as a commercial entity, to its environmental sustainability, its quality and control services, and as an energy source for communities.

Further, these numerous interests need to be balanced together. However, the Laws of Tonga requires that any significant development, such as the proposed TPL Wind Farm, be accompanied by an Environmental Assessment (Environmental Impact Assessment Act 2003). In terms of the EIA Act,
this development project could be classified as a ‘major’ project, warranting an assessment of the magnitude of this report.

2.0 The proposed development

2.1.0 Overall goal

Overall goal of the Project is to reduce the dependency on imported fossil fuel for energy and power supply in Tonga. Through introducing sustainable non-fossil fuel fired generation and state of the art micro grid management, the outcome will enable reduction in the global Green House Gas (GHG) emissions and improvement of national energy security and quality of supply. Ultimately it is the overall goal of the project to decrease the electricity tariff to electricity consumers by 4% to 4.5% as a result of this project.

The average wind speed at Niutoua at 50 metre height is 7m/s. It is estimated that with 5 turbines at 785MWh each will produce 3925MWh annually. The total generated power for Tonga is about 56,000MWh annually. Hence, 3925/56000 * 100 gives 7%. This 7% reduction of fuel component on our tariff is estimated to equate to 4%.

2.1.1 Project objective

The purpose of the project is to introduce renewable energy sources for power generation in Tonga by introducing large-scale wind generation. The Government target to introduce renewable energy to a level not less than 50% of total generation by 2020 is a measure of urgency for this project. The ratio of solar and wind farm contribution to this target are 11% solar and 16% wind. Alongside the commitment by Tonga Power to upgrade the network and ensure availability of firm generation through diesel powered generation, additional support is required urgently to help realize a much higher share of renewable, intermittent, energy sources and meet TERM’s objectives.
In the meantime, to increase renewable energy means to be open to risks posed by natural disasters. As a solution to vulnerable infrastructure, the tiltable wind turbine to be introduced. Advantage of this system is being able to tilt the system in the event of cyclone, thus, enables keeping integrity of the system, especially the blades, with less repair cost if any.

2.1 Impending Benefits

2.1.1 Energy security

The following are the benefits from this proposed wind farm envisaged:

✓ This proposed wind farm project is a TPL initiative, but acting on the TERM’s goal to reduce reliance on diesel for power generations;
✓ TPL strongly believes that utilising and optimising of such a strong, endless, renewable energy source such as wind, is a sensible and practical way to reduce its reliance on diesel fuel, and effectively sustain the environment by reduction in burning of fossil fuel;
✓ Eventually, reducing Tonga’s electricity costs;
✓ Resilient to world crude oil price impacts;
✓ Creating skilled jobs in renewable energy generation;
✓ Building Tonga’s international profile as more environmentally smart;
✓ Encouraging other pacific islands to move into wind energy generation;
✓ The wind turbine is expected to generate around 3.9GWh of electricity annually which is 7.3% of Tonga’s electricity demand. The renewable energy system will offset approximately 968,000 litres of diesel and around 2400 tonnes of CO₂ annually. The price of delivered diesel to Tonga is currently approximately $US180 per barrel ($US1.5 / litre), therefore the proposed wind turbine would save approximately $US 1,452,000 per year in diesel costs alone.

\[
\text{Petrol Save} = \frac{\text{Energy generated}}{\text{Fuel Efficiency}}.
\]

At the moment TPL fuel efficiency is 4.05kWh/L.

\[
\frac{3925\text{MWh}}{4.05} = 968,000\text{litres saved}
\]

\[
\text{CO}_2\text{ saved} = \text{Litres of diesel} \times 2640
\]

\[
968,000 \times 2640 = 2,555 \text{ tonne of CO}_2
\]

The proposed wind farm is not only economically beneficial but also environmentally advantageous, putting Tonga’s electricity sector in line with the Government’s overall goal.
2.1.2 Employment Benefits:

The project will employ up to 25 local workers during the 8 month civil works and construction phases. On top of that, several local staff will become trained in the complex, internationally relevant and environmentally sustainable field of wind turbine operation.

2.1.3 Social benefits:

The project will further illustrate Tonga’s commitment to renewable energy generation, as well as being a flagship wind project for TPL. Successful completion of the project will also demonstrate the benefit of the renewable energy technology for the kingdom.

The success of the project will raise confidence and attract potential investors and aid agencies to commit and to develop further renewable energy projects in Tonga. Ultimately, this will increase the proportion of renewable energy generated on the island and significantly reduce the dependence on costly and environmentally detrimental diesel fuel.

2.1.4 Political benefit:

This project will further reveal the Government’s commitment under its Tonga Energy Road Map commitment to the twin challenges of reducing the Tongan contribution to global Green House Gas (GHG) emissions and improving national energy security by approving a policy to supply 50% of electricity generation through renewable resources by 2020.

2.3 Local infrastructure required

a) Required Land Area (& likely spacing between turbines)

The estimated land area to be leased for each turbine is about 5,000m². However, the construction platform will 600m² each. The foundation will be concrete anchored by 15m³ – 30m³ depending on the soil physiology. However, the general plan now is to spread the 5 turbines along the area identified in a row facing the trade wind.
b) Road (access to turbine sites)

With the exception of a few roads, most of the access roads to the tax allotments in the Hahake districts are dirt road. The latter, are in fair to poor condition, and will need upgrading. Given that the tower locations will be adjacent to the road, access roads are not necessary.

c) Orientation

Preferably the turbines placement will be appropriately spread out, and in a line perpendicular to the SE trade winds. The proposed site at Niutoua and the land allotment layout allow the towers to be orientated in the preferred arrangements – perpendicular to the trade wind.

2.4 Input

The TPL proposed Wind Farm is expected to cost $15,000,000 US (excluding TPL costs to secure land) as shown in the following table. An estimated 1.5km of connecting cables and transformers would be required from the site to the power lines up on Liku Road. The electricity is generated as AC, which is what the power lines carry, therefore no inverter is needed. Once operational, the facility will have some natural resource requirements, other than the occasional 6 monthly maintenance checks and overhaul or lowering of the Turbines during cyclone warnings.

<table>
<thead>
<tr>
<th>Items</th>
<th>Cost (US$ or other currency)</th>
</tr>
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<tbody>
<tr>
<td>Facilities</td>
<td>N/A</td>
</tr>
<tr>
<td>Sub-total</td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
</tr>
<tr>
<td>Five(5) Wind Turbines (275kW)</td>
<td>US$9.0M</td>
</tr>
<tr>
<td>Plant</td>
<td>US$0.5M</td>
</tr>
<tr>
<td>Network Equipment</td>
<td>US$1.0M</td>
</tr>
<tr>
<td>Storage Facilities</td>
<td>US$4.0M</td>
</tr>
<tr>
<td>Sub-total</td>
<td>US$14.5M</td>
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<tr>
<td>Soft (Non-physical) components</td>
<td></td>
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<tr>
<td>Operation and Maintenance and TPL staff Training</td>
<td>US$0.5M</td>
</tr>
<tr>
<td>Grand total</td>
<td>US$15.0M</td>
</tr>
</tbody>
</table>

Table 2: Wind Farm Costing
2.5 The technology

In summary, the five 275kW Wind turbines will have a rotor diameter of 32m and a tower length of 38m. These have a very compact nacelle. The blade design is a 2-blade with rubber/metal dampening with a hydraulic pitch control. The cut-in wind speed is 3.6m/s and cut-out wind speed is 20.0m/s. The rotation speed ranges from 31min⁻¹ to 46min⁻¹ (about 50Hz & 60Hz).

The turbine performance is based on a 2-stage planetary gearbox; with a generator 2-speed, asynchronous, squirrel case generator. The grid connection includes a power factor compensation, and a cabinet including by capacitor bank and transformer at tower base. Emergency and parking brake is a Aerodynamic and sic on high speed shaft. The yaw is hydraulic active yaw, automatic cable unntwisting.

The tower is a Guyed-Lattice made of galvanised stell with anchors (boreshole with steel rods cast in concrete).

The light guyed towers will require a very small foundation (approxm. 9m²). Hence, the amount of concrete can be largely reduced comparing to other versions available.

TPL proposed to install a wind generation system that would seek to accommodate:

a) Stability of voltage and power flows;

b) The need for network information and control to optimize power flows and manage losses;

c) Improve network infrastructure to cater for wind capacity;

d) Integration of demand side management and control, in conjunction with long duration storage capacities, to optimize generation mix and lessen diesel fuel consumption. Noting the drastic drop in generation base-load levels;

e) Impact of intermittent generation on the lifecycle and efficiencies of the base diesel generation;

f) Network management and automation through remote supervision and communications capabilities;

g) Tiltабle design designated for geographical areas such as Tonga, and advantages such as:

i. Protected from natural disasters such as cyclones

ii. Easy to install, operate and maintain

iii. Low operating and maintenance cost
iv. Tested and proved in the remote islands such as Okinawa

Figure 4: Wind Tower to be used.

Figure 5: Wind Towers as it stands and rests on the ground.

2.6 Implementation Period

On acquisition of finance the following timeline is expected to be followed for the installation of the proposed wind farm:
## 3.0 Development Project Justification

Tonga is primarily dependent on costly imported diesel to meet its energy requirements. The municipal electricity grid supplies approximately 98% of Tonga’s energy, of which 94% is generated by diesel fired generators. In 2013, TPL used 12,941,465 litres of diesel for power generation. The cost of diesel to TPL in 2013 was around $US19,500,000.

### Table 3: TPL Work Plan

<table>
<thead>
<tr>
<th>Phase</th>
<th>Project Activities</th>
<th>Month 1</th>
<th>Month 2</th>
<th>Month 3</th>
<th>Month 4</th>
<th>Month 5</th>
<th>Month 6</th>
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<td>Metering and communication</td>
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It is noted here that additional pressures of climate change, climate variability, increased frequency and intensity of natural disasters, and sea-level rise which have been compounded by the international fuel, food and financial crises.

The Navigant Research has highlighted that the wind power currently (July 2014) supplies about 3% of the world’s electricity and will rise to 7.3% by 2018. This report follows the latest scenario from EWEA which stated that the EU’s installed wind capacity is set to reach 192GW by 2020. There is a general trend for wind generated power to increase globally.

3.1 There are three options for TPL:

3.1.1 Option One: Maintain status quo (Diesel Generation).

This would be the simplest but a naive approach for Tonga. Not seeking to develop and improve, and continuing to rely on fossil fuel as the only source of energy in Tonga has an accumulated costs in terms of finance and environmental expenses in the long term.

3.1.2 Option Two: Implement the proposed Wind Farm at Hahake Coastal Area.

Tonga needs to be vigilant in its effort to seek energy security, at the same instance, protect the environment.

3.1.3 Option Three: Relocate the proposed Wind Farm to another location.

The area of interest is the most viable and practical location for the proposed Wind Farm according to its location namely; its exposure to the trade wind, and it is the elevated part of the island. Hence, relocating to other part of Tongatapu Island is impractical.

3.2 Option Taken by TPL: Option Two

It is commonly understood that Tonga need to act in an appropriate manner to address its energy issues. TPL strongly believed that the most viable and practical option Tonga can take is Option Two. Hence, the provisions in the TSDF and TERM Tonga, and accordingly, TPL endeavours to provide
affordable, secured, and environmental friendly source of energy for the people. Hence, the focus of this report will be on assessing this option.

3.3 TPL’s responsibilities with Option Two

TPL fully comprehends its role as the leading agency in the energy sector in Tonga; and appreciate its responsibilities towards the environment.

As a result of discussions regarding the environmental responsibilities; TPL will implement Option Two with specific care and take into account the following:

3.3.1 Mitigative measures

a) Administrative measure

i.) TPL retains overall responsibility for the construction and operation of this project. The CEO of TPL will take responsibility for the environmental management and will employ special technical environmental consultants as required for particular incidents that impact upon the environment and routine monitoring and reporting.

ii.) The TPL staff, specifically the Manager and staff at the TPL power production site, and subcontractors has responsibility for environmental management and mitigation.

iii.) The Ministry of Environment and Communication will ensure compliance with the EIA code on all phases of the project.

b) Landscape

i.) Design of the wind turbine according to the peculiarities of the proposed site (gentle slope contour);

ii.) Select a neutral colour and anti-reflective paint for towers and blades;

iii.) Install lights for low altitude flights.

c) Birdlife

i.) Environmental monitoring programme before, during and after construction in order to provide the needed information to evaluate the impact on fauna (birds).

ii.) Adequate environmental training for site personnel.

iii.) Increase the visibility of rotor blades (low-flying lights at night).
3.3.2 Monitoring Activities

a) During Construction
   i.) Daily site inspections by supervisors/managers to observe progress of works during the implementation phase assuring environmental and, health and safety mitigation tasks are adhered to.

b) During Operation
   i.) TPL in addition to its technical data collection should also record any birdlife impact (injury and death).
   ii.) Regular maintenance of the turbines; and secure turbines at times of cyclonic weather system.

c) Contingency Plan
   i.) TPL will prepare a Natural Hazard Prevention and Response Plan for the site, particularly for cyclones. This should also include spillage plan of any chemical or fuel used on project site.
   ii.) In addition to the safety plan, environmental aspects of the site operation are included, and also identify risk areas.

d) Training Needs
   i.) Pollution control / Health and Safety / Environmental training are strongly recommended for staff working on site.
   ii.) TPL collaborate with relevant regulatory authorities on issues pertaining to its operations and the wind turbine site.

4.0 Baseline Conditions : Hahake District Area and Locality

4.1 Physical Environment

4.1.1 Geology

Tonga is located in the equatorial Pacific and is one of the world’s last and smallest kingdoms, consisting of 169 islands, of which 36 are inhabited. Depending on tectonic activities along the Tonga fault line, it can be over 170 islands for short periods. The island kingdom has four main
groups of islands, namely the Niuas (Niua-toputapu and Niua-fo’ou) in the far north; the Vava’u Group; the Ha’apai Group; and the Tongatapu Group (including ‘Eua), which is the main group. Overall Tonga has a total land area of 720 square kilometres not all of which are habitable.

The Tonga islands are built on two ridges, the Tonga Ridge and the Tofua Ridge, running in parallel to one another in a southwest-northwest direction. In parallel to these ridges is the axis of the Tonga-Kermadec Trench, which is one of the deepest locations on earth. The islands on the Tonga Ridge are coral in origin and low and flat; these include the Tongatapu Group, Ha’apai and Vava’u groups, which accommodate almost all the national population. The Tonga Ridge is not volcanic but it is tectonically active. The islands on the Tofua Ridge are volcanic in origin, high and rugged, including the islands of ‘Ata (southernmost island), Kao and Tofua (Ha’apai Group), Late Island (Vava’u Group), and the Niuas.

4.1.2 Soil

The coral islands have poor soil but Tonga is fortunate because the volcanic islands on the western side provide the necessary minerals for fertile soil on the eastern coral islands. Early works on Tongan soil include a preliminary survey by the New Zealand Soil Bureau and selected sample analyses (Halatuituia, 2002). These studies allow some general descriptions of the soils. A general classification of the soils of Tongatapu into two main classes, namely the kelefa, upland soils, and the tou’one, lowland soils. The former are deep friable clays of moderate to high natural fertility, which cover approximately 90 percent of Tongatapu Island, and are the most valuable for agricultural purposes. Gibbs (1967) separated the kelefa into two subgroups: the ‘Lapaha clays’ and the ‘Vaini clays’.
In general, the Lapaha clays are predominant in Eastern Tongatapu (Vahe Hahake) and the Vaini clays cover most of Western Tongatapu (Vahe Hihifo) including the subject site (Mataliku). The Tou’one lowland soil was also divided into two subclasses, namely the ‘Nuku’alofa soils’ and the ‘Sopu soils’ (Gibbs, 1967). These soils cover most low-lying areas, mainly along the northern coasts of Tongatapu. These are considered useful for most crops except for the frail ‘ufi (yams). Note that the soils in Tongatapu provided an excellent basis for traditional Tongan agricultural practices.

4.1.3 Climate

In general Tonga’s climate is sub-tropical rather than tropical. There is a slight cool season between the months of June to October with a mean temperature of 24.5°C, and a rather hot and humid season from November to May with a mean temperature of 29°C. The cool season runs from June to October and the warm or summer season runs from November to May.

The spread of two general types of small islands over a considerable ocean area means that rainfall varies temporally and spatially. The period between the months of December to April are the wettest and from June to August the driest. This is a common scenario with the heaviest rainfall during the hot season but it varies from year to year and between the northern and the southern islands. These are further influenced by the El Nino and La Nina phenomena. Niuatoputapu in the north has an average rainfall of about 2540 mm while Tongatapu in the
south has an average of 2032 mm per year. The variation between the northern islands and the southern islands affects land use.

On the main island of Tongatapu rainfall is generally convective because of the dominance of ocean over land area. Tongatapu generally experiences adequate rainfall but there were extensive droughts in the periods 1982-1983, 1986-1987, and 1991-92, which brought down the average from 1770 mm to 1406 mm for Tonga.

Tonga’s prevailing winds blow from the east and the southeast at an average of 9 knots throughout the year. Tonga’s location puts it well within the ‘hurricane belt’ in the Southwest Pacific, consequently it experiences severe weather systems, averaging half a dozen tropical cyclones per year. Cyclone activities mostly occur during November to March when the sea is warmest. Wind damage can also affect the foliage of root crops, which are usually inter-cropped. Climatic hazards mainly cyclones and droughts, are not uncommon in Tonga and pose problems for a country dependent on agriculture.

4.1.4 The vegetation

The TPL area of interest is predominantly agricultural locality with various vegetation cover. For instance, there are areas of grassland, cropland, coconut-cropland, and coconut-grassland. However, there are also patches of scrub and woodland.

However, plants are often classified by their distribution namely; either native (plants occur in the area having arrived by non-human transport; or alien (introduced species having arrived by direct/indirect human transport). It is noted here that alien species have introduced by the Polynesians (early settlers); Europeans (since circa 1773); and in modern Tonga (boats, planes). Tonga’s native plants are classified as either endemic (restricted to Tonga), and indigenous (native plants with a wider distribution).

In the Hahake Coastal Area; much of the vegetation had been modified, and endemic plants are becoming rare. The main cause is the human activity, and some are due to natural causes. Native plants disappear due to:

a) loss of habitat;
b) competition from invasive species;
c) herbivory;
d) abandonment of cultigens; and
e) natural rarity.
Loss of habitat due to the increasing human activities in terms of area and intensity has been the most serious causes. This means that there is none or very little remains of the native vegetation. In fact, pockets of the native plant are found further inland, in areas such as Toloa and Lafalafa.

![Figure 7: Area cleared for garicultural use (ma’ala), Niutoua](image)

Unfortunately, the forest ecosystem in Tonga continues to decrease, and this is relatively coincides with an increase in agricultural land use area. Admittedly, it is naïve to correlate this in terms of unit area loss for forest ecosystem and gain for agriculture, but it does reflect the absence of or limited integrated land use system in Tonga.

### 4.1.5 The ornithology

It is commonly known that there are 74 species in Tonga; 2 endemics; 7 globally threatened species; and 5 introduced species. In fact, 10 of the region’s endemic birds can be seen in Tonga and these include two of its own endemics, the Tongan Megapode which is restricted to the isolated Nuiafo’ou and the Tongan Whistler which is found only in the Vava’u Group. However, species are likely to be seen depending on the time of the year.

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5 Bird Checklists of the World is part of Avibase and Bird links to the World, which are designed and maintained by Denis Lepage, and hosted by Bird Studies Canada, which is a co-partner of Birdlife International.
On the area of interest, such as the Hahake Eastern coasts, the ubiquitous White-collared Kingfisher is common and Pacific Swallows, a rare species in Tonga, may be seen. Unfortunately, none was spotted during this exercise.

It is believed that prior to human settlement in Tonga, at least 27 species of land birds lived on the islands, where 13 species are mostly found on ‘Eua. In general, the avifauna of West Polynesia (Fiji-Tonga-Samoa) is more closely related to that of Melanesia than that of East Polynesia. Regrettably, the human arrival on Tonga islands influenced Tongan avifauna more than any climatic, tectonic, or biological event.

Unfortunately, the main island of Tongatapu has been mostly stripped of its native forests for subsistence and commercial plantations. Consequently, there are a few native birds existing but those that can be seen include lorikeets and the koki parrot (‘Eua Island) and the endemic malau which incubates its eggs on the warm volcanic slopes of Niuafo‘ou Island.

During site visits to the area of interest (June-July); only a few of the bird species sighted and named as follow:

<table>
<thead>
<tr>
<th>Name</th>
<th>Common Name</th>
<th>Scientific name</th>
<th>Sightings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kulukulu</td>
<td>Crinson-crowned Fruit Dove</td>
<td>Ptilinopus porphyraceus</td>
<td>&lt;10</td>
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<tr>
<td>Misi</td>
<td>Polynesian Starling</td>
<td>Aplinis tabuenis</td>
<td>&lt;20</td>
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<tr>
<td>Veka</td>
<td>Banded Rail</td>
<td>Gallirallus philippensis</td>
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<tr>
<td>Moa Kaivao</td>
<td>Jungle Fowl</td>
<td>Gallus gallus</td>
<td>&lt;10</td>
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<tr>
<td>Pekapeka</td>
<td>Pacific Swallow</td>
<td>Hirndo tahitica</td>
<td>&lt;30</td>
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<tr>
<td>Fuleheu</td>
<td>Wattled Honeyeater</td>
<td>Triller lalage maculosa</td>
<td>&lt;20</td>
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<tr>
<td>Sikota</td>
<td>White-collared Kingfish</td>
<td></td>
<td>&lt;10</td>
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<tr>
<td>Kalae</td>
<td>Purple Swamphen</td>
<td>Porphyrio pohyrio</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

Table 4: Bird species sighted.

Unfortunately, the number of sightings were low which may be due to time of the day or human presence. It is noted that a lot of various bird sounds were heard but not necessarily sighted for confirmation of species. The above results were recorded for information of this report, but a comprehensive bird survey exercise. However, it is suspected that the loss of habitat, impact of

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rodents and ferral animals (cats), human deterreents (noise, fire), are a couple of the underlying reasons for this result.

### 4.1.6 Water Resources

The primary source of water in Tonga is groundwater with some people using rainwater as a supplement. Geologically, limestone, which is typically porous, formed most of the inhabited islands. Subsequently, the islands built up from a heterogeneous mixture of coral, shells, shell fragments, algae and foraminifer cemented together by carbonate cement. Rainfall permeates to form a lens of fresh water on top of the underlying seawater. There are no perennial streams in Tonga due to the high rainfall infiltration. In general, the amount of water trapped in the lens depends on the cross-section of the island. The largest and most densely populated island is Tongatapu, which has the biggest lens, which is about 41 feet (12.5 m) to 1 foot (0.305 m) above the mean sea level (Tonga Water Board, 1992). In Tongatapu, there is no overuse of water but rather under-development. There are plans to improve the public water systems operated by the government among the main settlements on each island group. The groundwater quality is commonly hard as the rainwater infiltrates through the limestone. The hardness of the water leads to problems like scaling when it is heated or deposited in and around metal plumbing.

Despite these problems, groundwater is still the main source of water for Tonga. Individual villages in the rural area of Tongatapu, unlike Nuku’alofa, have their own water bore. Committees (commonly known as the Komiti Vai) maintain these water sources in each respective village. However, the national water resources are watched over by the Ministry of Health and the Ministry of Lands and Natural Resources, in terms of maintaining the quality and quantity of the water table. In terms of daily maintenance of water, the Tonga Water Board, especially in rural areas provides technical assistance.

The rural komiti vai(s) are made up of selected local individuals to manage and maintain the village water source (bore and pump) and the distribution system around villages. These organisations are non-profit and non-governmental; they answer to their respective communities’ needs. In terms of funding, the komiti vai(s) are self-funded therefore each committee is responsible for raising and managing its finances.
Rainwater is another source often collected by the local people for daily use. Water tanks are either made out of concrete, fiberglass or heavy duty plastic.

4.2 Social and Economic Environment

From a national point of view, the initiatives such as the proposed Wind Farm is not only good for the environment but critical to the economy.

4.2.1 Population and Urbanisation

Since the unification of the island groups and the emancipation of the people from serfdom in the 1800s, Tonga’s population has steadily grown until the second half of the twentieth century.

Figure 8: Population of Tonga

![Population of Tonga 1911 - 2011](chart.png)

**Sources:** Halatuituia 2002, Census 2011.

The population has grown since the early decades of last century. However, the population has grown very little since the 1970s, as the annual growth rates experienced by the Kingdom over these years have been countered by emigration and social changes, leaving a low real annual growth rate. The annual rate of population growth pattern has declined since the period 1956-66, when it was about 3.6 percent to 1.6 percent in 1966-76 and 0.5 percent in 1976-86 (1993 Statistical Abstract) to
0.3 percent in 1986-96 (Statistics Department 1999). Since the 1970s, the total population has stayed around the 100,000 mark. Some 70 percent of the population resides on the largest island of Tongatapu, on which Nuku’alofa is situated. Nearly half of these people reside in the Nuku’alofa area, the capital of Tonga. It should be noted that about half of the population also settles within the Fanga’uta/Fangakakau Lagoon systems water shed, that include Pea-Tokomololo area.

Tonga’s population at the time of this survey was estimated at 103,365 persons. Tongans have become the third largest Pacific Island population in New Zealand (Statistics New Zealand 1995:11) and are also numerous in Australia and the United States of America. Population growth is an issue of importance in any area of study in Tonga due to the limited resources available. Population growth in Tonga, although slight but localised, strains both bureaucracy and the natural resources such as land.

The population has increasingly become concentrated on the main island, Tongatapu, as in other Pacific Island states. Nearly half the island population reside in the Nuku’alofa area, which is the political and economic centre of the kingdom. The urban population is almost 40 percent of the population. For internal migrants the most obvious attractions of Tongatapu, especially Nuku’alofa, are education and employment, followed by family reunion and to a lesser extent valued land availability. Consequently, the population distribution is nationally uneven and also concentrated in Nuku’alofa. Nuku’alofa’s share of the Tongatapu population has grown continuously over the years. The population density in Nuku’alofa increased from 184 persons/km² to 245.1 persons/km² over three decades which is well above the national figure of 150.5 persons/km².

The area of this study is actually consists of the townships of Niutoua; Haveluliku; Fatumu; Lavengatonga; Hamula and Ha’asini. The following shows the population of each township based on the 2011 Census.
The population growth in the last decades has been relatively low, meaning that the population had been relatively stable. An influential factor on this would be international emigration. However, the population pressure progresses as land use and land practice continue to evolve. In effect, the population pressure on land intensifies on certain areas, and unfortunately in some cases, on vulnerable and sensitive areas. However, the population growth in the area of interest were as follow:

Table 5: Annual Growth for each township.

<table>
<thead>
<tr>
<th>Township</th>
<th>2006 Census</th>
<th>2011 Census</th>
<th>Average Annual Growth (%)</th>
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<tbody>
<tr>
<td>Niutoua</td>
<td>636</td>
<td>740</td>
<td>3</td>
</tr>
<tr>
<td>Haveluliku</td>
<td>188</td>
<td>174</td>
<td>-1.5</td>
</tr>
<tr>
<td>Fatumu</td>
<td>414</td>
<td>449</td>
<td>1.6</td>
</tr>
<tr>
<td>Lavengatonga</td>
<td>188</td>
<td>174</td>
<td>-1.5</td>
</tr>
<tr>
<td>Ha’asini/Hamula</td>
<td>778</td>
<td>843</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Source: 2011 Census, Statistics Department

It is fair to say that growth in the is quite low relative to other parts of Tongatapu. However, a major reason for this is the rural-urban migration; and emmigration overseas.
Tonga had no formal National Land Use Policy to address short term leasing of land that contributed to massive land degradation up to the present times. Furthermore, other resource-related policies are not sufficient to address the alarming rate of degradation, particularly coastal forests. It should be noted though that a national urban and management act was approved by Parliament in 2011. However, it had not been implemented at the time of this report.

Population growth, coupled with urban migration especially on the island of Tongatapu is increasing the already growing demand for land for settlement purposes. Regulatory entitlements can no longer be fulfilled pushing families to put pressure on coastal areas and sensitive areas. If this rate of degradation continues unabated, the damage to natural ecosystems could seriously affect the government’s vision for a ‘high quality of life for the people of the Kingdom’.

Due to the limited availability of land, some mangrove areas and vulnerable areas have been subdivided and filled for settlement especially on the islands of Tongatapu. Unfortunately, some of these lands are rarely filled to sufficient heights to escape the impacts of climate change, particularly of rising sea levels.

4.3 The Economy

Tonga has an agriculture-based economy organized around semi-subsistence small holdings. Subsistence production focuses on a range of customary root crops such as yams, taro, sweet potato and more recently, cassava. Commercial production has focused on squash pumpkin over the last decade. However, considerable effort has been made to diversify into higher-value export crops notably vanilla, watermelon but these too, have proven hazardous ventures because of the problems of quality control, diseases and major fluctuations in supply and demand.

It is well known that the agriculture sector is the main contributor to the Tonga economy, considering the GDP in the last decade. However, the vulnerability of Tonga’s economy to
exogenous shock in EVI\(^7\) is 48.8 but the threshold is 33. Given Tonga’s EVI, the option is for Tonga to diversify its agricultural sector in terms of production and export.

At this junction, the three main sectors of the economy will be looked at briefly.

### 4.3.1 Tourism

It is common theme for Tonga that tourism is considered a priority for the kingdom’s development based on the tourism industry’s capacity to generate income and employment. The Government’s commitment is shown in its establishment of the Tonga Tourist Authority, an SOE to promote tourism commercially. However, great investments and/or foreign investments, are needed to put the necessary infrastructure for tourism to improve.

### 4.3.2 Fisheries

Tonga has a maritime territory of about 640,000 km\(^2\) with rich marine resources for both subsistence and commercial fishing. Unfortunately, lack of technology, air freight export capacity, and accessibility to credit limits the benefits from fisheries.

### 4.3.3 Agriculture

The dominance of this sector in terms of production is due to the fact that extensive involvement of households in this industry. It was estimated to be 64.2% of 15,738 households were involved in agriculture: 59% subsistence; and 38.6% mixed (subsistence and commercial); and 2.4% in commercial production\(^8\). Although, the agriculture’s contribution to the GDP has deteriorated in recent years, it is still the highest contributor.

However, the effect of commercial farming and monoculture in root crops is negative with root crops becoming more endangered than fruit trees. The treats to agriculture has now take on climate

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\(^7\) EVI or Economic Vulnerability Index reflects the risk to the development of a country caused by global shocks. EVI is a combination of 7 indicators namely; population size, remoteness, merchandise export concentration, share agriculture, forestry and fisheries in GDP, homelessness caused by natural disasters, instability of agricultural production, and instability of export or goods and services.

\(^8\) Tonga Agricultural Census 2001
change, and thus elevating the challenge for Tonga in the future. Overall, the survival of its agricultural species will depend on the resilience and adaptability of its ecosystem and species.

5.0 Environmental Impact Assessment:

5.1 The Physical Environment

5.1.1 Coastal Location

The area of interest runs from Niutoua, southeast parallel to the coastline, and continues down to Hamula, covering the townships of Niutoua, Haveluliku, Fatumu, and Lavengatonga. However, the following table shows the different estates along the area of interest.

Table 5: Townships and Estate Types.

<table>
<thead>
<tr>
<th>Estates:</th>
<th>Estate holder:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niutoua</td>
<td>Government</td>
</tr>
<tr>
<td>Kolonga</td>
<td>Nuku</td>
</tr>
<tr>
<td>Lapaha</td>
<td>Kalaniuvalu</td>
</tr>
<tr>
<td>Haveluliku</td>
<td>Government</td>
</tr>
<tr>
<td>Fatumu</td>
<td>Government</td>
</tr>
<tr>
<td>Lavengatonga</td>
<td>Government</td>
</tr>
<tr>
<td>(110A) Kalaniuvalu</td>
<td></td>
</tr>
<tr>
<td>Ha‘asini</td>
<td>Government</td>
</tr>
<tr>
<td>Hamula</td>
<td>Kalaniuvalu</td>
</tr>
</tbody>
</table>

It is predominantly a rural area with typical rural townships, surrounded by farm lands (tax allotments).
5.1.2 Geography

The area of interest is predominantly the higher parts of Tongatapu, with a ridge that is prominent and runs in parallel to the coastline. The area forms part of the main area for agricultural use but much of the land lay in idol.

5.1.3 Land Use

The common practice of root crop production is apparent in this area. The dominant root crops include yams, taro, and cassava. The traditional way of a planting sequence that ends with a period of fallowing is still practiced. However, the pressure from mono-cropping for commercial purposes has put pressure on the environment and the traditional system of fallowing.

However, the intended area needed for one turbine is estimated to be about $800m^2$. This is only about 3% of the total area of a tax allotment ($33386.57m^2$), an equivalent of one town allotment. It is envisaged that the area will be secured through formal leasing. Once this is signed in agreement with the landowner, the area will be fenced off, and access will be restricted. The wind turbine sites will be spread out in a row facing the trade wind. Similar to 5 town allotments spaced out in a row.

Further, the land owner has 85% of his tax allotment for his own usage. It is also noted here that there is no restriction on the types of agricultural use adjacent to a wind turbine. Overall, there will be very limited impact on the landowner’s benefit from his own land. More importantly, the landowner will have financial benefits from the leasing agreement, specifically the annual rental of the required area.

It is important to reiterate, as have been mentioned in previous sections that there is a height restrictions about 4km from Fua’amotu Airport. The Civil Aviation Director and Real Tonga pilot consulted, were satisfied that the location of these turbines are acceptable.

5.2 Social, cultural and Economic

5.2.1 Potential problems for the people concerned

a) Noise Nuisance

The noise from einf turbines originates from three sources:

- Aerodynamic Noise: The motion of the blades causes turbulence when passing the tower;
- Shaft Noise: This is the noise made by the shaft and bearings moving;
- Gearbox Noise: This noise is quite apparent in less expensive models such as the spur-gears. On the other hand, the helical-gears and herring-bone gears produces less noise.

Figure 10: Speed Pressure Level and Distance from towers.

It is encouraging that the technology proposed for this project; and potential sites, combined to negate any sound (noise) impacts. However, wind turbines are only about 40dB from a 500m distance, which is less noisy than talking (60dB).

b) Shadow Flicker

The sun rises from the east and set to the west of Tongatapu. Any wind turbine tower will cast a shadow on their vicinity in direct sunlight. Therefore, when the blades turn, they cut through the light beams, causing flickering effect. At its worst, this is an annoying impact but it is only experienced in one direction for a short period of time.
c) Visual Impact

The height of the proposed wind turbines is 50m; and 66m to the tip of the blades. Due to their heights, the turbines will be highly visible structures in the Hahake Coastal landscape.

d) Birds Collision

This is quite a sensitive issue because it can be emotional to some people. However, there is no bird conservation area or bird migratory corridor specified or identified along this coastal area. More importantly, it is well known that birds can and do readjust their flight path around wind turbines. The existing wind turbine in Nakolo has no recorded bird collision since it’s installation two years ago. This speaks volume of the natural and instinctive adaptation of local birds to introduced technology such as wind turbines.

5.2.2 Potential loss of medicinal and traditional vegetation

Although, Whistler (1989) recorded about 330 flowering plants described as native to Tonga, approximately one third of them ferns. Only 11 species were identified as endemic, two third of those are found in Samoa and even more in Fiji. Endemic tree species include Langakali vao (*Aglaia heterotricha*), Mo’otamea (*Dysoxylum tongense*), and Uhiuhi (*Podocarpus pallidus*) – all confined to the island of Eua. Several others (19 species) are proposed by the stocktaking report to be ‘likely endemics’. Unfortunately, the main island of Tongatapu has been mostly stripped of its native forests for subsistence and commercial plantations. Contributing to this, is the recent trend of monetisation of plant values, especially “ahi” (sandalwood), which led to over harvesting and illegal exportation. Further, the five species identified by Fusimalohi (1989) namely, “heilala” (*Garcinia sessillis*), “langakali” (*Aglaia saltatorium*), “mohokoi” (*Gananga odorata*), “puatonga” (*Fragaea berteria*), and “sialetonga” (*Gardinia toitensis*), are not present in the project site identified. In comparison, the proposed project has little impact since most of the traditional and medicinal plants have been harvested or cleared prior.

5.2.3 Health and Safety

Indifferent from its predecessor, TPL has taken on a rather high standard adopting various safety and operation standards. The proposed wind turbines, and operations has been designed to minimise impacts on the environment.

TPL’s general work instructions include the following:
i.) Construction will occur during standard daylight hours

ii.) Land clearing will be done with great caution, ensuring only the required flora is cleared. This activity will be done by experienced operators, with the use of adequate signage, barrier protection and standard PPE such as hard hat, high visibility clothing, Steel capped boots and safety glasses.

- Land clearing and earthworks forming a small drainage and access to tower position;
- Excavation for wind turbine foundation and substation foundation (Specification below).

Figure 11: Diagram for the Tower foundation.
iii.) The site will be fenced off and access to the site will be restricted, monitored, and reported to the Project Manager at a regular basis.

iv.) On site toilets and bins will be provided, with appropriate waste management guidelines.

v.) Any chemicals and fuels used on site will be avoided. However, in the unlikely event it occurs, a spill kit will be ready on site to be used.

vi.) The installation of the towers and turbines will be completed by professional operators, and assisted by experienced TPL personnel.
vii.) The site will include the required civil work (levelled ground, gravel filled and compacted surface, proper drainage).

viii.) Wiring the electrical components of the development will be done by well qualified and experienced electricians / engineers.

ix.) Dust controls such as barrier protection and fencing will be used during construction phase

x.) Site security and health and safety practices were developed for the Popua Solar Farm (Ma’ama Mai) and will be implemented for these sites as well.

5.2.4 Employment

The fact that the expansion and revitalised operation at the TPL energy production (diesel, solar and wind) had not only increased the number of employees but also the qualification and skill level. Further, the working conditions, such as health and safety, are much better than that availed by the former operators.

It is also noted that the TPL, as a power generating entity, also supports employment in other sectors, especially the construction industry. However, for this project, TPL will be vigilant in employing or sub-contracting qualified and experienced personnel and/or contractors.
5.2.5 Heritage Sites

The Ha’amonga ‘a Maui is located at Niutoua, but the project site will be located on the opposite side of the township, well into the rural area (tax allotments). Therefore the impact of this project will be insignificant.

5.2.6 Public Awareness

TPL has commenced engaging the public and it is welcoming that the public are quite aware of the wind as a renewable energy source. However, the TPL campaign needs to be consistently maintained over a period of time. Misinformed among the public and public concerns need to be dispose of in a timely manner.

At this point, TPL has raised general awareness of the proposed wind turbine project. Priority key stakeholders (local officials, land owners) have been engaged in dialogues that allow them to understand and support the project. Strategically, TPL has will continue engage the necessary members of the public given that JICA has identified the specific sites for the wind turbines. It is fortunate that the identified site involves the same people that had been engaged since the beginning of the dialogue.

5.3 Environment Quality

5.3.1 Land Management

Appropriate conditions will be adhered to when clearing, constructing, and installing the wind turbines. This include minimising tree cutting and utilise the most shortest route during the road design. The turbine sites will be kept as grassland to minimise soil erosion or runoffs.

5.3.2 Handling of Chemicals (Batteries)

Spillage Kit and First Aid kit will be always placed on each site. In addition, safety procedures for handling and storing any chemical on site will be available for all personnel, TPL or otherwise, working on these sites.
5.4 Cumulative Impacts

5.4.1 Road Access

The public access road leading to the turbine sites will be improved, thus allowing better access to and from the farming area for those who have tax allotments in the locality. At the moment, most of these access roads are dirt roads and are in poor condition. Better access will also promote farming activities and may lead to improved usage of idle lands.

5.4.2 New electrical lines

Similar to the roading improvements, electricity lines will be laid out, connecting the wind turbine sites to the main lines along Liku Road. This will allow people and farming activities that need electricity to progress, since the lines will already be installed.

6.0 Public Consultation

A sample survey of the households of Niutoua, Haveluliku, Lapaha, Fatumu, and Lavengatonga. The respective Town Officers were engaged to distribute the questionnaires. This done intentionally to minimise having an ‘outsider’ probing into local villagers daily activities. Thus allowing the village people to be ‘free’ in answering the questionnaire paper.

It is noted here that when specific turbine sites are determined, there will be further dialogue with the communities concerned. It is envisaged that this will be carried out in the last quarter of this year.

For six weeks (June-July 2014), various communities were approached regarding the TPL proposed wind farm in the Hahake Districts. This was followed on with a questionnaire survey, distributed through the Town Officers for each township.
<table>
<thead>
<tr>
<th>Township</th>
<th>Number of respondents</th>
<th>Total Households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niutoua</td>
<td>43</td>
<td>119</td>
</tr>
<tr>
<td>Haveluliku</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>Fatumu</td>
<td>36</td>
<td>67</td>
</tr>
<tr>
<td>Lavengatonga</td>
<td>26</td>
<td>69</td>
</tr>
<tr>
<td>Lapaha</td>
<td>63</td>
<td>343</td>
</tr>
<tr>
<td>Total:</td>
<td>186</td>
<td>626</td>
</tr>
</tbody>
</table>

Table 6: Number of household respondents.

The communities were very cooperative hence the good number of respondents. Admittedly, some participants did not return their questionnaires. However, this did not mean that they opposed the proposed project. The responds recieved are sum up in the following sections for ease of reference:

**6.1 Socio-Economic Characteristics:**

Generally, the responses from local people confirmed the official statistics on migration. It seemed that the population increased up to the 1950s. Then the emigration pattern was effective in the 1960s-1970s maintaining a slow growth. However, in the last three decades or so, internal migration (outer islands to Tongatapu), and population increase have pushed up the local population number again (Figure 14). This is supported by the fact that the number per household (‘api) have increased not necessarily in family size, but in the number of families per household (Figure 15).
It is fair to say that, although in small numbers, there is consistently increasing number of households until recently. However, both internal migration and international emmigration play a part in the changing number of households.
The quality of dwellings has improved as expected. Most of the older buildings are made of timber and on stilt posts. However, the building type showed a shift that favours timber on concrete foundation, and also block and concrete buildings. The number of buildings has increased in the last two decades. Two of the main reasons are; an increase in landholders, and improve in families financial status.

![Building Type in the Area of interest](image)

Figure 16: Building types

Further, the improvement of building types is not a short term development. The houses were mostly built in a 1980s-2010 period reflecting the impact of the lucrative primary produce, such as squash pumpkin export to Japan; and the remittances from overseas.

Interestingly, for an area that is referred to as rural, most households has at least one person that is working (paid employee). In some households, there are two or three people working full time. It was also noted that there are a lot of people working in the private sector (local and foreign businesses), and non-governmental organisations. The Government remains the main employer of formal paid employment in Tonga with 24%; 28% work for various non-government employers; and 48% declared unemployment status. However, with 52% having some type of paid employment is a promising sign.

It is also understood that remittance has decreased due to the impacts of the global economic downturn. However, people have resort to alternate sources of incomes whether it be from farming, self employ, and fishing. Despite the fact that a lot of the survey participants do not own a Tax Allotment (49%), that does not stop people from farming. Leasing land and sharing of rights to use,
provide a workable answer to the ownership issue. Further, mixed farming (subsistence and commercial) practice has increasingly popular among farmers. Unfortunately, there are still people with Tax Allotments who do not utilise their land.

Figure 17: Land use types

The above point, land use types, is reemphasised when participants declare their main source of income. These are typical rural townships, having agricultural activities as their main source of income.
Following the source of income, participants were probed on their monthly electricity bill. It highlights the need to utilise an alternative source of energy besides the diesel generation. The majority (43.5%) pay between $50-$100 per month; 22.5% pay less than $50; and 20% pay between $101-$150 per month. This is with an average wage and salary of $391/month\textsuperscript{9}. Therefore these people spend up to 40% of their income on electricity expenses.

Two fo the main evidence of change sighted by people in the locality were; increase in number of buildings, and population increase. The increase in local population was due to immigrants from the outer islands according to the respondents, and less on natural growth. Not surprisingly, emigration overseas was also noticed by the local people. Further, the improvements in terms of street lights, new electricity poles, new electricity meters, and underground lines were noticed and appreciated by the people in general.

6.2 Community Development Perceptions:

As expected, there were a lot of expectations ever since the installment of the monitoring tower in Lapaha about five years ago. This expectation was again brought to the forefront when TPL installed

\textsuperscript{9} Calculated from the Private households main source of income by constituency, 2011.
the micro-wind turbine in Nakolo in 2012. In hind sight, people expected to have some type of wind power initiative for some time now.

The general view on foreign aid was very positive and most people cited the projects that helped improve their water supply and reticulation lines. Further, assistances from local people who live overseas was also acknowledged by the local people.

However, the participants did raised their desires to see more street lights, and improvement of the lines (poles and poles position).

Figure 19: Needs required

![Needs Required](image)

It is quite interesting to see that the needs of the people are predominantly based on their daily life. Hence, the most people (32%) preferred more street lights; need additional lights and poles (17%); and there is need for renewable energy (17%). Only about 1% wished that the tarrif will be lower, which is oddly low figure. Despite this low expression of need to reduce the tarrif; more than 70% acknowledged that the tarriff is too high.

Understandably, about a quarter of the participants have needs that were not related to TPL; and some have expressed no needs (9%).
6.3 Community Perception of TPL and the proposed wind farm:

A lot of people admitted that they experienced and witnessed the improvements in TPL’s infrastructure and services. Further, most of the participants expressed their appreciation and support for TPL’s proposed wind farm.

Figure 20: Public support for the proposed wind farm.

7.0 Summary of potential impacts

Following are main points to note, as this study has identified both beneficial and adverse impacts of the proposed TPL development project (Table 7).
### Impacts

<table>
<thead>
<tr>
<th>Impacts</th>
<th>+/-</th>
<th>Type</th>
<th>Duration</th>
<th>Frequency</th>
<th>Scale</th>
<th>Mitigation</th>
<th>Probability</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Environment</td>
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<td></td>
<td></td>
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<tr>
<td>Soil Degradation</td>
<td>-</td>
<td>D</td>
<td>L</td>
<td>O</td>
<td>L</td>
<td>N</td>
<td>H</td>
<td>NS</td>
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<td></td>
</tr>
<tr>
<td>Flora</td>
<td>-</td>
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<td>L</td>
<td>O</td>
<td>L/N</td>
<td>Y</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Fauna</td>
<td>-</td>
<td>I</td>
<td>S</td>
<td>O</td>
<td>L</td>
<td>Y</td>
<td>L</td>
<td>NS</td>
</tr>
<tr>
<td>People &amp; Communities</td>
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<tr>
<td>Health</td>
<td>-</td>
<td>I</td>
<td>L</td>
<td>O</td>
<td>L</td>
<td>Y</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Employment</td>
<td>+</td>
<td>I</td>
<td>L</td>
<td>O</td>
<td>N</td>
<td>NA</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Environmental Quality</td>
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</tbody>
</table>

**Identified impact**

<table>
<thead>
<tr>
<th>+/-</th>
<th>Type</th>
<th>Duration</th>
<th>Frequency</th>
<th>Scale</th>
<th>Mitigation</th>
<th>Probability</th>
<th>Significance</th>
</tr>
</thead>
</table>

**+/-**  Beneficial or Adverse  
**Type**  Direct (D), Indirect (I), Secondary (S)  
**Duration**  Short-term (S), Long-term (L)  
**Frequency**  Construction (C), Continuous during Operation (O), Periodic (P), Rare (R)  
**Scale**  Local (L), Regional (R), National (N), Not Applicable (NA)  
**Ease of Mitigation**  Yes (Y), Partial (P), No (N), Not Applicable (NA)  
**Probability of Occurrence**  Low (L), Medium (M), High (H)  
**Significance**  Not Significant (NS), Low (L), Medium (M), High (H)

In brief the main points are:

- **Beneficial Impacts**

  There are number of beneficial impacts identified for people and communities at large; and government and commercial sectors alike. These are deemed of high significance.

- **Adverse Impacts**

  A number of potential adverse impacts identified on physical environment (potential degradation), on habitats flora and fauna (deforestation, bird collision), on people (aesthetic and noise pollution). These have been assessed as of low or medium significance. Despite the fact
that TPL operations may contribute to these, it is non-significant compared to the wider human impacts in the area over the years. However, these impacts from TPL operations can be avoided or reduced through mitigation measures and monitoring plans.

- Non-significant Issues

There are no direct significant impacts on habitats, flora, fauna, and communities at the time of this report. It should be reiterated that the potential impacts are a real risks, and TPL need to be vigilant in its safety procedures and operations.

8.0 Environmental Management Plan (EMP)

This sets out how adverse impacts could be managed and during construction and operation in order to minimise effects on the environment and the local communities. It should be noted that this is the first time that such consideration is seriously acknowledged over the history of energy production in Tonga. In Section 3.3 TPL and Option Two; TPL has expressed its commitment to sustainability and its environmental responsibility. However, the following are summary of these.

8.1 Protective Measures

Environmental protective design measures will be adhered as required in the Best Practices\(^\text{10}\) in the wind energy industry.

8.2 Administrative arrangements

1. TPL retains overall responsibility for the construction and operation. The CEO of TPL will take responsibility for the environmental management and will employ special technical environmental consultants as required for particular incidents that impact upon the environment and routine monitoring and reporting.

\(^{10}\) Proposed reference for TPL is the New Zealand Wind Energy Health and Safety Guideline, NZ Wind Energy Association, 2013.
ii.) The TPL staff, specifically the Project Manager and staff, and subcontractors has responsibility for environmental management and mitigation. This safety of the public and the environment is paramount.

iii.) The Ministry of Environment and Communication will ensure compliance with the EIA code.

8.3 Mitigation and Monitoring Measures

8.3.1 Mitigation Measures

TPL is committed to mitigate issues and address concerns with regards to the environment and the wider communities within the area.

Public Awareness
1. The public had been engaged during this exercise. However, the public awareness will be continued throughout the design, implementation, operation phases.

Designing Phase
1. The approved design are adhered to and implemented.

2. Preventative Measures to be considered:
   - Smarter siting: TPL will endeavour to do a better job in selecting sites for the wind turbines. Further, TPL will develop a clear siting practices and M&E.
   - Ultrasonic acoustic: It is noted here that potentially bats may die not only from hitting the turbine but from the lower wind pressure near the blades causes their lungs to explode. However, birds and bats react differently to wind turbines; so TPL will pursue different methods to protect them, including acoustic deterrents.
   - Turning the turbines off when wind speeds are low: This is because bats like to travel in very low-wind conditions; a second strategy is to turn on turbines when wind speeds are high. Unfortunately, turbines are commonly designed to start spinning 3.5m/s – 4 m/s; thus creating an economical dilemma for TPL when employing this method.
   - Painting turbines different colour: Making them less attractive to insects and number congregating around the turbines, thus avoid attracting bats and birds near the turbines.
   - Designing new turbine shapes: Old designs attract roosting birds (perch and nest, especially lattice-style structures; vertical axis are better.
Implementation Phase

1. Approved designs will be implemented and monitored accordingly during the construction phase.

2. Further, the proposed measures by this EIA report will be implemented and monitored.

8.3.2 Monitoring Program

a) During Construction

ii.) Daily site inspections by supervisors, observed progress of works, and implementation of environmental and health and safety mitigation activities.

b) During Operation

iii.) TPL will operate in a timely manner and within the official Government working hours (8:30a.m. – 4:30p.m.) to contain the noise pollution.

iv.) TPL will continue to carry out regular safety drills and workshops, on a regular basis.

v.) Health and Safety courses will be availed for staff concerned.

vi.) Annual environmental audit of the site by an environmental expert had been arranged to be done regularly.

vii.) TPL continues to maintain its public awareness campaign to inform the public. This includes staff attending public meetings to inform and clarify issues with the public.

viii.) Security had been tightened and entry to the TPL Operational sites will be restricted.

c) Contingency Plan

iii.) TPL will develop a Cyclone Response Plan (CRP) for the sites; and carry out a drill on a regular basis. In addition to the safety plan, environmental aspects of the site operation are included, and also identify risk areas.

iv.) Maintain all sites to minimise any hazards (fire, cyclone).

v.) TPL will solicit the necessary expertise to draw up the Contingency Plan, and have this endorsed by MEC.

a) Training Needs

iii.) Pollution control / Health and Safety / Environmental training will be carried out at a regular basis for all staff concerned.
iv.) TPL will continue to collaborate with relevant regulatory authorities on issues pertaining to its Wind Turbine operations.

9.0 National Plan and Policy

The Tonga Strategic Development Framework (TSDF) provides the guiding principles and directions for a four-year term, that the current administration. The actions and strategies are in sectorial plans.

The TSDF 2011-2014 affirmed Tonga’s vision “to develop and promote a just, equitable and progressive society in which the people of Tonga enjoy good health, peace, harmony, and prosperity, in meeting their aspirations in life.”

The nine outcome objectives: 1) Strong inclusive communities; 2) Dynamic public and private sector partnership; 3) Appropriate well planned and maintained infrastructure; 4) Sound education standards; 5) Appropriately skilled workforce; 6) Improved health of people; 7) Cultural awareness, environmental sustainability; 8) Better governance; and 9) Safe, secure and stable society, are reflected in the Budget Statement 2013/14. These are followed by four Enabling Themes. These are grouped with their respective strategies, 42 in total.

9.1 Sectoral Status

Sector VII Energy Resources

This is a priority sector for Tonga. Tonga Power Limited (TPL) is the only power company in Tonga, and it is a state owned enterprise. TPL as an SOE has to pursue its commercial agenda as well as address TSDF mandates.

Tonga’ is heavily dependent on imported fossil fuels for her energy needs. However, the economy is particularly vulnerable to oil price shocks, disruptions in the world supply of oil. Further, the risks and costs of bulk fuel transportation are exacerbated by Tonga’s small market and isolation.

Tonga Energy Road Map (TERM) provides the platform for Tonga to mobilise actions to secure energy future that is practical for the island state. The TERM plan is for 50% of the Kingdom’s energy
to come from renewable energy by 2020. The TERM’s objective is to lay out 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.\textsuperscript{11}

Achievements

- Tonga Electric Power Board Act
- Tonga Energy Road Map (TERM)
- \textit{Maama Mai} Solar Farm
- Micro-wind turbine trial
- Renewable Energy Policy
- Renewable Energy Act
- Pilot Micro-wind turbine (Nakolo)

Challenges

- Financial and Technical limitations
- Limited Technical Capacity and Expertise
- Resources for biofuel and biomass are not available in a large scale and it would require extensive rehabilitation of existing standings (coconut) or new crops.

\textsuperscript{11} Tonga Energy Road Map 2010-2020: A ten year road map to produce Tonga’s vulnerability to oil price shocks and achieve an increase in quality access to modern energy services in an environmentally sustainable manner. Final Report. Tonga Government. June 2010
10.0 Conclusion

TPL, as an SOE, has been endeavouring to generate and provide electricity for Tonga. At the same time, looking for alternative fuel, as in this case, wind power. TPL is also collaborating with various government agencies, especially the regulating agency MEC, under the EIA 2003.

The conclusion of this report is that TPL proposed wind farm project be approved for implementation with EMP conditions described, at the Niutoua site identified. The proposed wind technology can be implemented and managed so that the electricity production targets are realised without compromising environmental values in the locality.

The location of the TPL site is highly suited for its electricity production that is based on wind energy from Tonga’s trade wind. However, TPL must be profoundly vigilant in managing and monitoring the environmental impacts; and adopt mitigative measures as necessary. Overall, this will be realised when all stakeholders (donor, executing agency, implementing agency, community) are involved in all facets of the project (design, implement, operate, monitor); and work as equal partners toward a common goal; to reduce Tonga’s reliance on unpredictable and volatile fuel market for its electricity needs.
REFERENCES


PEIN Country Profile and Virtual Environment Library (SPREP)


Statistics Department, Tonga Census Reports (1911-2011), Tonga Government, Nuku’alofa.


Appendices
Appendix 1: Questionnaire Paper

Faka' cheeko 'o e kai 'o Hohake: Siuloi 2014

FAKAININI:

Hingoa tokotaha tali fehu'i:
Hingoa tokotaha ma'u'api (Kapau 'oku kehekehe):

NGAAHI FEHU'I:
1. Ta'u ne mou kamata nofo'i mai ai 'a e 'api ni? (Siakale'i 'a e toha 'o e ngaahi tali ni)
2. Tekolahi 'oku nofo he 'api ni? (Siakale'i 'a e fika totonu)
   1 2 3 4 5 6 7 8 9
3. Fa'unga Fale:
   Kapau Papa / Fakapou Papa Fakava'e Piliku Piliku
4. Fakatufa ta'u ne langa ai:
5. Toko fiha kou ma'ungaue i 'api?
   • Kau ma'u ngaue i'e toko:
   • Ngaua faka-Pula'anga pe 'ikai?

6. 'Oku'i ai hao 'Api Tukuhaul? 'Io pe 'ikai
7. Ko e ha e ngaue pe ngoue i 'uta? [Siakale'i ha taha 'o e ngaahi tali ni]
   i. Ngoue ki he ma'u me'atokoni
   ii. Ngoue ki he fakamaketi pa fakatau
   iii. Fanga monumanu
   iv. Lisi atu pe tuku atu ke ngoue ai ha tokotaha kohe
8. Ko e ho’o ngaahi ma’u’anga mo’ui he taimi ni?

9. Katak pe ’oku fiha ho’o totongi ‘uhila fakamahina?

10. Faktokanga’i ha ngaahi me’a ‘oku ha fo’ou pe liliu he kolo ni?

11. Ko e ha ha ngaahi tokoni ‘oku ke mahu’inga’ia ai ke fakahoko ki Niutoua?

12. Ko e ha ho’o fakaukau ki ho ma’u’anga ‘uhila mo e totongi ‘uhila he lolotonga ni?

13. Ono’i mo e fakaukau ki hono ngaue’aki e havili ke fo’u e ‘uhila (wind power)?
   i. Poupou ki ai pe ‘ikai teke poupou’i
   ii. Ko e ha ha ngaahi fakaukau ke poupou’i ho’o tali?

14. ‘Oku ‘ai ha ngaahi me’amakehe ‘oku ke toe tokanga kiai fekau’aki mo hono fokotu’u ‘o e me’angase ke fo’u e ‘uhila mei he ivi ‘o e havili?
### Appendix 2: List of Participants

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Kamoto Halafihi
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Lamona Moata'ane
Feleti Ma'umalenga
Salesi Vakapuna
Sione Nau Quensell
Taniela 'Ahotau
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Sione Tuifua Sili
Ikinasio Siale
Paki Sili
Tatonga Tangata'iloa

Niutoua

Kaluseti Holani
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Sione Tangitau Liku
Tu'ipulotu 'Otuhouma
Veisinia Kilikiti
Douscas Mahanga
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