SPREP

Pacific Islands Renewable Energy Project

A climate change partnership of GEF, UNDP, SPREP and the Pacific Islands

GEF

UNDP

The Secretariat of the Pacific Regional Environment Programme

Pacific Regional Energy Assessment 2004

An Assessment of the Key Energy Issues, Barriers to the Development of Renewable Energy to Mitigate Climate Change, and Capacity Development Needs for Removing the Barriers

TONGA

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our islands, our lives...

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ACRONYMS

AAGR	Average Annual Growth Rate
AC	Alternating Current
ACP	African, Caribbean, Pacific countries
ADB	Asian Development Bank
ADO	Automotive Diesel Oil
BP	British Petroleum
CAIT	Climate Analysis Indicators Tool (WRI)
CCA	Common Country Assessment (of the UN)
CIF	Cost+insurance+freight
CO_2	Carbon dioxide, a key greenhouse gas
CPI	Consumer Price Index
CROP	Council of Regional Organisations of the Pacific
DANIDA	Danish International Development Agency
DC	Direct Current
DSM	Demand Side Management for efficient electricity use
EC	European Community
EDF	European Development Fund
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ENSO	El Niño/El Niña oceanic climate cycle
EPU	Energy Planning Unit
ESCAP	Economic and Social Commission for Asia and the Pacific (UN)
EU	European Union
EWG	Energy Working Group of CROP
FY	Fiscal Year
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GMT/UTC	Greenwich Mean Time/Universal Time Coordinate
GNP	Gross National Product
Goa	Government of Australia
GoT	Government of the Kingdom of Tonga
HDI	Human Development Index (UNDP)
JICA	Japan International Cooperation Agency
kV	Kilo-Volts (thousands of volts)
kVA	Kilo-Volt-Amperes (Thousands of Volt Amperes of power)
kW	Kilo-Watt (Thousands of Watts of power)
kWh	Kilo-Watt-Hour (Thousands of Watt Hours of energy)
kWp	Kilo-Watts peak power (at standard conditions) from PV panels
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goals
NASA	US National Aviation and Space Administration
NRBT	National Reserve Bank of Tonga
NZAID	New Zealand Aid
OPEC	Organisation of Petroleum Exporting Countries
OTEC	Ocean Thermal Energy Conversion
PACER	Pacific Agreement on Closer Economic Relations
PEDP	Pacific Energy Development Programme (UN 1982-1993)
PIC	Pacific Island Country
PICCAP	Pacific Islands Climate Change Assistance Programme (GEF/UNDP)
PICTA	Pacific Island Countries Trade Agreement
PIEPSAP	Pacific Islands Energy Policies and Strategic Action Planning
PIFS	Pacific Islands Forum Secretariat
PIREP	Pacific Island Renewable Energy Project (GEF/UNDP)
PPA	Pacific Power Association
PREA	Pacific Regional Energy Assessment (1992)
PV	Photovoltaic
RET	Renewable Energy Technology

SDP7	Strategic Development Plan Seven: 2001-2004
Seniti	cent; T$ 0.01
SHS	Solar Home System
SOPAC	South Pacific Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
SWH	Solar Water Heater
SWOT	Strengths, Weaknesses, Opportunities and Threats
TEPB	Tonga Electric Power Board (utility regulator)
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States
USP	University of the South Pacific
V	Volts
WB	World Bank
Wh	Watt hours of energy
WRI	World Resources Institute (Washington, DC)
WSSD	World Summit on Sustainable Development

Energy Conversions, CO_2 Emissions and Measurements

The following conventions are used in all volumes of the PIREP country reports unless otherwise noted.

Fuel	Unit	Typical Density kg / litre	Typical Density l / tonne	Gross Energy MJ / kg	Gross Energy MJ / litre	Oil Equiv.: toe / unit (net)	Kg CO_2 equivalent [e]	
							Per GJ	Per litre
Biomass Fuels:								
Fuelwood (5% mcwb)	tonne			18.0		0.42	94.0	
Coconut residues (air dry) [a]								
Shell (15% mcwb) harvested	tonne			14.6		0.34		
Husk (30% mcwb harvested	tonne			12.0		0.28		
Average (air dry) [b]	tonne			14.0		0.33		
Coconut palm (air dry)	tonne			11.5		0.27		
Charcoal	tonne			30.0		0.70		
Bagasse	tonne			9.6			96.8	
Vegetable & Mineral Fuels:								
Crude oil	tonne			42.6		1.00		
Coconut oil	tonne	0.920	1,100	38.4		0.90		
LPG	tonne	0.510	1,960	49.6	25.5	1.17	59.4	1.6
Ethanol	tonne			27.0		0.63		
Gasoline (super)	tonne	0.730	1,370	46.5	34.0	1.09	73.9	2.5
Gasoline (unleaded)	tonne	0.735	1,360	46.5	34.2	1.09	73.9	2.5
Aviation gasoline (Avgas)	tonne	0.695	1,440	47.5	33.0	1.12	69.5	2.3
Lighting Kerosene	tonne	0.790	1,270	46.4	36.6	1.09	77.4	2.8
Aviation turbine fuel (jet fuel)	tonne	0.795	1,260	46.4	36.9	1.09	70.4	2.6
Automotive diesel (ADO)	tonne	0.840	1,190	46.0	38.6	1.08	70.4	2.7
High sulphur fuel oil (IFO)	tonne	0.980	1,020	42.9	42.0	1.01	81.5	3.4
Low sulphur fuel oil (IFO)	tonne	0.900	1,110	44.5	40.1	1.04	81.5	3.4

Diesel Conversion Efficiency:

	litres / kWh:	Efficiency:
Actual efficiencies are used where known. Otherwise:		
Average efficiency for small diesel engine (< 100kW output)	0.46	22%
Average efficiency of large modern diesel engine(> 1000 kW output)	0.284	36%
Average efficiency of low speed, base load diesel (Pacific region)	0.30 - 0.33	28% - 32%

Area: 1.0 km^2 = 100 hectares = 0.386 $mile^2$ — 1.0 acre = 0.41 hectares

Volume 1 US gallon = 0.833 Imperial (UK) gallons = 3.785 litres — 1.0 Imperial gallon = 4.546 litres

Mass: 1.0 long tons = 1.016 tonnes

Energy: 1 kWh = 3.6 MJ = 860 kcal = 3,412 Btu = 0.86 kgoe (kg of oil equivalent)
1 toe = 11.83 MWh = 42.6 GJ = 10 million kcal = 39.68 million Btu
1 MJ = 238.8 kcal = 947.8 Btu = 0.024 kgoe = 0.28 kWh

GHGs 1 Gg (one gigagramme) = 1000 million grammes (10^9 grammes) = one million kg = 1,000 tonnes

CO_2 equiv CH_4 has 21 times the GHG warming potential of the same amount of CO_2; N_2O 310 times

Notes: a) Average yield of 2.93 air dry tonnes residues per tonne of copra produced (Average NCV 14.0 MJ/kg)
b) Proportion: kernel 33%, shell 23%, husk 44% (by dry weight).
c) Assumes conversion efficiency of 30% (i.e., equivalent of diesel at 30%).
d) Assumes conversion efficiency of 9% (biomass - fuelled boiler).
e) Point source emissions

Sources:
1) Petroleum values from Australian Institute of Petroleum (undated) except bagasse from AGO below
2) CO_2 emissions from AGO Factors and Methods Workbook version 3 (Australian Greenhouse Office; March 2003)
3) Diesel conversion efficiencies are mission estimates.
` 4) CO_2 greenhouse equivalent for CH_4 and N_2O from CO_2 Calculator (Natural Resources Canada,

EXECUTIVE SUMMARY

1. Country Context

Physical Description. Tonga consists of 176 islands with a total area of 748 km^2 and an EEZ of about 700,000 km^2. Tonga is about two thirds of the way from Hawaii to New Zealand, located between 15° and 23°50′ South Latitude and 173-177° West Longitude. There are four groups of islands (Tongatapu, Ha'apai, Vava'u and Niuas) and 36 islands are inhabited. Most islands have a limestone base formed from an uplifted coral formation but some have limestone overlying a volcanic base. There is presently volcanic activity and there have been several eruptions over the past century. The largest island is the capital island of Tongatapu.

Population. The 1996 census counted 97,784 people and showed an average annual growth rate of 0.35% for the previous ten years. Over two thirds of the population is on Tongatapu. Urbanisation increased at nearly four per cent per annum with Tongatapu 80% urbanized.

Environment. The climate is tropical maritime with some differences between the south and northern island groups. The high population density on Tongatapu and the continuing drift to Tongatapu from the outer islands has created environmental problems of waste disposal, deforestation and some damage to the coral reefs. Cyclone passage is common and damage to infrastructure and crops possible. Tonga is a signer of most Pacific regional and international conventions on the environment.

Political Development. The four groups of islands were joined into a Kingdom in 1845 and a Constitutional Monarchy in 1875. Tonga became a British Protectorate in 1900 but has never been considered a colony. Independence from Britain was gained in 1970 though Tonga remains a member of the Commonwealth. His Majesty King Taufa'ahau Tupou IV was crowned in 1965.

The executive branch consists of the King in Privy Council, the Prime Minister, Ministers of the Crown and Governors of Vava'u and Ha'apai. Cabinet consists of the Prime Minister and Ministers of the Crown. The King appoints all members of the Privy Council. The legislative branch is unicameral with 30 members. Twelve are for Cabinet Ministers, nine nobles elected by the country's 33 nobles and nine seats filled by popular election. Elected members serve three-year terms. The Judiciary branch consists of an Appeals Court, a Supreme Court, a Lands Court and Magistrate Courts.

Economic Overview. Tonga has a small open economy with squash, coconuts and vanilla the main export crops that make up two thirds of total exports. A high proportion of food is imported, mainly from New Zealand. Remittances are important to the economy, as is tourism. Private sector development is emphasized in its Strategic Development Plan and there is a reasonably sound basic infrastructure and well-developed social services. Fisheries and tourism are considered as having the most potential for further economic growth.

In recent years, GDP growth has been nearly 3% per year. There have been concerns about inflation and declines in foreign reserves. ADB projects growth at 2.6% in 2004 and 2.8% in 2005. The GoT is projecting an optimistic 5.4% through 2009. Growth is vulnerable to increases in oil prices and transport costs.

The import tax on petroleum products is 35% for motor spirits and distillate and 30% for aviation gasoline and jet fuel. Fuel for electricity generation by the urban utility and outer island community electricity systems is imported duty free. There are no exemptions for energy efficiency or renewable energy systems though exemptions can be applied for on a case by case basis.

The Bank of Tonga, MBf Bank and ANZ Bank provide commercial banking services. The Tonga Development Bank focuses on higher risk development oriented loans though lending rates are comparable to those at the commercial banks.

Institutional and Legal Arrangements for Energy. The Ministry of Lands, Survey and Natural Resources includes an Energy Planning Unit (EPU) that is expected to deal with energy planning, policy development and project coordination.

Petroleum products are supplied and distributed by Shell and BP under annual government tender. Pricing is annually negotiated with bimonthly validation. LPG is imported by Tonga Gas and distributed through Tonga Home Gas. The Competent Authority (CA) establishes maximum wholesale and retail prices for key petroleum products.

Electricity on the urban islands is provided by Shoreline Power, Ltd., a locally owned private company. The larger rural islands have community operated diesel grids and smaller rural islands have solar power. The Tonga Electric Power Board (TEPB) is in principle the utility regulatory agency. Any entity wishing to generate electricity on an island or islands with a Shoreline grid must first obtain approval from Shoreline and a license from the TEPB. Individual tariffs are established for each island system, there is no cross subsidy from Tongatapu consumers.

There is a draft Tonga National Energy Policy that has not been endorsed as of mid 2004. There are several committees and working groups that meet on an *ad hoc* basis to consider energy related matters. Key legislation and regulations relating to energy includes:

- Price and Wages Control Act
- Electric Power Board Act
- Draft TEPB Bye-Laws
- Draft Energy Bill
- Draft bye-laws on regional rural electrification
- Environment Impact Assessment Act
- Draft Environment Management Bill
- Cooperative Societies Act
- Petroleum Act
- Forestry Act
- Lands Act
- Foreign Investment Act

2. Energy Supply, Demand and the GHG Inventory

Energy Supply. Although biomass remains important for cooking and crop drying energy, well over half of the national energy needs comes from imported petroleum. Solar energy accounts for less than one percent of the total and there have been no other renewable energy resource developments.

Petroleum accounts for around five percent of total imports by value though increasing prices are expected to increase that percentage in the future. Imports of motor spirits in 2000 were about 13,400,000 litres, distillate was about 18,800,000 litres and LPG about 1,270,000 litres.

Electricity on the urban islands is generated solely by diesel engines. The major customer groups include Tongatapu, ‘Eua, Lifuks (Ha’apai) and Neiafu (Vava’u). The quality of power has been good and reliability high. Small grid systems for larger Ha’apai islands (‘Uiha 168 customers, Ha’ano 106, Ha'afeva 69 and Nomuka 110) were constructed with AusAID funding in 2001-2003. The systems are powered by diesel generators and operated by an electricity cooperative on each island under license from TEPB. Hours of operation vary by island but typically are less than 12 hours a day. The per kWh cost of operation has been higher than predicted due largely to the actual loading being substantially lower than estimated for the design.

There is some private generation, particularly on church and commercial properties in the outer islands.

Solar home systems provide power for most of the smaller outer islands with the most recent installations including 150 Wp of solar capacity. The systems provide 24hour power for lighting and small communications and entertainment appliances.

Energy Demand. Sectoral sales data for petroleum products was not available so demand is assumed to be equal to imports but cannot be divided between commercial use and land or marine transport uses. Recent annual operational data for electricity generation was not available but is estimated at about 33 GWh with a total distillate fuel use of 8.5 ML so about 10,300 ML of distillate was apparently used for transport and commercial use. Motor spirit use is divided between land transport and small boat use with land transport dominating in the urban areas and small boat use in the rural areas. Jet fuel is used for inter-island air transport.

Biomass for cooking has increasingly been replaced by kerosene and LPG is presently replacing kerosene as the cooking fuel of choice. Therefore biomass energy use has fallen over the recent years.

Since recent data for annual electricity use by sector was not available, Sectoral use is estimated from earlier values and trends. In 1996, nearly 80% of homes were electrified and due to rural electrification programmes, that has probably risen to around 90% or more. An AusAID study in 1999 estimated average household use of electricity at 81 kWh/month with the domestic sector accounting for 72.5% of utility customers but only 37% of sales. In 1999, about 85% of Tonga’s electricity was generated on Tongatapu. The cost of electricity to domestic users in 2003 was 45.5¢ per kWh on Tongatapu, a price that is little changed in real terms since 1992. Fuel adjustments are applied to tariffs. For the community operated electricity systems of Ha’apai, the cost of generation is as high as T$2.00 per kWh and fees received are generally insufficient to pay operating costs with “fund raisers” sometimes needed to buy fuel for the diesels.

Future Growth in Energy Demand and GHG Emissions. The estimated GHG emissions from burning fossil fuels in 2002 were 104.31 Gigagrammes of CO_2 and an increase to 121.0 by 2010 appears reasonable. Very aggressive efforts in applying energy efficiency measures and renewable energy development could result in a total reduction of the 2010 emissions by 35%. Achieving that level depends strongly on the development of biofuel as a replacement for diesel fuel.

3. Potential for Renewable Energy Technologies

Biomass. Though around 65% of the land area is under some sort of tree crop, (mostly coconuts) for the near term, there is little opportunity for biomass from forest products to be a significant energy resource. Timber milling is a small scale industry with mostly senile coconut trees used as raw materials. Plantations of pine and hardwoods for export are being planted but it will be many years until they can be harvested. When harvesting does take place, there may be sufficient mill waste to provide biomass for energy.

Biofuels. In 1995, potential copra production was estimated to be sufficient to produce around 10 ML of coconut oil per year. If rehabilitation efforts for the coconut industry are carried out and if barriers to the production of biofuel can be eliminated, the maximum offset of diesel fuel by biofuel could be as high as 50 percent.

Biogas. Though there has been no assessment of the resource, sewage, urban waste and animal manure represent a useful resource though not sufficient to offset a significant percentage of petroleum imports. Should new sewage treatment facilities or land fill facilities be developed, including biogas generation in the plans could provide enough energy to operate the facilities themselves with some left over to feed power to the grid.

Solar. The solar resource is very good in Tonga, particularly toward the north where satellite measurements indicate as much as 5.8 $kW/m^2/day$ is present. Nearly 20 years of solar powered rural electrification experience confirms that there is a useable resource.

Wind. A resource assessment carried out on Tongatapu in the 1995 indicates a developable resource though locating the turbines away from tall coconuts trees will be necessary. Consideration should be given to locating turbines off shore or in open swampy areas to avoid turbulence from nearby trees as well as avoiding land use issues.

Hydro. There is no significant hydro resource in Tonga.

OTEC. Though a significant resource exists, the technology is still under development and there have not yet been any commercial scale installations in the world.

Geothermal. Though there have been no geothermal energy studies for Tonga, there is strong evidence of its presence. However, the location of the probable resource is not in locations where there is need for energy and development on Tongatapu is unlikely.

Wave. Wave energy is significant and was seriously considered in the late 1980s. However the lack of commercially available wave energy conversion machines and other considerations led to abandonment of the concept.

Tidal Energy. There are sites in Vava'u that could provide tidal energy but it is unlikely that the cost of installation can be justified.

4. Experiences with Renewable Energy Technologies

Biomass. The primary use for biomass is for cooking. Even in urban areas where the primary cooking fuel is kerosene or LPG, wood is used for the traditional *umu* or earth oven. Fuel wood is shipped in from other islands to Tongatapu for sale in the market and at retail outlets. In the late 1980s, a large scale coconut processing facility was funded by AusAID on Tongatapu that included co-generation through the burning of husks and shells. Unfortunately the system never worked properly and the plant design caused production problems that resulted in closure of the facility.

Solar Photovoltaics. For nearly 20 years, Tonga has used photovoltaics for household electrification in rural areas. Though early projects did not do well, as experience has been gained, each new project for solar implementation has improved in technical and institutional quality with the most recent implementation in the Ha'apai group includes 150 Wp of panels, a service fee sufficient to pay for operation and maintenance, an interest bearing battery replacement fund and an institutional structure that provides good maintenance and customer support. A project to bring solar electrification to the Niuas is now underway using a structure developed from the Ha'apai project experience. Tonga Telecom also routinely uses solar photovoltaic systems to reliably power outer island telephone networks.

Solar Thermal. Solar water heating has been utilized for over 20 years with one manufacturer of modular thermosyphon units in Tongatapu since 1986. Most hotels, guest houses and schools use solar water heating as do a significant number of private residences but the market is weak and the initial cost of the unit limits sales to households. A number of lessons were learned through the projects in Ha'apai, Vava'u and the Niuas. These include:

- The amount of money that people are willing to pay for PV electrification can be substantially greater than conventional "ability to pay" surveys predict;
- the rate of collection of user fees is directly related to the quality of service obtained;
- local, community based institutions are not adequate for sustainability;
- components must survive under very difficult environmental conditions;
- projects need to build on prior experience;
- the more remote the site, the higher need for high quality, long life components;
- preventive maintenance improves long term reliability;

Wind Power. There has been no significant development of wind power in Tonga.

Biogas. There has been no significant development of biogas in Tonga.

5. Barriers to Renewable Energy Development and Commercialisation

- low cost and convenience of petroleum fuels relative to renewables;
- import duty barriers since diesel fuel for power generation is duty free;
- increasing outer island labour costs;
- there is no energy policy that has been approved by government;
- regulation of solar based electrification is not defined;
- lack of technical and management capacity in the outer islands;

- lack of information at the utility on the potential for renewable energy and energy efficiency measures;
- lack of local training capacity in business management for energy service companies;
- lack of adequate training capacity for maintaining technical capacity on outer islands;
- difficult environment for electrical and mechanical equipment;
- lack of experience with hybrid and wind systems in the Pacific;
- capacity Development Needs for Removing the Barriers;
- dispersed rural population;
- rural sites are difficult and expensive to access;
- prior project failures;
- renewable energy business is perceived as being high risk and low profit; and
- lack of information about renewable energy and energy efficiency at all levels.

6. Other Implications of Large Scale Use of Renewable Energy

Large scale biofuel development implies rehabilitation of the coconut resource and development of an efficient process for gathering and processing coconuts into biofuel. This would provide economic benefit to both rural areas and urban areas through rehabilitation of the coconut industry in rural areas and stabilization of the price of fuel for urban areas. There are no serious environmental impacts expected though there would be an increase in transport volume between plantations and processing sites.

For the period 2003-2013, biomass is unlikely to have much more than its traditional uses of cooking and crop drying and is not forecast to reduce GHG emissions. The use of sawmill waste for energy provides both economic benefit and a reduction in the need for dumping of the waste but it is unlikely that there will be any significant amount of sawmill waste available for energy production over the next 10 years.

Solar energy has the potential to replace about five percent of the energy generated by diesel engines with minimal environmental or social impact. In rural areas, the use of solar energy requires lead-acid batteries that do represent an environmental hazard though recycling of spent batteries is a well developed industry in Australia and New Zealand and the problem can be easily solved by shipping failed batteries to recycling centres.

Large scale use of wind energy will require consideration of land use issues and location away from tall coconut trees.

7. Capacity Development Opportunities

- Fiscal policy development
- Energy policy development
- Training for EPU staff

- Assistance in the development of a biofuel production institution
- Capacity development for the design, installation and maintenance of renewable energy systems.
- Development of standards and certifications for RETs
- Development of local training capacity for energy service business management
- Decision maker information delivery
- Public information programmes

8. Implementation of Capacity Development Needs and Co-financing Opportunities

The only renewable energy project that has been approved for Tonga is a solar rural electrification project for the Niuas. It is likely to be completed before co-funding can be arranged. Plans are in place to rehabilitate and upgrade the Vava'u solar project. If the project is approved, this will be a co-financing opportunity.

All projects for the development of renewable energy in Tonga should include development of comprehensive training programmes relating to the installed technology with a particular focus on the management and maintenance of that technology. This training could be developed by the implementing organisation or separately with co-funding by another agency but coordinated with the hardware implementation.

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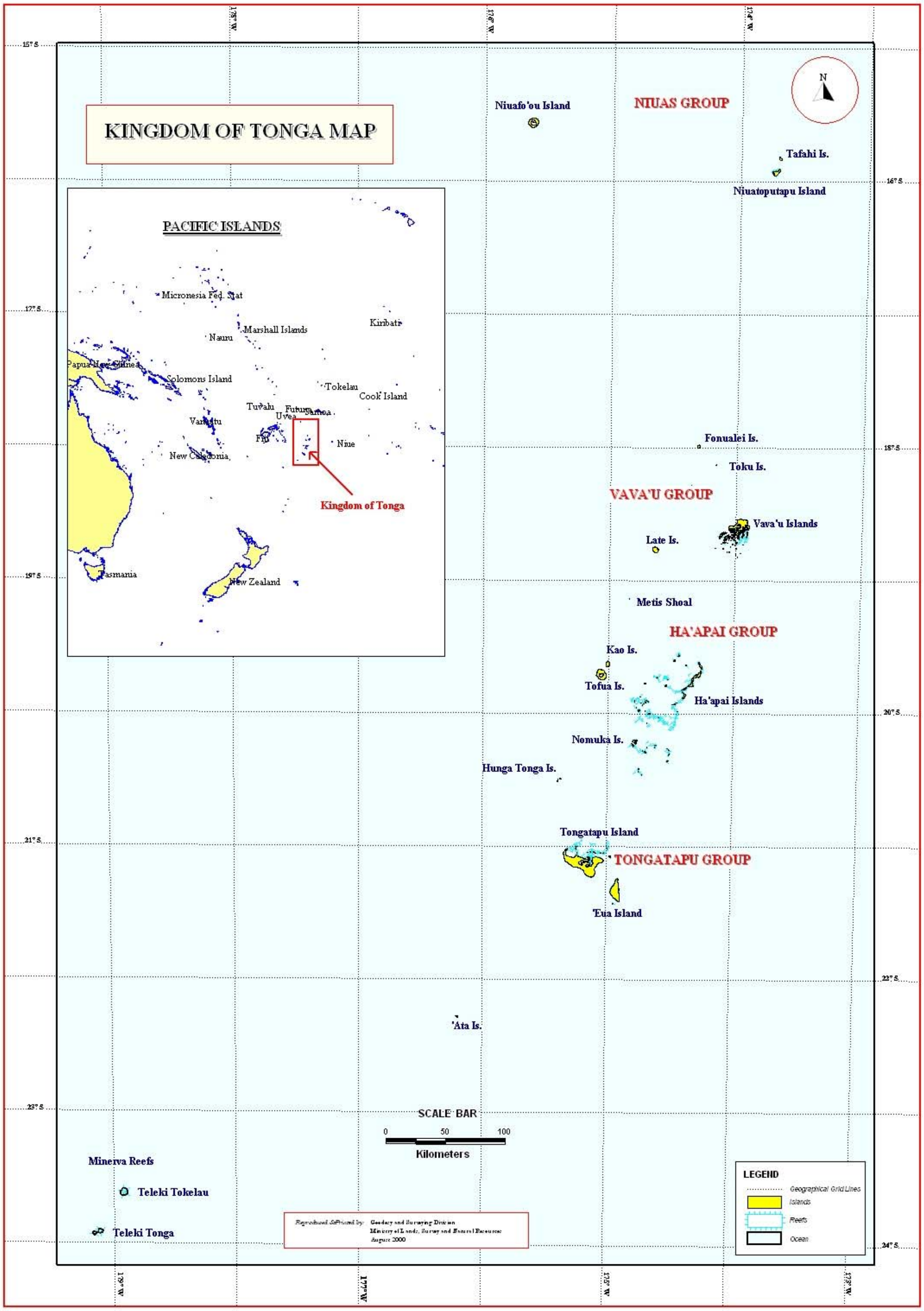


Map of Tonga (Provided by the Government of Tonga)

1 COUNTRY CONTEXT

1.1 Physical Description

The Kingdom of Tonga covers an area of 748 km^2, of which 30 km^2 consists of lakes, within 176 islands spread across 360,000 km^2 of the Pacific Ocean. There are four groups of islands (Tongatapu, Ha'apai, Vava'u and Niuas) and 36 islands are inhabited. Tonga is located between 15° and 23°50′ south latitude and 173-177° west longitude, about two-thirds of the way from Hawaii to New Zealand. An Exclusive Economic Zone (EEZ) extends over approximately 700,000 km^2. The climate is tropical, modified by trade winds with distinctive warm (December to May) and cool (May to December) seasons. Most islands have a limestone base formed from an uplifted coral formation but some have limestone overlying a volcanic base. There are active volcanoes in Tonga with several having erupted in the 20th century.

Table 1.1 - The Islands of Tonga

Island or Group	Size, location and number of islands	Island type	Soil type	Climate
Tongatapu	260 km^2 in the southern part of group; 1770 km NE of New Zealand; one island	Rose coral; low and flat. No rivers or streams	Mostly well drained andesite tempura with clay textures with sandy loam in the Nuku'alofa area	Ocean tropical with Mean annual rainfall of 1878 – 2100 mm; Mean air temp of 23.7°C
Ha'apai	118 km^2 with lake (Nomuka) of 10.7 km^2; 150 km NE of Tongatapu; 51 islands, 17 inhabited	Low raised coral – flat to undulating (Nomuka, Tungua, 'Uiha, Lifuka, Foa, Ha'ano), raised volcanic (Kao, highest point in Tonga and extinct volcano, Tofua, Kotu, Mango), sand cays (Uoleva)	Tropic brown granular loams	Average rainfall of 1,500mm – 1700mm (driest island group) Mean humidity of 77%
Vava'u	146.7 km^2 with Inland water area of 340 ha	Raised, terraced coral islands with hills of 150-300 m	Deep friable reddish brown clay of volcanic ash origin	Mean average rain of 2,250 mm
Niuafo'ou	50 km^2 with lake (Vailahi) is 1554 ha; Tonga's remotest island: 170 km NW of Vava'u; Crater lake and four subsidiary lakes	Volcanic	Little topsoil Volcanic basalt. High potential for organic farming	Mean air temperature of 27°C
Niuatoputapu	18.8 km^2 with lake Tafahi with 415.2 ha	Mixed limestone and volcanic; prominent coralline sands Low-lying, sea water intrusion in both NE & SE areas	Volcanic ash overlying raised coral platforms	Mean air temperature of 27°C
'Eua	87 km^2 in SE of Tongatapu	Mixed limestone and volcanic; raised coral limestone terraces with flat to sloping, rugged rolling and hilly land. Steep cliffs drop from terraces to the sea	Coral sands near the coast. Soils vary with topography ranging from brown clay to varying degrees of red soils	Highest precipitation

Sources: Dominant soil-forming parent material throughout all the islands is fine grained andesitic volcanic ash with smaller traces of coralline sands (Trangmar, B.B., 1992); Climate data from New Zealand Meteorological Service, 1983: Cowie, J.D. et al, 1991, *Soils of Tongatapu*, Kingdom of Tonga, DSIR Land resources Scientific Report No.21.

1.2 Population

The most recent population census, (Table 1.2) carried out in 1996, counted 97,784 people of which 50.7% were male and 49.3% Female. There was a modest annual average growth rate (AAGR) of 0.35% over the

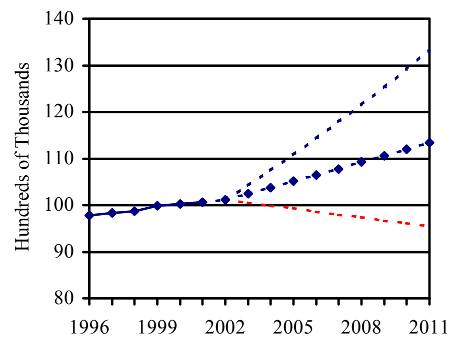
Table 1.2 – Population of Tonga, 1986 - 1996

Island or group	Population (1996)	% of total	AAGR (1986-96)	Urban (% of total; '96)
Tongatapu	66,979	69%	0.5%	80%
'Eua	4,934	5%	1.2%	27%
Ha'apai	8,138	8%	-0.9%	?
Vava'u	15,715	16%	0.4%	?
Niuas	2,018	2%	-1.5%	27%
Total	*97,784*	*100%*	*0.35%*	*> 60%*

Sources: 1996 Census (GoT); *Development Data, Country Profile Table* (World Bank, 2003); and Department of Statistics, January 2003 previous decade. Over two-thirds of the total live on Tongatapu. Both Vava'u and Tongatapu grew slightly faster than average, Ha'apai and the Niuas declined, and 'Eua (a short distance from Tongatapu) grew considerably faster than average. Urbanisation increased at nearly four percent per annum, with Tongatapu, where the capital Nuku'alofa is located, 80% urbanised. In 1996, the population density was 150.5 persons per km^2.

Figure 1.1 provides the estimated population from 1996-2001 and three projections from 2002 through 2011 based on 1999 Government of Tonga (GoT) low, medium and high growth scenarios. For the low-growth case, population declines to 95,500 in 2011; for the high case it reaches 133,600. The medium case is equivalent to an AAGR from 1996-2011 of 1.0% with a 2011 population of 113,400. There is no disaggregation by island or island group. Assumptions regarding population growth and the population distribution among islands have, of course, significant implications for the patterns of future energy use and practical options to provide the required energy.

Figure 1.1 - Population of Tonga, 1996-2011



Sources: Dept of Statistics (GoT, January, 2003) and *Summary and Population Projections* (Dept of Statistics, Sept. 1999)

1.3 Environmental Issues and Commitments

There has been deforestation in Tonga as a result of extensive land clearance for agriculture and settlement, there has been some damage to coral reefs from starfish and indiscriminate coral and shell collection, and over hunting threatens native sea turtle populations. Tonga is party to various international conventions and agreements regarding biodiversity (Convention on Biological Diversity), climate change (United Nations Framework Convention on Climate Change or UNFCCC), law of the sea, marine life conservation, nuclear test ban, ozone layer protection and marine pollution. The initial national communication to the UNFCCC Conference of Parties, indicating greenhouse gas (GHG) emissions in 1996, vulnerability options for adaptation to climate change, was submitted in 2004. Table 1.3 summarises the status and date of signing of several key environmental conventions.

Table 1.3 - Status of Ratification of Key Environmental Treaties and Conventions by Tonga

Status in Tonga	Hazardous wastes (Waigani Convention)	Nuclear free Pacific (Rarotonga Treaty)	UNFCC	Ozone depleting substances (Montreal Protocol, et al.)
Signed Ratified In force	16 Sept 95 22 May 03 22 Jun 03	06 Aug 85 16 Jan 86 18 Dec 86	Acceded 20 Jul 98 18 Oct 98	Acceded to Vienna Convention, 29 Jul 98

Notes: Treaties and conventions are briefly described in Volume 1, the PIREP Regional Overview report
* The Kyoto Protocol is in force from 15 February 2004 for European Union members only.
Sources: Websites for conventions, PIFS and SPREP (Jan. – March 2004)

Other environmental treaties and agreements include the Convention on Biological Diversity, Acceded 19 May 1998; the Stockholm Convention on Persistent Organic Pollutants, acceded 22 May 2002; the Cartagena Protocol on Biosafety, acceded 18 September 2003; and the Waigani Convention on trans-boundary movement of hazardous waste in the region – ratified May 2002.

Tonga is vulnerable to cyclones and lies in a region of the South Pacific where cyclones are common. Given the long north to south axis of Tonga, it is common for several cyclones to pass through the country each year, though passage over heavily populated areas is not common though major damage to infrastructure and crops has occurred.

1.4 History and Political Context

The Tongan archipelago, known as "The Friendly Islands", was united into a kingdom in 1845. Tonga became a Constitutional Monarchy in 1875 – the only remaining Kingdom in the Pacific – and a British Protectorate in 1900. It became independent from Britain in 1970 and joined the Commonwealth of Nations. The Head of State is His Majesty King Taufa'ahau Tupou IV, since December 1965. The head of government is the Prime Minister, HRH Prince 'Ulukalala Lavaka Ata, since February 2001.

The executive branch of government consists of the King in Privy Council, Prime Minister, Ministers of the Crown and Governors of Vava'u and Ha'apai. Cabinet consists of the Prime Minister and Ministers of the Crown. All members of the Privy Council are appointed by the King at his pleasure.

Tonga's Legislative Assembly (Fale Alea) is unicameral and consists of 30 seats. There are 12 seats reserved for Cabinet Ministers sitting *ex officio*, nine seats for nobles elected by the country's 33 nobles and nine seats for the people's representatives elected by popular vote. Elected members of the Legislative Assembly serve three year terms.

The Judiciary branch consists of an Appeals Court that acts on appeals to decisions by the Supreme court, a Supreme court that presides over cases brought against the government or appealed from the lower courts, a Lands Court that specialises in land issues and the Magistrate Courts that handle ordinary civil actions and criminal cases.

1.5 Economic Overview

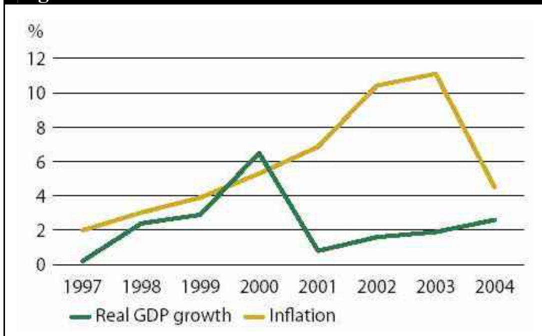
Tonga has a small, open economy with a narrow export base in agricultural goods. Squash, coconuts, and vanilla beans are the main export crops, with agricultural products making up two-thirds of total exports. A high proportion of food is imported, mainly from New Zealand. Tonga is highly dependent on transfers from nationals living abroad and tourism. Together, these cover about 85% of merchandise imports. The government has emphasised development of the private sector, especially investment. Government has committed increased funds for health and education. There is a reasonably sound basic infrastructure and well-developed social services.

Table 1.4 - Tonga and Regional Economic Treaties

Status	SPARTECA	PACER	PICTA
Signed	14 July 1980	18 Aug 2001	18 Aug 2001
Ratified	24 Dec 1980	27 Dec 2001	27 Dec 2001
Entered into force	01 Jan 1981	3 Oct 2002	13 Apr 2003

Source: Discussions with Pacific Islands Forum Secretariat

Figure 1.2 - GDP Growth & Inflation



Source: ADB

The government's overall national development goal, stated in its *Strategic Development Plan Seven, 2001-2004* (SDP7), is to improve the quality and standard of living for all Tongans through a stable macroeconomic environment and sustainable economic growth led by private sector development. This is to be supported by an efficient and well-structured public sector, maintenance of physical infrastructure, and protection of the environment. The economic and fiscal objectives were reaffirmed in the GOT's comprehensive *Economic and Public Sector Reform Programme* (EPSRP) approved by the Cabinet in early 2002, and supported by a US$10 million Asian Development Bank (ADB) loan with additional resources from others. The ADB (*Tonga Country Strategy and Programme Update: 2003-2005* (July 2002) considers agriculture, fisheries and tourism as having the most potential for further economic growth.

From FY 1996/97 to 2002/03, GDP in real terms (1995/96 prices) has grown at an AAGR of nearly 3%. The ADB (2004) expresses concerns about *"double digit inflation, sluggish economic performance and recent declines in foreign reserves."* Figure 1.2 illustrates recent GDP growth and high inflation rates; the latter is projected to drop in 2004. Real GDP growth, after improving in 1999/00 to almost 6%, declined to 2.5% in 2000/01, 2.6% in 2001/02 and 3.1% in 2002/03.[1] The growth in 2002/03 was driven largely by reconstruction activities in the aftermath of Cyclone Waka, along with good weather for crops and continued increases in Government spending. The important tourism sector, however, has not grown. The ADB expects growth to be 2.6% in 2004 and 2.8% in 2005. The GoT is more optimistic, projecting an average of 5.4% through 2009, as shown in Figure 1.3.

The Ministry of Finance notes that the outlook for the medium term is uncertain and recently projected a short-term growth of 2.6%, in line with ADB's estimates. Downside risks in the world economy could affect both exports and inflows of private remittances. Growth is also vulnerable to increases in oil prices and transportation costs. There is growing pressure on the national budget, with the deficit expected to widen in the short term.

Table 1.5 -

Tonga Selected Economic Indicators (1999/00 - 2002/03)

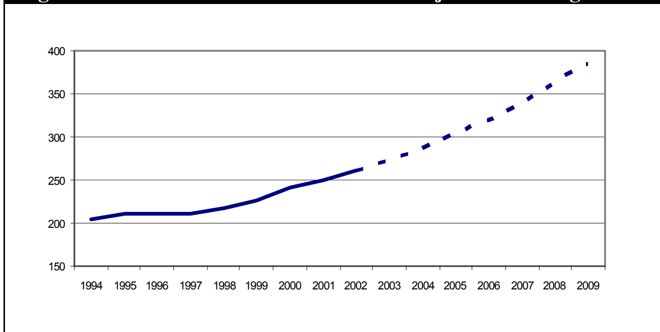
Economic Indicator	1999/00	2000/01	2001/02	2002/03 (p)
Real GDP Growth (in 1995/1996 prices)	5.6	2.5	2.6	3.1
A. Agricultural & Fisheries Exports ($m)				
Squash Export Value	8.9	5.3	7.1	12
Fish Export Value	7.7	8.1	10.5	10.7
Vanilla Export Value	0.83	0.3	0.3	4.6
B. Tourism				
Tourism Receipts ($m)	16.51	12.7	12.4	12
Tourist Arrival (no.)	33916	33,722	34,918	36583
C. Consumer Price Index (CPI)				
Inflation Rate (%)				
All Items	4.9	7.3	10	10.6
Imported	9.9	7.2	12.4	13.2
Local	-0.2	7.3	7.3	7.9
D. Banking Statistics ($m)				
Money Supply (M2)	97.2	123	132.7	150.5
Domestic Credit	123.7	152	164.4	195.2
Private Sector Credit	121	141.9	162.6	183.2
Private Sector Credit Growth Rate (%)	4	17.3	14.6	12.7
Total Domestic Deposits	103.4	121.5	134.2	145.2
E. Exchange Rate (end-period)	1.727	2.179	2.191	2.185
T$ per US$	1.69	2.153	2.15	2.144
F. Government Finance Statistics ($m)				
Total revenue & Grant	71..3	78.5	95.2	99.3
Total Expenditure and Net Lending	72.2	82.8	99.9	110.5
Overall Surplus/Deficit	-0.9	-4.3	-4.7	-11.2
G. Balance of Payment ($m)				
Total Imports (c.i.f.)	96.2	121.5	157	151
Total Exports (f.o.b.)	21.4	12.8	23.7	40.1
Private Remittances	78.6	105.7	131.5	119.1
Gross Foreign Reserve ($m)	26.2	25.8	39.6	36.9
Import Cover (number of months)	2.6	2.3	2.5	2.3

Sources: Ministry of Finance; Statistics Department

[1] It should be noted that quality of economic data in Tonga (as in most PICs) is subject to many limitations, particularly in the areas of national accounts, government finance and balance of payments statistics.

GoT macroeconomic policies are broadly in line with the goals of the Barbados Programme of Action (BPOA), Agenda 21, and the Millennium Development Goals (MDGs), including MDG goal 7, environmental sustainability. An assessment of progress toward achieving the MDGs in the region (*Millennium Development Goals in the Pacific: Relevance and Progress*; ADB, March 2003) reports that:

Figure 1.3 – GDP Growth 1994-2000 & Projections through 2009



Sources: *Tonga Key Indicators* (ADB, 2003); projections from SD7 (2002)

> *"Tonga has already achieved or almost achieved several of the targets specified in the Millennium Development Goals. It has a very high literacy rate and high primary and secondary enrolment ratios. The health indicators have been steadily improving, but there is a rapid increase in life-style diseases. Available data suggest that access to safe water and sanitation is widespread. There are, however, signs of rising unemployment and a rural-urban drift towards main islands … Efforts need to be strengthened to ensure that all parts of the population have access to essential basic social services and quality education."*

A more recent *Tonga Hardship and Poverty Status Discussion Paper* (Draft Final Report as presented to government; ADB, November 2003), assessed hardship in sixteen communities throughout the Kingdom, from 'Eua in the south to Niuatoputapu and Tafahi in the far north, and concluded that:

- Economic growth (in terms of GDP/capita), averaged a modest 2.0% per year from 1990/91-2000/01 along with a marked increase in wealth and asset ownership of many households, particularly on Tongatapu. Much of this seems to have been financed from remittances, which increased from 26% of GDP in 1990/91 to 37% in 2000/01.
- Remittance flows are placing ever-greater demands on households for cash resources to purchase goods including food, to pay utility bills, and to make contributions toward education and for social events. Often, traditional gifts are no longer adequate: cash donations or cash-oriented gifts are increasingly expected.
- The continued migration of outer island people to Tongatapu (and overseas) is depopulating the outer islands and increasing the financial load on those remaining since those migrating tend to be persons above average in productivity. At the same time the increasing population on Tongatapu is generating environmental and other problems.

1.5.1 Investment law

Tonga is amending various laws to entice more investment. Currently, investment is covered by the Companies Act of 1995 and the Industrial Development Incentives Act (IDI –Cap 114) which is to be amended. The Companies Act has simplified the process of registering new enterprises and regulations for the IDI Act is being developed and will include: i) identifying and establishing a more transparent policy for sectors and sub-sectors where foreign investors can or cannot invest, ii) establishing a more transparent foreign investment registration system, iii) introducing a more transparent business licensing process, and iv) abolishing the requirement to obtain a new business license if existing activities are expanded. The Foreign Investment Advisory Service has recommended various amendments to the Licenses, IDI, and other related Acts. A new Foreign Investment Act has been passed and will come into force on a day proclaimed by His Majesty in Council.

1.5.2 Import duties and taxes

In addition to investment regulations, foreign trade is regulated by a system of tariff and duty controls. Petroleum and petroleum product imports are the only important imports subject to licensing. Custom duties are levied on an *ad valorem* basis (according to the c.i.f. value of imports), key exceptions including petroleum products, which are charged a fixed amount per unit of volume. A 20% Port Services Tax is levied on all imports, unless specifically exempted by the Privy Council. Import duties and charges for petroleum are summarised in Table 1.6. There are no reduced duties or exemptions specifically meant to encourage energy efficiency or renewable energy use. However, under current regulations, local investors can apply for exemptions for such equipment.

Table 1.6: Customs Duties and Charges

Product	Customs Duty	Exemptions and Comments
Petroleum fuels:		
Aviation Jet Fuel	30%	
Aviation Gasoline	30%	
Motor Spirit	35%	
Distillate (ADO)	35%	Duty exempt for public power production (i.e. Shoreline & communities) & fishing boats
Kerosene	none	
White Benzine		
Liquid Petroleum Gas	35%	

Source: GoT
Notes: All imports charged 20% port services tax unless exempted.
For fuels there is also sales tax (3 seniti/l) & wharfage (2.2 seniti).

1.5.3 Banking

There are three commercial banks operating in Tonga: Bank of Tonga, MBf Bank and Australia New Zealand Bank (ANZ Bank). The Tonga Development Bank (TDB) provides higher risk, development oriented borrowers with lending rates that are broadly consistent with those of the commercial banks. Growth in lending by the banking sector to the private sector is estimated to have been 40% between 1999/00 and 2001/02, which brought the ratio of bank loans to deposits close to a five-year high by the end of 2002. About two-thirds of the increase in credit involved a few companies in key sectors (such as power, telecommunications, and retail services) with the remainder for housing and personal consumption. Credit to public sector enterprises also expanded rapidly, but represented only 5% of total banking sector credit by the end of 2002.

Table 1.7 - Interest Rates on Bank Lending (%/year)

End of:	Rates on commercial bank loans:		Rates on Non-Monetary Financial Institution (NMFI) loans:		
	Prime range[1]	Residential homes[2]	Prime range[3]	Business loans maximum [4]	Small scale subsistence[5]
1996 / 97	9.0	10.0	8.5	12.0	9.5
1997 / 98	9.0	10.0	8.5	12.0	9.5
1998 / 99	9.0	10.0	10.5	14.5	10.5
1999 / 00	9.0	10.0	10.5	16.5	10.5
2000 / 01	9.0	10.5	10.5	16.5	10.5
2001 / 02	9.0	10.5	10.5	16.5	10.5

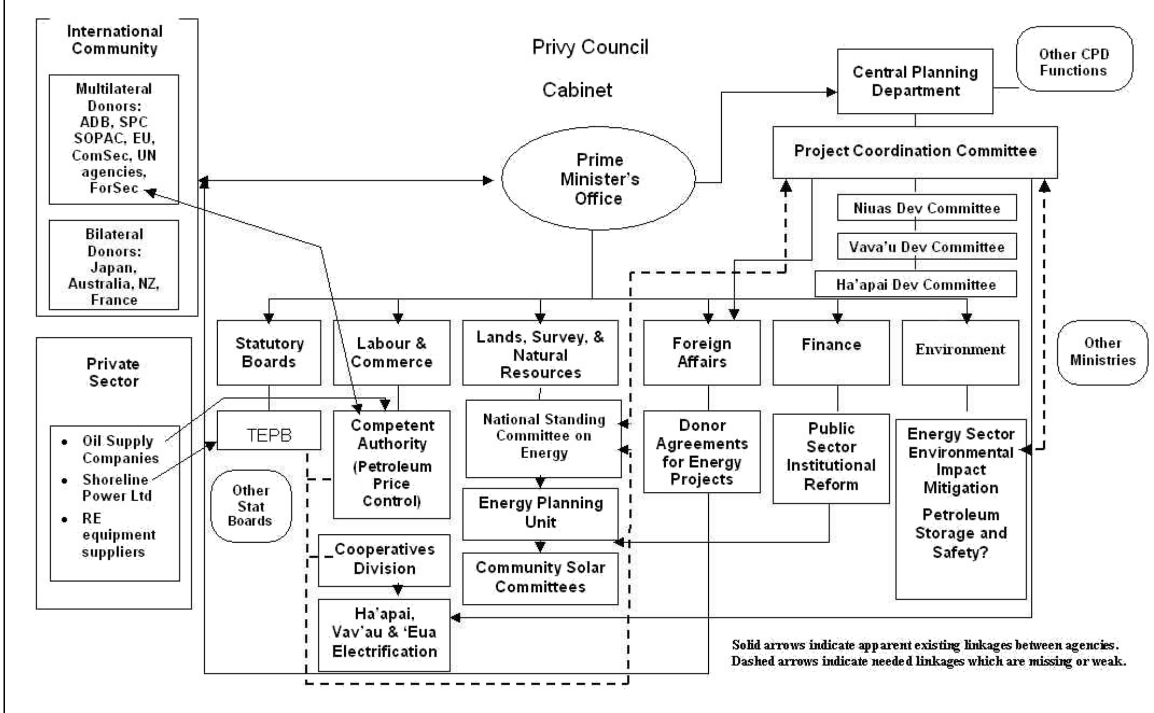
Source: National Reserve Bank of Tonga (NRBT) (www.spc.int/prism/country/to/stats)
Notes 1) Base rate is lowest rate charged. Prior to last quarter of 1992, this was the preferential rate. It is average minimum prime rate published by the commercial banks
2) Average minimum rate of commercial banks
3) For export-oriented industries, manufacturing and raw materials processing, and tourism except restaurants
4) Maximum rate published by the NMFI on their business loans
5) Less than $1,000 for activity in agriculture, fisheries and livestock

Interest rates became increasingly stimulatory, with deposit rates negative and lending rates barely positive in real terms. Nominal interest rates for loans for small business range from 10-15% depending on the borrower's equity, assets and a risk evaluation. Recent interest rate trends are summarised in seven. According to one commercial bank, solar and other renewable energy systems, and service companies providing them, would probably be considered high risk, probably resulting in high interest rates.

1.6 Institutional and Legal Context for Energy

The key GoT agency with energy sector responsibilities is the Ministry of Lands, Survey and Natural Resources (MLSNR), within which an Energy Planning Unit (EPU) deals with national energy planning, energy policy and coordination as well as project coordination. Figure 1.4 summarises overall responsibilities. As indicated, there are overlapping and unclear energy sector responsibilities, an example being the electrification of outer islands. There are more detailed discussions of petroleum and electricity in Section 2 of this report under energy supply and demand.

Figure 1.4 - Government Ministries and Departments with Energy Sector Management Responsibilities



Source: Updated from Sustainable Energy Policy: Overview Report on Advisory Mission to Tonga (C Cheatham, ESCAP, Oct. 2001)

1.6.1 Petroleum

Petroleum fuels are supplied and distributed by Shell[2] and BP. There is a contract (awarded by tender every year) with the GoT to supply public needs. A pricing template, agreed by the GoT and the oil companies during annual price negotiations, is validated bimonthly with assistance from the Pacific Islands Forum Secretariat (PIFS). Liquid petroleum gas (LPG) is imported by Tonga Gas Ltd (formerly Boral). The sole distributor of LPG is Tonga Home Gas, which is 50% owned by the GoT through Tonga Investment Enterprise. There are bulk LPG terminals in Tongatapu and Vava'u. Ha'apai receives LPG from Vava'u use in tanks of 1000 kg capacity. 'Eua receives cylinders of 50 kg capacity from Tongatapu.

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2 A local distributor, Three Star Petroleum is under Shell Supervision following the death in 2003 of the owner.

The MLSNR has no formal role in petroleum fuel quality or pricing. The "Competent Authority" (CA)[3] establishes maximum wholesale and retail prices for key petroleum products. The system has been basically unchanged for well over a decade. Petroleum storage and safety are the responsibility of the Ministry of Works and Environment though the Ministry of Police (Fire Services) deals with the petroleum storage installation standards and safety from the fire angle.

1.6.2 Electric power

Until 1998 the Tonga Electric Power Board (TEPB) was a government-owned utility responsible for the generation and distribution of electricity on Tongatapu and the main townships of Ha'apai, Vava'u and 'Eua under a national tariff structure with the higher costs away from Tongatapu subsidised by Tongatapu consumers. Today TEPB is in principle the utility regulatory agency, with the generation of electricity and its distribution through the power grids being the responsibility of Shoreline Power Ltd. (Shoreline) – a locally owned private company serving the main islands – and community operated power systems serving some outer islands. Although MLSNR is the ministry with the overall energy sector mandate, it is not currently represented on the TEPB Board of Directors which has four members appointed by Cabinet.

Institutional arrangements for electric power are summarised below:

- *Tongatapu*. For several years from early 1998, Shoreline generated all electricity on Tongatapu with TEPB operating as a distribution and retailing company. From February 2002, Shoreline leased the TEPB distribution network and since April 2003, it has owned both the generation and distribution system. Shoreline is responsible for planning future expansion throughout Tongatapu and establishes the tariff in consultation with the TEPB.
- *Vava'u, Ha'apai and 'Eua grids*. Shoreline has the sole generation rights for electricity, transferred from TEPB, for the small grid systems of the "central outer islands" of Vava'u, Ha'apai and 'Eua, where it owns both the generation plant and the distribution network. In Vava'u, Shoreline built a new power station several years ago and has provided electricity for the main island and two others connected by a causeway (Pangaimotu and Utungake) since 2001. In Ha'apai, the grid covers the islands of Lifuka and Foa, also connected by a causeway. The Ha'apai and 'Eua systems were acquired from TEPB in 2002. Any entity wishing to generate electricity on an island or islands with a Shoreline grid must first obtain approval from Shoreline and a license from the TEPB. This requirement appears to apply to the main islands of each group only, not the remote islands. Electricity costs in the islands are no longer cross-subsidised by Tongatapu consumers; Shoreline establishes individual tariffs for each island system. However the TEPB would prefer to see a single national electricity tariff.[4]
- *Ha'apai outer island diesel generation*. Australian Aid (AusAID) has assisted the GoT provide diesel electricity systems to four 'outer' islands in the Ha'apai group (Ha'afeva, Nomuka, 'Uiha and Ha'ano, with a total of about 450 households electrified). These power systems were commissioned between 2002 and October 2003 and are managed by community-based Electricity Co-operatives (ECOs) which are licensed, trained in operations, accounting and management, and supervised by the Department of

[3] The Competent Authority works through the Ministry of Labour, Commerce and Industries and consists of the Ministers for MLCI, Finance and Works, the Secretary of MLCI, the President of the Chamber of Commerce and a representative of the private sector.

[4] Interview with TEPB, November 2003)

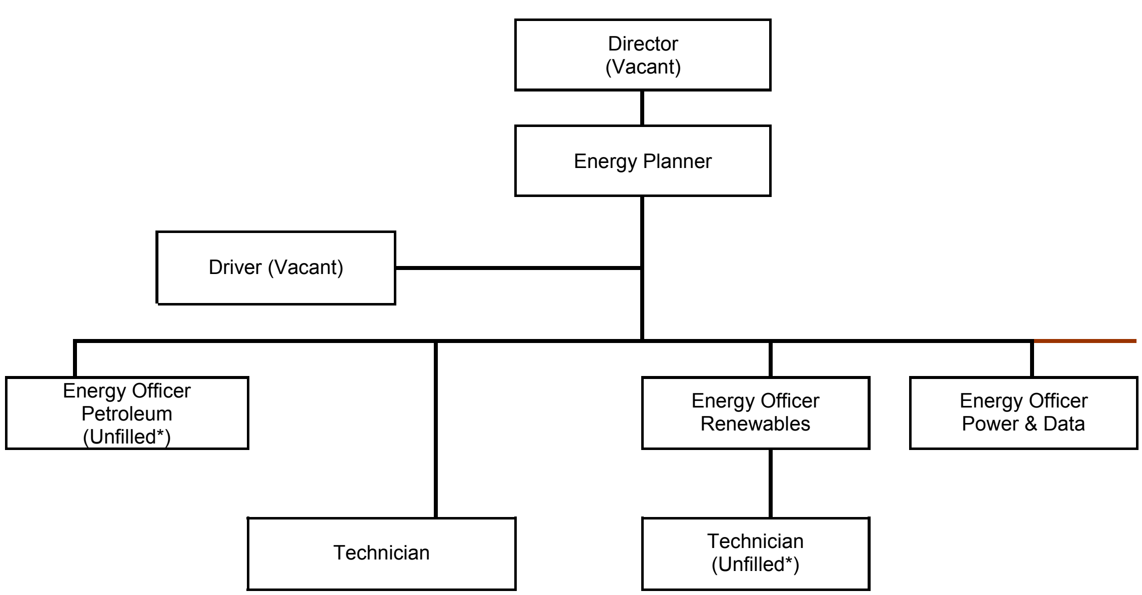
Cooperatives and Credit Unions (DCCU) through its Ha'apai office.[5] Each ECU has a license to operate from TEPB, and this must be renewed annually. The ECOs establish tariffs, which are meant to cover operating and maintenance (O&M) costs plus – in principle – replacement of the generators after seven years or as required. Actual tariffs are insufficient to cover capital replacement and in some cases, do not even cover operating costs; separate fund raising activities have had to be held by some islands to raise money for fuel purchases.

- *Ha'apai outer island community PV.* There is a Ha'apai Regional Solar Electrification Committee (HSEC) comprising the Governor of Ha'apai, a user representative from each island and an EPU Officer overseeing a solar photovoltaic (PV) projects installed under the PREFACE project. Earlier projects are expected to be rehabilitated and brought under the HSEC management.
- *Other PV*. Various PV projects for Ha'apai, the Niuas and Vava'u were funded in the 1980s and 1990s by the EU, France and New Zealand. They are all still managed by local committees with technical support from the EPU but the intent is to upgrade the projects and incorporate a regional electrification committee on the model of the HSEC since the local committee structure has not been successful.

1.6.3 The EPU

Figure 1.5 shows the structure and staffing levels within the EPU. Although EPU has broad energy sector responsibilities, it is often perceived within the public service and by the public as primarily a solar PV project agency, implementing donor-supported community PV projects. The EPU's operational budget is insufficient to allow routine monitoring of many

Figure 1.5 - Organisation of the Energy Planning Unit (2003)



*** to be advertised in 2004**

PV installations and it lacks the professional staff levels needed to deal with its petroleum

[5]The New Zealand company that installed the systems is responsible for quarterly inspections and maintenance for twelve months after commissioning, after which the ECOs are responsible for all O&M.

and power responsibilities, neither of which is clearly defined. As in many PICs, energy is often considered a high priority by GoT officials during presentations in international fora but this is not reflected in budget allocations or staffing. The current arrangements in Tonga arguably hinder the development and implementation of consistent energy policies and their administration.

1.6.4 Energy policy

There is a draft *Tonga National Energy Policy* (May 2002) which is essentially an incomplete and slightly edited form of the *Pacific Islands Energy Policy and Plan* (PIEPP), prepared in 2002 by the Energy Working Group (EWG) of the Committee of Regional Organisations of the Pacific (CROP). The draft includes a "vision" for the energy sector and a range of policy statements covering broad energy policy and planning, power supply, transportation, renewable energy, energy for rural and remote islands, petroleum fuels, environmental aspects of energy use, energy efficiency and conservation, and human and institutional capacity development. There is a strategic planning component for each of the above topics, has specific activities, a lead organisation responsible for implementation, indicators of success, assumptions and risks with suggested ways to mitigate them, and a time frame for implementation. The draft has not been endorsed at ministerial or cabinet level, there are no budget allocations for its activities and there is no prioritisation of the large number of activities. It requires considerable development and consultation before it can be of real practical use for Tonga.

There has been at least one earlier draft *National Energy Policy of the Kingdom of Tonga*, prepared with the assistance of the Forum Secretariat in 1995. This too was generic, being quite similar to other policy drafts throughout the region and was deferred by cabinet awaiting more information and justification.

1.6.5 The Standing Committee on Energy

A ministerial-level National Standing Committee on Energy (NSCE) was established MLSNR chairmanship in 1979, primarily to deal with the effects of international petroleum supply disruptions and fuel prices. It met sporadically for some years but later became moribund. In 1995, membership was revised[6] to reflect a broader energy policy focus with the EPU assigned as committee Secretariat. However, the NSCE remains inactive and reportedly last met in 1997.

At the level of public service officials, there is a PIREP working group chaired by the Secretary and Surveyor General of the Ministry of Lands Survey and Natural Resources with members from EPU, Environment, Crown Law Office, Meteorological Office, Statistics Office and the Forestry Division of the Ministry of Agriculture. It has met several times in the past year and functions as a *de facto* energy policy and planning group. However, there is limited interaction among ministries and the private sector on energy policy and planning matters. The working group tends to meet on an *ad hoc* basis. There is a high-level National Coordination Committee on Environment under the Environment Dept that the PIREP working group reports to.

[6] The members comprise the Ministers of MLSNR and MLCI, the Secretary of Finance, a representative from the oil companies and a representative of the TEPB Board.

1.6.6 Energy Legislation

There is a range of legislation in Tonga pertaining to energy sector matters. Key legislation, including drafts which have not been enacted, includes:

- *Price & Wages Control Act* (CAP113) under the Ministry of Labour, Commerce and Industries) establishes the power for pricing petroleum fuels and other consumer essentials through the 'Competent Authority'.
- *The Electric Power Board (CAP93) Act* provides the TEPB with exclusive rights for the generation of electricity and the power to licence generation by others and impose licence fees and standards. The terms of such licenses require regulatory approval by the Privy Council. Although the Act does not mention low-voltage solar energy, the TEPB believes that community solar PV systems, whether or not operating under Cooperative (i.e. DCCU) guidelines and legislation, are illegal and require licensing under the Act. TEPB intends to eventually enforce such licensing.
- *Draft TEPB Bye-Laws.* The TEPB Act requires considerable amendment – or replacement – as it no longer generates or distributes electricity and has only limited regulatory authority. Draft bye-laws were prepared by the EPU and the Crown Law Office in 2002 to redefine TEPB's roles, responsibilities and powers regarding electricity policy, rural electrification, and regulation. However, the draft had not by May 2004 been submitted to Cabinet or Parliament as the Minister for LSNR reportedly feels that these matters should be addressed within a proposed new comprehensive Energy Act. In addition TEPB could possibly be transformed into more general national regulatory agency, beyond just electric power, which would require new legislation.
- *Energy Bill (draft).* An Energy Bill was drafted in 1995 outlining functions of the EPU and NSCE, defining the relationships between the NSCE, the EPU and other public and private sector stakeholders in the energy sector, and granting the EPU sufficient authority to carry out its mandate and functions. It has not been finalised or approved.
- *Bye-laws on regional rural electrification (*draft). This draft legislation has not yet been through the process of consultation by stakeholders.

1.6.7 Legislative needs

A 2001 study (*Sustainable Energy Policy: Overview Report on Advisory Mission to Tonga;* C Cheatham, UN Economic and Social Commission for Asia and the Pacific [ESCAP], October 2001) concluded that the most serious energy sector legislative and regulatory issues in Tonga involve electricity and the regulation of the private and public companies providing electrical services.

1.6.8 Other relevant legislation

Other bills and acts with implications for the energy sector include[7]:

- *Environment Impact Assessment (EIA) Act (2003)* (passed November 2003), which stipulates (S10(e)) EIAs of projects that may *"result in the allocation or depletion of any natural and physical resources in a way or at a rate that will prevent the renewal by natural processes of the resources or will not enable an orderly transition to other materials."*

[7] Legislation relevant to biomass energy is treated separately.

- *The Environment Management Bill* (draft; yet to be passed) which is expected to control effluents and pollutants;
- *Cooperative Societies* Act (CAP118) *and Credit Union* Act (CAP 107), under which community electrification in Ha'apai and the Niuas operate (in addition to TEPB licensing).
- *The Petroleum Act* (CAP134) that controls exploration for petroleum in Tonga.
- *The Forestry Act (CAP 126)*, which contains provision for biomass supply and conservation measures;
- *The Lands Act* (CAP 132), which has possible land use implications for both energy and climate change policies and programmes;
- *Foreign Investment Act*. has been passed but work is currently being done on regulations pending submissions to the cabinet and parliament

2 CONVENTIONAL ENERGY

2.1 Energy Supply

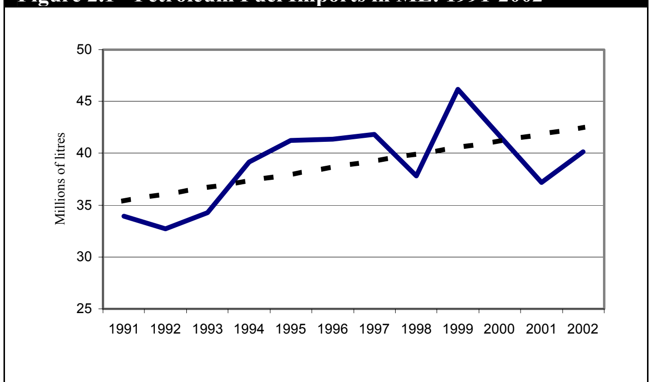
Tonga is overwhelmingly dependent on imported refined petroleum fuels (about 34,000 tonnes of oil equivalent or toe) for its national commercial energy needs, for electricity generation, for transport and for lighting and cooking. Biomass may provide about 27,000 toe, or 44%[8] of gross national energy production, but this is based on crude estimates, not recent surveys or measurements. Solar energy accounts for well under 1% of the total and there has been no development of Tonga's other renewable energy resources.

Petroleum

Supply and pricing

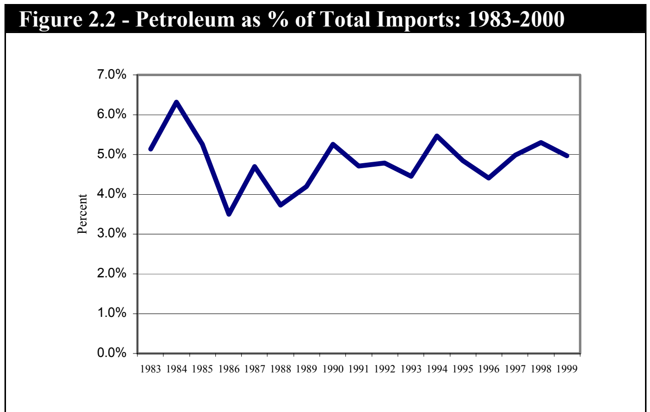
As Figure 2.1 shows, petroleum imports have risen by volume during the past decade, but erratically, the solid line showing imports and the dashed line indicating the trend. Petroleum sales in Pacific Island Countries (PICs) can differ significantly from imports during any given year, depending on the number of fuel shipments during the year (often less than once per month) and changes in stock levels at the end of the year. In the early-mid 1980s, there was considerable concern regarding the rising cost of petroleum and the growing percentages of imports accounted for by petroleum products. Figure 2.2 suggests that petroleum fuel imports as a percentage of total imports by value US$ terms) remained around 5% for the decade through 2000, well below the 6.5% peak of 1984. However, petroleum prices have since risen sharply and are likely to have accounted for a much larger percentage of import expenditures from 2001-2003. In 2004, petroleum is likely to surpass the early 1980s peak of 6.5% of all imports.

Figure 2.1 - Petroleum Fuel Imports in ML: 1991-2002



Source: EPU database and Customs reports

Figure 2.2 - Petroleum as % of Total Imports: 1983-2000



Sources: 1983-99 from Tonga: Key Development Indicators (ADB, 2003)

Trends in petroleum imports

The last comprehensive assessment of energy sector issues in Tonga was the 1991 Pacific Regional Energy Assessment. As shown in Figure 2.1, the PREA (World Bank, UNDP, Forum Secretariat & ADB; 1992) predicted that petroleum use would grow at an AAGR of

8 The GoT's draft *National Inventory of Greenhouse Gasses* (October 2003) based on 1996 energy use patterns, estimated that only 25% of energy was from biomass. This is about the same as the estimate of 27% for 1989 from *Tonga: Issues and Options in the Energy Sector* (PREA volume 10; World Bank, UNDP, et. al., 1992), despite an increase in LPG use for cooking in the past decade. The 45% estimate is from the current PIREP mission.

5.5% from 1990–2000, with the most rapid growth being in distillate, due mainly to increased electric power generation. If available data are correct, the actual growth was only about 1.5% per annum, illustrating the difficulty of making accurate predictions of growth in energy use in small countries. As Figure 2.2 illustrates, however, even the "actual" data of Table 2.1 are questionable as different sources suggest very different levels of imports for the years around 2000. The official import data of Table 2.1 that was obtained from the Government Statistics Office is used as the reference data in this report though other sources considered to be reliable indicate higher usage.

Table 2.1 - Petroleum Imports in Tonga in 1990 and 2000

Product	1990		2000		1990 – 2000 AAGR (% per year)	
	KL (Actual)	Share (%)	KL (1992 prediction)	KL (actual)	Predicted	Actual
Gasoline (motor spirit)	11,024	32	15,000	13,400	3.1	2.0
Jet fuel	5,215	15	9,000	1,270	5.6	-15.0
Kerosene	518	1	800	4,230	4.4	23.3
Distillate (ADO)	15,055	43	30,000	18,800	7.1	2.2
Aviation gasoline	1,511	4	2,000	1,250	2.8	-1.9
Liquid petroleum gas	844	2	1,500	1,270	5.9	4.2
Other (lubes, solvents)	1,098	3	2,000	898	6.2	12.0
Total	*35,265*	*100*	*60,300*	*41,118*	*5.5*	*1.5*

Note: Gasoline is also called motor spirit, mogas and petrol; there is only one grade of distillate imported: Automotive Diesel Oil (ADO).

Sources: 1990 sales and 2000 predicted sales from PREA (Volume 10, Tonga; WB/UNDP, 1992); 2000 actual from GoT Statistics Office.

Petroleum fuel suppliers

Petroleum fuels are supplied to Tonga by Shell and British Petroleum (BP) who ship their products from refineries in Australia and sometimes New Zealand via Fiji by local coastal tankers (LCTs; about 700–5,000 dry weight tonnes) to bulk storage in Tongatapu. Both Shell and BP provide a full range of petroleum products. Shoreline is the biggest buyer of distillate. A three-year supply contract for the utility, specifying a range of 8 million litres (ML) to 10 ML of ADO per year, was held by Shell but expired in December 2003. A new contract had not been awarded at the time of the PIREP mission. In early 2004 Shell had the contract with the local airline, Royal Tongan, for aviation fuel. Over the past several years, BP has increasingly dominated the ground transport market supplying around 55% (of diesel, benzine, lubricants) in 2001, 65% in 2002 and 75% in 2003 (source: BP General Manager, 2003). Both companies have supply contracts with retailers and service stations.

Table 2.2 - Apparent Fuel Imports in KL, 1997/98 – 2001/02s

Product	1997/98	98/99	99/00	00/01	01/02
Motor Spirit	13,970	17,510	19,990	17,870	21,130
Distillate	19,970	23,400	21,940	24,320	26,440
LPG	1,050	1,130	1,160	1,290	1,320

Source: Calculated from Maka, 2004 from NRBT; LPG may be calendar year

Petroleum product pricing

Under the Price Control Act, the Competent Authority (CA) has authority to establish maximum prices for goods in Tonga including Petroleum products. Petroleum prices are monitored and reviewed bi-monthly based on statement submitted by the oil companies. Oil companies submissions are forwarded to the Forum Secretariat (PIFS) for verification of international components based on Singapore Platt's. The oil companies and the public are notified of the verified data and prices are to be effective on the first of every second month.

The vendor's distribution costs and returns add an average of 20 seniti[9] per litre. Since August 1998, BP's prices have been used as the baseline price for all companies and BP remains the price leader for all products in Tongatapu, 'Eua and Ha'apai (Maka, 2004).

Recent wholesale prices of gasoline and ADO (i.e. excluding taxes and duties) are shown in Figure 2.3. Prices in Tongatapu are about average for PICs. Wholesale prices of kerosene and LPG (also duty and tax-free) are shown in Figure 2.4 and Figure 2.5. These prices are also about average for the region but the retail prices are above average, which suggests higher retail margins than those of other PICs. The team had no information on prices away from Tongatapu as the fuel price advisory and information service of the PIFS only covers the main islands of PICs.

Figure 2.3 - Tax-Free Wholesale Petrol and ADO Prices

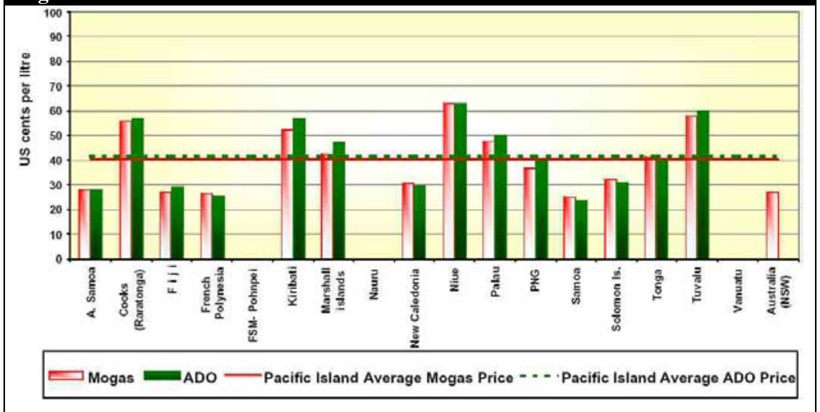


Figure 2.4 Tax-Free Kerosene Prices

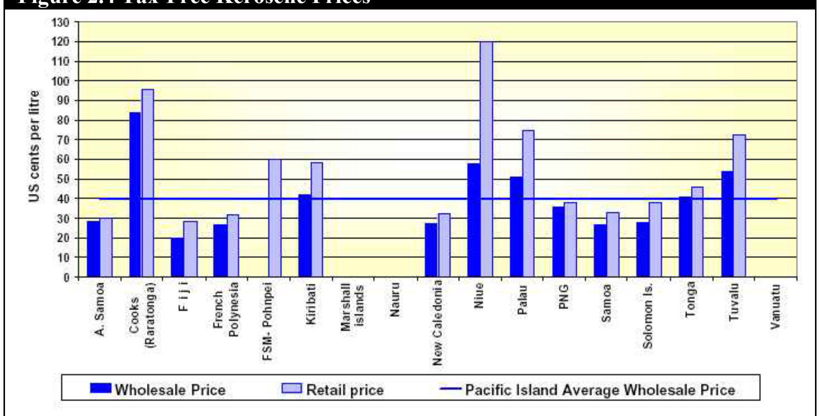
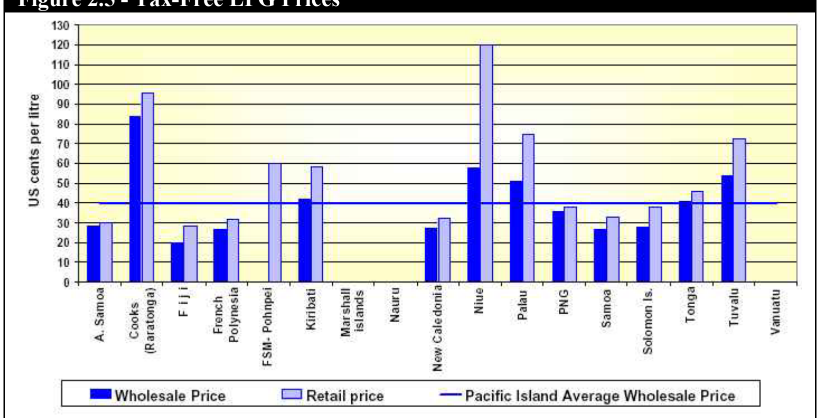


Figure 2.5 - Tax-Free LPG Prices



Source: *Pacific Fuel Price Monitor, Edition 7version 2* (PIFS; 12 May 2004) (excludes import duties and taxes; December 2003)

The two principal suppliers of petroleum in Tonga, Shell and BP (formerly British Petroleum), ship their products directly from refineries in Australia via Fiji using Local

[9] The Competent Authority sets a maximum retail price. Following a 1999 price review of return on investment (ROI) for retail outlets, the Authority agreed to a four seniti/litre increase in mark-ups as the ROI had been based on a three seniti mark-up for almost two decades.

Coastal Tankers (LCT). Tonga has been receiving fuel from the LCT voyages for the last 50 years. The LCT currently serves Tonga every 3-4 weeks and delivering petroleum products from Fiji.

The Government of Tonga through the Ministry of Labour, Commerce and Industries is currently coordinating a new project called MRX. Based on the use of medium range tankers, one of the larger types of oil tankers for transporting products directly from oil refineries around the world, the government believes the project will help to reduce transport costs related to transporting oil to Tonga via Fiji. The medium range tanker would discharge an equivalent of three to four Local Coastal Tankers (LCT) in one trip.

2.1.1 Electricity

Shoreline

Until 1998, the major customer groups on Tongatapu, ‘Eua, Lifuka (Ha’apai) and Neiafu (Vava’u) received grid delivered electricity services from the Tonga Electric Power Board, (TEPB), a government company. In 1998, Shoreline, a private registered company, took over generation by leasing existing TEPB generation plus power plant upgrades made by Shoreline. In 2000, Shoreline also took over TEPB distribution leaving the TEPB with only a regulatory function. All Shoreline generation is diesel based. It was reported that the quality of power has been good and system reliability generally high.

Community Power Systems

Small grid systems for the larger Ha’apai islands (‘Uiha 168 customers, Ha’ano 106, Ha'afeva 69 and Nomuka 110) were constructed with AusAID funding in 2001-2003. The systems are powered by diesel generators and operated by an electricity cooperative on each island. Hours of operation vary by island but typically are less than 12 hours a day. The diesel engines installed by the AusAID contractor are very much oversized and their efficiency of operation poor and maintenance costs expected to be high. Distribution is of high quality and underground with substantial excess capacity available for future expansion. The installations have not been operating long enough for good quality operating cost data to be developed but early reports are that costs are considerably higher than those predicted by AusAID even though arrangements have been made to purchase fuel duty-free. A 2002 operating cost analysis by PREFACE project reviewers indicated that the cost of service for the island diesel systems would be about the same as using PV (with 24-hour power from solar and only peak demand operation of diesels) but early cost data indicated that the diesel systems are substantially more costly to operate than the PREFACE PV even with diesels operating less than 24- hours a day.

Private Generation

In areas where commercial energy delivery is not available, private diesel or petrol fuelled generation – often supplying several homes – exists, particularly on church and commercial properties in Vava’u, Ha’apai and the Niuas.

2.1.2 Biomass

Tonga has minimal natural forest remaining, with only about 4000 hectares (5% of total land area) of mostly hardwood species. On Tongatapu, about 1700 ha (5% of the island’s area) remain. A mixture of native and imported species form the dominant secondary forests of Tonga. The main timber resource consists of senile coconut palms although Tonga is trying to establish commercially viable plantations of other species, particularly pine (*Pinus* *caribaea*). The largest plantations are of coconut palms that have an annual productivity of about 120 nuts per palm[10].

2.2 Energy Demand

As shown by Table 2.1 and Table 2.2, fuel import data differ significantly depending on the source used. Small discrepancies can be accounted for by different reporting periods (calendar year versus fiscal year) but differences exceeding 20% suggest that the data are suspect. In this section, the patterns of petroleum demand must therefore be considered approximate and indicative only. This is, of course, even more true of biomass demand for which there have been no usage measurements in recent years.

2.2.1 Petroleum

Fuel to Shoreline and the AusAID funded diesel power systems in Ha'apai is provided duty free. Also, approximately 3ML of ADO per year is provided to commercial fishing boats on a duty free basis. Removal of this duty free status could result in a reduction of use in those sectors but would impact on any economic activity supported by duty-free fuel use.

There are only very limited data from which to estimate the end-use of petroleum fuels in Tonga for 2000 (Table 2.3), the latest year for which some data are available. The following assumptions were used:

- Distillate used for electricity generation is estimated from the power sector data shown later in this section. In 2,000, gross generation was about 33 GWh of which Tongatapu accounted for 85%. TEPB data suggest ADO consumption of 4.0kWh/l for Tongatapu and 2.95 kWh/l for the other islands, a total demand of 8.5 ML. It is assumed that self-generation in remote homes and church institutions accounts for another 0.5 ML. Of the remainder, it is assumed that 80% is used for transport and 20% for commerce/industry.
- Petrol, aviation gasoline and jet fuel are all used for transport.
- Kerosene is assumed to be used mainly for household cooking (70%) with some commercial/industrial use (30%).
- LPG is mostly used by households with some restaurant and hotel use. Assume 70% and 30% respectively.

Table 2.3 - Consumption of Commercial Energy in Tonga by Sector (ToE; 2000)

Source	Imports		– Consumption in Thousand Tonnes of Oil Equivalent –				GHG emissions (Gg)
	KL	'000 TOE	Transport	Electricity	Household	Commercial & industry	
Motor spirit	13,400	10,661	10,661	0	0	0	33.50
Jet fuel	1,270	1,099	1,099	0	0	0	3.30
Kerosene	4,230	3,630	0	0	2,530	1,100	11.84
Distillate	18,800	17,062	7,115	8,168	0	1,779	50.76
Aviation gasoline	1,250	972	972	0	0	0	2.88
LPG	1,270	758	0	0	531	227	2.03
Total	40,220	34,182	19,847	8,168	3,061	3,106	104.31
% of total ToE	–	*100*	*58%*	*24%*	*9%*	*9%*	–

Source: Imports from Table 2.1.

[10] *Regional Biomass Assessment*, SOPAC (Imperial College, London) 2003

Notes:	TOE and GHG converted from data of Annex 2;	Excludes losses/transformations	n/a = not applicable

Table 2.3 suggests that about 34,200 tonnes of oil equivalent (toe) of petroleum fuels were used in Tonga in 2000, resulting in the production of about 104 gigagrammes (Gg) of GHG emissions, Gg being the standard internationally used unit used. Considering the data gaps and uncertainties, this is consistent with earlier GoT calculations of GHG emissions.[11]

2.2.2 Biomass

There is no longer any commercial use of biomass for energy in Tonga but biomass still dominates household cooking. In 1996 (Table 2.4) 74% of households reported fuel wood as their main cooking fuel but most households do use other cooking fuels as well with 55% using LPG (which is quite high for the region) and 23% use kerosene. Most families continue to use fuel wood for weekend 'umu' cooking and for special occasions. Assuming similar patterns of fuel wood cooking as the Tonga surveys of the early 1980s, but assuming that on average households that use wood have replaced one quarter of the wood used per household in the 1980s with other fuels, biomass in 2000 accounted for roughly 20,300 tonnes of oil equivalent (toe) or 33% of total energy consumption.[12]

Table 2.4 - Main Energy Source for Cooking and Lighting, 1996

Energy Source	Cooking		Lighting	
	HH	%	HH	%
Electricity	1,723	10.6	12,727	78.6%
LP Gas	8,827	54.5	–	–
Firewood	11,947	73.8	–	–
Kerosene	3,797	23.4	5,888	36.4%
Benzine	–	–	673	4.2%
Solar PV	–	–	430	2.7%
Genset	–	–	355	2.2%
Other	87	0.5	320	2.0%
Total Households	16,194	–	16,194	–

Source: 1996 Population Census; HH = households

Table 2.5 - Appliances and Services, 1986 & 1996

Device or service	1996 HH	1996 %	1986 %
Electric lighting	12,727	78.6	n/a
Electric cooking)	1,723	10.6	n/a
Refrigerator	5,387	47.6	4.2
Radio	13,858	88.4	16.0
Television	6,286	40.1	1.5
Boat	938	6.0	0.8
Computer	225	1.4	0.0
Total households (in 1996)	15,670	–	–

Source: See Table 2.7 n/a = not available

The total percentages of Table 2.4 add up to well over 100% showing that most households use a combination of fuels for cooking. Nearly 80% of households use electric lighting and over a third sometimes use kerosene. Fewer than 3% report the use of solar PV for lighting. As Table 2.5 shows, the penetration of electric (and other) energy-using appliances increased dramatically between 1986 and 1996. There are no more recent data.

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11 According to a draft *National Inventory of Greenhouse Gases* (GoT, 2003a to be finalised in 2004), in 1996 Tonga produced 85.07 Gg of CO_2 emissions from petroleum consumption excluding the effects of CH_4, N_2O, NO_x and CO. Assuming 1.5% AAGR in fuel use since, this would have increased to 91.7 Gg by 2000.

12 The estimate assumes 1% annual population growth since 1996, 1.74 kg/capita/day of fuelwood use and 1.0 kg of coconut husk/shell for the 74% who cook only with wood (or other biomass) and 0.7 kg/capita for all others. (The 1989 PREA estimate was about 24,000 toe for household cooking.)

2.2.3 Electricity

There have been no publicly available reports on overall electric power production and sales, the percentage of the Tongan population with access to electricity, or sales by consumer class since 2000. Neither Shoreline nor TEPB release such reports publicly. There are some limited data available from the EPU. According to the 1996 census report, nearly 80% of households nationally were electrified but no breakdown by island group was made available to the PIREP team. An AusAID feasibility study on Ha'apai electrification (AusAID, 1999) stated that about 95% of Tongatapu households had access to electricity in 1999 and 85% in Vava'u. In early 2001, domestic (i.e. household) consumers consumed on average 81 kWh per month. They accounted for 72.5% of TEPB customers but 37% of sales during an eight-month measurement period.[13]

Table 2.6 - Electricity Sales per Customer per Month, 2000/'01

Category	Number	Percent	kWh/m
Domestic	10,185	72.5%	81.4
Commercial	1,266	9.0%	301.9
Industrial	200	1.4%	1,680.3
Schools	184	1.3%	354.0
Churches	318	2.3%	190.1
Other	1,897	13.5%	295.9
Total customers	14,050	100%	–

Source: calculated from TEPB data (Ave. Nov '00–June '01)

In 1998/99, the last full year for which data were available to the PIREP team, about 85% of public generation and 86% of sales were accounted for by Tongatapu. Table 2.7 summarises data for the four systems. Table 2.8 summarises trends in consumption of electricity during the 1990s.

Table 2.7 - National Power Summary (TEPB); 1998/1999

Characteristic	Tongatapu	Vava'u	Ha'apai	'Eua	Total
Gross Generation (GWh)	25.7	3.1	0.9	0.6	30.3
Sales (GWh)	22.4	2.3	.8	0.5	26
Peak demand (kW)	5,042	625	197	165	6,029
System Losses	11%	21%	12%	18%	12%

Source: TEPB Annual Report, 1999

Table 2.8 - Electricity Consumption by Sector in Tonga: TEPB and Shoreline (1991 – 2000)

Year	Sales to End-use Sectors (MWh)	Consumption by End-use Sectors:								
		Mining & Quarrying	Manu-facture	Water & Sewerage	Construc-tion	Wholesale / Retail Trade & Recreation	Transport & Commun.	Finance & Business Services	Community & Social Services	Street Lighting	Residential (Domestic)
1991	22,496.00	701.07	795.08	277.34	993.85	198.77	0.00	6,622.54	198.77	1,072.42	11,636.16
1992	23,150.00	721.84	815.04	286.68	1,018.80	203.76	0.00	6,796.72	203.76	1,101.72	12,001.68
1993	24,774.00	770.87	878.76	303.54	1,098.45	219.69	0.00	7,309.58	219.69	1,182.30	12,791.12
1994	25,738.00	800.58	904.56	317.76	1,130.70	226.14	0.00	7,541.88	226.14	1,222.32	13,367.92
1995	27,034.00	843.23	952.52	334.76	1,190.65	238.13	0.00	7,942.26	238.13	1,287.28	14,007.04
1996	29,346.37	915.75	1,032.40	364.19	1,290.50	258.10	0.00	8,612.84	258.10	1,396.59	15,217.90
1997	28,906.81	919.33	1,032.40	366.87	1,290.50	258.10	0.00	8,621.78	258.10	1,399.27	14,760.45
1998	28,902.81	920.33	1,032.40	367.62	1,290.50	258.10	0.00	8,624.28	258.10	1,400.02	14,751.45
1999	29,645.81	924.09	1,032.40	370.44	1,290.50	258.10	0.00	8,633.68	258.10	1,402.84	15,475.65
2000	28,806.81	929.39	1,030.08	375.14	1,287.60	257.52	0.00	8,632.72	257.52	1,405.22	14,631.61

Source: TEPB Energy Database

[13] This assumes that Table 2.8 is correct as other TEPB reports suggest about 20,00 consumers at that time.

The cost of electricity to Tongatapu's household consumers is shown in Table 2.9. Costs dropped when Shoreline took over production but after their takeover, prices increased at an AAGR of 11% from mid 1998 to mid 2003 when the charge was 45.5 T¢/kWh on Tongatapu, 47.5 T¢/kWh in Vava'u and Ha'apai and 51.5 T¢/kWh in 'Eua. These costs remained in effect in early 2004. Note that these prices are not corrected for inflation and in real terms the prices in 2003 are somewhat lower than those of 1992.

Table 2.9 - Tongatapu Domestic Electric Power Charge

Effective Date	Minimum Charge (T$/m)	Base rate (T¢/kWh)	Fuel Surcharge (T¢/kWh)	Total Charge (T¢/kWh)
December 1992	4.11	23.85	10.42	34.27
July 1993	4.11	25.58	10.42	36.00
March 1994	4.32	36.00	–	36.00
June 1998	3.24	27.00	–	27.00
July 2000	4.08	34.00	–	34.00
February 2001	4.08	34.00	3.50	37.50
January 2003	4.55	45.5	–	45.50

Source: Report of TEPB on Its Charges to Consumers (May 2001); TEPB (2004)

The cost of electricity supply from small diesel systems in the outer islands of Ha'apai were calculated by AusAID in 1999 and are shown in Table 2.10. Full estimated costs ranged from about T$1.40/kWh in Nomuka to nearly T$2.00 in Ha'ano. Though complete operating cost information is not yet available, early data indicates a substantially higher cost of supply than predicted.

Table 2.10 - Cost of Supply to Ha'apai Outer Islands in 1999

Location	Recurrent Costs (T¢/kWh)	Full Recovery Cost (T¢/kWh)
Nomuka	71	1.36
Ha'afeva	85	1.55
'Uiha	73	1.59
Ha'ano	70	1.93

Source: Ha'apai Electrification Study (AusAID, 1999)

Each island has developed its own consumer payment scheme though all use pre-payment type meters. Typically, a consumer has a base fee of T$10 plus a use fee depending on the appliances used with use fees ranging from T$10 for basic lighting and radio up to T$40 for users with videos, refrigerators and washing machines. Payments often fail to meet the cost of generation and fund raising in the form of mat weaving, traditional kava circles and events for raising funds on Tongatapu are not unusual. The cost to the consumer for basic services is much higher under the diesel schemes than those seen by PREFACE PV project consumers even though power is available 24-hours for the PV but typically less than 12- hours a day for the diesel systems.

2.3 The GHG Inventory and Future Growth in Energy Demand

Small economies such as that of Tonga, especially those heavily reliant on a narrow range of exports and services, tend to have highly variable growth in both GDP and energy use. As shown in Table 2.1, the PREA estimates of petroleum fuel use in 2000, made nearly a decade earlier, were highly overestimated: 5.5% annual growth compared to about 1.5% actual. There are no obvious structural changes in the Tongan economy that would indicate a major change in future patterns of energy use. The fishing industry is small and is not expected to grow rapidly. Economic growth is dependent on tourism and remittances, both of which can be quickly affected by a range of internal, regional and international factors. In the short term, tourism will be affected by a crisis in internal air transport (the failure of Royal Tongan Airlines) but should improve in the middle to longer term.

As noted in Section 1.5, the GoT has estimated real growth in GDP averaging 5.4% per annum through 2009, which seems optimistic considering the weak and sporadic economic performance of recent years. For the purposes of this report, assume that GDP growth is similar to that of the last decade and recent ADB forecasts: about 3% per year. This suggests that fuel use may grow at approximately the rate of the past decade, perhaps 1.5% per year.

The data are not good enough to allow any meaningful breakdown by product so it is assumed that consumption of all products grows at the same rate. As Table 2.11 shows, under these assumptions, petroleum fuel use and GHG emissions would each increase by about 16% from 2000 – 2010 to nearly 47,000 KL and 121 Gg respectively.

Table 2.11 - Petroleum Demand and GHG Emissions in 2000 and Projections for 2010

Product	2000			2010	
	KL sold (Actual)	Share (%)	GHGs (Gg)	KL sold (projected))	GHGs (kg CO_2
Motor Spirit	13,400	33	33.50	15,550	38.9
Jet fuel	1,270	3	3.30	1,474	3.8
Kerosene	4,230	11	11.84	4,910	13.7
Distillate	18,800	47	50.76	21,800	58.9
Aviation gasoline	1,250	3	2.88	1,450	3.3
Liquid Petroleum Gas	1,270	3	2.03	1,475	2.4
Total	*40,220*	*100*	*104.31*	*46,659*	*121.0*

Note: 2000 is from Table 2.6. See Annex 1 for CO_2-equivalent emissions for various fuels

Assuming the maximum practical use of solar PV and wind energy for power generation, only about 15% of the electricity generated on the larger islands could be from wind and solar. Larger GHG savings from renewable energy will depend largely on the ability of the ToG to mobilise the coconut industry for biofuel manufacture since the wood products industry will not be generating enough waste over the next 10 years to provide much energy potential. If a there is very aggressive program to rehabilitate the coconut industry and convert its output to biofuels, conceivably 50% of ADO use could be offset by biofuels.

Energy efficiency improvements could account for a reduction of around 10% of all fuel use.

Table 2.11- Indicative Maximum Energy Savings and GHG Reductions, 2013

Resource or technology	Potential fuel savings, energy or power production	Potential CO_2 savings (Gg / year)	% of total savings	Comments
Biofuel	10.9ML	29.5	69%	50% of ADO
Solar and Wind	1.5 ML	4	10%	15% of ADO used for electricity
Energy efficiency	4.7ML	9[14]	21%	10% of all fuel used
Total	*16.0*	42.5	100%	Total 35% reduction

Note: ADO used for electricity and for marine transport is assumed to grow at the same rate over the 10 year period

If all these very aggressive efforts at implementing large scale solar, wind and biofuel production are carried out over a ten year period plus there is an overall 10% improvement in energy efficiency, a total reduction in GHG of 35% could be the result.

[14] Since 50% of ADO is assumed to be from biofuels (about 10.9ML) and 15% of ADO for electricity is from Solar and Wind (about 1.5ML) imports will be reduced by 12.4 ML only the remaining 34.3 ML will still produce greenhouse gas and be reduced by 10% by energy efficiency measures.

3 RENEWABLE ENERGY

3.1 Resources

3.1.1 Biomass[15]

For at least twenty years, concerns have been expressed regarding the effects of deforestation on fuel wood supplies in Tonga (Fortech, 1982): *"A critical shortage of fuel wood is imminent and can be averted by an effective fuel wood planting programme on Tongatapu."* Fortech carried out a limited pilot survey (172 people in nine rural and four urban households, with fuel wood use weighed at 1.74 kg/person/day of wood, 0.8 kg of husks/shells and 0.23 kg of fronds) suggesting that the household supply (and demand) on Tongatapu in 1982 was 40,800 tonnes per year (air dried basis) of wood, 18,700 tonnes of coconut husk and shell, and 5400 tonnes of coconut frond, nearly all from Tongatapu *'apis*. The results were almost identical to a survey of 13 Tongan households in 1982 by Suliana Siwatibau of Fiji. Meeting this per capita demand was projected to require 2,200 ha of fuel wood plantation in 1985 and 2600 ha by 1995, assuming little or no continuation of fuel wood supplies from *'apis*. Fortech stated that *"almost all domestic cooking is done with fuel wood, 63% of which was from trees, and mostly on open fires."* In 1982, Fortech found the price to be T$2 per 30 kg bundle (air dry) or about T$67 per tonne. Bakeries used a small amount of wood (1,400 tonnes per year) but none used wood in 2003. In 1982, there was a rough estimate (based on one week's observation) of 364 tonnes sold per year at the Nuku'alofa market. In 1982, only a small amount of wood (about 65 tonnes/year) reportedly came from 'Eua to Tongatapu.

Logging has exhausted the most accessible forest, with remaining forest located primarily on steep or inaccessible areas, in swamps or mangroves, or on uninhabited islands. Around 65% of all land is under coconut plantations or agro-forestry. Under traditional agro-forestry systems, food crops are cultivated under a canopy of trees, usually coconut. Land clearing is typically by felling or ring-barking large trees and burning the underbrush. Selected species may be protected or allowed to regenerate along with deliberately planted tree and ground crops. The trees preserved are usually slow-growing timber species, fruit or nut trees, and trees of medicinal or cultural importance.

Forest Management

The Forest Act of 1961 (CAP 126 amended in 1991) controls the legal use of forests. Protection and conservation measures include the establishment of forest reserves and the protection of water catchments. A 1988 *Parks and Reserves Act* (PRA-CAP 89) provides for *"the establishment of a Parks and Reserves Authority and for the establishment, preservation and administration of parks and reserves.'' The Preservation of Objects of Archaeological Interest Act* (Cap. 90) of 1969 provides for the protection of a number of historical, cultural and archaeological sites, many of which are also protected by traditions in the culture. The 2003 *Environment Impact Assessment Act* contains provisions relating to forest management, although some of these overlap with Ministry of Agriculture and Forestry (MAF) responsibilities and may be a source of confusion. Under the laws of Tonga, land may be leased but not sold. Until recently, all male taxpayers were entitled to an 8-acre (3.24 ha)

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[15] The first several paragraphs are summarised from *Tonga Biomass Resource Assessment Profile* prepared by Imperial College, University of London (SOPAC, 2003).

'api' or allotment, which made landholding subject to considerable fragmentation. More than 60% of the country's land area is held in *apis*, an arrangement which appears to limit forestry development to small scattered woodlots.

Biomass energy-related concerns

The principle biomass/forestry concerns in Tonga relate to deforestation and forest degradation. Most lowland forest has been cleared, raising concerns over biodiversity loss, increased soil erosion and the spread of anthropogenic grasslands. Other issues include: i) an increase in commercial farming of short-term crops replacing traditional practices, the main cause of forest loss on private lands; and ii) lack of experience in environmental management.

During the 2003/04 PIREP mission, a few vendors were seen selling near the airport at T$5-8 per bundle of roughly 15 kg, said to be sufficient for one 'umu (earth oven) or two or three typical meals. Most of the fuel wood now sold in Tongatapu is from 'Eua and Vava'u (Maka, 2004 from Head of the Forestry Division of MAF). Following commercialisation of Nuku'alofa's Talamahu market in 2002, fuel wood is no longer sold at the market or the Tofoa fair outlet, reportedly due to non-payment of rent by the vendors.

According to FAO data, Tonga has little native forest left, mostly in difficult to access areas, probably totalling less than 4000 ha. Only around 1700 ha of native forests are on Tongatapu but around 65% of the land is under some sort of tree crop, primarily coconuts though small pine plantations and hardwood species amounting to less than 1000 ha have been established with those efforts concentrated on 'Eua. As of 2004, no cutting of the pine or hardwood trees has commenced though when it does, there should some opportunity for co-generation using sawmill wastes. Currently, around 80% of timber operations are using senile (over 60- years old) coconut trees. The main mill is private and located at Mataliku, Tongatapu, with smaller private mills on 'Eua, Ha'apai and on Tongatapu. Sawmill waste is used for swamp fill and sold for firing the traditional *umu*. No data was available to the team as to production, though it is not large. When the pine forests mature, it is estimated that Tonga will be at least 80% self-sufficient for wood products with the ultimate goal full self-sufficiency.

Plantations

In the medium to long term, plantations are intended to replace indigenous forest for domestic wood supply and to ultimately achieve self-sufficiency in wood products. The GoT is interested in promoting planting for timber and fuel wood, planting improved varieties of fruit trees and nitrogen-fixing trees, coconut rehabilitation and replanting, and commercial intercropping. Tonga hopes to establish 1500-2000 hectares of plantation forest with efforts concentrated on 'Eua near Tongatapu, with *Pinus caribaea* and *Toona australis* predominating.

Tonga Timber has 540 hectares of forest plantation in 'Eua and expects to have 1200 ha planted by 2008 for exploitation by 2020. Table 3.1 summarises current plantations and plans. The Royal Estate in 'Eua has 45 ha of forests plus about 1500 ha unsuitable for anything but forestry. The company hopes to negotiate a lease with the King to use the land for forestry. There are about 700 ha of additional suitable land on nearby uninhabited islands ('Ata, Tofua, Kao, etc.) which can also be set aside for forestry (Tonga Timber, 2003 and

2004.[16] Waste from pine products mills could be a modest future source of energy but is unlikely to be significant within the next ten years.

Table 3.1 - Tonga Timber Forest Plantation Statistics: 2003 and Estimated Future Sustainable Output per Annum				
Product:	**'Eua Plantation** (m^3)*	**2020 projection** (m^3)**	**'Eua Royal Estate*****	**2020 projection** (m^3)
Plantation size	520 ha	1200 ha	45 ha	1500 ha
Sawlogs	3,043	7,000	450	9,012
Post/Poles	400	920	4	1,180
Thinning logs	400	920	4	1,180
Fuel wood (logging)	200	460	2	920
Fuel wood (sawmill)	1,041	2,330	150	3,004

* This represents harvesting and replanting 18 ha per annum. ** Harvesting and replanting 40 ha p.a.

*** Harvesting and replanting 2.5 ha p.a. Source: Tonga Timber Statistics, 2003

Coconut Oil

Coconut oil or its esters is technically a potential replacement for ADO for both transport and for electricity generation. Wastes from coconut timber are useful for fuel wood. Unfortunately, there are no current reliable data on the number or percentage of trees in Tonga which are of economic bearing age (for coconut oil) and those which are

Table 3.2 - Production of Forest Timber and Coconut Timber (m^3): 1990 – 2003

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Forest Plantation* -Timber (m^3)						395	420	472	530	462	572	417	480	596
Coconut Timber														
- Sawn (m^3)	2040	1980	1625	1870	1220	1220	750	700	940	875	843	762	790	720
- Fuel wood (logging)	560	495	406	470	305	300	190	175	235	220	211	190	200	185
- Fuel wood (Sawmill)	612	594	490	564	370	360	230	210	282	264	25	228	240	220
- Sawdust	120	119	98	132	74	72	46	42	56	52	50	46	48	44

* Tonga Timber Ltd took over the management of the forest in July 2003. Production is expected to reach a sustainable output of 3004 m^3 of logs (1500 m^3 of timber) in 2004 Source: Tonga Timber Statistics, 2003

senescent (for timber and fuel wood). A 1996 survey (Burrows and Douglas, 1996)[17] was unable to determine the age structure of coconut trees but estimated a senile 'resource' of 21,182 m^3 for all of Tonga.[18] The survey also found that the number of palm trees had declined by 27% between 1979 -1995 (Table 3.3) for the surveyed area, with 20-25% of felled palms being used for timber. Replacement plantings were about 25,000 new palms per year between 1979 and 1995 but maintenance of the resource would require at least 100,000 new palms per year.

Table 3.3 - Number of Coconut Palms in Tonga, 1979 and 1995

Island group	**Cultivated Area** (ha)	**Palms/ha** 1979	**Total Palms** (millions) 1979	**Palms/ha** 1995	**Total Palms** (millions) 1995	**Difference** (%)
Tongatapu	19,268	111.9	2.156	71.6	1.380	36.0
Ha'apai	6,476	150.5	0.975	135.6	0.878	9.9
Vava'u	9,604	130.2	1.250	78.7	0.756	39.5
Overall	35,347	124.0	4.383	91.0	3.217	26.6

Source: Burrows & Douglass, 1996.

16 This is from Tonga Timber Statistics, 2003 and interview by national Consultant Lia Maka with Tonga Timber's Chief Executive Officer Kaveinga Fa'anunu in 2004.

17 The surveyed areas were all of Tongatapu, five central islands of Ha'apai (Ha'ano, Foa, Lifuka, Uoleva and 'Uiha), and central and northern districts of Vava'u (Pangaimotu, Neiafu, Holonga and Leimatu'a). The survey was carried out between October and December 1995.

18 Maka, 2004, notes that the senile resource was estimated to be sufficient for only 3.6 years demand. However, if this demand was based on 1995 production of sawn timber and fuelwood, i.e. 1,880 m^3, the resource would last over 11 years. The reason for the discrepancy is unknown.

In 1995 potential copra production was about 10,000-15000 tonnes/year, sufficient in principle to produce about 6700 - 10,000 tonnes (7.4 - 11 ML) of coconut oil per year. At 1996 re-establishment rates, there would be very few productive trees after the subsequent 20-30 years. A later Tonga Agroforestry Project[19] aimed to plant 50,000 coconut seedlings per year of various varieties by 2002. A "fuel wood production systems subcomponent" at MAF was to assess suitable tree species for fuel wood production and market acceptability.

Biofuels

With 65% of the land under coconuts, clearly there is a substantial resource base for developing coconut oil for biofuel use. The maximum production with the existing tree resource base is estimated at about 10Ml/year of coconut oil. There has been no attempt to develop biofuel and, relative to the large area under coconut trees, copra production is not great. Exports declined from 4342 tonnes in 1986/87 to 56 tonnes in 1993/94, increased to 817 tonnes in 1996/97 then dropped to 107 tonnes in 1998/99. It is not known how much copra might be available in practice to produce fuel.[20] The land under coconut cover represents the primary agricultural area for cash and subsistence crops and coconuts are often used only as animal feed and for household cooking use.

If rehabilitation efforts for the coconut industry are carried out and if barriers to the production of biofuel can be eliminated, the maximum offset of diesel fuel by biofuel represents about 50% of the fuel used for electricity generation (around 10Ml/year).

Biogas

The production of biogas for energy requires a consistent supply of feedstock in a quantity large enough to produce enough gas to be useful. The feed stocks most commonly used is animal manure harvested from animal feed lots, human waste concentrated in sewage and land fill waste from urban areas. There has been no assessment of these resources though it is likely that sewage and urban waste may be practical for biogas generation development. Most families keep several pigs but it is unusual to find them penned in groups large enough to make biogas production economically practical. Although biogas should be considered as a practical renewable energy source for Tonga, it is not likely to provide even 1% of the total energy used in Tonga over the next decade.

3.1.2 Solar Resource

The solar resource on Tongatapu has been well documented with a specific solar resource assessment carried out by the Forum Secretariat in 1995-1997 near Cook Point on Tongatapu[21] but no long term measurements have been taken on other islands of Tonga. The only country wide resource for solar system design remains the 10 years of satellite measurement data made available by NASA. The data is based on large area measurements that cover far more than the individual islands of Tonga, therefore, where the islands cause local climate effects, notably clouds due to rising air currents over larger islands, the solar resource may be significantly different. For most of Tonga, the differences are not likely to be great and the satellite measurements can be used for solar design purposes if the designer assumes a 10% to 15% lower average solar resource than indicated by the satellite data. For

[19] This was part of a Tonga-France Partnership from 1997/98 – 2000 to promote a sustainable coconut resource.

[20] No more recent data were available from recent economic reports by IMF, ADB or the Reserve Bank of Tonga.

[21] *Southern Pacific Wind and Solar Monitoring Project, Vol. D. Final Report Tonga*, Forum Secretariat 1998

mountainous islands where local cloud cover may vary significantly from that of the surrounding ocean, a local assessment of the solar resource is necessary. Future measurements should be made using pyranometers tilted the same as the installed panels. Although it is possible to estimate the energy received on a tilted surface, different algorithms for those computations provide results differing by more than 10 percent..

The satellite data indicates a generally increasing solar resource going north through the Tonga groups of islands though the Niuas' measurements indicate a slightly lower resource than Vava'u.

Table 3.4 - Satellite measurement of solar radiation on horizontal surface and tilted surface computations

						Tongatapu							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Horizontal	6.78	6.34	5.56	4.61	3.79	3.53	3.7	4.38	5.16	6.17	6.62	6.47	5.25
OptimumTilt	6.21	6.18	5.89	5.37	4.78	4.47	4.59	5.31	5.68	6.18	6.17	6.64	5.62
						Ha'apai							
Horizontal	6.57	6.07	5.54	4.71	4	3.68	3.95	4.62	5.3	6.01	6.52	6.3	5.27
OptimumTilt	6.76	6.02	5.91	5.47	5	4.74	5.09	5.57	5.84	6.1	6.1	6.52	5.76
						Vava'u							
Horizontal	6.42	5.99	5.57	4.77	4.13	3.92	4.08	4.76	5.4	5.95	6.36	6.17	5.29
OptimumTilt	6.38	5.47	5.76	5.64	5.45	5.6	5.67	5.99	5.93	5.66	6.06	6.21	5.82
						Niua							
Horizontal	5.82	5.53	5.31	4.79	4.39	4.27	4.42	5.12	5.77	5.95	6.05	5.81	5.27
OptimumTilt	5.79	5.03	5.4	5.52	5.62	5.81	5.85	6.23	6.22	5.61	5.92	5.96	5.75

Source: NASA (http://eosweb.larc.nasa.gov)

Table 3.5 - Photocell radiometer measurements of horizontal global solar radiation (1996)

						Tongatapu							
Horizontal	**5.09**	**5.84**	**4.49**	**4.5**	**3.36**	**2.16**	**3.04**	**3.99**	**4.91**	**4.9**	**5.89**	**5.97**	**4.51**

Source: *Southern Pacific Wind and Solar Monitoring Project, Vol. D, Final Report, Tonga*, Forum Secretariat 1998

The one year of solar data from the Forum Secretariat Pacific Wind and Solar Monitoring Project indicates a solar resource about 15% lower than the 10 year average shown by the satellite measurements. This could be due to 1996 being a lower than average year, to calibration errors with the instruments used or could be due to the land mass of Tongatapu inducing increased cloud cover locally over the island causing lower solar radiation on land than on the surrounding ocean[22]. Both sets of measurements show sufficient solar energy available for cost effective solar. Since rural electrification is close to complete, solar energy is expected to be primarily beneficial for grid supplementation. If barriers against its introduction are removed, about 5% of electrical energy can be provided by solar photovoltaics.

3.1.3 Wind Resource

The South Pacific Wind and Solar Monitoring Project of the Forum Secretariat installed wind and solar monitoring equipment in Tonga with overall results tabulated in Table 3.6.

[22] The satellite measurements cover an area several times larger than Tongatapu and therefore reflect the oceanic solar climate more than the local solar climate on Tongatapu.

Although the average energy content is not considered excellent, given the high cost of diesel power, supplementation of existing grids may be cost effective, particularly with the small committee operated diesel systems on Ha'apai and Vava'u. Since larger wind farms for Tongatapu will probably have to be off shore or located in swampy areas that have no economic value for trees or agriculture, a specific assessment for those areas at 30-50 meter heights would be worth while to better understand the wind regimes that can actually be tapped for energy. If barriers to wind energy use are removed and the resource is proven to be economically reasonable, a maximum of 15% of electricity generation could be provided from wind.

Table 3.6 - Wind speed measurement (at 10 metres)

Tongatapu													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
1995	5.8	3.6	4.0	4.3	4.2	3.7	3.2	5.0	5.6	n/a	n/a	n/a	4.38
1996	4.5	3.7	5.0	4.8	3.9	4.7	3.6	3.7	4.0	5.3	3.2	4.7	4.26

Source: *Southern Pacific Wind and Solar Monitoring Project, Vol. D. Final Report Tonga*, Forum Secretariat 1998

3.1.4 Hydro Resource

None of the mountainous islands of Tonga have a large enough rainfall catchment area to provide reliable, economically developable hydropower having a capacity greater than a few hundred watts. The uplifted coral islands have no permanent streams.

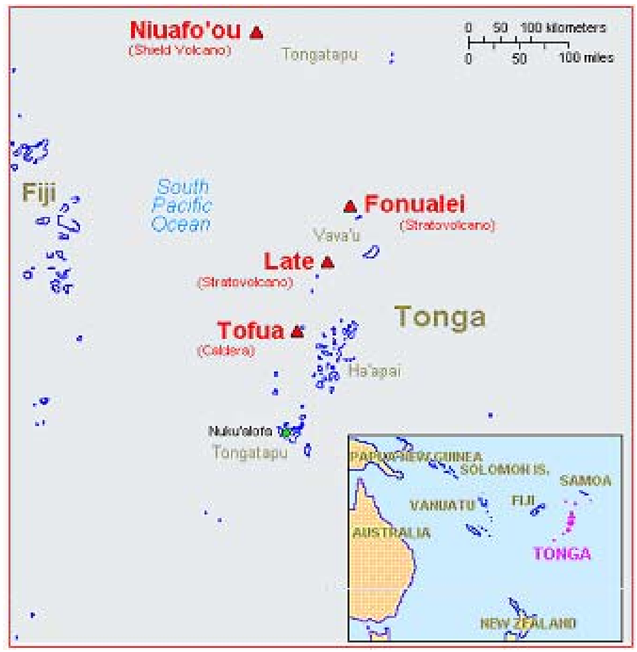
3.1.5 OTEC Resource

Although substantial OTEC resources are undoubtedly present at a number of locations in Tonga, OTEC remains an experimental technology with no commercial scale installations yet made. The largest OTEC installation yet attempted, 1 MW gross and around 700kW net, has been under construction on a barge off the coast of India for several years but as of mid 2004, has not yet operated despite major overruns of both cost and time.

Hawaii based OTEC expert, Dr. Luis Vega, notes that *"Technical and economic studies as well as experimental work have been conducted by numerous private and public entities in France, Japan and the USA. It was concluded that, for example, in Hawaii electricity production with OTEC technology is cost effective for 50 MW or larger plants. This conclusion is independent of the type of OTEC power cycle (i.e., Open, Closed, Kalina or Uehara) utilized. Moreover, it was concluded that commercialisation ought to be preceded by the design, installation and operation of a pre-commercial plant sized at about 2 to 5 MW.The situation in some Pacific Island Nations is such that smaller OTEC plants (e.g., 1 to 10 MW) configured to produce desalinated water in addition to electricity could be cost effective.*

However, because the technology is presently not commercialised, proposed installations in independent island states must be implemented without any financial responsibility assumed by their governments.[23]*".*

Figure 3.1 - Location of Island Volcanoes of Tonga



Source: U.S. Geological Service, (Simkin and Siebert), 1994

3.1.6 Geothermal Resource

There have been no geothermal resource surveys of Tonga and the SOPAC geothermal assessment does not include Tonga. However, Tonga lies in an area of very active volcanism and is perhaps the only PIC increasing in size due to volcanism faster than it is shrinking due to sea level rise. A number of undersea volcanoes and several volcanic islands exist within Tonga.

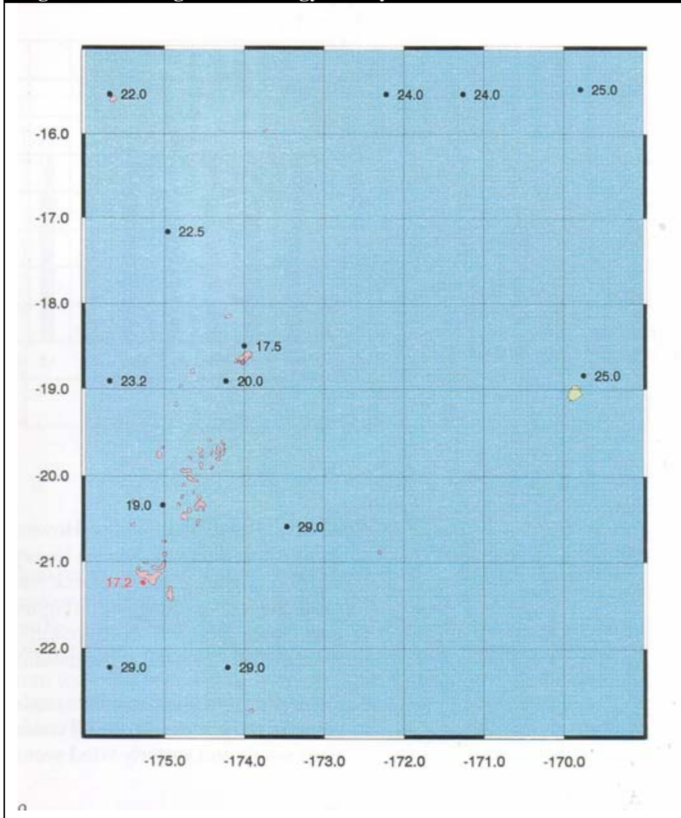
In the 1980s an undersea volcano spread floating pumice ask over thousands of km^2 of sea, extending coverage well into Fiji waters and causing major problems with cooling water intakes and pumps on ships passing through the area. In 1999 a tiny new island emerged from the sea spewing steam and lava only 50km from Tongatapu. The highest point in Tonga is an intermittently active volcano, Tofua, in the Ha'apai group.

An inhabited active volcano island is Niuafo'ou. It has had eruptions recorded several times in the 20th century, including an eruption in 1946 that resulted in the loss of villages to lava flows. The 1300 residents of Niuafo'ou were then evacuated but in 1958 the residence ban was lifted and many returned. In 1985 a small earthquake followed by emissions of steam and gasses showed that the magma remains near the surface. However, since the cost of geothermal development is high, only Tongatapu with its relatively large electricity demand could possibly take advantage of any geothermal resource for power generation and the

[23] Vega, Luis "Ocean Thermal Energy Conversion Primer" Marine Technology Society Journal, Vol. 36, No. 4, pp 25-35, Winter 2002/2003

geological structure of Tongatapu makes it less likely to have accessible geothermal resources than some other islands of Tonga.

Figure 3.2 - Tonga wave energy survey.



Source: Ocean Wave Energy in the South Pacific, the Resource and its Utilisation, Barstow and Falnes, SOPAC and Norway, 1996

Note: Blue points from satellite observations, red point near Tongatapu from Waverider buoy readings

3.1.7 Wave Energy Resource

A wave energy resource study done by SOPAC[24] concluded that there is significant potential for wave energy utilisation in Tonga with measurements from a Waverider buoy at Tongatapu recording an average energy of 17.2kW/m and wide area satellite measurements above 20kW/m in the open ocean near Tonga islands.

However, the statement in the 1992 PREA regarding wave energy remains relevant: *"In the 1980s, the GoT expressed strong interest in the use of wave energy for power generation and several potential sites on Tongatapu's coastline were identified. Negotiations with a Norwegian company for an installation on Tongatapu were well under way when the company's Norway sea trials failed causing a loss of faith in the technology. The technical and economic viability of the technology has yet to be demonstrated despite numerous trials of different designs. Until that demonstration occurs and there is a commercial product that cost effectively converts wave power to electricity in an environment like that of Tonga, it would be risky for Tonga to attempt to utilise wave power for electricity generation unless the installation is fully funded, operated and maintained by the technology developer as an independent power producer."*

3.1.8 Tidal Energy

The tidal range in Tonga is typically less than two metres, making it necessary to funnel a large volume of tidal flow through a turbine to provide useful power. Vava'u has possible potential for tidal energy since the main island includes several large enclosed pools with narrow connections to the sea making it possible to construct diversions to force all tidal flow through turbines for electricity generation. In the late 1980s a bridge was being considered across the narrowest sea passage and propeller type turbines were briefly considered as possible for installation in the structure for power generation. However, the electricity produced would be intermittent due to the flow to changing direction twice a day and the cost

[24] *Ocean Wave Energy in the South Pacific, the Resource and its Utilisation*, Barstow and Falnes, SOPAC and Norway, 1996

of the bridge would have been greatly increased due to the need to divert all water passage through the turbines. Considering that only intermittent power could be generated, the added cost could not be justified.

3.2 Appropriate Technologies for Development

Based on available data and considering experiences in Tonga and elsewhere in the region and abroad, solar photovoltaics, solar thermal for water heating, biofuels for diesel fuel replacement and grid-connected wind power technologies are promising in the short- term. For the others, it is worth monitoring their development and use overseas but to avoid the use of scarce financial resources to invest in them until well proven commercially.

4.1.1 Biomass

Figure 4.1 - Energy Officer Winnie Veikoso with the woodstove at Queen Salote College

Peter Johnston 2003

The primary use of biomass resources continues to be for cooking. On Tongatapu, the high population density has made firewood increasingly scarce and most households have shifted to LPG or kerosene as their primary fuel source. Today, the primary use of firewood on Tongatapu is for *umu* cooking (traditional earth oven cooking) that is commonly used for special events and on Sunday. To meet that demand, firewood is shipped in from other islands, particularly ‘Eua, for sale in the market and at retail outlets.

Over the past 20 years, there have been several government and NGO based projects to improve woodstove efficiency, particularly in schools where an institutional stove design initially developed in Fiji has been widely promoted. The popularity of the installations does not, however, appear to have been greatly improved fuel efficiency but rather better control over the cooking process and a better quality of food preparation at the schools

In 1985 a project was proposed to use senile coconut trees on Tongatapu to fire a 1.5 MW steam power plant but the plans were not carried forward, instead senile trees are being used for lumber production.

In the late 1980s, AusAID funded a large whole nut coconut processing facility on Tongatapu. Included in the design was co-generation through steam production from the burning of shell and husk residues. Unfortunately the boiler design was not appropriate for that fuel and never worked well. The plant design also resulted in production problems that were never solved and the facility ultimately was abandoned.

4.1.2 Biofuels

There have been no biofuel development projects carried out in Tonga.

4.1.3 Wind power

Other than small mechanical wind powered pumps that were in limited use in the past, there has been no wind energy development in Tonga.

4.1.4 Solar thermal

Figure 4.2 - Local Manufacture of SWH, FAO, Nuku'alofa

Peter Johnston 2003

Solar water heating is commonly used on guest houses, schools and hotels. Penetration of solar water heating into the household market has not been great partly due to initial cost but mostly due to a lack of general interest in piped hot water for homes that extends to all energy sources.

A company located in Nuku'alofa, PAO Plumbing Co. Ltd, has manufactured integral thermosiphon solar water heaters since 1986 but finds the market difficult to penetrate. Besides the limited acceptance of piped hot water in Tongan households, there is a problem with calcium carbonate deposition on the inside of solar water heater collectors when ground water is used and that has resulted in maintenance problems for some users. Where rain- water is used in solar water heaters, maintenance requirements are generally much lower but, unlike some atoll countries, rain water is not commonly used for piped household water supply in Tonga.

4.1.5 Solar Photovoltaics

In the nearly 20 years since the first village electrification projects in Tonga, both the technical and the institutional systems have gradually improved with the most recent installations highest in quality utilizing well proven components and having a capacity well matched to the climate and user requirements. User acceptance has also risen as installations have become more reliable and capable of providing the desired services. Interestingly the acceptance has also increased along with user fees. The first installations in the late 1980s included a T$2 per month fee, later installations raised the fee to T$6 and the latest projects have a T$13 per month fee. This shows the EPU has an understanding of the relationship between fees and the sustainability and success of these projects and their real commitment to bring fees into line with real costs.

The Tonga Outer Islands Solar Electrification Programme (TOISEP) has been in operation since 1987 with its first EU-funded project on the islands of Taunga and then Mango in 1988. These first two projects were part of the Lomé II Pacific Regional Energy Programme's pilot photovoltaic programme aimed at reducing the dependence on petroleum fuels and assessing these technologies in terms of their technical and economic suitability in the region. Residual funds from the same programme provided for the electrification of the island of Mo'unga'one in 1994. There have been a total of at least 752 systems installed throughout the Kingdom under public projects.

Some private systems are known to exist but no survey has been made to determine their number or characteristics. Table 4.1 provides a list of the PV installations, their size and locations. Note that not all listed systems are currently operational.

4.1.6 Institutional structures

All solar development at the village scale has been in the form of an energy service company (ESCO) where systems are not owned by the users but by government, a cooperative or community and fees are charged to offset the cost of maintenance. However, the actual mode of implementing this structure varies from place to place since there has been no national policy addressing these issues. They have all been based on moving the direct management of rural PV projects away from government, leaving only an advisory and policy role, and empowering the communities to have a stronger say in the management of their projects.

Table 4.1 - Existing Solar Project Sites (2002)

Island Group	Island	Year	Source of funds	System type	Number	Panel Peak Power	Panels per system	Total Peak Power (kWp)
Tongatapu	Atata [phase1]	1997	UNESCO	SHS	23	50	2	2.30
	Atata [phase2]	1998	Japan	SHS	18	50	2	1.80
	'Eueiki	1999	AusAID	SHS	26	50	2	2.60
Ha'apai	Mango	1988	EU	SHS	26	50	2	2.60
	Mo'unga'one	1994	EU	SHS	49	50	2	4.90
	Fonoifua	2002	PREFACE	SHS	24	75	2	3.60
	'O'ua	2002	PREFACE	SHS	38	75	2	5.70
	Kotu	2002	PREFACE	SHS	35	75	2	5.25
	Tungua	2002	PREFACE	SHS	32	75	2	4.80
	Matuku	2002	PREFACE	SHS	22	75	2	3.30
	Fotuha'a	2002	PREFACE	SHS	18	75	2	2.70
Vava'u	Taunga	1987	EU	SHS	32	50	2	3.20
	Hunga	1995	EU	SHS	47	50	2	4.70
	Kapa	1995	EU	SHS	31	50	2	3.10
	Lape	1995	EU	SHS	7	50	2	0.70
	Matamaka	1995	EU	SHS	42	50	2	4.20
	Noapapu	1995	EU	SHS	43	50	2	4.30
	'Otea	1995	EU	SHS	35	50	2	3.50
	Ofu	1995	EU	SHS	43	50	2	4.30
	'Olo'ua	1995	EU	SHS	21	50	2	2.10
	'Ovaka	1995	EU	SHS	26	50	2	2.60
	Falevai	1995	EU	SHS	42	50	2	4.20
Niuatoputapu	Tafahi	1999	NZ	SHS	36	50	2	3.60
Niuafo'ou	Niuafo'ou	1993	France	SHS	35	50	2	3.50
	Niuafo'ou	1996	NZODA	Freezer	1	n/a	n/a	n/a
	Tafaki	2003	NZODA	SHS	rehab†			
Total					752			83.55

Source: *Tonga Rural Electrification: Harmonisation Study* (Solomone Fifita; SPC; 2002) updated with information from EPU

† Rehabilitation included replacing all components for the 33 existing systems except panels (110Wp/SHS) which were still fully functional

Project structure up to 2000

In 1987, government approved that the monthly fee on the Taunga and Mango (EU Funded) domestic lighting projects be T$2 per system with a $20 connection fee. In 1992, it approved that the monthly fee for the Niuafo'ou institutional lighting project be $10 (NZODA and French funded projects) with a T$20 installation fee. The Mo'unga'one (EU funded Ha'apai project) domestic lighting project of 1994 was approved at T$6 in 1993 with a T$20 installation fee.

In an attempt to standardise the projects in the program, government in 1994 approved a standard fee for the Taunga, Mango and the Mo'unga'one domestic lighting projects at six dollars. The Vava'u domestic lighting project of 1996 (EU) adopted a T$50 connection fee with a T$6 monthly fee. The Atata domestic lighting project of 1997 (UNESCO) and the Tafahi domestic lighting project (NZODA) all adopted a T$10 monthly fee with a T$20 connection fee.

Figure 4.3 - Atata SHS Installation 1997 (2003)

Peter Johnston (2003)

All projects were managed by individual village committees with the Vava'u committees taking a more communal payment approach and the Ha'apai committees taking an approach that placed payment responsibility onto individual households. The committees were expected to collect the fees and turn them over to the Energy Planning Unit (EPU) to offset the cost of maintenance. Funds were supposed to be deposited in a revolving account at the Treasury where they did not draw interest and a government "commission" of five percent was charged to each deposit for servicing the account. Basic system maintenance was the responsibility of the committees and EPU staff was called upon for more complex maintenance. Service delivery was not considered satisfactory. Some of the systems broke down and were not repaired promptly. These problems made it difficult to impose a disconnection policy. Visits by EPU technicians were irregular and often long delays occurred between breakdowns and repairs. For these reasons, fee collection was generally poor (no more than 40% typically) with Vava'u payments less consistent than those from Ha'apai.

Figure 4.4 - Mango Island Solar Home – 1990 Installation (2002)

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That the lessons learned in earlier projects have not always been consistently applied to later projects has been more due to the lack of a clear national policy than a lack of understanding or will on the part of the Energy Planning Unit. This has largely been a result of the government never having officially endorsed the concept of solar based rural electrification and has not attempted to ensure that the development of projects would be carried out with a consistent policy or even with a consistent objective. For example, the largest single PV project for Tonga, the EU funded Vava'u outer island electrification project, was conceived, planned and implemented by the Vava'u Development Committee and the Central Planning Department without participation by the EPU. Indeed, the EPU did not even know about the project until the negotiations with the EU for its funding had been nearly completed by the Ministry of Planning. Only after the project had been commissioned was the EPU requested to participate by taking over the operational support of the 337 systems installed – but with no additional budget accompanying the request. That there is reasonable operational consistency between projects is due mainly to the fact that the only real technical knowledge about solar photovoltaics in government resides within the EPU making their participation at some point essential in all projects.

Project structure after 2000

- In 1998, a review of the Tonga Outer Island Solar Programme (TOISP) was carried out by SOPAC. The conclusion was that the structure did not meet the needs of either fiscal or technical sustainability. Specific problems of the TOISP structure were noted as:Failure to present the participation in the programme as voluntary resulting in households participating that cannot afford the fees or do not really want the services being offered making non-payment likely and disconnects difficult;
- Failure to impose on the islanders a serious financial commitment to participate in the projects. Fees were set too low in relation to the services offered since the PV systems actually reduced household payments for kerosene and dry batteries more than was being charged for the PV;
- Lack of on-going consultations through meetings and training workshops with the islanders. The EPU budget for travel and training were insufficient to maintain the close contact with the project recipients needed for proper management;
- Absence of resident technical officers in the island centres to readily provide technical assistance and spare parts. All services and supplies came from Tongatapu with corresponding delays and added cost;
- Total reliance on island technicians, who are not responsible to the EPU, for the fee collection and the maintenance. Technicians were responsible to the island committees, not the EPU, and often ignored EPU policies regarding system modifications and maintenance; and
- Unclear responsibilities for the Solar Energy Committees. The projects were owned and said to be managed by the EPU yet there was no local EPU presence and communications with the EPU infrequent; and
- EPU was unable to provide islanders with up to date information on revolving fund account balances with funds going into a government treasury account that bore no interest and was charged a five percent servicing commission.

In 2000, the Australian-France funded PREFACE project agreed to assist the government in funding further Ha'apai PV electrification and PREFACE proposed doing so under a new structure designed to solve most of the problems that had arisen in earlier projects. Notably a connection fee of T$200 and a monthly fee of T$13 was established in order to cover O&M costs in their entirety.

Table 4.2 – Comparison of TOISP structure and the PREFACE structure	
1990's PV Project Structure (EU) in Ha'apai and Vava'u	**2000's PV Project Structure in Ha'apai (PREFACE)**
•All island households are expected to take systems and consumers sign an agreement with the EPU	Consumers apply to the HSEC to be provided with solar electricity and contract with HSEC for service. If a household does not want service, it is not installed.
Consumers pay an installation fee of T$50	•Consumers pay an installation fee of T$200
Monthly fee of T$6 [T$10 at Niuafo'ou]	•Monthly fee of T$13 (Approx .5 US$)
Fee was mostly a political decision	•Fee based on the recovery of operational and maintenance costs
Individual village solar committees	•Ha'apai regional Solar Electricity Committee [HSEC]
Island technicians selected and paid by village solar committees	•Island technicians selected and paid for by the HSEC
Managed from Nuku'alofa by the EPU	•Managed from the Ha'apai administrative centre [Pangai] by the HSEC
Spare parts kept at Nuku'alofa	•Spare part kept and stored on the islands and at Pangai
All project funds and revenue pass through Treasury and not earmarked specifically for the project	All project funds and revenue through the HSEC's bank and earmarked exclusively for the project
No interest received on deposits and 5% tax charged	Interest received and deposits not taxed
Government owns all the components	HSEC owns the system up to and including the circuit breaker. Consumers own everything from the circuit breaker to the load
EPU responsible for maintaining the lights	Consumers maintain the lights at their cost
Solar committees set the fees and collect them	•Fees set regionally by HSEC. Individual committees vote on fees but do not set them
No clear arrangement on disposal of used batteries	•To be collected for export and recycling
No fixed meeting time with the island communities management [EPU]	Annual meetings of HSEC to review the management structure and approve the annual work programme and budget
No disconnection or removal for non-payments	•Disconnection or removal for non-payments

Project ownership and management was shifted from village committees to a registered NGO, the Ha'apai regional Solar Energy Committee (HSEC) which is managed by a Management Committee made up of key civil servants at Ha'apai, from the EPU and a representative from each of the participating island communities. Fees are set by that committee and are considered annually. They are specifically to be based on actual O&M cost though there is no capital repayment included.

Instead of fees going into a treasury account that lost both interest and gained a government charge of five percent of the deposited funds, two private accounts for the HSEC were established with one as an interest bearing battery replacement fund where a fixed percentage of collected fees would be placed in that fund each month and used solely for battery replacements. The remainder of the fees go into a checking account for use in day to day operations. All expenditures are reviewed by the HSEC. Because all financial decisions are made by the HSEC which includes representatives of all stakeholders, operations are transparent and understood by all affected parties.

The EPU agreed to provide a technician permanently located on Pangai (the Ha'apai district administrative centre) who assists both administratively and technically. Island technicians were selected and hired by the HSEC, trained by the EPU and supervised by the EPU technician in Pangai. Customers signed a contract noting that non-payment of fees or tampering with the system would result in disconnection and possible removal of systems.

Village committees are responsible for keeping panels shade free and ensuring that panels are protected against damage by free ranging animals and hurricanes.

The PREFACE project installations were completed in 2002 and thus far collections have been nearly 100% on time and disconnects have been enforced for non-payment.

4.1.7 Technical Structure

As with most PV electrification projects, system design has incrementally improved with experience. Early projects were undersized and batteries generally were not appropriate for long life. By the mid-1990s, system design had stabilized with panel size around 110 to 150Wp, deep discharge high quality batteries were being used and control electronics and lights that had long been successfully used in the Pacific environment were installed. Early systems were roof mounted while later installations use external poles in order to avoid roof damage and to ensure panel mounting in minimum shade areas. These later system designs have proven to be high in reliability with battery life in excess of 8-9 years and in some cases exceeding 10-years. Thus even with relatively poor maintenance, a visit to Mango Island in 2002 found 17 out of the original 26 installations upgraded in 1990 still operational with the original equipment still functioning. Several panels and lights from the original 1988 installations were found to be operational. All the original controllers were operational.

The technical design of the 2002 PREFACE installations included:

- Two 36 cell 75Wp Photowatt PV panels providing 150 Wp per installation;
- 12V Hawker-Oldham open cell, tubular positive plate, deep discharge battery with a capacity of 108 Ah at C10;
- Total Energie charge controller;
- Four High efficiency 13 Watt tube type fluorescent lights with three having an open housing for inside use and one with a weather proof housing for external use;
- DC/DC converter for radio operation; and
- LED type night light (orange colour).

Battery and controller are contained in a locked, white coloured, polypropylene box mounted at the base of the wooden pole used to support the panels.

The system is sized to allow the external light to be left on all night to act as street lighting thereby avoiding the problems associated with installing and maintaining separate systems for public lighting. A visit to the site in 2002 found that this approach did provide good lighting for walking on the village streets at night. This approach also allows street lighting power to be diverted to home use during cloudy periods thereby increasing system reliability and reducing the depth of discharge of batteries.

Batteries and controllers are in a locked, weather tight box placed at the base of the panel mounting pole instead of in the house as was the case in earlier projects. This was intended both to facilitate maintenance when occupants are not at home and to discourage tampering with power system connections and controls. Some problems have arisen with the use of the external battery boxes. Pigs have in some cases caused boxes to be shifted on their base by rubbing against them. Also during heavy rains, some sites have flooded where the battery boxes are located and they may have to be raised on a platform to prevent damage. A potentially serious problem is that the interior of the boxes has too high a temperature for good battery performance and low water loss. Cell temperatures have been monitored and found to be nearly 40°C, a temperature the battery manufacturer states as one that will shorten the life of the battery and result in several times the water loss as would be seen at

Figure 4.5 - PREFACE SHS installation

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25degrees celcius. The addition of shades for the boxes is being tried in order to lower the battery temperature to a more acceptable level.

System performance so far has been good with minor problems with some controller malfunctions surfacing shortly after installation. Several users have complained because they wanted one of the lights to be on a long (10 metre) cord for use outside but it was not provided in the project. Some users have made their own jury-rigged portable lights to meet this need.

The quality of installation was generally excellent though there were several installation errors, the most important being the use of wire that was too small between the battery and load. Those errors have been corrected by the installer. Installations were supervised by the project contractor, Pacific Energie (New Caledonia), but actual installations were done by an electrical contractor from Tongatapu, ALPA Electric, who had also participated in installations in Vava'u a few years earlier.

4.1.8 Telecom PV

Tonga telecom has installed solar powered telephones outer islands and do their own design and maintenance.

4.1.9 Lessons Learned

From the point of view of project design and implementation, the most important lessons learned from the Tonga experience have been:

Fig 4.6 - Mango Island PV powered phone

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1. **The amount of money that people are willing to pay for PV electrification can be substantially greater than conventional "ability to pay" surveys predict.** The earliest projects based fees on stated "ability to pay" and those projects mostly failed. In an attempt to improve sustainability, each following project has more than doubled fees yet there has been no reduction in the percentage of households accepting systems (always over 90%). Also, each time there has been increasing long term project success. When it was announced that PREFACE would charge

T$200 for installation and T$13 per month, there were predictions that the Ha'apai households could not and would not pay such a "huge" amount just for lighting and radio power. But they have paid and thus far collections remain 100% — though it is much too early to know if that will continue for the long term.

2. **The rate of collection of user fees is directly related to the quality of service obtained**. Early projects in Vava'u charged only $2 per month but systems were technically deficient and proved unreliable for the long term. To collect even this very small fee soon became difficult and collection rates became very low. The EU funded Vava'u systems are newer than the EU funded Ha'apai installations and fees were both T$6 per month. However the Vava'u technical quality was lower – particularly as regards charge controllers and batteries which were not units that had been tested previously in the Pacific environment – and the arrangements for maintenance also poorer. As a result, system reliability has been lower in Vava'u than Ha'apai and so has been the fee collection rate. Collections began at a high level but now are less than 40 percent.

3. **Local, community based institutions are not adequate for sustainability**. For long term success, the greater technical, financial and management resources of an external institution is needed for management of small island electrification projects. Also, local community management finds it very hard to disconnect users that do not comply with project requirements for fees and system use. The external institution must, however, have a local presence. Distant management is not effective.

4. **Components must survive under very difficult environmental conditions**. System controllers not specifically designed for the difficult Pacific Island environment have had an especially poor record and have been the reason for a significant number of technical problems with systems. The Lomé II PREP (EU) project provided controllers designed especially for the Pacific Island environment and system reliability has been dramatically better than that of projects using commercial, "off the shelf" controllers.

5. **Projects need to build on prior experience**. Creating new projects without taking advantage of the knowledge and experience already in country results in projects that repeat mistakes of the past.

6. **The more remote the site, the higher need for high quality, long life components**. The more costly and difficult to access the site, the higher the cost of spare parts provision and maintenance. A low cost battery that has to be replaced every two years may be the most cost effective choice for an easily accessible site but a battery that costs eight times as much but lasts only five times as long may be the best economic choice for a remote site where the cost of access is very high.

7. **Preventive Maintenance improves long term reliability.** A PV system is literally a system. Each component has a specific requirement for operation and if that requirement is not met, the system as a whole suffers from reduced output or lowered reliability of operation. It is not enough to just repair systems that do not work. Most problems with PV systems are the result of an accumulation of small problems, not catastrophic failure of a component. Corroding connections, encroaching shading, changes in controller settings with time, user modifications that change the electrical load and changes in use patterns all can result in a gradual loss of system reliability.

To keep the systems operating at peak efficiency for the long term requires periodic checks and continuing correction of these many small problems. This has been carried out more consistently in the Ha'apai projects than in Vava'u and the lower operational reliability of Vava'u systems reflects that fact.

4.1.10 Current Projects

A PV project for household electrification of the eight villages on Niuafo'ou (Tin Can Island) is presently at the tendering stage. The installations, expected to reach around 85 households, will have the same design and component specifications as the PV systems provided under the PREFACE project for Ha'apai. The institutional approach is proposed to be the same regional solar committee approach that apparently is successful for Ha'apai. To take advantage of the rehabilitation (replacement of battery, controller and 4 lights), households had to pay T$200 installation fee and agree to T$13 per month in payments.

4.1.11 Proposed Projects

Vava'u PV rehabilitation. With the completion of the Ha'apai and Niuas electrification, technical and institutional rehabilitation of the Vava'u EU PV electrification project of 1994 and the addition of the few households not participating, will essentially complete rural electrification in Tonga.

Biofuel and wind for the Ha'apai diesel systems. The community operated diesel systems installed under AusAID funding in 2002 have proven to be considerably more expensive to operate than anticipated by the recipients and a shift to locally produced biofuel and supplementation by wind may be welcomed by the island residents.

Solar powered water pumping for village water supply. As stated in the 1998 JICA project development report, there remains an opportunity to develop outer island village water systems using PV powered pumping systems and small pumping systems for use with rain water catchments.

Biofuel development study. There is only sketchy information available to determine the requirements for upgrading of plantations, development of supply logistics and proper processing approach for large scale biofuel use. A comprehensive study focused on the entire biofuel development process, from tree to end user, is needed to ensure that development follows the least cost and highest reliability path.

Biogas development study. Although pigs are generally free ranging, making biogas generation impractical, consideration of community pig facilities that include biogas generation could make this resource available for use. The study should also consider land fill and human waste for biogas generation.

5 Barriers to Renewable Energy Development and Commercialization

5.1 Known Barriers

5.1.1 Fiscal and Financial Barriers

At the top of the list of barriers must be those relating to the relative cost of renewable energy, both in terms of its actual financial cost and the cost of shifting from familiar and convenient fossil fuels to unfamiliar technologies. Fiscal policies include import duties that unfairly tax renewable energy systems, taxes applied to renewable energy systems that are biased against renewable energy and inadequate government budgets for renewable energy development.

Cost of Petroleum. The primary barrier remains the lower financial cost and greater ease of use of petroleum fuels. Introducing a more inconvenient and higher cost energy source to replace petroleum fuels will require both additional money and the willingness of the residents of Tonga to accept the problems associated with large scale use of the available renewable energy resources.

Import duty barrier. Diesel fuel for electricity generation throughout Tonga is duty free. Renewable energy equipment is not provided any preferential status on taxation. For private purchasers, such as by Shoreline or an IPP, this widens the cost gap between diesel generation and solar or wind supplementation for the grid. It is not a barrier to SHS since even with duty free fuel for diesel generators, SHS is clearly more cost effective than small village diesel systems.

Increasing outer island labour costs. As the outer islands move away from subsistence activities and into the money economy – something that is accelerated by the development of rural electrification – the cost of labour rises making it more difficult to develop labour intensive renewable energy capacity such as biofuels, biomass and biogas at a competitive cost. This can be offset by reducing the labour requirement for the energy production through mechanisation of production processes such as copra cutting but that will require an initial investment and development of a maintenance capability for the equipment. It also is offset by increasing the price of fossil fuels to allow the higher cost renewable energy fuels to compete. Providing a direct subsidy for the production of renewable energy based fuels is another possible option though it should be transparent and paid at the fuel delivery point directly relating to the volume of fuel produced.

5.1.2 Legislative, Regulatory and Policy Barriers

In terms of legislation and regulation, Tonga is still transitioning from a government owned utility to a fully private utility structure. Therefore the legal and regulatory situation is also in flux. These changes have not created further barriers to the introduction of renewable energy and energy efficiency measures though the approach that must be take for their implementation is also changing. The primary barrier in this category is the lack of a clear set of guidelines for government to follow in energy development and a clear definition of what the roles are of the various government agencies that have a role in energy.

There is no energy policy defining the role of the EPU or the place of renewable energy in Tonga. Large scale use of renewable energy requires a governmental focus, particularly in countries with a private electricity supply. A well defined policy accepted and used at the highest level in government is required to maintain that focus.

No definition as to who regulates PV. Although all the technical competence regarding renewable energy for Tonga resides in the EPU, there are indications that the TEPB now considers itself as the appropriate authority to develop standards and licensing for solar, wind and other renewable energy applications that provide some form of electrical services. If, as is intended, ultimately the private sector is to accept responsibility for maintaining and operating outer island PV systems, a clear legal structure for their operation needs to be defined and put into place under a single regulatory agency.

5.1.3 Institutional Barriers

Each form of renewable energy has specific technical and institutional structures that must be in place. There must be a system for receiving payment for energy services, for maintenance of equipment and for installation of new components. Throughout the Pacific, one of the main points of failure in renewable energy projects has been institutions that are inadequate and cannot provide sustainable operation. Some renewable energy sources, notably biofuels and biomass, also must include a structure to bring together large numbers of independent fuel producers into an efficient operational entity so that the energy source is continuously and readily available as well as at a minimum cost.

Lack of technical and management capacity in the outer islands. Sufficient capacity has been developed to adequately manage and technically support the Ha'apai PV projects but development of a similar structure for the Niuas and Vava'u will require technical and project management training not presently available in Tonga.

Lack of information at Shoreline on the potential for energy efficiency and renewable energy. The management of Shoreline needs to be informed of the commercial advantages that can accrue from integrating energy efficiency and renewable energy measures into their operations.

Lack of local training capacity in business management. The energy service business is fairly new to Tonga and the management problems quite different from the trade related businesses that have long experience in the country. The business needs up to date and detailed customer records, good spare parts control and a service approach that maintains customer confidence and provides technical reliability. Thus there is a need for training and advisory support until the industry gains more experience. Although USP maintains a facility in Tonga and provides basic business courses, they are primarily intended for students seeking a certificates or degrees and are not oriented toward the practical problems of managing a service oriented business.

Lack of adequate training capacity for maintaining technical capacity on outer islands. A continuing problem with outer island development of energy supplies is obtaining and keeping an adequate technical staff that can properly operate, maintain and repair the energy systems. Technical training is not readily available, especially for renewable energy technologies. The turnover of personnel is frequent since once a person is technically trained, moving to urban areas to a better job is made much easier.

5.1.4 Technical Barriers

As with most PICs, electrical and mechanical equipment is at risk due to the tropical, marine environment. Solar PV, wind, biofuels and possibly biogas are the technologies most likely to be used in Tonga and all are mature technologies. However special characteristics of the equipment are needed for long, trouble free life in the Tonga environment.

Difficult environment for electrical and mechanical equipment. The tropical marine environment of Tonga is hard on mechanical and electronic equipment, particularly on outer islands. Obtaining equipment suitable for installation in Tonga is difficult and expensive. Electronic control systems for wind machines and DC to AC converters for grid connected solar PV are particularly vulnerable and must be designed specifically with the salt laden air, high ambient temperature and moist conditions in mind,

Lack of long term experience with hybrid and wind systems in the Pacific. Although there is a wealth of experience with solar home systems in Tonga and the Pacific in general, integrating solar energy or wind energy into an existing grid has no long term, successful experience in the Pacific that is consistent with Tonga's requirements. Although both technologies have long been used in industrialised countries of the world, most of the experience is on a scale that is not directly transferable to Tonga. While there has been practical experience in Vanuatu with biofuels, that has been transport related where Tonga's need is for power generation. Though there are similarities there are also differences and the experience is useful but cannot be directly transferred. Demonstration projects, pilot projects and technology transfer programmes are needed to gain experience with hybrid technologies and biofuel preparation for power generation.

5.1.5 Physical Barriers

Rural population is dispersed over many islands separated by long distances. Most of the renewable energy activity to date has been on outer islands. The long distances between island groups and the large number of small islands make servicing the energy systems of the rural islands expensive and time consuming.

5.1.6 Market Barriers

Accessibility to rural sites. The cost of access to rural islands is high making maintenance, spare parts provision and project support difficult and expensive. To offset this problem, very high quality components need to be used to minimise the need for parts replacement or maintenance visits. This increases the installation cost substantially.

Prior project failures. The poor performance of many renewable energy projects, particularly on Vava'u, has created scepticism among both local governments and households in those project areas that makes marketing of new systems difficult.

Renewable energy business is perceived as being high risk and low profit. Over the years several businesses have attempted to provide renewable energy components and services but none have survived for the long term except for one solar water heater manufacturer.

5.1.7 Informational and Public Awareness Barriers

Lack of information about renewable energy and energy efficiency at all levels. Although there have been outer island electrification projects using PV, in general there needs to be more information available to decision makers, the general public and businesses regarding the advantages, disadvantages and costs of renewable energy and energy efficiency technologies other than for solar home systems. In particular, biofuel is the only renewable energy technology available in Tonga that is likely to replace more than a few percent of fossil fuel imports. Decision makers, farmers and the general public need to clearly understand what biofuel is, how it compares with diesel fuel and what its disadvantages are.

6 Implications of Large Scale Renewable Energy Use

6.1 Potential for GHG reduction

The large scale development of biofuel as a diesel replacement has the greatest potential for GHG reduction. In theory, it would be possible to develop the coconut production and solar/wind grid supplementation to the point where about 15Ml of annual ADO imports could be eliminated (about 10Ml/year from biofuels and 5Ml/year from solar+wind). That would reduce GHG in 2010 by around 26%. Some expansion of coconut plantations may be possible and the replacement of senile trees with species that have a higher oil productivity may also allow increased oil production. Since all coconut oil output can be used for electricity generation, no impact on transport energy is expected.

6.2 Biofuel

Since most agricultural production already takes place under a coconut tree canopy, large-scale biofuel production would not compete with agriculture for land use though it would limit the further development of other tree crops. The primary problem that would be faced with large scale development of biofuels would be variability of supply with weather, particularly droughts, and the problem of maintaining the supply at maximum production without a dramatic increase in the market price for copra.

The rehabilitation of the coconut resource will require the replacement of a large number of senile trees. Prompt removal of the cut trees is vital to the environment and will have to be considered in developing plans for large scale biofuel implementation.

From a social perspective, biofuel is one of the few energy technologies that provide major benefits to both urban and rural sectors. The urban sector benefits from increased reliability of fuel supply, more stable fuel prices and lowered import costs while the rural sector benefits economically from the sale of the coconut products. This would be particularly beneficial to the outer island economies.

6.3 Biomass

To maintain a high production level of coconuts, replacement of the large number of senile trees will be necessary. With proper planning, it should be possible to rotate the trees on a cycle equal to their productive life and thereby maintain a relatively constant rate of biomass production for household energy, grid power production and increase production in the coconut wood product industry. If this proves practical, it would eliminate the primary environmental problem associated with large scale biofuel production and further benefit rural economies. Increasing the coconut wood product industry has the further advantage of providing a relatively high value export product.

The development of hardwood and pine plantations holds the potential for future biomass use for energy through use of the waste from the milling process. The use of this waste for energy both benefits Tonga environmentally by reducing the build-up of mill wastes and by offsetting fossil fuels.

Social benefits/problems relating to biomass use appear to be minimal other than the obvious economic benefits to rural areas and to Tonga in general. For the period 2003-2013, biomass is unlikely to have much more than its traditional uses of cooking and crop drying and is not forecast to reduce GHG emissions.

6.4 Solar Energy

Photovoltaics has limited potential in Tonga beyond the rural electrification that has already

been installed. As a grid supplement without energy storage, it is unlikely that solar will be able to provide more than 5% of the energy requirement on Tongatapu even if solar panel prices are reduced dramatically since the limit is technical not financial. The primary value of solar PV for the next 10 years is expected to be for the expansion of installed SHS capacity in step with the developing electricity demands of outer island households.

Figure 6-1 - Corroded BP Solar Panels from 1985 Ha'apai projects

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Increased energy services to outer island households can provide social benefits though only of an incremental nature once basic services have been provided. Rural productivity is not likely to be affected in a major way by SHS though improved communications, improved education and improved health services can be powered by PV.

Environmental problems associated with PV are limited to disposal of worn out lead-acid batteries. Since recycling of spent batteries is commonly provided by battery manufacturers, this should not be a problem for Tonga.

Solar thermal has no opportunity for electricity generation in Tonga but for any application requiring hot water up to about 80ºC, solar water heating can be cost effective and should be used. Its use can help slow the growth of electricity and LPG demand though it would have little effect on GHG reduction.

6.5 Wind

Large scale wind production and large scale biofuel production will be competing for land since wind power systems function poorly in areas dominated by tall coconut trees. Off shore wind power and the location of wind systems in low productivity swampy land may make it practical for Tongatapu though resource surveys need to confirm the availability of a satisfactory wind regime for those areas well away from coconut trees.

It is probable that wind power would be primarily used on outer islands where the small power requirements would allow acceptably sized wind farms for supplementation of existing grid power systems. The PREFACE trial of wind supplementation of a small diesel grid in Mangaia, Cook Islands, should provide useful experience transferable to Tonga. Given the relatively mediocre wind regime and the limited technical capacity available, it is unlikely that wind power will penetrate more than 15% into the electricity supply in the foreseeable future even though it is theoretically possible to extend the penetration to a much greater level under favourable conditions by using complex load control systems. Unfortunately such systems are not yet suitable for outer island use. This level of input will have only modest effect on GHG production but may reduce the need for diesel fuel to the point where local coconut production can supply sufficient biofuel to eliminate the need for diesel fuel.

7 Capacity Development Opportunities

7.1 Petroleum

Technical capacity development does not appear to be necessary since the oil companies are providing training to local managers and technical personnel.

7.2 Electricity

Capacity needs at Shoreline could not be estimated since the team was unable to access upper management for determination of their needs.

7.3 Renewables

The continuing expansion of solar photovoltaic electrification to the Niuas and the rehabilitation of the Vava'u SHSs will require additional personnel to manage the operation and to maintain the systems. Existing staff capacity is adequate in the Ha'apai group though continuing availability of training in project management and PV maintenance will be needed as staff turnover occurs.

7.4 Regulation

There is little capacity in Tonga for the establishment of technical standards and personnel certification for renewable energy. Both need to be developed relative to biofuel production and grid connected biomass, solar or wind power, if renewable energy is to become a reliable large scale energy source for Tonga. There does not appear to be a need for regulatory capacity building for outer island solar electrification since systems are not connected to a public grid and operate at a voltage too low to be an electrical safety hazard.

7.5 EPU and Planning

The upgrading of existing outer island SHS projects and their expansion would benefit from further development of capacity at both Planning and at EPU. Project development training could improve the fundability of future projects and technical capacity development for component specification and system design will be needed. This level of training should be available continuously to develop new staff as personnel change.

As site manager of the Ha'apai PV rural electrification programme and proposed site managers of future Vava'u and Niua programmes, the EPU will need access to continuing training in management and PV technology to maintain and upgrade staff capacity.

7.6 Private Sector

Several electrical contractors have participated in solar development on the outer islands and have shown a strong interest in developing further capacity for renewable energy system installation and maintenance. If the private sector is to ultimately take over the maintenance of outer island solar systems as energy service companies, technical and management training will be required. Training developed for the EPU in management and PV technology should be made available to the private sector.

7.7 Reducing Barriers Through Capacity Development

7.7.1 Reducing Fiscal and Financial Barriers

Fiscal policy development. Taxes, import duties and government purchasing policies have an impact on the cost of renewable energy relative to fossil fuels. Government officials responsible for these policies should be made aware of the effect these policies have on the development of renewable energy and energy efficiency measures. This can be done through a regional capacity building programme that provides informational materials and training for the appropriate officials. As this is a need for more than three PICs, it could be implemented under a regional project.

7.7.2 Reducing Legislative, Regulatory and Policy Barriers

Energy policy development. Over the past decade there have been several attempts to assist PICs to develop energy policies. A problem that has been common to those attempts is that the policy concepts have been developed externally and though those policies have sometimes been formally accepted by countries, their application has been minimal because the governments that must implement the policies had little real input to the policy making process. For written policy to be effective it must be implemented and for implementation to take place, implementers must have a stake in the success of the policy. The PIEPSAP project is addressing this issue starting in late 2004 and is expected to thoroughly involve the government in the policy development process so that the resulting policy will be one that is acceptable by the present government and can be expected to continue to be acceptable by future governments.

7.7.3 Reducing Institutional Barriers

Training of Energy Unit Personnel. Typically, energy office personnel move to another position after a few years. That means that training for energy officers is needed continuously to support capacity development so they can properly fulfill the technical and administrative tasks set before them. There is no training available in Tonga for the technical component of their work and the training needs to be made available without more than a few months delay after a new person takes an energy position. This implies that the training will need to be external and regional in nature since a training programme cannot be sustained on the basis of the needs of Tonga alone. The regional training concept being developed by ESCAP in late 2004 should address this issue.

Development of a biofuel production institution. If biofuel is to be a cost effective replacement for diesel fuel, an institutional structure will have to be developed that will (i) enable a large number of small coconut growers to pool their resources; (ii) ensure that each grower receives proper compensation for their efforts; (iii) minimizes the labour component of the biofuel production process; (iv) manages small biofuel facilities on each island having diesel power to avoid the problems and expense of shipping; and (c) ensure that the fuel supplied is of consistent quality and available as needed. This institution needs to benefit from the experience of actual biofuel suppliers and funding will be needed to bring together persons from other countries with commercial biofuel experience (e.g. Vanuatu, Philippines) to work with Tonga to design an institutional structure that specifically fits its needs. Since this problem is common to several countries, a regional conference plus a follow up outreach programme may be appropriate.

7.7.4 Reducing Technical Barriers

Capacity development for the design, installation and maintenance of renewable energy systems. Although there is experience with the design of solar home systems, hybrid systems are unfamiliar and considerably more complex. EPU and Shoreline technical staff will need to understand the design parameters and characteristics of the various types of hybrid systems possible for Tonga and at least be able to judge whether or not externally developed designs are appropriate. Also, training in the operation and maintenance of the systems will have to be continued within the EPU so that field technicians can be trained and their skills maintained. A training of trainers programme is needed to bring EPU trainers up to date and assist them in further developing the training programme for field technicians. Since several countries will require the design training and also will need to develop local training capacity, a regional programme for that purpose appears appropriate.

Development of standards and certifications for RETs. Although there are international standards already developed and being developed for RETs, they are generic and must be fitted to the local situation. Because equipment must be manufactured to survive under the harsh conditions of the outer islands of Tonga, those requirements need to be embodied at least as purchasing guidelines or, better, as actual standards for the purchasing of RET equipment. Unlike the training programme, a standards and certification development programme needs to be done only at several year intervals. As this is a multi-country issue a regional programme is appropriate.

7.7.5 Reducing Market Barriers

Development of local training capacity for energy service business management. Providing energy services, both renewable energy and energy efficiency, is new to Tonga and training in the specific business structures and methods is needed to help new businesses understand the business and begin operations with confidence and achieve early profitability. Most of the larger PICs will have businesses that can benefit from this type of training programme making it reasonable to include it in a regional capacity building programme.

7.7.6 Reducing Informational and Public Awareness Barriers

Decision maker information delivery. Through in country programmes, sessions at international assemblies of decision makers, PPA annual meetings, SOPAC meetings, Forum meetings and other venues, information needs to be provided decision makers regarding the appropriate renewable energy technologies for Tonga and problem areas that need to be avoided. EPU staff and Cabinet advisory staff should receive specific information packages and, where possible, actual training on the manner that RETs can aid national development and on the best approaches to energy strategies using energy efficiency and renewable energy methods. This is a need common to most of the PICs and can be developed into a regional programme.

Public information programmes. Although solar energy for home electrification is well known in Tonga, there is little public knowledge about biofuel, biogas, wind power or hybrid systems. As this is a need for most of the PICs, the necessary public information materials can be developed regionally and delivered to countries along with short term training and advice in their proper delivery.

8 Implementation of Capacity Development Needs and Co-financing Opportunities

At this time, the only renewable energy project that has been approved for Tonga is the solar rural electrification project for the Niuas. Unfortunately, it is likely to be completed before co-funding can be arranged.

Plans are in place to rehabilitate and upgrade the Vava'u SHS project and bring its institutional structure into line with that now present in Ha'apai and the Niuas. Should this project be approved, there would be an opportunity for co-financing training of installation, maintenance and administrative personnel and other activities associated with the project such as public information programmes and business development programmes.

All projects for the development of renewable energy in Tonga should include development of comprehensive training programmes relating to the installed technology with a particular focus on the management and maintenance of that technology. This training could be developed by the implementing organisation or separately with co-funding by another agency but coordinated with the hardware implementation.

9 ANNEXES

Annex1 – Persons Interviewed by the local and international consultants for PIREP

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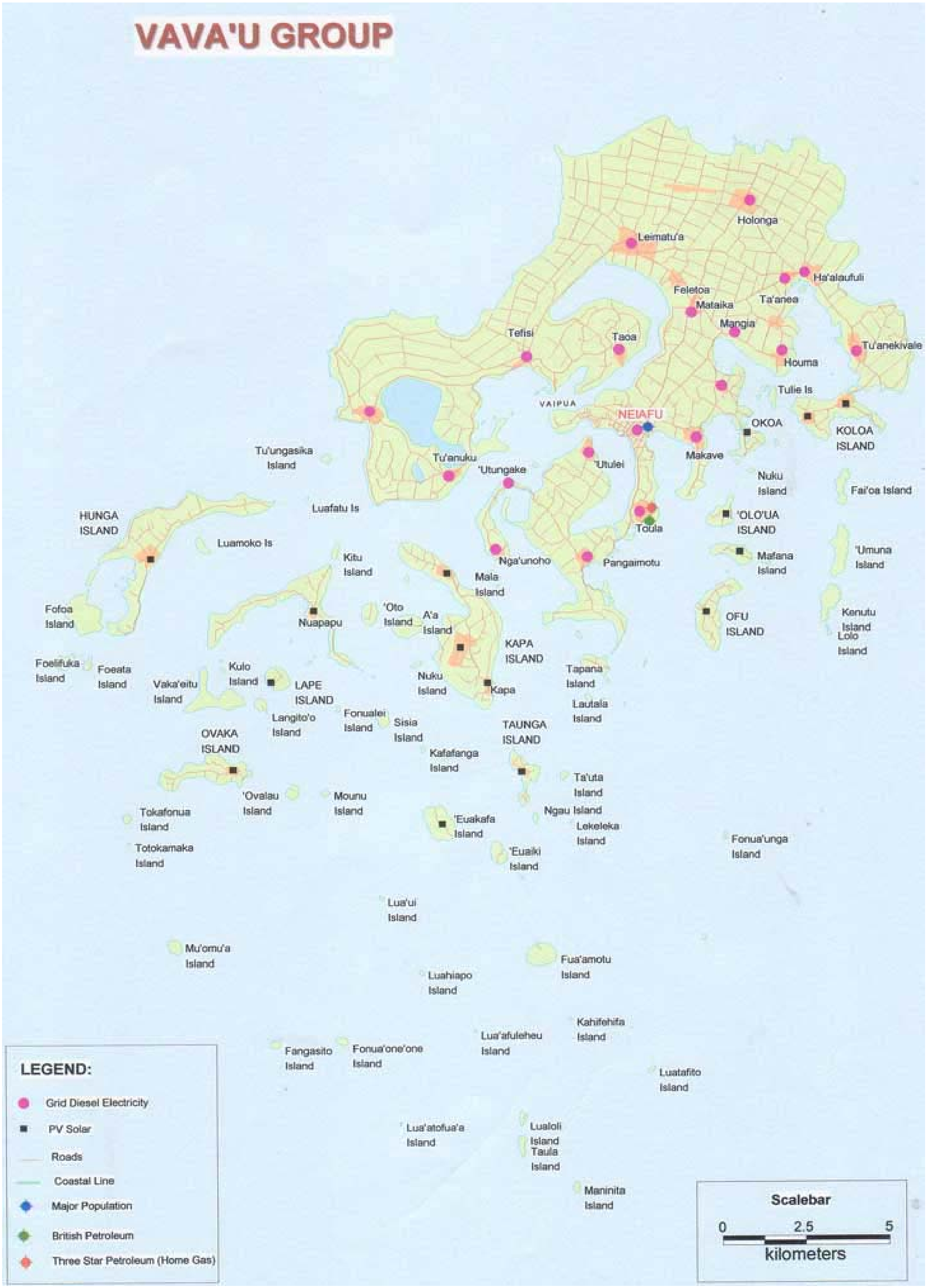
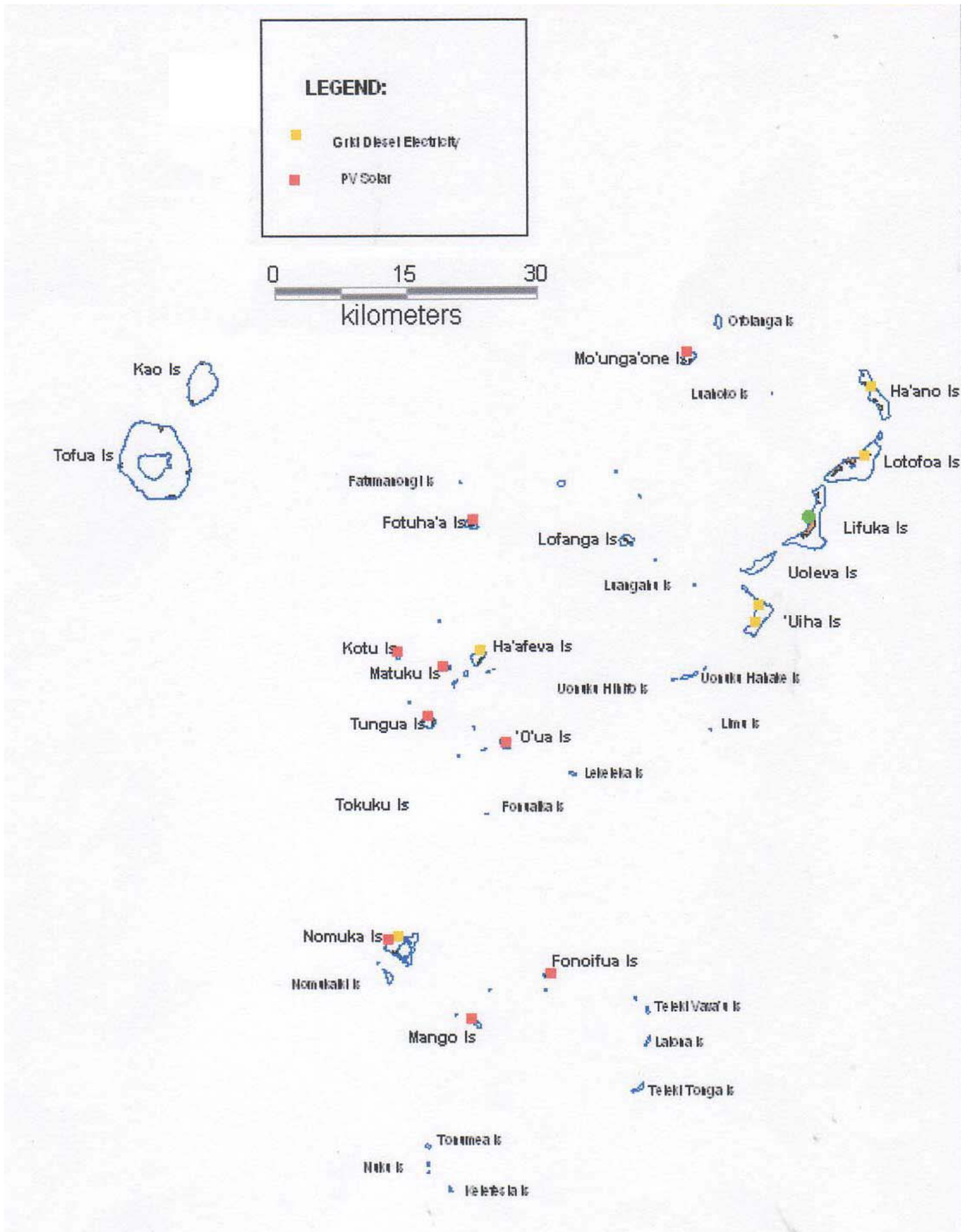
Annex 3 – Vava'u Electrification Map



Source: EPU (2004)

Annex 4 – Ha'apai Electrification Map



Source: EPU (2004)