A Technical, Institutional, Environment and Economic Impacts Assessment of the Mango and Mo'unga'one Solar Photovoltaic Rehabilitation Project

A capacity building exercise by the PIGGAREP in Tonga involving principally

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ACRONYMS

Ah	Ampere hour
BAU	Business as Usual
BCR	Benefit Cost Ratio
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DCF	Discounted Cash Flow
EESLI	IUCN's Energy, Ecosystems and Sustainable Development Livelihood Initiatives
EIA	Environment Impact Assessment
ENPV	Economic Net Present Value
EPU	Energy Planning Unit of the Ministry of Lands, Survey, Natural Resources and Environment
ESTI	European Solar Testing Institutions
EU	European Union
FNPV	Financial Net Present Value
GHG	Greenhouse Gas
GoT	Government of Tonga
HSEC	Ha'apai Solar Electricity Committee
HSEI	Ha'apai Solar Electricity Incorporated
IRR	Internal Rate of Return
ISEC	Island Solar Electrification Committee
IUCN	International Union for the Conservation of Nature
NREP	National Renewable Energy Policy
O & M	Operation and Maintenance
PICs	Pacific Islands Countries
PIGGAREP	Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project
POPs	Persistent Organic Pollutants
PREFACE	Pacific Renewable Energy France-Australia Common Endeavour
PV	Photovoltaic
RE	Renewable Energy
REEEP	Renewable Energy and Energy Efficiency Partnership
RET	Renewable Energy Technology
SEPPSIS	Sustainable Energy Programme for Pacific Small Island States
SHS	Solar Home Systems
TSECS	Tuvalu Solar Electricity Cooperative Society
TOISEP	Tonga Outer Islands Solar Electrification Programme
Wp	Peak Watt

EXECUTIVE SUMMARY

Tonga is among the fourteen (14) Pacific Island Countries (PICs) that are benefiting from a cooperation programme funded by the Government of Italy to address one of the key global challenges of the next decades, namely adaptation to climate change, protection from the vulnerability to extreme climate variability and mitigation of harmful emissions generated by energy utilisation.

Under the Communiqué signed by the Italian government and the PICs, a Sustainable Energy Programme for Pacific Small Island States (SEPPSIS) will be in five (5) sub-programmes:

i) Development of climate change adaptation measures
ii) Assessment of energy requirements and strengthening of energy policies and action plans
iii) Rural electrification
iv) Development of biofuels
v) Development of RE sources

The PICs were provided with funds to prepare project proposals under their identified priority areas from among the five (5) sub-programmes. A Joint Committee of representatives from the PICs and the Government of Italy is responsible for approving proposals to be funded under the programme.

At meetings of the Joint Committee, it was agreed that the following five countries would implement their projects through and in conjunction with International Union for the Conservation of Nature (IUCN): Palau, Samoa, Tonga, Tuvalu and Vanuatu. The Suva-based IUCN office for Oceania is therefore responsible for providing (i) financial assistance, (ii) project supervision and engineering as required, (iii) training, and (iv) technical assistance for environmental assessments, policy development and institutional capacity building. IUCN will also assist in reshaping the national implementation plans in collaboration with the representatives of the PICs, and ready them for implementation. Furthermore, PICs will be expected to negotiate and enter into a project agreement with the IUCN Oceania which will spell out the obligations of both parties during implementation.

Managing the Ecosystem and Livelihood Implications of Energy Policies in the Pacific Island States is the Pacific component of the IUCN's Energy, Ecosystems and Sustainable Development Livelihood Initiatives (EESLI). The EESLI forms part of the Sustainable Energy Programme for the Pacific Small Island States (SEPPSIS) funded by the Italian and Austrian governments. The IUCN Oceania regional office based in Suva, Fiji, is the Executing Agency of the 3-year Pacific EESLI programme. The programme's activities are supported by a grant of 3 million euros from Italy and an additional 1 million euro from the government of Austria.

The aim of the Pacific EESLI programme is to accelerate the transition to energy systems that are ecologically efficient, sustainable, and socially equitable, by:

i) supporting beneficiary countries in the development and implementation of environmentally sound, sustainable energy policies;
ii) implementing a number of RE pilot projects focusing on ecosystem conservation and livelihood enhancement.

Essential elements of the approach to achieve these aims include (i) feasibility studies and implementation of RE pilot projects in selected Pacific countries; (ii) provision of management tools for the projects and assistance in the development of sustainable energy policy in the selected countries; and (iii) networking with small island states in the Pacific and globally to share lessons learned, skills, and technology.

Tonga submitted few proposals to be considered for funding under the SEPPSIS and the Joint Committee had approved that the Rehabilitation of the Mango and Mo'unga'one photovoltaic (PV) project be funded for a budget of US$230,000.

Tonga is also among the eleven (11) participating PICs in the Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project (PIGGAREP). The PIGGAREP is a regional climate change mitigation project funded by the Global Environment Facility and various co-financing partners.

This study was funded by the PIGGAREP to complement IUCN's effort. It involved conducting a meeting of the Management Committee of the Ha'apai Solar Electricity Incorporated (HSEI), consultation meetings with the target communities, a technical assessment of the existing installations and the conduct of a household survey. The study was also a capacity building exercise in which locals, who have not been directly involved in a study of this kind, were engaged and guided by the EESLI and PIGGAREP in the conduct of this study.

Technical Design

Preliminary assessments of the electricity supply options included biofuel for power generation, diesel generation, wind power, hybrid systems and a rehabilitation of the existing stand alone solar home systems.

The study found that rehabilitating the existing systems to be the most technically, financially, socially and environmentally viable option.

Varying results were found on the status of the existing PV equipments on both islands and this is mostly due to Mango being an older installation (1988) as compared to Mo'unga'one (1994). The controllers and batteries on both islands are beyond repair and need to be replaced. Forty percent (40%) of the panels at Mango are still in good working order while all of the panels at Mo'unga'one are no longer functioning. The rehabilitation should therefore provide each participating household with at least a new solar panel, a battery and a controller.

The technical design of the rehabilitation systems should align as closely as possible with the existing solar home systems under the Pacific Renewable Energy France-Australia Common Endeavour (PREFACE)[1] project to ensure compatibility of parts and coherence in the management system.

Institutional and Management Structure

The rehabilitation project will benefit from aligning its institutional and management structure to that of the Ha'apai Solar Electricity Incorporated (HSEI). This is in terms of

[1] The PREFACE electrified six (6) islands in the Ha'apai Group with solar home systems and established the HSEI.

Mango and Mo'unga'one becoming members of the HSEI and endorsing the management guideline of the HSEI. The management guideline spells out the composition, functions and obligations of the members, the ownership of the PV systems, the installation and monthly fees, the replacement of system parts, the disconnection and reconnection of electricity services and management guidance to the finances of the HSEI. However, the inclusion of the two target islands in the HSEI should be taken as an opportunity to reverse the declining technical and financial performance of the HSEI. There is therefore an urgent need that the installation of the rehabilitation project should go hand-in-hand with a strengthening of the capacity of the HSEI to effectively and sustainably manage the PV installations in its member communities. There is therefore a need for more consultations with the HSEI communities to enhance their understanding of the management guidelines governing the operations of the HSEI. There should be some training at all levels targeting the island technicians and the HSEI office manager trainee. The technicians and the HSEI staff should be given the appropriate technical tools and office equipment to be able to perform their functions to the satisfaction of the communities.

The rehabilitation project, like most other rural electrification projects in the region, will require continuing support by the government. It is therefore important that the reports of the HSEI and its meetings be submitted to the National Energy Committee and subsequently, as appropriate, to Cabinet.

Economic

Households, public and religious institutions in the two target communities can afford and are willing to pay the T$200 installation fee and the T$13 monthly fee that are presently applied in the HSEI.

The Government of Italy's approved funding of US$230,000 for this project is barely sufficient to cover all that is required to ensure the success and sustainability of this project. There is therefore a need for co-financing support from other sources like the PIGGAREP, the Renewable Energy and Energy Efficiency Partnership (REEEP) and the Government of Tonga (GoT).

The economic analysis demonstrated that the benefits of the rehabilitation outweigh the costs of the project and the other electrification options like the business-as-usual, the use of wind power, diesel generation and hybrid systems.

The rehabilitation of the Mango and Mo'unga'one PV systems will improve the livelihoods and the quality of the environment on both islands. As weaving is the major source of income for women, the provision of better quality lights will support this plus their other household chores of looking after the family, etc. On the other hand, the improved lighting will help the men with the preparation of their fishing gear and catches at night. The schools and churches on both islands, together with any community or family gatherings at night, will benefit from the project. The reliance on kerosene for lighting in the islands will be significantly reduced, thus freeing up family incomes for other priority family obligations.

The provision of solar electricity in the islands would facilitate the participation of the islands in the Secretariat of the Pacific Community's One Laptop per Child Initiative.

Maintaining traditional cultural ceremonies such as weddings and funerals is an important element of island life. The provision of portable PV systems on hire under this project would facilitate the maintenance of these cultural values.

Environmental Impacts

The risks that the rehabilitation poses to the environment of the two islands are low and manageable. The project will provide a net benefit to the natural environment by reducing greenhouse gas emissions from the use of kerosene for lighting. While there are no foreseen detrimental impacts on the environment, ensuring the collection of used batteries, controllers and lights and their proper disposal and recycling must be taken very seriously.

CHAPTER 1: INTRODUCTION

Tonga is overwhelmingly dependent on imported petroleum for its commercial energy needs. About 98% of the urban households in Tonga are electrified but only about 75% of rural households are. Overall, more than 80% of the population of Tonga has access to electricity. Providing a reliable, affordable and an environmentally sound source of electricity to the people of Tonga is a priority of the GoT.

The GoT endorsed a National Renewable Energy Policy (NREP) in 2006. Due to the rapid increases in petroleum prices during 2008, the GOT has also endorsed a national renewable energy (RE) target of 40-50% by 2010.

The RE target is being supported by the Tonga Renewable Energy Bill which was passed by Parliament in October 2008. The Bill provides for the formulation of regulations that will govern and standardize the operations of RE operators in the Kingdom. Specifically, the principal objects of this Act are:

i) To promote the development of the RE industry in Tonga by:
   - researching and developing opportunities of RE in the Kingdom;
   - encouraging the use of commercially sustainable renewable energy technology (RET) for both grid connected and stand alone power supply systems;
   - regulating the technical and safety standards for RETs;
   - regulating the licensing of persons involved in the design, research, installation and management of RE projects;
   - regulating RE operators;
   - regulating the feed-in tariffs for RE generated electricity;
   - support the engagement of the private sector in RE projects in the Kingdom.

ii) To establish an authority to deal with matters relating to RE.

iii) To empower such authority to regulate all matters relating to RE.

iv) To promote the implementation of commercially sustainable RE-based electrification services by encouraging economically efficient investment in the use of and infrastructure to provide electrification services.

v) To promote access by people resident in the remote areas of the Kingdom to RE services to the extent that it is reasonably and commercially practicable to provide such services.

Outer Islands Electrification Programme in Tonga

Tonga is among the island countries in the region with the most number of installed PV systems. Prior to the PREFACE intervention in 2002, there were 582 installations in the Tonga Outer Islands Solar Electrification Programme (TOISEP) as shown in **Table 1**.

The TOISEP has been in operation since 1987. It has evolved over the years and the management structure has been along the following lines:

i) A user agreement is signed between the Ministry of Lands, Survey and Natural Resources and each household, which wants to participate in the programme. This agreement covers, among other things, the ownership of the entire PV system by the Ministry and the right for the Ministry to remove them if they are abused and if the monthly fees are not paid;

ii) An installation fee is paid;
iii) A monthly rental fee is paid to cover the future maintenance of the installed systems;
iv) An Island Solar Electricity Committee is established in each electrified island to liaise between the community and the Ministry on matters such as the needs for spare parts and technical assistance, and
v) Island solar technicians are employed by the Committee and trained by the Ministry to look after the PV installations and to collect the monthly fees.

This structure has, to some extent, worked well over the years. However, with the TOISEP's monthly fee collection rate currently at below 50%, it is obvious that the programme cannot finance its own costs in the longer term.

The PREFACE project of 2002, which electrified with solar 169 households in six islands of the Ha'apai Group, introduced some significant changes to the ways of managing the TOISEP. These are discussed in details in Chapters 4, 5 and 6.

Mango and Mo'unga'one were electrified with solar photovoltaic under the European Union-funded Lomé II Pacific Regional Energy Programme with the installation of the Mango equipments in 1988 and later upgraded in 1991 while the installation of Mo'unga'one's was in 1994. This was the first solar PV projects in the Ha'apai group of Tonga and was installed at a time when there was very little experience with PV in the country. The projects did not work as planned but they provided valuable lessons for later PV projects in Tonga, like the PREFACE.

Under the IUCN's EESLI project, the participating PICs were required to submit proposals to be considered for funding by the Joint Committee. It is quite interesting to note that Tonga did not submit a project proposal in accordance with the template that was approved by the Joint Steering Committee. Instead, Tonga submitted a report of an appraisal of the Mango and Mo'unga'one PV for rehabilitation.

The appraisal was conducted in 2005 and it highlighted the poor technical and financial status of the PV projects in the two islands. Interestingly, at this time the HSEI with its six islands and 169 installations was only three years old. At that time, the management, institutional and financial structures of the HSEI were working very well with a reported monthly fee collection rate of 99%. The appraisal therefore recommended a wholesale adoption of the HSEI's management, institutional, technical and financial structures for the rehabilitation.

The government of Italy has now approved to fund, through the IUCN office for Oceania, the rehabilitation of the solar photovoltaic systems on the islands of Mango and Mo'unga'one in the Ha'apai Group of Tonga. This study is therefore part of the preparatory works for the rehabilitation.

The objective of the study was therefore to assess technical, institutional environment and economic impacts of the proposed rehabilitation project. The Terms of Reference is provided as **Annex 1**.

In the absence of a proper proposal for this rehabilitation project, the study team has constructed a project log frame, which is attached as **Annex 2.**

Table 1 : The Existing TOISEP Project Sites

Island Group	Island	Year of Installation	Source of Funds	System Type	Qty	Module Wp	No. of Panels	Total Wp
Tongatapu	‘Atataa Phase 1	1997	UNESCO	SHS	23	35	2	1610
	‘Atataa Phase 2	1998	Japan	SHS	18	50	2	1800
	‘Eueiki	1999	AusAID	SHS	26	50	2	2600
Ha’apai	Mango	1988	EU	SHS	5	35	2	350
	Mango Upgrade	1991	EU	SHS	21	48	2	2016
	Mo’unga’one	1994	EU	SHS	49	55	2	5390
	Fonoifua	2002	FREFACE	SHS	24	80	2	3840
	‘O’ua	2002	FREFACE	SHS	38	80	2	6080
	Tungua	2002	FREFACE	SHS	33	80	2	5280
	Matuku	2002	FREFACE	SHS	22	80	2	3520
	Kotu	2002	FREFACE	SHS	34	80	2	5440
	Fotuha’a	2002	FREFACE	SHS	18	80	2	2880
Vava’u	Falevai	1995	EU	SHS	42	50	2	4200
	Hunga	1995	EU	SHS	47	50	2	4700
	Kapa	1995	EU	SHS	31	50	2	3100
	Lape	1995	EU	SHS	7	50	2	700
	Matamaka	1995	EU	SHS	42	50	2	4200
	Nuapapu	1995	EU	SHS	43	50	2	4300
	Otea	1995	EU	SHS	35	50	2	3500
	Ofu	1995	EU	SHS	43	50	2	4300
	Olo’ua	1995	EU	SHS	21	50	2	2100
	Ovaka	1995	EU	SHS	26	50	2	2600
	Taunga	1987	EU	SHS	32	35	2	2240
	Taunga Upgrade	1991	EU	SHS	4	35	2	280
Niuatoputapu	Tafahi	1999	NZAID	SHS	32	48	2	3072
Niuafo’ou	Niuafo’ou Phase 1	1993	France	SHS	35	55	2	3850
	Niuafo’ou Upgrade	2006	NZAID	SHS	169	80	2	27040
TOTAL					**920**			**110988**

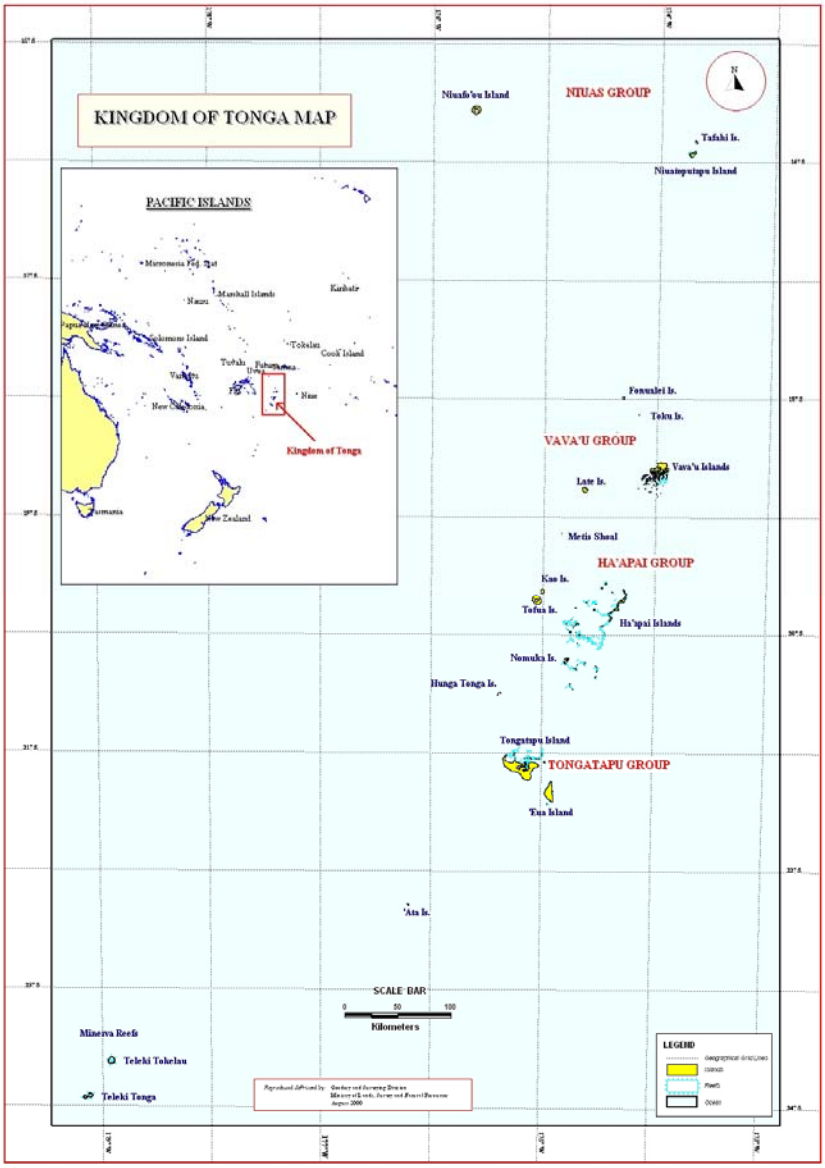
Source : Energy Planning Unit, September 2008

CHAPTER 2: THE TARGET ISLANDS - MANGO AND MO'UNGA'ONE

Location

The Ha'apai Group, where Mango and Mo'unga'one, are located, lies 200 km to the north of Tongatapu (the main island) and consists of 2 bigger islands (Lifuka and Foa) which are supplied by the Tonga Power grid. The rest of the Group is made up of almost 30 scattered islands, six of which are in the HSEI while the 4 larger ones of 'Uiha, Ha'afeva, Ha'ano and Nomuka are powered with diesel generators. A map of the Ha'apai Group and the layout of Mango and Mo'unga'one can be seen in **Annex 3**.

Fig 1: Map of Tonga



Pangai, in the island of Lifuka, is the administration centre of the entire Ha'apai Group. The Ha'apai Group is made up of 6 districts. Mango is in the Mu'omu'a district whose administration centre is Nomuka. Five of the HSEI islands are in the Lulunga district whose

administrative centre is Ha'afeva. Mo'unga'one is in the Ha'ano district and whose administration centre is Pangai the main island. The Ha'apai Group is governed by a Governor, who is the chairperson of the HSEI. Under the governor are district officers and there is a district officer for each of Lulunga and Mu'omu'a. Under the district officers are town officers in each of the islands. Both the district and the town officers liaise between their respective communities and the government through the governor's office. Village meetings or "*fono"* are usually held on a monthly basis where government directives are channeled down to the people and where people's concerns and needs are channeled up to government.

Accessibility

The weekly ferries from Nuku'alofa to Pangai usually make brief stops at Nomuka and Ha'afeva and the outlying islands come on open dinghy to collect / send cargoes and passengers. The islands have a population of about 324 (Mango = 140, Mo'unga'one = 184) with a total of 60 households (Mango=23; Mo'unga'one=37).

Flights are between Nuku'alofa and to Lifuka in the Ha'apai Group and onwards to Vava'u and return. Two airlines have been serving these domestic routes and the licence of one was recently suspended. Since Mango is somewhere in between Nuku'alofa and Lifuka, it is not normal for people in Mango to fly to Lifuka and then take a 3-4 hours boat from there to Mango. People normally take the ferries that come through Nomuka. On the other hand, Mo'unga'one is only about 1.5 hours by boat from Lifuka so people usually take the 45 minutes flight from Nuku'alofa to Lifuka and then the outboard motor boat trip to Mo'unga'one.

Infrastructures and Social Services

Both islands don't have proper berthing for boats.

Both have primary schools, but the children have to leave for Lifuka or Tongatapu for secondary schools and higher education.

Each island has one community telephone. The households at Mo'unga'one, being closer to Pangai, now have landline phones, which are powered from their solar batteries.

None of the two target islands has a medical clinic with a doctor or nurse and will have to go to their respective administration centres for such services.

Mango has only one church, Free Wesleyan Church, while Mo'unga'one being the bigger island has 3 churches.

Trade and Economic activities

There are no shops in Mango but there are two retail shops at Mo'unga'one. The people of Mango do their shopping from Nomuka and sometimes from Nuku'alofa when they need to buy in bulk, including kerosene and gasoline for outboard motors. Mo'unga'one, on the other hand, have to travel to Lifuka for their shopping.

The most important commodity in the two islands is a boat with an outboard motor. The islanders need the boat for transporting goods and people and also for their fishing activities. Diving for sea cucumbers is one of the popular fishing activities and profitable,

bringing earnings as much as T$22 or US$11 for a good sized cucumber. Gasoline for the islanders' boats is therefore their major energy costs.

Fishing is mostly by the men and their catches are sold to others in the islands with ice boxes who then send ice boxes and the fish via the weekly ferries to be sold in Nuku'alofa. Mango is better known than Mo'unga'one for selling dried octopus. Women do the fishing for octopus at low tides and are more engaged in handicraft making / weaving.

Remittances from family members in other parts of Tonga and overseas are a very common source of cash income in the target islands.

Physical Environment

The two islands have a limestone base formed from an uplifted coral formation. Mango's cultivated area is on the southern side of the island while that of Mo'unga'one is on the western side of the island – an area that is mostly rugged yet quite flat in the residential areas. Both islands have fertile soils partially derived from volcanic ash. Agriculture is known to be more varied and successful at Mo'unga'one than in Mango due mostly to salty and harsh environment. Climate is tropical with warm-humid (December – May) and cool (May – December) seasons. Winds are seasonal with tropical cyclones most likely December through March.

Fig 2: Sun-drying octopus at Kotu

The Social Environment

As in most small islands, it is typical for persons to be related through inter-marriages within the community. Both islands have traditional chiefs or talking chiefs who are the

centre of attention and the focus during ceremonial and community events. They are often consulted on matters relating to the affairs of their communities. Administratively, it is the town officers / district officers who lead and coordinate the communities' participation in government-related matters. Churches do play a key role in the social affairs of the communities, with church leaders always consulted and actively participating in development projects in their communities.

Energy Use

The households' energy consumption in the two islands is relatively low. The primary use of biomass is for the traditional earth oven "*umu*" open fire for cooking and drying of fish products.

Kerosene lamps are the primary source of lighting in the two islands, with all the households having at least one kerosene wick and torch and some having pressure lamps.

Torch and radios are the most common electrical appliances. Radio is a primary form of entertainment on the islands, and is commonly switched on as long as 15 hours a day. Most of the dry cells used are "D" size. The dry cells are installed in the torch when new for night fishing, and people usually remove them to power radios when their charges are lower. An average of six dry cells are purchased weekly (around T$22 per month).

Most of the energy usage in the islands is gasoline for their outboard motors. In the remote islands of Mango and Mo'unga'one, gasoline consumption is mainly for fishing and inter-islands transportation. The outcomes of the household survey indicated an average consumption volume of gasoline per household in both Mango and Mo'unga'one of approximately 5-6 litres per day. The stated rate of gasoline consumption then provides an average monthly consumption of 9000 litres of gasoline for both islands.

CHAPTER 3: METHODOLOGY FOR THE STUDY

As part of strengthening the local capacity in Tonga to perform feasibility studies, the study team was comprised of local civil servants and a local consultant and guided by the project managers of EESLI and PIGGAREP.

The methodology adopted for the study was the following:

i) Consultative meetings of the study team

The members of the study team, including the EESLI and PIGGAREP project managers, met at Nuku'alofa prior to the field mission. The meetings were to confirm the administrative arrangements for the study and as well as confirming the approach to be taken for the field mission.

ii) Meeting of the Ha'apai HSEI

A meeting of the HSEI was convened on the island of Kotu and was attended by the town officers and the islands solar technicians from the six islands which are members of the HSEI as well as representatives from both Mango and Mo'unga'one. This meeting was aimed at capturing the islanders' view on the effectiveness of the HSEI's current institutional and management structures as well as the financial viability of the HSEI. It provided an opportunity for the representatives from Mango and Mo'unga'one to be exposed to the structures of the HSEI and to determine whether their communities would accept those if their rehabilitated project were to come under the HSEI. The Summary Record of this meeting is attached as **Annex 4**.

iii) Meetings with the communities of Mango and Mo'unga'one

Meetings with the entire communities of Mango and Mo'unga'one, including their representatives to the HSEI meeting, were conducted to go through, in details, the current management, institutional and financial structures of the HSEI. The outcomes of the meetings and discussions are discussed in Chapters 4, 5 and 6.

iv) Physical inspection of the existing installations

The study team carried out a physical inspection of the existing PV installations so as to assess the current physical and technical status of the system components. The inspection was also to assess the effectiveness of the institutional set up for the technical as well as the financial aspects of the HSEI. This include the assessment of the effectiveness of the HSEI technician that is based at the HSEI office at Pangai, how effective are counterpart resident technicians in the islands and also how well families have cared for their respective solar installations.

v) Households Survey

The household survey was designed to extract institutional, social, economic, technical and environmental information from the households. A selected sample of households was interviewed and the interviewee was restricted to household parents and adults only.

Questionnaires were prepared and used to gather information on the islanders' demand for electricity, their current energy expenses and how much are they willing to pay for their solar electricity, etc. Questions were also raised with regards to their views on the institutional, management and financial structure for the HSEI.

vi) Assessment of the effectiveness of the HSEI office at Pangai.

The record-keeping and daily operation of the HSEI and how it contributes to the sustainability or otherwise of the HSEI were assessed. The outcomes of this assessment are discussed in Chapters 4, 5 and 6.

CHAPTER 4: ASSESSMENT OF THE TECHNICAL FEATURES OF THE PROJECT

In considering the technical design and related aspects of the Mango and Mo'unga'one rehabilitation project, it is important to draw some lessons based on the current technical status of the existing PV installations at the two target islands as well as the existing installations at Kotu and experiences from other installations in the TOISEP.

Assessment of the technical status of the existing PV installations
The panel and battery used in the Mango installations comprised of 1 roof-mounted 50Wp Photowatt panel and an Oldham 6MLTS 100 batteries. Mo'unga'one on the other hand consisted of 2 pole-mounted Pro Charger TM-S panels and Oldham 6MLTS 100 batteries.

The assessment revealed that some of the systems were still in operation on both islands through the own individual effort of the respective households. Interestingly, some of the Oldham 6MTS 100AH deep cycle tubular plate batteries installed in 1991 at Mango were still working. The same battery brand were installed at Mo'unga'one in 1994 and some are still in operation.

Newer version of Oldham deep cycle tubular plate battery, 12 GLS 130AH, was installed in the PREFACE project at Ha'apai (2002) as well as in Niuafo'ou Solar Electricity project in 2006.

Households with failed batteries at Mango had already switched back to kerosene lamps for lighting. Few households afforded to buy new car battery for replacement while others continue to live with their solar panels and lights unused.

The outcomes of assessment showed that 100% of the surveyed households in Kotu have experienced no major problems with their batteries and panels, and 70% of the controllers (6 years old now) were in good condition while 30% should be replaced. In Mango and Mo'unga'one, most batteries and controllers should be replaced. This is however constrained by the availability of funds, i.e, the funds collected so far from the monthly fees are not sufficient to cover the costs of replacing parts. In Kotu, only 53.3% of the lights were functioning while 46.7% should be replaced. In Mango, a former island technician's household PV system is still fully functional as he maintains it himself and provides his own spare parts when needed. In Mo'unga'one all lights are not operational and need to be replaced, but there are no spare lights.

In view of simple maintenance of panels, there is significant percentage of households with shaded panels from shaded trees or released dots of dirt from birds. As shown in the table below 50% of the panels in Kotu is shaded compared to 100% in Mango and 100% in Mo'unga'one. This showed the lack of commitments on the parts of the solar technicians and the communities to carry out simple maintenance work such as cleaning the panels and the timely trimming of nearby trees and removal of dirt.

For the maintenance of the batteries, most of the surveyed households have experienced power disruptions due to low battery charge and low level of battery water. The analysis showed 20% of households in Kotu and 100% of households in both Mango and Mo'unga'one have experienced problems with their batteries. The main reason for Mango and Mo'unga'one being the failure to top up the battery water, ensure battery terminals are

connected properly and the cleaning of the batteries. These are less prevalent at Kotu where the batteries are stored in locked boxes outside the residential houses.

Table 2: Current Status of the existing installed system components

	KOTU		MANGO		MO'UNGA'ONE	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**
Easy access to the key system components	100	0	0	100	0	100
System Accessibility	100	0	100	0	100	0
Are the batteries OK?	100	0	0	100	0	100
Low water level in the battery	20	80	100	0	100	0
Low battery charge	10	90	100	0	100	0
Panels OK	100	0	40	60	0	100
Panel Shaded	50	50	100	0	100	0
Controller OK	70	30	0	100	0	100
Lights are still functioning	53.3	46.7	20	80	0	0
Radio connected to system	10	90	0	100	100	0
Other unauthorised accessories are connected to the system	10	90	0	100	66.7	33.3

System Layout

The technical design and layout of the system installations should be in line with, and support, the proposed management, financial and institutional structures for the project. **Figures 3 - 6** show the evolution of the system designs, components specifications and the system layout. It reflects not only the local capacity at the time, the donors' attitude and the available resources and also the local inputs into the system design.

Figure 3 reflects the first introduction of the technology through a major donor-funded programme. Whatever was recommended by the donor via its paid consultants was accepted to be the best for the project. Amorphous-type cells were used in panels sufficient only for two lights. Panels were roof-mounted on wooden mounts of questionable strength. The management and financial structure at the time included a T$50 installation fee while the monthly electricity fee was T$2 per month (later increased to T$6). Overall management of the project was by the Energy Planning Unit of the Ministry of Lands, Survey and Natural Resources. The Ministry owned all the system components. Over the years, the lessons learnt from these were the following:

i) Amorphous type cells did not last.
ii) A single panel with two lights was not sufficient. The houses may have an average of two bedrooms but residents prefer to have an exterior light and another for adjacent houses.
iii) Design should be based on hours of use and people should be taught that the design is for a certain number of hours and that with a fixed number of lights they have an average of so may hours per light per night.
iv) It is extremely difficult to enforce the disconnection policy for non-payment of the monthly electricity fees particularly when you have to enter the house to disconnect

and remove some of the key system components in front of the very eyes of people who are in need of development assistance.

Fig 3: A Mango installation (1991)
Roof Mounted; other PV components inside

Fig 4: A Mo'unga'one installation (1994). Pole Mounted; other PV components Inside

Fig 5: A Kotu installation (2002). Pole mounted panels. Controller and battery in a box attached to the pole.

Fig 6: A Niuafo'ou installation (2006) Pole mounted panels. Controller and battery in a box attached to the pole.

Figure 4 shows the first introduction of pole mounting the solar modules while the rest of the system components, including batteries are inside the house.

Figures 5-6 show the latest layout of the system installations. It is based on the effort to align the management of the solar electrification management systems as closely as possible to conventional power utilities or the *utility concept.* The principle of the utility concept is based on a utility providing a satisfactory service to its customers and then being fairly compensated by its customers for the quality service that it provides. It is based on the strong inter-linkages between the provision of a satisfactory service and the automatic willingness of the customers to compensate for the satisfactory services that they receive.

In the conventional power utility, the utility owns everything from the generator right up to the circuit breaker. The house owner then owns everything from the circuit breaker right up to the load. The latest technical layout in the TOISEP, as in Figures **5-6** is along these lines. The *solar utility* shall own the panels, the batteries, the controllers and up to the circuit breaker. The consumer shall own the switches, the lights, the radio socket and all the cabling coming out of the main in-house circuit breaker. The household then owns and is responsible for the maintenance and replacement of the parts and accessories from the circuit breaker to the loads.

Under this structure, a household will then be required to pay an installation fee of T$200. This fee represents the house wiring for four lights and the initial costs of the components from the controller to the loads and represents about one fifth (20%) of what it would cost to perform the same service and provide the same goods under the conventional power utility system.

The outcomes of technical assessment of selected PV lighting systems in Kotu, Mango and Mo'unga'one revealed key technical issues and concerns (see **Table 3**) that must be considered in preparing for the rehabilitation project in Mango and Mo'unga'one. It is important to realize that the technical set up of PV systems installed in Mango in 1988 and Mo'unga'one in 1994 through the EU Lomé II Pacific Regional Energy Programme is quite different from the technical set up adopted in Kotu in 2002 through the PREFACE project.

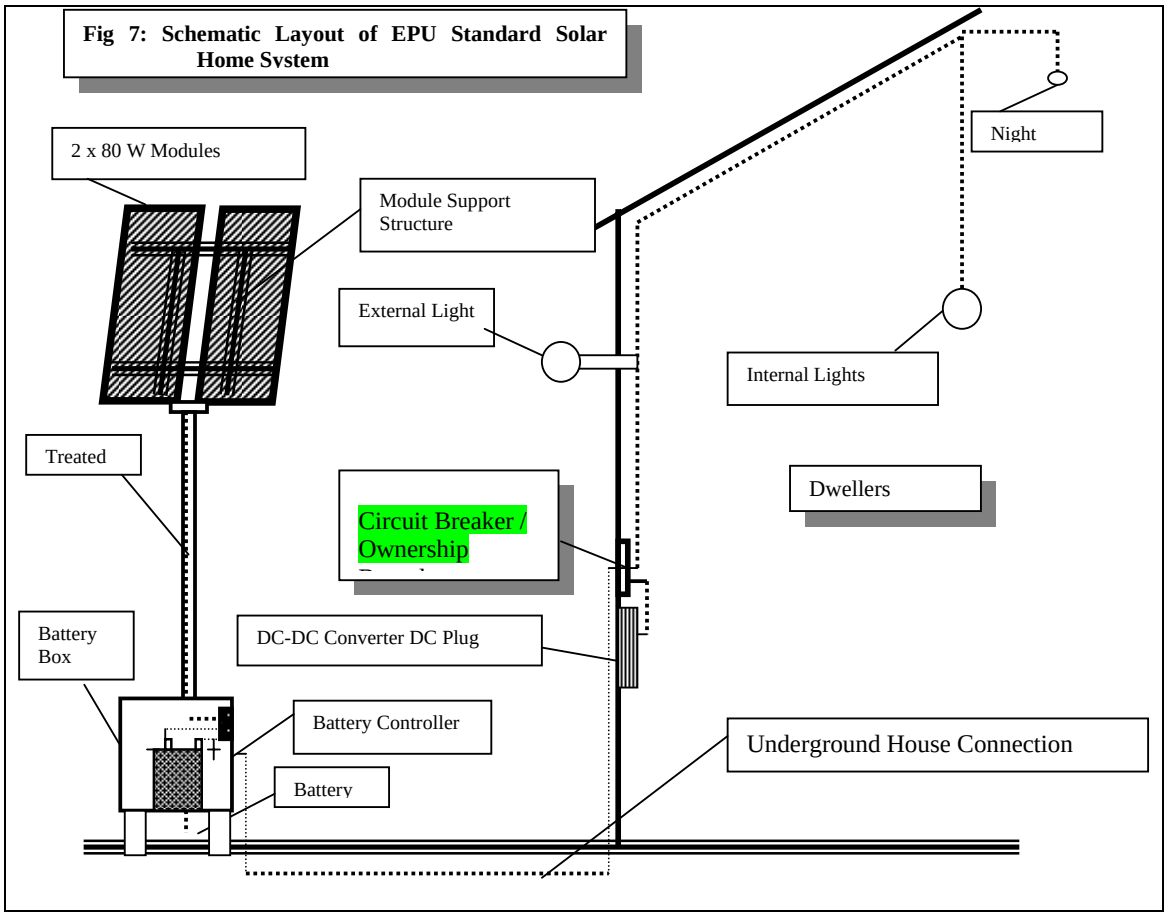
Table 3: Key Technical Issues, Concerns and Experiences

Technical Aspects	Mango	Mo'unga'one	Kotu / PREFACE	Comments
No. of panels and their placement	1 – roof mounted	2 – pole mounted	2 - pole mounted	Much easier to maintain the pole mounted ones
Panels junction-box brand and construction materials	50Wp Photowatt Panel conjunction box. - Tattered after 5 years.	Pro Charger TM-S Junction-box [Siemens] - Cover could not be opened after 6 years.	80Wp Photowatt Panel conjunction box. - Still in good condition	Panel warranty period be closely tracked. Specify better construction material which suit local conditions
Proper installation and appropriate PV components	Pole mounting - Treated lumber rots after 6 years	Panel Racks - Wooden racks	Pole mounting - NZ Treated pole last longer - Ground conduit tattered due to high temperature.	Proper and Complete mounting racks & pole for panels are needed.
No. of batteries and their placement	1 – inside the house	1 – inside the house	1- outside in a locked sealed box beside the pole for the	Batteries can be serviced anytime regardless of whether there is

Table 3: Key Technical Issues, Concerns and Experiences

Technical Aspects	Mango	Mo'unga'one	Kotu / PREFACE	Comments
			panels	someone in the house or not
Battery Brand	Oldham 6MLTS 100. Maximum level indicator closer to top of the plate	Oldham 6MLTS 100. Maximum level indicator closer to top of the plate	Oldham GLS130 High maximum level of electrolyte is higher	Would take longer period for technician to add water when "max" level is higher. Less chance of contaminating electrolyte.
	Battery case translucent	Battery case translucent	Battery case translucent	Easier to inspect
Battery maximum designed critical temperature	40^0C	40^0C	40^0C	Even if battery locates outside the house, the electrolyte highest temperature ever recorded was 34^0C. Even lower inside the house.
Voltage drop	Acceptable -	Acceptable -	Fairly high in some systems.	Wire should be limited to a acceptable length

The differences in the technical layout above, in view of the installed locations of the PV components must be taken into consideration in working out the technical specifications of the system components, the plans for the installations and the maintenance. The set-up model adopted in Kotu allowed full accessibility to all the components that are owned and for which the HSEI is responsible for. As indicated in **Table 2** above, the systems are 100% accessible because the panels, controllers and batteries are safely installed outside the house, so maintenance of PV components is easy and can be done by the island technicians at any time. On the other hand, the accessibility to the PV components in Mango and Mo'unga'one, under their existing installation layout, would not be always easy as technicians would only access the system if the house is open and is occupied. As a result, maintenance work and replacement of parts would be more conveniently conducted according to the in Kotu/PREFACE layout.



The above schematic layout, which is the one found in Kotu and in the other later PV installations in the TOISEP, have been designed to facilitate the EPU's new utility concept approach and also to facilitate the institutional and management arrangements in terms of "Who Owns and Responsible for What." Under the above layout, the internal house wiring and appliances belongs to the consumer and are clearly distinguished in order to mirror similar arrangement under a conventional power utility. The ownership boundary that defines the responsibilities for the two main components of the system is the main circuit breaker. All generating parts upstream from the circuit breaker are the responsibility of the utility. All inside the house are owned and are the responsibility of the house owner / consumer.

System Abuse

Abusing the installed PV systems is common in the islands. All of the surveyed households in Mo'unga'one have connected radio to the system, but the installed system in Mo'unga'one had no installed plug for radios in the first place. It was also noted that mobile phones are carried by the people at Mo'unga'one, and they admitted using the PV batteries for charging their phones.

Fig 7: Portable DVD in Mo'unga'one

Fig 8: Mobile Phone and Portable DVD in Mo'unga'one

Fig 9: New Setup for telephone charger

Portable DVD and line telephones are also available at Mo'unga'one. The Tonga Communication Corporation has just put up a new telephone antenna and people are using the PV system to charge the batteries for their phones.

System Design and Specifications

Lighting is the most basic need, with 3 x 13W interior lights used for four hours per day on average is assumed. All homes indicated on the survey that this was a need as an average household has at least 3 rooms including living area. One 13 W exterior light (either portable or fixed) would also be useful for night fishing preparation and outdoor activities as well. In order to reduce energy consumption, a night light would also be installed to avoid excessive light usage. A maximum of 10 W radio is intended to be connected to the system as well for 15 hours every day.

A total daily load of 414 Watt hours is therefore expected to be delivered by the system for each household and that covers losses. A 5 day autonomy period was considered in the calculation. SHS System design and Specification is as follows:

Table 4 : SHS Design Components

	Components	Specification
i)	Photovoltaic Panels	2 x 80Wp Panels
ii)	Battery	1 x 130AH Battery
iii)	Controller	At least 10Amps
iv)	Interior Light	3 x 13W Light
v)	Exterior Light	1 x 13W Light
vi)	Night Light	1 x 5W Light
vii)	Wires	2.5mm 2 minimum

Given the above design and the fact that the system installations and layout will be in accordance with Kotu's, the following are some of the specific considerations and requirements for the system components:

Distribution of the PV systems

The distribution of the PV systems must be standardized with every recipient receiving the same set of systems components and number of lights. This would then simplify applying a uniform set of installation and monthly fees among the islands.

The PV Modules

The photovoltaic modules shall provide the rated output within ±15% for a minimum of ten years under tropical coastal conditions, which include exposure to high ambient temperature, high humidity, and high levels of atmospheric salt. The photovoltaic modules will be used to charge 12V batteries which will be cycled an average of 20% of their capacity each day.

The modules shall have a rated peak power at 1000 W/m^2 and 25° C of between 70-80 Wp +/- 5% and framed with marine graded aluminium to withstand the corrosive environment in the islands. It must have 36 cells connected in series, made of mono or polycrystalline silicon. Amorphous type cells must be avoided. The modules must have been tested at the ESTI (European Solar Testing Institutions) using CEC Specifications No. 503 or certified according to the international standard IEC – 6125. By-pass diodes may be required.

PV Modules Support Structures

All support structures components must be able to resist at least ten years of outdoor exposure without any appreciable corrosion or fatigue. All bolts or screws used for mounting panels to the structures must be marine grade stainless steel. The PV modules are to be mounted on treated wooden poles having a minimal diameter of 20 centimetres and a minimal length of 3.5 meters and the length to be buried shall be 80 cm long. The pole mounting shall be by means of a steel collar and clamps accepted electrical utility grade, aluminium, stainless steel or hot dipped galvanized steel with marine grade stainless steel fasteners (screw, nuts, rings, etc…). The mounting assembly must be capable of resisting winds up to 180 km/hour (tropical cyclone).

Batteries

The lead-acid batteries provided shall power the lighting systems after charging by photovoltaic modules. The design is based on a load of 30-35 Ah per day at 12V. Sealed or maintenance free batteries, automotive or starting batteries need not be used but lead-acid, open cell construction type are preferred. Batteries shall be shipped dry with sufficient acid supplied separately for filling at the time of installation. The battery bank must be made of 12V nominal operating voltage units, at least 100 Ah capacity at the C100 discharge rate, monobloc construction with positive tubular plates. The container shall be of molded, translucent construction with bonded lid and polarity markings. Batteries shall be supplied with explosion-proof, twist on cell caps with protection against acid leakage. The battery manufacturer must have received ISO 9001 certification. The battery shall be of the deep discharge, solar type with a life cycle in excess of 1000 cycles at 80% discharge and a self-discharge rate, when new, of less than 5% per month (at 25°C and fully charged) of its nominal capacity. The battery shall have a columbic efficiency of at least 85% and an energy conversion efficiency of at least 75% when new and charged in excess of 50% of capacity.

Battery Charge Controllers

The battery charge controller will be housed in the battery box to prevent any access and tampering by users. The charge/discharge controllers shall be capable of protecting a 12V lead acid battery from damage due to overcharging and damage due to excessive discharge. The voltage settings shall be fixed to prevent change and tampering or the controller enclosure will be sealed. A temperature correction of –4 to –5 mV/°C/cell must be applied to the end of charge and reposition voltage ranges v. The load disconnection voltages must correspond to a maximum depth of discharge of 60%. The end of charge voltage must lie in the range 14.2– 14.4 Volts at 25°C.

Fluorescent Lamps for General Lighting

All lamps must be equipped with fluorescent bulbs. One of the lamps for each system must be designed for outdoor use. Power consumption should be equipped with 11-13 Wp bulbs at a nominal 12 VDC supply. The Ballast must ensure safe and regulated ignition in the range 10 V – 15 VDC input voltage. The Ballast must be protected against non-performance (destruction) when the lamp is removed during operation or the ballast is operating without the lamp.

PV Installation

The PV installation will benefit from a compliance with a well known PV codes and standards. Installation should meet the requirements of the Universal Standard for Solar Systems. For instance, batteries should be installed within five meters of the photovoltaic module, in a ventilated shelter with the ability to check battery's electrolyte level. The distance between the regulator and load should not exceed 10m to ensure voltage drop of less than five percent. PV panels should be installed at the correct tilt angle with no shading from surrounding structures and trees. Red wires should be used for positive and black for negative, with wire sizes of 4 mm^2 for main wires and 2.5 mm^2 for secondary wires, and the connection between module, regulator and battery should use 6mm^2 wire double insulated wires.

Maintenance and Spare Parts

In Ha'apai, locally appointed technicians undertake the basic maintenance of PV systems in the islands on very low wages but which should be based on a percentage of the collected fees. The EPU qualified PV technicians visit the islands every three months to conduct more advanced maintenance, in which all system components are checked and maintained. The maintenance record collected so far is restricted to the measurement of the open circuit voltage of the battery and specific gravities of the battery cells. This record has no indication of the panel's performance, controller's function, load performance or the overall system conditions. It is suggested that this practice be replaced with regular overhaul maintenance by skilled technicians. This should include measurement of battery voltage, load current and panel operating voltage and current, and the using of proper instruments and equipment should be used to measure the actual performance of the system. During the maintenance and monitoring, it is important to use amp and voltmeters and other maintenance tools to be able to better assess the true performance of the systems.

Longer-term monitoring arrangements can provide crucial information on the technical indicators such as battery voltage, number of days of low voltage supply, breakdowns and repairs conducted, average daily use of system and so on. Special attention should be given to batteries during the maintenance period because the cost of batteries and its maintenance is usually high. Maintenance must be conducted regularly and spare parts should be readily available in the islands.

PV Testing, Codes and Standards

System designing requires the need to adopt appropriate codes and standards for PV equipment design, testing, installation and maintenance to enhance PV system performance in the field. As noted from the outcome of the technical survey, some of the PV panels showed early appearance of EVA melting. Evidence suggests that despite the increasing reliability and efficiency of PV modules nowadays, some PV modules are still under-rated. The installation of a model system at the HSEI office for testing and training is essential to reduce the technical risks of over estimating PV equipment performance. Maintenance must be conducted regularly and spare parts should be readily available.

The permanent population of the islands is decreasing steadily due to migration. Effective policy should be implemented to ensure that PV systems are installed in houses that are occupied throughout the year in order to ensure their utilization, regular maintenance, general care and the payment of the monthly user fees.

Alternative Electrification Options

The study looked at the technical feasibility of leaving the installed PV systems as they are and found that the blame on the current status of the systems should be on the communities only, therefore the communities deserve a second option. There are not sufficient land area and coconut coverage to justify using biofuel. The wind resources potential has not been measured but experiences of the communities indicate that this resource does not hold much promise. Much larger nearby islands in the Ha'apai group are currently struggling with their grid-connected diesel generation and much smaller islands like Mango and Mo'unga'one will not find diesel generation any easier. Power Generation from hybrid systems would not only be too much for the income levels of the communities but too complex a technology for the island residents.

CHAPTER 5: ASSESSMENT OF THE INSTITUTIONAL AND MANAGEMENT ASPECTS OF THE PROJECT

The identification of an appropriate institutional and management structure for the Mango and Mo'unga'one PV upgrade project has taken into consideration that the Tonga Renewable Energy Bill passed through its readings in the House in early October 2008 and the development of regulations relating to the Bill may begin within the next three years. It has also taken into account the institutional structures in other PICs plus the current experiences from the PREFACE project.

The Renewable Energy Bill

The principal objects of the Bill are discussed in Chapter 1. "Renewable energy operators" are defined in the Bill as persons involved in the ownership, management, maintenance, design or installation of RE projects. In this respect, the HSEI could be defined as an RE operator. The Bill talks of establishing a RE authority and an advisory committee to the authority. The Functions of the Authority include:

- carrying out all activities necessary or desirable for the licensing of RE operators as may be prescribed by regulations made under this Act

- developing and recommending regulations establishing standards for any matter relating to the specification of RE equipments and the production, storage and distribution of RE

It is noted that the HSEI is currently registered as a non-profit entity. When the Bill and its regulations come into force, the HSEI would have to deregister itself and be licensed as a RE Operator under the Bill. The HSEI may also have to readjust the specifications of its equipments and it ways of producing, storing and distributing RE to comply with the regulations under the Bill.

Institutional PV Models in the PICs

Following are some institutional approaches used to introduce PV systems in the PICs, adopted from earlier works of Mr Herb Wade, including issues such as system ownership, technical support and the project finances.

i). Village cooperative-owned and maintained individual home systems, government installed with government technical support

This approached was first used in Fiji in 1982-1984 in three village cooperatives. Although people in each village were trained as maintenance technicians and carefully instructed regarding the need for consistent fee collection to pay for repairs, fees were not properly collected after an initial period, and maintenance soon become nonexistent. Funds that had been collected during the first year were quickly spent on other village projects since PV system repairs had not been needed, and it appeared that fees would not be needed. By the fifth year of the project, however, two villages had no functional systems and the third only a few.

ii). Government-owned and installed systems, with basic maintenance by owner and energy office technical assistance on call for periodic maintenance

This is a common approach that has been used in other PICs like the Cook Islands, Fiji, FSM, Palau, PNG and RMI. This was also used in Tonga in the days prior to 2002. Projects range in size from more than 200 systems in Fiji to a few units for technical trial in PNG. In practice, the users did not provide the proper basic maintenance and government assistance in maintenance was generally sporadic, of widely varying quality, and with long repair delays common. Fees collection, if ever begun, was generally discontinued after a few months. Designs generally were inadequate in size to meet the real demands of users. Moreover, because of the common government requirement of purchasing based on lowest quoted cost, low-reliability equipment, in particular lighting fixtures and controllers, was often provided. In no case have the PV systems performed consistently as intended by the governments or expected by the users. The systems have either been abandoned, are operational at reduced capacity, or work but have had unacceptably high maintenance costs because of frequent battery replacements.

iii). Commercially sold, vendor-or user installed, user financed, owned and maintained systems with commercial maintenance available on call.

Fiji, Kiribati and PNG have the largest number of systems of this type. In general the systems were badly undersized because of the purchasers' desire to keep initial cost to a minimum. Many systems purchased by religious institutions have suffered the same sort of problems, with a notable exception of institutions that have a competent general maintenance person on staff whose duties and aptitudes include PV system maintenance. Indeed the oldest successful rural PV systems in the Pacific are at outer island missions, showing that such systems can work with proper institutional support.

iv). Commercially installed and owned, with commercial maintenance on call

In 1983-1984 a foreign owned private company reported installing nearly 200 lighting systems in rural Fiji under a leasing arrangement that included a monthly fee of US $15 and free maintenance on call. That business failed, partly because the maintenance costs proved higher than anticipated, largely because of under sizing, resulting in early battery failures. Finally, the company had a poor collection rate for the monthly fee partly because of problems with field agents and partly because customers were unwilling to pay for a level of service below what they had been led to expect.

v). Commercially installed and owned, with commercial periodic maintenance

In a pilot project for a new commercial company, a rural village in Fiji was equipped with well-designed, high quality individual lighting systems that were self contained and sealed. The systems provided 24 hours of lighting after insertion of a plastic "key" purchased from the village store. Users appeared to like the systems and purchased the daily service "keys" as expected. Unfortunately the business lacked adequate financing and failed before the approach could be properly evaluated.

vi). Cooperative-owned, installed and periodically maintained systems with fee collections by the cooperative.

This approach was used by the Tuvalu Solar Electric Cooperative Society (TSECS). The main feature is that the organisation provided rural members with solar lighting. This system has proved to be best in all of the seven categories, although there were technical problems in the early years.

vii). Solar Utility owned, installed and periodically maintained systems with fee collection by the utility.

This approach is being used by Kiribati and is used in Tonga too and patterned closely on the TSECS. The main difference is that the organisation providing the services is a government-owned / supported corporation / institution rather than a cooperative, and as a result it has better access to capital and support services although generally it can be flexible in its operations. The Kiribati Solar Energy Company and the Ha'apai Solar Electricity Incorporated are structured as a rural electrification utility.

The HSEI can be categorized under this model. The solar utility owns the solar panels up to the circuit breaker while the household owns and is responsible for the maintenance of the part from the circuit breaker to the load. The solar utility employs its own technicians who are responsible for maintaining the system components and collecting the monthly fees.

The HSEI

The management of the TOISEP is currently under a transition from being a *village cooperative-owned and maintained individual home systems, government installed with government technical support* to a *solar utility-owned, installed and periodically maintained systems with fee collection by the utility.* This transition can be better seen in Table 4 below:

Table 5: Comparison of the practices in earlier PV projects and the Ha'apai PREFACE project

Practices Prior to 2002 (used in the original Mango and Mo'unga'one installations)	Practice during 2002 – 2008 (used for 6 islands in the HSEI)	Comments on current status and applicability to the Mango and Mo'unga'one rehabilitation, assuming both will join the HSEI
Consumers sign an agreement with the EPU	Consumers apply to be provided with solar electricity	Consumers should still apply. Application form and the management guidelines should be in Tongan language and updated.
Consumers pay an installation fee of T$50	Consumers pay an installation fee of T$200[2]	For consistency purposes, maintain the T$200 installation fee
Monthly fee of T$2 and later increased to $6	Monthly fee of T$13	For consistency purposes, maintain the T$13 monthly FEE
Fee was more politically set	Fee based on the recovery of operational and maintenance costs	The monthly fee for all islands in the HSEI should be reviewed given future maintenance needs and increased technician wages
Individual village solar committees	Ha'apai district Solar Electricity Committee	Has been registered as Ha'apai Solar Energy

[2] T$ is approximately 100 US$

Practices Prior to 2002 (used in the original Mango and Mo'unga'one installations)	Practice during 2002 – 2008 (used for 6 islands in the HSEI)	Comments on current status and applicability to the Mango and Mo'unga'one rehabilitation, assuming both will join the HSEI
	(HSEC)	Incorporated. Register Mango and Mo'unga'one as members of the HSEI.
Island technicians selected and paid by village solar committees	Island technicians selected and paid for by the HSEC	Island technicians selected and paid for by the HSEI
Managed from Nuku'alofa by the EPU	Managed from the Ha'apai administrative centre (Pangai) by the HSEC	Continue to be managed from the Pangai HSEI but with closer monitoring from the Nuku'alofa EPU office
Spare parts kept at Nuku'alofa	Spare parts kept and stored in the islands and at Pangai	Frequently needed spare parts like spare lights and fuses be kept on the islands with the island technicians
All project funds and revenue kept at Treasury	All project funds and revenue through the HSEC's bank account	All project funds and revenue through the HSEI's bank account
No term investment	Term investment	Continue with the term investment
Government own all the systems	HSEC owns the panels up to the circuit breaker. Consumers own everything from the circuit breaker to the load	HSEI owns the panels up to the circuit breaker. Consumers own everything from the circuit breaker to the load.
EPU replace the lights	Consumers replace the lights at their costs	Consumers replace the lights at their costs
Solar committees have a direct say on their collected fees	Individual committees don't have a direct say, only indirectly through the HSEC	Representatives of the individual island committees have a direct say at the HSEI meetings.
No clear arrangement on the used batteries	To be collected for export and to be recycled	To be collected for export and to be recycled
No fixed meeting with the island communities	Annual meetings to review the management structure and approve the annual work programme and budget.	Annual meetings have not been on a regular basis. The HSEI must meet annually.
No disconnection for non-payments	Disconnection for non-payments	Disconnection must continue even though it is not effectively carried out now.

Practices Prior to 2002 (used in the original Mango and Mo'unga'one installations)	Practice during 2002 – 2008 (used for 6 islands in the HSEI)	Comments on current status and applicability to the Mango and Mo'unga'one rehabilitation, assuming both will join the HSEI
Operating under no license from the Tonga Electric Power Board (TEPB)	Operating under no license from the TEPB	Operating under no license from the Tonga Power[3]. Need to watch the implications of the October 2008 passed renewable energy bill.
Operating without any legal by-law, etc	Operating without any legal by-law, etc	Relevant regulations will be enacted for the renewable energy bill.
Subject to government auditing	Subject to government auditing	Subject to government auditing. Audit report should be made available to all members of the HSEI.
Initial equipments are subsidized by aid	Initial equipments are subsidized by aid	Initial equipments to be subsidized by IUCN/Italy
Aid programme was coordinated by the EPU	Aid programme was coordinated by the EPU	Aid programme to be coordinated by the EPU

The HSEI is the solar utility and is being managed according to a management guideline/constitution which has been endorsed by its Management Committee. The management guideline is subject for review at the annual meetings of the HSEI and cover the following broad areas:

Management
Each member island forms an island solar electrification committee (ISEC) from where representatives from each island are selected to make up the Management Committee of the HSEI. The Management Committee shall provide policy guidance and approve the annual work programme and budget of the secretariat of the HSEI.

The solar utility shall employ a well-trained and equipped resident island technician in each of the project sites and he/she shall be responsible primarily to the monitoring and the maintenance of the installed systems as well as the collection of the monthly electricity fee.

System ownership
The solar utility shall own the panels, the batteries and the controllers. The consumer shall own the switches, the lights, the radio socket and all the cabling coming out of the main in-house circuit breaker.

Installation and monthly fees
The consumer, once his/her application for a PV system has been approved by the Hon. Minister of Lands, Survey and Natural Resources, shall pay an installation fee of $200 prior

[3] TEPB used to be the service provider but is now the regulator while Tonga Power is the service provider.

to the provision of a standard solar home system with three to five lamps, depending on the size of his/her house, and a radio socket.

The consumer shall pay a monthly electricity fee of $13.

Replacement of parts
The solar utility shall be responsible for the replacement of the panels, the batteries and the controllers. The consumer shall be responsible for the replacement of the lights, the switches and the radio socket. The consumer shall also be responsible for the replacement of the panels, the batteries and the controllers if they are damaged due to his/her negligence.

System Extension and Alteration
The consumer can have additional loads to those initially installed but he/she must first get the approval of the solar utility and pay for the required supplies and the additional installation costs (labour and transport).

Disconnection and reconnection of service
A consumer who fails to pay for his/her monthly fee for two continuous months (60 days) shall be disconnected from service.

A disconnected consumer must pay the total monthly fee owed and $20 for a reconnection of service and shall be made a month (60 days) after disconnection.

The solar utility's PV components (panels, batteries and controllers) shall be removed from a consumer who fails to pay the monthly fee for a period of four continuous months.

The solar utility's PV components (panels, batteries and controllers) shall be removed from a consumer who shows total disregard for their safety and proper functioning.

Given the above, it would make sense for the rehabilitation of the Mango and Mo'unga'one PV projects to be managed through a modified HSEI. The modifications should include the following measures in Table 5:

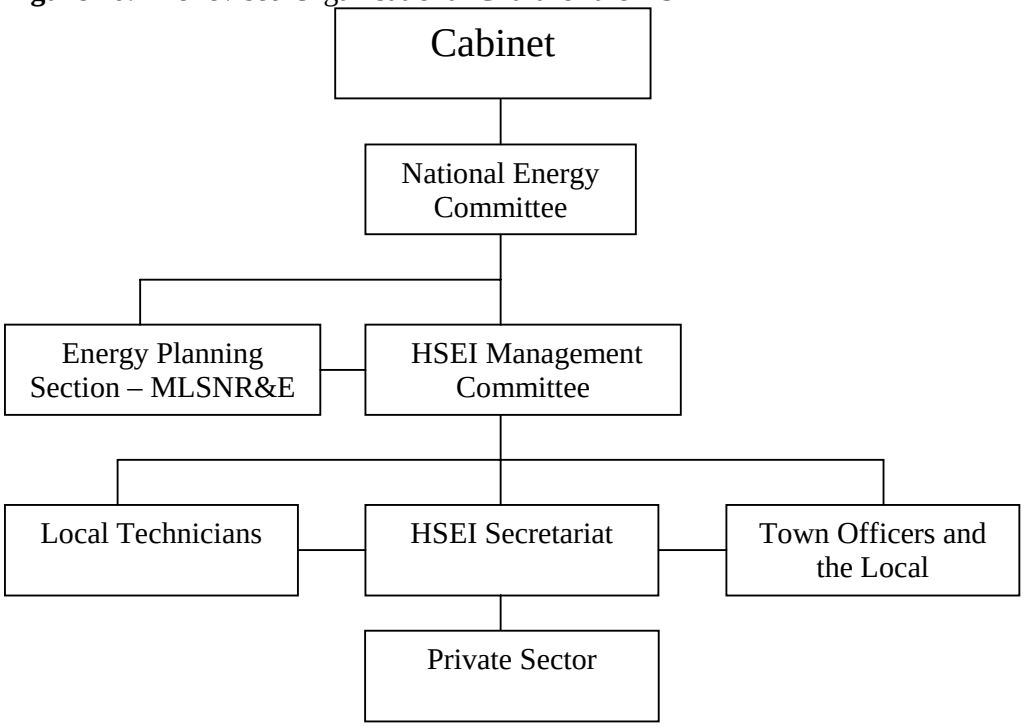
Table 6: Management and institutional issues were raised during the field mission for this study

Issues to be addressed	Comments	Measures to be taken to avoid repeating the same problems at Mango and Mo'unga'one
Stakeholder participation	Running of the HESI is still being dominated by government with little inputs from the communities and the private sector	Inclusion of the "Solar Electricity Supply" in the agenda of the monthly community meetings / "*fono*". That the outcomes of the *fono* are relayed to the HSEI office and the EPU Inclusion of representatives of the Tonga Communication Corporation and Chinese Importing Companies as members of the HSEI Management Committee
Mandate	Unclear mandates as to the roles of the	Review the terms of reference for both and to be discussed and clarified at the

Issues to be addressed	Comments	Measures to be taken to avoid repeating the same problems at Mango and Mo'unga'one
	Town Officers and the Technicians in relation to the disconnection consumers for non payment of fees	Management Committee meeting and the *fonos*
Government Support	There will always be a need for government's financial and technical support	That the Minutes of the Management Committee Meetings be submitted to the Chair of the National Energy Committee thereby allowing relevant issues to be forwarded to Cabinet for their consideration / information EPU to include in its annual budget specific financial and technical assistance to the TOISEP
Spare parts are not readily available in the islands	Some systems are not working because spare parts are not available on the islands	Review ToR of the technicians to include spare parts and include stock taking in their training and documentation responsibilities

The revised institutional and management structures can be seen in the revised organisational chart in **Figure 10** below:

Figure 10: The revised Organisational Chart for the HSEI



CHAPTER 6: ASSESSMENT OF THE ENVIRONMENT IMPACTS OF THE PROPOSED REHABILITATION PROJECT

The GoT's Environmental Impact Assessment (EIA) Act of 2003 - EIA Act 2003, Part III Section 8 stipulates that the EIA for major projects in the Kingdom be subject to the assessment of the effect the project is likely to have on:

i) any ecosystems of importance, especially those supporting habitats or rare, threatened, or endangered species of flora or fauna;
ii) areas, landscapes, and structures of aesthetic, archaeological, cultural, historical, recreational, scenic or scientific value;
iii) any land, water, sites, fishing grounds, or physical or cultural resources, or interests associated with such areas, which are part of the heritage of the people of Tonga and which contribute to their well-being;
iv) the social and the economic well-being of communities; or
v) whether any project is likely to —
   (a) result in or increase pollution;
   (b) result in the occurrence, or increase the chances of occurrence, of natural hazards such as soil erosion, flooding, tidal inundation, or hazardous substances;
   (c) result in the introduction of species of types not previously present that might adversely affect the environment and biodiversity;
   (d) have features, the environmental effects of which are not certain, and the potential impact of which is such as to warrant further investigation;
   (e) 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; or
   (f) whether utility services are available and adequate for that activity.

Description of the propose action and alternatives

Proposed Action

The proposed action is the installation of 60 (23 at Mango and 37 at Mo'unga'one) stand-alone solar home systems and four portable systems for hire. The proposed action will be providing electricity for lighting in the islands. Each participating household would be provided with two solar panels, one battery, controller, wiring, and four lights (three interior and one exterior in addition to a night light). The installation process would be carried out by the staff of the EPU of the Ministry. The solar panels are to be roof-mounted and to be placed facing the true north on a tilt equivalent to the latitude of Ha'apai (20^{o}) to allow maximum capture of solar energy from the sun.

Alternative Action

Analogy to the proposed action but instead of installing the solar panels on the roof of the houses, it has to be placed away from the houses in an open space. The solar panels would then be mounted on wooden poles cemented into the ground with concrete.

No Action

Under the no action, the PV system would not be installed at all. The two islands would continue to keep their non-functioning PV systems and batteries and will continue using kerosene for lighting.

Possible Detrimental Impacts on the Environment

Land-use
There is no land-use issue in this project as the installation of the PV systems will mostly be within the privately-owned town allotments and church and government land (schools). Eligibility requirements for the installation of PV systems at both islands will include an application where the land owner will declare that there is no objections to the installation of the PV systems outside and inside his/her house.

Air quality
There will be little or no impact on air quality as a result of this project since the project's installation will not involve the use of fossil fuel-powered tools. The only contribution to the air quality problem will be in the transportation of the equipments to the islands which will be on fossil fuel-powered boats.

Water resources
Both islands Mango and Mo'unga'one are exclusively using rain water for drinking, cooking, and bathing. Rain water is collected in cement tanks, and almost every household have their own tanks. Surface and underground water are never used as they are brackish. The project will require minimal use of water in the installation. About a litre of water per installation per month will be needed for topping up the battery water and also for cleaning the solar panels.

Occupational Health
The key occupational health-related problems relate to the project will be in the hydrochloric acid in the batteries. However, since the batteries will be locked in a special box outside the house and accessible only to the solar technicians, the risks to family members is minimal. From a health perspective this is much better than the use of kerosene and the resulting inhalation of toxic gases released from the burning and incomplete combustion of fuel.

Hazardous waste
One of the environment drawbacks of PV systems is the lead acid batteries which are often guaranteed to last five years. It is crucial that all the used battered in the old projects are collected and to be exported to be recycled. It is also important that plans are put in place to collect all future used batteries in the rehabilitation project for export and recycling. On the other hand, the most replaced parts would be the light tubes and the contollers. Arrangements should be made with Tonga Waste Management for the collection and disposal of these wastes.

Solid waste
Recent studies on solid waste characterization in Tonga indicated that electrical appliances including solar panels and PV appliances showed a promising contribution to the quantity of waste being disposed of at the waste management facility. However this project is only for 64 PV systems and so their impacts on the future volume of organic and non-organic wastes at the islands and nationally would be minimal.

Flora
Both islands are covered by common native, introduced and even endemic flora. Patchy secondary native forest remains on the two islands even though some have been removed

from agricultural purposes and for settlement. Floral agro-biodiversity including yams, taro, giant taro, sweet potatoes, bananas, cassava, and so forth are commonly planted in these two islands. Fruit trees such as mangoes, nuts, apples, coconut, *tava, fekika* are also planted or naturally grown in these areas. Typically, a few vegetables are also planted for food security purposes.

The impacts of the project on the flora in the islands would be minimal.

Fauna
Faunal organisms found in both islands are commonly native, introduced and presumably some endemic species could be found on both islands. Domestic animals are also identified like pigs, horses, dogs, cats, and cows to name a few. In general, there would be no impact of the proposed action on the biological diversity (flora and fauna) in both islands. Since the PV system project involved no major construction apart from the embedded concrete or wooden postings, which could be seen as having no major impacts on the environment.

Cultural Resources
Traditionally, in the olden days biofuel and biomass were commonly used as sources of energy. Dried coconut or coconut oil was used for lamps and lighting, while fire wood was used as source of energy for cooking, whether in an *umu*, by boiling or even *tunu*.

It has changed from biofuel to non renewable energy such as oil (kerosene and benzene) as sources of energy especially for lighting, and gas stove for cooking.

This project is trying to remove the barrier of utilising environmentally unsound and uneconomical practices such as combustion of fossil fuels, to a more environmentally sound energy source, i.e, RE from the sun.

Geology and Soil
Since the proposed action would involve no major construction except for the embedded concrete/wooden footings which will utilize minimal geological resources such as cement, sand, and gravels, there would be no major impact as far as the geology is concerned. In terms of the impacts on soil, the only affected areas would be where the poles for the panels would be located. The other possible impact on soil would be the disposal of used batteries, controllers and lights, as earlier covered under “wastes.”

Depletion of Abiotic Raw Materials
This study also considered the consequences of the production of PV system appliances and its impacts on the abiotic raw materials. Production of batteries, solar panels, cables and lights all involved the utilisation and depletion of these raw materials abroad.

Positive Impacts

Reduction in Greenhouse Gas (GHG) Emission
Mitigation measures including utilising RE technologies such as PV contributes largely to the reduction of GHG in the atmosphere. The ever-increasing concentration of GHG in the atmosphere is attributed to the fact that the world is heavily dependent on the combustion of fossil fuel as sources of energy. The introduction of new technologies including RE, such as PV, is a practical measure that could mitigate the production of GHG such as carbon dioxide (CO_2), sulphur dioxide, and nitrous oxide.

In the target islands, approximately 4 gallons of kerosene oil are being consumed monthly per household. This is equivalent to approximately 42 kg of CO_2 per household per month. With 60 households to be electrified, the project would save approximately 2.52 tons of CO_2 monthly or approximately 600 tons over the 20 year life of the project.

Persistent Organic Pollutants (POPs)
POPs including dioxin and furan are basically produced from the incomplete combustion of any matter. This would include the burning and or incomplete combustion of fossil fuel. Incomplete combustion of kerosene in lamps could sometimes produce dioxin and furan. These two chemicals are toxic and dangerous to the health and the environment. The PV system, on the hand, does not produce these two types of toxic chemicals.

Ozone Depletion Gas
Burning of fossil fuels also releases ozone depleting gases such as sulphur dioxide and nitrous dioxide. CO_2 and CO also contributes to the depletion of the ozone layer. The PV system reduces the production of these gases.

Environmental Impact Mitigation
As seen above, the only possible detrimental environmental consequences that this analysis could identify are in the hazardous and solid wastes from the used PV parts. The impacts of these could be mitigated through:

i) Recycling programme.
The HSEI in cooperation with the Ministry of Lands, Survey and Natural Resources & Environment should set up a recycling programme for the used PV components. The used PV components should be safely stored and to be transported to Nuku'alofa to be recycled / exported.

ii) Re-use
Some of the appliances could be re-used for other purposes, rather than discarding or dumping onto the environment. For instance, some of the islanders have used the lead in the batteries as weights for their fishing gears. Some have filled the used batteries with water and use as weights to hold down the roof of their houses.

iii) Awareness Programme
Community awareness programmes should be conducted on the two islands. The awareness programme should focus on teaching local communities about the advantages of recycling and re-use programmes.

The environmental impacts of the proposed action and its alternatives were thoroughly considered and analyzed. The analysis indicated no significant impacts to the natural resources and environment now or in the future. However, the disposal of the used PV components, in particular the batteries, must be considered in light of a need to be transported out of the islands for recycling.

CHAPTER 7: ASSESSMENT OF THE FINANCIAL AND SOCIO-ECONOMIC ASPECTS OF THE PROJECT.

Context analysis and project objectives

Socio-economic context

Mango is 6 Nautical Miles away from Nomuka, the neighbouring island where they usually do their shopping, and 37.5 nautical miles away from Lifuka the capital town in the Ha'apai Group. Mango lies at latitude 20º 19´500 South and longitude 174º 46´.000 West. Mo'unga'one, on the other hand, is 12.5 nautical miles away from Lifuka and locates at Latitude 19º 48.000 South and longitude 174º 20.500 South. The target islands are located in a very remote area and comprised of 324 inhabitants (Mango = 140, Mo'unga'one = 184) in 60 households (Mango=23; Mo'unga'one=37).

There is no retail shop in Mango whereas in Mo'unga'one there are two. It is obvious that transport cost plays a vital role in both islands' development and standard of living. The population of Mango does their shopping from Nomuka and sometimes from Nuku'alofa when they need to buy at bulk. Mo'unga'one, on the other hand, have to travel to Lifuka for most of their shopping since the local retail shops cannot meet their demand. Travelling to and from the islands relies heavily on weather conditions due to their geographical position, leading to very low monthly average spending as trips to the main islands are not frequent.

The major sources of income in both islands are fishing and weaving. Some families receive remittance in cash and in-kind from time to time. According to the surveys conducted in this study, the average household income per month for Mango is T$300 and T$400 for Mo'unga'one. Comparing that to their monthly average spending, a household in Mango spends T$85 while a household in Mo'unga'one spends T$120. The large surpluses in the households' budgets reflect on their church donations/*"misinale"* where more than 85 per cent of those surveyed on both islands donate more than T$1,000. It is obvious from the survey findings that every household surveyed in both islands is happy and can afford to pay the installation fee (T$200.00) and a higher tariff rate than the initial rate of T$6.00.

Church functions are the most frequent social gathering in both islands. As a result, many families have identified religious commitments as the most important obligation and a higher priority than anything else, including power bill. Since there is no entertainment at night, men spend the evening hours sitting around the *"kava"* bowl while women may form small groups in several accommodations doing weaving. These social gathering happen only occasionally and for a short period of time as the supply of kerosene is very limited. Kerosene lamps are the only source of lights (at night) in both islands. To economize their supply some families do away with kerosene lamps whenever there is sufficient moonlight. Each household buys about 15 litres of kerosene a month. The other social institution exists in both islands is the government primary schools.

Definition of project objectives

The general objective of this exercise is to identify the most appropriate technical, institutional, financial/economic and environmental friendly way of rehabilitating the solar PV projects at Mango and Mo'unga'one. By doing so, this study will provide direction and guidance to the achievement of the project's objective of "Accelerating the transition to national energy sectors that are ecologically efficient, and socially equitable through implementation of renewable energy projects."

At the implementation of the project it is expected that the social and economical life in both islands will be enhanced leading to reducing hardship and poverty which is parallel to the GOT national goals to ensure macroeconomic stability, promoting sustained private sector-led growth, and ensure equitable distribution of the benefits of growth.

The Beneficiaries

It is obvious that the primary beneficiaries will be the population of Mango and Mo'unga'one. However, the spill over benefits will satisfy the GOT to a great extent as the project will definitely contribute to achieving some of its goals already mentioned above.

Other PICs will also benefit from the programme as it is part of a global environment and development goal of PIGGAREP and IUCN-Oceania to reduce the growth rate of GHG emissions from fossil fuel use in the PICs.

Elimination of the available options

The solar home systems that are currently in both islands are now at the end of their operational lives and there is no possibility of extending their working life. So, the do-nothing scenario was discarded at the beginning of this analysis. But due to the rather inelastic demand for electricity in both islands other options were identified such as:

i) employing different energy generation technologies (e.g. diesel generated electrification system, wind power, biofuel, hybrid systems, etc) for energy supply;
ii) just continue with the existing systems is a business-as-usual scenario
iii) energy efficiency improvements rather than construction of new power plants; and;
iv) scrapping the old infrastructure and building a new one with a different design.

Concerning employing a different power generation technology such as a diesel-generated electrification system, the infrastructure may be located in the islands, but many factors were looked at including the level of income, population size, available technology, the production plan (including the utilization rate of the infrastructure), personnel requirements, the infrastructure's scale, location, physical inputs, timing and implementation, phases of expansion and financial planning and environmental aspects. In view of these factors, the costs for achieving the optimal level of energy supply in using a diesel-generated electrification system in both islands far outweigh the potential benefits. As a result, this alternative was deleted.

The "business as usual" (BAU) scenario was also looked at; unfortunately, this option will only benefit those very few with the funds to pay for their own spare parts and their installations. It will therefore stimulate a biased growth within the economy leading to greater inequality in income distribution. Basing on that expected outcome this option was omitted.

With regards to energy efficiency improvements scenario, there wouldn't be much difference in costs with totally replacing the whole systems. Improving efficiency will include maintaining the few parts and components that are still working. The risks of doing this is that the retained old parts will fail first and this will not only be a strain on the newly established financial resources for the islands but would have a negative impact on the communities' confidence in solar PV technology.

Finally, other generation options like biofuel and wind power and hybrid systems were looked at and the resources are not sufficient in the islands and the technologies are too technically complicated for the residents of the islands with the best solution being the scrapping the old infrastructure and building a new one with a different design. The option is therefore being assessed below.

Feasibility analysis

The geographical features and remoteness of both islands are contributing natural barriers to the success of the project. This binding constraint cannot be removed; however, excellent management skills and a well and effective operational plan may assist in reducing these obstacles. Such a well operational plan may include accumulating the stock of materials needed for maintenance (e.g. lights and fuses) which will avoid the costs for frequent travels to Lifuka for supplies.

At the heart of this is a major managerial constraint that is obvious at this stage. The officers selected to take charge of the project in both islands need special project management, technical, financial and reporting training as their performance will affect the technical and financial viability of the project.

On the economic barriers, the islands' level of income is not stable. Though their level of income is at a satisfactory level, these flows are not on regular basis as flows depend very much on the weather conditions and the market for their fishing and weaving products. However, conducting more awareness and educational campaigns with regards to household budgeting will eliminate or at least minimize the impacts of this constraint. In addition, care should be taken to ensure unauthorized use of electrical appliances is avoided as they may lead to faster deterioration of the system components.

Financial Analysis

The methodology used in this analysis for the determination of the financial return is the Discounted Cash Flow (DCF) approach. This analysis employed the following assumptions:

i) only cash inflows and outflows are considered (depreciation, reserves and other accounting items which do not correspond to actual flows are disregarded);
ii) costs are based on incremental values
iii) the horizon of the analysis is assumed to be 20 years
iv) the financial discount rate is 5%, expressed in real terms
v) constant prices are used
vi) the production of electricity is assumed to be constant over the project life
vii) project installation will be completed within a month
viii) estimated lifetimes for components: (1) fluorescent lamps – 1.5 years; (2) Batteries 12V/141Ah C/100 tubular and other battery components – 6 years.
ix) for simplicity's sake, the whole replacement cost of the aforementioned components with the exception of fluorescent lamps in the sixth (T$64,000.00), twelfth (T$64,000.00) and eighteenth (T$64,000.00) year (these values are not discounted)
x) the systems will be sold to households at the end of the 20 years at T$32,793.60 for Mango and T$52,754.91 for Mo'unga'one. The residual value in this analysis is equivalent to the market value of the facilities plus the expected revenue collection of five years beyond the project life-cycle.
xi) the investment is co-funded by the PIGGAREP and IUCN-Oceania.

Having set the project horizon, the investment costs are classified as followed:

i) fixed investments,
ii) start-up costs,
iii) the changes in working capital over the entire programme. Since there is no loan or any expected accounts payable involved, current liability equals zero for the total life cycle of the project. Therefore, changes in working capital equal current asset which is a positive sign in the costs table.

The fixed investments in the analysis are: buying of the panels, batteries and the supplement components, plus other equipments; extraordinary maintenance and the residual value which is positive as it is counted as an inflow.

The start-up costs in this analysis include costs such as: preparatory studies (including the feasibility study itself), costs incurred in the implementation phase, contracts for the use of some consulting services and training expenses.

The operation and maintenance (O&M) costs, excluding CT (when applicable), of the infrastructure (running normally) are as follows:

i) labour costs: 1 employee for each island (at 30% of island total revenue collection per year);
ii) other costs: raw materials; and administration costs which based on the wages of one employee for each island. The wage is set at 30% of each island total revenue collection per year.

The financial inflows come from the residual value of the investment and the monthly tariff paid by each household:

i) residual value of the investment: the residual value, over the 20 years of life of the plant, is set to be 34% of the equipment initial costs of both long- and short-life parts of the investment plus $255.24 expected to be collected from each solar home system each year for the next three years after the 20 years of the project life cycle. This revenue is allocated in the last year (20^{th}) of the analysis period;
ii) energy revenues: the generated electricity is sold at a flat price of $15.00 a month, in the operational condition of the solar system, that is a revenue of $180.00 per year from each solar home system except the first year which revenue collection will only be done for 10 months.

Having collected the data on investment costs, operating costs and revenues, the analysis looks next at the evaluation of the financial return on the project.

The indicators for decision criteria in this analysis are:

i) the financial net present value of the project (FNPV);
ii) pay-back period;
iii) benefit-cost ratio; and
iv) the financial internal rate of return (IRR).

Financial Net present Value (FNPV)

The financial net present value (FNPV) is defined as the sum that results when the expected investment and operating costs of the project (suitably discounted) are deducted from the discounted value of the expected revenues. Using the FNPV, both projects (Mango = $54,620.61; Mo'unga'one = $361,425.00) are potentially worthwhile (or viable) as both

projects FNPV is greater than zero; i.e. the total discounted value of benefits is greater than the total discounted costs. Therefore, the analysis suggests that both projects should be accepted.

Benefit – Cost Ratio (BCR)
This is the ratio of the present value of benefits to the present value of costs. The Mango project is potentially worthwhile as its benefit-cost ratios (Mango = 2.87) is greater than 1 whereas it is the opposite for Mo'unga'one as its Benefit-Cost ratio (0.60) is less than 1. However, this analysis does not adopted BCR as the prime decision rule as BCR can sometimes confuse the choice process when the policies under consideration are of a different scale, yielding misleading results.

Internal Rate of Return (IRR)
The analysis showed that the IRR for both island projects (Mango = 0.07; Mo'unga'one = 0.16) are greater than the discounted rate applied in this analysis, therefore, both projects are potentially worthwhile.

Payback Period
Each project's payback periods is determined by counting the number of years it takes before cumulative forecast cash flows equal or exceeds the initial investment. Mango will recover the initial costs of investment in 20 years, while Mo'unga'one recovers its initial investment costs in 15 years.

Financial sustainability
The net flow of cumulative generated cash flow for Mango is negative for all years except the last during the project life cycle. In view of that the analysis argues that Mango project is not financially sustainable until the year 20 while Mo'unga'one will be financially sustainable toward the end (15th year onwards) of the project.

Socio-Economic Analysis
The conversion factors allowed for the calculation of the social costs due to the investments, the running costs and the replacement of 'short' life equipment (see financial analysis), the social benefits due to the residual value of the investment, and the revenues of the waste treatment and energy production. The economic analysis also considers the externalities (positive and/or negative) that are not accounted for in the converted financial inputs and outputs quoted above.

Conversion factors adopted in economic analysis
First, the negative externalities are taken into account: the cost of improper disposal of batteries when replaced; cost of misusing and unsafe handling of hydrochloric acid; and improper disposal of any solid wastes used in the solar home systems.

Next, the positive externalities deriving from the reduction of kerosene consumption and smoke emission are taken into account.

ENPV
As both ENPV (Mango = 310,104; Mo'unga'one = 1,133,829.73) are positive both island projects are potentially worthwhile.

Benefit–Cost Ratio (BCR)

Contrasting to the financial analysis results, both projects (Mango = 4.55; Mo'unga'one = 2.53) are potentially worthwhile since both benefit-cost ratios are greater than 1.

Internal Rate of Return (IRR)
The IRR for both island projects (Mango = 1.85; Mo'unga'one = 1.01) are greater than the discounted rate applied in this analysis, which is 0.05, therefore, both projects are potentially worthwhile.

Payback Period
Both island projects will recover their initial investment costs in 3 years.

Sensitivity Analysis
Given the above analysis it involves estimating many factors that are subject to uncertainty; therefore sensitivity analysis is used to gauge the potential for a decision variable to diverge from its estimated value.

Sensitivity analysis here is also used to calculate the effect of variation of monthly generated electricity fee on the decision criteria, such as NPV and/or BCR.

When varied the price of generated electricity from $15 a month to $13 a month, holding other factors constant, NPV changes from $54,620.61 to $47,806.62 for Mango and from $361,161 to $340,346.28 for Mo'unga'one. This means that both projects are potentially worthwhile as both NPV are positive.

About the BCR, Mango changes from 2.87 to 2.63 while Mo'unga'one changes from 0.59 to 0.57. This means that Mango project is potentially worthwhile as its BCR is greater than 1 while Mo'unga'one project is not potentially worthwhile as its BCR value is less than 1.

If the price increases to $18 then NPV for Mango changes to $58,839.31 while Mo'unga'one changes to $361,633.31. This means that both the Mango and Mo'unga'one projects are potentially worthwhile as both NPV values are positive. For BCR Mango project stays potentially worthwhile as its BCR value (2.68) is greater than 1 while Mo'unga'one is not potentially worthwhile as its BCR value (0.73) is less than 1.

CHAPTER 8: ASSESSMENT OF THE CAPACITY BUILDING NEEDS OF THE PROJECT

Capacity development is required to offset barriers (institutional, financial and technical) of inadequate capacity in the implementation of the proposed solar photovoltaic rehabilitation project for Mango and Mo'unga'one. In the 1980s and early 1990s, technical problems were the dominant reasons for PV project failures. The HSEI was launched in the year 2002 with a new institutional model which basically built on lessons learnt from the experiences of the past. It aimed at bringing all existing and future solar PV installations into one standard institutional and management model. Management and institutional guidelines have now been developed to suit the local socioeconomic circumstances and are being closely monitored and changed to suit the overall objective of the TOISEP.

Several management, institutional, technical and financial barriers to the performance of the HSEI were identified during the Annual General Meeting held at Kotu Island and are considered relevant in the implementation of the Mango and Mo'unga'one PV rehabilitation project. They included the following:

i) Island Technicians failed in their reporting responsibilities
The study found that there was no monthly technical report from the islands to the main office. This was for various reasons, including the fact that some technicians were just recruited, some were unable to understand the forms being supplied by the HSEI office and because the HSEI office did not demand the timely submission of the monthly reports. It was also stated that the technicians did not fully understand the technical information that has to be entered into the monthly report.

ii) Lack of commitments by the island technicians to their duties
HSEI management committee on its meeting in Kotu realized that the current wage level for the technicians was not enough of an incentive and agreed to raise the wage level from it current 10% to 30% of each technician's monthly collection.

iii) Misunderstanding between Island Technicians, Town Officers, and Users on their responsibilities
There have been cases is which the island technicians cannot conduct the disconnection of power from some households because of interventions by the Town Officers. There is therefore not a clear understanding of the demarcation of responsibilities between the technicians, the town officers and the users.

iv) Lack of understanding of the HSEI management guidelines
Some electricity users at Kotu were surprised to learn of the provisions for tampering with the system components, the unauthorized connection of electrical appliances, the $20 reconnection fee, etc.

v) Inadequate managerial skills in the HSEI office.
This issue creates incompleteness in accounting records and technical records of the office. A more comprehensive computerized accounting and technical system is needed in order for the HSEI secretariat to effectively manage the programme.

vi) Poorly equipped HSEI office

The HSEI office is in need of a computer for storing and analyzing the technical and financial data. It should also have internet connection to facilitate the sharing of data and communication with the EPU office.

Public Awareness and Training

There is obviously a need for some awareness and training activities for the communities of Mango and Mo'unga'one, with the participation of the of all the other islands communities in the HSEI. The following should be considered and implemented as part of this rehabilitation project:

i) Consultation meeting with the island communities on the management guidelines, in particular, clarifying the responsibilities of the technicians, the town officers and the users. The issues regarding the monthly fees and the disconnection policy should be clarified too.

ii) Training for the technicians. There should be at least some serious intensive training for the technicians which should not only cover the technical aspects of solar PV but more importantly their reporting obligations. The payment of the technicians' wages should not be based on the 30% of the collected fees only but also on the completeness of their reporting responsibilities.

iii) Training for the HSEI office manager trainee
The office manager trainee will benefit a lot from being exposed to other PV programmes in neighbouring PICs. He/she should also undergo training by the EPU on its administrative, coordination, technical and financial responsibilities.

iv) Providing the necessary tools and equipments to the HSEI office and the island technicians. The HESI office manager trainee and the island technicians cannot function effectively unless they are provided with the necessary tools. The island technicians should at least be supplied with a basic maintenance kit which should include amp and volt meters. On the other hand, the office manager trainee should have a master maintenance kit together with a computer and internet connection. While a boat is a necessity for the HSEI, the costs of owning and operating one will be too much of a financial drain on the HSEI resources. Hiring of a boat on costs only basis and planning the trips on a co-shared basis would be a more cost effective option for the HSEI.

CHAPTER 9: CONCLUSION AND RECOMMENDATIONS

The communities of Mango and Mo'unga'one would benefit socially, environmentally and economically from a rehabilitation of their solar photovoltaic systems. While few within the communities have kept their PV systems working through their own effort and funds, most would benefit from a subsidization of the capital costs by the IUCN EESLI.

The existing HSEI structure should be employed for the management of the rehabilitation project. The communities must apply to participate in the rehabilitation programme and commit themselves to abide by the rules and management procedures of the programme. The advance payment of the installation fee (T$200) should still apply as should the $13 monthly fee.

It therefore means that Mango and Mo'unga'one should each form their island solar energy committee and seek full membership in the HSEI. The inclusion of Mango and Mo'unga'one provides an opportunity to review, make changes and strengthen the capacity of the HSEI to effectively manage the PV projects in its member communities.

The sustainability of the HSEI is presently at a crossroads. Changes and capacity building measures must be conducted to improve its viability. The following are recommended as a matter of priority and urgency:

i) Conduct intensive consultation meetings with the communities to clarify the management guidelines for the project and to clarify the roles and responsibilities of the major parties to the project (HSEI office manager, town officers, technicians and users).
ii) Provide the necessary incentives to the office manager trainee and the technicians. While it is noted that a wage increase has been approved by the Management Committee of the HSEI, this is expected to result in a corresponding improvement in the project's technical and financial performance. If this can not be achieved then the wage increase is not justified.
iii) Provide a stronger link between government and the HSEI. It is noted that the report and minutes of the HSEI go only as far as the Chair of the HSEI. The reports and minutes should now be forwarded from the chair of the HSEI to the National Energy Committee whereby relevant information and recommendations can be forward to Cabinet.
iv) Train the island technicians and the HSEI staff on their administration, financial and technical responsibilities and provide the necessary technical tools and office equipments.

Annex 1

TERMS OF REFERENCE

Technical, Institutional, Economic and Environmental Assessment of the Mango and Mo'unga'one Rehabilitation Project – FEIA PROJECT

Background

Tonga is overwhelmingly dependent on imported petroleum for its commercial energy needs. About 98% of the urban households in Tonga are electrified while it is only about 75% of rural households. Overall, more than 80% of the population of Tonga has access to electricity. Providing a reliable, affordable and an environmentally source of electricity to the people of Tonga is among the priority of the government.

Rural areas in the outer islands are still home to a significant percentage of the population of Tonga. The Government sees the provision of improved infrastructure services including basic electrification as an important contribution to the creation of a more attractive environment in the outer islands thus helping to mitigate urban drift. Against this background the Government of the Kingdom of Tonga (GoT) has proposed an electrification programme be undertaken in the island of Mango and Mo'unga'one. Both islands were part of a solar rural electrification programme funded under the LOME Convention for Pacific Island Countries (PICs) during the late eighties. The Mango solar systems were installed in 1987 under the LOME II Convention and the Mo'unga'one systems were installed in 1995 under the Lome III agreement. A survey carried out in 2006 found that most of the systems are not operating due to a number of reasons including, lack of maintenance, poor quality parts, poor management structure and lack of Government support. The GoT has requested the Government of Italy (GoI) for financial assistance to rehabilitate the solar systems in both Mango and Mo'unga'one islands. Funding has been provided through a grant provided by the GoI to Tonga and 11 other PICs under an agreement signed between the PICs missions in the United Nations in New York and the GoI.

The major objective of the project is to rehabilitate all the solar home systems at Mango and Mo'unga'one islands in the Ha'apai group to bring them to operational status. A new management and institutional arrangement will be put in place to ensure the sustainability of the solar systems. The project will be implemented by the Energy Section of the Ministry of Lands, Natural Resources, and Environment in collaboration with IUCN-Oceania and the PIGGAREP.

The PIGGAREP, [Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project] a regional programme implemented by SPREP aiming at reduction of the growth rate of GHG emissions, will support the FEIA Project through the conduct of a detailed Financial, Economic and Environmental Impact and Institutional Assessment of the Mango and Mo'unga'one Rehabilitation Project.

This project will contribute to the reduction of the growth rate of GHG emissions from fossil fuel use in Tonga, particularly in the country's electricity sector. Generally this will be achieved through the removal of barriers hindering the promotion and application of renewable energy technologies practices and technologies in the country's electricity sector.

It will also address the barriers to the widespread utilization of inappropriate renewable energy appliances in the rural and remote sector.

The Target Communities
The islands of Mango and Mo'unga'one in the Ha'apai Group.

Name of Island	Number of Households	Population
Mo'unga'one	37	184
Mango	23	140
TOTAL	**60**	**324**

The islands consist of approximately 324 people in about 60 households with two primary schools. The communities also include four community halls and four church buildings. The major economic activities comprise of the selling handicraft, fishing and sometimes root crops and the operation of some few small businesses (e.g. retail stores)

Objectives of the Assessment

General
The general objective of this exercise is to identify the most appropriate technical, institutional, financial/economic and environmental friendly way of rehabilitating the solar PV projects at Mango and Mo'unga'one.

Specific
The specific objective is to assess the technical, institutional, environmental and economic issues related to this proposed photovoltaic rehabilitation project. In identifying the most suitable option the study should include a comprehensive analysis of the resulting project impacts.

Specific Tasks

The study shall generally comprise of the following tasks:
- Assess the current and potential future demand for electricity in the target communities;
- Assess the costs of the electricity by type of generation and assess the community's willingness and ability to pay for the electricity; and
- Identify an institutional and management system that would best support the future sustainability of the electricity supply.
- Assess the potential impacts of the proposed photovoltaic rehabilitation on the environment of the target communities.

A team consisting of four locals is to be engaged to carry out this task.

The above tasks shall be accomplished, but not restricted, through the following activities:

1. Technical
- Assess the current technical status of the installed PV systems on the islands
- Assess the effectiveness of the maintenance systems employed in the two islands

- Conduct a technical design of the rehabilitation project including the specifications for the system components
- Identify measures for ensuring the sustainability of the rehabilitation project

2. Institutional

- Identify an institutional and management structure that would best promote the sustainability of the electrification services in the target communities
- Assess the social benefits of the proposed rehabilitation programme to the target communities, including gender, women, youth and underprivileged
- Assess the potential productive uses of renewable energy in the two islands.
- Asses the potential impacts of the electrification options on the livelihoods of the target communities, highlighting particularly how the project is going to improve the social and cultural obligations of the disadvantage groups especially women
- Assess the perceived benefits of the project are (to the different social groups e.g. women, men school children, etc) and Assess the perceived benefits of the project are (to the different social groups e.g. women, men school children, etc) and whether these perceived benefits were realised (this would be applicable to the previous solar systems)
- Assess how the project will improve the living standard and reduce hardship for different social groups or the community at large. How does the project reduce the burden on women's chores? What lessons can be learnt from the project that be useful to replicate?
- Assess the capacity of Mo'unga'one and Mango Islands to sustainably manage their electrification programme and identify required capacity building and awareness initiatives

3. Environment

- Assess the potential impacts of the electrification options on the environment, in particular to land use
- Assess the compliance of the electrification option with environmental and other safeguards, government clearances and approvals, and identify any inconsistencies with current government policies.
- Assess the potential greenhouse gas savings from the generation options
- Assess potential CDM benefits to the target communities from the electrification options

4. Economic

- Conduct an economic analysis of the electrification options including life-cycle costs, benefits and risks and constraints for the project activities and outputs
- Identify economic indicators for the electrification options including, but not limited to, cost benefit ratio, pay back period and internal rate of return
- Assess the economic benefits of the project or components of the project to the disadvantage especially women
- Assess the existing monthly fees currently applied in the HSES Inc. and a proposed monthly fees for Mango and Mo'unga'one Rehabilitation Project.

Reporting

The team shall provide an updated feasibility report [both hard and electronic copy] so as to enable the Tonga Government, SPREP and IUCN to decide on how best to proceed with the

proposed photovoltaic rehabilitation project. The team may also be required to make a presentation in Tonga to stakeholders. The report shall be submitted in duplicate (both hard and electronic copy) to the Energy Section of the Ministry of Lands, Survey, Natural Resources and Environment.

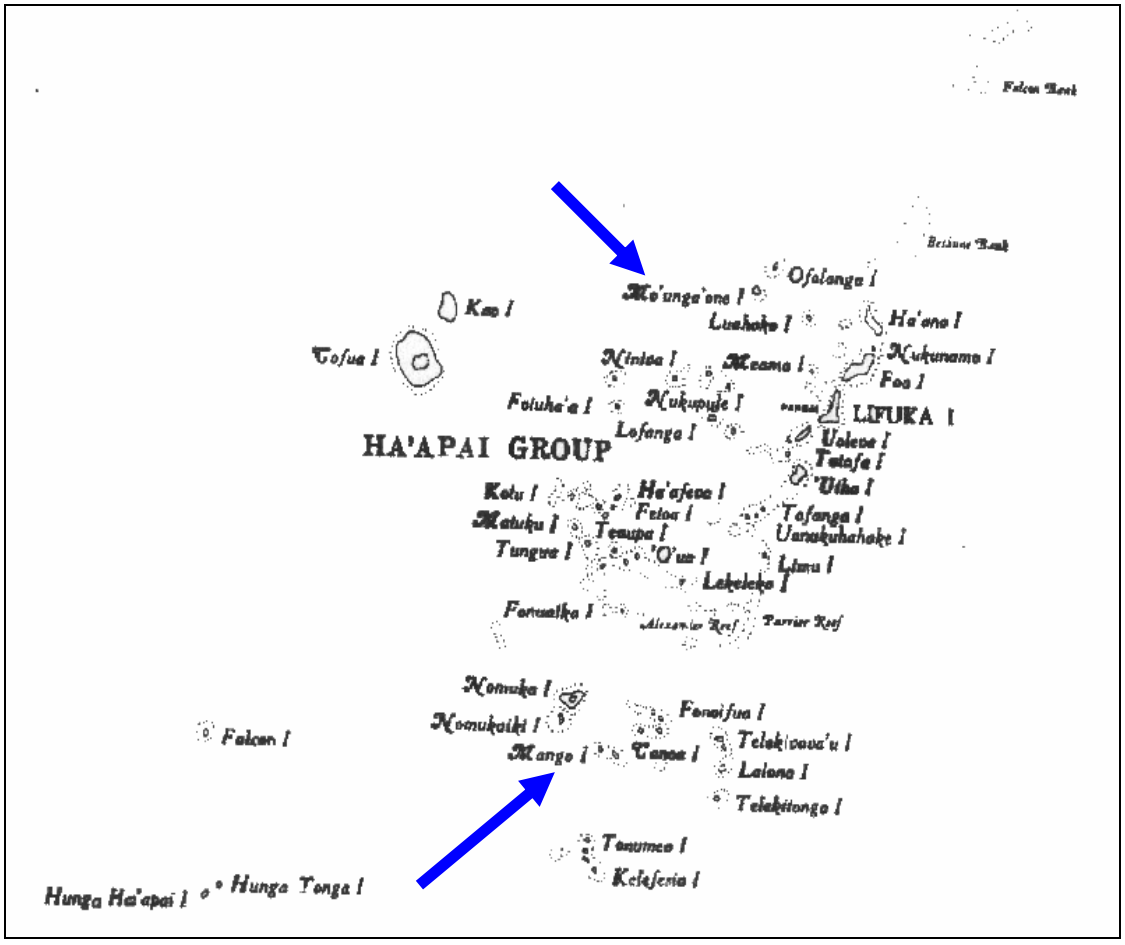
Annex 2: Project Logframe

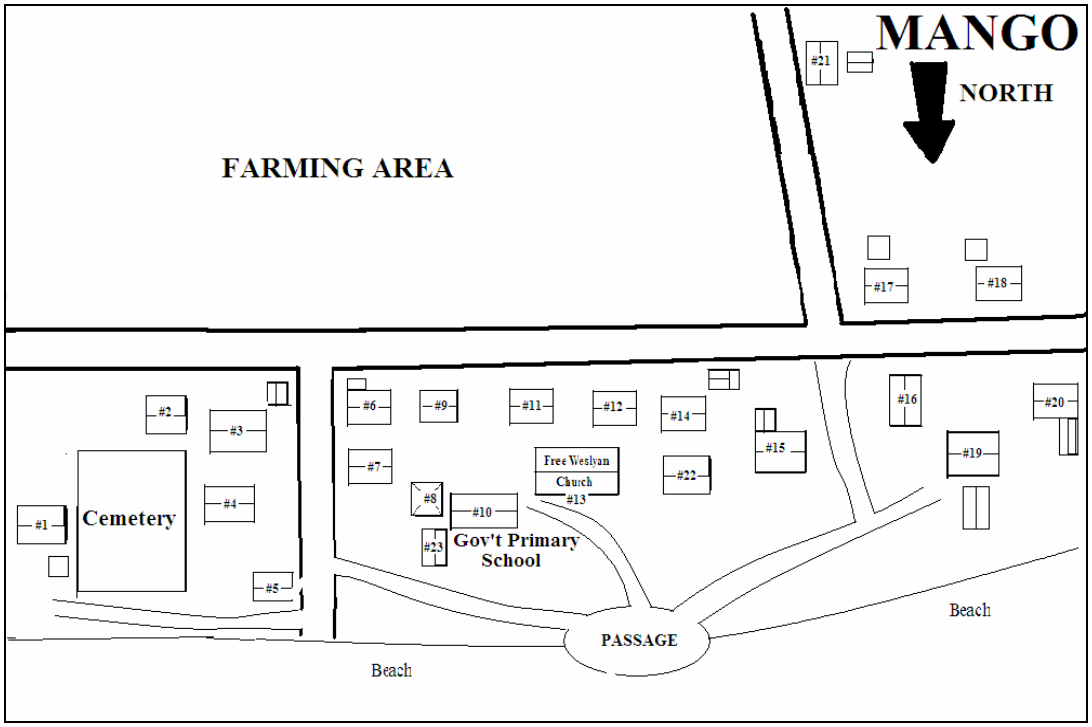
The project planning matrix (PPM) presented below was developed to assist in the implementation of the project. It reflects all expected activities and outcomes/outputs of the Mango and Mo'unga'one PV Rehabilitation Project.

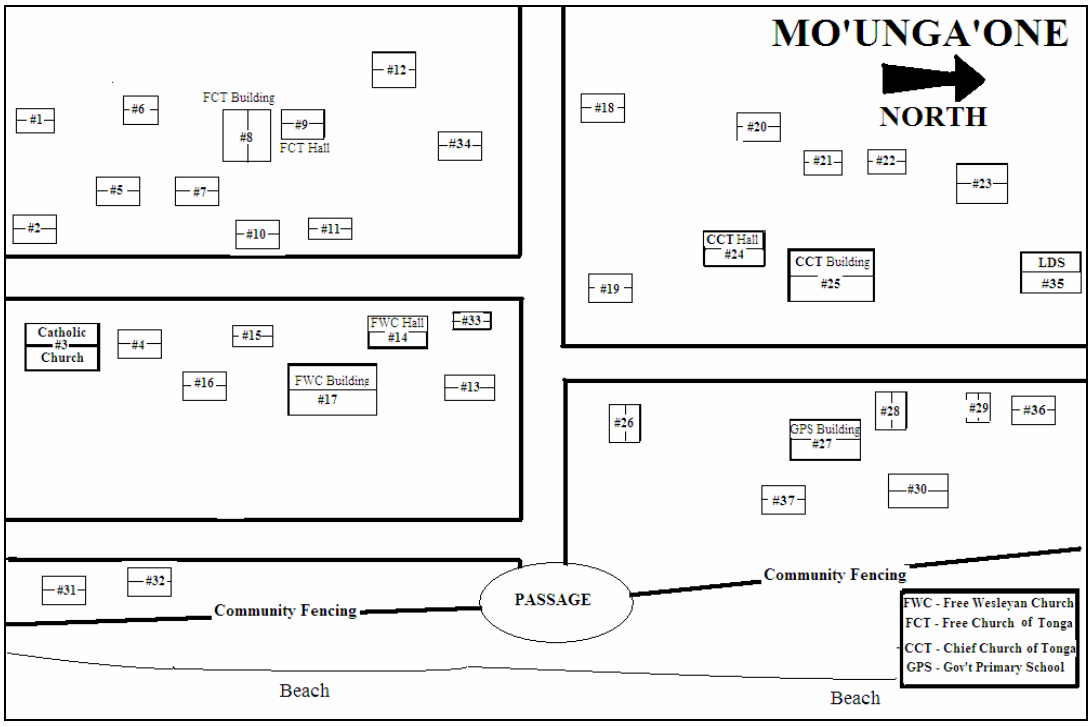
Strategy	Objectively Verifiable Indicators (OVI)	Means of Verification (MoV)	Critical Assumptions and Risks
I. DEVELOPMENT OBJECTIVE/GOAL			
Accelerating the transition to national energy sectors that are ecologically efficient, and socially equitable through implementation of renewable energy projects	Tons of GHG saved Improved Income Better equipped community facilities	GHG Inventory Household surveys Survey of community facilities	Support from relevant Government, NGO and community stakeholders throughout project life
II. IMMEDIATE OBJECTIVES/OUTCOMES			
Improved quality of the environment and social life at Mango and Mo'unga'one	tons of CO2 mitigated No. of community facilities electrified	Project Reports	Installed equipments withstand the corrosive environment of the islands
Improved income for the Mango and Mo'unga'one communities	Household disposable incomes	Household survey	Community halls will be for women to weave in there as a group
Improved knowledge and technical experiences with solar PV within the Ha'apai communities, Mango and Mo'unga'one included.	At least 20 trainees from Ha'apai undergo practical training on PV.	Training Report, EPU Annual Report and HSEI Annual Report	Migration and long absences of trained technicians from the islands
Strengthened institutional structure for managing solar PV projects at Ha'apai	No. of members in the HSEI	Registry of Incorporated Societies Minutes of the meetings of the HSEI	Cooperation of the existing members of the HSEI and the EPU
III. OUTPUTS / ACTIVITIES			
Establish battery charging stations for people with special needs for electricity Make available portable PV systems on hire for special social events like funerals, feasts, fund raising, special church services, etc.	At least one battery charging station established in each island At least one full portable PV system for hire in each island	Installation Report Installation Report	Islanders will buy rechargeable batteries A fair and equitable system is adopted for the hiring of the portable PV systems
Electrify the community halls and encourage women groups to do their weaving in the halls	A community hall each on both islands is electrified	Installation Report	Groups that use the lights in the halls pay for their use
Conduct training workshop for the Ha'apai Solar Technicians	At least 20 technicians, including 3 technicians each, from Mango and Mo'unga'one receive practical training on PV	Training workshop report	The training and assessment will be conducted as joint EESLI-PIGGAREP activities

Strategy	Objectively Verifiable Indicators (OVI)	Means of Verification (MoV)	Critical Assumptions and Risks
Support to the assessment of the PV installations prior to the project commissioning	At least 5 trained solar technicians take part in the post installation assessments	Assessment and Commissioning Reports	
Conduct a review of the effectiveness of the HSEI as part of the rehabilitation feasibility study	Review study completed	Feasibility study report	Cooperation of the members of the HSEI
Conduct and support the annual meetings of the HSEI	2 successful meetings of the HSEI are completed	Minutes of the HSEI meeting	

Annex 3: Map of the Ha'apai Group and the layout of Mango and Mo'unga'one




MANGO
NORTH
FARMING AREA
#21
#17
#18
#2
#3
#6
#9
#11
#12
#14
#16
#20
#7
#15
#19
#4
#8
#10
#22
#1
Cemetery
Free Weslyan Church #13
#23
Gov't Primary School
#5
PASSAGE
Beach
Beach


MO'UNGA'ONE
NORTH
#12
#1
#6
FCT Building
#8
#9
FCT Hall
#34
#5
#7
#2
#10
#11
#18
#20
#21
#22
#23
CCT Hall #24
CCT Building #25
LDS #35
#19
Catholic #3 Church
#4
#15
FWC Hall #14
#33
#16
FWC Building #17
#13
#26
GPS Building #27
#28
#29
#36
#37
#30
#31
#32
Community Fencing
PASSAGE
Community Fencing
FWC - Free Wesleyan Church
FCT - Free Church of Tonga
CCT - Chief Church of Tonga
GPS - Gov't Primary School
Beach
Beach

Annex 4: Summary Record of the Meeting of the HSEI

Seventh Meeting of the Management Committee of the Ha'apai Solar Electricity Incorporated, Kotu Island, Ha'apai: 14th October 2008

The Seventh Meeting of the Management Committee of the HSEI was held on the 14th October at Kotu Island. The following members were present

1. Hon. Malupo	Chairperson	Governor of Ha'apai
2. Kepueli 'Ioane	Governor's Office	Secretary to the Governor
3. 'Atu He	Kotu Island	Town Officer
4. 'Iloa 'Alafoki	Kotu Island	Solar Technician
5. Lasitani Levani	Mango Island	Town Officer
6. Tu'a Telefoni	Mo'unga'one Island	Town Officer
7. Anau Poutele	Mo'unga'one Island	Solar Technician
8. Sifa Fualalo	Fotuha'a Island	Town Officer
9. Saia Vaisima	Fotuha'a Island	Solar Technician
10. Feleti Faha'ivalu	Fonoifua Island	Solar Technician
11. Siua Moimoi	Fonoifua Island	Solar Technician
12. Sione Finau	Tungua Island	Solar Technician
13. 'Uluakiola Kafoika	Mango Island	Solar Technician
14. Sione Malupo	Tungua Island	Solar Technician
15. Fainga'a Pule'anga	Kotu Island	Solar Technician
16. Metui Fakatou	'O'ua Island	Solar Technician
17. Sione Topui	Mango Island	Solar Technician
18. Rev Viliami 'Epenisa	Free Wesleyan Church	Church Minister, Kotu
19. 'Asipeli Palaki	MLSNR&E	Acting CEO
20. Tevita Tukunga	MLSNR&E	Chief Energy Planner
21. 'Ofa Sefana	MLSNR&E	Energy Officer
22. Simote Mahe	MLSNR&E	Surveyor
23. 'Aisea Tu'itupou	HSEI Office	Office Manager Trainee
24. Sione Fifita	Private	Consultant
25. Solomone Fifita	SPREP	Project Manager

The meeting started with a prayer led by the church minister from the Free Wesleyan Church of Tonga, Kotu.

The Chair in delivering the opening address emphasized the need to work cooperatively and honestly for the improvement of the standard of living in the islands. He welcomed the delegates, particularly the representatives from Mango and Mo'unga'one.

In providing a background to the meeting by Ofa Sefana [Secretary], he emphasized the fact the HSEI Management Committee is still the decision making body of the programme. He stated that the Committee has the authority to direct its Secretariat what to do and how its resources should be spend and invested.

Nine papers were presented to the meeting. The following were the major decisions made:

1. The Agenda of the meeting was endorsed.
2. The minutes of the committee's last meeting was endorsed.
3. The meeting endorsed the annual report of the Secretariat, including the Committee's financial report, pending an Audit which will be conducted by the Government Auditor in late October;
4. In sharing the experiences from the islands, the Committee noted with satisfaction the current working status of the PV systems although component failures have been reported from a few of the islands;
5. The Committee noted the need to provide additional funds to cater for the Secretariat's annual financial obligations and agreed that the following amendments be made to HSEI Management Guidelines:
   – That Clause 7 [iii] be amended to reflect that not less than 45% of the monthly fee collected shall be put aside for future maintenance while 55% be used to cover the Committee's Annual Operation and Maintenance costs.
6. Agreed that the Office Manager Trainee's [OMT] salary be adjusted to reflect the Government's 80% salary adjustment. The approved new salary scale for the OMT is equivalent to Government Civil Servant salary scale Level 13A and be effective on 1st October 2008.
7. Agreed that the Island Technicians' wages be readjusted and to be increased by 10% to 30% of collection. This new wages adjustment is to be effective on 1st October 2008.
8. Noted that Mango and Mo'unga'one islands are not yet full members of the Committee and the fact that the IUCN would assist to rehabilitate the PV systems in these two islands before they can become full members.
9. Noted with concern the low rate of the monthly fee collection.

The Chair in closing the meeting and thanked everyone for their participation and extended to SPREP, through PIGGAREP, the appreciation and the gratitude of the Committee for their generosity to review the HSEI. The Chair personally thanked Solomone Fifita for his continuing assistance to the Committee and the town officer of Kotu and his people for their friendliness and hospitality. He concluded by cautioning the town officers and technicians not to get too entangled with who is in charge but what can and everyone can do to promote the sustainability of the project.

The meeting was closed with a prayer by Reverend Viliami 'Epenisa.

Ofa Sefana
HSEI Secretary