

Pukapuka Power Sector/Feasibility Report 2004

*Prepared as part of the UNDP/UNESCO Technical Assistance
Project “Increase the Utilisation of Renewable Energy
Technologies in the Cook Islands Energy Supply”*



Foreword

The consultants would like to thank the many people who provided information for this report, responded to the energy surveys and assisted in carrying out the energy surveys. These include the Director and staff of the Energy Division who assisted in the many aspects of the field visits and data collection as well as advising on cultural and traditional protocols, the respective Island Councils, Mayors, Island Secretaries, Administrations and Aronga Mana for their kind assistance and hospitality. Our thanks also go to the Government Ministries and Departments which provided assistance and in particular to the people of Atiu, Mauke and Mitiaro for their warmth and generosity whilst visiting their communities.

However, the contents are solely the responsibility of the undersigned and do not necessarily represent the views of the Government of the Cook Islands (national or local), UNESCO, UNDP, nor the many individuals who kindly provided information on which the study is based.

Bruce Clay

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October 2004

ACRONYMS and ABBREVIATIONS

A	Ampere (measure of electrical flow rate)
a.g.l.	Above ground level
a.s.l.	Above sea level
AAGR	Average Annual Growth Rate
ABC	Arial Bundled Cable
AC	Alternating Current
ACP	African Caribbean Pacific Countries under the Cotonou Agreement with the EU
ADB	Asian Development Bank
Ah	Ampere Hour (measure of electrical energy)
Al	Aluminium
AVR	Automatic Voltage Regulator
CEO	Chief Executive Officer
CCCE	Caisse Centrale de Coopération Economique (Central Economic Cooperation Bank of France)
COE	Cost of Energy
DSM	Demand Side Management
Eff	Efficiency
EIA	Environmental Impact Assessment
ENSO	El Niño/El Niña oceanic climate cycle
GDP	Gross Domestic Product
GoCI	Government of the Cook Islands
Ha	Hectare
hr	Hour
HV	High Voltage
Hyab	Hydraulic hoist truck
Hz	Hertz (measure of electrical alternating current frequency)
IC	Island Council
IRR	Internal Rate of Return
JCB	Loader/backhoe tractor
kg	Kilogramme
kM	Kilometre
km²	Square kilometre
kV	Kilo Volts
kVA	Kilo Volt Amperes
kVAr	Kilo Volt Amperes Reactive
kW	Kilowatt
kWh	Kilowatt Hour
kWp	Kilowatt Peak output from a solar photovoltaic panel at standard testing conditions
LPG	Liquid Petroleum Gas
lt	Litre
LV	Low Voltage
m	Metre
m/s	Metres per second
m³	Cubic Metre
MFEM	Ministry of Finance and Economic Management
min	Minute
mm	Millimetres
MPS	Mitiaro Power Supply

MWh	Megawatt Hour (millions of Watthours)
NEP	National Energy Policy
NPV	Net Present Value
NZ	New Zealand
OMIA	Office of the Minister of Island Administrations
PACER	Pacific Agreement on Close Economic Relations
PEIA	Preliminary Environmental Impact Assessment
PIC	Pacific Island Countries
PICTA	Pacific Islands Trade Agreement
PREFACE	Rural Renewable Energy France-Australia Common Endeavour (SPC)
PV	Photovoltaic
qty	Quantity
SFC	Specific Fuel Consumption
SHS	Solar Home System
SWH	Solar Water Heater
SOC	Specific Oil Consumption
S.P.I.R.E.	South Pacific Institute for Renewable Energy (Tahiti)
Sq km	Square kilometre
TA	Technical Assistance
TAU	Te Aponga Uira O Tumu-Te-Varovaro (Rarotonga Power Utility)
tCO₂	tonnes of CO ₂
THD	Total Harmonic Distortion (measure of AC power quality)
TOR	Terms of Reference
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
V	Volt (measure of electrical pressure)
W	Watt (measure of electrical power)
Wp	Watts Peak (Peak power rating for solar panels)
WTG	Wind Turbine Generator

\$ = NZ\$ unless stated otherwise

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1 SUMMARY OF FINDINGS AND RECOMMENDATIONS

A household survey was made in Pukapuka in 2004 to determine the status of power availability from the 1992 PV installations and to determine the preferred characteristics for any future power system. The survey reached about 70% of the households and indicated that:

- Basic power services have been provided reliably by the PV systems since 1992 with only one household stating that no lights were working in the house at the time of the survey and with all houses indicating historically very low rates of power outages.
- More capacity is needed to operate refrigerators, videos and other mainstream, consumer grade appliances though the priority for obtaining those appliances appears low for the majority of the respondents.
- 24 hour power as is presently available is strongly desired to be continued.
- The great majority of households are willing to agree not to use small, high demand appliances such as electric kettles, electric toaster ovens, coffee makers, etc. if reliable 24 hour power is supplied.

Four technically practical options were considered for the expansion of electrification on Pukapuka that provide 24 hour power and allow the use of conventional AC appliances. The options are:

1. Diesel generation with the installation of reticulation for the distribution of power from a central location
2. Solar photovoltaic (PV) generation with the installation of reticulation for the distribution of power from a central location
3. Independent PV generation for each household with all generators the same size and sufficient for refrigeration, video and lighting
4. Independent PV generation for each household with generators sized to fit the expressed needs and willingness to pay of each household

Table 1-1 Multi-factor comparison of types of installation

Type of installation	First cost	Life cycle cost	Power reliability	Load growth flexibility	Maintenance and operational requirements
Diesel	Lowest	High	Lowest	Good	Highest
Central PV	Intermediate	Intermediate	Fair	Good	High
Identical individual PV	Highest	Highest	Highest	Good	Lowest
Individual PV sized to fit household needs	Intermediate	Lowest	High	Fair	Low

Consideration was also given to combining diesel generation with solar power but the concept clearly was inappropriate for the conditions on Pukapuka. It is noted that no

successful hybrid power systems have been installed and operated in the Pacific and in any case, for Pukapuka a hybrid systems could not represent a least cost option nor could it be an option with high reliability of power service. Therefore a detailed analysis of a hybrid system for Pukapuka was not carried out.

Although at the current diesel fuel and equipment costs, a diesel generator and associated reticulation system provides the lowest installation cost and an life cycle cost only slightly more than the lowest cost solar option, two factors greatly reduce its utility on Pukapuka:

1. *Uncertainty of fuel supply.* Shipping is irregular, capacity limited and historically fuel supply has not been reliable even with the existing small volume required. Maintaining a much larger volume of supply can be expected to be even less reliable.
2. *Maintenance requirements.* Twenty-four hour operation of a diesel generation system results in maintenance requirements that are quite high with regards to personnel skills and spare parts availability. Given the limited access to Pukapuka by ship or plane, delivery of parts for engine repair can be expected to be on the order of weeks or even months during which time the system will be crippled or power not available at all. The continuing availability of trained operators and diesel repair personnel is also difficult to assure for Pukapuka.
3. *Component failure results in major power outage.* Any failure of any component that shuts down an engine would cause the reduction in availability of power or loss of all power to the island thereby making power reliability only poor to fair.

Though the life cycle cost of the central PV approach is about the same as that of the diesel system (assuming no diesel fuel cost changes for 15 years), centralised PV generation systems are technically complex and obtaining spare parts for repairs is typically slow and problematic. Such systems have not yet been attempted in the Pacific but in other countries the results of trials of centralised PV power systems for village electrification in remote sites have generally not been successful.

Providing identical PV installations for all households is the highest in initial cost but also offers the highest power reliability and fewest maintenance and repair problems since the systems are technically simple and all systems use the same components. Multiple spares for all components of the systems can be easily kept on island. This approach also provides the maximum in load growth flexibility since an initial overcapacity would be installed and little or no added investment would be needed for a substantial increase in overall village load.

The lowest life cycle cost option is that of providing individual PV systems for each household that are sized to fit the expressed energy needs for each household. Maintenance complexity is not great but is higher than that of the approach using all identical systems since several different sets of components would be required to fit the differing power needs of households. Load growth flexibility would be very limited since system size would be fitted closely to the currently existing demand for energy and increasing system size to accommodate increased load would require substantial added investment.

Based on the above considerations, the consultants consider the installation of PV systems sized to meet individual household requirements as providing the best overall value while still providing excellent 24 hour power system reliability. However, this

option does limit the available power for each house to that initially installed making it necessary to make major technical changes in installed systems if there is the need to increase energy delivery capacity of a household system more than 15-20% above that of the initial installation. If economic development occurs and there is a desire for increased use of electricity, individual PV systems for each house that are all the same size and are sufficiently large to accommodate a full mix of appliances can provide the highest reliability of service of all options while providing for considerable load growth over the 15-20 year service life of the installations.

1 PROJECT BACKGROUND

1.1 Project Background and Objectives

The goal for renewable energy of the Government of the Cook Islands (GoCI), as stated in its National Energy Policy (2003), is to increase the utilisation of renewable energy technologies in the Cook Islands energy supply.

UNDP (Samoa) funded a Technical Assistance (TA) project to further this goal for renewable energy covering the islands of Atiu, Mauke, Mitiaro and Pukapuka. The project was executed by UNESCO (Apia) in cooperation with the Energy Division, Ministry of Works, GoCI.

The project has the following specific objectives with regard to the islands of Atiu, Mauke, and Mitiaro:

- To determine in detail what improvements, in the short term, should be undertaken in the current diesel based power systems.
- To determine in detail the technical, socio-cultural, economic, financial and institutional/management feasibility, in the medium term, of supplementing the current diesel systems with renewable energy sources.
- To determine in detail the technical, socio-cultural, economic, financial and institutional/management feasibility, in the long term, of replacing 100% of the current diesel based power systems with renewable energy sources.

With regard to the island of Pukapuka the specific project objective is:

- To preliminarily assess and recommend if the most optimal power solution is to improve the existing PV Solar Home Systems (SHS) or to install an AC power system based on diesel generators.

In addition based on the findings and recommendations a draft concept proposal for each of the four (4) islands will be developed. For detailed Terms of Reference (TOR) please refer to Annex G

1.2 Overall Methodology

Due to the high cost and difficulty of visiting Pukapuka, this report is based on a desk study and is considered the best estimate that can be made without an actual visit. A physical survey will need to be performed before a final rural electrification design for Pukapuka can be developed. However, since the preliminary estimates herein are based on recent experience for similar implementations, though the cost estimate may change following a physical survey and completion of the detailed design process, the relative cost ranking of the options is not likely to change.

Since the project design and cost is very dependent on the electrical requirements of the households and the choice of type of power system installation is dependent on the household's need for service reliability and type of appliances to be used, a household survey was made with 98 households (70%) responding. The results of the survey are attached as Annex A.

At this point, no recommendations for an institutional structure have been provided since that will vary according to the type of power system installed. In any case, the

institutional structure will necessarily have to concentrate its support structures on Pukapuka with minimal dependence for technical and spare parts support from the outside. For this reason, a technically complex hybrid type of system that employs both diesel and solar PV into a single power supply is not considered since experience in the Pacific and elsewhere indicates a low reliability for such systems when there is not good access to external technical support.

2 NATIONAL BACKGROUND INFORMATION

2.1 Physical Description & Population¹

The Cook Islands, as shown in Map 2-1, consists of fifteen small islands with a total land area of only 240 square kilometres (km²) located between latitudes 9°-22° South and longitudes 157°-166° West, about half way between Hawaii and New Zealand. Over 88% of the land is concentrated in the southern group of eight mostly elevated, fertile, islands where 90% of the populace lives. The northern Cook Islands are low-lying, sparsely populated, coral atolls. There are 120 km of total coastline. Arable land comprises 17% of the total and 13% is under permanent crops. The Exclusive Economic Zone (EEZ) is 1.8 million km².

The total population of the Cook Islands, as enumerated on 1 December 2001, was 18,027 including 3010 visitors, a 5.6% decline since the 1996 Census. Rarotonga, with 12,188 people, grew by 8.6% since 1996, the other Southern Group islands (4,013 people) declined by 26.0%, and the Northern Group (1,826 people) dropped by 25.6%. Although Rarotonga's total population has grown, the resident population – i.e. those usually resident on the island – decreased by 17% since the 1996 Census, largely due to out migration to New Zealand since Cook Island citizens have free access to New Zealand and through New Zealand on to Australia. Overall growth is due to an increase in tourists and short-term foreign workers. Current estimated population is 21,200 showing an increase over the 2001 Census figure of 18,027.

Table 2-1 summarises key physical characteristics and population by island. The capital, Avarua, is located on Rarotonga, the country's largest and highest island. All islands are inhabited except Manuae and Takutea although Suvarrow has only a caretaker living on the island.

Map 2-1 – Cook Islands



Source – CIA Factbook 2004

¹ The SPREP/GEF/UNDP Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report, May 2004 was used extensively for National background information

Table 2-1 – Key Features by Island

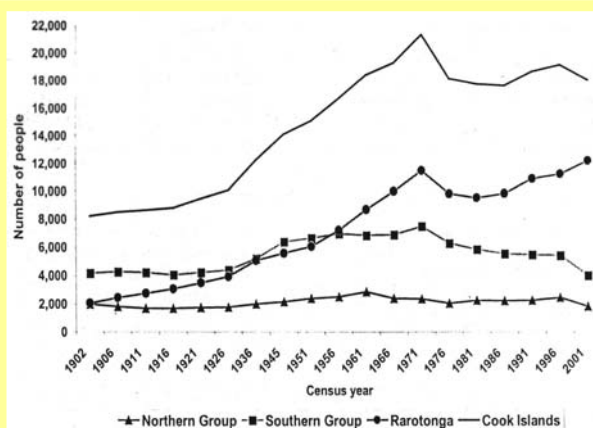
Island	Island Type	Area Sq Km	Maximum Elevation (meters)	Population (Dec 2001)	Principal Habitat
Southern					
Rarotonga	High Volcanic	67.1	652	12,188	Strand vegetation, extensively modified coastal forest & wetlands, fern lands, cloud forest, inland forest
Aitutaki	Volcanic & Coral	18.3	124	1,946	Strand vegetation, lowland forest greatly modified by agriculture, salt marsh wetlands
Atiu	Raised Coral	26.9	72	623	Makatea forest, wetlands greatly modified by agriculture, freshwater lake, fern lands
Mangaia	Raised Coral	51.8	169	744	Makatea forest, wetlands modified by agriculture, fern lands, cloud forest, inland forest, freshwater lake
Manuae	Atoll	6.2	10	0	Strand vegetation; significant seabird nesting sites
Mauke	Raised Coral	18.4	29	470	Makatea forest, wetlands greatly modified by agriculture, fern lands
Mitiaro	Raised Coral	22.3	15	230	Makatea forest, wetlands greatly modified by agriculture, freshwater lakes
Takutea	Sand cay	1	5	0	Strand vegetation; seabird & turtle nesting sites
Northern					
Manihiki	Atoll	5.4	5	515	Strand vegetation; seabird & turtle nesting sites
Nassau	Sand cay	1.3	9	72	Strand vegetation; seabird & turtle nesting sites
Palmerston	Atoll	2.1	5	48	Strand vegetation; seabird & turtle nesting sites
Penrhyn	Atoll	9.8	5	357	Strand vegetation; seabird & turtle nesting sites
Pukapuka	Atoll	1.3	5	664	Strand vegetation; seabird & turtle nesting sites
Rakahanga	Atoll	4.1	5	169	Strand vegetation; seabird & turtle nesting sites
Suvarrow	Atoll	0.4	5	1	Strand vegetation; seabird & turtle nesting sites

Source – 2001 National Census & Draft PIREP Cook Islands National Report, May 2004

Figure 2-1 shows the population trend from 1901 – 2001. In November 2003, the Ministry of Finance and Economic Management (MFEM) projected population through 2022, shown in Figure 2-2, with low, medium and high growth rates dependent on government policies regarding migrant labour, absorptive capacity for tourists (the mainstay of the economy) and assumptions regarding economic growth.

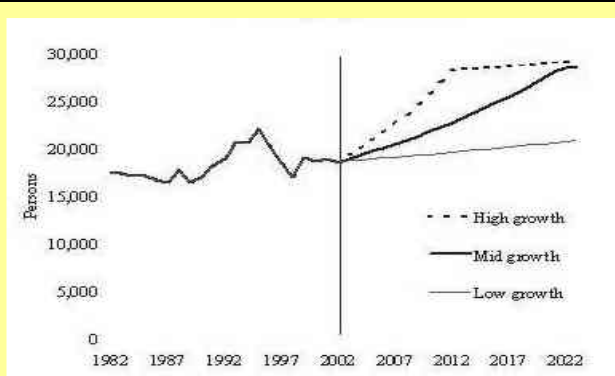
For the low growth scenario, the population's average annual growth rate (AAGR) over the next twenty-years is 0.8%; for the medium and high scenarios, it is about 1.6%. There are no projections by island or island group but outer island populations are expected to continue to decline. Assumptions regarding the population growth and the distribution among islands have, of course, implications for the likely patterns of future energy use and the preferred options to provide energy.

Figure 2-1 Cook Islands Population from 1901 – 2001



Source: SPREP/UNDP/GEF Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report May 2004

Figure 2-2 Population Projections



Source: SPREP/UNDP/GEF Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report May 2004

2.1.1 Environment

With the northern most island at 9° and the southernmost at 22°, the southern group experiences a somewhat different climate than the northern group. Throughout, however, the conditions are maritime tropical with a small range of temperature between day and night and only modest seasonal changes in temperature that increase in degree towards the south.

Rainfall typically is around 2000 mm with two thirds falling from November to April. Winds tend to be easterly trade winds with some seasonal variation. Rainfall patterns are strongly affected by the El Niño-Southern Oscillation (ENSO) with southern group rainfall falling by as much as 60% and northern group increasing by up to 200% during El Niño conditions.

On average, three cyclones every two years occur with November to April the usual cyclone season. A cyclone severe enough to seriously disrupt the economy occurs often enough for there to be a significant risk of flooding, storm surge and wind damage warranting its consideration in development activities.

The southern group, largely of volcanic origin, has 88% of the land area in the country and with its fertile soils represents most of the agricultural production and a

land based life style. The northern group, mostly atolls, is more dependent on the sea – particularly the atoll lagoon – as the land has poor soil and problems with water supply.

Biodiversity is not high anywhere in the Cook Islands but the northern atolls are very low in land-based biodiversity.

The Cook Islands has signed various treaties and conventions related to environmental protection, including the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, the United Nations Convention to Combat Desertification (UNCCD) and the Convention on Biological Diversity. The initial national communication to the UNFCCC, indicating greenhouse gas emissions, and vulnerability and adaptation to climate change, was submitted in October 1999. Table 2-2 summarises the status and date of signing of key environmental conventions.

Table 2-2 Status of Ratification of Environmental Treaties and Conventions by Cook Islands

Status in Cook Islands	? (SPREP Convention)	Conservation of nature (Apia Convention)	Hazardous wastes (Waigani Convention)	Nuclear free Pacific (Rarotonga Treaty)	GHG reductions (Kyoto Protocol)	Ozone depleting substances (Montreal Protocol, et al.)
Signed	25 Nov 87		17 Sep 95	06 Aug 85	16 Sep 98	Acceded to Vienna Convention,
Ratified	9 Jul 89	24 Jun 87	30 Oct 00	28 Oct 85	27 Aug 01	21 Mar 86
Entered into force	22 Aug 90	26 Jun 90	?	11 Dec 86	n/a *	

Note: The above treaties and conventions are briefly described in volume 1, the PIREP Regional Overview report

* The Kyoto Protocol is in force from 15 February 2004 for European Union members only.

Source: SPREP/UNDP/GEF Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report May 2004

2.1.2 Political Development

Named after Captain James Cook, who sighted them in 1770, the islands became a British protectorate in 1888, with administrative control transferred to New Zealand in 1900. In 1965 Cook Islanders chose self-government in free association with New Zealand, with the right to full independence at any time by unilateral action. The GoCI is fully responsible for internal affairs, with New Zealand retaining responsibility only for external affairs and defence. The government is a Westminster-style parliamentary democracy with Queen Elizabeth II as head of state. Parliament is unicameral with 25 members elected by popular vote to five-year terms under a voting system which gives considerable power to very small outer island constituencies. There is also a House of Ariki (chiefs), which controls large areas of customary communal land (and all land is customary), advises on traditional matters, and maintains considerable influence, but has no legislative powers. Each outer island has an elected Island Council presided over by a mayor.

As shown in Table 2-3, the government is signatory to the three Pacific regional trade and economic trade agreements, the most important of which are the Pacific Islands Trade Agreement (PICTA) and the Pacific Agreement on Closer Economic Relations (PACER; between PICTA signatories and Australia and New Zealand). The GoCI has also signed the Cotonou Agreement, providing membership in the African Caribbean Pacific (ACP) group of countries, and thus access to further development assistance from the European Union (EU).

Table 2-3 The Cook Islands and Regional Economic Treaties

Status	SPARTECA	PACER	PICTA
Signed	14 July 1980	18 Aug 2001	18 Aug 2001
Ratified	12 Nov 1980	28 Aug 2001	28 Aug 2001
Entered into force	01 Jan 1981	3 Oct 2002	13 Apr 2003

Source: SPREP/UNDP/GEF Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report May 2004

2.1.3 Economic Overview

The Cook Islands' economic development is hindered by the isolation of the country from foreign markets, the very limited size of domestic markets, limited natural resources, periodic devastation from natural disasters, a diminishing skilled labour force due to emigration, and inadequate infrastructure, particularly in the more remote islands. Tourism provides the economic base, agriculture has limited potential, and manufacturing is mainly fruit processing, clothing, and handicrafts.

Table 2-4 GDP at Constant 2000 Prices by Industry: 1997 – 2002 (NZ\$ millions)

Year	1997	1998	1999	2000	2001	2002	%%contribution in 2002
Total	153.3	152.1	156.2	177.8	186.6	193.3	100 %
Agriculture & fishing	16.3	21.8	23.8	23.8	23.1	25.3	13.1 %
Mining & manufacturing	4.0	5.0	5.1	6.1	7.0	6.9	3.6 %
Electricity & water	2.8	2.8	3.1	3.5	3.7	3.9	2.0 %
Construction	3.3	4.0	4.3	5.1	6.1	6.8	3.5 %
Wholesale & retail trade	29.2	30.7	33.6	39.7	42.3	45.6	23.6 %
Restaurants & accommodation	16.5	15.9	17.0	23.3	25.0	24.7	12.8 %
Transport & communications	18.4	17.1	20.2	25.2	28.0	29.0	15.0 %
Finance & business services	14.2	15.8	15.0	16.9	17.0	16.8	8.7 %
Community & personal services	3.8	3.8	4.4	5.2	5.7	6.4	3.3 %
Public administration	377.8	29.0	23.8	23.2	22.6	22.4	11.4 %
Ownership of dwellings	11.6	11.5	11.4	11.3	11.3	11.2	5.8 %
Less imputed bank charges	4.6	5.3	5.6	5.5	5.3	5.3	2.7 %

Source: SPREP/UNDP/GEF Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report May 2004

In 2002, pearls – although less than half the value of 2000 and 2001 exports – constituted 60% of all exports followed by fish and fruit. Trade deficits are offset by remittances from emigrants and by aid supplied overwhelmingly from New Zealand. In the 1980s and 1990s, the country lived beyond its means, maintaining a bloated public service and accumulating a large foreign debt. Recent trends in Gross Domestic Product (GDP) are summarised in Table 2-4 and key economic indicators are shown in Table 2-5.

Table 2-5 - Key Economic Indicators for the Cook Islands: 1997 - 2004

Indicator	1997	1998	1999	2000	2001	2002	2003 e	2004 p
GDP growth (% per year)	-1.5	-3.5	0.7	7.9	5.1	0.3	2.4	2.5
GDP/capita growth (% per year)	–	1.2	7.8	14.5	9.6	4.0	1.5	3.2
Value added in agriculture (% per year)	12.2	-17.2	-28.2	32.3	-24.0	–	–	–
Value added in industry (% per year)	6.4	3.3	7.0	6.8	-0.8	–	–	–
Value added in services (% per year)	-7.4	-0.8	13.9	6.6	0.6			
Inflation rate (% per year)	-1.2	1.2	1.3	1.7	9.4	3.9	3.4	3.4
Growth in merchandise exports (% per year)	-39.5	-10.0	41.2	38.6	100.9	-39.1	–	–
Growth in merchandise imports (% per year)	-4.8	-10.2	-3.6	18.0	13.0	-8.8	–	–
Balance of trade (US\$ m / yr)	-41	-37	-35	-40	-41	-40	–	–
BOP on current account (US\$ m / yr)	-4	-2	-2	-2	5	6	–	–
BOP on current account (% of GDP)	-3.7	-2.9	-2.2	-2.6	6.3	6.3	5.9	–
External debt outstanding (US\$ m)	31	65	64	58	53	54	–	–
Debt service ratio (% of exports)	11.0	3.7	4.8	3.5	3.5	–	–	–
Exchange rate NZ\$ / US\$1.00 (annual ave.)	1.5	1.9	1.9	2.2	2.4	2.1	–	–

Note: GDP and exchange rates for calendar year; other data for fiscal year (e.g. FY2003 = July 2002–June 2003); – = unavailable
Data from ADB differ somewhat from that of GoCI but both sets are broadly indicative of economic trends.

Source: *Asian Development Outlook* (ADB, 2003)
e = estimated; p = projected; BOP = balance of payments

Source: SPREP/UNDP/GEF Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report May 2004

Reforms from the mid-1990s, including the sale of state assets, the strengthening of economic management, a dramatic reduction in public sector employment, the encouragement of tourism, and a debt restructuring agreement have collectively rekindled investment and growth.

Outer islands development suffers from poor infrastructure and emigration. Outer island populations have decreased over the last decade since reforms were introduced to reduce the size of the public sector and bring about improved economic management. Public sector employment on outer islands has nearly been halved in the process. These reforms and the growth in tourism have seen positive GDP growth for the last five years.

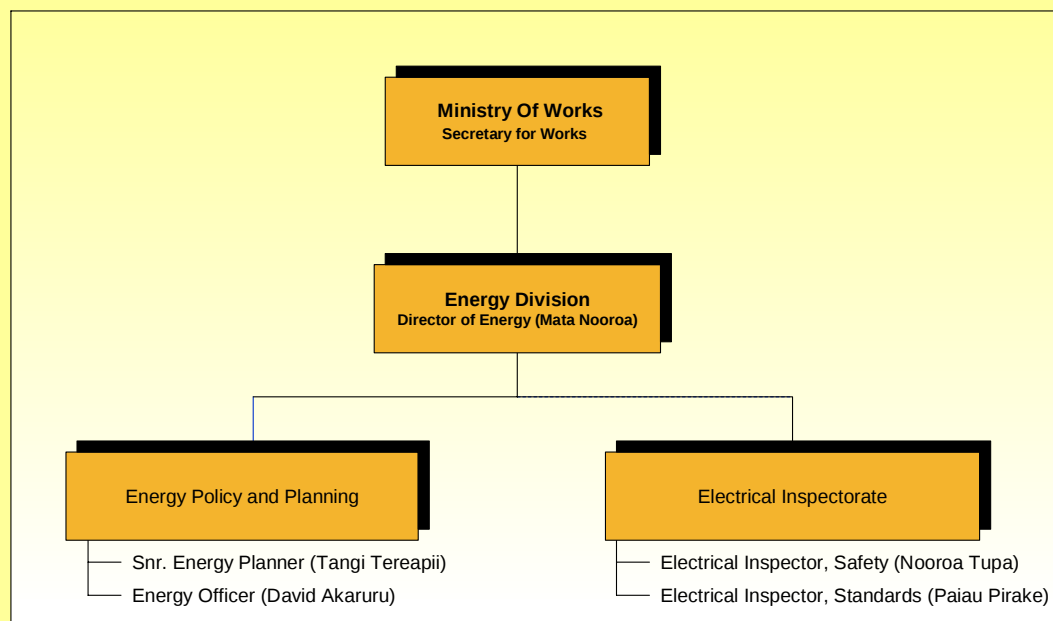
2.1.4 National Government Energy Arrangements

The Energy Division established within the Ministry of Works, is responsible for development of national energy policy, energy planning and electrical inspection. Its organisational structure is shown in Figure 2-3. An important function is to act as the interface between internal and external agencies supplying funding for renewable energy and energy efficiency projects. The Minister of Works is responsible for energy policy and electrical safety while the Minister of Energy is responsible for renewable energy through the Sustainable Energy Committee (SEC).

The capacity for energy planning, administration and policy is even weaker than the small number of staff suggest. Two of them deal primarily with inspections of electrical wiring and related electrical standards and safety issues, matters not normally handled by energy planning officials in other Pacific Island Countries (PIC).

The Director is also the Chief Electrical Inspector and spends up to half of his time managing inspection and safety matters.

Figure 2-3 Organizational Chart of the Ministry of Works, Energy Division (2004)



Source SPREP/GEF/ UNDP Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report May 2004

The Director is also responsible to the Minister for Energy for some aspects of the Division's work with an informal allocation of responsibilities shared between the Energy and Works Ministers. As shown in Table 2-6, Ministerial responsibilities for matters related to energy are actually scattered over a number of separate ministries and the mandates overlap. There appears to be some confusion among public servants and others regarding authority, responsibility, accountability and reporting.

The Energy Division responsibilities include the development of national energy policy, energy planning and the gathering of energy related statistics. The Division monitors electricity tariffs and petroleum usage but has no regulatory power or responsibility. The majority of the activity of the Energy Division is in the electrical inspection area and in acting as an interface between internal and external agencies supplying funding for renewable energy or energy efficiency projects and the project recipients. Energy Division staff also regularly provide technical advice and support to the outer island governments in energy matters though not formally mandated to provide that service.

Table 2-6 - De Facto Ministerial Responsibilities for Energy Matters (December 2003)

Ministerial Responsibility:	Prime Minister		Minister for Energy [†]		Minister for Island Administration	Minister for Works	Minister for Internal Affairs	
<i>Responsible for:</i>	Oil spills; Waste oil management; Env. impact assessments; Emissions	Electricity policy and tariffs on Rarotonga	Renewable energy; Sustainable Energy Committee	TAU social issues (e.g. street lighting)	Implicit subsidy for outer islands electricity (See note 5)	Energy policy overall; Electrical safety	Petroleum storage and safety	Petroleum pricing and quality
<i>Responsible through:</i>	Environmental Services	TAU	OMIA as Committee secretariat	Cabinet	OMIA	Energy Division	Labour and Consumer Services (including Dangerous Goods Inspector)	

Notes: 1) Energy Division staff report informally to the Minister of Energy for renewable energy matters and to the Minister for Works for energy policy matters (including electricity planning, electricity tariff and monitoring fuel standards and quality)
2) The PM is responsible for government-owned corporatised entities, including TAU, through the Cook Islands Investment Corporation.
3) A 'Sustainable Energy Committee' was established by Cabinet in September 2001 but apparently has never met.
4) There are no formal cash subsidies for outer island electricity supply. The office of the Minister for Outer Island Administration (OMIA) administers general grants to the islands some of which are used for electricity.
Source: SPREP/UNDP/GEF Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report May 2004

In PIC, it is normal that the Energy Division does not handle all energy sector matters. For example, in small countries with petroleum fuel price controls the Finance Ministry often administers pricing whereas other Ministries or the petroleum company (with better technical skills) will oversee petroleum transport, storage and safety. It is also common for an energy office to deal with overall electricity utility policy but with Cabinet, the Finance Ministry or utility itself having the final say on tariff levels. However, the responsibilities for energy in the Cook Islands are unusually dispersed and are seen to hinder the development and implementation of consistent energy policies and their administration.

Each of the outer island local administrations is responsible for the operation of their respective electrical generation and distribution under the provisions of the Energy Act 1998, particularly the areas of electrical safety and inspection. OMIA is responsible for implicit subsidies for the outer islands in the form of grants that offset the island's budget deficits.

TAU is the government owned electricity utility on Rarotonga. The Director of Energy is a board member of TAU. The utility has become increasingly commercialised and expected to recover all operating costs from consumers. A GoCI Cabinet Memorandum of May 2004 has directed TAU to take over responsibility of the Aitutaki and Atiu Power Supplies as requested by the Island Councils of the two islands. At present the procedures and budgetary implications are being investigated by TAU.

2.1.5 National Energy Policy

In 2003, Cabinet endorsed a National Energy Policy (NEP), which is similar to the format and structure of the 2002 Pacific Islands Energy Policy and Plan (PIEPP). The NEP includes an overall national energy policy statement, "to facilitate reliable, safe, environmentally acceptable, and cost-effective sustainable energy services for the people of the Cook Islands" and a number of guiding principles with goals for sustainability, self-sufficiency, efficient service delivery, and financial independence.

Over time, for example, cross-subsidies among electricity users are to be eliminated and those who receive electricity through renewable energy systems are to pay monthly fees sufficient to meet operating and maintenance costs – including the eventual replacement of the system components. There are broad policies for overall energy planning and management, the power sector, renewable energy, petroleum fuels, transportation, and environmental aspects of energy – with efficient energy use specified throughout. The NEP includes a Strategic Plan with specific activities, lead agencies, indicators of success, assumptions and risks, and a time frame for each policy area. The policies and activities are well thought-out, clear and consistent. However, there are no specific budget allocations for implementing any activities or indications of priority among them. The NEP has not been an input to a new economic national planning exercise coordinated by MFEM, but the planning only began in September 2003.

3 PUKAPUKA

3.1 Physical Description and Population

Pukapuka, the northernmost atoll of the Cook Islands, is closer to American Samoa than to 1400 km distant Rarotonga. There are three villages: Yato, Roto and Ngake that are on one islet of the atoll located along about 2km of road. The total population was 664 as of 2001. The passage into the lagoon is not navigable by larger vessels so the landing of heavy freight is difficult and damage to shipped goods common. In addition to about 140 homes, there is a government administrative building, a medical centre, a community building and a school. The government compound is electrified by a small diesel generator operated approximately 12 hours a day.

Map 3-1 – Pukapuka Atoll



Source – New Zealand Department of Survey and Land Information

Shipping is irregular and unreliable. Access by air is possible as there is an airstrip on the atoll but there are no scheduled flights and charters are very expensive. Due to the problems and expense of access, development of tourism is not possible and trade possibilities are limited to goods that do not spoil during the long and often irregular time between ship visits. Thus cash generation for households is difficult and much of the cash input to the island is through government employment and remittances from family members on other islands or overseas.

3.2 Local Government

The governing body of the island is the Pukapuka Island Council. A Secretary of Island Administration appointed by the GoCI Cabinet through consultations with the Island Council, is responsible for administering and managing the various Island Administration services and works closely with the Mayor and Island Council for the benefit of the island community.

Goals identified in the strategic plan for Pukapuka² are as follows:-

- To instil into the people of Pukapuka a sense of pride and self-reliance.

² From *Strategic Directions 2005 "Te Wenuake Malanga"* Pukapuka Island Government 2000

- To encourage the people of Pukapuka to develop and implement new revenue generating activities.
- To provide appropriate quality advice and support to existing ventures on how to maximise their economic potential.
- To maintain and improve a high standard of education and health.
- To reduce the incidence and effects of crime on the island.
- To improve the quality of leadership skills on the island.

Infrastructure development and maintenance is a key area identified by the Island Council. At the time of writing the report in 2000 the Island Council was committed to undertake the following:

- To improve Pukapuka's Harbour facilities in order to minimize or remove the danger to boat owners as well as to our people.
- To start construction of Hurricane Centres on the island.
- To maintain and improve existing roads on the island
- To ensure that an adequate supply of quality water is available for all households on Pukapuka. This is considered an absolute priority.
- To ensure a quality and adequate supply of electricity for the island

All four of the electrification options meet the basic requirement of ensuring a quality and adequate supply of electricity for the island though quality of supply for diesel power will depend strongly on the reliability of shipping and spare parts support. The solar PV options also provide benefits in the area of island pride and self-reliance.

3.3 1992 Solar Electrification by S.P.I.R.E.

In the 1980s, French Polynesia had the most advanced solar rural electrification programme in the Pacific. The programme was facilitated by the South Pacific Institute for Renewable Energy (S.P.I.R.E.), an engineering and research and development organisation, and G.I.E. Soler, a non-profit company specialising in solar energy implementation. The programme included installing photovoltaic systems of sufficient size to provide for rural electricity services comparable to those available in urban areas with over 2,000 installations completed in the 1980s. In 1987 discussions were held between the Government of the Cook Islands (GoCI) and the S.P.I.R.E. regarding the best approach for the electrification of Pukapuka. Given the remoteness of the island, it was agreed that high reliability would be a primary requirement and the generation scheme should have sufficient capacity to allow for refrigerators, videos and other common domestic appliances. With solar power offering 24 hour power and no susceptibility to outages due to irregular shipping, solar was considered the preferred electrification method for Pukapuka.

Agreement was concluded in 1990 between the Caisse Centrale de Coopération Economique (CCCE), the French Central Bank for Economic Cooperation, and the GoCI for a treasury loan of FF3,850,000. In 1991 a loan from the Bank of Indosuez to GoCI was agreed in the amount of FF3,150,000. In 1990 the CCCE contracted with S.P.I.R.E. to carry out a feasibility study.

After the feasibility study was completed and the situation was found to be favourable for solar, S.P.I.R.E. became the primary contractor for the project with responsibility

for technical design, equipment selection, equipment purchase, installation and at least one year of post-installation monitoring. Installation was sub-contracted by S.P.I.R.E. to Soler Energie (Tahiti), the commercial company that evolved from G.I.E. Soler.

To test the use of PV on the atoll, an initial phase was for electrifying three public buildings. Each of the three public solar systems included 28 panels and a 880 Ah (C10) 24V Oldham battery intended to operate up to a 200 litre 24VDC refrigerator, a 300 litre 24VDC freezer, a video system operated from a small inverter and six 24VDC lights. The Phase 1 installations were completed in October 1990.

During this phase a household survey determined the appliances that households anticipated purchasing once electricity was available. The survey indicated that less than 50% of the households intended to purchase a refrigerator and less than 30% had plans to purchase a video system. Because of the high cost of solar panels and for equipment suitable to power conventional 240VAC refrigerators, the use of high efficiency DC refrigerators, such as those being used in French Polynesia solar electrification programme, was determined to be economically necessary should refrigeration be desired by the households.

After about a year of successful operation of the Phase 1 equipment, S.P.I.R.E. began Phase 2 and installed systems on 110 homes with 8 modules of 45Wp each and 17 homes with 12 modules of 45Wp each. The 8 panel PV design was intended to power a maximum of six high efficiency tube type fluorescent lights (2 at 18W and 4 at 13W) for 3 hours a day, small entertainment appliances (radio or cassette player) and either a solar type refrigerator (less than 0.7 kWh/day usage) or three hours of video use per day. The 17 homes having 12 modules shared their PV system with a nearby smaller house where additional lights were installed. To fit the needs of the households that did not intend to purchase a refrigerator or video, 3 houses were fitted with only 4 panels and a 24V 150 Ah (C10) battery to minimize the maintenance cost to the household while still providing adequate power for lights and small entertainment appliances. The total installed power of nearly 50kWp allowed for all households and public buildings to be electrified and components for 10 more systems were left on island for future expansion.

Twenty 300 W 240V 50Hz inverters were provided for distribution by the Island Council to households wishing to operate small AC appliances such as video systems. Also ten 24V/12V DC-DC converters were provided to allow those households to operate 12VDC equipment, such as two-way radios, from the installed 24V system.

Eighteen dawn to dusk street lights were included with 12 on streets, two acting as locator beacons for returning fishermen and the rest at the CICC, Catholic and Seventh Day Adventist churches. The churches also had small lighting systems installed. The street lights included 2 panels of 45Wp capacity, a 100Ah (C10) 12V battery and a low pressure 18W sodium light. Spare parts for the street lights included 10 Ballasts, 20 bulbs, 2 controllers and 6 batteries.

The primary problem with the implementation of the project was the delivery of the materials and the installers who had to come from Rarotonga and Tahiti. Though the GoCI had promised shipping for the project, problems with vessels and with the shipping schedule prevented them from being able to fulfil that obligation and after several months of delay, S.P.I.R.E. arranged for the French Navy to assist by

providing transport from Tahiti to Pukapuka for the installation personnel and the 130 tonnes of materials for the project.

Installation was carried out by two teams, each consisting of one person from S.P.I.R.E. or Soler Energie and two persons from the Cook Islands who had previously been trained at S.P.I.R.E. in Tahiti. The Pukapuka residents who were designated as maintenance technicians participated in the same S.P.I.R.E. training and assisted in the installations. The installation phase lasted three months and was completed in December 1992.

3.4 Post installation monitoring

The relative isolation of Pukapuka made direct monitoring of the project difficult. Though S.P.I.R.E. intended to make several monitoring visits during the year following the installation, access problems made it impossible for a S.P.I.R.E. team to visit before 1994 and even then it was possible only by chartering an aircraft. The monitoring team found the household systems to be working well though the community systems and street lights were not successful with most of them out of service. Another problem was that most of the spare parts stock had disappeared off island. Users were found to be disappointed that arrangements had not been made by the GoCI for users to be able to purchase the special 24VDC refrigerators that could be used with the PV systems so the systems remained in use primarily for powering lights and a few video systems.

In April 2001, during the preparation for the France-Australia regional renewable energy project, PREFACE, a team from the Cook Islands Energy Unit and personnel representing the PREFACE project (accompanied by one of the original installing technicians from Soler Energie of Tahiti), flew on a chartered aircraft to Pukapuka to check on the condition of the systems. Although most household systems were operational, it was then clear that the batteries were approaching the end of their useful life and would need to be replaced in five or six years.

In 2003, UNDP/UNESCO was asked by the Cook Island Government to provide technical assistance for the improvement of the power systems on Atiu, Mauke and Mitiaro and to analyse the relative costs and benefits of diesel and solar power for Pukapuka. A contract was let for this purpose in 2004 and the UNESCO contractor, through the Energy Division, Ministry of Works requested the local government of Pukapuka to conduct a survey of the households on Pukapuka regarding their experience with the solar systems, their preference for the mode of electrification that would be installed to upgrade the electrification on Pukapuka and other information relative to the structure needed for upgrading the electrification on the island.

3.5 Pukapuka Household Survey Results 2004

In July and August of 2004, households on Pukapuka were surveyed regarding their experience with the solar systems and their preferences for future electrification approaches. The survey questionnaire and tabulated results are shown in Annex A.

The survey indicates that:

- Of the 98 houses that responded to the survey (around 70% of the houses electrified by solar), only one had no lights operating at the time of the survey.
- The solar PV system has reliably provided lighting for Pukapuka for the past 12 years (61% considered the performance of the systems as excellent with

very few problems, 96% had no serious complaints citing only a few outages over the years)

- Only 5% of the respondents complained that there was not enough power available for their needs and only 1% complained that they could not use the appliances they wanted to use. The primary complaint was a lack of availability of replacement lights (32%).
- 96% of the respondents consider having 24 hour power to be important
- 97% stated that it would be acceptable to have 24 hour power but not be able to use high demand small appliances like electric fry pans, cookers, irons or tea makers.
- 68% said that if the power was off because of a lack of fuel, it would be a large problem for them.
- 64% said they considered \$25 per month a reasonable cost to have lights and video
- 69% said that \$35 per month was a reasonable cost for lights and refrigerator
- 57% said that \$10-\$15 per month was reasonable for just lights.

Based on the survey responses, it is clear that the solar installed in 1992 has provided reliable lighting power up to 2004 and that the respondents consider solar electrification to be a reasonable choice for the future. Also it is clear that 24 hour power is important to households and operating a diesel system only part of the day would be much less desirable than 24 hour access to electricity. The survey indicates that it may be incorrect to assume that households consider refrigerator and video use as a high priority if the cost of their operation is over around \$35 per month, a cost that will be exceeded whether diesel or solar is used for power.

3.6 Solar-Diesel Comparison Methodology

To compare diesel electrification with solar photovoltaic electrification, a mix of household loads approximating those of Mitiaro and Mauke was assumed and those loads applied equally to computer models of three PV options and a diesel option. Since PV is always 24 hour power, and since the community overwhelmingly stated in the survey that 24 hour power is preferred, operation of the diesel for 24 hour power was assumed. Fuel efficiencies for the diesel engines were estimated based on experience on Mauke, Mitiaro and Atiu.

All of the options provide 240V AC power for appliances. No DC appliances are assumed though costs could be lowered by using DC appliances specifically designed for solar use. The options examined are:

24 hour diesel electrification with all houses connected to the grid;

24 hour PV electrification with each household having an individually sized PV system to match the household requirements

24 hour PV electrification with all households receiving the same PV system sized large enough for washer, freezer or refrigerator, video, radio, lights and small miscellaneous appliances such as table fans and stereos.

24 hour PV electrification with a central PV power station with all households connected to a grid powered from the PV system.

No hybrid combination of solar and diesel was considered because: (a) the experience with such systems in the region for rural electrification has thus far been poor due to technical support problems mainly because two different technologies have to be simultaneously supported with trained personnel and spare parts and that has proved to be very difficult in remote locations; (b) since the life cycle cost of a pure PV grid with batteries is greater than for pure diesel grid, there is no cost advantage to justify the added technical complexity of combining these two technologies in one power system; and (c) though solar PV power can be injected directly from PV panels into a diesel powered grid at low levels (15% of the current demand or less) without using batteries and can therefore provide a theoretically lower cost hybrid system, the complexity of the interface between the solar PV and the diesel system has resulted in poor reliability when used in remote island environments. Also the total fuel saving is typically 5% or less leaving 95% of the energy to be still produced by diesel.

If both PV and diesel were to be installed on Pukapuka as a “hybrid”, the approach most likely to technically succeed would be a separate PV minigrid serving part of the load and a Diesel minigrid serving the rest (as is intended for trial on Fakaofu in Tokelau). This avoids the complexity associated with interfacing the two technologies, provides the best operating efficiency for both systems and highest reliability of power. This approach, however, is not recommended as it would markedly increase the maintenance problems since two separate technical systems would have to be maintained requiring both a reliable source of fuel, spare parts and technical competence for the diesel systems and a reliable source of spare parts and technical competence for the solar system.

Basic assumptions for the cost estimation for all systems include:

- *The same appliance load structure is assumed for all options.*
- *The overall island load is assumed to be mature for all years (no load growth)*
The load estimate is based on the appliance mix found on other islands that have been electrified for many years and have 24 hour power. This assumption will result in some oversizing of systems – both diesel and PV – for the early years of operation and somewhat higher operating costs per kWh during that time for the diesel system (making the actual operating cost somewhat higher than the estimate for diesel power during the early years). The operating cost for PV would actually be slightly lower during that initial period since battery and inverter stress will be lower and therefore faults fewer. However, over the full 15 year period, these cost variations can be expected to even out and to have little effect on the results of the life cycle cost comparison between diesel and PV power.
- *No land use charges.* It is assumed that the community will allow placement of any power house or distribution system without right-of-way rental or land purchase charges. Any land charges would significantly increase the cost of grid based, central generation systems but would not affect individual household systems.

3.7 Option 1: Diesel electrification

The diesel system cost and performance was estimated based on data and experience from Atiu, Mauke and Mitiaro in 2003 and 2004. A full complement of well trained power system staff was assumed. The size of the system is sufficient to handle

household loads comparable to the types found on Mauke and Mitiaro, the two systems most comparable to the expected needs of Pukapuka.

All reticulation would be underground and all at low voltage so no transformers or special high voltage servicing equipment would be needed. This requires some oversizing of the cabling and placing the power plant in the centre of the populated islet to keep cable losses to an acceptable level, but the oversized cable with central power house placement is substantially lower in cost and higher in system reliability than a high voltage system with transformers installed at houses to lower the voltage to 240V 50Hz.

The proposed diesel installation would be comprised of:

Table 3-1 – Estimated capital cost of diesel electrification	
Item	Estimated Installed Cost
4- Deutz 28kW gensets	\$112,000
Switchboard and controls	\$20,000
Distribution	\$187,925
House wiring	\$197,710
Power house, supplies and equipment	\$155,000
Used Hyab truck	\$50,000
Travel and DSA for external labour	\$35,000
TOTAL CAPITAL INVESTMENT	\$757,635
See Annex E for a more detailed costing	

For proper operation, staffing will need to include:

1 – Power system manager (full time)
1 – Mechanic/electrician (full time)
1 – Operator (full time)
2 – Operators (half time)
1 – Distribution electrician (full time)

The cost of fuel and oil delivered at Pukapuka is assumed to be unchanged from the present cost and without incremental increase over time. Since increasing fuel cost over time is likely, this assumption probably somewhat under prices the estimated diesel electrification costs. It is also assumed that there will be no disruption of fuel supply to the Cook Islands (as was the case in the 70's when fuel rationing had to be imposed) due to problems with the overseas suppliers.

3.8 Option 2: PV Minigrid option

Since the physical distribution of houses and loads on the islet being served was not available to the consultants, it is not possible to determine if dividing the power system into separate systems for each of the three villages would result in lowered overall cost through eliminating cable connection between villages. Therefore for

estimating purposes it was assumed that the overall power distribution system would remain the same as was proposed for a pure Diesel power system except, of course, that the power supply would consist of PV panels charging batteries and delivering AC power through inverters. To increase system reliability and lower capital cost, modular power units in the 5-10kW size are assumed to be paralleled rather than installing a single large system. This approach (equivalent to having multiple generators in a power house) allows ‘off-the-shelf’ components and lower cost, lower weight batteries to be used. Modular generation also provides the ability to still deliver power at a lower level rather than losing all power if there is an inverter failure. Should a physical survey indicate that substantial saving can be made by eliminating village intertie cabling, that could lower the overall cost of this option though it would likely be largely offset by the cost of building three small power houses instead of a single large one.

There is no experience in the Pacific with PV mini-grids and the experience in other parts of the world is mixed. This option is therefore considered to be the one with the highest technical risk.

The proposed PV mini-grid installation would consist of:

Table 3-2 – Estimated cost of a PV mini-grid installation	
Item	Installed Cost
165.3kWp of solar panels	\$1,487,378
Switchboard, inverters and controls	\$108,000
Distribution	\$187,925
House wiring	\$197,710
Power house, supplies and equipment	\$155,000
Battery cost	\$578,425
Travel and DSA for external labour	\$35,000
TOTAL CAPITAL INVESTMENT	\$2,749,438
See Annex D for a more detailed costing	

For proper operation, staffing will need to include:

1 – Power system manager/technician (full time)
2 – electrician/technician (full time)

3.8.1 Advantages and Disadvantages

The primary advantage of combining all the PV panels and batteries into a single power system to provide electricity for the entire islet is that a major part of the system load is expected to be in freezers and refrigerators. Since their power demand is determined by automatic thermostats, the load is distributed over time more or less randomly and the actual kW demand is typically 20%-30% less than the sum of the demand from each installed appliance since not all will be running at the same time. Thus the inverter capacity for the combined grid can be significantly less than the sum of the inverter capacities that would have to be installed on individual house PV systems. In particular, the size of the individual household inverters must be sufficient to handle the high current surge needed to start the refrigerator motors. If connected to a common grid, these surges would be distributed over time and the inverter size

would need to match only the running current, not the high starting current of the appliances.

A secondary advantage is that maintenance can be concentrated at the power house. In the case of individual PV systems on each house, maintenance requires periodic visits to all houses.

The primary disadvantage is that any fault in the system results in power loss to all households connected to that system.

A secondary disadvantage is that the cost of spare parts stores would be higher since the components are larger and individually more costly.

3.9 Option 3: Individual house PV system - one size for all households

In this option, all houses would receive sufficient solar capacity to operate a freezer, lights, video and washer (equivalent to about 136 kWh/month per house). This is technically the simplest option since installations will be the same for all houses. However, this approach means that many systems will be oversized since 136 kWh available power is around 30% higher than the average household use of electricity for Mitiaro and Mauke. Also it means that a few houses will be undersized since around 15% of households can be expected to require more than 136 kWh/month.

Table 3-3 – Estimated cost of provision of identical individual household PV

Item	Installed Cost
219.3kWp of solar panels (1567Wp/house)	\$1,974,194
Switchboard, inverters and controls (2kW/house)	\$406,000
House wiring	\$210,000
Battery cost	\$1,120,000
Travel and DSA for external labour	\$35,000
TOTAL CAPITAL INVESTMENT	\$3,745,194
Existing panels available for use	\$414,000
TOTAL CAPITAL REQUIRED	\$3,304,194

See Annex C for a more detailed costing

For proper operation, staffing will need to include:

- 1 – Power system manager/technician (full time)
- 2 – electrician/technician (full time)

3.9.1 Advantages and Disadvantages

The primary advantage is the simplicity of design and installation and the ease of maintaining spare parts and training technicians since all installations are identical. A secondary advantage is that most households would have the ability to increase electricity usage without need for system modification.

The primary disadvantage is the high capital cost and the fact that user cost will, on average be higher under this scheme. A secondary disadvantage is that a small percentage of households may desire more capacity to operate multiple refrigerators and other appliances.

User charges for this approach should be based on appliances installed with charges calculated annually to allow raising sufficient money to cover costs according to the

then existing appliance mix in the households. Under this approach, the houses with more appliances would end up subsidising the low use houses since the unused capacity installed for the low use households will still have to be paid for by the community as a whole.

3.10 Option 4: Individual PV installations to fit individual household needs

In this approach, before installation each household must make a decision as to the capacity of the PV system to be installed and the cost will depend on the capacity selected. The cost of individual systems in the Pacific has been typically US\$10 per installed Wp making a 400 Wp system (one suitable for most household appliances except refrigerator) about US\$4000 and a 1 kWp system (suitable for full electrification of most rural households) about US\$10,000. Thus the user cost would be in proportion to the installed capacity. Five standard sizes would allow a close match to the common appliance mixes found in rural Cook Island households as determined from appliance surveys on Mauke, Atiu and Mitiraro. Since the number of each size of system will not be known until a site survey is made, the cost estimate can only be based on the statistics of power usage on other islands where metered electricity is provided.

A technical problem with this approach is that if all systems operate at the same DC voltage, each size of system will require a different size of battery. That can be a major problem for stocking spare parts. Also large systems will then require very large, very expensive and very heavy batteries. Since all but perhaps basic lighting system installations will provide 240VAC, the voltage of the DC section of the system can be changed to best fit the system requirements since inverters are readily available for use on a wide range of DC input voltages.

By increasing the DC voltage with increasing system capacity, the same size of battery can be used for all systems by simply adding more batteries in series to increase overall system capacity. This will allow all spare parts to be identical except for the inverters and will also greatly reduce the battery handling problems since individual battery size can be kept in the 50-75kg range rather than the 200-300kg cells that would be required for the larger capacity systems if all systems are designed to supply power at the same, 24VDC or 48VDC voltage.

Table 3-4 – Estimated cost of individual PV systems with size to match loads

Item	Installed Cost
151.9 kWp of solar panels	\$1,367,000
Switchboard, inverters and controls	\$269,000
House wiring	\$210,000
Battery cost	\$594,600
Travel and DSA for external labour	\$30,000
TOTAL CAPITAL INVESTMENT	\$2,470,000
Existing panels available for use	\$414,000
TOTAL CAPITAL REQUIRED	\$2,056,000

See Annex B for a more detailed costing

For proper operation, staffing will need to include:

- 1 – Power system manager/technician (full time)
- 2 – electrician/technician (full time)

3.11 Summary of Comparisons

A summary of the relative advantages and disadvantages of the four options is provided in Table 3-5. The primary risk factor associated with developing diesel power for Pukapuka is the uncontrollability and uncertainty of fuel cost and supply reliability. The primary risk factor associated with developing grid-delivered AC solar power for Pukapuka is the limited experience in the Cook Islands with solar powered 240VAC systems.

Table 3-5 - Relative advantages and disadvantages of diesel and PV power for Pukapuka

Diesel Grid (not 24 hour power)	Diesel Grid (24 hour power)	PV Mini Grid (24 hour power)	Individual PV (24 hour power)
High experience level in the Cook Islands	High experience level in the Cook Islands	No experience in the Cook Islands	Over 10 years Experience in the Cook Islands (Pukapuka)
Significant risk of major cost increases over time due to increasing fuel price	Significant risk of major cost increases over time due to increasing fuel price	Small risk of unexpected price increases affecting the cost of power	Small risk of unexpected price increases affecting the cost of power
Total dependence on external supply of fuel for operation with risk of shutdown due to loss of fuel supply from overseas	Total dependence on external supply of fuel for operation with risk of shutdown due to loss of fuel supply from overseas	No strong dependence on overseas supply for day to day operation. Some risk of disruption due to delays in receiving spare parts	No strong dependence on overseas supply for day to day operation. Risk of power loss due to delays in receiving spare parts limited to individual households not the entire power system
A fault causes loss of all power to everyone	A fault causes loss of all power to everyone	A fault causes loss of all power to everyone	Fault causes loss of power only in one household
Fuel delivery problems	Fuel delivery problems	No fuel delivery problems	No fuel delivery problems
Significant environmental problems	Significant environmental problems	Minimal environmental problems	Minimal environmental problems
Noisy part time but quiet late at night	Noisy 24 hours a day	No noise	No noise
Either large spare parts stock or long delays for repair	Either large spare parts stock or long delays for repair	Small spare parts stock	Small spare parts stock
Limited appliance use	Full appliance use with limited use of high demand appliances such as fry pans	Full appliance use with limited use of high demand appliances such as fry pans	No high demand appliances such as fry pans or electric jugs

Table 3-6 summarises the estimated cost of power for each of the options considered for Pukapuka. To ensure comparability, the cost is based on specific services to be

provided not strictly on kWhr cost. Two costs for each option were calculated, one with repayment of all capital investment as well as operation and maintenance costs and the other with no capital payback.

For the solar options, the cost of power without capital payback is essentially to pay the cost of maintenance labour and to replace batteries when needed. Since the cost of battery replacement is not strongly affected by the amount of energy delivered to loads, the payment for power from the off-grid solar systems should be a function of the size of system installed, not kWh delivered to loads. For sustainable operation of the PV systems, it is vital that at least the operation and maintenance cost is recovered from users. A capital subsidy, either from the Cook Islands Government or an external donor, would be acceptable as it would not be likely to affect sustainability over the 15 year project life.

Table 3-6 –Summary of estimated monthly cost of service for households

Appliance Use	Cost includes capital investment				No capital repayment included			
	Diesel 24 hour powerk	PV Mini Grid 24 hour power	Individual PV 24 hour power <i>all systems the same size</i>	Individual PV 24 hour power <i>systems sized to each house load</i>	Diesel 24 hour power	PV Mini Grid 24 hour power	Individual PV 24 hour power <i>all systems the same size</i>	Individual PV 24 hour power <i>systems sized to each house load</i>
Lights and Radio (11 kWh/mo estimated)	\$18.76	\$19.94	\$218.59	\$15.63	\$10.95	\$7.03	\$86.85	\$6.76
Lights, video or washer and radio (23 kWh/month estimated)	\$39.22	\$41.69	\$218.59	\$32.69	\$22.89	\$14.70	\$86.85	\$14.13
Lights, freezer or refrigerator and radio (76 kWh/mo estimated)	\$129.60	\$137.76	\$218.59	\$108.02	\$75.63	\$48.57	\$86.85	\$46.68
Lights, freezer or refrigerators, radio and video or washer (136 Wh/mo estimated)	\$231.91	\$246.51	\$218.59	\$193.30	\$135.33	\$86.92	\$86.85	\$83.53
Lights, freezer, refrigerator, radio, video, washer (251 kWh/mo estimated)	\$445.06	\$473.09	\$218.59	\$370.96	\$259.72	\$166.81	\$86.85	\$160.30

Note that because all the PV systems are the same size and cost depends on the size of the system, not on energy use, all households cost the same to service. That does not mean that it is necessary to charge all households the same fee, that can be adjusted to fit the use of each household with users having many appliances paying much more than users with only lights. The only requirement would be that the total collected would be sufficient to pay the operating and maintenance costs plus any capital payback that is required.

3.12 Recommendations

If the goal is to provide reliable 24 hour power at the least life cycle cost, the use of individual solar installations fitted to the needs of the individual households is clearly the best choice. This approach eliminates both the serious problem of irregular fuel deliveries, the risk of major cost increases due to fuel price upward trends, the risk of loss of power for extended periods by all users due to a system fault that requires spare parts from overseas and this option requires technical support that can be easily managed by personnel from Pukapuka. The primary disadvantages are: (a) the capital cost is much higher than diesel so if a donor wants to save money in capital investment, passing the running cost on to the users or the GoCI, the diesel option provides the least cost to the donor; and (b) the size of the PV system installed has to be matched to the expected needs of the households (and their willingness to pay for those services) and load growth requires the ability to add panels and battery cells to systems in the future – not a technical problem but to do this requires additional investment in materials that may be difficult to meet from operating budgets.

Since there are already nearly 50kWp of panels on Pukapuka, it may appear attractive to create a hybrid PV/diesel system using the existing solar panels but it is not recommended. For such a system to work reliably and to properly utilise the available power from the PV panels, a major investment in battery storage will need to be included. If battery storage is included, creating a separate mini-grid system powered solely by PV makes more technical and economic sense than attempting to integrate both diesel and PV on the same network.

If diesel is installed on Pukapuka, it is recommended that the PV panels presently in Pukapuka be recovered by the GoCI for use elsewhere. Leaving the panels on Pukapuka for continuing to provide household lighting appears to be a bad idea both socially and economically since the investment in the diesel system would then be exclusively for the benefit of the rich households desiring to use large appliances. This would result in lower operating efficiencies for the diesel system, higher subsidies that would be mostly directed to rich households and a substantially higher overall cost of power for the island.

4 ANNEXES

Annex A - Pukapuka Household Electrification Survey July-August 2004

House identifier or head of household name _____ *Total 98 responses* _____

How many persons in the household? *566 total (5.77 persons/household)* _____

Name of village *covers all three villages* _____

Survey of experience with solar PV

1. How many panels are installed with your solar system? *876 total (8.9 panels/household)* _____
2. Does your solar system work now so that you have lights?
 - a. Yes, I have lights *97 (99%)*
 - b. No I do not have any lights. *1 (1%)*
3. If not, about when did it stop working _____ *Only one says no lights and no reason was given for its problems* _____
4. Why is it not working?
 - a. Battery does not work
 - b. Lights are broken
 - c. I don't know it just doesn't work
5. If it does work, how many lights do you have that work? _____ *total of 413 (4.2 lights/house)* _____
6. Have you ever had anything but lights powered by the solar?
 - a. Only lights *40%*
 - b. Yes other appliances. I have powered the following appliances with the solar sometime in the past 10 years. *56% (no information provided regarding what appliances were used)*
7. What would you say has been your main complaint about the solar:
 - a. The lights break down and I cannot get them fixed or replaced for a long time *32%*
 - b. The solar system is too small to do what I want *5%*
 - c. I cannot use the appliances I want to use *1%*
 - d. Power is often off and I cannot use the system at all *0%*
 - e. The solar has been fine for me, I have no real complaints *5%*
8. How would you rate your experience with the solar lights before 2000?
 - a. Excellent, I always had light when I needed it *61%*
 - b. Very good. Almost all the time it has worked ok *22%*
 - c. Good. I have had a few times without lights but usually have light ok *13%*
 - d. Average. Since the beginning, the lights have only worked part of the time *3%*

- e. Fair. Since the beginning, the lights have not worked most of the time
0%
- f. Poor. I have had few times when the system provided lights.0%

The decision will soon be made whether to upgrade the existing solar systems to allow refrigerator and video use (regular 240VAC appliances not special ones) or to install diesel electrification on Pukapuka. Note that it will NOT be possible to both repair the solar and install a diesel generator.

1. A diesel system will only be operated for a few hours a day because it will cost too much for 24 hour power. A solar system will provide power for 24 hours a day. How important is it to you to have 24 hour power?
 - a. Very Important 79%
 - b. Important 17%
 - c. Not very important 2%
 - d. Not important at all 1%
2. Would you be unhappy with a solar PV system large enough to operate a refrigerator and a video along with lights but not large enough to operate electric fry pans, cookers, electric irons or electric tea makers?
 - a. Happy, I don't care about the other appliances 71%
 - b. It would be acceptable 26%
 - c. It would not be acceptable 3%
3. Diesel power may have problems running out of fuel between ships. Will that be a problem for you?
 - a. No problem 16%
 - b. A little problem 14%
 - c. A large problem 68%
4. How much are you willing to pay per month for operating just lights?
 - a. \$20 – 9%
 - b. \$15 – 39%
 - c. \$10 – 18%
 - d. \$5 – 0%
 - e. \$0 – 3%
5. How much are you willing to pay per month for operating a refrigerator and lights?
 - a. \$50 – 3%
 - b. \$40 – 7%
 - c. \$35 – 69%
 - d. \$30 – 6%
6. How much are you willing to pay per month for operating just a video and lights?
 - a. \$40 – 6%

- b. \$35 – 2%
 - c. \$30 – 13%
 - d. \$25 – 64%
7. Which would you rather have? 6 hours of electricity and be able to use any appliance or 24 hours of electricity and be able to operate lights, refrigerator and video but no cookers, no tea makers and no electric irons.
- a. 24 hour power 83%
 - b. 6 hour power 17%

Annex B - Cost details of PV systems to fit each household's estimated need
Estimated Cost – Individual PV systems sized to fit individual household loads (2004 NZ\$)

Number of houses		140							Cost/No.		Life years	
Total Wp required		151935.5			Controller cost				\$250		10	
Total Wp on island now		46000			Fridge inverter cost				\$500		6	
Total Wp to be Installed		105935.5			Video inverter cost				\$150		6	
Total cost for the village		\$2,474,819			Main inverter cost				\$2,000		7	
Cost/Wp		\$16.29			Installation labour cost				\$1,500		20	
		Cost/No.	Life (yrs)		Generation factor (Wh/day/Wp)				2.8			
Panel cost per Wp		\$9	30		Storage days of autonomy				5			
Battery volts		6			Miscellaneous materials/year/house				\$25			
Battery Ah		250			Monthly cost per Wp of panel				\$0.129	with capital payback		
Battery cost		\$400	8	Monthly cost per Wp of panel				\$0.0533	without capital payback			

	Number of Fridge Inverters per house	Total number of fridge inverters	Number of video inverters per house	Total number of video inverters	Number of main inverters per house	Total number of main inverters	System cost	Village cost	Cost/mo per house with capital payback	Cost/mo per house without capital payback
1. Lights only	0	0	0	0	0	0	\$3,691	\$103,335	\$16	\$7
2. Lights + video	0	0	1	14	0	0	\$5,885	\$82,387	\$34	\$14
3. Lights + Freezer	1	42	1	42	1	42	\$16,280	\$683,768	\$113	\$47
4. Lights + Video + Fridge	1	42	1	42	1	42	\$24,901	\$1,045,858	\$202	\$84
5. Urban scale use	2	28	1	14	1	14	\$39,962	\$559,471	\$388	\$160
TOTALS		112		112		98		\$2,474,819		
						Existing panel value		\$414,000		
Resident Technician salary		2 persons	Half time	\$16,000	total	Assume 2% salary increase/year				

Annex C - Cost details of identical individual PV systems for each household

Estimated Cost: Most technically simple option: All PV systems are identical with sufficient capacity for major AC appliances (2004 NZ\$)

Item			Cost/Number	Years Life						
Panel cost per watt			\$9	30	Labour consists of two local technicians, each working half time for \$8,000 per year. The analysis assumes an annual salary increase of 2% up to a maximum of 5 years after hiring.					
Battery voltage			6							
Battery Ah			250							
Battery cost			\$400	8						
Controller cost			\$250	10						
Fridge inverter cost			\$500	6						
Video inverter cost			\$150	6						
Main inverter cost			\$2,000	7						
Installation cost			\$1,500	20						
Generation factor (Wh/day/Wp)			2.8							
Storage days of autonomy			5							
Miscellaneous materials/year/house			25							
Monthly Payment per Wp of panel			\$0.1395	with capital payback						
Monthly Payment per Wp of panel			\$0.0554	without capital payback						
Total Capital Investment			\$3,304,194							
Voltage	kWh/mo	=Wh/day	System Wp	Battery kWh	Ah	Total Panel Capacity	12V Battery capacity	Number of batteries	Number of Houses	Total Number of Batteries
120	136	4387	1567	22	183	219355	250	20	140	2800
Number of Fridge Inverters	Total number of fridge inverters	Number of video inverters	Total number of video inverters	Number of main inverters	Total number of main inverters	Single system cost	Village cost	Cost/mo per house with capital payback	Cost/mo without capital payback	
1	140	1	140	1	140	\$23,601	\$3,304,194	\$218.59	\$86.85	

Annex D - Cost details of centralised PV power system
Estimated Cost – Centralised solar powered mini-grid (2004 NZ\$)

Total Panel Capacity Needed	165,264	(Based on requirement for capacity during first 15 years)	
Total Wh/day available	462,740		
Total Battery Capacity Needed Wh	2,313,699		
DC Voltage	240		
Ah required	9640		
Battery Voltage	2		
Number of batteries	120		
Cost per battery kWh	\$250		
Total battery cost	\$578,424.66		
Item	Cost/Number	Life	Maintenance %
Panel capacity required			
Total Battery Cost	\$578,425	10	
Reticulation cost	\$385,635	20	1%
Building and grounds	\$190,000	20	1%
Panel cost	\$1,487,378	30	
Control cost	\$8,000	8	
Total Inverter kW	50		
Inverter cost per kW	\$2,000		
Total Inverter cost	\$100,000	6	
Capital investment required	\$2,749,437		
Capital cost/kW	\$54,988.75		
Annual general maintenance	\$5,756.35		
Personnel	\$39,000	(3 persons - two electricians, one linesman and meter reader)	
Annual salary increment first 5 years	2%		
Tariff per kWh no capital payback	\$0.59420		
Tariff per kWh with capital payback	\$1.6847		

Annex E - Details of Diesel installation estimate

Summary of Costs			
ITEM	Number	Unit cost	Total Cost
Mains reticulation	1	\$187,925	\$187,925
House Wiring	140	\$1,412	\$197,710
Engines	4	\$18,000	\$72,000
Electrical generation component	4	\$10,000	\$40,000
Switchboard	1	\$20,000	\$20,000
Vehicle	1	\$50,000	\$50,000
Power House and support materials	1	\$155,000	\$155,000
Installing personnel travel	1	\$20,000	\$20,000
Installing personnel accommodation	1	\$15,000	\$15,000
	Total Installation Cost		\$757,635
For travel allow for 2 charter flights at \$10,000 each			
Accommodation allow for 6 men for 1 month @ \$80/day ie say \$15,000			

Main power house cost details

Generator Building 14mtr x 7 mtr = 98m2				
	Cost/unit	Unit	# of units	Total cost
Building cost incl labour	98	sqm	1000	\$98,000
Switchboard incl sync panel	1	at	20,000	\$20,000
Fuel & Elec fitout incl labour	1	at	6,000	\$6,000
Fuel Storage bulk tanks	2	6,000lt	5,000	\$10,000
Mobile tank	8	1600lt	2,000	\$16,000
Deutz gensets ~ 28kW	4	each	28,000	\$112,000
Hyab truck	1	2nd hand?	50,000	\$50,000
Tools, meters etc	1		5,000	\$5,000
Engineering/Civil Design	1	fee	20,000	\$20,000
				\$337,000
Total power house	\$155,000			

Diesel system distribution system cost estimate details

Pukapuka Island Electrical Services				
			\$	\$NZ FOB Fiji
item	Description	qty	unit	cost
Mains & Sub mains incl pillar boxes				
Roto 1	50mm 4c +E orange circular	644	47.46	\$ 30,564.24
	63mm HD Pvc conduit	160	26.1	\$ 4,176.00
	Pillar box	50	257.06	\$ 12,853.00
	HRC fuse 20 A	150	3.3	\$ 495.00
	Neutral links	50	62.01	\$ 3,100.50
	Phase link	150	62.01	\$ 9,301.50
	Earth Rod	50	6.6	\$ 330.00
	Earth clip	50	1.85	\$ 92.50
	63mm Pvc orange bend	34	31.41	\$ 1,067.94
	Machine screw nuts	490	1.8	\$ 882.00
	Pvc glue	1	2.11	\$ 2.11
	Zelmate 400 x 400 x 10	50	48	\$ 2,400.00
				\$ -
Roto 2	10mm 4c + E orange circular	450	8.81	\$ 3,964.50
	40mm HD Pvc conduit	113	5.4	\$ 610.20
	40mm Pvc orange bend	20	5.4	\$ 108.00
	Pvc glue	1	2.11	\$ 2.11
				\$ -
Yato 1	25mm 4c + E circular	542	25.32	\$ 13,723.44
	50mm HD Pvc conduit	135	17.85	\$ 2,409.75
	50mm Pvc orange bend	32	7.05	\$ 225.60
	Pvc glue	1	2.11	\$ 2.11
				\$ -
Yato 2	25mm 4c + E circular	526	25.32	\$ 13,318.32
	50mm HD Pvc conduit	130	17.85	\$ 2,320.50
	Pvc glue	1	2.11	\$ 2.11
				\$ -
Ngake 1	50mm 4c + E orange circular	790	47.46	\$ 37,493.40
	63 HD Pvc conduit	198	26.1	\$ 5,167.80
	63mm Pvc orange bend	34	31.41	\$ 1,067.94
	Pvc glue	1	2.11	\$ 2.11
				\$ -
Ngake 2	10mm 4c + E orange circular	250	8.81	\$ 2,202.50
	40mm HD Pvc conduit	63	5.4	\$ 340.20
	40mm Pvc orange bend	8	5.4	\$ 43.20
	Pvc glue	1	2.11	\$ 2.11
				\$148,270.69
	Freight allowance to Pukapuka = 20%			\$177,924.83
	Allow 300 man hours to install mains @ \$20/hr			\$ 6,000.00
	Equipment allowance (ditch digger etc)			\$ 4,000.00
			Total	\$187,924.83

Life Cycle cost calculations for 24 hour diesel power on Pukapuka

24 HR/DAY DIESEL ELECTRICITY SYSTEM FOR:					PUKAPUKA, Cook Islands		
FINANCIAL ANALYSIS							
	Costs are in Fixed	2004	NZ Dollars				
6%	INTEREST RATE (no inflation applied) for borrowing						
4%	Interest Rate (no inflation applied) for investment of funds collected for replacement of components						
CAPITAL COSTS (including installation and shipping costs)							
			% End of Life	End of 15 years			
		INITIAL	Residual Value	Residual Value			
	Diesel Engines	\$122,000	0	25.0%	Used vehicle cost is included with engine cost		
	Generation Equipment	\$40,000	0	25.0%			
	Switchgear	\$20,000	0	25.0%			
	Distribution system	\$385,635	0	25.0%	Includes house wiring		
Building, grounds, fuel storage and right of way		\$190,000	25	25.0%	Includes cost of labour travel and subsistence		
	Total Capital Investment	\$757,635					
RECURRENT COSTS - Maintenance, Overhaul and Replacement							
		Maintenance	Years to	Overhaul cost	Years to		
		%/yr	Overhaul	% of new	Replacement		
	Diesel Engines	5	5	35	20		
	Generators and switch gear	3	10	30	20		
	Transmission and distribution	1	15	10	20		
	Building, grounds, fuel storage and right of way	2	15	15	20		
PERSONNEL COSTS							
		Initial Payroll					
	Costs:	\$63,000	2	% Annual increment until year 5			
LOAD GROWTH							
	kWh sold the first year	168900	Percent generated by diesel		100		
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 5-15
Load Growth Rate %/year		0	0	0	0	0	0
FUEL COSTS		Fuel Efficiency	2.18	kWh/litre	Oil Efficiency		250 kWh/litre
Diesel Fuel Use	0.459	l/kWh used	at	\$1.10	/Litre landed price		
Lubricating Oil use	0.004	l/kWh used	at	\$4.20	/Litre landed price		
ANNUAL CASH FLOW							
2004 NZ	Fixed Dollars				Set tariff	\$1.54460	\$22.33 NPV

Year	Initial Capital Invested	Cost of Replacing Equipment	kWh Sold	Fuel and Oil Cost	Personnel Cost	Maintenance Cost	Total Overhaul Costs	Non-Capital Payments	O&M Cost per kWh	Net cash Flow and Tariff
0	\$757,635									(\$757,635)
1		\$0	168,900	\$88,062	\$63,000	\$15,556	\$0	\$166,619	\$0.99	\$9,990
2		\$0	168,900	\$88,062	\$64,260	\$15,556	\$0	\$167,879	\$0.99	\$9,990
3		\$0	168,900	\$88,062	\$65,545	\$15,556	\$0	\$169,164	\$1.00	\$9,990
4		\$0	168,900	\$88,062	\$66,856	\$15,556	\$0	\$170,475	\$1.01	\$9,990
5		\$0	168,900	\$88,062	\$68,193	\$15,556	\$42,700	\$214,512	\$1.27	\$4,990
6		\$0	168,900	\$88,062	\$69,557	\$15,556	\$0	\$173,176	\$1.03	\$8,990
7		\$0	168,900	\$88,062	\$69,557	\$15,556	\$0	\$173,176	\$1.03	\$8,990
8		\$0	168,900	\$88,062	\$69,557	\$15,556	\$0	\$173,176	\$1.03	\$8,990
9		\$0	168,900	\$88,062	\$69,557	\$15,556	\$0	\$173,176	\$1.03	\$8,990
10		\$0	168,900	\$88,062	\$69,557	\$15,556	\$60,700	\$233,876	\$1.38	\$2,990
11		\$0	168,900	\$88,062	\$69,557	\$15,556	\$0	\$173,176	\$1.03	\$8,990
12		\$0	168,900	\$88,062	\$69,557	\$15,556	\$0	\$173,176	\$1.03	\$8,990
13		\$0	168,900	\$88,062	\$69,557	\$15,556	\$0	\$173,176	\$1.03	\$8,990
14		\$0	168,900	\$88,062	\$69,557	\$15,556	\$0	\$173,176	\$1.03	\$8,990
15		\$0	168,900	\$88,062	\$69,557	\$15,556	\$109,764	\$282,939	\$1.68	(\$22,990)
TOTALS	\$757,635	\$0	2,533,500	\$1,320,934	\$1,023,425	\$233,345	\$213,164	\$2,790,869		
Averages	\$50,509	\$0	168900	\$88,062	\$68,228	\$15,556	\$14,211	\$186,058	\$1.10	\$1.54
	Per year average of capital investment	Average annual equipment replacement cost	Average annual kWh sold	Average annual fuel and oil cost	Average annual personnel cost	Average annual maintenance cost	Average annual overhaul costs	Average annual O&M cost	Average cost per kWh excluding capital cost	Average cost per kWh including capital cost
	Average Cost per kWh not including capital cost						\$1.10	Per kWh		
	Average Cost per kWh including capital cost:						\$1.54	Per kWh		
	Average cost of Lighting Only						\$16.99	Per month		
	Average cost of lighting plus video						\$35.53	Per month		
	Average cost of lighting plus refrigerator						\$117.39	Per month		
	Average cost of lighting plus video plus refrigerator						\$210.07	Per month		
	Average cost of urban electrification (fridge, freezer, video, washer, radio, lights, fans)						\$403.14	Per month		
	Average monthly payment needed from each electrified household						\$110.75	Per month		
	Average cash required from the village for power per month						\$15,505	Per month		
	Average cash required from each electrified household per year						\$1,329	Per Year		
	Average cash required from the village for power per year						\$186,058	Per Year		

Annex F - House connection and wiring detail estimate

Pukapuka Island Electrical Services			\$ per	FOB Fiji
item	description	qty	unit	cost
Sub-mains				
House units				
	6mm single Pvc red	20	\$1.05	\$21
	6mm single Pvc black	20	\$1.05	\$21
	25mm HD Pvc orange conduit	5	\$6.30	\$32
	25mm Pvc orange bend	3	\$3.73	\$11
	4mm single Pvc green	5	\$1.05	\$5

Lighting & Power Cabling				
House				
	Lighting	6	\$23.55	\$141
	GPO	4	\$11.42	\$46
	1.5mm light wire	40	\$0.82	\$33
	1.5mm switch wire	30	\$1.03	\$31
	2.5mm power wire	60	\$1.09	\$65
	Mounting block	10	\$2.49	\$25
	Wire clip	5	\$4.88	\$24
	Junction boxes	3	\$1.90	\$6
	Screws & plugs	10	\$2.00	\$20
	Distribution board	1	\$250	\$250
	Earth rod with plate	1	\$10.50	\$11
	25mm Pvc conduit	3	\$6.30	\$19
	32A MCB 1P	1	\$12	\$12
	16A MCB 1P	2	\$12	\$24
	10A MCB 1P	1	\$12	\$12
	Earth rod	1	\$6.60	\$7
	Earth clip 16mm	1	\$1.80	\$2
	Switch	6	\$4.40	\$26
	Wall box	10	\$2.04	\$20
	Corrugated conduit 20mm	5	\$2.03	\$10
			Subtotal	\$874
	Freight allowance to Pukapuka at 25%			\$218
	16man hours per house @ \$20/hr			\$320
			Total	\$1,412

Annex G - Terms of Reference

Terms of Reference for
Power Sector/feasibility Study Report with regard to Atiu, Mauke, and Mitiaro and
Power Recommendation Paper with regard to Pukapuka ³

1. INTRODUCTION

The Government of the Cook Islands recognises the significant potential contribution that renewable energy can make to the economy, the environment and social development in the medium and long term. In this context UNDP (Samoa) has funded the Technical Assistance (TA) project *Increase the Utilisation of Renewable Energy Technologies in the Cook Islands Energy Supply* executed by UNESCO (Apia) in cooperation by the Energy Division (ED), Ministry of Works, Government of the Cook Islands.

In line with the National Energy Policy (2003) and the Budget Policy Statement (2003-2004) the TA is primarily designed to assist the Government of the Cook Islands in assessing the possibilities to increase the utilisation of renewable energy sources on three (3) of the Outer Islands in the Southern Group in the medium to long term. In addition a minor part of the consultancy is designed to advise the Government whether the Outer Island of Pukapuka in the Northern Group should improve the current photovoltaic (PV) Solar Home Systems (SHS) or install (in addition) an AC power system based on diesel generators.

2. OBJECTIVES

With regard to the islands of Atiu, Mauke, and Mitiaro:

- (a) To determine in detail what improvements, in the *short term*, should be undertaken in the current diesel based power systems.
- (b) To determine in detail the technical, socio-cultural, economic, financial and institutional/management feasibility, in the *medium term*, of supplementing the current diesel systems with renewable energy sources.

³ The Government of the Cook Islands has identified the overall scope for this technical assistance consultancy during a UNESCO Apia mission to Rarotonga, Cook Islands in July 2003. The detailed Terms of Reference (TOR) subsequent has been prepared by UNESCO Apia with input from the Energy Division (ED), Ministry of Works, Government of the Cook Islands. In addition a rural energy expert has provided input on the TOR. UNESCO Apia would like to thank very much the rural energy expert for his invaluable and continued support.

- (c) To determine in detail the technical, socio-cultural, economic, financial and institutional/management feasibility, in the *long term*, of replacing 100% of the current diesel based power systems with renewable energy sources.

With regard to the island of Pukapuka:

- (a) To preliminary assess and recommend if the most optimal power solution is to improve the existing PV Solar Home Systems (SHS) or to install (in addition) an AC power system based on diesel generators.

3. OUTPUTS ⁴

- (a) An inception note.
- (b) A debriefing note and minutes from the debriefing meeting(s).
- (c) A power sector/feasibility study report with regard to Atiu, Mauke, and Mitiaro.⁵
- (d) A power recommendation paper with regard to Pukapuka.

4. ACTIVITIES

The scope of work for the consultancy will include, but not necessarily be limited to, the following activities:

REGARDING OUTPUT A – INCEPTION NOTE:

- (a) Study and review relevant background material.
- (b) Identify key project stakeholders.

⁴ All outputs from the consultancy are solely the property of UNESCO. E.g. UNESCO can distribute as widely as it finds appropriate.

⁵ Depending on the preference of the Government of the Cook Islands, it might be required that the most optimal is to have three (3) separate power sector/feasibility study reports for Atiu, Mauke, and Mitiaro respectively.

- (c) Write-up inception note, comprising the consultant's understanding of the consultancy and associated tasks; identification of issues crucial to the viability of the consultancy; and comments to this TOR.

REGARDING OUTPUT B - A DEBRIEFING NOTE AND MINUTES FROM THE DEBRIEFING MEETING(S):

- (a) Prepare debriefing note, based on preliminary findings, conclusions and recommendations.
- (b) Discuss debriefing note with the Director, Energy Division (ED), Ministry of Works. Prepare minutes of the meeting. Present debriefing note to the Minister of Energy.

REGARDING OUTPUT C - A POWER SECTOR/FEASIBILITY STUDY REPORT WITH REGARD TO ATIU, MAUKE, AND MITIARO:

In general:

- (a) Specify what improvements in the short term (i.e. 0-1 years) should be undertaken in the current diesel based power systems.
- (b) Describe and assess the technical, socio-cultural, economic, financial and institutional/management feasibility in the medium term (i.e. 1-5 years) of supplementing the current diesel systems with renewable energy sources.
- (c) Describe and assess the technical, socio-cultural, economic, financial and institutional/management feasibility in the long term (i.e. 5-10 years) of replacing 100% of the current diesel based power systems with renewable energy sources.
- (d) Develop an overall, balanced and realistic power sector plan for the short, medium and long term for installation of new generation capacity in order to meet the requirements of load growth, reliability, operating costs and environmental sustainability.
- (e) Consider appropriate Demand Side Management (DSM) strategies of all the supply options to be investigated.

- (f) Undertake a preliminary Environment Impact Assessment (EIA) in line with the Government's EIA procedures/guidelines of the recommended supply option interventions.
- (g) Consult during the whole process as appropriate with major stakeholders such as the Energy Division (ED), Ministry of Works; relevant Island Councils/mayors; Office of the Minister for Islands Administration (OMIA) and the Environment Service, Government of the Cook Islands.
- (h) Ensure that all short, medium and long-term interventions proposed are consistent with the Cook Islands National Energy Policy (2003).
- (i) Consult relevant sections of the Outer Island Power Development Study for the Cook Islands from 1998 (ADB, TA no. 2264-COO) in particular the sections on Atiu, Mauke and Mitiaro.
- (j) Coordinate and collaborate to the extent possible with activities undertaken in the Cook Islands as part of the Pacific Islands Renewable Energy Project (PIREP) executed by the South Pacific Regional Environment Programme (SPREP).

In particular:

- (k) *Briefly describe background and immediate objectives.* The description might include but not necessarily be limited to the following: 1) the project idea, its immediate objectives and beneficiaries; 2) dates of essential events; and 3) relevant studies and investigations already undertaken.
- (l) *Briefly describe the socio-economic context.* The description might include but not necessarily be limited to the following: 1) geography, climate and main economic activities; 2) structure of local administration overall and more specifically how it relates to power supply services; 3) size of population, population density, 4) average income per capita; 5) income distribution; 6) occupational distribution; 7) economic growth and growth potentials; 8) willingness and ability of the concerned project beneficiaries to pay for the services; 9) relevant forecasts (e.g. extension of service area(s); population/target group(s); per capita income, etc.). As part of this task, briefly undertake an analysis of general development priorities for the island/village in question. An appropriate methodology could possibly be a qualitative survey technique such as Participatory Rural Appraisal (PRA). Among others

this will enable island/village development problems to be ranked according to priority and gender (and/or other relevant variables).

- (m) *Briefly describe the power sector.* The description might include but not necessarily be limited to the following: 1) the relevant public authorities for the sector at national and local levels, roles and responsibilities; 2) government policy and plans for the sector, objectives, strategies, programmes and activities; 3) sector national and local budgets in relevant details and measured in relation to total budgets and other sectors; 4) overall legislative framework for the sector; 5) the organisation of the sector itself, ownership within the sector, degree of organisational and financial autonomy of the power supply entities; 6) service sector coverage at national and local levels; and 7) national norms and standards for the sector (e.g. fuel, efficiency, emissions, treatment and disposal of waste oil, cooling water, etc.).
- (n) *Describe and assess power/electricity demand, tariff structure and rates.* The description and assessment might include but not necessarily be limited to the following: 1) size and composition of present power/electricity demand; 2) demand projections (these are to be compared with the supply forecasts); 3) tariff structure and rates strategy and forecasted power/electricity rates in fixed prices; and 4) procedure to follow for changing of tariff structure and rates.
- (o) *Undertake problem analysis.* The analysis might include but not necessarily be limited to the following: 1) the present power supply situation; 2) present and potential demand for power services; and 3) short, medium and long term problems to be addressed (legislative, institutional, human resource, technical, environmental, financial, security of supply, etc.). A key here will be the load structure including peak and minimum power requirements, daily load curves and their variability, and forecasts of these parameters for a 5 and 10 years period respectively. Further, a survey of existing appliances being used in households and their daily use times and the inventory of other loads on the islands should be undertaken if needed.
- (p) *Specify in detail what improvements in the short term (i.e. 0-1 years) should be undertaken in the current diesel based power systems.* Proposed interventions should look at generation as well as distribution.
- (q) *Preliminary assess local energy resources.* The analysis might include but not necessarily be limited to the following: 1) describe the technical possible local energy resources that can be utilised presently and realistically in a 1-10 years period for power generation; and 2) recommend the most viable of the local energy resources. The resource assessments must include solar, wind and biomass (notably coconut oil).

- (r) *Assess in detail, technology and project engineering.* This assessment might include but not necessarily be limited to the following: 1) present and forecast needed power supply capacities and characteristics; 2) proposed standards of power supply; 3) power plant technology options including merits and disadvantages and recommended option; 4) power supply network technology options including merits and disadvantages and recommended option; 5) infrastructure (e.g. site, wharf, access roads, etc; 6) overall plant lay out; 7) overall building, machinery and equipment specifications; 8) overall procurement and construction supervision model (foreign – local supplies); and 9) overall operation and maintenance engineering requirements (e.g. spare parts and after sales services).
- (s) *Assess production, operation and maintenance of inputs.* The assessment might include but not necessarily be limited to the following: 1) overall supply programme for fuel, lubricants and cooling water; qualitative properties; quantities; source and origin; availability; unit costs; and 2) overall utilities; needs; availability; and unit costs.
- (t) *Describe possible future project/power plant organisation.* The description might include but not necessarily be limited to the following: 1) project preparation organisation (e.g. involved parties, possible technical support and their roles and responsibilities); 2) project implementing organisation (e.g. implementing agency, other involved parties, their roles and responsibilities including construction and installation supervision), 3) power supply entity organisation (e.g. roles and responsibilities); and 4) job positions to be filled (e.g. recruitment needs, availability of relevant workforce within reasonable distance from the project).
- (u) *Briefly outline needed training and technical assistance programme.* The outline might include but not necessarily be limited to the following: 1) specification of staff/positions to be trained and the training subjects; 2) training programme (e.g. content and duration of courses, participants, on-the-job or classroom; local, regional or overseas); and 3) technical assistance programme (e.g. specification of expertise needed, time schedule for inputs, placing and the role of expert(s) in the project/plant organisation).
- (v) *Briefly undertake preliminary Environmental Impact Assessment (EIA) of current and recommended future supply option(s).* The general framework for the assessment will be the Cook Islands Government's EIA procedures/guidelines, but since no specific procedures/guidelines are available with regard to power sector interventions, the Asian Development Bank (ADB) Environmental Guidelines for Selected Industrial and Power Development Projects (1993) will be applied. Thus, included will be a description of the actual and potential positive and negative environmental impacts during: i) construction and erection period; and ii) operations period (e.g. external and internal environment, occupational health and safety). The assessment under *the construction and erection period* might include but not

necessarily be limited to the following: 1) social impacts due to employment creation; 2) social impacts due to population relocation; 3) noise impact from construction works; 4) disposal of excavated materials; 5) construction waste, dust and other pollution; 6) disruption of access to houses and business; 7) impacts on surface and groundwater sources; 8) use of and impact on other natural resources; 9) potential areas of conflict with: coastal/inland water, agriculture, forestry/uncultivated land, and other types of area. The assessment under the *operations period* might include but not necessarily be limited to the following: 1) social impacts due to improved living conditions; 2) reduced air pollution; 3) increased employment conditions; 4) impacts on surface and groundwater resources; 5) cooling water disposal; 6) fly ash and waste oil treatment and disposal; 7) social impacts, including public nuisance due to fuel transport; 8) noise impacts from the operation; 9) energy consumption; and 10) health and safety of workers and the public. Consult extensively among others with Environment Service, Government of the Cook Islands for this activity.

(w) *Outline the budget for different power supply options.* The outline might include but not necessarily be limited to the following: 1) investment budget and 2) operation budget.

(x) *Undertake economic analysis.* A 15-year term and 6% discount rate (when inflation is not considered) should be applied for the analysis.

(y) *Undertake financial analysis.* The analysis might include but not necessarily be limited to the following: 1) net present value (NPV) of the investment; 2) financial internal rate of return (FIRR); 3) a cost recovery analysis; and 4) relevant sensitivity analysis.

(z) *Briefly undertake assumptions and risks analysis.*

(aa) *Develop power sector plan.* Based on outcomes of the above mentioned activities develop an overall, balanced and realistic power sector plan for the short (0-1 years), medium (2-5 years) and long (6-10 years) term for installation of new generation capacity to meet the requirements of load growth, reliability, operating costs and environment sustainability.

REGARDING OUTPUT D – A POWER RECOMMENDATION PAPER WITH REGARD TO PUKAPUKA

In general:

- (a) Undertake a desk study to be based primarily on available information, but if needed, additional information obtained through electronic means of communication (i.e. fax, email and telephone).

In particular:

- (b) Using consumer bills and user data from an appropriate island in the Cook Islands having non-24 hour power estimate the number of Pukapuka households in the use ranges of less than 30 kWh/month, 31 to 50 kWh/month, 51-75 kWh/month, 76-100 kWh/month and greater than 100 kWh/month.
- (c) Prepare a preliminary PV Solar Home Systems (SHS) design suitable to provide 240V, 50Hz AC power at a level permitting operation of appliances typically used in rural households connected to non 24-hour diesel power systems in the Cook Islands. The base design should be based on the existing solar panels in place in Pukapuka with expansion designs for systems capable of 2 kWh/day and 4 kWh/day. Estimate the number of systems of each size that would be required on Pukapuka using the consumer profile estimated in (b).
- (d) Compare upgrading of existing SHS - to the preliminary design determined in part (c) - to diesel grid electrification suitable for operation 6-8 hours per day at peak demand periods considering demand estimates of (b). This assessment should be undertaken respectively from the perspective of: i) the Government of Cook Islands, ii) Island Councils; and iii) the consumers. Consideration in the comparison should be given to: i) costs; ii) environmental impact; iii) relative value of 24-hour SHS power to part-time diesel power; iv) cost to consumers; and v) reliability of power regarding access to maintenance and fuel.
- (e) Using the past 2 years shipping data for Pukapuka, estimate the size and cost of the diesel fuel storage facility necessary to maintain reliable 8-hour diesel power on Pukapuka. It has to be ensured that existing shipping systems can handle the fuel requirements for diesel power safely and that space is available for the quantity required.
- (f) Preliminarily recommend the most optimal power solution (i.e. either to improve the existing PV SHS or to install (in addition) a new AC power system based on diesel generators).
- (g) Outline for the recommended power solution, steps that need to be undertaken and issues that need further clarification.

5. INPUTS

Organisation

Input

Energy Division (ED), Ministry of Works, Government of the Cook Islands

a) Provide relevant background information and documentation to the consultant(s) regarding strategies, policies, programmes, plans, activities, projects; etc.; b) Assist with logistics concerning the field visits; c) If appropriate participate in the field visits; and d) Coordinate input from relevant national and local stakeholders on the draft documents.

UNESCO/UNDP-Apia

a) Organise the consultancy; b) Fund the consultancy; c) Provide consultant with copies of relevant documentary sources; d) If possible participate in the field visits; and e) Provide input on the draft documents.

Annex H - List of People Consulted⁶

- Ministry of Works Energy Division – Mata Nooroa; Director of Energy
- Ministry of Works Energy Division – Tangi Tereapi; Snr Energy Planner
- Ministry of Works Energy Division – David Akaruru; Energy Officer
- Environment Services - Vaitoti Tupa; Director of Environment
- Meteorological Office - Arona Ngari; Director of Meteorology
- Meteorological Office - Nga Rauraa; Support Services Manager
- Mauke Island Secretary - Tai Tura
- Mauke Island Council and Aronga Mana
- Mauke Member of Parliament - Hon Mapu Taia (*He was at meeting, and ex officio a member of Mauke Island Council and Aronga Mana*)
- Mauke Telecom Station Operator - -Marae Turaki
- Mauke Power - Ngatuaine Tutere; Officer in Charge
- Tua Trading, Mauke (largest consumer) – Patrick Tua; Owner
- Mitiaro Island Secretary - Tai Topa (Also acting Officer in Charge of Power)
- Mitiaro Island Council and Aronga Mana
- Patai Store, Mitiaro – Peter Van Dongen; Manager/Owner
- Mitiaro Member of Parliament - Hon Tangata Vavia
- Office of the Minister for Island Administrations – Nandi Glassie; CEO
- Ministry of Foreign Affairs & Immigration - Assistant to Secretary; Carl Hunter
- Ministry of Works – Ben Parakoti; Water Works, Vaipo Mataora; Survey Division, Timoti Tangiruaine; IT Manager
- Atiu Island Secretary - Charlie Koronui

⁶ This list does not include the energy survey participants or details of all staff in the various administration consulted

- Atiu Island Council and Aronga Mana
- Atiu Member of Parliament – Hon Upoko Simpson
- Atiu Power Supply - Teura Kea; Acting Officer in Charge
- Atiu Villas & Central Store – Roger Malcolm; Manger/Owner
- Atiu Coffee – Jurgen Manske-Eimke; Manager/Owner
- Cook Islands Tourism Corporation - Chris Wong; CEO
- Ellena Tavioni; Tapuata Eco Retreat Developer, Atiu Is
- Ministry of Agriculture - Secretary Nga Mataio
- Te Aponga Uira (Rarotonga Electricity Authority) – Apii Timoti; CEO
- Te Aponga Uira (Rarotonga Electricity Authority) - John Christmas; Consultant/Engineer
- Minister of Energy & Finance – Hon Tapi Teremoana Taio
- Ministry of Finance & Economic Management, Aid Management Division - Temarama Anguna; Acting Manager
- Office of the Leader of the Opposition; George Turia, CEO

Annex I - Inception Note

**Increasing Utilisation of Renewable
Energy Technologies in the Cook Islands**

Project CKI/03/009, UNESCO, Apia Samoa

INCEPTION NOTE

Prepared by:

Bruce Clay

Herbert Wade

21st June 2004

1. INTRODUCTION

Renewable energy has been identified by the Cook Islands Government as having the potential to contribute significantly to the economy, environment and social development. The title of this project is the National Energy Policy 2003 goal for renewable energy.

The project aims to determine short-term improvements in the current diesel based power systems on Atiu, Mauke and Mitiaro in the Southern Group and assess the feasibility of utilising local renewable energy resources in the medium and long term to supplement or replace existing diesel power systems and to prepare draft project concept proposals for each island. Additionally the project will undertake a desk study to assess the options of either upgrading the PV systems or diesel grid electrification for the island of Pukapuka in the Northern Group. A draft project concept proposal will also be prepared for Pukapuka.

2. KEY STAKEHOLDERS

The following have been identified as key stakeholders in the success of this project:

- Ministry of Works and in particular the Energy Division
- Office of the Minister for Islands Administration
- Atiu, Mauke, Mitiaro & Pukapuka Island Councils and Aronga Mana
- Members of Parliament for Atiu, Mauke, Mitiaro & Pukapuka
- Ministry of Environment
- Tourism Corporation

3. OBJECTIVES AND METHODOLOGIES

With regard to the islands of Atiu, Mauke and Mitiaro:

(a) Determine short term improvement of existing power system

All three islands indicate in their respective 2004/2005 budget statements various degrees of improvement and upgrading of power systems. These include provision of 24hr power, upgrading of equipment, improved maintenance and energy efficiency.

During the field trips to the islands power system operational data will be collected, equipment listed and discussions had with power system operators, island administration and council. Based on data and feedback gathered recommendations will be made for short term improvements. Both generation and distribution will be addressed and suitable interventions developed.

(b) Determine medium term feasibility of supplementing current diesel power systems with renewable energy

In line with the National Energy Policy of promoting the increased use of feasible renewable energy technologies, this project aims to determine medium term (1-5 years) options of supplementing the current diesel systems with local indigenous renewable energy sources. Assessment of the various intervention options will consider technical, socio-cultural, economic, financial and institutional/management feasibility as well as environmental impact.

Data and information gathered during missions including operational, load profiles and consultations with stakeholders will be combined with existing studies undertaken in the Cook Islands in developing feasibility options and developing an overall, balanced and realistic power sector plan. Existing relevant studies include the Pacific Islands Renewable Energy Project (PIREP), Outer Island Power Development Study (1998 ADB) plus statistical data from the 2001 Census.

Technically mature renewable energy technologies to be considered for supplementing the current diesel power systems include; solar thermal, solar photovoltaic, wind and biomass. Local energy resource assessment will be based on available resource data and field visit observations. Feasibility analysis will include civil, operational and maintenance requirements and the difficulties of operating and maintaining power systems in remote locations.

(c) Determine long term feasibility of replacing 100% of the current diesel power systems with renewable energy

Much of the background for the analysis of medium term feasibility for renewable energy will be utilised in the long term (5-10years) analysis.

Replacing 100% of the existing diesel power systems with renewable energy offers the best opportunity to meet the National Energy Policy Statement as a long term mission for the nation's energy sector.

Maturing technologies showing long term potential may be considered in this assessment. In general energy storage is a major issue for a 100% renewable energy power system. In the long term feasibility analysis the system design would differ from the medium term and subsequently so will the technical, economic, financial and environmental analysis.

(d) Preliminary Environmental Impact Assessment

For each recommended supply option intervention a preliminary EIA will be undertaken. The EIA will be based on the ADB Environmental Guidelines for Selected Industrial and Power Development Projects 1993.

Data for the assessment will be gathered during the field visits to the islands and from local sources where available.

(e) Power Sector Plan

A power sector plan addressing short, medium and long term will be developed. The plan will encompass a synthesis of project recommendations developed during the feasibility analysis. This plan will be consistent with the National Energy Policy 2003 and will examine various issues including:-

- Operational Costs and Budgets
- Capital Budgets
- Tariff Structure
- Demand Growth
- Organisational requirements
- Human resources development
- Environmental sustainability
- Demand side management strategies
- Reliability

With regard to the island of Pukapuka:

(f) A Power Recommendation Paper for Pukapuka

A desk study will be carried out to recommend whether to upgrade existing PV systems or implement an AC diesel electric grid. Information will be gathered from existing reports and enhanced through communication with stakeholders including the Energy Division, OMIA and Island Councils.

The study will develop an estimated household power profile and appropriate PV systems. A comparative analysis would then be undertaken between the Solar Home Systems and diesel grid electrification. This comparison would be taken from the Government, Island Council and consumer's perspective.

The PIREP report on Pukapuka provides a collaboration of operational information on the SHS in use and provides insight into addresses the upgrading and sustainability of these systems. As per this report, organisational structure, tariffs and operational/maintenance procedures need to be developed and implemented to ensure the long term sustainability of any power system on this remote island.

(g) Draft Project Concept Proposal

Progressing from the power sector/feasibility study for Atiu, Mauke and Mitiaro and the Pukapuka power recommendation paper, draft concept proposals will be developed for the four islands. The proposed interventions are to be agreed upon by the Cook Islands Energy Division and UNESCO Apia prior to drafting. Format will be agreed upon with UNESCO Apia and guided by AusAID's guideline for Preparing Project Design Documents, 20th June 2003 version.

4. COMMENTS ON CRITICAL ISSUES AND THE TERMS OF REFERENCE

Following is a listing of several issues are critical to the effectiveness of this project :-

ISSUE	ACTION/COMMENT
Quality Data and Information	Identification of required information and principal sources. Power system logging to cover as long a time period as possible. Information, observations and data from previous studies to be corroborated where ever possible. Effective consultations with stakeholders.

Island Community Involvement in Consultations	Consultation with Energy Division, OMIA and Island Councils/Administrations to ensure consumer expectations are appraised accurately. Where necessary carry out qualitative surveys.
Local Energy Resource Assessment	A lack of site specific resource data, particularly wind, will require estimation and sensitivity analysis

5 PROPOSED WORK PLAN

Outlined below is the proposed schedule. Dates and activities for Mission 1 & 2 have been agreed by the Cook Islands Director of Energy, UNDP/UNESCO Apia and the consultants. Background material is currently being reviewed by the consultants and project preparation is well underway.

Activity or Milestone	Scheduled Date(s)
Project Preparation: Mission Programs, Inception Note, Background material review	6 – 25 June
Mission 1: Field visits to Mauke & Mitiaro, meetings with relevant stakeholders	26 June – 9 July
Preliminary analysis, debriefing note preparation for Mauke & Mitiaro	12 – 16 July
Mission 2a: Field visit to Atiu, meetings with relevant stakeholders. Preliminary analysis, debriefing note preparation for Atiu	17 – 28 July
Mission 2b: Debriefing Note presentation	29 – 30 July
Detailed Analysis and report preparation	2 – 19 August
Submission of Draft Report	20 August
Review Period for Draft Report	21 Aug – 14 September
Submission of Final Report	15 September

Annex J - Documentary Sources

ADB	ADB Cook Islands Power Development Study 1998
ADB	ADB EIA Guidelines for Power Projects 1993
AIC	Atiu Island Profile, September 2003
AIC	Water Supply and Sanitation Assessment Report prepared by Flotek Systems, Rarotonga 2003
CIA	<i>World Factbook: Fiji chapter</i> 2004
FED	Pacific-Danish Environmental Education and Action Program – Feasibility Study of Phase 1, prepared by COWI/Risoe, January 1998
GoCI	Cook Islands National Energy Policy 2003
GoCI	Environment Act 2003
GoCI	Environment Service Environmental Significance Declaration
GoCI	Cook Islands 2001 Population Census
GoCI	Cook Islands Budget Policy Statement 2004-2005
GoCI	Outer Island Budget Outputs 2003-2004 & 2004-2005
GoCI	Record for Technical Data for the Outer Islands prepared by the Energy Division
GoCI	Mangaia AWS Wind Data 2001-2003 prepared by the Meteorological Office
GoCI	Mauke AWS Wind Data 2001-2003 prepared by the Meteorological Office
GoCI	Cook Islands 2000 Census of Agriculture & Fisheries
GoCI	The Climate and Weather of the Southern Cook Islands prepared by New Zealand Meteorological Service
MIC	Mitiaro Strategic Directions 2003-2008. Draft supplied by Island Secretary.
PREFACE	Mangaia – Cook Islands Feasibility Study for a Wind Farm Connected on the Diesel Grid, prepared by Vergnet SA December 2001
PREFACE	Pre-feasibility study of wind power projects on Rarotonga, Atiu & Mangaia – May 1999 – Prepared by Vergnet SA, Laurent Albuisson
PREFACE	PUKAPUKA Trip Report (Jean-Michel DURAND) 2001
SOPAC	Copra Oil as a Biofuel in Pacific Islands - Challenges and Opportunities prepared by Jan Cloin
UNDP	GEF/ UNDP Pacific Islands Renewable Energy Project (PIREP) Draft Cook Islands National Report May 2004
S.P.I.R.E.	Contract for the Solar Electrification Project of Pukapuka -1992
S.P.I.R.E.	Post evaluation of the solar electrification in Pukapuka, two years since implementation 1994
S.P.I.R.E.	Puka Puka Solar Electrification Jean-Denis DURAND 1995

Annex K - Debriefing Note

Increasing Utilisation of Renewable Energy Technologies in the Cook Islands

Project CKI/03/009, UNESCO, Apia Samoa

DEBRIEFING NOTE

Prepared by:

Bruce Clay

Herbert Wade

28th July 2004

Introduction

Renewable energy has been identified by the Cook Islands Government as having the potential to contribute significantly to the economy, environment and social development. The title of this project is the National Energy Policy 2003 goal for renewable energy.

The project aims to determine short-term improvements in the current diesel based power systems on Atiu, Mauke and Mitiaro in the Southern Group and assess the feasibility of utilising local renewable energy resources in the medium and long term to supplement or replace existing diesel power systems and to prepare draft project concept proposals for each island. Additionally the project will undertake a desk study to assess the options of either upgrading the PV systems or install a diesel grid electrification for the island of Pukapuka in the Northern Group. A draft project concept proposal will also be prepared for Pukapuka.

Key Stakeholders

The following have been identified as key stakeholders in the success of this project:

- Ministry of Works and in particular the Energy Division
- Office for the Minister of Island Administration
- Atiu, Mauke, Mitiaro & Pukapuka Island Councils and Aronga Mana
- Atiu, Mauke, Mitiaro & Pukapuka Power Supplies
- Members of Parliament for Atiu, Mauke, Mitiaro & Pukapuka
- Environment Services
- Cook Islands Tourism Corporation
- Cook Islands Investment Corporation
- Ministry of Foreign Affairs and Immigration
- Aid Management Division, Ministry of Finance & Economic Management

Activities To Date

Activities carried out to date for Atiu, Mauke and Mitiaro are as listed in the following table:-

Activity or Milestone	Dates
Project Preparation: Mission Programs, Inception Note, Background material review	6 – 25 June 2004

Mission 1: Field visits to Mauke & Mitiaro, meetings with relevant stakeholders	26 June – 9 July 2004
Mission 2: Field visit to Atiu, meetings with relevant stakeholders. Preliminary analysis, debriefing note preparation	17 – 28 July 2004

Over the last five weeks two missions have been carried out which have involved field visits to the three islands and consultations with relevant stakeholders and interested parties. During these missions extensive information has been gathered on existing power system infrastructure, both physical and operational, individual island administration operation, strategic plans and development aspirations plus national issues pertaining to this project.

Local energy resource data and information has been collected for each island during field visits and from previous studies. Information was also gathered for assessment of environmental impacts of existing and planned energy generation development.

Household energy surveys were carried out to assess present power usage and enabled feedback from the wider community.

A power quality analyser (data logger) was used during each island visit which stored information on the power system operation allowing assessment of power quality and quantity.

The desk study for Pukapuka is currently underway with the Island Administration presently carrying out an energy survey to assess the needs and expectations of the population in regards to electricity requirements. Once the survey results have been received assessment of appropriate interventions (diesel grid or solar upgrade) will be finalised.

During the two missions meetings and consultations were had with the following stakeholders and involved parties:

- Ministry of Works Energy Division – Mata Nooroa; Director of Energy
- Ministry of Works Energy Division – Tangi Tereapi; Snr Energy Planner
- Ministry of Works Energy Division – David Akaruru; Energy Officer
- Environment Services - Vaitoti Tupa; Director of Environment
- Meteorological Office - Arona Ngari; Director of Meteorology

- Meteorological Office - Nga Rauraa; Support Services Manager
- Mauke Island Secretary - Tai Tura
- Mauke Island Council and Aronga Mana
- Mauke Member of Parliament - Hon Mapu Taia (*He was at meeting, and ex officio a member of Mauke Island Council and Aronga Mana*)
- Mauke Telecom Station Operator - -Marae Turaki
- Mauke Power - - Ngatuaiane Tutere; Officer in Charge
- Tua Trading, Mauke (largest consumer) – Patrick Tua; Owner
- Mitiaro Island Secretary - Tai Topa (Also acting Officer in Charge of Power)
- Mitiaro Island Council and Aronga Mana
- Patai Store, Mitiaro – Peter Van Dongen; Manager/Owner
- Mitiaro Member of Parliament - Hon Tangata Vavia
- Office of the Minister for Island Administrations – Nandi Glassie; CEO
- Ministry of Foreign Affairs & Immigration - Assistant to Secretary; Carl Hunter
- Ministry of Works – Ben Parakoti; Water Works, Vaipo Mataora; Survey Division, Timoti Tangiruaiane; IT Manager
- Atiu Island Secretary - Charlie Koronui
- Atiu Island Council and Aronga Mana
- Atiu Member of Parliament – Hon Upoko Simpson
- Atiu Power Supply - Teura Kea; Acting Officer in Charge
- Atiu Villas & Central Store – Roger Malcolm; Manger/Owner
- Atiu Coffee – Jurgen Manske-Eimke; Manager/Owner
- Cook Islands Tourism Corporation - Chris Wong; CEO
- Ellena Tavioni; Tapuata Eco Retreat Developer, Atiu Is
- Ministry of Agriculture - Secretary Nga Mataio
- Te Aponga Uira (Rarotonga Electricity Authority) – Apii Timoti; CEO

- Te Aponga Uira (Rarotonga Electricity Authority) - - - John Christmas; Consultant/Engineer
- Minister of Energy & Finance – Hon Tapi Teremoana Taio
- Ministry of Finance & Economic Management, Aid Management Division - Temarama Anguna; Acting Manager
- Office of the Leader of the Opposition; George Turia, CEO

Preliminary Findings and Observations

Detailed analysis is currently underway and as such at this stage most finding and observations relate to the existing power systems. The following table shows current installed capacity and tariff.

	Supply Hours	Generators	Installed Capacity (kW)	Base/Max Load (kW)*	Tariff	
					Domestic	Commercial
Atiu	24	1 x Hino 110kW 2 x Deutz 45kW 1 x Lister 42kW	244	35 / 80	\$0.40/kWh + \$5/month	\$0.62/kWh + \$5/month
Mauke	24	4 x Lister 42kW	168	25 / 78	\$0.36/kWh + \$5/month	\$0.58/kWh + \$5/month
Mitiaro	19	2 x Lister 28kw 1 x Lister 21kW	77	9 / 26	\$0.36/kWh	\$0.58/kWh + \$5/month

*These are based on preliminary analysis of data logged during field visits

As a general observation most islands power generation operations suffer from limited resources, both physical and human, for the sustainable and reliable operation of the power generation and distribution systems.

Preliminary analysis would indicate medium and long term potential for local renewable energy sources to substitute imported diesel. Whilst wind power generation appears to be the most feasible medium term renewable energy technology solar and perhaps biomass may have a significant role in diesel substitution.

Following is an island by island synopsis of preliminary findings and observations made during the two recent missions. These were communicated to the stakeholders during debriefing meetings.

a. Atiu

Atiu Island Council has requested Government to return Atiu Power Supply to Te Aponga Uira (TAU) to operate. In a Cabinet Memorandum dated 4th May 2004, the request was approved and TAU was instructed accordingly. Presently the Board of TAU has asked for power, financial and operational, information from Atiu Island Council to assess the best method of implementation. Although not part of this project it should be noted that Aitutaki Power is also included in this Cabinet decision.

Existing Diesel System;

- Generation capacity with 4 sets of an installed capacity is adequate however is vulnerable to insufficient capacity should the Hino 110kW break down.
- Power quality is reasonable with relatively stable line voltage and frequency at power house.
- Power station only manned during peak load periods.
- Age of generating sets will continue to tax the already limited maintenance budget.
- LV distribution and switchgear requires considerable maintenance and in certain areas replacement. Consideration should be given to replacement of ageing overhead LV 4 wire configuration with aerial bundled cables.
- No suitably qualified Officer in Charge of power.
- No organised training and upskilling program in place for power personnel, in particular for electrical engineering.
- Mechanics in the Infrastructure department appear competent for general engine maintenance.
- Lack of electrical and engine maintenance tools, test instruments and safety equipments.
- Fuel and oil handling facilities and procedure causing considerable fuel and oil contamination of environment, particularly in and around power station.
- Power house building has poor sound level suppression and ventilation. Building requires maintenance.
- Street lighting is a significant non-metered power consumer with no budgetary allocation.
- Existing tariff is below full recovery tariff. (Final report to quantify)
- Existing energy budget only covers fuel, oil, personal and generator set maintenance. No allocation for training, distribution maintenance and equipment.
- Meter reading and billing system reasonably thorough and adequate.
- Security of metering on consumers premises need to be tightened.

- Ageing consumer installations require upgrading, and on some installations the standards are well below the regulatory safety requirement.

Renewable Energy and DSM;

- Potential wind sites identified in area of old airport and South East coast. Old airport site is adjacent the existing HV distribution line whilst the South East coastal area would require grid extension.
- Appears to be considerable land area available for solar power including area within power station compound.
- Extensive pine and Gaisher plantings and to a lesser extent coconut plantations may offer biomass opportunities.
- DSM, in particular implementation of energy efficiency program, could contribute to significant reduction in diesel consumption. Household survey results will assist in calculation of potential energy efficiency measures.
- DSM could reduce peak loads and improve system reliability.

Medium and Long Term Considerations;

- Tourism considered the major priority in the medium to long term economic development by the Island Council, Tourism Corporation and Government.
- Eco tourism development planned for South East coast with up to 42 rooms/suites.
- Provision of reliable electricity and infrastructure a requirement for island development.
- Interruption to diesel supply, due to external circumstances, identified as a significant issue.

b. Mauke

Existing Diesel System;

- Generation capacity with 4 sets of an installed capacity of 168kW is adequate however is vulnerable to insufficient capacity should one generating set break down.
- Power quality is reasonable with relatively stable line voltage and frequency at power house.
- Power station only manned during peak load periods.

- Age of generating sets will continue to tax the already limited maintenance budget.
- LV & HV distribution and switchgear requires considerable maintenance/upgrade and in certain areas replacement. Consideration should be given to replacement of aging overhead LV 4 wire configuration with aerial bundled cables.
- New 50kVA transformer and associated cabling to be installed in Oiretumu village to alleviate low voltage at grid extremities to the East.
- No organised training and up skilling program in place for power personnel.
- Lack of electrical maintenance tools, test instruments and safety equipments.
- Fuel and oil handling facilities and procedure can be improved to reduce fuel and oil contamination of environment, particularly in and around power station.
- Power house building has poor sound level suppression and ventilation. Building require some maintenance.
- Existing tariff is below full recovery tariff. (Final report to quantify)
- Existing energy budget only covers fuel, oil, personal and generator set maintenance. No allocation for training, distribution maintenance and equipment.
- Meter reading and billing system could be improved by utilising accounts computers to calculate and print monthly bills rather than manually as is done presently.
- Individual diesel powered water bore pumps presently in use are consuming considerable diesel (~400lt/month) and contaminating ground adjacent pumps with fuel and oil.
- Security of metering on consumers premises need to be tightened.
- Ageing consumer installations require upgrading, and on some installations the standards are well below the regulatory safety requirement.

Renewable Energy and DSM;

- Potential wind sites identified in Nooangatua and South East coast. Nooangatua site is in the centre of the island on the raised plateaux within 300mtr of the existing HV distribution line whilst the South East coastal area would require almost 3 km of transmission line.
- Wind powered water bore pumps have performed well in the past but are presently requiring maintenance. Parts for repair of the wind pumps are currently awaiting shipment from Rarotonga.

- Considerable land area available for solar power particularly on the Nooangatua site.
- Coconut plantations may offer biomass opportunities.
- DSM, in particular implementation of energy efficiency program, could contribute to significant reduction in diesel consumption. Household survey results will assist in calculation of potential energy efficiency measures.
- DSM could reduce peak loads and improve system reliability.

Medium and Long Term Considerations;

- Tourism considered by Island Council and Government to be a significant contributor to the medium to long term economic development of Mauke.
- Several smaller tourism accommodation developments under construction.
- Provision of reliable electricity and infrastructure a requirement for island development.
- Interruption to diesel supply, due to external circumstances, identified as a significant issue.

c. Mitiaro

Existing Diesel System;

- Generation capacity with 3 sets of an installed capacity of 77kW is not adequate to provide reliable power of reasonable quality.
- Lack of ability to synchronise and run 2 generators to carry peak loads causes large power fluctuations.
- Out of balance phase loadings need to be rectified.
- Power station only manned during peak load periods.
- Age of generating sets will continue to tax the already limited maintenance budget.
- Power Station building is in a poor state of repair and inadequate for any future expansion.
- Location of Power Station within 100mtr of dwellings poses health and safety risks.
- LV distribution and switchgear requires considerable maintenance/upgrade and in certain areas replacement.
- Island Secretary presently acting as Officer in Charge of power.

- Island Secretary is the only licensed electrical tradesman on Mitiaro.
- No organised training and up skilling program in place for power personnel apart from that given by the Island Secretary
- Lack of electrical maintenance tools, test instruments and safety equipments.
- Fuel and oil handling facilities and procedure require improvement to reduce considerable fuel and oil contamination of environment, particularly in and around power station. (Capex approved in current budget)
- Existing tariff is below full recovery tariff. (Final report to quantify)
- Existing energy budget only covers fuel, oil, personal and generator set maintenance. No allocation for training, distribution maintenance and equipment.
- Meter reading and billing system could be improved by utilising accounts computers to calculate and print monthly bills rather than manually as is done presently.
- Security of metering on consumers premises need to be tightened.
- Ageing consumer installations require upgrading, and on some installations the standards are well below the regulatory safety requirement.

Renewable Energy and DSM;

- Potential wind and solar site identified 200-300 metres East of existing power station.
- Potential wind site on South East Coast would require a transmission line of approximately 4km.
- Given the need to upgrade power station building, fuel handling and generation capacity the potential wind/solar site East of existing power station could also incorporate a new power station. This site would reduce present safety and environmental concerns.
- Coconut plantations may offer biomass opportunities.
- DSM, in particular implementation of energy efficiency program, could contribute to significant reduction in diesel consumption. Household survey results will assist in calculation of potential energy efficiency measures.
- DSM could reduce peak loads and improve system reliability and should be considered immediately to address lack of generator capacity during peak load periods.
- Present 3 phase submersible water supply pump is drawing around 1.5kW and should, if possible, only be run during off peak. Solar or wind powered pumping could be considered.

Medium and Long Term Considerations;

- Power system including fuel storage, generation and distribution will need upgrading to cater for any further growth in power demand.
- Tourism considered by Island Council and Government to be a significant contributor to the medium to long term economic development of Mitiaro.
- Island Strategic Plan identifies low impact tourism including homestays as a starting point for tourism development.
- Provision of reliable electricity and infrastructure a requirement for island development.
- Interruption to diesel supply, due to external circumstances, identified as a significant issue.