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The Secretariat of the Pacific Regional Environment Programme

Pacific Regional Energy Assessment 2004

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

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Herbert Wade

July 2004

ACRONYMS

AAGR	Average Annual Growth Rate
AC	Alternating Current
ACP	African, Caribbean, Pacific countries
ADB	Asian Development Bank
ADO	Automotive diesel oil
CIF	Cost+insurance+freight
COFA	Compact of Free Association
CPI	Consumer Price Index
CROP	Council of Regional Organisations of the Pacific
CTF	Compact Trust Fund
DC	Direct Current
DSM	Demand Side Management
EC	European Community
EDF	European Development Fund
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ENSO	El Niño/El Niña oceanic climate cycle
EPA	Environmental Protection Agency (USA)
ESCAP	Economic and Social Commission for Asia and the Pacific (UN)
EU	European Union
EWG	Energy Working Group of CROP
FY	Fiscal Year
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GMT/UTC	Greenwich Mean Time/Universal Time Coordinate
Hp	Horsepower
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
kV	Kilo-Volts (thousands of volts)
kVA	Kilo-Volt-Amperes (Thousands of Volt Amperes of power)
kW	Kilo-Watt (Thousands of Watts of power)
kWh	Kilo-Watt-Hour (Thousands of Watt Hours of energy)
kWp	Kilo-Watts peak power (at standard conditions) from PV panels
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goals
NASA	US National Aeronautics and Space Administration
OEK	Olbiil Era Kelulau (legislature)
OTEC	Ocean Thermal Energy Conversion
PACER	Pacific Agreement on Close Economic Relations
PIC	Pacific Island Country
PICTA	Pacific Island Countries Trade Agreement
PIEPSAP	Pacific Islands Energy Policies and Strategic Action Planning
PIFS	Pacific Islands Forum Secretariat
PIREP	Pacific Island Renewable Energy Project (GEF/UNDP)
PMDC	Palau Mariculture Demonstration Center
PPUC	Palau Public Utilities Corporation
PREA	Pacific Regional Energy Assessment (1992)
PV	Photovoltaic
PWD	Public Works Department
RET	Renewable Energy Technology
ROC	Republic of China (Taiwan)
SHS	Solar Home System
SOPAC	South Pacific Applied Geoscience Commission

SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
SWH	Solar Water Heater
UN	United Nations
UNDP	United Nations Development Programme
US	United States
V	Volts
Wh	Watt hours of energy

Energy Conversions, CO2 Emissions and Measurements

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

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

Diesel Conversion Efficiency:

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

Area: 1.0 km^2 = 100 hectares = 0.386 $mile^2$ 1.0 acre = 0.41 hectares
Volume 1 US gallon = 0.833 Imperial (UK) gallons = 3.785 liters 1.0 Imperial gallon = 4.546 liters
Mass: 1.0 long tons = 1.016 tonnes
Energy: 1 kWh = 3.6 MJ = 860 kcal = 3,412 Btu = 0.86 kgoe (kg of oil equivalent)
1 toe = 11.83 MWh = 42.6 GJ = 10 million kcal = 39.68 million Btu
1 MJ = 238.8 kcal = 947.8 Btu = 0.024 kgoe = 0.28 kWh
GHGs 1 Gg (one gigagram) = 1000 million grams (10^9 grams) = one million kg = 1,000 tonnes
CO_2 equiv CH_4 has 21 times the GHG warming potential of the same amount of CO_2; N_2O 310 times

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

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

EXECUTIVE SUMMARY

1. Country Context

Physical Description. Palau is located about 660 km north of Papua New Guinea and 1300 km West of Guam. The 458 km^2 of land area is spread over more than 200 islands though over 95% of that area is within a single reef structure that includes Babeldaob, Peleliu, and Koror where over 90% of the population resides. Babeldaob is the largest island with about 75% of the total land area of Palau. The outlying populated islands include Sonsorol, about 300 km to the south east of the main island group, with Tobi and Helen's Reef around 300 km further to the south east. Angaur is 20 km to the south west of the main island group and Kayangel about 30 km to the north east.

Babeldaob and Koror are mountainous and volcanic in origin though Palau includes raised coral islands and atolls as well. Koror is connected with Babeldaob by a suspension bridge allowing easy access between the two most populous islands.

Population. The 2000 census showed 19,129 persons residing in Palau with 13,364 of them ethnic Palauan. The rest are largely foreign workers from the Philippines and other Asian neighbors. Over 70% of the population lives on Koror, and another 20% on Babeldaob and Peleliu. Koror is densely populated and with the recent establishment of the national capitol complex on Babeldaob, a population shift to that much larger island is expected.

Political Development. Palau has been inhabited for at least 5000 years with early settlers probably from the Philippines, Malaysia, Indonesia and Melanesia. The first recorded visit of Europeans was in the 1500s but there was little contact until the 1700 when missionaries arrived. In 1885, Palau was claimed by Spain but the claim was short lived after the Spanish-American war was won by America in 1898. After the war, Germany purchased the Caroline Islands, Palau and part of the Marianas from Spain. Germany's control only lasted to 1914 and WWI when Japan took possession. Japanese administration was legitimized by the League of Nations in 1920. By 1935, Japanese immigration had swelled the population from 5000 to over 25,000.

World War Two saw several major battles in and around Palau with Peleliu the biggest. Nearly 500 Palauan's died along with 9000 Japanese and 1800 Americans during that battle. In 1947, Palau was made a Trust Territory of the United States under United Nations supervision.

In 1978, Palau elected to not join in the creation of the Federated States of Micronesia but to become an independent state. The U.S Government model was followed with separate executive, legislative and judicial branches. The government is headed by a president through popular elections. The Olbiil Era Kelulau (OEK) includes a nine member Senate elected at large and a House of Delegates with one representative from each of the 16 states. The Judiciary includes a Court of Common Pleas, a National Court and a Supreme Court.

A Compact of Free Association (CFA) was confirmed in 1994 making Palau an independent nation and providing for a total grant payment of $500 million spread over 15 years as well as other support from the USA.

Environment. Palau has an equatorial, marine environment. No cyclones have been recorded though near passages are not unusual when high waves can be a problem. Palau has a strong program for preserving the environment, particularly that of the major tourist attractions including the Rock Islands and the reefs where some of the best diving in the world is found. Marine biodiversity is high and land biodiversity moderate. Strict USA regulations for water and air pollution have been adopted and despite the dense population, environmental quality is generally good though waste management is a problem with some 6500 tonnes of urban waste generated annually. There is a sewer system on Koror but the sewage is dumped beyond the reef without treatment.

Economic Overview. Of the $500 million scheduled for payment under the COFA, $70 million was set aside in a Compact Trust Fund (CTF). That has grown to around $140 million. Compact grants cease in 2009 and the CTF is intended to help fund government activities after the loss of COFA grants. GDP is of the order of $120 million per year representing a per-capita GDP of about $6200, one of the highest in the Pacific. Salaries are high with the mean income for employed workers over $8000 per year. The economy is over 80% service oriented, primarily the public sector and tourism. The public sector accounted for about 25% of GDP in 2001 and is the main employer and primary supplier of services. Tourism type services have grown rapidly in the last decade and in 2001 accounted for around 51% of GDP.

Fisheries accounted for less than 3% of GDP but aquaculture, particularly of the giant clam, is hoped to add to exports in the future.

Garment manufacturing was tried for a few years but the factories closed in 2003. In any case the factories did not represent much benefit to Palau since all employees were foreign workers, typically Chinese or Vietnamese.

The large capital projects – the capitol complex, the Koror/Babeldaob bridge and massive road construction on Babeldaob – contributed around 10% of GDP in recent years. This sector is expected to shrink as projects are completed and the COFA funds are lost.

Besides the grant under COFA, the US is the largest donor with Japan also being a major donor.

Institutional and Legal Arrangements for Energy. The Energy Department is under the Public Works Department though the Director of Energy reports directly to the minister. Only one position, that of Director, is established in the department though other persons are hired as needed either as un-established staff or contract workers. The Energy Department responsibilities are not well defined as there is no national energy policy, but has in the past taken responsibility for outer island electrification and renewable energy development.

The electricity supply is provided by the Palau Public Utilities Corporation (PPUC). It is owned by the government but operated as a private enterprise and is required to break even on operating and maintenance costs. Capital costs are not included in the profit figures. Though the legislation forming the PPUC states that renewable energy should be considered by the PPUC, to date there has been no renewable energy installations made by the PPUC.

2. Energy Supply, Demand and the GHG Inventory

Energy Supply. Mobil Oil and Shell supply Palau from Guam. The government tenders for its own petroleum purchases though large users often make their own purchase arrangements. Pricing of petroleum products is not regulated. The oil companies set their own prices based on cost of supply plus profit.

Fuel is stored in bulk at two major sites, one on Babeldaob and one on Koror totaling nearly 40 million liters. USA storage and safety standards are used by Shell and Mobil for storage and operations.

Except for fewer than 100 buildings powered by solar PV in the distant south-western islands, all generation is powered by diesel engines. About 23 MW of capacity is presently split about half and half between Babeldaob and Koror and capacity is shared through a 34.5 kV inter-tie. New capacity is planned for the Babeldaob plant to support the new Capitolcomplex and expected growth on Babeldaob. Around 2 MW of capacity is present on Peleliu with Angaur having 500 kW and Kayangel 200 kW.

The electricity tariff is complex and is adjusted for fuel price change. The base tariff for domestic users is $0.1674 and currently the fuel price adjustment adds around $0.05 to the base price. Charges increase with increased use with the first increase at 500 kWh per month. There also is a minimum monthly charge that is $8.00 for domestic users along with a monthly fixed charge of $3.00 for domestic users and $10.00 for commercial and government users. Very large users may use demand metering.

Energy Demand. Petroleum use in 2002 was about 51 ML of ADO that was split about half and half between power generation and marine use, 56 ML of petrol also split between land and marine transport and about 4 ML of Aviation Gasoline. There were around 4800 vehicles on the Palau roads in 2001 and almost all use petrol for fuel. Some kerosene is used for cooking but is being slowly replaced by Liquefied Petroleum Gas (LPG).

Gasoline use for boats is closely linked to tourism since high horsepower outboard engines are typically used for tourist transport to the Rock Islands and to dive sites. Automotive use is likely to increase when the Capitol complex is fully occupied since most of the employees will need to commute the 50 km or so from homes on Koror. There are inter-island flights between Babeldaob, Angaur and Peleliu and a number of small aircraft operate for sight-seeing tours and charters.

Electricity demand grew rapidly in the 1990s as tourism increased but has slowed in recent years. The per-user demand fell in FY 2003 to about 535 kWh/month for households with a total demand of 81.2 GWh for Koror and Babeldaob combined. With the large capital developments on Babeldaob, a spurt in electricity demand is expected for the next five years or more then most likely will fall to about the population growth rate. Commercial use in 2003 was about 33 GWh, government about 4.1 GWh and domestic about 28.3 GWh. Non-technical and technical losses were high for PPUC, partly because public lighting is not metered, and there appears to be considerable room for supply side efficiency improvements. There is also considerable room for energy efficiency improvement through DSM in all sectors. The PPUC system reliability has been good and the power quality good, even on rural islands.

Future Growth in Energy Demand and GHG Emissions

Palau is by far the highest per-capita producer of GHG emissions with CO_2 emissions on a par with Europe. A fairly rapid increase in petroleum use is expected over the next 10 years with a business as usual scenario indicating that GHG will rise from about 286 Gg to 441 Gg.

Unfortunately, there is no renewable energy technology that is commercially proven that can provide more than about 5% of electrical energy by 2013 without massive investment that is only reasonable if petroleum prices increase dramatically. Energy efficiency offers a larger reduction in GHG and less investment would be required. Assuming that by 2013, 5% of electricity can come from solar energy and overall efficiency measures lower use by 20%, about 90 Gg of GHG can be saved in 2013.

3. Potential for Renewable Energy Technologies

Solar. Though good quality solar radiation measurements are not available, satellite measurements and estimates based on sunshine hours place the resource at probably somewhat more than 5.5 kWh/m^2/day, a very good resource. There is little potential for solar photovoltaics other than for connection to the PPUC grid. Solar water heating is clearly cost effective and a number of units are in use on houses and tourist facilities.

Wind. There have been no wind resource measurements in Palau though a trial wind generator was installed in the 1980s. The trial was a failure, however. Based on wind measurements made for climate records, it appears unlikely that wind energy is a useable energy resource but because wind power is very site specific, a proper assessment should be carried out.

Biomass. There is about 75% forest coverage with 15% coastal mangroves and 6% swamps. About 60% is densely forested. However harvesting of this resource as biomass or planting of large fuel plantations for is not likely to occur for environmental, economic and land tenure issues. Large coconut plantations are not present and biofuels are not likely to be practical for the foreseeable future.

Biogas. Although there is little opportunity for biogas production using animal waste, there is some potential for generating methane from human waste. If the sewer system on Koror were to be upgraded and sewage treated before dumping into the sea, there would be potential for energy production from biogas if a digester were added to the treatment system. Also, as land fills are developed, consideration should be made for methane generation to reduce GHG production and to provide energy as a useful by-product.

Hydro. There is no developable hydro resource.

Ocean Thermal Energy Conversion (OTEC). Although there is a good OTEC resource, the technology is still a long way from commercial use. It appears unlikely that a cost effective OTEC facility for Palau can be provided within the next decade.

Geothermal. There is no known geothermal resource in Palau.

Wave energy. The wave energy resource is modest, probably about 10-15 kW/m. That is not sufficient to be very useful for power generation even if there were commercially available wave energy conversion equipment.

4. Experiences with Renewable Energy Technologies

Solar Photovoltaics. Solar lighting systems were installed in the1980s on Kayangel, Sonsorol, Tobi and parts of Babeldaob. There were institutional problems that prevented their long-term survival though a few systems have been sustained by individual households. The main problem was that services were too limited, the cost of service high for the limited services that could be provided and the structures for maintenance and repair were inadequate.

In recent years, much larger systems have been installed on the two islands that have not received diesel generation: Sonsorol and Tobi. The systems are large enough to operate refrigerators, washers and videos as well as lights and entertainment appliances. Unfortunately the installations are poorly designed for the Palau environment and inadequate support structures were included in the institutional design so the projects are not doing well.

Communications on outer islands are also powered by PV and for that purpose, PV power has proven reliable and cost effective.

The European Union has targeted Palau for € 1.7 million in grants for renewable energy projects and € 0.3 million for non-state community development activities. Projects are expected to be starting in 2005. The specific projects to be carried out have yet to be identified though there have been discussions about using the funding for installing solar street lighting along the new road from Koror to the Capitol Complex on Babeldaob.

Solar Thermal. Most tourist facilities include solar water heating as do a number of private homes. Systems are imported but locally installed.

Wind Power. A 1.5 kWr wind generator was installed in 1982 on Koror. It never provided its rated power and was disassembled in 1985.

Biofuels and Biomass. Biomass gasification was tried on a small scale (15kW) at a forestry site using wood chips as the fuel. The unit worked poorly and was not considered suitable.

5. Barriers to Development and Commercialization of RETs and Energy Efficiency Measures

Barriers to Renewable Energy Development

- High income expectations limit the possibility of biomass and biofuel development.
- The very high per-capita energy use makes it difficult to shift from conventional to renewable energy.
- Tariffs for electricity do not include capital costs.
- There is no national energy policy.
- Renewable energy projects have no focal point for implementation and implementation is fragmented.
- Lack of renewable energy experience.
- There are few developable renewable energy resources.
- The wind resource has not been assessed.
- Palau has a difficult environment for electrical and mechanical equipment.

- Lack of experience with renewable energy and energy efficiency in the private sector.
- Limited market for renewable energy and energy efficiency products and services.
- Energy development is a low priority for business since other more profitable. opportunities are present.
- Lack of renewable energy and energy efficiency information at all levels.

6. Capacity Development Needs for Removing the Barriers

Specific capacity development needs include assistance to develop capacity for:

- producing high quality project designs and preparing the necessary paperwork for obtaining finance;
- developing electricity tariffs, taxes and duties and to consider the social and economic implications of tariffs, taxes and duties and how they effect renewable energy development;
- energy policy development;
- PPUC in the development of renewable energy and energy efficiency actions;
- development of standards and certification processes relevant to renewable energy and energy efficiency;
- Palau Community College to provide technical training support for renewable energy and energy efficiency;
- market development for companies providing solar water heating and energy efficiency services;
- renewable energy and energy efficiency information delivery to decision makers;and
- renewable energy and energy efficiency information delivery to the general public.

7. Other Implications of Large Scale Use of Renewable Energy

The only renewable energy technology likely to be developable on a large scale over the next 10 years is grid connected solar photovoltaics. Since there will be no batteries included in the PV systems and installations are likely to be on the roof of existing structures, there is no social or environmental impact of consequence.

8. Implementation of the Capacity Development Opportunities

Opportunities for co-financing for renewable energy capacity development currently exist only in relation to the EU renewable energy project expected to commence in 2005. There are several capacity development activities that are needed in Palau but most are best handled at a regional level and can then be provided to Palau even though Palau's co-financing opportunities are very limited.

9. Energy Efficiency Activities

Transport use. There is significant potential for improved efficiency of fuel used for tourist boats. Engines tend to be oversized and petrol based. A gradual shift to more efficient diesel engines of adequate but not excessive horsepower could improve fuel efficiency markedly with little effect on tourist boat utility while at the same time yielding improved profitability for operators. A transport fuel savings of at least 10%

appears possible and probably considerably more than that could be achieved with an aggressive program.

Electricity Supply. PPUC statistics indicate a technical loss of 7% for Koror and Babeldaob. That is not excessive for Palau though it probably could be reduced to 5% or less if an aggressive program for efficiency improvement was carried out. The 14% non-technical loss is excessive. While improving non-technical losses will probably not significantly impact on demand, it would bring PPUC closer to fully commercial operation.

Electricity Use. There is considerable improvement possible through DSM measures. Though there have been no specific DSM programs for Palau, the tariff increases that have followed the diesel fuel price increases has tended to reduce electricity waste. A stronger, focused DSM program directed at all sectors could reduce electrical energy use as much as twenty percent.

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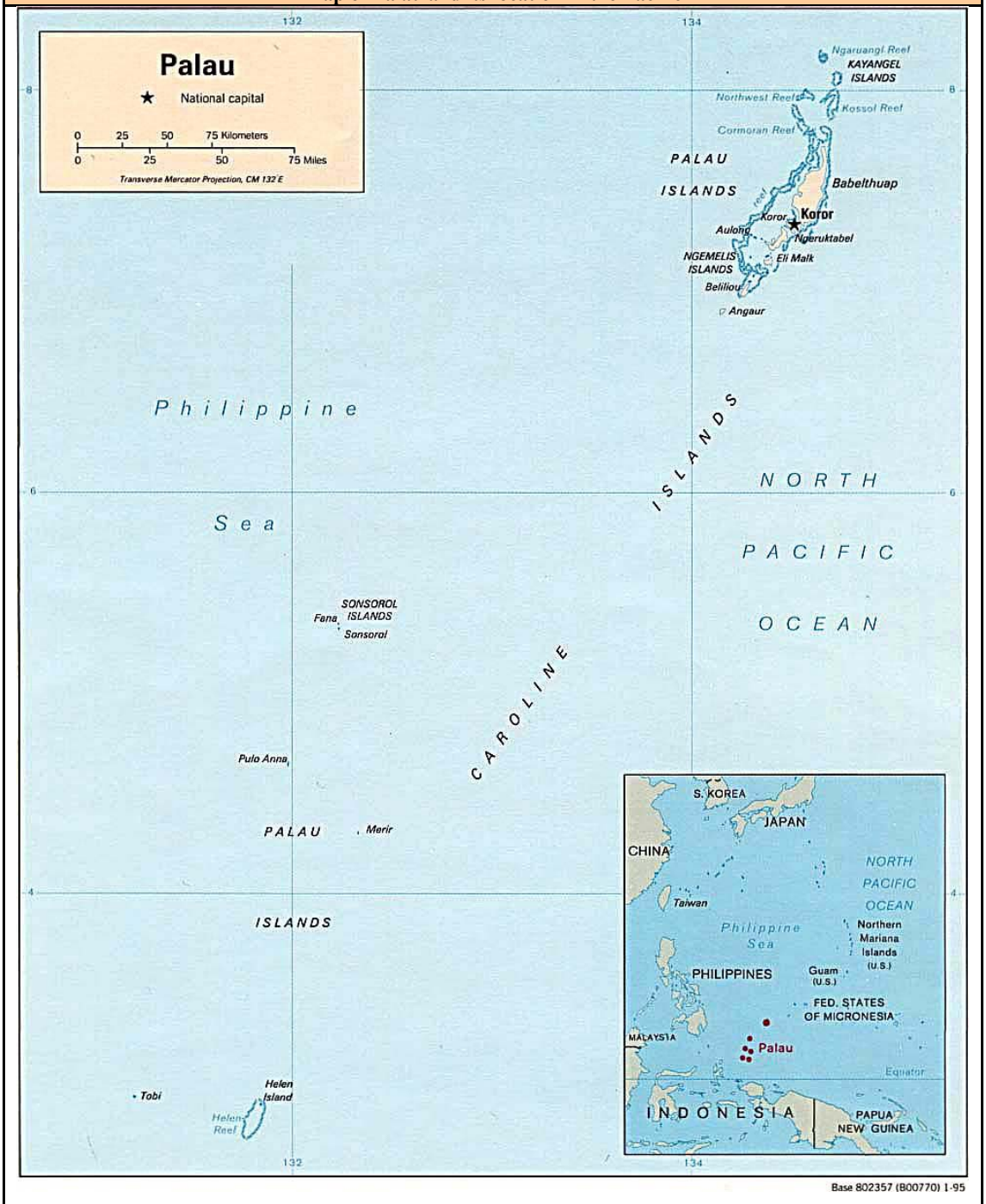
Map of Palau and its location in the Pacific



Source:

1. COUNTRY CONTEXT

1.1 Physical

Though Palau includes well over 200 islands, most are very small and only nine islands are permanently inhabited. The group lies along a north-east by south-west axis situated between about 8º 10´ north and 3ºnorth latitude and about 132º 45´ east and 134º 25´ east longitude at the western end of the Caroline archipelago. Palau and its 629,000 km^2 EEZ lies some 660 km north of Papua New Guinea (PNG) and 1,300 km SW of Guam. Over 95% of the islands and more than 90% of the 19,129[1] population lie within a single large, complex reef structure. Within the main reef are Babeldaob, Koror and Peleliu. Babeldaob has over three quarters of Palau's total land area of 458 sq. km., and is the largest island in Micronesia after Guam. Babeldaob is the location of the international airport and the new national capitol complex. The $25 million, recently opened (2002) Japan-Palau Friendship Bridge connects the south end of Babeldaob with Koror, the island that is home for over 70% of the population and the business centre of the country. The Japan funded suspension bridge replaces a concrete arch bridge that collapsed in 1997 and the temporary ferry and pontoon bridge service that followed.

Figure 1.1 – Rock Islands from the Air

Peleliu (population of 571 in 2000) is the southernmost inhabited island within the main reef. Outside the main reef, Kayangel (population of 130 in 2000) lies around 30 kilometers to the north-east and Angaur (population of 188 in 2000) around 20 kilometers to the south west. Sonsorol (population of 39 in 2000) is about 300 km further to the south west with Tobi and Helen's Reef (population of 23 in 2000) yet another 300 km south- west of Sonsorol.

Although Babeldaob and Koror are mountainous and volcanic in origin, Palau island structures are varied and include atolls, raised coral islands and the beautiful Rock Islands that are eroded limestone pinnacles covered with lush vegetation.

1.2 Historical, Social and Political

There is evidence that Palau has been populated for at least 5000 years by people most likely from the Philippines, Malaysia, Indonesia and Melanesia. The recorded population has varied from over 50,000 in the 1800s to a low of around 3500 in the early 1900s[2]. The 2000 census found a population of 19,129 that included 13,364 of Palauan origin, 4882

[1] *Republic of Palau 2001 Statistical Yearbook*, Bureau of Budget and Planning, Ministry of Information, population numbers from the national census of 2000.

[2] *A Personal Tour of Palau*, Ann Hillman Kitalong author and publisher, 1998

Asian, 482 other Micronesian and 401 of other ethnicity. Most of the non Palauan population is foreign workers mainly coming from the Philippines. The annual rate of growth of the Palauan population declined from 2.9% in 1995 to 2.1% in 2000 and is expected to further decline to under 2% for the next decade with large fluctuations due to changing levels of foreign labor possible. Official projections are for a population of around 23,000 by 2025.

The first recorded contact with European visitors was in the 1500s. Sir Frances Drake records stopping in 1579 for provisioning and trading. There was little further contact over the next 150 years though Spanish and British ships are known to have visited. In 1710, Catholic missionaries landed in Sonsorol though they were not able to found a permanent mission to Palau. In 1783 the wreck of the British packet ship *Antelope* near the island of Ulong stranded the crew and began friendly and cooperative relations between the British and Palau people with the British assisting the local chief in war and the chief providing labor to help construct an escape vessel. By 1800, whalers and traders stopped regularly in Palau for provisioning and for a safe harbor. In 1885, Palau was claimed by Spain but their claim was short lived and in 1898, after the Spanish-American War, Germany purchased the Caroline Islands, Palau and part of the Marianas from Spain. Germany's political control ended in 1914 and the First World War when Japan took possession. In 1920, as part of the settlement after the war, the Japanese control over Palau was formalized through the League of Nations and by 1935 Japanese immigration had increased the Japanese population to over 25,000 and had turned Palau into a bustling, modern, island country.[3]

Unfortunately, by then the build up of the Japanese empire's military had extended to Palau and Peleliu was fortified along with Angaur, an action that placed Palau in harm's way when war broke out between Japan and the USA in 1941. In 1944, the war came to Palau with a vengeance as the Americans fought to open and protect their route to the Philippines and on to Japan. During the fierce fighting, mostly on Peleliu, nearly 10% of the total Palauan population of 5,000 died along with over 9000 Japanese and 1800 Americans. At the close of the battle, the US military took political control and Palau was administered by the U.S. Navy until 1947 when the United Nations made Palau a Trust Territory of the U.S. with the ultimate goal of self-determination by the Palauan people.

In 1978, Palau rejected joining the Federated States of Micronesia and in 1980 held their first elections after adopting its own constitution patterned after the U.S government structure that includes separate Executive, Judicial and Legislative branches acting in a system of checks and balances. Sixteen states were established, each with its local governor, judges and legislature. The traditional Council of Chiefs was made advisor to the executive branch of government that is headed by a president who is directly elected by citizens 18 and older. The Olbiil Era Kelulau (OEK-House of Whispers) was formed as the legislature comprised of a Senate with nine members at large and a House of Delegates with a representative elected from each of the 16 states. The judiciary was established with a Supreme Court as its head and includes a National Court and a Court of Common Pleas.

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[3] *A Personal Tour of Palau*, Ann Hillman Kitalong, 1998

The Constitution provides for free compulsory education and health care for all citizens. Schooling is required by law for all children aged 6-17 or until graduation from high school. There are 21 elementary schools (nineteen public and two private) and six high schools (one public and five private). The Palau Community College provides two year programs in business, vocational trades and commerce.

To reach true independence under the constitution, an agreement had to be reached with the United States in the form of a Compact of Free Association (COFA). The Constitution of Palau required a plebiscite with a 75% majority vote for approval of such a Compact. After seven attempts from 1983-1992, and significant violence and argument – the Constitution was amended in 1992 to allow the Compact to be accepted with just a majority vote allowing the Compact to come into effect in November of 1993 with 64% of the voters approving. The approved Compact reduced the amount of military access the U.S would have to Palau and shortened the term of the payments from 50 years to 15 years though the term of the Compact itself remains at 50 years. With the final signing of the Compact in 1994, its termination year is 2044 with scheduled payments from the U.S ceasing in 2009. During the Compact period, the US agreed to provide a total grant payment of nearly $500 million and to take care of national security and defense (also assisting with the postal and meteorological services) while Palau agreed to provide limited military access to the USA including exclusive strategic access to its waterways. The US Dollar is the official currency.

The population of Palau is neither particularly young nor old. The 2000 census showed about 40% of the population to be between 25 and 44, with around 38% under 25 and 22% over 44. Koror has a very high population density and one of the policies is to shift the population from Koror to Babeldaob. To that end, the new $30 million Palau capitol complex is being built on Babeldaob with financial assistance from the ROC (Taiwan). A 54 km sealed road is being built across Babeldaob connecting Koror and the Capitol along with a "ring road" around the island. Grid electrification has been extended to almost all populated areas of Babeldaob.

Table 1.1 – Population of Palau by state, ethnicity and land area

State	Sq km	Pop.	Density	Palauan	Other Micro.	Asian	Other
Total	444	19129	43	13364	482	4882	401
Aimeliik	52	272	5	230	3	33	6
Airai	44	2104	48	1378	8	671	47
Angaur	8	188	24	176		12	
Hatohobei	3	23	8	4	18	1	
Kayangel	3	138	46	132	4	2	
Koror	18	13303	739	8870	342	3770	321
Melekeok	28	239	9	213	2	22	2
Ngaraard	36	638	18	383	50	186	19
Ngarchelong	10	286	29	303		64	
Ngardmau	47	221	5	271	12	3	
Ngaremlengui	65	367	6	203		18	
Ngatpang	47	280	6	224	5	50	1
Ngchesar	41	267	7	251		14	2
Ngiwal	26	193	7	178	2	11	2
Peleliu	13	571	44	542	3	25	1
Sonsorol	3	39	13	6	33		

Source: 2001 Census of Palau

Water supply is also mostly from public sources and is provided by the national government with bills paid separately from those of the PPUC to the "Utility Collection Office."

Figure 1.2– The Palau National Capitol Complex (February 2004)

Herb Wade 2004

With the occupation of the Capitol complex will come the shift of up to 1000 workers from Koror to Babeldaob. How many of them will choose to move their families to Babeldaob and how many will choose the 45- minute commute from Koror will have a significant effect on electricity, public services and petroleum use but only time will tell since there are pressures both ways and different but equally plausible scenarios lead in opposite directions.

In 2000, the census counted 3350 occupied housing units typically occupied by four or five persons. Most of the houses are "western" style usually with multiple rooms having a concrete floor with walls of wood or concrete and a metal roof. Over 95% of houses had piped water in 2000 though around 20% did not have access to a flush toilet. Around 60% used rainwater for drinking. Only around 20% reported having piped hot water.

Electricity, gas and kerosene had about equal shares of the cooking fuel market with the fastest increase in the use of gas. Wood use for cooking was negligible.

Electrification in 2000 was 93% (estimated at 97% in 2004) with 80% of households having a refrigerator and 40% an air conditioner. Over 85% of homes reported having a television, telephone and radio. Around 30% reported having a microwave oven.

1.3 Environmental

1.3.1 Climate

The tropical oceanic climate of Palau has an average day time high temperature of 32° and a 25º night time low that varies little over the year. The average of 3700 mm of rainfall is spread over the full year with somewhat more than average in December and January while February, March and April tend to have below the monthly average in rainfall. July through November rainfall is typically in the form of brief but intense showers.[4]

There have been no wind energy measurements but the weather observation site records show an average wind speed of only 2.5 m/s for the year with only modest variation in

[4] *1996 Local Climatological data, Annual Summary with Comparative Data, Koror Island Pacific*, US Department of Commerce

speed from month to month although the direction shifts from easterly in the December - March months to westerly in the June - September months. Undoubtedly higher wind speeds could be found with careful attention to the site but whether or not the increase in speed would be sufficient to result in economically useful energy production cannot be determined without further measurement and analysis. At this time, it appears unlikely.

The risk of tropical cyclones is low. About five cyclones a year pass near enough to affect Palau with markedly increased rainfall but none is known to have struck the Palau Islands with full force. However, in May 1927-May 1928 storm centers passed so near to Palau that winds approached full cyclone violence and some buildings were destroyed so the risk is not negligible.

1.3.2 Environmental quality

In 1956 the 1215 ha Ngerukewid Islands Wildlife Preserve was set aside in the Rock Islands as a positive step in the maintenance of the biodiversity of the islands. Entry is by permission only. Since that time there have been continuing efforts to maintain the quality of the environment and to control exploitation of the remaining forests and mineral resources. Deforested more than 100 years ago, Babeldaob remains thinly populated and reforestation by high value trees, such as mahogany, is being tried though not yet on a large scale.

Palau is noted for its biodiversity with at least 10,000 marine and terrestrial species including over 1500 species of fish and 300 species of coral making it a world class diving venue. The physical beauty of the Rock Islands is also a major draw for tourists. Since the tourism trade is economically dominant in Palau and is largely dependent on maintaining the visual beauty and the high marine diversity of the islands, there are strong economic forces in place for environmental maintenance and improvement. Palau has adopted many of the US EPA regulations regarding air and water pollution and despite the dense population of Koror the level of pollution is generally low and, when compared to other island states, environmental protection is relatively well managed.

The decline of threatened species of giant clams on the Palau reef – due somewhat to local over harvesting but mainly to widespread poaching by Asian fishing vessels – is being reversed through the development at the Palau Mariculture Demonstration Center (PMDC) of a process for cultivating giant clam spawn and using the spawn from the farm to reseed the reefs and sell to other island nations that have also lost much of their naturally occurring giant clam population to over-harvesting. The facility is now the largest giant clam spawn producer in the world. The PMDC also has worked on restoring dwindling trochus and grouper populations though with less success so far.

A growing economic product that could lead to danger for marine species is the export of fish and invertebrates for aquariums. Presently most of the export products are cultivated but as the connection between Palau and the aquarium market is expanded there is potential for over-harvesting of aquarium species from the reefs.

Waste management is a serious concern in Palau. The total mass of solid waste generated is estimated to be 17.8 tones per day (equivalent to 6500 tones a year) and likely to

double by 2025[5]. There is a sewer system on Koror with outfalls beyond the reef dumping the raw sewage into the sea. Most homes on other islands have either a cesspool that is periodically pumped or a septic tank. There remain some outhouses in use but their number is rapidly dwindling.

1.4 Economic

Under the COFA, Palau receives grants totaling nearly $500 million over a fifteen-year period ending in 2009. $70 million has been set aside in a Compact Trust Fund (CTF) which is now valued at around $140 million. Similar to the Kiribati and Tuvalu trust funds that have been important sources for government operational budgets, the CTF is intended for use after Compact grants cease in 2009 though the government is now drawing against interest at the rate of about $5 million a year.

The GDP appears to have grown an average of 2% per year since 2000[6]. The 2001 value was listed by the 2001 Statistical Yearbook as $120,834,000 which represents a per-capita GDP of $6,157, one of the highest in the Pacific.

Nearly 30% of the Palau working age population surveyed in the 2000 census reported employment related to the government sector, either national or state. Around 45% of the households responding to the 2000 Census claimed a household income higher than $25,000 a year and the mean income for the 8068 employed workers was $8520, quite high relative to the other Pacific countries.

The economy is dominated by services, primarily the public sector, and tourism. In 2001, the public sector accounted for about 25 percent of GDP in 2001, an amount that had been mostly unchanged since 1996. Government is currently the major employer and primary supplier of services. Other service sectors, including trade, hotels and restaurants, transport and communications, accounted for about 51 percent of the 2001 GDP, almost twice as much as in 1990. Overall, the services sector accounted for over 80 percent of the 2001 GDP and employed more than three-quarters of the workforce (see **Table 1.2**).

Agriculture

Food production for many years has been through family gardens or for import substitution with little exported. Agriculture accounted for only slightly more than 1 percent of GDP in 2001. Locally produced food accounts for less than 20% of consumption. The high labor cost in Palau coupled with land tenure problems make it difficult to develop agricultural plots large enough to achieve the necessary economies of scale to compete with imported food. This is of strategic concern since it places the populace at risk of food shortages in case of an extended interruption in shipping.

Fisheries

In 2001, fisheries contributed approximately 2.8 percent to GDP. Much of this comes from license fees paid by Chinese and Taiwanese fishing fleets for tuna, mackerel and

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[5] *Country Strategy Paper and Indicative Program 2002-2007*, Republic of Palau-European Community

[6] *IMF Country Report No. 04/85*, March 2004

other pelagic fish species taken from Palau's EEZ. The fees paid vary with the activity and in the 2000s have fallen from 1990s highs.

The fisheries sector consists of two sub-sectors, coral reef (in-shore) fisheries, and pelagic fisheries (deep-water). In-shore fisheries are largely worked by Palauan fishermen while deep-sea fishing is mainly undertaken by Palau fishermen in joint venture with foreign companies. The Palau Maritime Agency is responsible for regulating offshore fisheries and for issuing foreign fishing licenses.

Aquaculture

Clam "farms" to supply the market for the giant clam meat, considered by many as a delicacy are a potential export earner for Palau. The farms are proposed to be developed at various sites around Palau both to provide economic benefit to local people and to relieve the pressure for illegally harvesting the remaining giant clams found on the reefs. Since the clams take 10-15 years to mature (some species though small can be harvested for food after five years), the effects on the environment and the economy will not be seen for a decade or more. The export of the spawn, sold at prices ranging from $0.50 to $9.00 each, is of immediate benefit to the economy with millions having been produced and sold since the government owned PMDC facility began operation in 1976.

A major player in the mariculture industry is Belau Aquaculture. The company exports marine invertebrates (such as corals and clams) and fish for the aquarium trade. In addition to buying giant clam spawn from the PMDC for growth and resale, the company cultures and exports soft corals and captures small fish that are popular with public and private aquarium owners. This is Palau's second largest fisheries export industry (the tuna fishery is first), with gross receipts reaching $40,000 per month. Unlike the tuna fishery, however, most of the money earned by Belau Aquaculture stays in Palau. Export demand is high and the company is intending to expand.

Manufacturing

In recent years, manufacturing has not accounted for even one percent of GDP and consists mainly of the production of handicrafts, processed foods and locally produced furniture. In the early 2000s, there were three garment manufacturers on Koror to take advantage of the advantageous trade status between Palau and the USA. The garment industry workforce was all foreign workers, mostly Chinese and Vietnamese workers. No Palauan's were employed in this industry since the wage that was offered was below the minimum wage of $2.50 per hour – that only applies to Palauan's. The factories closed in FY2003[7].

Construction

In the early to mid-1990s, the construction sector was strong due to the rapid rate of tourist facility construction. With the economic turndown of the late 1990s, few new tourist facilities were built but still construction has contributed nearly 10 percent of GDP in recent years mainly due to the large infrastructure projects on Babeldaob – the Japan-Palau Friendship Bridge, the Babeldaob Ring Road, the Compact Road and the Capitol

[7] *IMF Country Report No. 04/85*, March 2004

complex, all projects completed or in the last stages of completion in 2004. The construction sector is expected to shrink somewhat after 2005 but continue to be strong with a shifting focus from large infrastructure projects to residential and commercial development in Babeldaob.

Tourism

Tourism is the leading income source for Palau and offers potential for further growth, though some of the attractions, such as diving, are nearing their maximum sustainable tourist load. Tourism peaked at 73,719 in 1997 with the majority of arrivals from Japan. The downturn in the Asian economy has affected the industry but numbers are recovering. Japan and Taiwan have a strong lead in the number of tourist arrivals with Japanese numbers relatively constant and Taiwan on the increase. North American tourists are a distant third in numbers.

There is concern that the main attractions for Palau, diving and the Rock Islands, are nearing or perhaps have passed the level of tourist activity that can be sustained without damage. The need is for the shift of tourism away from the mass market to the development of high value, low volume tourism. Since a high percentage of the visitors from both Japan and Taiwan are on group tours that tend to leave a high percentage of the tourist payment in the home country, shifting to a smaller number of less group oriented, high value tourists should dramatically increase the dollars that remain in Palau while allowing, indeed requiring, the careful protection of the environment.

A new airline, Palau Micronesia, is proposed to start in mid-2004. It will connect Palau to the Philippines to the west and Guam and FSM to the east.

Donor assistance

The USA remains the largest donor outside of the compact with an in-kind grant of $149 million for the Babeldaob ring road construction and other "off Compact" grants for specific projects.

Japan is also a major donor. During the 1990s, Japan provided $8.8 million in grants for water supplies, $7.8 million for fisheries development, $32 million for power line upgrading and extension of power lines, $2.8 million for dock improvement/boat access channel dredging, $7.3 million for the construction of the Palau International Coral Reef Centre, $28.5 million for the Koror-Babeldaob bridge and $11.9 million for the construction of the new airport terminal.

Table 1.2 – Gross Domestic Product, 1996-2001 (at Current Prices)

	1996	1997	1998	1999	2000	2001
Nominal Gross Domestic Product (in $ million)						
Agriculture	1,231	1,312	1,398	1,358	1,372	1,399
Fisheries	2,973	2,057	2,038	3,148	3,274	3,372
Mining and Quarrying	158	138	176	218	229	240
Manufacturing	997	1,403	1,702	1,609	1,690	1,774
Electricity, Gas and Water	-8	-388	2,360	3,393	3,563	3,741
Construction	8,545	8,834	10,389	8,249	8,661	9,181
Trade	20,995	23,913	24,837	23,165	23,860	24,337
Hotels and Restaurants	15,360	13,986	12,370	11,938	12,057	12,419
Transport and Communications	7,270	8,734	9,191	9,846	10,338	10,855

Finance and Insurance	5,294	6,573	5,706	4,297	4,511	4,647
Real Estate and Business Services	7,570	6,298	6,555	4,611	4,842	5,036
Public Administration	26,813	29,401	28,462	29,374	30,255	30,860
Other Services	9,807	9,211	9,907	9,691	9,982	10,381
Subtotal	107,006	111,471	115,091	110,897	114,634	118,242
Less (imputed bank serv. char.)	2,100	2,101	2,640	2,384	1,250	1,250
Plus (import duties)	3,298	3,842	4,869	4,972	3,842	3,842
Gross Domestic Product	108,204	113,212	117,320	113,485	117,226	120,834
GDP growth rate	13.6%	4.6%	3.6%	-3.3%	3.3%	3.1%
Population (mid-year)	17,600	18,061	18,494	18,882	19,129	19,626
GDP per capita	6,148	6,268	6,344	6,010	6,128	6,157
			Percentage			
Agriculture	1.1	1.2	1.2	1.2	1.2	1.2
Fisheries	2.7	1.8	1.7	2.8	2.8	2.8
Mining and Quarrying	0.1	0.1	0.2	0.2	0.2	0.2
Manufacturing	0.9	1.2	1.5	1.4	1.4	1.5
Electricity, Gas and Water	0.0	-0.3	2.0	3.0	3.0	3.1
Construction	7.9	7.8	8.9	7.3	7.4	7.6
Trade	19.4	21.1	21.2	20.4	20.4	20.1
Hotels and Restaurants	14.2	12.4	10.5	10.5	10.3	10.3
Transport and Communications	6.7	7.7	7.8	8.7	8.8	9.0
Finance and Insurance	4.9	5.8	4.9	3.8	3.8	3.8
Real Estate and Business Services	7.0	5.6	5.6	4.1	4.1	4.2
Public Administration	24.8	26.0	24.3	25.9	25.8	25.5
Other Services	9.1	8.1	8.4	8.5	8.5	8.6
Subtotal	98.9	98.5	98.1	97.7	97.8	97.9
Less (imputed bank serv. char.)	-1.9	-1.9	-2.2	-2.1	-1.1	-1.0
Plus (import duties)	3.0	3.4	4.2	4.4	3.3	3.2
Gross Domestic Product	100.0	100.0	100.0	100.0	100.0	100.0

Source: *Statistical Yearbook, 2001,* Republic of Palau

Taiwan (ROC) provided a donor grant of $10 million in 2000 for roads, water system and sewer system improvements. It provided a $20 million soft loan for the construction of the Capitol Complex, a $600,000 grant for schools, a $450,000 grant to the Health Ministry and $355,000 for sports facility improvements.

Australia, New Zealand, UNDP, World Bank and the IMF also have provided financial and/or technical assistance to Palau in recent years.

Now that Palau is an ACP EU member, €2 million in donor assistance, mostly for renewable energy development, is expected to begin in 2005 and additional assistance may become available in the future.

1.5 Institutional Context for Energy

The Energy Department is technically under the Public Works Department of the Ministry of Resources and Energy however the Director of Energy reports directly to the minister. Only one position, that of director, is established in the department though one

unestablished staff person assists and contract workers may be brought on board as needed.

Petroleum is almost exclusively the responsibility of the private sector though the PPUC owns the tank farms at Aimeliik and leases it to private users. Two companies, Mobil and Shell, operate retail outlets in Palau with fuel sourced mostly from Guam. Private companies also import fuel under private tender including international airlines and Daiwoo Construction, the company building the Compact Road.

Commercial electricity and the national grid is the responsibility of the Palau Public Utilities Corporation (PPUC). The PPUC is owned by government but operated as a private enterprise and required by law to break even on operation and maintenance costs. Capital costs are not included as costs required to be recovered under law. A Board of Directors oversees the PPUC, establishing operating policies and setting tariffs after public discussion. The law establishing the PPUC specifically mandates it to consider and, where appropriate, to use renewable energy.

In actuality, the PPUC has participated in no renewable energy projects and various ministries and departments have been the implementers. There has been no consistent government focal point for renewable energy though the Energy Department has been the recipient of almost all regional and international training associated with renewable energy development and in theory is the source of policy, planning and coordination for energy in general. One result of the *ad hoc* implementation of renewable energy projects has been a general lack of development of local experience and competence in renewable energy project design and implementation. Project design and implementation problems that have long since been corrected in other PICs through experience – including lessons learned in Palau itself – continue to be made in Palau projects. If renewable energy is to become a useful, integral part of the energy supply in Palau, development will have to become more focused and existing technical and institutional experience better utilized. With the foreseeable future for renewable energy in Palau most likely to be as supplements to the PPUC grid, the PPUC appears to be the obvious candidate for renewable energy development and its mandate to include renewable energy as part of its mission is already in law.

2 ENERGY

2.1 Energy Supply

2.1.1 Petroleum

Petroleum products represented about 12% of the total value of 2001 imports.

Institutional structure

Mobil Oil and Shell supply Palau from Guam. Daewoo also directly imports the fuel used in the construction of the Compact Road but does not resell.

Source and delivery mechanisms

The government tenders for its purchases. Jet fuel is purchased by the international airlines (currently from Mobil) separately from the government supply contracts.

Pricing

Pricing is not regulated. Imports are at the prevailing price set by the oil companies.

Storage

The 22.7 million liter (six million gallon) fuel storage facility at Aimeliik was built in 1984 in conjunction with the Aimeliik power plant. The facility belongs to the PPUC and is leased to oil companies, mostly Shell, for their use as needed. Mobil and Shell both own storage facilities on Koror. Mobil has a Koror storage capacity of 11.1 million liters (2.94 million gallons) and Shell owns 1.89 million liters (500,000 gallons) of storage on Koror. Daewoo has a storage capacity of 2.65 million liters (700,000 gallons) of diesel fuel on Babeldaob.

Distribution

Distribution is through private retailers.

Regulation

USA storage and safety standards are used by Shell and Mobil. There is no price regulation.

2.1.2 Electricity

Institutional Structure

Palau Public Utilities Corporation (PUC) was established by a Bill first presented to OEK in October 1993 and signed on 16 February 1994 as RPPL 4-13. Specific responsibilities specified in section 8 include:

s.8.1 to establish and operate electrical power services within the republic
s.8.2 to establish and implement a structure of rates, ensuring adequate and equitable charges for services
s.8.3 to take over complete control and operation of existing government owned electrical power services

s.8.5 to plan, develop and execute a national program for electrification of the republic

s.8.6 to co-ordinate activities with other government agencies to ensure efficient and comprehensive development of systems which meet energy needs of the republic

s.8.12 to borrow or raise money (but such debts do not become the obligation of the government)

s.8.14 to investigate, and where feasible, implement renewable energy resources.

The PPUC is based on Koror but operates generation stations on Koror, Babeldaob, Kayangel, Peleliu and Angaur. All PPUC generation is diesel based with the grids for Koror and Babeldaob inter-connected. PPUC commenced operations in Peleliu in FY1999 and in Angaur and Kayangel in FY2002. Prior to the PPUC taking over, small generators were operated privately and by the Public Works Department (PWD). The PPUC takeover included reconditioning and extension of the existing generation and distribution systems on the islands. The distant south-western islands of Sonsorol and Tobi have solar photovoltaics as their primary source of electricity for households and public buildings though there are a number of small diesel generators on those islands as backups and supplementary power.

Generation, transmission and distribution system

All commercial electricity is generated by the Palau Public Utilities Commission. The PPUC and its Government predecessor have been generating on Koror and Babeldaob for more than 20 years though the two systems were separate until the construction of the IPSECO generation plant at Aimeliik that commenced in 1984 and their connection by a 34.5kV line between the Malakal (Koror) and Aimeliik (Babeldaob) generation stations. Since that time, the grid has been continually expanded, mainly with 13.8kV medium voltage distribution and low voltage extensions. All power generation is with diesel engines and ADO is used as the fuel.

Table 2.1 – Palau PPUC installed capacity

Location	Installed Capacity kVA	Fuel efficiency kWh/liter	Peak Load MW
Malakal (Koror)	11,900	3.5	
Aimeliik (Babeldaob)	11,200	4.1	
Peleliu	2,000	2.3	
Angaur	500	2.4	
Kayangel	200	2.4	

Source – PPUC (2004)

In 2000, the PPUC took over generation on Peleliu from PWD and in 2002 Angaur and Kayangel generation was begun by the PPUC. Originally, the equipment to be provided for upgrading the outer island generation had Peleliu to receive 2-750kVA, Angaur 2-250kW and Kayangel 2-100 kW generators. Unfortunately a political decision resulted in the installation of generators in Kayangel, Angaur and Peleliu that in each case was more than double the capacity required to meet peak demands, therefore the fuel efficiency has been poor on those island with each kWh of power generated requiring about 40% more diesel fuel than the Koror-Babeldaob generation. Presently it is planned to move the 1.2 MW Peleliu generator to Koror, the 500 kW generator from Angaur to Peleliu and the 200 kW

generator from Kayangel to Angaur. The move will be costly but the fuel savings resulting from the more efficient generation and the lowered maintenance costs for the engines will more than pay the cost in a few years. Kayangel will either get a new 100 kW generator or possibly will return to solar power, though with much higher capacity PV systems than the original single panel lighting systems that were installed in the 1980s so that the same appliances would be possible to operate as would be the case with diesel generation.

A 20-24 MW power plant is expected to be built in 2004-2005 in Aimeliik since the IPSECO generators are reaching the end of their useful life.

The Babeldaob and Koror grids have been interconnected for over 10 years by a 34.5kV intertie paid for by Japan. Primary distribution is by 13.8kV lines that, along with low voltage secondary distribution lines, have carried power to virtually every household on the five PPUC islands since the completion of the JICA Babeldaob electrification project in 1999. Although much of the distribution system on Koror is ageing and will need upgrading in the near future, the Babeldaob system is mostly new, though some parts of the system are expected to be rerouted over the next few years to follow the right of way of the new Compact Road so only one public right-of-way needs to be maintained and the existing power line right-of-way can revert to the land owners.

Pricing

By Public Law 4-13 with amendments and codified at 37 PNCA 401 et seq., the PPUC is required to charge a tariff that recovers all operating and maintenance costs. By omission the law does not include capital recovery as a requirement. The electricity tariff structure in Palau is based on US utility tariff structures and is complex as is seen in Table 2.2.

The tariff structure consists of a fixed component plus a fuel adjustment component. The fixed component can only be changed by the PPUC Board after public hearings and deliberations and has a strong political component. The fuel adjustment portion can be updated monthly according to a formula that relates actual fuel cost to a standard value that is the fuel component of the fixed tariff. The existing fixed tariffs went into effect on 1 October 2001 and have been in effect for FY2002-2004. The Tariff set in 2001 lowered the base tariff one or two cents per kWh for each class of service except demand based service and stand by service which were unchanged (and mostly unused).

Fuel adjustment is calculated with a $0.01 per kWh increase for every $0.127/US Gallon ($0.0335/litre) fuel price change above or below $0.6336 per US Gallon ($0.1674/litre) but if the fuel price falls below $0.50 per US Gallon ($0.132/litre), the fuel adjustment amount remains fixed as though the price were $0.50 per US Gallon ($0.132/litre). The charge is shown on the bill separately as a “fuel charge”

Thus with the average fuel price for generation on Koror for 2003 about $0.22/litre, that is $0.0526 higher than the base price of $0.1674/litre and results in an increase over the base tariff of about $0.05/kWh for all classes of consumers. If the fuel price were to fall to the minimum price that would affect the tariff ($0.132/litre) then the adjustment would result in about a $0.01 per kWh reduction from the fixed tariff.

In effect, the minimum possible residential bill is $11 (the minimum kWh rate of $8.00 and the fixed price of $3.00) since even if the fuel gets cheaper than $0.50/gal lowering

the effective tariff to $0.07, 150 kW will cost eight dollars. Obviously there is zero incentive to use less than 150 kWh, an amount around three times that used in the average urban Kiribati residence but at the low end of household use in Palau where the residential average is about 545 kWh/month per customer.

Table 2.2 – Fixed Tariff Structure From 1 October, 2001

Customer	Minimum monthly charge	Monthly fixed charge	kWh charge	Installation Fee	Over 100,000 kWh/mo	Stand-by charges*
Residential	$8 up to 150 kWh/month	$3.00	$.08 per kWh from 1-500 kWh $.10 per kWh from 501 to 2000 kWh $.12 each kWh over 2000 kWh	$50 plus any cost over $1800 (about 90 meters of line	$18.60/kW maximum demand + $0.095/kWh Power factor must be more than 0.80 lagging If kVA demand metering is used the charge will be 85% of the kW rate	$18.60/kW maximum demand (estimated or actual whichever is higher) plus $0.095/kWh metered
Commercial	$10 up to 100 kWh/month	$10.00	$.10 each for 1-2000 kWh $.12 each for all over 2001 kWh per mo.	Single phase: $50 plus any cost over $400 (about 30 meters of line) Three phase: Actual cost.		
Government	$10 up to 100 kWh/month	$10.00	$.11 each for 1-2000 kWh $.13 each for all over 2001 kWh/mo.			

* Stand-by charges refer to customers who normally generate their own power but wish to have a PPUC connection in case their supply fails. The estimated demand is established at the time of the connection and represents the minimum charge. Higher demand charge applies if the actual demand is higher than that estimated.

Theoretically since fuel cost is higher on the rural islands, there should be a higher tariff. Actually, the tariff based on the urban generation fuel cost is used for all customers effectively resulting in a cross subsidy for both the base tariff and the fuel adjustment for rural consumers.

Regulation

There is no specific regulator for electricity prices. When a tariff change is needed, the PPUC Board sets the proposed tariff then must hold public hearings on the tariff proposal before setting the final rate. However, the board is not bound by the results of the hearings nor are they required under the law to formally justify the tariff that is proposed. The tariff is, however, a major political issue with constant pressure on the PPUC to keep the price down. So the board is more likely to have to fight strong political pressure in order to raise the price to maintain break even financial status – as is required by law – than to abuse their power and set the tariff too high.

2.1.3 Renewables

Currently, only solar water heating on Koror and Babeldaob and solar photovoltaics on Babeldaob, Tobi, Kayangel and Sonsorol use renewable energy.

The demand for domestic hot water heated from any source is not high; most households do not set a very high priority for piped hot water. Solar water heating is not promoted by government and is not commonly used. Where it is used, the installations have been purchased by the users from private dealers or imported directly from overseas. No solar water heaters are manufactured in Palau.

Table 2.3– Estimated Sectoral Use of Petroleum

Sector	Percent of total imports	2002 kilolitres
Land and water transport (Petrol)	51%	56,081
Fishing fleet (ADO)	21%	23,459
Electricity supply (ADO)	24%	27,106
Local air transport (AvGas)	4%	4,026
TOTAL	100%	110,672

Small PV lighting systems remain on Babeldaob and Kayangel and are left over from pre-grid connection days. They are little used now that grid delivered electricity is available though a few households continue their regular use. The larger PV systems on Tobi and Sonsorol are intended to be the primary power source on those islands but institutional and technical problems have prevented their reaching their full potential.

2.2 Energy Demand

2.2.1 Petroleum

Unfortunately the oil companies in Palau failed to provide the requested sales statistics for petroleum. End use must be estimated from import figures obtained from the customs department. Fortunately in Palau there is little use of petroleum for anything but electrical generation and transport. A high percentage of gasoline use is for automobiles but there is significant use for boats, particularly in the tourist industry where high powered outboard engines are commonly used.

In 2001, there were 4452 private vehicles licensed in Palau plus about 300 government vehicles. The trend has been for a slow increase in numbers (though numbers actually fell from 2000-2001). Although the vehicle registration data that was made available does not differentiate between diesel and gasoline powered vehicles, there are few diesel powered vehicles in Palau relative to gasoline powered vehicles and fuel prices are such that there is no price incentive to shift to the higher cost diesel car or truck. The primary transport application of diesel fuel is for marine use and that is mainly for tuna boats. Palau is not

Table 2.4 – Petroleum Imports for Local Use

Product	1999 (Liters) $ f.o.b.	2000 (Liters) $ f.o.b.	2001 (Liters) $ f.o.b.	2002 (Liters) $ f.o.b.
Av Gas	3,156,382 $731,300	10,083,273 $2,376,555	2,573,906 $640,069	4,026,100 $804,426
ADO	26,134,665 $4,391,011	58,779,057 $15,157,734	49,167,154 $10,098,829	50,565,379 $8,759,684
Petrol	24,095,891 $3,323,604	25,135,717 $6,481,893	19,739,541 $4,168,425	56,081,141 $9,935,862
Jet Fuel	Re-export	Re-export	Re-export	Re-export

Source: Palau customs statistics

one of the preferred refueling stops for foreign tuna boats due to its high fuel prices and the sale of diesel fuel is largely to the local fleet.

All jet fuel is considered as a re-export product since no local aircraft use it, only international and military use is recorded. Domestic kerosene is not shown as a separate product in the available petroleum statistics but its use is only for cooking and that use is declining in favor of LPG and electricity with their greater convenience and lack of odor. The 2000 census showed 22% of all households using kerosene as the main cooking source and another 18% sometimes use kerosene but also use gas or electricity for cooking.

There is no industry on Palau that uses significant petroleum for process heating.

Based on the factors listed above, the estimated end use of petroleum in Palau is shown in Table 2.3.

Land Transport

Land and water transport represents about half the volume of imported petroleum products. Water transport use is largely dependent on tourism. The number of vehicles registered in Palau has not shown any particular pattern of growth in recent years though there has been a long term trend toward increasing numbers of vehicles. It is reasonable to anticipate a growth in vehicle numbers more or less in step with the anticipated population growth of around 2% per year.

With growth in numbers of vehicles slow, land transport fuel use is largely dependent on the pattern of use of automobiles. A significant question for the future is how will government workers respond to the shifting of the Capitol complex to Babeldaob. If the response is to move their families to an area near to the Capitol, petroleum use will not be affected and, though unlikely, could even fall since present commuters from Babeldaob will be closer to work. If, however, large numbers of government workers maintain their homes on Koror and commute the 50-70 km to the Capitol, petroleum use in vehicles will increase significantly. There is no way to predict what will be the case though commuting will most likely be the dominant response in the early years after the opening of the new Capitol complex.

Gasoline use for water transport is closely linked with tourism since high horsepower outboard engines are common on boats used for touring the Rock Islands and for reaching dive sites. Since records could not be provided separating land and water transport use of gasoline, the link between tourist travel by boat and gasoline use could not be quantified.

Marine Transport

Based on the assumption that the only two significant uses of ADO in Palau are the Tuna fleet and PPUC, the fleet was estimated to use 23,459,000 liters of diesel fuel in FY 2003. Since few foreign vessels purchase fuel in Palau because a better price can be obtained in other area ports, the ADO use is assumed to be essentially all local with no significant re-export.

Air Transport

There is scheduled inter-island air transport between Babeldaob, Peleliu and Angaur thous seating and freight space is very limited. A number of small aircraft are present in Palau for charter and for tourist related flights, particularly flights over the Rock Islands, renowned for their beauty from the air. To date, all jet fuel has been used by scheduled airlines, tourist charter flights or by military flights and is considered as a re-exported product. The imminent formation of a Palau based international carrier, Palau Micronesia Airline, will begin the local use of jet fuel and will cause a large increase in apparent petroleum imports as it will not be classed as a re-export.

Electricity Generation

For the past several years, electricity generation growth has followed population growth with an actual decline in use per customer in all sales sectors for FY 2003. However, the opening of the new Capitol Complex and the growth associated with its development and spurred by the new road system for Babeldaob can be expected to drive up the rate of growth for electricity generation. A growth figure for FY 2005 of four percent or more can be expected with an average growth from one to two percent higher than population increase for the next five years or more. The rate of growth will most likely gradually fall to little more than the rate of population growth by 2015 since the primary growth factor in the past has been tourism facility construction and the sustainable capacity of the tourism attractions of diving and the Rock Islands is generally considered to have been reached if not actually exceeded.

Household Lighting and cooking

No records of recent household surveys showing type of lighting were available. It is known that there is widespread use of low efficiency incandescent lighting in homes and in some commercial buildings, but the level of opportunity for change to more efficient lighting types cannot be estimated without more data.

Cooking is by electricity, LPG or kerosene with LPG use growing fastest. The 2000 Census listed only one household in Palau not using LPG, kerosene or electricity for cooking but did not identify the fuel though almost certainly it is wood. Note that the use of microwave ovens is classed as electric cooking and is likely to be a common use of electricity for cooking when multiple fuels are listed as being used since 30.2% of all households report having a microwave oven.

Table 2.5 – Fuel for Cooking by percentage of Occupied Housing Units (2000)

Electricity only	Gas only	Kerosene only	Electricity and Gas	Electricity and Kerosene	Gas and Kerosene	Electricity Gas and Kerosene	None	No Response
23.2%	20.9%	21.6%	9.9%	8.3%	10.2%	5.0%	.1%	0.9%

Source: 2000 Census of Population and Housing, Republic of Palau

Thus for cooking, 35.8% of households in 2000 used gas at least part of the time, 38.1% used electricity at least part of the time and 36.8% used kerosene at least part of the time.

LPG

LPG appears to be used almost exclusively for cooking since less than 1% of households reported using LPG for refrigeration and there are no known industrial users. Sales figures separating commercial and residential sales are not kept though it appears likely that residential use is somewhat higher than commercial use since sales fluctuations are not closely correlated with tourism changes.

According to data provided by LPG distributors, sales have been growing at an average rate of more than seven percent since 1999, almost three times the rate of increase of the population. Unfortunately it cannot be determined whether this increase in LPG use has been at the expense of electricity or kerosene for cooking though anecdotal evidence is that it is mainly replacing kerosene.

2.2.2 Electricity[8]

Table 2.6 – Palau PPUC generation and sales statistics FY1996-FY2003									
Island	Megawatt Hours per year								
	Data set	FY1996	FY1997	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003
Malakal (Koror)	Generated	15,644	20,905	33,921	38,180	41,825	54,396	55,582	57,701
Aimeliik (Babeldaob)	Generated	63,557	61,449	53,371	55,856	58,599	47,816	45,813	44,433
Koror and Babeldaob	Total Generated	79,201	82,354	87,292	94,036	100,424	102,212	101,395	102,134
	Billed	59,127	64,706	64,491	70,510	76,727	81,922	81,668	81,248
	Losses	20,074	17,648	22,801	23,526	23,697	20,290	19,727	20,886
	% losses	25.3%	21.4%	26.1%	25.0%	23.6%	19.9%	19.5%	20.4%
	Customers	4249	4166	4211	4719	4805	4999	5267	5467
	Growth		3.83%	5.66%	7.17%	6.36%	1.75%	-0.81%	0.72%
Peleliu	Generated					437	1,139	1,242	1267
	Billed					274	821	857	859
	Losses					163	318	385	408
	Customers					180	178	186	193
Angaur	Generated							263	438
	Billed							133	232
	Losses							130	206
	Customers							71	65
Kayangel	Generated							101	227
	Billed							77	151
	Losses							24	76
	Customers							52	53
National Totals	Generated	79,201	82,354	87,292	94,036	100,861	103,351	103,001	104,066
	Billed	59,127	64,706	64,491	70,510	77,001	82,743	82,735	82,490
	Losses	20074	17648	22801	23526	23860	20608	20266	21576
	Growth		3.83%	5.66%	7.17%	6.77%	2.41%	-0.34%	1.02%
Source –*Fiscal Year 2003 Performance Report* PPUC (2003)									

Due to the rapid expansion of tourist facilities and increased consumer demand, electricity generation grew at an AAGR of 5.6% from 1996-2001. With the completion of grid expansion projects, nearly 100% of households were connected by 2000 and that combined with the slowing economy caused a leveling of demand for electrical energy after 2001. With the completion of the new Capitol complex in 2004 and rapid development of Babeldaob resulting from that and other infrastructure development, the rate of generation growth can be expected to return to 4- 5% per year for the next decade.

[8] All data tabulated in this section was reformatted from data provided directly by PPUC

Table 2.7 – Electricity billing per customer class – Koror and Babeldaob									
Koror & Babeldaob	FY1996	FY1997	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	AAGR 1998 2003
Commercial MWh	26,422	33,017	26,769	29,483	31,921	34,573	33,787	32,960	3.53%
Customers	n/a	n/a	543	591	595	610	652	672	3.59%
Avg customer's per Month kWh	n/a	n/a	4108.2	4157.22	4470.7	4723.1	4318.4	4087.3	-0.09%
Government MWh	12,615	10,500	15,697	16,840	18,669	19,533	19,413	19968	4.09%
Customers	n/a	n/a	329	369	403	423	449	466	5.98%
Avg customer's per Month kWh	n/a	n/a	3975.9	3803.07	3860.4	3848.1	3603	3570.8	-1.78%
Residential MWh	20,090	21,189	22,024	24,188	26,137	27,816	28,469	28320	4.28%
Customers	n/a	n/a	3,339	3,759	3,807	3,966	4,166	4,329	4.42%
Avg customer's per Month kWh	n/a	n/a	549.67	536.22	572.13	584.47	569.47	545.16	-0.15%
Total MWh	59,127	64,706	64,491	70,511	76,727	81,922	81,668	81,248	3.93%
Source –*Fiscal Year 2003 Performance Report* PPUC (2003)									

In 2003 the customer mix included 672 commercial customers, 466 government customers, no industrial customers and 4329 residential customers. However the commercial customers used more energy in 2003 than all residential customers. This reflects the relatively high tourist hotel component with their high energy requirement, over 4000 kWh/month per electricity customer, that largely comes from air conditioning and service systems. On a per customer basis, government used less than commercial customers but again air conditioning drove the usage up to more than 3500 kWh/month per customer. Residential customers on average used 545 kWh per month, in the Pacific second after Nauru in the magnitude of their household electricity use.

It is important to recognize that the increase in energy use was entirely due to the increase in the number of customers. In fact, the average customer use in all three sectors declined in FY 2003 from 2002 and earlier levels. This reduction in energy use appears to be due primarily to tariff increases inducing increased efficiency of energy use since no programs of note intended to encourage energy efficiency were implemented during that time. Increasing fuel costs did cause electricity price increases since rates are adjusted according to fuel price changes.

Past energy growth has been driven by the connection of new customers, the rapid development of the tourism industry on Koror and the increasing inventory of major electrical appliances in households. Future growth can be expected to focus on the development of Babeldaob, particularly around the new Capitol complex.

In Peleliu, the average use of commercial and government customers was far lower than that in Koror because the size of the individual customer facilities are also far smaller than in Koror.

Residential use was about 2/3 that of Koror and Babeldaob customers reflecting the lower income levels on Peleliu and fewer appliances in use. Both government and residential customers lowered their energy use from 2002-2003 but commercial customers increased their use by 8% for reasons that are not clear.

Table 2.8 – Peleliu Electricity Billing by Customer Class

Peleliu	FY2001	FY2002	FY2003	AAGR 2000-2003
Commercial MWh	38	38	49	8.8%
Customers	5	6	6	6.3%
Avg customer's per Month kWh	630	527.78	686.11	2.9%
Government MWh	155	162	170	3.1%
Customers	14	16	20	12.7%
Average/customer	923.21	845.31	708.33	-.845%
Residential MWh	628	657	639.7	0.62%
Customers	159	164	167	1.70%
Avg customer's per Month kWh	329.35	333.69	319.21	-1.05%
Total MWh	821	857	859	1.52%

Source –*Fiscal Year 2003 Performance Report* PPUC (2003)

Table 2.9 – Electricity Billing by sector, Angaur and Kayangel

Angaur	FY2003	Kayangel	FY2003
Commercial MWh	20	Commercial MWh	1
Customers	3	Customers	1
Avg customer's per Month kWh	555.56	Avg customer's per Month kWh	108.33
Government MWh	51.9	Government MWh	48.1
Customers	10	Customers	10
Avg customer's per Month kWh	432.5	Avg customer's per Month kWh	400.83
Residential MWh	160.3	Residential MWh	101.8
Customers	52	Customers	52
Average/customer	256.89	Avg customer's per Month kWh	163.14
Total MWh	232	Total MWh	151

Source –*Fiscal Year 2003 Performance Report* PPUC (2003)

Angaur was even lower in demand for each customer class again reflecting the lower income levels and lower use of appliances. No trends in energy use can be seen since the installation had not been in place for enough time to allow more than one full year of data to be collected. Kayangel also has had only one full year of PPUC service so no trends can yet be seen. However the trend for lowered energy use correlating with a lower level of economic development continued with Kayangel having the lowest average energy use in all three classes

Table 2.10 shows the relationship between generation efficiency and the portion of energy cost that is attributed to fuel cost. The oversized generators installed on Kayangel, Angaur and Peleliu operate at a much lower fuel efficiency than the appropriately sized units at Aimeliik and Malakal. As a result of that and the higher cost of fuel on the rural islands, fuel cost per kWh in Peleliu ($0.18) was over double that of the Koror/Babeldaob generation ($0.07) and on Angaur and Kayangel it was around three times as much ($0.26 and $0.20 respectively). While it is normal for smaller systems to incur greater fuel costs per kWh, the difference is usually on the order of 25%-30%, not 200 - 300%.

Shifting the generators to a more appropriate size may save as much as $40,000 per year in fuel costs on Peleliu alone.

Table 2.10 – Fuel Use Statistics for the PPUC in 2002 and 2003

	MWh Gen	MWh billed	1000s of liters	kWh per liter of fuel	$ per liter	Total $1000s	Fuel $ per total kWh	Fuel $ per billed kWh
Aimeliik FY2003	44,883	n/a	12840	3.4955	0.2394	3073	0.0685	n/a
Malakal FY2003	57,701	n/a	14180	4.0691	0.2167	3072	0.0533	n/a
Total FY2003	102,584	81,248	27020	3.7966	0.2275	6146	0.0599	0.0756
Aimeliik FY2002	44,883	n/a	12870	3.4873	0.2304	2965	0.0661	n/a
Malakal FY2002	57,701	n/a	13726	4.2038	0.2160	2965	0.0514	n/a
Total FY 2002	102,584	81,668	26596	3.8571	0.2230	5930	0.0726	0.0726
Peleliu FY2003	1,270	859.17	547.37	2.3202	0.2785	152	0.1201	0.1775
Peleliu FY2002	1,241	857.08	510.27	2.4320	0.2439	124	0.1003	0.1452
Angaur FY2003	438	232.19	180.73	2.4234	0.3299	60	0.1361	0.2568
Kayangel FY2003	227	151.29	92.879	2.4474	0.3315	31	0.1354	0.2035

Source –*Fiscal Year 2003 Performance Report* PPUC (2003)

System reliability has been good and overall quality of power good, even on the rural islands. The leveling off of the load growth has provided the PPUC several years to prepare for anticipated future growth as Babeldaob development proceeds. Growth on the rural islands is not expected to be as rapid as that of the urban islands since there are no existing plans for large scale development as is the case on Babeldaob. Existing plans for expansion of the Koror-Babeldaob generation includes the shifting of the 1.2MW generator from Peleliu to Malakal and the retirement of the old generator there. Additionally there are longer range plans for the replacement of the ageing Pielstik generators at Aimeliik and the addition of increased interconnection capacity between Aimeliik and Malakal.

2.3 Energy Use GHG Inventory

2.3.1 GHG related to energy use, opportunities for reduction

The primary opportunity for reduction appears to be demand side management for electricity, particularly air conditioning and lighting, and the improvement of transport efficiency. There are no immediate opportunities for significant impacts through renewable energy though trials of grid connected PV and a resource assessment for wind energy, solar energy and geothermal energy would be useful in preparation for the future.

There is an opportunity for improvement in the efficiency of use of gasoline by limiting the size of outboard engines to a specific ratio of horsepower to boat size. Also instituting a bus service for Koror government employees whose work is shifted to the new Capitol complex may help control the increase in gasoline use due to longer commutes. Public

information campaigns for more efficient use of transport could provide some benefit both to fuel use and traffic congestion.

Table 2.11 - Greenhouse gas production due to petroleum imports for 2003 and projections for 2013

		2003						2013	
Fuel	**KL**	**KT**	**TOE**	**GHG (tonnes)**	**GHG (Gg)**	**% of GHG**	**AAGR**	**GHG**	**% of GHG**
Gasoline	56,081	40,935	44,619	140,203	140.2	*49.0%*	4%	207.5	*47.0%*
Aviation Gasoline	4,026	2,796	3,131	9,260	9.3	*3.2%*	2%	11.3	*2.6%*
Jet fuel	0	0	0	0	0.0	*0.0%*	0%	0.0	*0.0%*
Distillate (transport)	23,369	19,638	21,209	63,096	63.1	*22.1%*	5%	102.8	*23.3%*
Distillate (electricity)	27,196	22,854	24,682	73,429	73.4	*25.7%*	5%	119.6	*27.1%*
LP Gas	1.2	0.6	0.7	1.9	0.0	*0.0%*	5%	0.0	*0.0%*
Total	*110,673*	*86,223*	*93,642*	*285,990*	*286.0*	*100.0%*		441.2	100.0%

In a practical sense strong energy efficiency measures could slow the growth of petroleum use and allow as much as a 20% reduction in the 2014 "business as usual" total estimate but even with aggressive action, renewable energy is unlikely to have more than a 5% share of total energy use by that time since only electricity production using solar PV is likely to provide an opportunity for the significant use of renewable energy.

OTEC has the potential for large greenhouse emission reductions by offsetting significant if not all diesel fuel use for electricity generation. However the technology is immature and is not likely to be of near term value.

In theory using solar, wind or OTEC to produce hydrogen as the energy carrier for transport use could eliminate the need for gasoline imports but that is not a near term solution.

Table 2.12 - Indicative Maximum Fuel Savings & GHG Reductions, 2013

Resource or technology	Potential CO_2 savings (Gg / year)	% of total savings	Comments
Solar PV	6.0	7%	5 % of all ADO for electricity
Energy efficiency	84	93%	20% of all fuel use saved
Total	*90*	*100 %*	

Source: mission estimates

Conceptually, large areas of Babeldaob could be dedicated to coconut or other vegetable oil production for diesel replacement. A large area also could be dedicated to plantations for growing feedstock for alcohol production to offset gasoline use. Land issues would cause complications and the fact that the replacement fuels would be substantially more expensive than existing petroleum products makes this an unlikely scenario unless there is a clear issue of national security or rapidly rising fuel prices that are expected to continue for the long term.

3 TECHNICAL POTENTIAL FOR RENEWABLE ENERGY DEVELOPMENT

3.1 Resources

3.1.1 Solar Resource

Solar radiation measurements are not taken at the weather observation sites, only sunshine hours. Though it is likely that sometime in the past there have been solar radiation measurements taken for agricultural, climate or energy purposes, no records could be made available. Based on the sunshine hours, it appears likely that the horizontal global radiation is around the 5.5-5.9 kW/m^2/day range found in other Pacific Islands at similar latitudes. That value is also supported by the NASA satellite data that indicates a 5.5 kW/m^2/day value for the horizontal global radiation average for the large block of ocean around Palau. Although there appear to be very few totally clear days, the level of cloudiness is not high and though there is a slight dip in sunshine hours for May- July, it is not marked and the solar climate appears very similar to that of Majuro and Tarawa.

Since the most likely application for solar energy in the future will be for grid connection, long term measurements of the solar resource at several sites on Babeldaob, Koror and Peleliu should be started since the economics of grid connected PV systems are very much related to the solar resource and proper evaluation of designs cannot be made without a better understanding of the solar resource. For measurements of the solar resource for PV power generation it is recommended that the measuring instruments be tilted to match that of the solar panels themselves.

3.1.2 Wind Resource

There has been no recorded attempt to measure the wind resource other than at the meteorological station. The data from there indicates an average wind speed of 2.5 m/s, well below the level needed for economically useful power generation. However, the station's site was not selected with wind energy measurements in mind and it is likely that a substantially better resource can be located on Babeldaob though the likelihood is that it will not be sufficient for cost effective power generation. Since it is important to focus only on those renewable energy technologies that have an adequate resource for development, determination of the wind resource now can help avoid directing future effort toward implementing a technology that may not be appropriate for Palau.

3.1.3 Biomass

As with all Pacific Island Countries (PICs), land tenure issues make it difficult to establish the large scale biomass plantations needed for an assured supply of fuel for energy production. According to the Energy Office, there is about 75% forest coverage with 15% coastal mangroves and 6% swamps. About 60% of the land area is densely forested.

Trials are underway for mahogany production with about 15 ha presently about twenty years away from harvesting. There are no statistics on the number of coconut trees and

there is no commercial copra production since prices are too low in relation to the high labor cost in Palau.

3.1.4 Biogas

Although it is possible to produce household biogas using the waste from two or three pigs and the household residents, there is substantial labor involved and the practice is generally limited to rural areas where labor costs are very low such as in China and India. For high labor cost areas, biogas production is unlikely to be economic unless the wastes are concentrated in a small area and labor used efficiently. Even in the most favorable cases, the value of the gas produced is unlikely to be sufficient to offset the operating cost. However, the increasing attention focused on environmental protection has made anaerobic digesters primarily useful for environmentally appropriate animal waste control with gas and fertilizer essentially as by-products or for reduction of greenhouse gas release from urban land fills. The gas can be used to provide hot water for cleaning and can also be used to produce co-generated power, though having a significant production of power from a land fill, piggery or chicken farm in Palau is not likely.

There is little cattle production in Palau. Commercial pig production declined from 780 in 1999 to 702 in 2001 while commercial chicken production rose during the same period from 13,617 to 21,944. Interviews indicate a tendency to increasingly concentrate animal production which provides increasing opportunity for economically sized waste digesters to produce methane gas for energy, fertilizer for sale and controlling the environmental impact of the waste. Commercial pig and chicken producers should be made aware of the value of anaerobic digesters for waste control, energy production and the production of a valuable fertilizer by-product.

Urban waste is a serious problem for Koror and as land fills are developed, consideration should be made for methane generation to reduce GHG production and to provide energy as a useful by-product. Also, if the sewer system on Koror were to be upgraded and sewage treated before dumping into the sea, there would be potential for energy production from biogas if a digester were added to the treatment system.

3.1.5 Hydro Resource

Although there are some small streams on Babeldaob and Koror, their hydro potential is too limited and seasonal to be economically reasonable for energy development.

3.1.6 OTEC Resource

The OTEC resource appears good with a rapid drop off to cold water depths beyond the reef along the fringing reef on the east coast of Babeldaob. This could allow a shore based OTEC installation close to the new Capitol complex and existing villages which would be lower in cost and less prone to storm damage than the more common floating design. The technical conditions appear good for development of OTEC though the economics must still be shown to be favorable and the environmental impact to the reef and foreshore must be shown to be acceptable.

3.1.7 Geothermal Resource

There has been no recorded survey of the geothermal resource.

3.1.8 Wave Energy Resource

Wave energy measurements have not been carried out but satellite data indicates a modest resource probably in the 10-15 kW/m range. That is not sufficient to be very interesting for power production even if wave energy conversion equipment were commercially available.

3.2 Appropriate Technologies for Development

3.2.1 Summary

In Palau, solar thermal can be economically developed for water heating but its potential is limited by the low demand for piped hot water in homes. What industry there is in Palau has little requirement for thermal energy. Commercial use in tourist accommodations is viable, is widely used and should be promoted.

Virtually all energy use is now and for the foreseeable future primarily associated with transport and electric power production. Though biofuels are possible for transport use, their cost of preparation in Palau makes their use unlikely unless the economic cost of petroleum fuels increases several fold. Therefore for the near term at least, the use of grid connected solar photovoltaics appears to be the renewable technology closest to being economically reasonable for large scale us in Palau though a careful evaluation of the wind energy resource should be made before assuming that wind is not economically reasonable. OTEC has great technical potential and is perhaps the ocean based energy technology for Palau that is closest to commercialization but the technology has been stuck in the pilot stage for 20 years and remains to be commercially developed. It is not reasonable to make any investment of the limited financial and human resources available in Palau for OTEC though external investment in an OTEC plant for selling power to the Palau grid as an IPP may be rational – but even then a thorough environmental impact assessment should be carried out to ensure minimal adverse effect on the surrounding waters.

3.2.2 Solar

Considering the indigenous energy resources known to be present and considering the state of the art of the technology to transform that energy into useful form, it is clear that solar thermal conversion for heating water is the most economically favorable use. Solar photovoltaic electricity generation also appears economically justifiable for provision of electricity through independent generation in Kayangel, Tobi and Sonsorol and is approaching being competitive without subsidy for providing supplementary power to the main PPUC grid.

3.2.3 Wind

Wind power presently appears unlikely to be economic due to resource constraints but carefully sited wind resource measurements should be made for a final determination.

3.2.4 OTEC

OTEC offers a continuous, high quality electricity supply in the multiple megawatt range but is currently experimental and uneconomic when compared with conventional power

sources. However, if an installation were to be capitalized using donor funds that have little or no opportunity cost and if the generation system were operated and maintained by a private company with the sale of power to the Palau grid being made at a per kWh price comparable to or even slightly higher than the marginal cost of diesel power, then its development may be economically reasonable. Palau should not, however, accept any of the financial or technical risk associated with operating and maintaining an OTEC plant until a decade or more of real commercial operation for similar plants has passed. If the company providing the equipment and the design has sufficient confidence that the system will work well, then they should be expected to also be willing operate the system and make a profit through the sale of electricity to PPUC. If they are not, that should be taken as an indication that the technology may not be as reliable and cost effective as is being claimed.

Also, a careful evaluation of the probable effect of dumping thousands of cubic meters of cold water per hour in the area of the reef should be made to ensure that the important reef resource is not likely to be damaged.

3.2.5 Biomass

At this time, there is no agricultural or forest product processing on a scale sufficient to provide useful energy from biomass but if they are developed, the use of mill waste for energy should be included.

If the plans for developing hardwood plantations on Babeldaob are carried out on a large scale, when the trees mature and are harvested and if the wood is processed in Palau, the waste products from milling probably will be sufficient to not only power the mill but also to feed some energy to the grid.

3.2.6 Biofuel

While in the long term, it appears to be technically possible to develop coconut plantations on Babeldaob that could provide useful quantities of oil to offset diesel use, it is a labor intensive activity and the labor cost in Palau is high making it unlikely that the resulting fuel would be competitive with imports from the Philippines, Indonesia or other Pacific Islands having low labor costs such as PNG, Solomon Islands and Vanuatu. Also, the complex land tenure issues present in Palau combined with the expectation of high returns from land leases or land use also are factors that make the market driven development of biofuel in Palau unlikely.

Similar problems exist for the development of alcohol fuels to offset gasoline use.

3.2.7 Biogas

Anaerobic digesters for existing large piggeries and chicken farms should be considered for improved waste control and energy production. Should local pig or chicken production methods follow the pattern found in many countries that includes an increasing concentration of animals, biogas generators will become increasingly appropriate. Since animal waste digesters provide both gas for energy and an environmentally acceptable method for waste disposal, their use with animal feed lots and large scale chicken production facilities can provide energy for operating the facility

as well as fertilizer and waste management. Significant excess energy to feed to the grid is not likely, however.

Sewage and municipal waste also represents a potential source of biogas energy. When planning for new public waste disposal facilities, biogas production should be considered as the power source for the facility and for possible cogeneration.

Biogas use for energy also reduces the atmospheric release of methane from wastes, a much more potent contributor to the greenhouse effect than carbon dioxide.

3.2.8 Geothermal

Though indicators of geothermal resources, such as hot springs or volcanism, are not present in Palau, a resource evaluation by an expert in the field should be carried out before assuming that there is no developable geothermal resource. Until there is such an assessment, the use of geothermal energy should not be a part of renewable energy development planning.

3.2.9 Wave Energy

Though clearly there is a wave energy resource, it appears relatively small, probably on the order of 10-15 kW/m. The equipment for converting wave energy to electricity or other useful forms of energy is not commercially proven. Until commercially available wave machines have been proven to be reliable and economically appropriate for the conditions found in Palau, wave energy assessment and development is not considered reasonable. In any case, there should be careful consideration of the effects of wave energy machines on the reef environment before a commitment to their installation is made.

4.1.1 Past Projects

Solar Lighting

In the 1980s, Kayangel, Sonsorol, Tobi (Hatohobei) and unelectrified areas of Babeldaob were provided with PV lighting systems. Sonsorol (11 systems) and Tobi (14 systems) households received a single 33 Wp panel, a 12V battery and 1-14W and 1-8W fluorescent light. Kayangel (30 systems) and Babeldaob (14 systems) households received two 33 Wp panels, 2-100Ah 12V batteries and 3-22W fluorescent lights. These projects were funded by the USA and mostly carried out by PWD and the energy department. There are few records of the installations and fewer records of the operation of the systems or their acceptance by the residents. One reason for the paucity of records is that once the systems were installed, the users were required to do all maintenance and repairs, the government agencies that installed the systems had no further responsibility.[9]

Some of the systems are known to be still in use in Kayangel and Babeldaob even though there is now grid power available. The reason given by those households is that all that they desire are lights and the minimum charge of $11 per month for grid power is much more than the cost of keeping the PV systems working (essentially a $50 battery replacement every year or two). The main problem with these projects was the limited services available from the PV systems that were provided. The incomes available even in rural Palau allow the purchase and operation of appliances beyond basic lighting. So user acceptance was limited and the desire for increased services high. The second problem was a complete lack of spare parts support and technical support capacity making it necessary for users to substitute lower efficiency lights and lower quality batteries when the original stock of spare parts was exhausted.

Solar power for communications

The Palau National Communications Company (PNCC) powers its communications systems on Tobi, Sonsorol and Kayangel with eight panels of 60Wp each operating at 48 volts. Operation has been reliable and cost effective.

Solar powered navigation lights

Around 30 solar powered marine channel marker beacons and one larger navigational light were installed in the 1990s. Ten marker beacons and the larger navigational light remain operational.

Wind demonstration

In 1982, the US Department of Energy provided funding for Rockwell International to install a 1.5 kW EnerTech wind generator in Palau. Similar wind generators were installed in each of the other TTPI. These small units were not intended to be economic producers of power and there was no attempt to do a resource assessment or a detailed

[9] *JICA Project Identification Study for Renewable Energy in Tonga, Tuvalu and Palau*, JICA 1998

site selection based on energy production. The intent was to demonstrate to government and the public the use of wind power for energy production with a secondary function of making an empirical measurement of wind resources in each territory and obtaining a first estimate of the operation and maintenance requirements of wind systems.

The Palau wind demonstration was set up adjacent to the office of the president. The generator was very visible and publicly notorious for its obvious lack of significant energy production. It never provided power greater than a small fraction of its rated capacity for any significant time and was disassembled around 1985.[10]

4.1.2 Biomass Gasification

In 1984, the USDoE provided $25,000 to fund the installation of a 15 kW gasifier made by North American Gasifier Co. of the USA. The gasifier was installed at the Nekken Forestry site and used wood chips as the fuel. The gas was fed to an engine for production of power. The unit worked poorly and was not kept in service long. The project is not considered appropriate for replication.

Lessons Learned

- Although visibility and access is certainly important to a successful demonstration, for the demonstrated technology to be accepted, it must be shown to work. Demonstrations that are intended to result in acceptance of a new renewable energy technology need to be not only a demonstration of the technical hardware itself but also of site selection, installation and the maintenance process.
- Solar home systems are simple in principle and require little effort in their maintenance but do require some periodic maintenance if they are to be reliable and are to retain their operational capacity.
- Replacement lights, fixtures and solar components need to be readily available at the project site. Long, frustrating delays in getting replacement components and repairing user systems reduces confidence in and acceptance of the technology even though the technology itself is not really the problem.
- The concept of "one size fits all" used in the Kayangel solar project is flawed in that the wealthier users – typically also among the more politically powerful in the community – typically did not receive the services that they desired and could pay for, limiting community acceptance of the solar systems and only temporarily relieving the pressure for "proper" electrification by diesel.

4.1.3 Current Projects

The only renewable energy project of significance carried out since the Kayangel solar home project is the solar electrification of the distant southern islands of Tobi and Sonsorol. Remarkably, the project was carried out by the Office of Capital Improvements

[10] Correspondence and discussions with the wind project manager, Mr. Gregorio Decherong and *A Guidebook to Alternative Energy Project on American Samoa, The Commonwealth of the Northern Mariana Islands, The Federated States of Micronesia, Guam and the Republics of the Marshall Islands and Palau*, Office of Capital Improvement Programs, Trust Territory of the Pacific Islands, Saipan, Commonwealth of the Northern Mariana Islands 96950, May, 1987.

Programs without reference to the expertise available at the energy office, technical support from PPUC or evaluation of the experiences from similar projects in other PICs. Although the intent and overall concept of the project – to provide an urban level of electrical energy to remote dwellers through solar home systems – avoids the problem of inadequate services that was one of the causes of failure in the Kayangel solar project, by not drawing on the considerable experience available in Palau and the Pacific region, the project has serious, perhaps fatal technical and institutional flaws that could have been avoided. These flaws have resulted in many households being without power for months with no expectation of resolution in the near future.

According to a project document[11] a total of 58 PV systems were supposed to be included in the project to electrify all homes and public facilities in the states of Sonsorol and Hatohobei. Each system was specified as containing 1000 Wp of solar panels per and would provide both DC and AC power. Additionally 16 solar street lights, each having 100Wp of PV panels, were specified. Four 3 to 5 kW diesel generators were included in the project as backup power. Sonsorol was slated to receive 35 large PV systems, eight streetlights and three back up generators. Tobi (Hatohobei State) was to receive 23 large PV systems, eight streetlights and one backup generator. Also the public building installations would include a 2000 Watt inverter that could also act as a battery charger when the backup generator was running and home systems each included a 400 Watt inverter.

According to the project records that were available to the Sonsorol Governor at her Koror office, Sonsorol actually received 20 large PV systems (16 for homes and for four public buildings) and eight street lights. The public buildings were slated to receive six lights and four lights each for homes. The total budget for Sonsorol was $630,000 (over $30,000 per installation, around three times the cost that would be expected if purchased on international tender). Although the exact budget for the smaller Tobi project was not made available, the total project for both states was said by the Energy Division to be $1 million making the Tobi project an estimated $370,000 dollars.

The actual systems installed[12] for both Sonsorol and Tobi included:

- 8 – BP Solar BP280 solar panels (640 Wp total);
- 6 – BP PVStor PV1110 batteries connected in series for 12VDC. (661 Ah at C_{10});
- 2 – GCR 3000M microprocessor controlled charge regulators connected in parallel;
- 1 – Trace SW2512 AC inverter (120V, 60HZ, 2500 Watt continuous capacity since wave);
- required ground mounting hardware, wire, 12V lights and other miscellaneous components to complete the system installations; and
- 16 solar streetlights with 100Wp of panel capacity each, charge controller and associated sealed lead-acid storage battery.

[11] Provided by the office of the Governor of Sonsorol but not identified as to origin

[12] Palau Rural Infrastructure Project Solar Power System, System Manual, BP Solar Australia (provided by the Lt. Gov. of Tobi)

Also provided by BP in the total package were the seven backup generators, Hatz 1B30 diesel engines driving a Mecc alte spa 2-pole alternator providing 120V, 60 HZ at 3600 RPM.

The mounting system provided by BP Solar placed the panels close to the ground, at a level where residents complain that children can easily climb on the panels. The installing company, Takanashi Sangyo, refused to take any responsibility for the installation stating in their formal reply to complaints about the construction that it was BP Solar's responsibility, the company only followed BP's designs and stated that in any case that "the damage rate due to winds in bad or typhoon weather would be greater" with the panels mounted higher and that it would be "extremely dangerous to place panels on higher levels". This seems a weak argument since there is no record of any typhoon ever passing near enough to Tobi or Sonsorol or winds high enough to endanger a well built solar array placed high enough off the ground to be out of the reach of village children. The thousands of PV systems of similar size and type in French Polynesia installed over the past 20 years (where typhoons *do* occur) placed the panels in arrays about 1.5 to 2 meters off the ground without serious problems.

Technical critique

Using 12V as the system voltage is a poor technical choice. The lower the system voltage, the higher the current passing through connections and wiring with the potential for energy loss increasing in proportion. At 12V the 2500 W inverter draws over 200 Amperes when operating at full load. The wire provided by BP to connect the inverter to the battery has a cross section of 95mm^2 (as compared to standard house wiring which is typically less than 2mm^2) in order to carry this high current. This makes the installation difficult and the quality of the connections critical since the voltage drop at a connection is proportional to the current flowing through it and even a small voltage drop at 12V can incur significant energy loss. Also, 12V makes it necessary to use giant storage battery cells (the largest made by BP in the PV Stor series) since each cell provides 2V and only 6 cells can be used to make up a 12V system. Use of a 48V system allows the use of 24 cells, each being on quarter ofthe weight and volume of those used for a 12V system. This makes handling and shipping for installation in remote sites much easier and damage less likely. Good solar design uses progressively higher system voltages as the system size is increased. For an 800 Wp system, a system voltage of 48V would normally be chosen and certainly no less than 24V. Since both lights and inverters are readily available for 12V, 24V and 48V operation, the use of 12V appears to be a technical design choice with no obvious justification. Whether the 12V voltage was specified by the Palau implementing agency or by the BP Solar Australia designer could not be determined but certainly system reliability suffers from that specification. At 48V the enormous 95mm^2 feeder wire could be reduced to a mere 6mm^2 and still have a similar percentage of power loss due to the voltage drop in wires and connections. Although raising the operating voltage increases the chance for electrical shock, the conservative National Building Code used in the USA for solar power systems does not consider

voltages lower than 50V to constitute a sufficient shock hazard to warrant any different construction standards than those applied to similar 12V systems.[13]

The original specification that specified an 800 W inverter for houses with the larger unit reserved for public buildings appears more appropriate than the use of a 2500 W inverter for all installations. The sizing of the inverter should be appropriate to the size of the probable load since inverter efficiency is best near the rated load for the unit. Good practice is to provide dedicated inverters for each major appliance (particularly refrigerators or freezers) so that the characteristics of the inverter can match the operational needs of the appliance. Appliances with motors, like refrigerators, require quite different inverter characteristics than do electronic systems such as computers, stereos and videos. By having a small, dedicated inverter for each major appliance an inverter failure also results in the failure of only the affected appliance not all the household power. Even if a single inverter is installed, Tobi and Sonsorol households can reasonably be expected to only have a refrigerator or freezer and a video as the primary non lighting loads for a total continuous power requirement of 500-700 Watts. Thus a smaller inverter makes more sense both as to operating efficiency and capital cost. The Trace inverter selected by BP is very complicated. As BP Solar notes in the manual:

> *"Should the Trace inverter be disconnected from the battery bank, or be caused to loose [sic] battery power the programmed settings will be lost, it is therefore **VERY IMPORTANT** to note that the factory defaults of the inverter are **NOT** suitable for extended application in the Palau system. This procedure must be followed for each new inverter for the purpose of commissioning and **ALSO** if the DC power is lost to the inverter. It is best to follow the instruction in the inverter manual for adjusting these settings to the values shown below."* (caps and bold type from the original)

What follow that statement are 15 pages of the step by step instructions needed to program the inverter to recover from a disconnection.

A Fiji PV system supplier has provided a number of similar Trace inverters to customers and notes that they have had a history of needing much more frequent repair than the other components in the PV system. Finally as BP notes in the system manual devoted to inverter maintenance and repair:

> *"Under no circumstances is any repair or modification work to be performed on the inverter, if there are any problems or apparent faults it must be returned to BP Solar for electrical maintenance."*

which of course is a costly and time consuming process when the installation is on a remote island in the Pacific. According to the information provided by both the Lt. Governor of Hatohobei and the Governor of Sonsorol, the inverter appears to be the malfunctioning component in most if not all the systems that have failed though whether there is an actual component failure or the units have simply lost their proper programming is not clear.

Institutional critique

The only training in system maintenance and repair has been that provided at the time of installation and that was apparently minimal and carried out by the Japanese installer who had no prior solar experience. No one in Palau is available to provide the local

[13] *Photovoltaic Practices and the National Electrical Code: Recommended Practices*, Sandia National Laboratories, USA, 1994

technicians with technical support, there is no ongoing training program for the maintenance and repair of PV systems, and there was no formal user training at all. The spare parts stock provided was primarily focused on lights and light bulbs. No well defined process of periodic monitoring of important system parameters has been put in place so there are no records of past battery charging patterns or operational problems to help determine the cause of system failures.

Similar large PV systems with inverters have been provided to remote island households in French Polynesia routinely for over 15 years. Over the years an approach to system design, spare parts provision, user training and maintenance technician training and system monitoring has been developed that has resulted in installations that work reliably and meet user needs. Spending $1m dollars on a project of a type never before attempted in Palau without making any attempt to learn from the considerable experience of other Pacific nations for similar projects appears to have been unwise. Not calling on the experience and training of the Palau energy planner regarding the project design and implementation is also surprising.

Financial critique

There is no evidence of attention being paid to the requirement to set aside funds for the very expensive battery replacement that will be needed by 2010 if not before. The estimate for operating costs under the project shows a total of $30,000 for spare parts and repairs allowed for the first ten years of operation of the Sonsorol and Tobi projects combined. Since the 2500 Watt inverters cost around $1500 each and repairs (with removal, shipping, repair and re-installation included) are likely to be at least $800 for each unit returned to BP Australia for repair, $30,000 does not even allow for the repair of all the trace inverters at least once during the first 10- years of project operation. The over $100,000 that will be required for replacement of the huge PV Store batteries 10-12 years after commissioning is not considered in the operational budget at all.

For solar home systems, the installed price in remote Pacific sites has been typically less than $20 per Wp of capacity (including installation and design costs) with the cost going down for larger systems when purchased on international tender. The cost of these systems appears to have been over $30 per Wp of installed capacity. If the systems were purchased on open, well advertised international tender, the $1m dollars appropriated for the project should have been sufficient for the 57 large PV systems necessary to provide all Hatohobei, Sonsorol and Kayangel households with full solar based, 120VAC electrification and still have sufficient money left over to fully electrify all public buildings on the three islands and establish an adequate store of spare parts.

Lessons Learned

- Manufacturers and dealers cannot necessarily be trusted to provide proper technical designs and component specifications when remote island installations are involved. When a million dollar project is being contemplated, it is a good idea to use a small amount of the project budget to get outside opinions from several unbiased experts before making a project design decision.
- Complex systems are not a good choice for remote installations

- Take advantage of the extensive pool of project experience available at home and in other Pacific countries when undertaking projects new to the implementing agency.
- Million dollar solar projects are worth going to the trouble of purchasing on open well advertised international tender.

4.1.4 Confirmed Future Projects

Palau became a member of the Africa-Pacific-Caribbean (APC) group of developing countries in 2000 under the Cotonou agreement. The five new members from the Pacific (Palau, RMI, Nauru, Niue and FSM) will each receive funding during the period 2002-2007 for projects emphasizing poverty alleviation and renewable energy development. Palau is slated for € 1.7 million for renewable energy projects and € 0.3 million for non-state community development activities.

The President has proposed that € 1.2 million of the allocation be for the installation of solar street lights for the new road to the Capitol Complex. Even ignoring the obvious question as to the economic value of street lighting along 40km of a high quality road passing through an unpopulated area with very few intersections, the choice of expensive solar lighting is questionable and should be reviewed carefully. It is proposed that € 1.2 million for solar street lights along the Compact road be carefully evaluated and the economics compared with either:

- direct connection of an equivalent number of solar panels (around 100 kWp estimated) through the installation of around 25 separate 4kWp grid connected modules mounted on public buildings in various locations around Palau; and
- the full solar based electrification of Kayangel using large, individual PV systems using the concept for the Sonsorol and Tobi installations but using the appropriate technology and an institutional approach allowing sustainability.

The Energy Department was not involved in any analysis of the economics of street lighting and no economic analysis could be located justifying the use of the EU renewable energy funding for street lighting. In any case, if, as appears probable, the existing power line right-of-way is reverted to land owners and the power lines moved to the new road right-of-way, the relative economics of powering the lights from the PPUC grid paralleling the road versus solar power should be carefully considered. It is also noted that with each light costing over $1500, there is insufficient money available in the EU project for properly lighting the entire length of the new road.

4.1.5 Proposed Projects

1. The rehabilitation of the Sonsorol and Tobi solar systems should be carried out before batteries are ruined by sulfation. While it would not be economically reasonable to reconnect the system into a 24V or 48V configuration as long as the expensive 12V batteries that have been deployed are in good shape, it would be appropriate to install inverters that better fit the environment and the needs of the users. Consideration should also be given to replacing the semiconductor type charge controller with a relay type controller (such as those manufactured in Kiribati under their EU program) that is much less sensitive to heat, humidity and salt air. Local technicians should be

properly trained and a comprehensive operation and maintenance manual provided both to the local technicians and to the Energy Office for reference.

2. Since the oversized Kayangel generator is to be shifted to Angaur, consideration should be given to the installation on Kayangel of a solar PV mini-grid or individual solar PV systems of a size similar to those installed on Sonsorol instead of just replacement by a smaller diesel generator.
3. An energy efficiency for transport project that considers the efficiency of use of transport for commuting between the new Capitol complex and Koror could be of value in controlling the increase in petroleum use that is likely to result from the transfer of a number of government jobs from Koror to Babeldaob.
4. Existing large scale piggeries and chicken farms should be surveyed and considered for installation of anaerobic digesters for energy and waste processing.
5. A wind resource assessment should be carried out to determine whether or not further consideration should be given to development of wind for supplementation of the diesel generation.
6. Given the positive experience in Europe, the USA and Japan with 4-10 kW roof top mounted, grid connected solar systems, a project to install several trial units would be useful to provide the PPUC with experience in the connection of renewable energy to the grid with the expectation that falling prices for PV and increasing diesel fuel prices will soon combine to make electricity production from PV comparable in price to diesel and make reasonable the larger scale use of PV generation for the PPUC.

5 BARRIERS TO DEVELOPMENT AND COMMERCIALIZATION

The barriers to renewable energy and energy efficiency development have been listed and categorized but it must be recognized that the categories are somewhat arbitrary and some barriers can fit several categories. The listing is not prioritized since there is no justifiable scheme for designating one barrier as "worse" than another.

5.1 Fiscal and Financial Barriers

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

Taxes and import duties for renewable energy in Palau are much less of an issue than in larger countries since virtually all renewable energy development of any capacity will have to be developed by government. The PPUC will necessarily have to take the lead role and private sector activities are expected to be limited to solar water heating, a market that has yet to develop strongly.

High income expectation. Rural incomes and wage expectations are higher than can be provided for economically viable biofuel or biomass fuel production and form a barrier to biomass based renewable energy development.

Very high per-capita energy use. There is a very high per-capita energy use making the shift from conventional fuels to renewable energy expensive on a per-capita basis.

5.2 Legislative, Regulatory and Policy Barriers

The legislation establishing the PPUC requires the use of renewable energy where appropriate though it does not limit renewable energy development to PPUC or give it a mandate for development outside of its own power generation needs.

Tariffs for electricity do not reflect all costs. Electricity tariffs are artificially low because the PPUC is legally required to recover only the operational and maintenance cost of the electric power system and does not include capital investment costs.

There is no national energy policy. Without an energy policy that clearly spells out the roles of the various government departments, the PPUC and the general public, development of renewable energy and energy efficiency technologies are likely to remain fragmented and unsustainable.

5.3 Institutional Barriers

In Palau the only existing institution likely to develop renewable energy on any scale is the PPUC. Since renewables that impact GHG production will be grid-connected, integrating the renewable energy management into the PPUC structure appears appropriate.

Fragmented implementation. Renewable energy development and project preparation has been fragmented with none of the organizations individually having sufficient technical capacity to properly design and implement renewable energy projects.

Lack of experience. There is a lack of understanding of institutional requirements for rural energy projects due to lack of experience and little interaction with other Pacific countries regarding their experience. There is little experience with grid connected renewable energy systems anywhere in the region..

Renewable energy project implementation is fragmented. Energy projects are not channeled through energy office staff. Despite having an energy office that includes personnel with considerable training in RET development, there is no requirement for energy projects to even be vetted by the energy office. Palau is too small to justify a capacity to do renewable energy projects in more than one or two agencies.

5.4 Technical Barriers

Although solar photovoltaics and solar water heating are technically mature, there remain technical barriers that must be overcome that are related to the special conditions present in Palau.

Limited developable renewable energy resources. Useable resources appear to be limited to solar, biogas and possibly wind. There is no opportunity for hydro development. Biomass and biofuel development face major additional barriers of labor cost and land tenure problems. OTEC and wave energy are not yet commercially proven.

Inadequate knowledge of the size of the wind resource. Until the resource is well understood, wind systems cannot be considered.

Difficult environment for electrical and mechanical equipment. The tropical marine environment of Palau is a problem for mechanical and electronic equipment. Electronic control systems and DC to AC converters are particularly vulnerable and must be designed specifically with the salt laden air, high ambient temperature and moist conditions in mind.

5.5 Market Barriers

Market barriers are those that reduce opportunity for private enterprise to participate in developing renewable energy. The primary market barrier of Palau's small size is basic and not amenable to externally delivered barrier reduction programs.

Lack of experience in the private sector. There are no experienced persons in the private sector available to fully develop renewable energy projects and provide for their sustainable operation.

Limited market opportunity. The market is mostly limited to renewable energy for feeding the PPUC grid except for solar water heating.

Other opportunities for business development. The limited business resources available in Palau tend to be directed toward the potentially high profit tourism industry and few resources are available for high risk, low return investments such as renewable energy.

5.6 Informational and Public Awareness Barriers

For renewable energy and energy efficiency technologies to be accepted, it is important that people at all levels understand the benefits and the problems and become familiar with the idea of replacing fossil fuels with renewable technologies. Various public awareness programs have been established in the region but Palau has none presently in place.

Lack of information about renewable energy and energy efficiency at all levels. Although there have been outer island electrification projects using PV, in general there needs to be more information available to decision makers, the general public and businesses regarding the advantages, disadvantages and costs of renewable energy and energy efficiency technologies.

6 CAPACITY DEVELOPMENT NEEDS

6.1 Electricity

The Palau Community College has an electricity trades program that appears adequate for preparing students for further on-the-job training with the PPUC, commerce or industry. However it includes almost no reference to renewable technologies and could benefit from the inclusion of short training modules to introduce PV, wind and other renewable technologies.

The PPUC has access to various utility training programs in the USA as well as from regional and international sources. Therefore there does not appear to be a need or the capacity to absorb a significant increase in technical capacity development efforts for the conventional electricity supply sector. As the likely dominant developer of renewable energy and energy efficiency in Palau, the PPUC does need capacity development focused on renewable energy and energy efficiency.

There is a significant need for the development of the public's capacity to understand the rational use of energy, to accept renewable energy and to take part in energy efficiency measures.

Further development of the capacity of both the PPUC and the Energy Department to create and deliver effective renewable energy and energy efficiency programs is needed.

6.2 Renewables

The very limited experience with renewable energy projects in Palau has resulted in there being a marked lack of capacity in Palau with regards to renewable energy project design, evaluation and operation. The Tobi and Sonsorol solar project clearly shows this lack as it includes many serious technical, institutional and financial errors. That project requires immediate rehabilitation and both technical and institutional changes if it is to function as a sustainable, reliable source of electricity for the island residents. Unfortunately, there is no one with the necessary experience and technical knowledge available in Palau to design and direct the technical and institutional rehabilitation needed.

Staff in infrastructure development agencies that may have responsibility for renewable energy projects need training in the basics of renewable energy technology, renewable energy project design as required by the Pacific Island environment, training in the design of sustainable institutions for operating and maintaining those projects and training in making sustainable financial arrangements for the long term success of the projects.

Competency in renewable energy project technical and institutional design should reside in a single organization and all renewable energy projects should be required to at least be vetted by that organization before implementation.

The PPUC can expect to be increasingly called upon to consider developing renewable energy generation. Several members of the PPUC engineering and technical management staff should receive immediate training in the general concepts of grid-connected distributed solar PV, wind power and OTEC based generation. They should also receive training in other renewable technologies so they can recognize and avoid the "scams" and well meaning but inappropriate renewable energy proposals that frequently reach the

Pacific. Since the PPUC, under law, has the mandate to include renewable energy in its portfolio of generation technologies, the Sonsorol and Tobi solar electrification project could reasonably be transferred to PPUC for rehabilitation and operation if training in PV system design, operation and maintenance is provided to selected technical staff.

6.3 Regulation

At present there are no obvious needs for energy legislation or regulation. Though it may be premature to establish formal standards for renewable energy equipment, guidelines for component specification and purchase are clearly needed. To ensure that rural electrification projects are properly maintained, certification of field technicians is also needed.

The system for assigning electricity tariffs appears sufficiently self-regulating and has avoided abuses. Adding a layer of government regulation to the tariff setting process could be counter-productive.

6.4 Implementation of Capacity Development

6.4.1 Reducing Fiscal and Financial Barriers

Project development support. Although there do not appear to be out of the ordinary problems in locating finance for renewable energy development, there is some problem accessing it due to lack of capacity for the development of project documentation acceptable by financing institutions. As part of regional capacity building efforts, specific programs in project development, project document preparation, economic analysis and interfacing with international finance agencies should be developed and delivered to Palau. These need to focus not only on the PPUC and Energy Office but also on any other agency, public or private, that has a need to access international finance for renewable energy or energy efficiency projects.

Fiscal Policy development. Taxes, electricity tariffs, import duties and government purchasing policies have an impact on the cost of renewable energy relative to fossil fuels. Government officials responsible for these policies should be made aware of the effect these policies have on the development of renewable energy and energy efficiency measures. This can be done through a regional capacity building program that provides informational materials and training for the appropriate officials.

6.4.2 Reducing Legislative, Regulatory and Policy Barriers

Energy policy development. Assistance is needed in the development of a well formulated, country specific energy policy document that addresses issues of energy efficiency, renewable energy and conventional energy and can be accepted by all political factions as a genuine long term guiding policy for government. The PIEPSAP project under SOPAC is expected to focus on these issues.

6.4.3 Reducing Institutional Barriers

PPUC capacity for energy efficiency and renewable energy. No one at the PPUC has received training in renewable energy development such as can be applied to the PPUC system. Management needs assistance in developing a full understanding of the economic

and technical issues associated with integrating renewable energy, technical staff needs training in the details of that integration and operations needs training in the operational and maintenance requirements of the technology. This need is found in several PICs and could be met through a capacity development program provided at the regional level.

6.4.4 Reducing Technical Barriers

Standards and certification development. The PPUC will need to develop purchasing guidelines and specifications for the renewable energy equipment to be integrated into the PUC grid. The Energy Office needs to develop equipment standards for renewable energy equipment to be used for rural electrification projects and also certification processes for personnel assigned to care for those projects. This need is found in several PICs and should be met through a regional program.

Palau Community College. To ensure wider understanding and competence in renewable energy in Palau, the Palau Community College electrical trades curricula should include short modules on solar PV both for grid connection and for stand alone applications. The plumbing trades program would also benefit from a module on solar water heater installation and maintenance. These needs are common to most PICs and development of the modules and assistance for training instructors could be provided through a regional project.

6.4.5 Reducing Market Barriers

Market development. Though the opportunity for private development of renewable energy is generally limited to solar water heating, there is significant opportunity for working with households, tourist facilities and other commercial enterprises to improve energy efficiency. Since several PICs share the need to develop private sector energy efficiency business capacity, a regional program could be developed.

6.4.6 Reducing Informational and Public Awareness Barriers

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

Public information programs. What knowledge there is of solar PV is largely based on failed projects. There is little public knowledge about energy efficiency or hybrid systems. As this is a need for most of the PICs, the necessary public information materials can be developed regionally and delivered to countries along with short term training and advice in their proper delivery.

Only solar and OTEC are known to have sufficient resource in Palau for large scale use. Biomass resources are present but their harvesting on a large scale is prevented by land use issues and the need for protection of the environment.

Closest to commercial viability is grid connected solar photovoltaics.. However, in order to assure grid stability the kW input from the solar installations cannot generally be more than about 15% to 20% of the existing kW noon time demand. Higher percentages are possible but involve complex energy management systems or a very expensive energy storage system and both approaches generally result in higher than acceptable cost per kWh. Also adding the solar component does not reduce the requirement for conventional generation capacity since solar cannot be assured to be available when needed. In Palau with its large air conditioning load, the peak demand occurs at about the same time as the peak output from a solar generator so with a 20MW peak, about three to four actual megawatts of solar power can be installed (about 4-5 MWp of solar panels). Since the solar provides energy only when the sun shines, from an energy point of view probably less than five percent of the existing energy provided from diesel can possibly be offset by solar photovoltaics unless very expensive energy storage such as batteries or hydrogen generation is included. While PV plus storage could become economically practical due to very large increases in fuel prices and/or a dramatic fall in photovoltaic generator or energy storage system prices, it is unlikely that solar PV with massive energy storage will be economically reasonable for Palau within the next twenty years.

In order to address the base load requirement, OTEC appears to be a possible renewable energy technology. There is known to be a sufficient resource to cover the full electrical energy requirement of Palau though the environmental effects of using that resource at the scale needed to provide base load power for Palau are completely unknown. Since the largest operational OTEC plant built to date (Hawaii) produced a net power of only about 1% of the peak load projected for 2014 in Palau, even OTEC does not provide much hope for the large scale, near term conversion of PPUC generation to renewable energy. The largest OTEC system currently under construction is the 1 MW gross (probably 700-800 kW of net deliverable power) floating plant being built in India. The plant is to be purely experimental with no power delivered commercially. Its commissioning has repeatedly been delayed year by year due to serious technical problems, particularly with the cold water piping system.

Therefore for the period ending 2014, unless wind resource surveys indicate a significantly better wind energy resource than appears likely from available data, it appears improbable that renewables can economically substitute much more than around 5% of the electricity used in Palau. For the period 2004-2014, there appears to be much more potential in Palau for the reduction of petroleum use – and greenhouse gas emissions – by improving the efficiency of energy use in transport and electricity demand side management than by implementing renewable energy systems. However, renewable energy development certainly should not be ignored since the longer term potential is great and the PPUC needs to gain experience in integrating renewable energy into its system. Since the solar energy installations would not use batteries and probably will be roof mounted, no social or environmental effects appear likely.

8 Co-Financing and Capacity Development Opportunities

Though there are a number of possible opportunities for GEF funding in Palau for co-financing and for capacity development. Only the EU project has firm funding and can be considered as firm. However, other renewable energy funding from the US, Europe, Japan or other international donor may develop in the future. Also, there is expected to be some local investment in renewable energy though no specific plans have been made. The team has identified the following as having particular near-term relevance and being appropriate to consider for co-financing when renewable energy investment is confirmed.

1. Immediate capacity building for renewable energy and energy efficiency measures concentrating on grid-connected renewable energy and energy efficiency for electricity and transport. Capacity building for grid connected photovoltaics should be provided from Germany, the US or Japan since only those countries have extensive experience with grid connected PV systems. A much wider base of expertise is available for wind power training should a suitable wind resource be found in Palau. As this is a general requirement for many PICs, a regional program should be considered rather than a program co-financed with just Palau projects.
2. Continuing technical training for personnel to operate and maintain renewable energy and energy efficiency equipment. The EU funded renewable energy project being considered for Palau will probably include a training component for installation and maintenance of the project but, if past projects are an indication, it is unlikely to provide for long range training and technical support for PPUC in renewable energy system operation and maintenance. Given the high turnover of technical personnel, particularly at the lower levels, continuing availability of specialized training in the maintenance and repair of the renewable energy systems is an issue that needs to be addressed. As it is an issue throughout the Pacific, the opportunity exists for the GEF or other multi-lateral agencies to fund development of a regional training capability that can bridge the gap between the focused trainings provided with donor projects.
3. There have been no significant public information efforts relating to renewable energy and energy efficiency. Neither the general public nor businesses have a good understanding of the methodology and benefits of renewable energy and energy efficiency technologies. Developing a quality public information program is an opportunity for co-financing by an external organization in association with the Palau government and local sources. This is a need in most PICs and a regional program that includes Palau seems appropriate.
4. Management capacity for renewable energy and energy efficiency project design and implementation at the PPUC and within the Energy Office needs further development using external resources. It is also an area of training and education that represents a regional need and is an opportunity for GEF or other multi-lateral organization to provide valuable input. ESCAP is developing a regional training development document that will address this issue and should provide guidance for co-financed capacity development that is focused on management capacity building.

9 Energy Efficiency

9.1 Transport Use

Although there are no definitive statistics on the fuel used by the large number of outboard powered boats used in the tourist industry, efficiency of use appears less than optimal and there probably is considerable latitude for improvement. Since each incremental increase in engine power does not result in a corresponding increase in speed, there is a point of diminishing returns but industry observers note that there has been a gradual "horsepower creep" over the last 20 years with the average engine horsepower per meter of boat length estimated by some persons interviewed to be more than double that of the early 1980s. No energy efficiency program has ever been mounted to address this issue but it appears that considerable import savings could be made with little effect on tourist boat utility. A gradual shift to more efficient diesel and inboard engines as the present inventory of boats is replaced would also benefit the profitability of tourist boat owners and improve fuel use efficiency.

There is no significant use of fuel for commodity transport though there has been a short term increase in utility vehicle use due to the large road and capitol construction projects. For the foreseeable future, transport fuel use will be primarily for passengers. Up to now, the heavy concentration of the population on Koror has kept the average vehicle kilometers per trip small but the rapid development of the much larger island of Babeldaob is likely to dramatically increase the annual kilometers per passenger. In the near term this increase is going to be largely determined by the response of government employees residing on Koror whose jobs are moved to the new Capitol complex on Babeldaob. Although a bus service on Koror has not been considered necessary, instituting a public bus service at least for government workers from Koror to commute to work on Babeldaob may be useful to consider as a measure to keep fuel use from dramatically expanding.

9.2 Electricity Supply

PPUC statistics indicate a supply side technical loss of less than seven percent of generation for Koror and Babeldaob. That is a value that will be difficult to improve significantly. However, the fuel efficiency for Kayangel, Peleliu, and Angaur is poor due to the installation of generators that are much too large for their loading. If the planned exchange of generators takes place and the installed generators are better matched to the load, the fuel efficiency can be expected to improve greatly with the savings in fuel quickly paying the cost of the generator exchange.

The non-technical loss of about 14% is excessive. A few percent of that is because street lights are not metered but at least 10-12% of unexplained loss remains. The exact reasons for this large difference between kWh sold and generated needs to be determined and losses reduced.

9.3 Electricity Use

There is considerable opportunity to improve the efficiency of electricity use in Palau. Indeed, that appears to have the most potential for carbon emission reduction, higher than renewable energy development at least in the near term. The small but significant

reduction in per customer electricity demand by all user classes in 2003 represents increased efficiency of electricity use and appears to have been the result of increased electricity cost due to the recent increase in fuel prices that was passed on to electricity customers through the fuel adjustment applied to tariffs. In fact, the per-customer electricity use was lower in 2003 that any year for which data was provided by PPUC – all years since FY1998.

LPG represents a more efficient energy source for cooking than electricity so the trend toward increasing use of LPG for cooking is favorable for energy efficiency. The largest use of electricity appears to be for air conditioning with refrigeration second. The PPUC and energy office believe there to be considerable opportunity for increased efficiency in electricity use as regards air conditioning and lighting (where inefficient incandescent lights are commonly used), but currently they have no specific programs focusing on demand side management (DSM). Both the energy office and the PPUC indicate that past attempts at DSM through customer information programs and energy audits of commercial facilities have included no objective evaluation processes so their effectiveness is not known.

10 ANNEXES

Annex A - Persons Interviewed

Hon. Fritz Koshiba	Minister of Resources and Development
Hon. Laura I. Ierago	Governor of Sonsorol
Mr. Crispin Emilio	Lt. Governor, Hatohobei State
Mr. Noriwo K. Udedei	General Manager, PPUC
Mr. Andy Finey	Power Plant Manager, PPUC
Ms. Rukebai Kikuo Inabo	Comptroller, PPUC
Dr. Joel E. Miles	Chief Terrestrial Unit, Office of Environmental Response and Coordination, Office of the President
Mr. George Ngirarsaol	President George Ngirarsaol Company
Ms. Karen Etpison	General Manager NECO Gas Co.
Mr. Siobo Masang	Gas Manager, PECI

Annex B - References

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