SPREP

Pacific Islands Renewable Energy Project

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

GEF

UNDP

The Secretariat of the Pacific Regional Environment Programme

Pacific Regional Energy Assessment 2004

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

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PIREP

our islands, our lives...

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This report is based on data gathered by a PIREP team consisting of:

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Mr Peter Johnston, International PIREP Consultant.

The international consultants visited Papua New Guinea from 15-23 January 2004. Information for the report was gathered both during and after the visit by the national consultant. The national coordinator provided excellent support and assistance throughout the visit. Among the many individuals who provided useful information and comments, the mission would like to especially acknowledge the help of Australian renewable energy consultant Andrew Mears of Majority World Technology, whose knowledge of recent renewable energy initiatives in PNG has been invaluable. The four 'casual' Research Officers of the Policy and Planning Branch of the Department of Petroleum and Energy's Division of Energy were very helpful with their time and information. Because of the short time the mission was in PNG, all discussions were held in the National Capital District and the capital of Morobe Province (Lae), with other communications by telephone and e-mail. Considering the limited time and resources available for the study, the huge size and diversity of PNG, and the paucity of recent data on provincial energy use available in Port Moresby, the authors are well aware that this report contains gaps and provides an incomplete assessment of both national energy sector issues and barriers to renewable energy. The report reviews the status of energy sector activities in PNG through January 2004.

Unfortunately, staff of several key government departments were unavailable for discussions, (including National Planning and Rural Development, despite being a member of the PIREP coordinating committee). The local offices of the international oil companies were unwilling to provide any information on their product sales, an omission that hindered some analysis.

An April 2004 draft of this report was provided to the PNG government, SPREP, UNDP and others. Some minor comments were received by the PIREP team. The contents are the responsibility of the undersigned and do not necessarily represent the views of the Government of Papua New Guinea, the national PIREP committee, SPREP, UNDP, GEF or the many individuals who kindly provided information on which the study is based.

Peter Johnston

John Vos
October 2004

ACRONYMS

A$	Australian dollar
AAGR	Average Annual Growth Rate
ACP	African, Caribbean & Pacific group of countries
ADB	Asian Development Bank
ADO	automotive diesel oil or distillate
APACE	Appropriate Technology for Community and Environment (Australia)
APEC	Asia-Pacific Economic Co-operation
APERC	APEC Energy Research Group
ATCDI	Appropriate Technology & Community Development Institute (Unitech)
BPNG	Bank of Papua New Guinea
CAIT	Climate Analysis Indicators Tool (WRI)
CCA	Common Country Assessment (UN)
CDS	Community Development Services (AusAID programme)
CHOGRM	Commonwealth Heads of Government Regional Meeting (for Asia/Pacific)
CIA	Central Intelligence Agency (USA)
CIDA	Canadian International Development Agency
CM&P	PNG Chamber of Mines and Petroleum
CO_2	Carbon dioxide, a key greenhouse gas
CPL	Coconut Products Limited
CROP	Council of Regional Organisations of the Pacific
CSIRO	Commonwealth Industrial and Scientific Research Organisation
CSO	Community Service Obligation (under PNG law)
CURES	Citizens United for Renewable Energy and Sustainability (NGO network)
DANIDA	Danish International Development Agency
DEC	Department of Environment and Conservation
DF	Department of Forestry (GoPNG)
DME	Direct Micro Expelling (coconut oil processing)
DNPRD	Department of National Planning & Rural Development
DPE	Department of Petroleum and Energy (GoPNG)
DPRP	Diesel Power Replacement Programme (GPNG)
EDF	European Development Fund
EFI	European Forest Institute
ELCOM	Electricity Commission of PNG (now PNG Power)
ESCAP	Economic and Social Commission for Asia and the Pacific (UN)
EU	European Union
EWG	Energy Working Group of CROP
FAO	Food and Agricultural Organization (UN)
FRI	Forest Research Institute (Lae)
GDP	Gross Domestic Product
GEF	Global Environment Facility (UNDP, World Bank and UNEP)
GHG	Greenhouse Gas(es)

GoPNG	Government of Papua New Guinea
GTZ	Deutsche Gesellschaft für Technische Zusamenarbeit (German Technical Cooperation)
HDI	Human Development Index (UNDP)
ICCC	Independent Consumer and Competition Commission
IEA	International Energy Agency
IFC	International Finance Corporation (World Bank)
IMF	International Monetary Fund
IPA	Investment promotion Authority
IPBC	Independent Public Business Corporation
IPP	Independent Power Producer
IRN	International Rivers Network
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
K	Kina, PNG currency
KIK	Kokonas Industri Koperesen.
kWe	Kilowatts, electric output
LGM	Lihir Gold Mines
LLG	Local Level Government
MDG	Millennium Development Goals
MHDP	Micro-Hydro Development Programme (GoPNG; successor to DPRP)
MTDS	Medium Term Development Strategy: 2003-2007
MTFS	Medium term Fiscal Strategy: 2003-2007
NBPOL	New Britain Palm Oil Limited
NCD	National Capital District
NEC	National Executive Council (Cabinet)
NSO	National Statistical Office
NZAID	New Zealand Aid
OTEC	Ocean thermal energy conversion
OTML	Ok Tedi Mining Ltd.
PACER	Pacific Agreement on Closer Economic Relations
PCC	PNG Coconut Commodities
PDF	Project Development Facility (GEF)
PDMC	Pacific Developing Member Country (of ADB)
PEDC	Paruparu Education and Development Centre
PEDP	Pacific Energy Development Programme (UNDP/ESCAP, 1983-1992)
Pers. com.	Personal communication
PIC	Pacific Island Country
PICCAP	Pacific Islands Climate Change Assistance Programme (GEF / SPREP)
PICTA	Pacific Island Countries Trade Agreement
PIEPP	Pacific Islands Energy Policy and Plan (CROP EWG)
PIEPSAP	Pacific Islands Energy Policy and Strategic Action Planning project
PIFS	Pacific Islands Forum Secretariat

PIREP	Pacific Islands Renewable Energy Programme (GEF/UNDP/SPREP)
PJV	Porgera Joint Venture
PNG	Papua New Guinea
PNGP	PNG Power Ltd
PNGVEC	PNG Village Electrification Council
PPA	Pacific Power Association (also Power Purchase Agreement)
PREA	Pacific Regional Energy Assessment (World Bank, PEDP, ForSec, ADB; 1992)
PREF	Pooled Rural Energy Fund (proposed by DPE)
PREFACE	Pacific Rural Renewable Energy France-Australia Common Endeavour (SPC)
PV	Photovoltaics
RDS	Rural Development Services (RDS) Ltd.
RERG	Rural Energy Research Group (Unitech)
RET	renewable energy technology)
RSL	Ramu Sugar Limited
RSM	Ramu Sugar Mill
SOPAC	South Pacific Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
SWH	Solar water heater
SWOT	Strengths, Weaknesses, Opportunities and Threats
toe	Tonnes of Oil Equivalent
UNCT	United Nations Country Team, Port Moresby
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organisation
UNITECH	PNG University of Technology, Lae
UN-OCHA	UN Office For Coordination Of Humanitarian Action
UPNG	University of Papua New Guinea
UPNG	University of Papua New Guinea (Port Moresby)
USDoE	United States Department of Energy
UTC/GMT	Universal Time Coordinated / Greenwich Mean Time
WB	World Bank
WCD	World Commission on Dams (WB & IUCN)
Wp	Watts peak (i.e. peak output of a PV panel or wins turbine)
WRI	World Resources Institute (Washington, DC)
WWF	World Wide Fund for Nature

Energy Conversions, CO_2 Emissions and Measurements

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

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

Diesel Conversion Efficiency:

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

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

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

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

1. Country Context

Physical Description and Population. Papua New Guinea (PNG) is by far the largest of the Pacific Island Countries (PICs), with over 600 islands, immense physical variety, and 5.6 million people (2003), 80% of who live on the eastern half of New Guinea, the world's second largest island. Of all PICs, PNG is the most affected by natural disasters and has the lowest life expectancy. Nearly half the population are below 17 years old and 87% are rural. Although population growth was reportedly 3.1% annually between the 1990 and 2000 censuses, this is believed to be an overestimate. Nonetheless, by 2010, population may exceed 6.7 million.

Environmental Issues. Logging, over-hunting, over-fishing, clearing for agriculture and plantations, and trade in threatened or endangered species of wildlife are all environmental issues in PNG. The main threats to the forests are industrial logging and conversion for agriculture and plantations. The marine environment is threatened by logging, destruction of mangroves, over-harvesting and coral reef destruction. About 97% of land is under traditional clan ownership, providing an opportunity for people to manage land for their long-term benefit. Unfortunately, ruthless developers often gain access to land belonging to disempowered, poorly organised, and easily exploited landowners.

Political Development. PNG is a parliamentary democracy that became independent of Australia, which governed under a United Nations (UN) trusteeship, in September 1975. A House of Assembly is elected by popular vote, under generally free and fair elections, for five-year terms. The Prime Minister is Sir Michael Somare. A nine-year revolt on Bougainville Island ended in 1997 but some Bougainvillians still press for more autonomy or independence. A UN review in 2000 concluded that development was fairly steady until the early 1990s when progress slowed significantly for complex reasons related to law and security, civil strife on Bougainville, inequality among provinces, and a macro-economic crisis in 1994-95 which continues to the present. Nonetheless, PNG's rich cultures, democratic heritage, independent judiciary, free press and robust civil liberties, and abundant resources provide strong potential for future development.

Economic Overview. PNG has two distinct economies: i) a modern, cash economy dominated by mining, timber, gas and oil, and agricultural exports (coffee, cocoa, tea, oil palm and copra); and ii) the traditional subsistence economy and semi-subsistence farming, with most villages producing little or no surplus for trading. Economic growth has varied considerably but averaged less than 3% annually in real terms since independence in 1975, with per capita income less in 2002 than at Independence. The government expects real growth to average 2.1% from 2003-2008, a continued decline in real GDP per capita: Current development plans aim at public debt reduction, reduced budget deficits, and more stringent cost controls.

Institutional and Legal Arrangements for Energy. The Energy Division of the Department of Petroleum and Energy (DPE) is responsible for energy policies and plans, data collection and analysis, and advice to the government on energy sector issues. In practice, it concentrates on electric power, although PNG Power, the national electricity utility, undertakes most power sector planning. DPE itself reports that extremely limited resources have seriously hampered data collection and analysis. For renewable energy, data collection nearly ceased by the mid 1980s.

PNG Power operates three interconnected distribution systems plus many provincial power systems. About a hundred small rural electricity systems called C-centres are operated by local authorities at government administration centres, through diesel generators, small hydro and occasionally solar photovoltaics (PV). Responsibility for financing, managing and planning rests with provincial authorities but many systems are badly managed and not operating. The Independent Consumer and Competition Commission licenses electric power, establishes electricity tariffs and controls maximum prices of some petroleum fuels. There is a national power tariff for those served by PNG Power. Fuel prices are the same at the four main ports but are considerably higher, though still controlled, in remote areas.

The Petroleum Division of DPE is responsible for oil and natural gas exploration and development, with the industry controlled by foreign companies. Shell, Exxon-Mobil and British Petroleum market most petroleum fuel. A 36,000 barrel per day refinery began producing fuel for the local market in 2004, with some exports planned to neighbouring countries.

Policies and Laws Regarding Energy. There were several policy-related studies underway in 2004: an Australian Aid funded energy policy review project; World Bank (WB) assistance to build the capacity of DPE's Petroleum Division; a WB rural electrification policy and strategy; and a review of petroleum product pricing. The most recent energy policy documents are a draft *National Energy Policy Statement* and accompanying *National Energy Policy Guidelines of 2001* with no formal status. Rural electrification policy guidelines were developed in 1993 to address the low rate of rural electrification, high costs and subsidies to C-centres, high costs of grid connections, and the relative effectiveness of mission station electrification compared to government initiatives. The guidelines advocated decentralised diesel generators, very small hydro and PV. Despite these and more recent policy initiatives, rural electrification remains *ad hoc* and C-centres perform very poorly. A draft Energy Division strategic plan for 2004-2008 calls for creation of a Rural Electrification Authority with enabling legislation.

Acts of Parliament that deal with energy issues include: the *Electricity Supply Act* regarding powers of the minister for energy for generation, supply and extension of electricity from power facilities built with government funds; the *Electricity Industry Act* regarding the functions and powers of PNG Power; the *Independent Consumer and Competition Act* regulating electricity, petroleum and their pricing; the *Independent Public Business Corporation Act* under which the government holds all shares of PNG Power; the *Organic Law on Provincial Government and Local Level Government* which grants authority to 19 provincial and 299 local (district/sub-district) governments to regulate electricity; the *Community Services Trust Act* which could in principle require PNG Power to supply services at subsidised rates to rural or low-income populations; and the *Environmental Act* which can require environmental impact assessments for prescribed energy investments.

2. Energy Supply, Demand and the GHG Inventory

Energy Supply. Since 1992, PNG has exported about 340 million barrels of light crude oil, about 100,000 bbl/day on average, from recoverable reserves of roughly 550 million barrels. In 2003 exports were 15 million barrels earning about US$ 520 million. Production will steadily decline over the next decade as the resource is depleted. The natural gas resource is equivalent to about 2700 million barrels of oil (perhaps far more), over ten times PNG's remaining recoverable oil reserves. PNG is investing about US$ 4.5 billion in a 'Gas to Queensland Project', which may earn over US$ 11 billion in exports over 28 years.

Imports of refined petroleum products vary considerably year-to-year but averaged nearly 7,000 million litres (ML) from 1997-2000 with Shell having roughly 40% of the market, Mobil a third and BP a fifth. Wholesale fuel prices in Port Moresby (excluding taxes and import duties) are slightly lower than the PIC average for diesel fuel, somewhat cheaper for gasoline and about average for kerosene.

The Asia-Pacific Economic Cooperation (APEC) prepared an energy balance for PNG in 2000. Net primary energy supply was 573 kilotonnes of oil equivalent (ktoe). Light crude oil and petroleum accounted for 61%, natural gas 25% and hydro fourteen percent. Seventy nine percent of indigenous commercial energy production (i.e. oil) was exported. In 2001, electric power capacity was reportedly 451 MW and generation was 2,638 GWh, about double 2000 output due to dramatic annual variation in mining. Hydro provided 35% of generation and thermal 65%, (of which gas 26%; and oil 39%). There are no recent studies of non-commercial energy use but the PIREP mission estimates that about 1000 ktoe of wood are used annually for cooking.

Energy Demand. In 2001, the end use consumption of commercial energy was 364 ktoe, a decrease of 58% from 2000. Industry accounted for 60%, transport 17% and agriculture/residential /commercial, twenty four percent. Petroleum provided 40% of energy consumption and other energy forms (mainly electricity) sixty percent.

In 1996, 2% of all households in PNG were surveyed. 12% had electricity and fewer than 9% had either a refrigerator or television. Over half of the households used inefficient kerosene lamps as the main source of light and a quarter relied on open fires. Nearly 90% cooked mainly with fuel wood and 3% each used liquid petroleum gas or electricity. For the Port Moresby area, 77% of households were electrified, 67% had refrigerators and 61% had television. Over 75% had electric lighting, 40% cooked with kerosene and nearly 30% reportedly cooked mainly with electricity. The results overstate the extent of electrification in Port Moresby, and probably nationwide, but are indicative of household energy use.

The WB estimates that in 2001, about 600 MW of installed electricity capacity (PNG Power and private) generated about 2,600 GWh. PNG Power supplies electricity to only 5.5% of households nationally, accounting for 82% of customers but 11% of sales. It is likely that under 10% of the population are electrified by all means: grid, self-generation, nearby industry, small hydro or solar.

PNG Power sales are expected to grow from 660 GWh in 2003 to 766 GWh in 2012, aggregate peak demand from 152 MW to 173 MW, and customer numbers from 76,000 to 103,000. The utility is under financial distress and has been unable to invest enough for adequate maintenance or expansion, resulting in high system losses, derated generating plant, and frequent outages. As a commercialised utility, it is reluctant to expand its unprofitable rural electrification.

Future Commercial Energy Demand and GHG Reductions. Accurately projecting future patterns of energy demand is difficult. For the PIREP analysis, it was assumed that PNG's population and real GDP will each increase at 2.7% annually and commercial energy use will grow slightly faster at three percent . If all energy growth were from fossil fuels, greenhouse gas (GHG) emissions from commercial energy would increase from about 1500 gigagrammes in 2001 to 2,060 Gg in 2011. If PNG invested massively in renewable energy technologies that are already commercially available, in principle it could reduce these emissions (from the 2011 level) by about 1000 Gg per year. This ignores various economic, financial, political, social, technical, environmental and other practical constraints and is thus only broadly indicative of possibilities. The bulk of potential reductions would come from hydropower, geothermal, and fuel ethanol. Even a large PV or wind energy programme would provide only modest GHG reductions.

3. Potential for Renewable Energy Technologies

The technical potential for renewable energy (RE) in PNG is enormous but much of the resource is in remote locations with limited demand and not readily exploitable. The University of Papua New Guinea, the University of Technology (Unitech), and the government energy and forestry departments have assessed rural RE potential between the early 1980s and 1994. There is only limited information since then.

Geothermal Energy. No systematic geothermal energy assessments have been carried out but reconnaissance studies suggest that the most promising area is the northern coast of New Britain with at least seven geothermal sites. The only commercial geothermal development has been at Lihir north of New Ireland, which may have up to 70 MW of developable potential.

Hydropower. Due to limited hydrological surveys, information on hydroelectric potential is approximate. In 1994, the World Bank estimated the gross potential of large-scale hydro as roughly 20,000 MW and 175,000 GWh/year, with a technically feasible potential of 14,000 MW and 122,600 GWh/year. The economically feasible sites total about 4,200 MW producing roughly 37,000 GWh/year. These estimates exclude micro- and mini-hydro for rural communities, which have a large exploitable potential. Over 100 potential mini-hydro sites near C-centres have been assessed in 17 provinces, 31 with field investigations. Of 6 MW identified, over half is in North Solomons Province but there are promising locations throughout the country

Ocean Based Energy. There is very limited knowledge of PNG's potential for ocean thermal energy conversion (OTEC), tidal energy or wave energy. Despite recent developments, there are no commercially available, proven technologies. Near Port Moresby, the tidal range is 2.7 metres compared to 1.1-1.6 m in much of the country. Reportedly, there is a 6 m range in parts of the Torres Strait. There have been very preliminary proposals to tap tidal currents (peaking at 7-11 km/hour) at Buka Passage, Bougainville. The PIREP mission is unaware of any measurements of deep sea versus surface ocean temperatures to estimate OTEC potential.

Wind Energy. There have apparently been no systematic estimates of wind energy since the 1970s when the best potential was estimated to be in portions of Central, Western, Milne Bay and New Ireland provinces and the Port Moresby area. These (and recent evaluations of the old data) were based on models, with very little wind gauging.

Solar Energy. Solar energy is among the largest potential sources of energy in PNG. Average insolation in much of the country is 400-800 W/m^2, with 4.5 to 8 sunshine hours daily. Of 23 locations assessed, Port Moresby is PNG's sunniest location with 2478 sunshine hours per year. The lowest is Tambul, Western Highlands, with 1292 hours. The best locations for solar PV are the off-shore islands and the southern regions.

Biomass Energy. Although two thirds of PNG is forested, much is inaccessible or unsuited for energy use. 58% of land is subject to strong or severe erosion and 18% is permanently inundated or regularly flooded. The main practical biomass energy potential is in areas of logging or agricultural production using either the crop output or residues. Log exports are about 2 million m^3 per year but very little is processed locally, leaving only small amount of biomass for energy production. There are 18 major wood-processing facilities but the amount of residue produced and available for energy use is unknown.

With additional processing, almost any vegetable oil can be used as a liquid fuel (biodiesel) but the practical potential depends on its value as an export commodity compared to diesel fuel. PNG produces about 330 ML of crude palm oil per year and about 33 ML of coconut oil. Ethanol (alcohol) can be produced from sugar cane, molasses, sago palm, nipa palm and other crops and blended with petrol as a vehicle fuel. Reportedly, 200-1100 ML of fuel alcohol per year could be produced from sago palm in the Gulf Province alone. Over 250 ML could be produced from nipa palm from the Purari Basin alone. In principle, PNG could manufacture a huge volume of fuel from local agricultural resources.

4. Experiences with Renewable Energy Technologies

Geothermal Energy. In 2003, a 6 MW geothermal power plant was commissioned on Lihir Island (the first geothermal power facility within the Pacific Islands). Another 20-30 MW of capacity is now being added. PNG Power may explore geothermal potential in East and West New Britain.

Hydropower. ELCOM (now PNG Power) carried out numerous feasibility studies to replace small diesel systems with small hydro in the 1980s-1990s but none were developed due to high costs. Five new small hydro systems are planned by PNG Power between 2005 and 2010 and four more afterwards. DME's Energy Division had assessed 45 potential hydro sites near C-centres by 1987, completed 14 feasibility studies and commissioned three small hydro systems (60-300 kW) by 1992. Apparently none have been constructed since then. In 2000, PNG Power had 162 MW of hydro capacity and Ok Tedi Mining nearly 60 MW. Church missions, NGOs and community organisations have built a number of small hydro systems but documentation is sketchy. The PIREP mission estimates that there may have been as many as 200 pico- (single household size), micro- and mini-hydro systems installed in rural PNG between 1960 and 2004, of which perhaps 20-25% are still functioning, about 20-25 systems on Bougainville and roughly the same number throughout the rest of PNG. Many more are planned if funding can be found.

Ocean Based Energy. There has apparently been no experience in PNG with seawave, tidal, OTEC or other ocean-based energy demonstrations.

Wind Energy. Several wind turbines were installed in Morobe Province after Independence but it is not known if any still function. PNG Power may consider a wind farm near Port Moresby but no wind monitoring has yet begun. In 2002, the Chinese government donated 50 small combined wind/solar generators to the government and a number have been installed in various coastal locations.

Solar Energy. There have been at least 25 small-scale applied research projects involving solar energy in PNG between 1989 and 1994, mostly at Unitech, including solar drying, water heating, PV monitoring, and solar pumping. In the 1980s, solar drying of copra, cocoa and coffee was widespread, particularly by small-holders. Also in the 1980s, the government supported a solar water heating retrofit programme for commercial users, industry and households, with at least 3000 household systems installed. In 2004, at least 7000 homes in Port Moresby use solar water heating but the total appears to be slowly declining.

Solar PV has spread gradually in PNG for the past 25 years, with systems ranging from 10-480 watts marketed by private suppliers, and used mainly for lighting, followed by communications. Some 3000 solar home lighting systems were sold to individuals between 1998 - 2002, with perhaps 1000 new systems sold per year since then. PNG Telecom has at least 173 sites with about 5000 PV panels with a capacity of over 200 peak kW. Some have reportedly been damaged or stolen. There were at least a dozen PV pumping systems and a dozen PV-powered refrigerators at health centres in the 1980s. A K15 million Japanese-supported project provided solar electrification for 320 schools in all 20 provinces in 1997-98. By 2004, few were still operating for a variety of reasons including poor quality installation, poor maintenance and support, poor transport of spares, and poor security (leading to numerous thefts). Since 2000, about 300 solar and gas-based vaccine refrigerators have been installed in health facilities, many suffering from poor design and panel theft. A large palm oil company has reportedly ordered 5000 small solar home kits in early 2004 to provide lighting for homes, schools and clinics.

Biomass Energy. Traditional biomass probably accounts for about 53% of PNG's national energy consumption in 2000, largely cooking, with some industrial use. Although hundreds of charcoal stoves were sold in PNG in the 1980s, most cooking is on open fires. There is some production of electricity from biomass wastes within the oil palm industry, and combined heat and power generation from wood waste in the wood processing industry. In 1990, about 80 Waterwide heat gasifiers used biomass waste in the copra, cocoa, coffee and tea industries to replace diesel fuel burners, with possibly 100 or so systems still in use. Ramu Sugar Mills, which produced about 4 ML of ethanol per year as a fuel in the 1980s, has reportedly established a 50 ha plantation to grow fuelwood to supplement bagasse (sugar cane waste) as a fuel, with plans to expand to 1,000 ha by 2010. Esterified coconut oil was used as fuel on a small scale in PNG for about a year in the mid-1980s, with no further reported use (except in Bougainville during the civil strife) until Unitech began tests again in 2002.

In the 1970s-1980s, several biogas systems operated for a short time at the Lae City Council and a coffee plantation in Mt. Hagen. Only one biogas plant is currently known to be operational, at a piggery near Port Moresby. In early 2004, a small twenty-pig system was under construction in Central Bougainville. There have been proposals to incinerate municipal waste in Port Moresby for energy but no details are available. However a SPREP study concluded that waste incineration was not suitable for Port Moresby, as it required complex technology, sophisticated operations and management and produced unacceptable emissions.

Unitech, the Forest Research Institute and the government's agriculture department are attempting to renew and expand bio-energy research activities, beginning with coconut oil as biodiesel, and extending later to agricultural residues.

Hybrid Energy. 50 hybrid energy systems (500w wind; 100 w PV) were provided by China in 2002 for use at coastal provincial centres. Apparently only a few had been installed by early 2004 with several failures of electronic components.

Summary. PNG has enormous renewable energy resources and a longstanding interest within its two universities to develop RE technologies. Until the mid-1980s, PNG was the region's leader in biomass energy for agro processing, biogas, biomass gasification, wood and charcoal cooking, ethanol production, solar PV, and resource assessments. Recently the private sector has largely driven RE use. The coffee industry still uses wood-burning driers, the palm oil industry exploits wood waste for electricity, and Ramu Sugar plans to use wood for combustion in its bagasse boilers. At least several thousand new solar home lighting systems are expected to be installed in rural PNG during 2004, overwhelmingly through private initiatives. Yet barriers to successful long-term use of RETs seem to be considerable. About three quarters of mini/micro hydro systems installed are no longer in use, a large percentage of PV systems have failed, and the majority of C-centre power systems are operating poorly or not at all.

5. Barriers Identified in the Development and Commercialisation of RETs

Barriers to the development and commercialisation of RE in PNG are summarised below.

Fiscal. Fiscal barriers include fiscal policies (import duties, taxes, charges) biased in favour of conventional energy or against RE. Barriers include: i) a temporary distillate tax exemption of US2¢/l for PNG Power which is a small disincentive against locally-produced biofuels; ii) identical fuel prices for Port Moresby, Lae, Madang and Rabaul providing a cross-subsidy for the three outer centres relative to Port Moresby, which could be a barrier for biofuels; iii) a national electricity tariff, providing a very substantial subsidy to consumers at provincial systems; and iv) no incentive for assembling, manufacturing or importing RETs compared to conventional systems, as duties and taxes do not differentiate and there no 'green' interest rates.

Financial. Energy Division funds are inadequate for surveys, travel and communications and funds for expanding rural electrification are meagre, both forming barriers to RE development. Other financial barriers include: i) lack of cash in most rural communities, which can seldom afford connection fees and usage charges, ii) very high costs of business in PNG, particularly those serving rural areas, iii) lack of recent donor support, iv) the high initial costs of RETs, v) unwillingness of many public servants in rural areas to pay for energy services, and vi) perceptions among financial institutions that RETs and energy service companies are high risks.

Legislative, Regulatory and Policy. There is no formal national energy policy, no clear rural electrification policy, inconsistent implementation of the informal policies, and a widespread belief that the government considers rural electrification to be low priority. There is a lack of appropriate legislation, guidelines and regulations. The regulatory framework for energy is unclear.

Institutional. Financial governance within government (national. provincial, local) is weak and PNG has not effectively tapped existing or potential sources of finance for RE. Specific issues include: i) low capacity of the Energy Division for research, planning and analysis; ii) lack of support from national government to provincial and local governments for planning, training, finance, operating guidelines, financial guidelines, etc for C-centres; iii) perceptions among some officials that PNG is marginalised by regional organisations dealing with energy matters and will receive little support; and iv) short-term donor policies which include little support for developing institutional arrangements required for sustainable RE.

Technical. Technical barriers in PNG are largely related to poor knowledge of RETs and include: i) limited knowledge of renewable energy resources; ii) lack of commercialised RETs to tap abundant local resources such as ocean energy; iii) limited finance for increasing local technical knowledge; and iv) limited knowledge of PNG's real biofuel potential.

Market and Private Sector. Among barriers are: i) small market size, ii) dispersed population, isolation and poor accessibility; iii) lack of productive demand for electricity in remote areas; and iv) limited RE knowledge within the private sector.

Knowledge and Public Awareness. Key barriers are: i) low level of public awareness of RETs; ii) low level of technical knowledge regarding RETs; and iii) inadequate technical training about RETs.

Environmental and Social. Environmental and social barriers include: i) PNG's vulnerability to natural disasters; ii) possible community biases against hydro development; iii) questionable long-term access to customary land and related compensation demands; iv) little sense of ownership of, or responsibility for, RE among recipient communities or institutions; v) high degree of theft and poor security; and vi) lack of respect for law and order and continued instability.

6. The Capacity Development Needs for Removing the Barriers

Fiscal. Barriers to the development and commercialisation of RETs include petroleum fuel pricing and cross-subsidies, electricity tariff policies, and lack of 'green' interest rates or incentives. There is a need to improve the capacity within government to analyse and address the impacts of interest rates, import duties, energy prices and taxes on the development of RETs and energy efficiency measures.

Financial. Access to finance is a barrier because so many PNG people are largely outside the cash economy and government budgets for rural energy services are low. Capacity development needs include: i) ability to prepare high quality project requests and ii) rules and mechanisms to collect payments for rural energy services.

Legislative, Regulatory and Policy. The lack of appropriate legislation, approved energy policies, guidelines and regulations form a significant barrier to the development of RE. Capacity development needs include: i) RET development and project management skills within the energy division; and ii) ability to develop comprehensive national energy policies, legislation and guidelines that addresses specific issues facing the country.

Institutional. Institutional issues requiring improved capacity, additional to those raised above, include: i) determination of the need, value and costs of developing a Rural Electrification Authority;

ii) at the regional level, improved ability of regional organisations to address PNG's energy needs; iii) skills to assess PNG's RE resource (particularly but not only hydro); iv) skills to evaluate and develop PNG's large-scale biofuel potential; and v) ability to develop easily understandable publicly-available reference materials on RETs.

Market and Private Sector. Market barriers include the lack of affordable transport to rural areas, small market size, dispersed population, and lack of productive demand for electricity. Capacity should be developed to understand genuine market barriers, and ways to overcome them. The inadequate experience within the private sector regarding technical, institutional, financial and management issues relating to RET development requite training. There is also a need for practical training in designing, marketing, installing, operating, maintaining, and repairing RET systems for the private sector, not just government officials.

Knowledge and Public Awareness. Any effects of awareness campaigns on energy efficiency and renewable energy are likely to be limited and temporary. Public funds should not be used for public awareness materials on RE unless focused on implementation of a specific RET project. As noted above, improving knowledge of RETs requires training for NGOs and the private sector, not just government.

Environmental and Social Barriers. Key barriers in PNG are poor access to land with secure arrangements for the long term; and the lack of law and order with associated theft of, and damage to, RETs. There is a need to develop the capacity to deal with landowners in a manner that gives them incentives to allow the use of their land for RETs and to keep the energy systems operating over time.

Hardware Investments for Removing Barriers. Large-scale hydropower offer the most practical opportunity for RE development in PNG followed by biofuels and geothermal. Where GHG reduction is a priority, investments in environmentally appropriate large-scale RETs should be considered. There are no firm investment recommendations due to the limited time and resources to address this. However, RE choices should not be made solely on the basis of reduced emissions, which are inconsequential on a global scale. For PNG, development impacts of RETs will be greater through large-scale solar home systems and micro-hydro, including institutions for finance and operation, than via large hydro, geothermal or biofuel.

7. Environmental Implications of Widespread Use of Renewable Energy:

For both GHG reductions and RE production, the biggest impacts may come from large hydropower, ethanol, geothermal, biodiesel and small hydro respectively. If poorly planned or implemented, any of these could have detrimental environmental impacts.

Hydro. Hydro projects above 10 MW can undermine moves toward sustainable development, people and ecosystems, and even energy security (where changes in weather patterns reduce rainfall). There could be GHG emissions from rotting matter in reservoirs. Smaller hydro can be environmentally and socially low-impact. For hydro projects to have low social and environmental impacts, they should be planned, built and operated in line with the recommendations of the World Commission on Dams.

Ethanol. Nearly 60% of PNG's land area is subject to severe erosion and nearly 20% is regularly flooded. Environmental issues for ethanol as a fuel in PNG are those of biomass use in general: conversion of forests to biomass plantations, encouraging clear cutting, nutrient draining, use of toxic chemicals, increased erosion, and possible loss of wetlands.

Geothermal. Despite possible hydrogen sulphide emissions, geothermal is relatively environmentally friendly, producing about 0.1% of the GHG emissions of fossil fuelled power plants for the same energy output. If carelessly developed, there can be negative impacts from drilling wells.

Biodiesel. It has been assumed that only 10% of vegetable oil production in PNG might be used for fuel so the impact should be no more severe than current agricultural practices. Vegetable oils are low in emissions, containing almost no sulphur or hazardous materials, and readily biodegrade.

8. Implementation of Capacity Development Needs and Co-Financing

The following are recommended as specific activities and co-financing opportunities for capacity development in PNG.

Biofuels. A study should be carried out of the impact of the production of coconut oil-based biofuel in PNG: i) at 20-200 ML per year scale for power and transport; and ii) at small-scale for remote islands and communities.

Import duties and taxes. A study should be carried out of import duties and taxes, and exemption policies, to determine if there is a bias regarding RETs at both small and national scale.

Effective RET project development for donor funding. Donors increasingly require high quality project documents with clear analysis, realistic budgets, logical frameworks and action plans. Preparations for GEF and ADB support are demanding. Training is needed for the private sector and government to develop good projects that are adequately documented.

Green interest rates. An assessment should be made of the viability of subsidised interest rates for majority locally-owned businesses for RE services, followed, if appropriate, by a subsidy fund or special loan arrangements for private RET development.

Energy policy development. Advisers should help PNG review national and rural energy policies, and prepare practical energy policy documents for Cabinet consideration. These should include strategic plans with activities, timeframes, priorities, and budgetary requirements.

Energy Division. The functions, authority, and responsibility of the Energy Division should be clarified and up-to-date staffing structure and job descriptions prepared and approved at the appropriate level.

Public information for RETs. Resources should be provided to develop a library of RET materials specifically selected and developed for the PNG government, NGO and private users.

Provision of Support for Unitech RET activities. Unitech may be a suitable institution to support for training on practical management and use of RETs and can assist in the preparation of a national RET library focused on PNG appropriate technologies and PIC experience.

Resource assessment. Assistance to the Energy Division and others should be provided to develop local capacity to assess wind, hydro, biomass and solar resources.

RET O&M training. Developing the capacity of rural technicians to install, operate and maintain RET systems requires local language training which in turn requires external assistance to develop manuals and training in English, translated to local languages.

Understanding market structures for RETs. A study of the reality and seriousness of market barriers to RETs, and ways to overcome them, is warranted if large-scale private sector development in RE is desired.

Vandalism and theft. The extent of vandalism and theft, and the degree of success of earlier awareness campaigns, should be ascertained. Guidelines for protection of RETs should be prepared and disseminated for PV systems, with similar preventive measures designed for other RETs.

Land Access study. A study with follow-up recommendations for action should be carried out on options and opportunities to involve landowners as potential partners rather than opponents in the development of both small scale and larger scale RETs.

Guidelines for village scale hydro. Guidelines should be developed for 5-20 kW hydro development, for which there significant opportunities in PNG. Finance is needed to develop guidelines for technical assessment, environmental impact assessment, economic analysis, technical design, institutional possibilities, operational requirements and maintenance requirements.

Hardware investments for co-financing. The following have the highest short-to-medium term potential for reducing GHG emissions from petroleum energy use in PNG: i) biofuels, which could eliminate two thirds of current emissions from fossil fuel use; ii) geothermal, which could displace 15%; and iii) mini and microhydro, which could displace 13 percent. If finance is available to develop relatively large-scale RETs, all of these should be seriously considered. However, choices regarding RET should not be made solely on the basis of their potential impact on GHG emissions.

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Map of Papua New Guinea

Source: *PNG Country Data* (ADB, www.adb.org)

1 COUNTRY CONTEXT

1.1 Physical Description

Papua New Guinea (PNG)[1] extends over 1300 km from north to south-from the equator to 12^0 south latitude - and 1200 km from the border with Indonesia in the west to 160^0 east longitude. It borders the waters of Australia to the south and Solomon Islands to the southeast. Although PNG is made up of over 600 islands, 80% of its population (i.e. over 4 million people) live on the eastern half of New Guinea, the world's second largest island (396,500 km^2), with 85% of the country's total land area of 462,800 km^2. The remaining 20% (about 1 million people) live on islands ranging from as small as 0.2 km^2 to several thousand square kilometres. Many of the small islands are very remote and accessible only by boat.

Table 1-1 – Natural Disasters in PNG

Disaster	Date	Killed
Drought	23-Sep-1997	100
Drought	23-Sep-1997	700,000
Drought	Mar-1981	40,000
Earthquake	13-Oct-1993	76
Earthquake	13-Oct-1993	20,200
Flood	Mar-1992	90,000
Flood	12-Jun-1993	54,000
Flood	23-Apr-1999	38,000
Flood	Sep-1983	13,000
Landslides	26-Feb-1991	200
Landslides	21-Mar-1971	122
Landslides	6-Sep-1988	114
Volcano	15-Jan-1951	3,000
Volcano	29-May-1937	506
Volcano	19-Sep-1994	152,002
Volcano	15-Oct-1983	25,000
Wave/Surge	17-Jul-1998	2,182
Wind Storm	14-May-1993	40,040

Source: EM-DAT: International Disaster Database (www.em-dat.net - Université catholique de Louvain, Brussels, undated)

PNG is subject to active volcanism and frequent and sometimes severe earthquakes; mudslides; tsunamis. Of all Pacific Island Countries (PICs), PNG is the most affected by natural disasters, with nine serious disasters occurring from 1990-1999 (WHO, undated).[2] Table 1-1 lists the worst of these that occurred during the twentieth century. Similar future disasters could affect otherwise reasonable decisions regarding renewable energy (RE) investments. PNG is also by far the largest of the PICs in both population and land area, with immense physical variety. Table 1-2 indicates the range of island types and their locations within the country. The climate is tropical, with northwest monsoons (from December through March), southeast monsoons (May to October), and slight seasonal temperature variation.

Table 1-2 – Island Types of Papua New Guinea

Island type	Location within Papua New Guinea
alluvial	e.g. many islands of Western & Gulf Provinces
continental	e.g chains of islands off Milne Bay Province
coral	Many atolls, e.g. North Solomons, Milne Bay, Manus
raised coral	In Milne Bay and North Solomons Provinces
volcanic	Islands off Madang Province & much of New Britain

Source: *A Factbook on Modern PNG* (Rannells, 1990)

Administratively (Figure 1-1) the country is divided into twenty separate provinces: Bougainville, Central, Chimbu, Eastern Highlands, East New Britain, East Sepik, Enga, Gulf, Madang, Manus, Milne Bay, Morobe, the National Capital, New Ireland, Northern, Sandaun, Southern Highlands, Western, Western High-lands, and West New Britain. Table 1-3 shows the sizes and

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[1] Annex 1 is a list of acronyms and abbreviations used in this report. Annex 2 provides energy conversions and Annex 3 a list of reference materials used.

[2] The source is the WHO website www.who.int summarising UN-OCHA's *Situation Reports on Natural Disasters*.

populations, at the time of the 2000 census, of those islands close to the PNG mainland and those associated with the island provinces.

1.2 Population

Papua New Guinea had a total population of 5.2 million in 2000 (Table 1-3), a reported increase of 1.5 million since the 1990 census. Nearly 48% are below 17 years of age and the vast majority (87%) are rural. 4.0 million people live on the mainland with the rest widely dispersed over hundreds of islands. Population density ranges from only two people per km^2 in the remote Western Province to 52/km^2 in the Western Highlands, averaging 11/km^2 overall. Based on census data, the average annual growth rate (AAGR) of population averaged 3.1% from 1990-2000 compared with 2.3% during the previous intercensal period of 1980-1990. This AAGR however may be a function of coverage errors in both the 1990 and 2000 censuses and may not reflect demographic reality (UNCT, 2001).[3] Regardless of the overall population

Table 1-3 – Population of Provinces and Associated Islands of Papua New Guinea (2000)

Island and Province	Inhabited islands	Area (sq km)	No. of persons	No. of islands
Mainland	n/a	396,452	4,033,598	n/a
Sandaun Province	*3*	*2.54*	*1,763*	*6*
<1 sq km	3	2.54	1,763	
East Sepik	*12*	*165.17*	*9,301*	*15*
10 - 99 sq km	4	138.01	5,533	
1 - 9 sq km	7	26.58	3,680	
<1 sq km	1	0.58	88	
Madang	*4*	*936.27*	*50,129*	*45*
100 - 999 sq km	2	821.8	40,809	
10 - 99 sq km	2	114.47	9,320	
Morobe	*6*	*964.06*	*14,152*	*57*
100 - 999 sq km	1	873.4	11,795	
10 - 99 sq km	2	88.55	1,256	
1 - 9 sq km	1	1.01	333	
<1 sq km	2	1.1	768	
Oro	*0*	*0*	*0*	*8*
Milne Bay	*65*	*6,126.44*	*136,848*	*438*
>=1000 sq km	1	1,332	23,184	
100 - 999 sq km	8	4,224.90	87,501	
10 - 99 sq km	13	452.7	12,802	
1 - 9 sq km	30	110.65	10,999	
<1 sq km	13	6.19	2,362	
Central	*8*	*8.86*	*2,878*	*33*
1 - 9 sq km	3	6.81	943	
<1 sq km	5	2.05	1,935	
Gulf	*5*	*273.22*	*2,165*	*48*
10 - 99 sq km	5	273.22	2,165	
Western	*8*	*819.91*	*19,625*	*52*
100 - 999 sq km	2	445.5	2,489	
10 - 99 sq km	6	374.41	17,136	

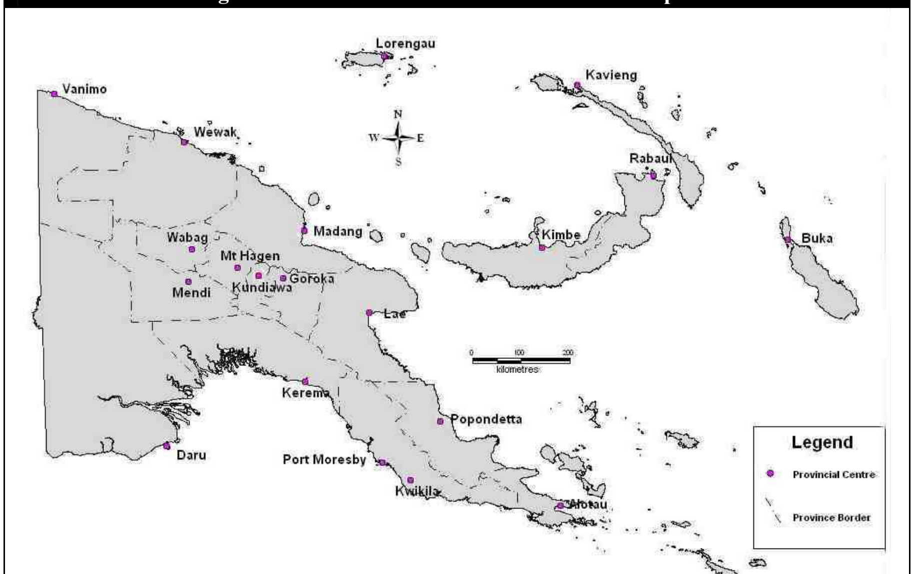
Province and Associated Islands	Inhabited Islands	Area (sq km)	No. of persons	No. of islands
Manus	n/a	1,895	29,475	n/a
Islands	35	226.69	13,912	208
10 - 99 sq km	5	173.99	5,152	
1 - 9 sq km	11	44.5	4,212	
<1 sq km	19	8.2	4,548	
New Ireland	n/a	7,066	66,108	n/a
Islands	54	2,556.59	52,242	149
>=1000 sq km	1	1,220	15,729	
100 – 999 sq km	4	830.52	16,200	
10 - 99 sq km	11	432.76	11,840	
1 - 9 sq km	21	67.11	6,873	
<1 sq km	17	6.2	1,600	
West New Britain	n/a	20,290	163,551	n/a
Islands	19	200.42	20,957	125
10 - 99 sq km	3	159.91	13,176	
1 - 9 sq km	13	36.32	5,462	
<1 sq km	3	4.19	2,319	
East New Britain	n/a	15,270	207,613	n/a
Islands	8	79.29	12,520	46
10 - 99 sq km	2	66.64	8,857	
1 - 9 sq km	3	11.31	2,380	
<1 sq km	3	1.34	1,283	
North Solomons *	n/a	8733	128,145	n/a
Islands	9	687.79	46,478	168
100 - 999 sq km	1	611.3	36,676	
10 - 99 sq km	2	56.8	6,735	
1 - 9 sq km	4	18.13	2,576	
<1 sq km	2	1.56	491	

Source: *PNG 2000 Census: Final Figures* (National Statistical Office, GoPNG; March 2002… …..*Bougainville Island

[3] The source is a report by the United Nations Country Team (UNCT) in Papua New Guinea, the *Common Country Assessment* (CCA) based on analysis by the Pacific office of the UN Fund for Population Activities (UNFPA).

growth, significant increases were recorded in some regions. Within the highlands, the Southern Highlands province accounted for almost half the regional population increase since 1990, an AAGR of 5.4%. In the southern region, the National Capital District (NCD, or Port Moresby and surroundings) fell well below the projected population based on previous patterns of in-migration and natural increase. Assuming 2.7% AAGR since the census, the national population in late 2003 was about 5.6 million. By 2010, it is expected to exceed 6.7 million.

Figure 1-1 – PNG's Provinces and Provincial Capitals



Source: PNG Resource Inventory Mapping System (slightly modified by P Johnston)

Urban dwellers constitute less than 14% of the total (Table 1-4). The proportion of the urban population living in smaller towns has been decreasing steadily in recent decades while the percentage in the NCD and Lae has been increasing. The *National Population Policy 2000-2010* (GoPNG; 1999) proposes measures to encourage the flow of rural-urban migrants away from the two largest cities and towards provincial capitals and other smaller towns, including improved economic options and better electricity supply.

Table 1-4 – 2000 Population by age and location

	Male	Female	Total
Urban	365,533	309,870	675,403
Total PNG	2,691,744	2,499,042	5,190,786
Percent Urban	13.6%	12.4%	13.0%
Percent Rural	86.4%	87.6%	87.0%
Percent by age:			
0-4 years	14.1	14.0	14.1
5-14 years	26.5	25.4	26.0
15-17 years	6.8	6.6	6.7
18-64 years	50.0	51.8	50.9
65 and above	2.6	2.2	2.4

Source: 2000 Census: Final Figures (GoPNG, 2002)

PNG's life expectancy is the lowest among the PICs, lagging almost 20 years behind Fiji. At the national level, 22% of the population is not expected to survive to age 40, rising to over 30% in several of PNG's least developed provinces, where infant mortality rates are particularly high.

1.3 Environmental Commitments and Issues

PNG has ratified a number of international environmental conventions including the Convention on Biological Diversity (1992), the Ramsar Wetlands Convention (1993), the Framework Convention on Climate Change (UNFCCC, 1993), the London Convention on the Prevention of Marine Pollution (1994), the Montreal Protocol on

Ozone-depleting Substances (1998), the Convention on the Illegal Trade in Endangered Species (CITES), the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean and the Apia Convention on the Conservation of Nature in the South Pacific. These conventions bind signatory countries to observe the regulatory measures contained in them.

An initial national communication to the UNFCCC, indicating greenhouse gas emissions, and vulnerability and adaptation to climate change, was completed in 2000. Table 1-5 summarises the status and date of signing of some key environmental conventions.

Table 1-5 – Status of Ratification of Environmental Treaties and Conventions by PNG

Status in PNG	Protection of natural resources (SPREP Convention)	Conservation of nature (Apia Convention)	Hazardous wastes (Waigani Convention)	Nuclear free Pacific (Rarotonga Treaty)	GHG reductions (Kyoto Protocol)	Ozone depleting substances (Montreal Protocol, et al.)
Signed	03 Nov 87	12 June 76	16 Sep 95	16 Sep 85	02 Mar 99	–
Ratified	15 Sept 89	No	11 Dec 95	15 Sep 89	28 Mar 02	3 Mar 98
Entered into force	22 Aug 90	26 Jun 90	21 Oct 01	15 Sep 89	n/a *	17 June 93

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

1.3.1 Environmental issues[4]

The problems facing the environment, on which Papua New Guineans rely so heavily, fall mainly under the heading of over-exploitation. Logging, over-hunting, over-fishing, clearing for agriculture and plantations, trade in threatened or endangered species of wildlife, all present environmental problems when they result in over-exploitation or over-harvesting. The main threats to the forests are i) industrial logging, ii) conversion for agriculture and plantations, and iii) over-hunting. The marine environment is threatened by logging, destruction of mangroves, over-harvesting and coral reef destruction.

Industrial logging is conducted by foreign companies, some of which show little concern for PNG's environmental laws. The Forest Authority indicates that nearly all loggable forest has already been logged, allocated for logging, or proposed as new concessions. Unless industrial logging is reduced to a sustainable level, it will not be long before it ceases to make a useful contribution to the economy. Most of the presently deforested lands were cleared long before there were logging concessions. Logging can lead to severely degraded forests but generally not deforestation unless followed by agriculture, plantations or other development. Increased population densities, shortened fallow periods, regular burning, and agriculture have resulted in extensive deforestation, particularly in the highlands. Industrial mining also has an impact on forests, through clearing for mining and construction activities, and the freshwater and marine aquatic environment, through leaching of effluents into watercourses.

About 97% of PNG's land is under traditional clan ownership. The land tenure system provides a unique opportunity for people to manage their land for their long- term benefit. Unfortunately the system has made it easier for ruthless developers to gain

[4] This is summarised from the UN's *Common Country Assessment for PNG* (CCA; UNCT, 2001).

easy access to land belonging to disempowered, poorly organised, and easily exploited land owners.

1.4 Political Development

The eastern half of the island of New Guinea was divided between Germany (the northern portion) and the United Kingdom (southern) in 1885. The British-controlled area was transferred to Australia in 1902. Australia subsequently occupied the north during World War I and continued to administer the combined areas as a United Nations trusteeship until independence on 16 September 1975, when the Independent State of Papua New Guinea was established.

PNG is a constitutional monarchy (with Queen Elizabeth II of the United Kingdom as chief of state since 6 February 1952) and a parliamentary democracy. The Queen is represented in PNG by Governor General Sir Silas Atopare (since 13 November 1997). While elections are generally free and fair, members of parliament (the House of Assembly) are being elected by ever decreasing proportions of the electorate, in some cases as low as 10% of voters.

The Prime Minister (PM) is Sir Michael Somare (since 2 August 2002 and also PNG's first PM in 1975) and the Deputy Prime Minister is Allan Marat (also since August 2002). The National Executive Council (i.e.Cabinet) is appointed by the Governor General on the recommendation of the prime minister. Following legislative elections, the leader of the majority party, or the leader of the majority coalition, is usually appointed P.M by the Governor General. The House of Assembly is elected by popular vote to serve five-year terms. There are 109 seats, of which 89 are from open electorates and 20 from provincial electorates. Elections were last held from 15-29 June 2002 but not finished until May 2003, as voting in the Southern Highlands was not completed during the June 2002 election period. The next election will be held no later than June 2007.

Since mid -1997, there have been three Prime Ministers: Bill Skate (22 July 1997 – 14 July 1999), Sir Mekere Morauta (14 July 1999 – 6 August 2002), and Sir Michael Somare (6 August 2002 – present). During the past six years, there have been eight Ministers responsible for energy, all but the first as Minister for Petroleum and Energy: Philemon Embel (Minister for Mining and Energy, from February 1998), Sir Rabbie Namaliu (August 1998), Tommy Tomscoll (July 1999 – 2000), Fabian Pok (2000), Tommy Tomscoll (2000), Chris Haiveta (Dec. 2000 – May 2001), Roy Yaki (May 2001 – 2002) and Sir Moi Avei (Aug. 2002 – present).[5]

The Supreme Court is led by a Chief Justice who is appointed by the Governor General on the advice of the National Executive Council. Other judges are appointed by a Judicial and Legal Services Commission.

A nine-year secessionist revolt on the island of Bougainville formally ended in 1997, after claiming some 20,000 lives, but some Bougainvillians continue to press for independence. A UN review of key development issues in PNG summarises political developments as follows (CCA; UNCT, 2000):[6]

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[5] As this report was being drafted in early 2004, the courts declared the Governor General's election to be invalid (as it had with his predecessor).

[6] The text has been edited for brevity.

"In the first decade after independence, PNG experienced slow but steady development. Social indicators improved steadily from a very low base. Life expectancy increased by 14 years (from 40 to 54) from the early 1970s to the mid-1990s as a result of improved health and survivability. The macroeconomic context was generally stable with a sound currency underpinned by responsible fiscal and monetary policy. PNG's Constitution and its legal and regulatory framework were among the best in the world with the news media relatively free.By the early 1990s, however, progress slowed significantly, notably infant and child mortality and overall life expectancy. PNG's development indicators compare unfavourably with its Pacific and SE Asian neighbours, and UNDP's 2001 Human Development Index (HDI) ranks PNG 122nd in the world[7] and near the low end of the range. The slow-down … appears paradoxical. PNG is rich in natural resources: copper, gold, oil, gas, land, forests, agricultural land, and a large and well-stocked marine environment. The establishment of a series of mines from the 1970s to the early 1990s provided a steady revenue stream to the national government, creating jobs and spin-off industries. PNG has continued to receive substantial amounts of foreign aid and technical assistance, largely from Australia. The development slowdown has complex causes.

One cause relates to security. Law and order problems first became evident in nascent towns … but later emerged in rural areas. Crime is no longer an exclusively urban phenomenon. The costs of starting new businesses or maintaining existing ones escalated because of the need to pay for a range of security services. Small businesses are unable to provide sufficient security to justify their operations. Coffee plantations have also contracted due to law and order problems.

Another causal factor has been civil strife on Bougainville island. The closure of the Panguna copper mine by a group of landowners and workers supported by the Bougainville Revolutionary Army, reduced national government revenue. It also increased the GoPNG costs of a police and military campaign to re-establish central government control. An August 1991 Peace Agreement resulted in a phased assumption of political autonomy which may evolve into independence.

A third major factor was a macro-economic crisis of 1994-95. Serious fiscal imbalance resulted in effective loss of foreign reserves and devaluations of the Kina and its eventual float. PNG was hit with two additional shocks, a widespread drought in 1997 that closed mines, and reduced agricultural production and real GDP by almost two percent; and the Asian financial crisis, which reduced demand and prices for a wide range of PNG's exports. A Tsunami, and a volcanic eruption that destroyed the town of Rabaul, added to PNG's problems. The monetary and fiscal crisis essentially continues up to the present with a range of measures being adopted (public sector reform, deregulation, privatisation of state-owned enterprises) to stabilise the macroeconomic situation, restore domestic and international confidence, and promote economic growth.

The policy responses of successive governments to these crises as well as other developments have led observers to suggest that poor governance remains a major impediment to development. In the meantime, development problems are accumulating. Of particular concern is the slow improvement in the nation's social indicators in comparison to most Pacific and Asian states."

The CCA suggests that inequality among provinces is worsening, an issue which is not being adequately addressed by the government.

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[7] The *Human Development Report* (UNDP, 2003) ranks PNG as 132nd of 175 countries listed (175 being the lowest), compared to 70th for Samoa, 81st for Fiji and 128th for PNG.

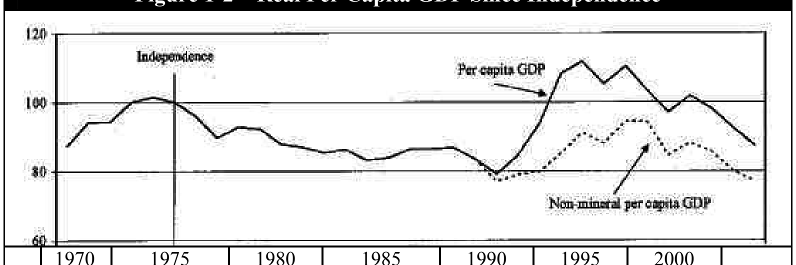
The International Monetary Fund (IMF, 2003) notes that in 2002, nearly 2,000 candidates contested 109 seats in Parliament. About 75% of incumbents, including most of cabinet, lost their seats: *"Political parties are typically formed on the basis of personal and tribal allegiances (especially to one's wantok, or extended family) rather than overriding ideological views. As a consequence, it has been difficult to undertake long-term planning."* Nonetheless, the IMF notes PNG's rich cultures, democratic heritage, independent judiciary, free press and robust civil liberties, which combined with abundant resources, provide a strong potential for future development.

1.5 Economic Overview

The ADB describes the economy of PNG as having several distinguishing features:

- Two distinct economies exist side by side – the modern, cash economy and the traditional economy. The traditional economy comprises subsistence and semi-subsistence farming, with most self-sufficient villages producing small or no surpluses for trading.
- Mining and other resource projects dominate this extremely resource-rich country. PNG has the advantage of plentiful minerals, oil, gas, timber and seafood. Mainly overseas companies develop these resources.
- The agricultural sector, which revolves around export commodities such as coffee, cocoa, tea, oil palm and copra, maintains an ongoing importance.

Figure 1-2 – Real Per Capita GDP Since Independence



Source: IMF, 2003; Note that 1975 is defined as 100

Average economic growth has been about 3% annually in real terms since 1984 (ADB, 2002) but with wide year-to-year variation. The ADB argues that the high degree of dependence on mineral resources needs to be reduced through economic diversification. Figure 1-2 illustrates that PNG's real per capita gross domestic product (GDP) was less in 2002 than at Independence. In current dollar terms GDP/capita was about US$580 in 2002. The figure also demonstrates PNG's heavy dependence on the minerals sector. Table 1-6 shows real GDP (in constant dollars of 1983 value) declining in four of the six years from 1997 to 2002. However (Figure 1-3), the Government of Papua New Guinea (GoPNG) estimated about 2% growth for 2003.

Growth is likely to continue in the short term due in part to China's rapid growth and increasing demand for PNG's minerals and timber. Reportedly (IB, 2004) China plans its first overseas mining investment, US$ 650 million in a new PNG nickel mine, with an agreement to purchase its entire output of 33,000 tonnes per year. Nonetheless, the economy faces the prospect of the depletion of known mining and oil resources within a decade, as well as continuing weaknesses in physical and social infrastructure.

The GoPNG (Figure 1-4) forecasts real economic growth of 2.8% in 2004, 1.7% in 2005, 2.1% in 2006, 1.7% in 2007 and 2.4% in 2008, an AAGR of 2.1% from 2003-2008, which is a continued decline in real GDP per capita: *"The predominant feature of the economy in these outer years is contraction in mining and petroleum production (particularly petroleum)."*

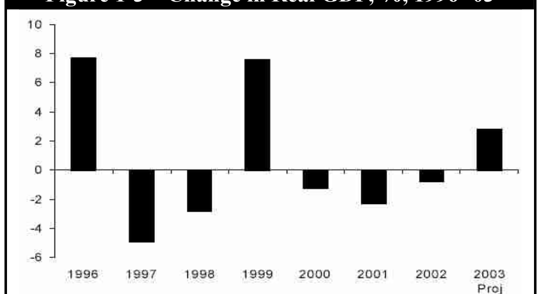
Table 1-6 – Real GDP from 1997-2002 in 1983 Kina (millions)

			——— Preliminary Estimates ———

Component	1997	1998	——— Preliminary Estimates ———			
			1999	2000	2001	2002
Real GDP	3,765	3,536	[illegible]	[illegible]	[illegible]	[illegible]
Mineral	636	743	817	784	780	705
Non-mineral	3,039	2,794	2,986	2,971	2,848	2,811
Of which: non agricultural	1,865	1,752	1,899	1,785	1,726	1,746
Agricultural, forestry, fishing	1,174	1,042	1,087	1,186	1,122	1,065
Mining and quarrying	636	743	817	784	780	705
Manufacturing	331	340	344	316	289	310
Electricity, gas and water	45	49	51	53	50	50
Construction	164	159	151	143	134	131
Wholesale and retail trade	405	396	426	368	346	339
Transport, storage and communications	187	188	192	162	172	173
Finance, insurance, real estate, business services	136	141	148	154	155	165
Less imputed bank service charges	98	101	105	108	112	116
Community, social and personal services	512	421	513	505	534	539
Import duties	146	161	181	193	155	155
Less subsidies	1	1	1	1	1	1
Annual Percentage changes:						
Real GDP	- 3.9	- 3.8	7.6	- 1.3	- 3.4	- 3.1
Mineral	- 26.0	16.8	10.0	- 4.0	- 0.6	- 9.6
Non-mineral	2.5	-8.1	6.9	- 0.5	- 4.2	- 1.3

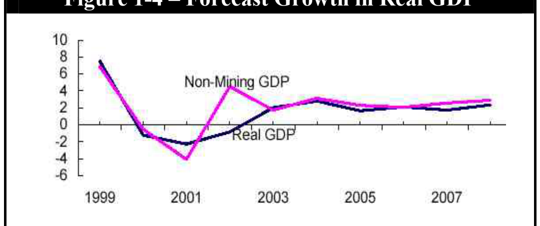
Source: PNG Country Report (IMF, 2003)

Figure 1-3 – Change in Real GDP, %, 1996-'03



Source: Treasury Economic Monitor (GoPNG; Sept '03)

Figure 1-4 – Forecast Growth in Real GDP



Source: 2004 Budget (GoPNG, Nov. 2003)

In 2002, the GoPNG announced a 'Programme for Recovery and Development' with three broad-based and interrelated objectives: i) good governance (through greater political stability, public sector reform, and enhanced transparency and accountability);ii) export-driven economic growth (focusing on agriculture, fisheries and forestry, supported by mining, petroleum, gas, manufacturing and services); and iii) rural development and poverty reduction through human resource development (provision of basic education, primary health services and infrastructure maintenance).Policy frameworks to support the recovery programme are being developed in two preliminary strategies for 2003 through 2007 completed in late 2003: i) the *Medium Term Development Strategy* for 2003-2007 (MTDS); and ii) the *Medium Term Fiscal Strategy* for 2003-2007 (MTFS), which aims at public debt reduction, reduced budget deficits with balances after 2007, and more stringent cost controls.

According to the ADB (2002), the GoPNG:

> *"has significantly improved governance. The government has i) re-established national and local planning processes, ii) strengthened public procurement processes, iii) made progress in privatising state-owned enterprises, and iv) introduced wide-ranging public sector reform. ... Although progress has been slow, the ... privatisation program [will]: i) improve service delivery and efficiency, ii)*

reduce involvement of the Government outside its core areas of competence, and iii) reduce debt. To liberalize and promote trade, the Government is implementing a seven-year program of tariff reform, with a value-added tax replacing most tariffs. The Government is also reviewing its investment and competition policies."

Table 1-7 – PNG and Regional Economic Treaties

Status	SPARTECA	PACER	PICTA
Signed	14 July 1980	05 March 2002	05 March 2002
Ratified	31 Dec 1980	05 Aug 2003	05 Aug 2003
Entered into force	01 Jan 1981	03 Oct 2002	13 April 2003

Source: Note from Pacific Islands Forum Secretariat (January 2004)

As shown in Table 1-7, the GoPNG is signatory to the three Pacific regional trade and economic agreements, the most important of which are the Pacific Island Countries Trade Agreement (PICTA) and the Pacific Agreement on Closer Economic Relations (PACER; between PICTA signatories and Australia and New Zealand). The GoPNG has also signed the Cotonou Agreement, providing membership in the African, Caribbean and Pacific (ACP) group of countries, and thus access to further development assistance from the European Union.

1.5.1 Millennium Development Goals

As noted in Section 1.4, PNG lags behind other PICs in the UNDP's Human Development Index. In September 2000, 147 countries adopted the Millennium Development Goals (MDGs), a set of targets with quantifiable indicators, now widely used to assess development progress. The Asian Development Bank (ADB, 2003) has reported on the progress of its Pacific Developing Member Countries (PDMCs) toward meeting the MDGs. For PNG, the ADB reported:

"Papua New Guinea is lagging far behind in achieving most of the Millennium Development Goals. Poverty is reported to be increasing in both urban and rural areas. Some indicators, particularly those for health, show deterioration, while in other areas, such as education and promoting gender equality, there is little or no progress towards meeting the targets by 2015. For most indicators there is a significant disparity between urban and rural areas and among islands. One of the key issues is delivery of basic social services, which often fail to reach the poorer strata of society and rural areas. Enrolment ratios at all levels and literacy are low. Papua New Guinea is also lagging behind in achieving the target of eliminating gender disparity in primary and secondary education by 2005 and in all levels of education by 2015. The gender gap is also noticeable in literacy rates. Child mortality rates remain extremely high compared to other developing countries with similar income levels. The maternal mortality rate (at least as reported) has more than doubled between 1995 and 1998. There are also indications that the country may soon face a serious HIV/AIDS epidemic. Access to safe drinking water is very low (42%) with huge discrepancies between urban (88%) and rural (32%) areas."

1.5.2 Investment climate

The ADB (*PNG Country Data*; undated) describes the commercial sector of PNG as well serviced by banks, leasing companies, accountancy and law firms and other service providers. The banks (Table 1-8) *"offer a full range of financial products and the larger accountancy and law firms are predominately subsidiaries of overseas companies."* The investment regime is described by the ADB as liberal, encouraging and welcoming foreign investment. The GoPNG *"has developed a long-term National Investment Policy, which builds on the considerable progress the government has made to curtail regulatory and administrative requirements. The NIP aims to provide the transparency, equal treatment and consistency required by foreign companies to enable them to make medium-term strategic decisions to invest in PNG. As part of its strategy to implement the policy, the government has established an Investment Promotion Authority (IPA) as a one-stop-shop facility for investment."*

The World Bank has prepared (http://rru.worldbank.org/Doing Business, undated) *"a snapshot of the business climate in Papua New Guinea by identifying specific regulations and policies that encourage or discourage investment, productivity, and growth. Key indicators are used to help measure the ease or difficulty of operating a business: starting a business, hiring and firing workers, enforcing contracts, getting credit, and closing a business. Regional and OECD averages are provided for each topic for comparison."* This is shown as Table 1-9.

Table 1-8 – Banks & Financial Institutions in PNG

Name of institution:
AGC (Pacific) Ltd
ANZ Banking Group (PNG) Ltd
Bank of Hawaii (PNG) Ltd
Bank of Papua New Guinea (BPNG)
Bank of South Pacific
Credit Corporation (PNG) Ltd
Finance Corporation Ltd (Fincorp)
First Investment Finance Limited
Kina Finance Ltd
Maybank (PNG) Ltd
Papua New Guinea Banking Corporation
Westpac Bank (PNG) Ltd

Source: ADB www.adb.org undated; Updated by John Wilmot (April 2004)

Table 1-9 – Snapshot of Business Climate in PNG

Starting a Business (2003). The challenges of launching a business in PNG are shown below through 4 measures: procedures required to establish a business, the associated time and cost, and the minimum capital requirement. Entrepreneurs can expect to go through seven steps to launch a business over 69 days on average, at a cost equal to 26.4% of gross national income (GNI) per capita.

Indicator	PNG	Regional Average	OECD Average
Number of procedures	7	8	6
Duration (days)	69	66	30
Cost (% of GNI per capita)	26.4	56.8	10.2
Min. Capital (% of GNI per capita)	0.0	646.8	61.2

Hiring and Firing Workers (2003). The flexibility or rigidity of labour regulations and laws in PNG is shown below, using three indices:: availability of part-time and fixed-term contracts, working time requirements, minimum wage laws, and minimum conditions of employment. Each index assigns values between 0 and 100, with higher values representing more rigid regulations. The overall Employment Laws Index is an average of the three indices. For PNG, the overall index is 26, compared with the regional index of 45

Indicator	PNG	Regional Average	OECD Average
Flexibility of Hiring Index	17	45	49
Conditions of Employment Index	57	60	58
Flexibility of Firing Index	4	30	28
Employment Laws Index	26	45	45

Enforcing Contracts (2003). The ease or difficulty of enforcing commercial contracts in PNG is measured using: the number of procedures counted from the moment the plaintiff files a lawsuit until actual payment, the associated time, and the cost (in court and attorney fees). An overall index of the procedural complexity of contract enforcement is calculated by averaging four sub-indices related to dispute resolution. The index varies from 0 to 100, with higher values indicating more complexity in enforcing a contract. The Procedural Complexity Index for PNG is 44, compared with the regional average of 55.

Indicator	PNG	Regional Average	OECD Average
Number of procedures	22	24	18
Duration (days)	270	193	213
Cost (% GNI per capita)	41.1	63.6	7.1
Procedural Complexity Index	44	55	49

Source: slightly edited from World Bank, undated

1.6 Institutional and Legal Arrangements for Energy

1.6.1 Institutional arrangements

Energy and minerals have accounted for over 20% of PNG's GDP in recent years and over half of exports. As oil production declines in the near future, production of natural gas will increase significantly. Unsurprisingly, oil and gas feature strongly in PNG's energy sector institutions. Although this section provides a brief overview of overall institutional arrangements, for the purposes of PIREP the emphasis is on general energy planning and policy, particularly as related to renewable energy (RE), not oil and gas. Figure 1-5 indicates the main energy sector responsibilities at national and regional government levels.

Figure 1-5 – Responsibilities for Energy Matters in PNG (January 2004)

National Level Energy Sector Responsibilities:

Department of Petroleum and Energy (DPE)		Department of Forestry (DF)	Department of National Planning and Rural Development (DNPRD)	Department of Environment and Conservation (DEC)	Independent Consumer and Competition Commission (ICCC)	Independent Public Business Corporation (IPBC)
Petroleum Division	**Energy Division**					
Oil and gas exploration and development	Energy policy, planning, data, etc.	Biomass assessment; Fuelwood	Sectoral policies; National development policies	Env. impact assessments; Environmental standards; GHGs and carbon credits	Electricity and fuel price control; Electric power licenses	Owns PNG Power (on behalf of GoPNG)

Note: Excludes some departments with energy sector responsibility such as Finance and Treasury (budgets and taxes), and several departments which deal with rural energy services for government complexes, e.g. Education, Health and Communications

Provincial and Local Energy Sector Responsibilities:

Provincial governments	Local governments
Rural energy planning and supply	Operation and management of most C-centres *

Note: * PNG Power handles rural electrification through grid extensions within 10 km of generation facilities and runs 10 rural C centres.

Figure 1-6 shows the structure of the Energy Division (ED) of the Department of Petroleum and Energy.

Figure 1-6 – Structure of the Energy Division of DPE (January 2004)

Director of Energy Division of DPE

Executive Secretary

Policy and Planning Branch

Manager of Energy Planning (vacant) *

- Executive Secretary
- Energy Planner (vacant) **
- Energy Economist
- Research Officer
- Data Entry Operator

Casual Professional staff: ***

- Petroleum/ and Gas Research Officer
- Renewable Energy Research Officer
- Electricity Research Officer
- Energy Efficiency and Labelling Res. Officer

Engineering Branch

Manager of Engineering Services

- Executive Secretary
- Principal Engineer (Alternative Energy)
  - Engineering Surveyor
- Principal Engineer (Hydro)
  - Engineering Draftsman
- Principal Engineer (Operations & Maintenance)
  - Senior Tech Officer (O&M)
- Liaison Officer

* Overseas assignment (APEC)

** Overseas postgraduate study

*** On full-time casual basis for 2-4 years

Source: Discussions with DPE (January 2004)

1.6.2 Energy Policy and Planning

The DPE's Policy and Planning Branch is responsible for developing energy policies, energy planning, data collection and analysis, and advice to the GoPNG on various energy sector issues. In practice, it concentrates primarily, although not entirely, on the electricity sector (GoPNG, 2004). At the time of the PIREP mission (January 2004), there were several vacancies in the branch and four professionals were not considered to be staff as they were on long-term casual contracts. There was also a Renewable Energy Consultant attached to the Engineering Branch, and an Australian Aid (AusAID) Energy Policy Adviser in the Policy Branch, both of whose contracts were about to end. There appeared to be very limited interaction between the Renewable Energy Research Officer and the Renewable Energy Consultant. A new and enlarged structure for the Energy Division has been proposed (GoPNG, 2004b) but is still (April 2004) under consideration. The status of energy policies is summarised later in this section.

In PNG, it is necessary to travel regularly to the provinces to obtain reasonably accurate energy data. Despite the presence of four (casual) enthusiastic and helpful research officers within the Planning Division with data collection and analysis responsibilities, extremely limited resources over a long period appear to have seriously hindered this work. As a recent DPE report notes, *"Most of the data collection in this department came to a halt in the 1980s, especially renewable energy data"* (DPE, 2004). In 1997 two extensive, and potentially very useful, national field surveys were carried out (Industrial/Commercial Energy Use Survey; Household Energy Use Survey, GoPNG, 1997) but analysis reportedly ended following the loss of computer files and the unavailability of key staff. Returns from a 2002 DPE industrial energy use postal survey (GoPNG, 2002) were very limited and returns from a 2003/2004 postal survey have been slow.

1.6.3 Environmental aspects of energy use

The Department of Environment and Conservation (DEC) is responsible for establishing environmental quality standards (and compliance with them) and environmental impact assessments. DEC is responsible for coordinating GoPNG policies on Greenhouse gas (GHG) emissions and is the focal point for accessing Global Environment Facility (GEF) and carbon credit support. It also chairs the national PIREP coordinating committee.

1.6.4 Electric power

PNG Power (PNGP)[8] is responsible for the generation, transmission and distribution of electricity throughout the country. PNGP operates three main interconnected systems: Port Moresby, Ramu (Lae-Madang-Goroka-Mount Hagen), and the Gazelle Peninsula plus nineteen smaller provincial systems. There are approximately a

[8] From 1963 until it was renamed and commercialised in 2002, the national power utility was known as ELCOM, the Electricity Commission of Papua New Guinea. PNG Power is wholly owned by the GoPNG, with all shares held by the Independent Public Business Corporation (IPBC).

hundred small rural supply systems called C-centres[9] – the number varies depending on the source – at government administration centres, electrified through isolated diesel, small hydro and occasionally solar photovoltaic systems. Responsibility for financing, managing and planning C-centres rests with provincial authorities but local governments (i.e. district or sub-district) are supposed to handle their operation and maintenance. In principle, PNG Power provides maintenance for some larger C-centres but the provinces can seldom pay for the services and many, if not most, of the systems are not operating. The Departments of Health, Education, and Communications also develop and manage small electric power systems for health centres, schools, and telecom facilities in rural areas.

Due in part to the nature of the PNG economy, with a number of large isolated enclave mines, and the rugged terrain, there are numerous large private electricity producers. In total, their installed capacity is the same order of magnitude as that of PNG Power. The electric power regulator, responsible for both licensing and setting tariffs, is the Independent Consumer and Competition Commission (ICCC).

1.6.5 Petroleum

The Petroleum Division of DPE is responsible for oil and natural gas exploration, development, with major financial issues – tax rates, incentives, etc. – being the responsibility of the Department of Finance and Treasury. The industry is predominantly controlled by foreign companies. Within PNG, the association representing oil and gas industry interests is the PNG Chamber of Mines and Petroleum. Petroleum product wholesaling and distribution is currently handled by three companies, Shell PNG Limited (Shell), Exxon-Mobil New Guinea Limited (Mobil) and BP Papua New Guinea Limited (BP) while a local company, Niugini Oil Company (NOC) based in Lae, distributes products to a small local customer base. Fuel products are to be produced locally by mid-2004, with some exports expected to neighbouring countries, from the first oil refinery ti be built in the Pacific Islands, the 36,000 barrel per day (bpd) InterOil refinery at Napanapa near Port Moresby (National, 19 January 2004).

1.6.6 Petroleum product price control [10]

The ICCC is responsible for price control (formerly the responsibility of the GoPNG's Price Controller) and consumer protection (formerly carried out by the Consumer Affairs Council). The ICCC currently regulates the maximum wholesale price of mogas (i.e. motor gasoline or petrol), diesel fuel (distillate), aviation gasoline (avgas) and kerosene imported into PNG, based on monthly submissions by the three major oil companies. The wholesale margin and prices in the four main ports (Port Moresby, Lae, Madang and Rabaul) have been set at the same level, reflecting a pricing methodology which effectively allows the oil companies to average their costs across the four main ports. Prices elsewhere are also controlled but are higher. There are also retail margins approved by the ICCC, currently mogas 8.50 toea[11] per litre, distillate 8.95 t/l and kerosene 8.82 t/l. Retail margins were last changed in April

[9] Over 30 years ago PNG electricity supply systems were apparently termed A-centres (over 1MW), B-centres (300 kW – 1 MW) and C-centres (under 300 kW) although others refer to a single A-centre (Port Moresby), about 19 B-centres for provincial capitals, and between 80 and 100+ C-centres at the district level. The term C-centre remains but the others are no longer in use.

[10] Information in this section is taken from *Petroleum Industry Pricing Review* (Draft Report of the Independent Consumer and Competition Commission; 24 March 2004).

[11] There are 100 toea (t) per Kina (K).

2001 at which time a 3.0 toea per litre increase was granted. Prior to that, the margins were last changed in December 1990.

With fuel production imminent from the InterOil refinery, the ICCC is currently considering new forms of price control or monitoring. *"The InterOil Project Agreement virtually requires the oil companies in PNG to acquire all fuel requirements from the InterOil refinery at the equivalent of internationally benchmarked import parity prices landed in PNG. For price regulation purposes, the products to be considered for the review from the refinery are unleaded petrol, diesel and kerosene. Avgas will not be produced by the Napanapa refinery at this time."* InterOil is acquiring all of Shell's PNG assets and, subject to regulatory clearance, it will acquire all the PNG assets of BP, the main supplier of crude oil to the refinery. A re-organisation of the wholesale industry in PNG, being proposed by InterOil, could offer opportunities for greater joint use of storage facilities and transport infrastructure, particularly for outer locations. As a result of these changes, the impact of a contractually-binding notional allowance for the shipments of crude oil from Singapore on the cost of freight from Napanapa to other main ports, demands for retailers for a higher retail margin, and some outdated elements of the price control system, the ICCC has made 16 tentative recommendations including:

- mogas, diesel and kerosene produced by the refinery are to be subject to price monitoring;
- there will continue to be some form of wholesale/distribution margin in the *'main ports and all 'outer locations'*;
- mogas, diesel, kerosene and avgas will continue to be subject to some form of price control and there may be regulation of marine fuel in outer ports; and
- subject to further review, there will be an average retail margin of 11.5 t/l for mogas, diesel and kerosene.

In effect, it seems that product prices are likely to remain the same at the four main ports, effectively a cross-subsidy from Port Moresby to other ports, which could potentially disadvantage the viability of renewable energy systems near these ports.

PNG imposes an excise tax of 61 toea per litre for mogas, 2 t/l for avgas, and 6t//l for distillate. For commercial fishing, the excise tax on distillate has been reduced to 3 t/l since 1998, although the Customs Tariff Act was only amended to reflect this in 2004 (2004 Budget; GoPNG).

1.7 Policies and Laws Regarding Energy

This section deals with broad policies and laws regarding energy but excludes petroleum/gas issues, which are not within the areas of emphasis of the PREP studies.

1.7.1 Energy policies

There are several activities underway in early 2004 within PNG assessing, or touching on, energy-related policy issues: an AusAid-funded *Energy Policy Review Project*;[12] assistance from the World Bank's (WB's) Gas Technical Assistance Facility to build the capacity of DPE's Petroleum Division; the WB's *Rural Electrification Policy and*

[12] This project has produced two papers in January 2004 by AusAID's PNG energy policy adviser, Dr Harry Zevon (who has since departed): i) *Issues Paper: Energy Sector Review*; and ii) *Five-Year Strategic Plan for Department of Petroleum and Energy: 2004-2008*.

Strategy to Improve Energy Access for Rural Services Delivery;[13] and the ICCC's current review of petroleum product pricing. Accordingly, some policies may well change in the near future.

The most recent policy documents are a draft *National Energy Policy Statement* (GoPNG, 2001) and *National Energy Policy Guidelines of 2001* (GoPNG, 2001a), which have no apparent formal status. Within them, the Energy Division has been allocated a number of responsibilities including the following:

- monitor, review and provide recommendations on fuel pricing, electricity tariffs, and government charges and subsidies, to ensure that the full and correct price signals are conveyed to consumers wherever possible;
- develop and maintain the capacity to monitor and evaluate the equivalent landed price of petroleum products, the petroleum company cost elements, the pricing formula, and government charges so as to negotiate and maintain equitable pricing;
- forecast future energy trends including opportunities for the development of alternative energy sources; and
- develop a rural electrification policy, recognising the role of private enterprise in rural electricity supply.

However, according to DPE (GoPNG, 2004), power sector planning is essentially carried out by PNG Power. DPE's Energy Policy and Planning Branch *"does not independently undertake research to collect and analyse energy data to complement or corroborate PNG Power's work. In its current state, [it] does very little to assist energy planning. The capacity to plan and undertake surveys, and to analyse data collected is woefully limited."*

Rural electrification policy guidelines were developed in 1993 (GoPNG, 1993) to address a number of issues including the low rate of rural electrification (under 10% of households), high costs and high government subsidies to C-centres (over K500 per consumer annually), exorbitant costs of grid connections through ELCOM, and the relative effectiveness of electrification at mission stations compared to GoPNG initiatives. The guidelines advocated decentralised diesel or petrol generators, micro-mini hydro systems where feasible, and solar photovoltaics (PV). A more recent draft *National Rural Electrification Policy* (GoPNG, 2001c) noted that rural electrification was a national priority under the GoPNG's development strategy and structural adjustment programme. The draft proposed, among other initiatives: i) a multi-stakeholder approach; ii) priority for renewable energy sources as the preferred option; iii) an incremental approach including demonstration projects and training rural people to operate and manage decentralised rural electrification projects; and iv) priority to community services, in particular education and health.

Despite these initiatives, DPE (GoPNG, 2004) notes that rural electrification remains *ad hoc* and the C-centres are performing very poorly. The Energy Division of DPE has developed a draft strategic plan for the period 2004-2008 (GoPNG, 2004b) which reintroduces two of the recommendations that were not acted upon in 1993 (or later when again proposed in 1999 and 2001), creation of a Rural Electrification Authority and enactment of enabling legislation for rural electrification. The strategic plan has a

[13] According to the World Bank's Country Manager for PNG (Maresh Sharma, January 2004), the project has nearly completed a *PNG Energy Sector and Rural Electrification Background Note*.

‘vision’, ‘mission statement’, and five tentative priority areas during the five-year period, possibly to be modified within a planned *Government White Paper on Energy* or new energy policies):

- systematic energy market reform and restructuring;
- research and information-based energy policy planning and programme co-ordination;
- an equitable and nationally coordinated rural electrification programme;
- active renewable energy development and promotion; and
- a dedicated and sustainable pooled Rural Energy Fund, with a robust governance system for oversight, funding and management of a national rural electrification programme.

1.7.2 Legislation

There are several Acts of the Parliament of Papua New Guinea that deal directly or indirectly with energy issues. These are briefly discussed below.

- *Electricity Supply (Government Power Stations) Act, 1970* (revised 1973 and 2002). The Act deals with the powers of the minister responsible for energy regarding generation, supply and extension of electricity from government power stations (which are not defined) but which DPE understands as “diesel generation assets, mini-hydro schemes and solar and wind energy facilities constructed with national Government funds together with PNG Power’s electricity generation assets”, which may conflict with the Organic Law (discussed below).
- *Electricity Industry Act of 2002.* Formerly the ELCOM Act, this spells out the functions and powers of the Electricity Commission (now PNG Power Ltd) to *“plan and coordinate the supply of electricity throughout the country and determine the standards and inspect and control the application of all matters relating to the operations of the supply of electricity.”*
- *Independent Consumer and Competition Act of 2002.* Under this Act, its 2003 regulations, and the Electricity Industry Act, the ICCC has granted PNG Power a contract fixing electricity tariffs under a formula. The formula for tariff adjustments includes changes in the consumer price index, the Kina/A$ exchange rate, fuel prices, and certain PNG Power capital investments. Under the Act, ICCC is also responsible for safety standards and technical regulation but has delegated technical regulation to PNG Power for a two-year period from 2004 (GoPNG, 2004). Finally, ICCC has granted PNG Power a series of four exclusive licenses for a 12 year period allowing PNG Power to: i) generate electricity; ii) transmit it through the Moresby, Gazelle and Ramu grids; iii) distribute electricity through existing networks and connect premises with 10 km of the networks; and iv) retail electricity to consumers at premises (with exclusive rights limited to demand of less than 10 MW). There is also an ICCC (Oil Refining Facility State Agreement Exception) Regulation of 2003 regarding pricing issues for the new refinery.
- *Independent Public Business Corporation of Papua New Guinea Act (2002).* Under this Act, the Independent Public Business Corporation holds all shares of PNG Power on behalf of the GoPNG.

- *Organic Law on Provincial Government and Local Level Government* (*1995*). The Organic Law grants authority to the 19 provincial governments and 299 local (district/sub-district) governments to pass laws and develop regulations for electricity generation and distribution in their areas of jurisdiction. Under the Law, responsibility for C-centre management and maintenance was transferred to provincial and local level government.
- *Community Services Trust Act* (2002). Under community service obligation (CSO) requirements of this Act, providers of essential community services are required to supply their services at subsidised rates to rural or low-income populations. For example, diesel fuel may be subsidised for electricity generation in C-centres or for use in farm equipment (GoPNG, 2004). There is currently no CSO affecting any electricity provider, whether PNG Power or private. However, this could be imposed in the future.
- *Environmental Act* (2000). The Environment Act, number 64, 2000 came into effect in January 2004. It provides for 'general environmental duty', under which activities causing or likely to cause an environmental harm are prohibited unless all reasonable and practical measures have been taken to minimise harm. Activities are divided into levels 1, 2 and 3. Level 2 activities require permits or plans and may require an environmental impact assessment (EIA). Under Schedule 1 of the Act, Level 2 activities include: i) operation of hydroelectric plants exceeding 2 MW, ii) operation of fuel burning plants exceeding 5 MW, iii) operation of fuel burning facilities such as boilers and furnaces above 20 MW of thermal output; iv) incineration plants exceeding 10 tonnes per year capacity; v) any damming of a river or stream, and vi) electricity transmission lines exceeding 10 km in length. Level 3 activities involve 'matters of national importance' or could have a serious environmental impact and require EIA. These include: i) any project exceeding K50 million in cost; ii) petroleum or gas production and processing; and iii) any hydro reservoir greater than 5 km^2 in area.

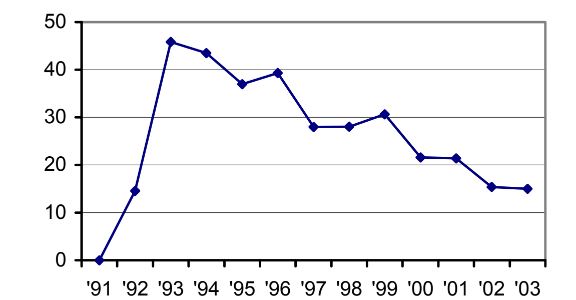
2.1 Energy Supply

Papua New Guinea is the only PIC that produces crude oil and, in 2004, will refine oil products for the local market and export. This section touches briefly on local oil and gas supply and the biomass resource.

2.1.1 Petroleum and gas

Since light crude oil production began in 1992, PNG has exported[14] about 340 million barrels (Figure 2-1), roughly 100,000 bbl/day on average, from an estimated recoverable reserve of 550 million barrels. Exports in 2003 were 15.0 million barrels (worth K1.63 billion in export earnings), a decline of 2.5% by volume from 2002 but an increase of 14% in value due to higher oil prices. It is expected that production will steadily decrease until about 2015 when the resource will be depleted.

Figure 2-1 – PNG's Crude Oil Exports, 1992-2003



Source: Bank of PNG, 2004 (million barrels per day)

The WB (2000) and APEC (2003) have estimated PNG's gas resource at about 400 billion m^3, equivalent to about 2700 million barrels of oil, more than ten times the remaining recoverable oil reserves of 200-250 million barrels. This is believed to be an underestimate[15] but, in any case, PNG's natural gas resource dwarves petroleum, which has itself contributed up to 30% of PNG's export earnings. PNG is investing about US$4.5 billion in the 'Gas to Queensland Project', which will require construction of a pipeline through rugged parts of PNG and under the sea to Australia and is expected to bring over US$11 billion in export earnings over 28 years (GoPNG, 2004). The upper part of Figure 2-2 shows actual and potential oil and gas projects in PNG, all of which are in the remote western part of the mainland.

2.1.2 Petroleum fuel products

PNG imported about 6700 million litres (ML) of refined petroleum products in 2000 (Table 2-1). In 2003, the approximate wholesale market share of each marketing company was Shell 43%, Mobil 33%, BP 20% and NOC 4%, the last only in the vicinity of Lae (ICCC, 2004).[16] Approximately 160 retailers operating throughout PNG retail petroleum products. As noted in Section 1.6, the market is in the midst of restructuring and a 35,000 to 40,000 barrel-per-day refinery will produce most products by mid 2004, at least for a decade or so.

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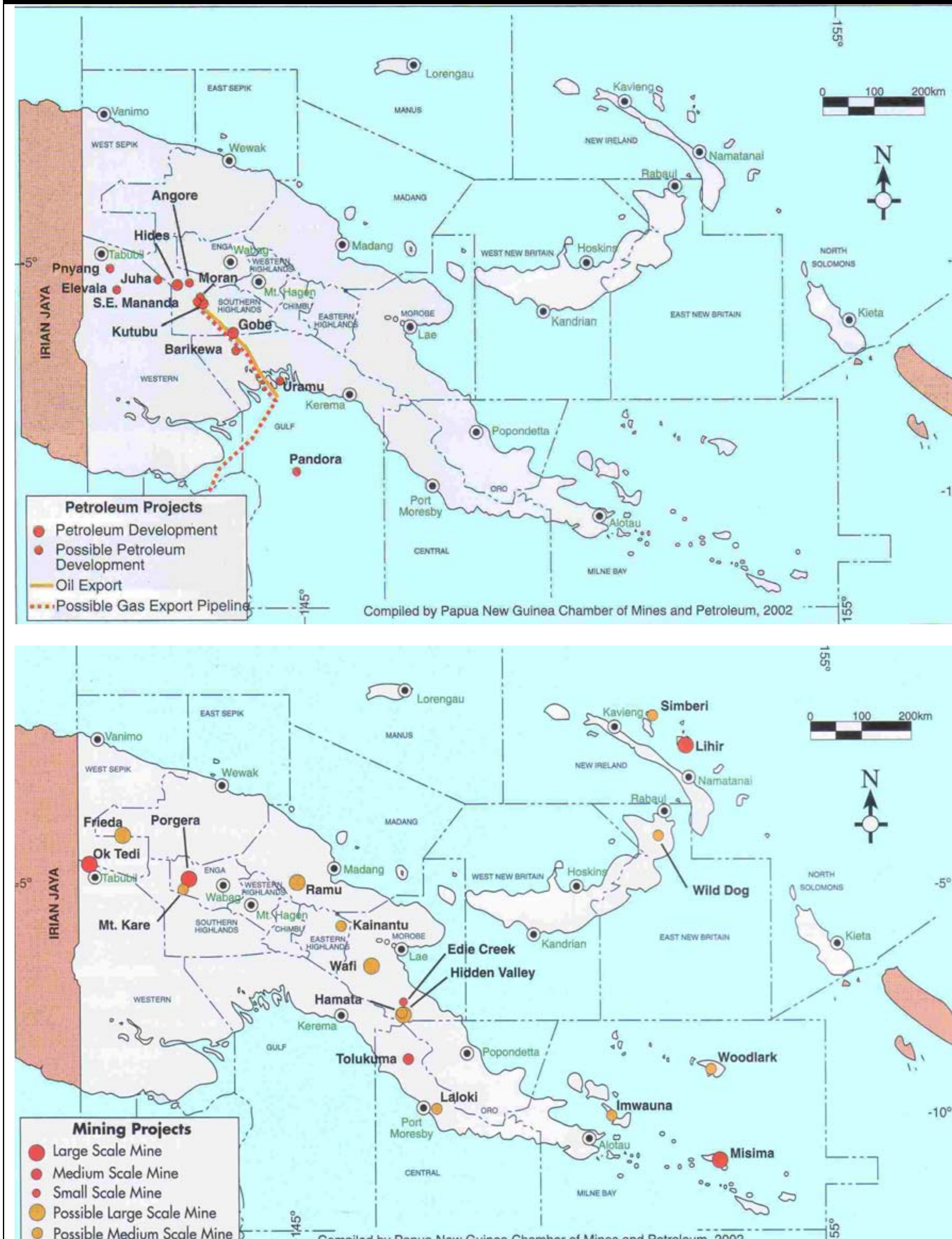
[14] The mission does not have production data for the entire period. According to The Asia-Pacific Economic Cooperation (APEC) Energy Data and Modelling Centre website www.ieej.or.jp/egeda/database, from January 2001 through October 2003, 84% of PNG's crude oil production was exported.

[15] More recent estimates (GoPNG, 2004) suggest that there are about 25 trillion cubic feet (700 billion m^3) of natural gas, about 4,500 million barrels of oil equivalent.

[16] This is very close to the 1990 market share: Shell 42%, Mobil 38% and BP 20% (PREA, WB, 1992).

Figure 2-2 – Maps of Mining and Petroleum Projects in Papua New Guinea



Source: *Profile of Mining and Petroleum in PNG* (PNG Chamber of Mines and Petroleum, 2002)

There are only limited data available on petroleum fuel imports to PNG in the past decade (Table 2-1) and even these are inaccurate.[17] From 1997 – 2000, PNG imported about 6,560 million litres of fuel per year, but this is only indicative and is not used in later analysis.

Table 2-1 – Petroleum Fuel Imports to Papua New Guinea, 1990 – 2002 (millions of litres)

Fuel	1993	1994	1995	1996	1997	1998	1999	2000	2001
Motor Spirit					58.854	70.54	50.946	4.91	
Aviation Gasoline					4.753	8.29	5.97	1.69	
Jet fuel (Jet A1)					53.42	53.802	54.49	28.51	
Kerosene					11.67	10.41	4.88	9.49	
Distillate Fuel *					275.25	290.17	342.12	672.27	
Heavy fuel oil					37.83	31.71	87.49	50.96	
LP Gas	11.26	9.36	12.49	11.43	14.33	11.90	18.21	11.88	10.56
Other					0.04	0.5	0.02	0.04	
Total (ML)					*6,446*	*6,468*	*6,556*	*6,773*	

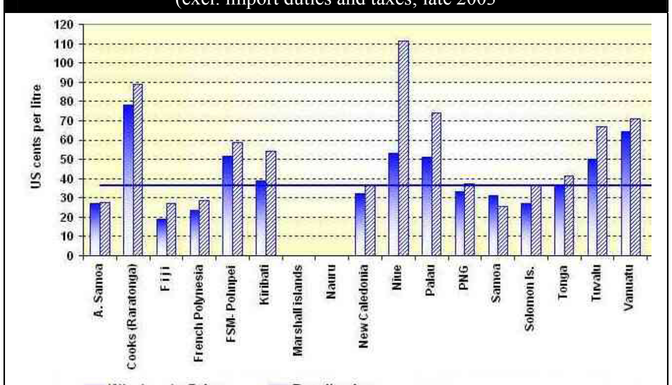
Sources: Customs Dept (provided by J Wilmot, April 2004) except Liquid Petroleum Gas (LPG) is imports from DPE (2004) survey. Totals are rounded off

Recent wholesale prices of gasoline and distillate (i.e. automotive diesel oil, ADO; excluding taxes and duties) are shown in Figure 2-3. Prices in Port Moresby are slightly lower than the PIC average for ADO and somewhat cheaper for gasoline. For kerosene (Figure 2-4), retail prices (again, free of taxes and duties) are average for the region but wholesale prices are below average, suggesting a high mark-up relative to other Pacific island countries.

Figure 2-3 – PIC Wholesale Petroleum Fuel Prices
(excluding import duties and taxes; late 2003)

Source: Pacific Fuel Price Monitor, Edition 6 (PIFS; 25 Feb. 2004)

Figure 2-4 – Wholesale and Retail Kerosene Prices
(excl. import duties and taxes; late 2003



Source: *Pacific Fuel Price Monitor, Edition 6* (PIFS; 25 Feb. 2004)
Note: solid line is average wholesale price)

2.1.3 Commercial energy balance

Table 2-2 provides an energy balance for commercially traded energy in PNG during 2001, prepared by the Asia-Pacific Economic Cooperation (APEC) Energy Data and Modelling Centre, with a

[17] Data from Customs Department are inconsistent. The row in Table 2-1 marked 'Motor Spirit' is listed by Customs as 'Motor spirit (gas) including aviation spirit', The other products may be OK except the row marked 'Distillate fuel' is called 'Spirit type (gasoline) Jet fuel' by Customs, which is bizarre.

summary in Table 2-3.

According to APEC, net primary energy supply was 573 thousand tonnes of oil equivalent (ktoe), down 42.5% from 2000. Light crude oil and petroleum accounted for 61% of the total, gas for 25% and hydro 14%. About 79% of indigenous energy production was exported. The natural gas produced in 2001 (144 ktoe) was used for electricity production at a large gold mine at Porgera (see Figure 2-2).

Table 2-2 – Papua New Guinea Commercial Energy Balance for 2001 (KTOE)

Indicator	Crude Oil	Petroleum Products	Mogas	Jet Fuel	Kero	Diesel Oil	Fuel Oil	LPG	Natural Gas	Hydro	Electricity	Total
Indigenous Production	2532	-	-	-	-	-	-	-	144	80	-	2756
Import	-	349	20	29	17	1	264	11	-	-	-	349
Export	-2477	-	-	-	-	-	-	-	-	-	-	-2477
Stock Change	-55	-	-	-	-	-	-	-	-	-	-	-55
Total Primary Energy Supply	-	349	20	29	17	1	264	11	144	80	-	573
Public Electricity	-	-33	-	-	-	-	-33	-	-	-47	96	16
Auto producers (Electricity)	-	-169	-	-	-	-	-169	-	-137	-33	131	-208
Loss and Own Use	-	-	-	-	-	-	-	-	-	-	-14	-14
Discrepancy	-	-	-	-	-	-	-	-	-	-	5	-2
Total Final Energy Consumption	-	147	20	29	17	1	62	11	-	-	217	364
Industry Sector	-	58	-	-	-	0	49	9	-	-	160	218
Transport Sector	-	61	20	29	-	0	12	-	-	-	-	61
Other Sector	-	19	-	-	17	0	-	2	-	-	58	77
Agriculture	-	0	-	-	-	0	-	-	-	-	-	0
Residential & Commercial	-	19	-	-	17	0	-	2	-	-	58	77
Non-energy	-	9	-	-	-	-	-	-	-	-	-	9

Source: Adapted from APEC Energy Data and Modelling Centre (Institute of Energy Economics) database: www.ieej.or.jp/egeda/database

Table 2-3 – Papua New Guinea's Commercial Energy Supply and Consumption, 2001

Primary Energy Supply	ktoe	%	Final Energy Consumption	ktoe	%	Electricity Generation	GWh	%
Indigenous production	2,756	-	Industry Sector	218	60	Total	2,638	100
Net imports and other	-2,184	-	Transport Sector	61	17	Thermal	1,708	65
Total	573	100	Other Sectors	86	24	Hydro	930	35
Oil	349	61	Total	364	100	Other	-	
Gas	144	25	Coal	-				
Other	80	14	Oil	147	40			
			Gas	-				
			Electr & other	217	60			

Source: Modified from *Energy Overview for Papua New Guinea* (APEC, 2003). Totals may ≠100% due to rounding errors

In 2001, installed electric power capacity was 451 MW and generation was 2,638 GWh, nearly double the 2000 output of 1,348 GWh, due to dramatic variation of demand in the mining sector. Hydro provided 35% of generation and thermal 65%, of which natural gas accounted for about 26% and oil thirty nine percent.

2.1.4 Non-commercial energy

In 1990, the PREA (WB, et. al., 1992) estimated that biomass accounted for 693.3 ktoe of gross energy production (and end-use consumption) in PNG as follows: fuelwood, mainly for household use, 540.6 ktoe; agricultural residue, three-fourths for agriculture and the rest for industry and household use, 149.5 ktoe; and ethanol from the sugar industry 3.2 ktoe. Solar energy for water heating and small-scale electricity production was estimated to provide 28 ktoe.

There are no reliable measurements of current non-commercial energy use in PNG. However, the PIREP mission has estimated (see Section 4.6) that about 1,000 ktoe of wood is used for cooking and a small amount of agricultural processing.

2.2 Energy Demand

In 2001, the end use consumption of commercial energy (Table 2-3) was 364 ktoe, a decrease of 58% compared to 2000. Of the total, industry accounted for 60%, transport 17% and agriculture / residential / commercial, 24%. Petroleum accounted for 40% of consumption and other energy forms (mainly electricity) sixty percent.

There are no recent estimates of household energy use in PNG. Results of a 1996 survey of 22,156 households (about 2% of all households) are summarised in Tables 2-4 and 2-5, which show the main energy source or fuel used. Of those households surveyed nationally, 12% had electricity and essentially all electrified households had electric lighting. Fewer than 9% had either a refrigerator or television. Well over half used inefficient non-pressurised kerosene lamps as their main source of light and fully a quarter relied on an open fire for light. Over 87% cooked mainly with fuelwood and 3% each used LPG or electricity. For the Port Moresby area, i.e. the highly urbanised National Capital District, 77% of households were electrified,[18] 67% had refrigerators and 61% had television. As Table 2-6 shows, over 75% used electric lighting, nearly 40% cooked with kerosene and, surprisingly, nearly 30% reportedly cooked mainly with electricity.

Table 2-4 – National Household Energy Use in 1996/1997

Energy for Lighting	%	Fuel for Cooking	%
Electricity	11.8	Electricity	3.3
Pressure lamp	3.6	LP Gas	2.8
Kerosene lamp	56.7	Kerosene	6.5
Candles	0.3	Charcoal	0.1
Open fire	25.6	Fuel wood	87.1
Other	2.1	Other	0.3
Total	*100*		*100*

Source: Demographic & Health Survey, June 1996 - July 1997 (GoPNG, 1997a)

Table 2-5 – Port Moresby Household Energy Use in 1996/1997

Energy for Lighting	%	Fuel for Cooking	%
Electricity	75.8	Electricity	28.9
Pressure lamp	3.6	LP Gas	18.7
Kerosene lamp	18.0	Kerosene	38.9
Candles	2.1	Charcoal	0
Open fire	0	Fuel wood	13.5
Other	0.6	Other	0.1
Total	*100*		*100*

Source: as for Table 2-4

[18] Data available from PNG Power (2003) suggest about a 63% electrification rate for the NCD so the survey results should be considered approximate only.

2.2.1 Electricity

The mission did not investigate the electric power sector in any depth, did not visit any industrial /mining enclaves, and did not assess any C-centres. The information in this section is indicative only, but does illustrate the huge size and diversity of the PNG power sector compared to other PICs. In 2001 (Table 2-6), there was roughly 600 MW of installed capacity generating about 2,600 GWh of electricity.

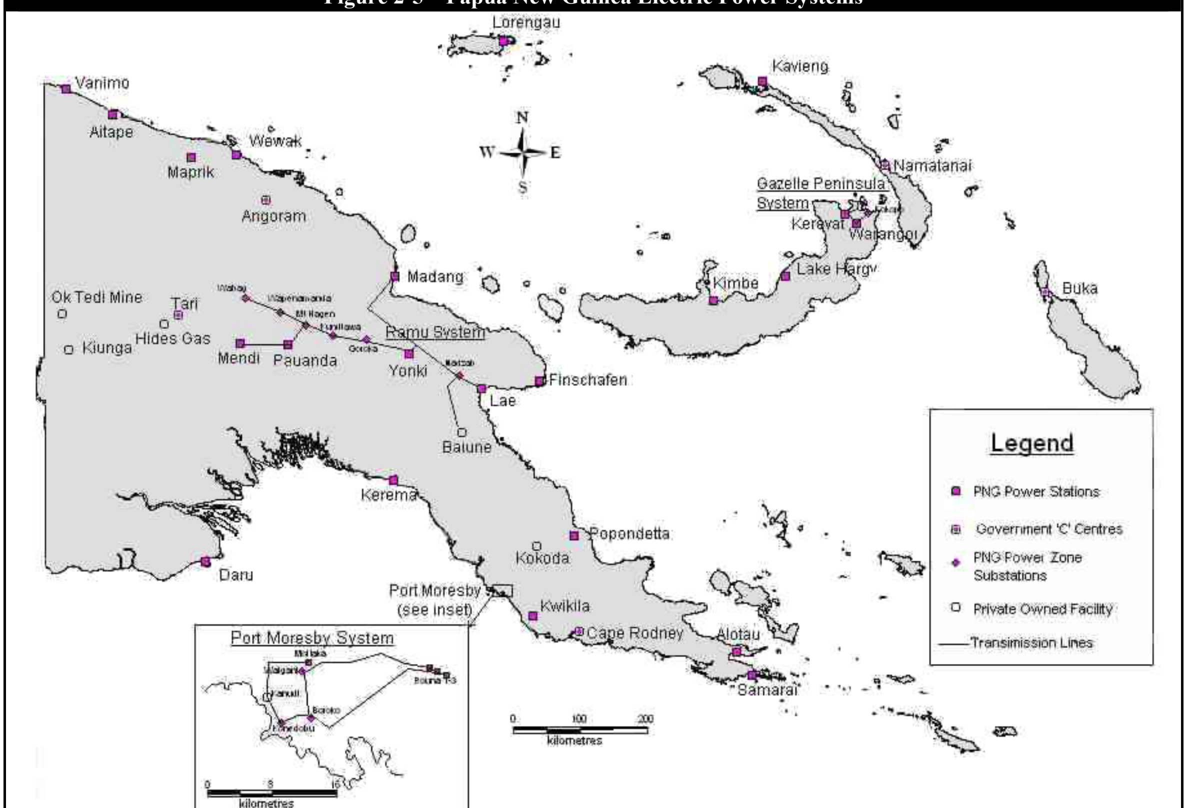
Table 2-6 – Overview of PNG Electric Power Sector (2001)

Component	Installed Capacity (MW) [1]	Generation (GWh / yr)
PNG Power (PNGP)	302 [1]	665 [2]
Hanjung-Kanudi sales to PNGP	24 [2]	105 [2]
Mining & Industry self-generation	280 [1]	1,200 [3]
C-centres	~ 7	??
Individuals, church missions, other	??	??
Approximate total	*614*	*2,638* [4]

Sources: 1) Issues Paper: Energy Sector Review (DPE, GoPNG, 2004)
2) PNG Power (2003
3) PIREP mission estimates
4) APEC 2003 (which, however, reports 451 MW capacity)
Note: ~ = approximately

PNG Power has over 73,000 customers (2002), and provides electricity to the Port Moresby area and nineteen provincial capitals. As shown in Figure 2-5, it operates three interconnected grid systems (Port Moresby and Ramu on the mainland; and the Gazelle peninsula in East New Britain) in addition to 17 smaller systems.

Figure 2-5 – Papua New Guinea Electric Power Systems



Source: *Ten Year Development Plan* (PNG Power, 2003)

About half of the PNG power capacity is thermal and half hydro, the main hydro systems being: i) Ramu (Yonki) in the Eastern Highlands, which supplies the highlands and Morobe and Madang provinces; ii) Laloki (Rouna) in Central Province, supplying the Port Moresby area; and Warangoi in the Gazelle Peninsula.

82% of PNG Power's customers are domestic but they accounted for only 11% of sales in 2002, using an average of 166 kWh per month (Table 2-7) or somewhat less, 123 kWh/m, if Port Moresby and Lae are excluded.

Table 2-7 – PNG Household Electricity Use, 2002			
Province	**Location**	**Domestic customers**	**kWh per m**
NCC/Central	Port Moresby	26,509	201
Western	Daru	554	148
Gulf	Kerema	383	133
Milne Bay	Alotau	817	207
	Samarai	70	80
Oro	Popendetta	772	128
S Highlands	Mendi	829	146
Enga	Wabang/Wape	1,037	69
	Porgera	367	1
W Highlands	Mt Hagen	4,670	92
Chimbu	Kundiawa	1,265	79
E Highlands	Goroka	2,759	134
	Kainantu	1,112	113
	Yonki	259	n/a
Morobe	Lae	6,534	198
	Wau	305	161
Madang	Madang	2,667	160
	Gusap	39	141
East Sepic	Wewak	1,519	140
	Maprik	405	74
Sandaun	Vanimo	561	182
	Aitape	210	115
New Ireland	Kavieng	772	146
E New Britain	Gazelle	4,084	123
W New Britain	Kimbe	1,190	163
	Biala	314	126
Total		60,003	166
Total excluding PM & Lae		26,960	123

Source: calculated from data in PNG Power (2003)

It is not possible to calculate the percentage of households in PNG with access to electricity due to large numbers of individual generators and the electrification of houses near mining enclaves (Figure 2-2). However, in 2002, PNG Power supplied electricity to about 5.5% of households nationally,[19] nearly all customers urban or peri-urban, and 55% being in the NCD or Lae. It is likely that well under 10% of the total PNG population, and perhaps 5% of the rural population, are electrified by all means: grid, self-generation, nearby industry, small hydro or solar.

PNG Power expects its sales to grow from 660 GWh in 2003 to 766 GWh in 2012 (Table 2-8), an AAGR of 1.7%, slightly less than the 1993-2002 growth rate of 1.8%. Aggregate peak demand is expected to increase during the same period from 152 MW to 173 MW, an AAGR of 1.4%. Customer numbers are forecast to grow more rapidly, from 75,557 (2003 estimate) to 102,085, an AAGR of 3.4%, somewhat faster than expected population growth.

Table 2-8 – PNG Power Maximum Demand, Sales and Forecasts				
System	**Energy Sales (GWh)**		**Maximum Demand (MW)**	
	2003	**2012**	**2003**	**2012**
Port Moresby / NCD	331.7	338.0	76.5	88.3
Ramu	234.3	271.9	53.3	58.3
Gazelle	29.0	33.5	6.7	7.7
Other provincial	65.1	122.8	15.9	18.8
Total	*2,663*	*2,778*	*2,155*	*2,185*

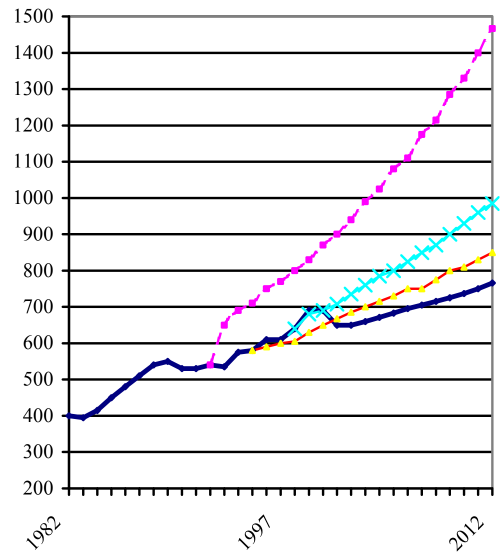
Source: PNG Power, 2003 Totals are rounded off

[19] This assumes 60,000 PNG domestic customers in 2002 and the total number of households grew from 1,008,969 by 2.7% annually from 2000-2002.

The sales forecast of Table 2-8 is illustrated in Figure 2-6 (bottom thick blue line) along with several earlier ELCOM forecasts of growth. Actual growth since 1982 has been irregular and earlier forecasts have tended to be optimistic. This is not meant to suggest that the latest forecast is too high, merely that estimating growth in a complex system like that of PNG is quite difficult.

PNG Power's generation by source is summarised in Table 2-9. Assuming that all purchases are from thermal facilities, the percentage of generation from hydro is expected to steadily drop.

Figure 2-6 – PNG Power Historic Growth and Various Forecasts (Sales in GWh)



Source: Adapted from PNG Power (2003)

Table 2-9 – PNG Power Generation by Source (GWh)

Year	Hydro	Heavy diesel	Light diesel	Gas turbine	Power Purchase	Total	% hydro	System losses
1993	428	64	78	44	4	624	69 %	13.6 %
2002	513	0	99	14	156	781	66 %	16.9 %
2007	506	0	176	1	157	839	60 %	16.0 %
2012	522	0	222	1	157	901	58 %	15.0 %

Source: PNG Power (2003) Note: GWh rounded to nearest whole number

ELCOM/PNG Power has been under financial distress for some years, and has been unable to undertake sufficient new investment for either expansion or adequate maintenance. One result has been high (and growing) system losses, a substantial amount of generating plant derated, frequent equipment breakdowns, and power outages (GoPNG, 2004). PNG Power, as a commercialised utility with financial problems – and one which may be privatised – is understandably reluctant to undertake rural electrification in unprofitable areas, i.e. most of rural Papua New Guinea.

PNG Power has a complicated tariff structure summarised in Table 2-10. Easipay is a pay-in-advance metering system, which accounted in 2003 for about a third of domestic consumption. In early 2004, domestic credit customers pay a minimum charge of K7 per month, domestic Easipay consumers a minimum of K9/m, and general credit consumers K10/m. Charges have increased considerably since 2000. Domestic consumption above 30 kWh per month has increased by 86% in the past four years. Even before the most recent increases, the ADB (2003) notes that PNG's electricity prices are three times higher than those of neighbouring Indonesia (and labour costs four times higher and urban rents 10 times higher). Charges are, however, not unusually high for the PIC region.

Date	Domestic **			General		Industrial		
	Credit ≤ 30 KWh t / kWh	Credit > 30 KWh t / kWh	Easipay t / kWh	Credit t / kWh	Easipay t / kWh	toea per kWh	Demand Kina / KVA per month	Minimum Kina per KVA
2000	14.89	21.43	17.87	27.86	27.18	14.81	?	200
Jan 2003	19.66	32.52	27.13	41.82	40.80	22.78	24.42	200
Aug 2003	22.12	36.59	30.52	47.05	45.90	25.63	27.47	200
Jan 2004	24.13	39.92	33.30	51.33	50.08	27.96	29.97	200

Table 2-10 – PNG Power Tariff Structure, 2000 – January 2004 *

Source: PNG Power, 2004
Notes: * Includes VAT/GST of 10% through 2003 & 12% from January 2004
** For domestic credit consumers, there is a lifeline tariff for the first 30 kWh/month of consumption.

2.3 Future Commercial Energy Demand and GHG Reductions

In a relatively small economy dominated by minerals, oil and gas, accurately projecting future patterns of energy demand is difficult. A single mine closure or opening, a new oil discovery, or changes in natural gas prices can have a huge and immediate impact (as evidenced by a doubling of electricity generation between 2000 and 2001). In Section 1.2 it was noted that PNG's population is likely to grow at an AAGR of about 2.7 percent. Section 1.5 showed the highly variable pattern of past economic growth since Independence, with long term real GDP growth from 1975 through 2002 being less than population growth. It is assumed for the purposes of this study that real economic growth over the next 10-15 years will continue at about the same rate as population growth. PNG Power expects growth in generation to be considerably less than this, only 1.7% per annum, but the Gas to Queensland project and renewed exploration suggest that private industrial power growth could be more robust. Table 2-3 showed the extent to which industry dominates the economy in terms of final energy consumption, 60% of the total compared to 17% for transport and 24% for other (i.e.agriculture, government, households, and commerce.) Accordingly, and considering the paucity of information, no attempt is made to project different growth rates for different economic sectors. PIREP is forecasting economic growth at 2.7% per year, and growth in energy use at 3.0% annually, in order to estimate opportunities for replacing fossil fuels with renewable energy, and thus reduce greenhouse gas (GHG) emissions. For this purpose, it is first assumed as a 'baseline' or business-as-usual case that all growth in commercial energy use is from fossil fuels, in PNG's case, oil and natural gas.

According to PNG's initial communication to the UNFCCC (GoPNG, 2000), in 1994, PNG emitted 947.57 gigagrammes (Gg) of CO_2 from petroleum fuels.[20] Table 2-11 provides estimates of commercial energy use and GHG emissions in 2001 (1,470 Gg) and provides baseline estimates for 2016 (2,423 Gg). Assuming commercial energy growth of 3% annually, PNG's GHG emissions from energy use would grow about 3.4% annually. This would not change significantly if different assumptions were made about the relative contributions of petroleum fuels and natural gas.

[20] The report notes that PNG slightly modified the UNFCCC methodology but says this had little effect on the results. The volumes of fuel are not given but the report says that 61% was from diesel fuel, 15% from gasoline, 13% from kerosene, 11% from other oils and less than 1% from LPG. Jet fuel treated as a re-export, was not included.

Table 2-11 – Commercial Energy Demand and GHG Emissions, 2001 and projected for 2011							
Product	2001			2011			
	Actual Use (ktoe)	Share (%)	GHGs (Gg)	Projected Use (ktoe)	Share (%)	AAGR (%)	GHGs (Gg)
Petroleum products	349	61%	1,040.7	478	62	3.2%	1426.0
Natural gas	144	25%	429.4	211	27	3.9%	629.5
Hydro	80	14%	0	80	< 11	0	0
Total	*573*	*100%*	*1,470*	*769*	*100%*	*3.0*	*2055.5*

Source: 2001 use (consumption) from Tables 2.2 and 2.3 based on APC (2003).
Notes: 1) CO_2-equivalent emissions from Annex 2, petroleum fuels averaging 70 kg of CO_2/GJ; natural gas 50 kg/GJ.
2) This estimate does not take into account additional CO_2 emissions from the refinery or from gas production.

As discussed in the next chapter, PNG has tremendous potential for further commercial energy production from renewable indigenous resources, including hydropower development, biofuels and geothermal. Ignoring promising technologies that are very unlikely to be commercialised within the next decade or so (such as seawave or ocean thermal energy), Table 2-12 provides very rough, indicative, order-of-magnitude estimates of the potential from renewable resources and their associated GHG reductions.

Table 2-12 – Indicative Maximum Energy Savings and GHG Savings from Renewable Energy and Energy Efficiency in PNG, 2011

Technology	Potential fuel or energy savings	GHG savings (Gg)	% of savings	Comments
Hydro (> 10 MW) [1]	196 ML of fuel oil	666		Increase from 220 MW to 400 MW of hydro
Hydro (0.1-10 MW [2]	4.8 ML of diesel	13		6 MW of small hydro
Hydro (< 100 kW) [3]	4.6 ML of diesel	12		500 new systems, average of 22 kW
Geothermal [4]	98 ML of fuel oil	333		100 MW at mines
Biodiesel [5]	42 ML of diesel	113		10% of vegetable oil production as fuel
Fuel ethanol [6]	175 ML of petrol	430		Less than potential from E Sepik & Purari Basin
Other biomass [7]	~12,000 m^3 wood	minor		Very limited if most logs exported unprocessed
Solar PV [8]	3.5 ML of diesel	9		100,000 household PV systems
Wind [9]	3.8 ML of diesel	10		50 x 250 kW systems
Efficiency (electricity) [10]	13.6 ktoe of fuel	0	0	5% of fuel used for electricity generation is saved but displaces RE so no GHG savings
Efficiency (transport) [11]	4.3 ktoe of fuel	0	0	5% of ground transport fuel use but this replaces biofuels so no additional GHG savings
Total		*1586*	*100*	

Notes: See Box 2–1 for explanation of the assumptions. ~ = approximately RE = renewable energy

However, as the assumptions of Box 2–1 show, the assumptions of Table 2-12 are unrealistic and must be adjusted.

Box 2–1 – Assumptions for Estimating Potential for GHG reductions

1) *Large hydro*. Economically viable large hydro conservatively estimated (Section 3.2) as 4,200 MW (36,800 GWh/year). Current installed capacity is only 5% of this. Assume national installed large hydro capacity nearly doubles from 220 MW (Table 4-2) to 400 MW producing 3.3 GWh/MW (PNG Power average, Table 4-1). Assume the additional 180 MW replaces heavy diesel fuel which (Annex 2) saves 666 Gg of CO_2
2) *Small hydro*. There is vast small hydro potential (section 3.2) including perhaps 45 sites near C-centres. Assume 6 MW of new capacity is developed but with some diesel back up & hydro produces only 2 GWh/MW installed. Assuming ADO and 0.4 litres per /kWh, savings are 12.96 Gg of CO_2.
3) *Microhydro*. Even for 500 microhydro of 22 kW producing 1,000 useable kWh/kW, and replacing diesel at 0.46 l / kWh (Annex 2), CO_2 reduction is only 12.4 Gg.
4) *Geothermal*. At Lihir alone (sections 3.1 and 4.1) there is 70 MW of available capacity of which an additional 20 MW or more is already under development. Assume other mines with large demand and nearby geothermal potential. Assume 3.5 GWh/MW replacing fuel oil system using 0.28 l / kWh.
5) *Biodiesel*. The GoPNG (Table 3-4) expects about 30 kilotonnes per year of coconut oil and 350KT of palm oil (at about the same value per tonne) from 2004-2008. This is about 418 ML. Assume only 10% of some vegetable oil is used as diesel replacement. CO_2 reduction would be about 113 Gg.
6) *Ethanol*. There is vast potential for ethanol from sago and nipa palm (latter part of section 3.6). Conservatively, assume 300 ML of ethanol per year equivalent to about 175 ML of gasoline or diesel fuel. Ignoring CO_2 produced during manufacture, savings would be about 430 to 470 Gg depending on the fuel displaced.
7) *Other biomass*. Although (section 3.6) every 100 m^3 of logs produce about 45 m^3 of processed wood and 55 m^3 of potential biomass for fuel, nearly all the 2 million m^3 of logs produced annually are exported unprocessed. If 10% were processed in PNG, and 5% of that is available as fuel, this would provide 12,000 m^3 of fuel. Assuming 400 kg/m^3 and 14 MJ/kg, this is equivalent to 67,000 gigajoules (Gj) or only 1.6 ktoe.
8) *Solar PV*. There are over one million households in PNG of which at least 300,000 live in areas of high solar insolation. Assume 100,000 rural households receive. PV systems of 100 Wp & 0.25 kWh/day. Assume 300 days/yr operation = 2.55 million kWh/year. At 0.46 l/kWh for small diesel systems, this would displace 3.45 ML of fuel, equivalent to only 9.3 Gg per year.
9) *Wind.* Parts of PNG (section 3.4) could reportedly produce well over 2,000 kWh/kW of installed wind turbine capacity. Assuming a more conservative 1,000 kWh/kW and 50 sites of 250 kW each, this would displace 3.8 ML of diesel (assuming it replaced an efficient diesel plant using 0.3 l / kWh) or 10 Gg of CO_2 reductions.
10) *Energy efficiency (electricity*). It appears from Table 2-2 that about 57% of petroleum products (excluding natural gas used for electricity production at a gold mine) was used for electricity generation. If the same proportion applied in 2011 electricity would account for 0.57 x 478 = 272.5 ktoe. If this is reduced by 5% through end-use efficiency efforts, savings would be 0.05 x 272.7 ktoe = 13.6 ktoe, equivalent tor 40.6 Gg. However, the GHG savings in Table 2-12 from hydro and geothermal energy development for power production add up to 1024 Gg, which is equivalent to 343.2 ktoe of petroleum use. As this is about 26% above the total assumed demand for petroleum fuel for electricity generation in 2011, (i.e. 343.2/272.5), then efficiency measures could save fuel only, not reduce GHGs further.
11) *Energy efficiency (transport).* Transport accounts for about 18% of petroleum fuel use or 0.18 x 468 ktoe = 86 ktoe in 2011. If efficiency measures result in a 5% saving, this would reduce petroleum use by 55 x 86 = 4.3 ktoe reducing GHG emissions by 12.8 Gg. However, transport petroleum use of 86 ktoe is equivalent to about 257 Gg of GHGs. Biodiesel and fuel ethanol production could potentially reduce GHGs by 876 Gg (equivalent to 293.6 ktoe of petroleum fuels) which is more than triple the projected fuel demand in 2011.

As Box 2–1 shows, the potential GHG savings of Table 2-12 assume that PNG can develop renewable energy systems that produce more energy for electricity and transport than the demand assumed in the projections for 2011. About one third of transport fuel is motor spirit. At most (in the short to medium term), ethanol could replace about 20% of this in the form of motor spirit/ethanol blends, reducing the role of biofuels further. Table 2–13 revises the assumed level of renewable energy development downwards to match expected demand.

Table 2-12 – Revised Indicative Maximum Energy Savings and GHG Savings from Renewable Energy and Energy Efficiency in PNG, 2011

Technology	Potential fuel or energy savings	GHG savings (Gg)	% of saving s	Comments
Hydro, geothermal & wind	272.5 ktoe	813	80.3	Limited to 100% of projected electricity demand.
Biofuels [21]	63 ktoe	188	18.6	Limited to 100% of projected transport fuel demand.
Solar PV		9	0.9	As in Table 2–11
Efficiency [22]		3	0.3	Measures reduce biofuel use and have little impact on GHG emissions
Total		*1013*	*100*	

Notes: See Box 2–1 for explanation of the assumptions. ~ = approximately RE = renewable energy

Table 2–13 suggests that in principle, PNG could reduce CO_2 equivalent GHG emissions through renewable energy investments by over 1,000 Gg per year over the next decade or so, about 70% of total 2001 emissions. Almost all of this would be through renewable energy.

If this level of renewable energy were developed, energy efficiency efforts would reduce fuel consumption, but as this would displace renewable energy, there would be no significant further GHG reductions This indicative and crude estimate is based on proven technologies and more-or-less known resources but does not consider economic, financial, political, social, technical, environmental or other practical constraints. It does not consider emerging applications such as fuel cell technology using some of PNG's vast natural gas resource as fuel. Although this is not renewable energy, natural gas produces only about 60-70% of the emissions of liquid petroleum fuels, depending on the fuel displaced.[23]

Even a fairly large solar PV or wind energy programme would provide very modest GHG reductions. The basis for the above estimates, which are not meant to represent practical or achievable goals, is discussed in the next two chapters.

[21] For transport, assume biofuels can replace 100% of diesel fuel (2/3 of 86 ktoe =57.3 ktoe) and 20% of motor spirit (0.2 x 1/3 x 86 ktoe = 5.7 ktoe. The total is 63 ktoe.

[22] Motor spirit, reducing the ethanol blended in, would be 0.8 x 1/3 x 86 ktoe = 22.9 ktoe. 5% saved through efficiency measures is 1.1 ktoe, equivalent to 3.3 Gg.

[23] A recent study by the World Wide Fund for Nature (WWF) and Fuel Cell Europe, looking at life-cycle savings, estimates that "GHG reductions above 50% can be achieved with fuel cells powered by natural gas" (WWF, 2003). The authors expect fairly rapid development of small (under 10 kW) systems.

3 Potential for Renewable Energy Technologies

The technical potential for energy production from renewable energy technologies (RETs) from local renewable resources in Papua New Guinea is enormous. However, in practice much of this potential is far from locations with significant energy demand and cannot be readily exploited. Many of the resource assessments for hydropower are a decade or two old. Even good knowledge of the national technical potential provides only limited information on practical short-term options. Nonetheless, there is considerable value in estimating the potential resources and associated technologies for geothermal, hydro, ocean based energy, wind, solar and biomass for liquid fuels (coconut oil) and combustion (forest resources). These are discussed below.

PNG's two universities, the University of Papua New Guinea (UPNG in Port Moresby) and the University of Technology (Unitech in Lae), in collaboration with several government departments (Energy and Forestry), organised three national seminars/workshops on 'renewable energy for rural development' in 1987, 1989 and 1994. Some of the information in this chapter is from these meetings. Despite generating enthusiasm and producing a number of reports on RE potential in PNG, very little concrete action followed (Yarka, 1999). Since 1994, very little new information generation and dissemination on RE has taken place through workshops, conferences or seminars (Puy and Sumanasiri, 2003).

3.1 Potential for Geothermal Energy

No systematic assessment of PNG's geothermal energy potential has been carried out. However, reconnaissance studies of the country's geothermal potential suggest that the most promising area for investigation is the northern coast of New Britain Island, from the Willaumez Peninsula eastward to the Gazelle Peninsula. There are at least seven geothermal sites in the region: Bamus, Galloseulo, Walo, Kasoli-Hoskins, Garbuna, Pangalu-Talasea and Bola. At Talasea, Pangalu and Kasoli, all on the north coast of New Britain, the thermal fields are associated with a belt of recent volcanic activity. Numerous hot springs, geysers, fumaroles and mud pools are found at temperatures of 90-101^{o}C, reportedly significant H_2S and CO_2. Geothermometric equilibrium temperatures could be in the 300^{o}C range and a dry steam geothermal reservoir could underlie the region. The fluids in the four geothermal areas to the east of the Willaumez Peninsula have temperatures from 86-100^{o}C and are slightly to moderately acidic, suggesting near surface volcanic heat sources. Apparently AusAID and the Deutsche Gesellschaft für Technische Zusamenarbeit (GTZ, the German Agency for Technical Co-operation) have supported some investigation of geothermal energy resources in PNG but the mission has no details.

There has been only limited commercial geothermal development in PNG (discussed in Section 4.1), because of the small populations, low levels of industrial development and low demand for power in the areas of major volcanic activity. The island of Lihir, off the north coast of New Ireland, is a notable exception. Lihir contains one of the world's largest epithermal gold deposits within an active geothermal system. Geothermal drilling by the Philippine National Oil Company for Lihir Gold Limited, has estimated a geothermal power prospect of up to 70 megawatts.

In 2002 SOPAC, in collaboration with the US Geothermal Industries Corporation (USGIC) prepared a funding proposal for carrying out further assessment of the geothermal resource in five PICs (SOPAC, 2002), including PNG. No funding has thus far been found to implement the project.

3.2 Potential for Hydropower

Hydroelectric power potential in PNG is substantial, as a large part of the country is mountainous and receives substantial rainfall. Information on specific sites is limited, due to the absence of systematic hydrological surveys. The WB-funded *Hydropower Resources Inventory Study*, published in 1994, estimated the gross theoretical hydropower potential of PNG as roughly 175,000 GWh/year (20,000 MW). Defined as the sum of 90% dependable outputs with about 10 MW or larger capacity, the technically feasible potential was estimated at 122,640 GWh/year (14,000 MW). The International Energy Agency (IEA) estimates the economically feasible hydro potential at approximately 36,800 GWh/year (4200 MW) (IEA Small Hydro website, 2004). In November 1980, the GoPNG's DME had estimated gross potential at 25,000 MW (Kalimba, 2004). None of these estimates include small-scale (mini, micro and pico)[24] hydro potential scattered throughout the country, which could be an ideal source of energy for rural communities, and the exploitable potential of which is considerable.

The greatest hydropower potential in the country is in the Gulf Region. The river with the largest potential is the Purari, followed by the Kikori, Fly and Sepik rivers. Sizable potential at a number of medium-size sites is found in and around the large electric demand centres of Port Moresby and Lae, and the moderate demand centres of Madang and the highlands regions. Most estimates are based on run-of-river developments and would greatly increase if dams were constructed for flow regulation (PREA; WB *et al*, 1992).

A 1985 New Zealand Aid (NZAID) supported a DME assessment of mini hydro potential near 110 load centres in 17 provinces. Investigations were carried out at 31 centres, with the rest examined through desk study. Although the main focus was the power generation potential in the vicinity of C-centres, the study considered the resource potential in the vicinity of the nearby population centres as well. It identified 6 MW of mini hydro potential, more than half of which was concentrated in North Solomons province. Other promising locations were in Madang, Morobe, Eastern Highlands and Southern Highlands provinces. In some locations, the economic viability was judged to be low or uncertain due to low demand and/or cheaper power through grid extension or other renewable energy sources (Beca-Worley International, 1985).

3.3 Potential for Ocean Based Energy Technologies

PNG includes more than 600 islands. Several coastal and island areas, such as Aitape and Kavieng, are renowned for surfing and have wave energy and tidal potential although neither has not been measured (Puy & Sumanasiri, 2003). However, no use is made of ocean based energy technologies (OTEC, tidal or wave energy) and there is limited knowledge of its potential. This is unsurprising as ocean energy

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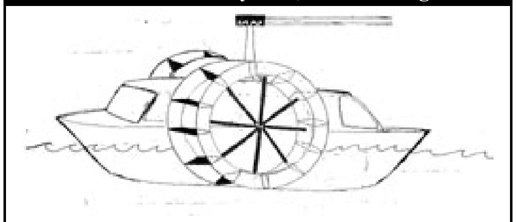
[24] Although classification can be vague and can seem arbitrary, the following range is often used: picohydro for output below 1 kW, microhydro for output below 300 kW and minihydro for output greater than 300 kW but less than 2 MW.

technologies, although much hyped, are not commercially available, proven technologies.[25]

Figure 3-1 – Sketch of Proposed Sea Current Power System, Buka Passage



Source: www.thenational.com.pg/0206/w3.htm

A recent paper presents limited data on tidal energy potential. The tidal range is far greater at Port Moresby (2.7m) than at Anewa Bay, Northern Solomons Province (1.6m); Lae (1.5m); Seeadler Harbour, Manus (1.3m); or Dreger Harbour, Morobe (1.1m). The range is about 6m in parts of the Torres Strait between PNG and Australia (Liu Zhaoxiang, February 2004). In early 2004, a Chinese renewable energy consultant then at DPE proposed a tidal current system of unknown size for Buka Passage, Bougainville (Liu Zhaoxiang, personal communication (pers.com.), 19 January 2004) with peak currents of about 4-6 knots (7-11 km/hour). It has been suggested that a refurbished boat be moored in the passage and retrofitted with a paddle wheel to extract energy (Figure 3-1), a low efficiency approach which would seem to be insufficiently roust for the conditions. The project, reportedly backed by the local governor, is at a very preliminary stage and requires careful technical and economic confirmation.

As far as the mission could determine, there has been no measurement of deep sea versus surface ocean temperatures to enable estimates of near-shore ocean thermal energy (OTEC) potential. Despite frequent announcements of seawave and OTEC demonstration projects, it is highly unlikely that PNG or other PICs will deploy ocean energy technologies at any scale for the next decade or so.

3.4 Potential for Wind Energy

The most recent known assessment of PNG's wind resource was carried out in the late 1970s by the Australian Commonwealth Industrial and Scientific Research Organisation (CSIRO) at the request of the Department of Minerals and Energy (DME). CSIRO (Table 3-1) estimated an annual power generation potential of 607 kWh per kW of installed capacity (J. D Kalma, 1980).

The study ranked the provinces according to wind power potential as follows:

- high: Manus, Central, Western, Milne Bay, New Ireland and NCD;
- medium: North Solomons, Gulf, East New Britain, Morobe and Oro; and
- low: Simbu, the Highlands, Enga, Madang, East Sepik, Sandaun and West New Britain.

Table 3-1 – Estimated Annual Wind Potential in 1979

Province	Location	Potential kWh / kW
Sandaum	Airape	602
East Seplk	Wewak	490
Southern Highlands	L. Kutubu	688
Western Highlands	Kagamuga	730
Simbu	Kundiawa	341
Eastern Highlands	Kainantu	466
Madang	Bogia	32l
Morobe	Gizarum Ptn	1,076
Manus	Momote	915
Western	Daru	1,076
Gulf	Kikori	769
Central	Amazon bay	1,089
National Capltal	Port Moresby	964
Oro	Dogura	555
Milne Bay	Misima	915
North Solomons	Kieta	993
West New Britain	Biala	816
East New Britain	Rabaul	779
New Ireland	Namatanai	902
Average over all sites		*607*

Source: Kalma, 1980

[25] A prototype seawave system has operated for about a year in Denmark.

If these wind speed estimates are accurate, with improvements in wind energy technology, the annual average potential in PNG could now be considerably higher, up to 2600 kWh/kW for properly sited machines (G Heffner, pers. com., 9 March 2004). However (Mears, 2004), these were mostly model based estimates with very little wind gauging and there is some evidence that weather patterns have since changed significantly, in some cases for the worse.

A Forum Secretariat Southern Pacific Wind and Solar Monitoring Project, which measured wind speeds in a number of PICs in the mid-1990s, did not include Papua New Guinea.

3.5 Potential for Solar Energy

Solar energy represents one of the largest potential sources of energy in PNG. Excepting cloud forest areas, it is in a favourable geographical location for year-round solar energy applications. The average insolation in most parts of the country is in the range of 400-800 W/m^2, with a mean sunshine hours ranging from 4.5 - 8 hours a day. Insolation averages 6 kWh/m^2/day with average sunshine hours varying across the country.

Based on measurements from 23 locations (apparently long-term but details unknown), the driest location in PNG is Port Moresby in the NCD with an estimated 2,478 sunshine hours per year and a daily range of 5.8 to 8.2 hours. The lowest sunshine duration is at Tambul in the Western Highlands, with an estimated mean annual of 1292 hours due to frequent fog and mist. On a regional basis, the Southern, Momase and Islands Regions are estimated to have a mean annual sunshine duration of more than 2000 hours, and the Highlands Region less than 1500 hours. Based on climatic conditions, the highest potential provinces for solar PV would be the islands and southern regions. The Momase and Highlands regions have less favourable conditions for solar but relatively high potential for mini hydro (PREA, WB, 1992 and Heffner, 2004).

3.6 Potential for Biomass Energy

Two-thirds of PNG is forested (Table 3-2) but much is inaccessible or unsuited for energy use. The government estimates that 58% of land area is subject to strong or severe erosion and 18% is permanently inundated or regularly flooded. About 200,000 hectares are cleared annually for traditional agriculture (GoPNG, 2000). This section does not attempt to estimate the total biomass resource but confines itself to areas of logging or agricultural production where the output or residues could have potential for energy use.

Table 3-2 – Forest Cover in PNG ('000 ha)

Type	Forest		Other wooded land		Inland water
	Closed	Open	Shrubs & trees	Other land	
Area	30,150	829	585	13,675	1,044
%	65.1	1.8	1.3	29.5	2.3

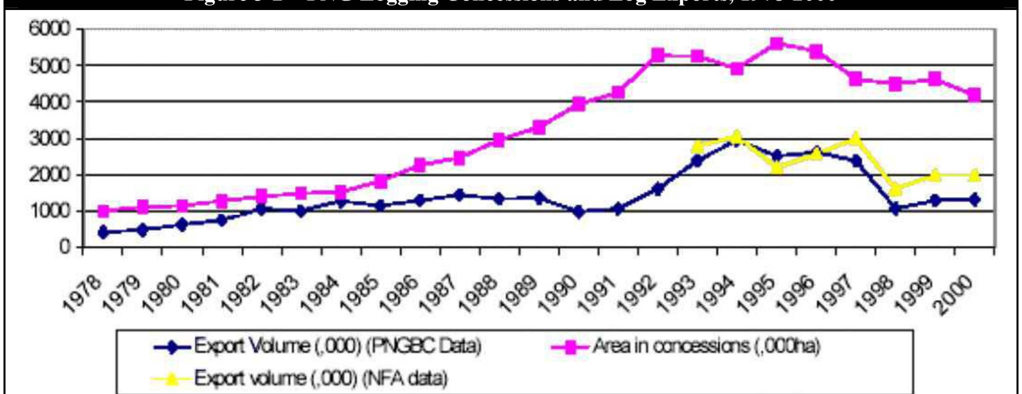
Source: FAO website: www.fao.org/forestry/foris/

3.6.1 Logging

Logging first began in PNG in the early 1920s, mainly in coastal areas. Sawmills were established, mainly by missionaries, to cut timber to build churches, schools, and health centres. The volumes extracted were low and logging was to service local sawn timber needs. Today commercial logging for export is fairly widespread throughout all regions of PNG. After restrictions on round log exports were removed in 1979 (when log exports were just below 0.5 million m^3), exports increased substantially.

The logging industry expanded beyond the capacity of regulatory authorities and an official Commission of Inquiry – the Barnett Inquiry – concluded in 1989 that the forest industry was effectively 'out of control'. Several forestry policies were developed to regain control of the sector but log extraction and exports continued to increase throughout much of the 1990s, peaking in 1997 when exports reached about 3m m^3. Since then there has been a steady decline: timber extraction is now around 2m m^3 per year and exports slightly lower[26] (European Forest Institute website). The best commercial forests have already been lost. As resource rich concessions are logged out, the logging companies shift to less desirable areas with lower densities, explaining the decline in production. The maximum sustainable harvest (from 11 million ha. of forest suitable for large-scale exploitation) is no more than 2m m^3 per annum[27] (Shearman & Cannon, 2002). Figure 3-2 shows logging concessions and exports in thousands of m^3.

Figure 3-2 – PNG Logging Concessions and Log Exports, 1978-2000



Source: Shearman and Cannon, 2002
Note: Until early 1990s, log exports were underestimated, largely due to unreported illegal exports

The logging industry is currently dominated by the Malaysian company Rimbunan Hijau, which controls more than 60% of the sector. Of the 1.85 million m^3 of declared log exports in 2002, 62% went to China and Hong Kong and 23% to Japan (Greenpeace, 2004). Despite the decline in log export licences granted by the National Forest Authority, declared log exports rose to 2.02 million m^3 in 2003, an increase of nearly 10% from 2002 (BPNG, QEB, Dec. 2003).

3.6.2 Wood processing

Although it has long been GoPNG policy to promote downstream processing of timber, only a very small portion of extracted logs are processed locally. In 1954 PNG's first plywood and veneer mill was established in Bulolo, remaining the only plywood mill until 1998. During the first three decades of operation, production peaked in 1973-1974 at 15,700 m^3 of sawn timber and 5000 m^3 of veneer. In 1969, production of woodchips started at the Jant mill in Madang, still the sole woodchip mill in PNG, accounting for some 200,000 m^3 of logs processed.

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[26] Although more precise data are available, sources differ regarding quantities. Therefore indicative data have been used.

[27] This is 40% lower than the 3.13m m^3/year that FAO estimates for the total potential sustainable production from PNG's forests (source: FAO website; undated).

Processing and exports of timber have increased sharply in the past several years, following the commissioning of the Rimbunan Hijau-owned Panakawa Mill at Kamusie in Western Province. Sawn timber exports grew from 32,000 m^3 in 1998 (23,000 m^3 in 1999) to 42,348 m^3 in 2002. Exports of veneer rose from 1,700 m^3 in 1999 to 71,615 m^3 in 2002 and plywood exports increased from 7000 m^3 in 1999 to 70,083 m^3 in 2002 (Greenpeace, 2004).

The wood processing industry produces waste products with potential use for energy production. Table 3-3 lists 18 major industrial facilities, including sawmills, plywood mills, veneer mills, woodchip mills and furniture factories The largest wood processing plants in the country are the PNG Forest Products plywood mill in Bulolo (Morobe); the Rimbunan Hijau veneer mill in Panakawa (Western Province), and the Jant Limited woodchips mill in Madang. Section 4.7 discusses the extent to which wood waste is currently used for energy production.

Table 3-3 – Major Timber Processing Plants in PNG

Facility	Location
Sawmills	
Steffin Bay Lumber Company	West New Britain
Ulamona Sawmilling Company	
Vudal Timbers	East New Britain
PNG Balsa Company	East New Britain
G.S. Models (Teperoi Timbers)	East New Britain
Mantua Timbers	East New Britain
Madang Timbers Limited	
Vanimo Forest Products Limited	
Milne Bay Industries Limited	
Timber and Forestry Training College	
Plywood Factory	
PNG Forest Products	Bulolo, Morobe
Veneer Mill	
Rimbunan Hijau Timber Processing Ltd.	Panakawa, Western Province
Woodchips Mill	
Jant Limited	Madang
Furniture Factories	
Pulumpa Limited	Port Moresby
Phillco Joinery Limited	Lae, Morobe
PI Logging	Taraka, Lae, Morobe
Timbersaws	Lae, Morobe
Pryde Furniture	Port Moresby

Source: National Policy on Downstream Processing of Forest Products (Draft; MoF; 28 August 2003).

3.6.3 Agro-industry

In both production volume and monetary value, the major agricultural products in PNG are palm oil, coffee and cocoa. In terms of value, copra and coconut oil are of much less importance, especially compared with the value of mineral exports. Table 3-4 presents the production of key agricultural commodities and GoPNG projections through 2008. Figure 3-3 shows the value of agricultural exports in 2002.

Table 3-4 – Production of Agricultural Commodities ('000 tonnes, except logs million m^3)

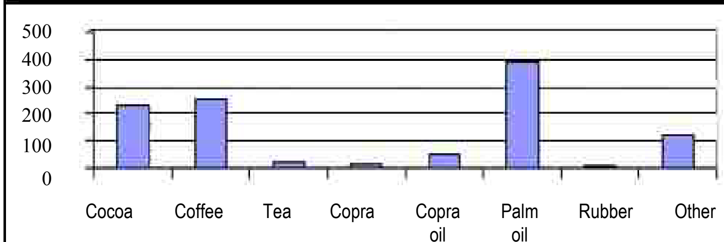
Commodity	1999 Actual	2000 Actual	2001 Actual	2002 Actual	2003 Proj	2004 Proj	2005 Proj	2006 Proj	2007 Proj	2008 Proj
Copra	63.5	67.2	21.8	15.8	15.0	15.2	15.4	15.7	15.9	16.2
Cocoa	29.0	38.0	36.5	34.9	35.7	38.4	38.6	42.6	45.1	47.7
Coffee	79.2	66.6	51.6	63.1	63.9	66.0	66.5	65.6	67.7	68.9
Palm Oil	253.8	336.3	327.6	323.9	335.3	341.8	352.7	363.7	376.0	388.2
Rubber	3.7	3.7	3.6	3.8	4.2	4.8	6.2	6.7	8.2	8.6
Tea	8.2	8.5	8.8	5.2	5.4	5.5	5.7	5.9	6.0	6.2
Copra Oil	50.3	48.0	27.1	28.2	29.7	30.2	30.7	31.2	31.8	32.5
Logs (m m^3)	1.31	1.405	1.21	1.830	1.75	1.82	2.00	2.08	2.28	2.70

Source: 2004 Budget Volume 1 (GoPNG, Nov. 2003); Note: Actual from Bank of PNG and projections from Treasury.

Coffee was until recently the most important cash crop in terms of foreign exchange. In recent years, levels of coffee production have declined

In 2000, *oil palm* exports overtook coffee exports for the first time. The volume of oil palm exports rose by almost 80% between 1995 and 2003. Some 100,000 hectares are cultivated for oil palm, almost half of which are managed by smallholders, the rest being estate plantations. There are four major oil palm projects in PNG, in the provinces of West New Britain, Oro, Milne Bay and New Ireland.[28] The leading producer in PNG – and the largest private sector employer – is New Britain Palm Oil Ltd. (NBPOL), which produces approximately 200,000 tonnes of crude palm oil per year, about two-thirds of the total. In 2002, the company built a refinery designed to process about half of its annual capacity. In principle, almost any vegetable oil can be used, sometimes requiring some additional processing, as a fuel.

Figure 3-3 – Value of Agricultural Exports, 2000 (Kina millions)



Source: BPNG Quarterly Economic Bulletin. (December 2002)

Sugar cane has been grown in PNG since 1979 when Ramu Sugar Limited (RSL) began operation. RSL can process over 500,000 tonnes of cane per season (April-October). Assuming a yield of 10%, the mill can produce 50,000 tonnes of processed and refined sugar per year. Sugar production exceeded 38,500 tonnes in 2000; 42,400 tonnes in 2001; and 49,100 tonnes in 2002 (IPA website). The main by-product is molasses, part of which is sold locally, primarily as cattle feed. The balance of around 15,000 tonnes per year is converted into alcohol[29] (Vulum, 2003). RSL is diversifying into oil palm, which may account for over 50% of its revenues by 2007 (World Reports website).

Alcohol can also be produced from sago palm or nipa palm, an option which was explored in the early 1980s by DME. Between 200 and 1,100 million litres of fuel alcohol from sago palm could reportedly be available in the Gulf Province alone, with other areas, such as East Sepik, offering further potential. Some 263 million litres of fuel alcohol from nipa palm could potentially be available from the 48,500 ha of palm in the Purari Basin, with much larger areas of nipa palm existing elsewhere in PNG.

Copra has been exported since the 1950s. The total area under coconut cultivation is 260,000 hectares or about 0.6% of PNG's land area. Coconut once accounted for a third of agricultural exports, but its contribution has decreased significantly over the years. Most coastal provinces produce copra but the bulk is from East New Britain, West New Britain, Madang, New Ireland and North Solomons. Smallholders account for 60% of production whereas 40% is from plantations. The Island Provinces combined produce 75% of the total. Madang produces 18,000 tonnes per year, the Southern region 4,000-15,000 tonnes, and Morobe and Sepik Provinces combined 20,000 tonnes. Copra, of course, is used to produce coconut oil (copra oil), which can be, and has been, used successfully as a diesel-fuel replacement.

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[28] Ramu Sugar is preparing to develop a further oil palm plantation and mill.

[29] Ramu's alcohol production activities are discussed in more detail elsewhere in this report.

As a rule of thumb, for each m^3 of logs extracted, about the same amount stays in the bush (i.e. is unavailable for productive use); for each m^3 of processed timber produced, at least the same amount remains as waste. 200 m^3 of logs cut generate about 100 m^3 of logs extracted, which generate about 45 m^3 of useful processed wood and 55 m^3 of waste. In PNG, however, as described above, only a small percentage of the wood extracted is processed locally and much of this goes to the chipmill. The bulk is exported as logs leaving a relatively small amount available in practice for potential energy production.

In principle, PNG could produce a large amount of energy (heat, electricity, liquid fuel) from wood waste, agricultural wastes, molasses, palm oil and copra. These are discussed further in chapter four.

4 Experiences with Renewable Energy Technologies

4.1 Experience with Geothermal Energy

Figure 4-1 – 6 MW Geothermal Plant, Lihir

Source: Profile (PNG Chamber of Mines & Petroleum)

In April 2003, Lihir Gold Ltd. commissioned a 6 MW geo-thermal power plant on Lihir Island (see Figures 2-2 and 4-1), the first such system in PNG. Four steam wells, initially drilled for cooling and depressurising the mine, provide the steam for power generation. The power plant requires over 100 tonnes of steam per hour to operate at maximum capacity. The 6 MW capacity is only 10% of total mine power requirements. Lihir Gold is currently installing a further 20-30 MW of geothermal capacity (PREA, 1992; SOPAC, June 2002; Bais, 2004). PNG Power is considering exploring the geothermal potential in both East and West New Britain (Bais, 2004).

4.2 Experience with Hydropower

4.2.1 GoPNG Hydropower Development Programmes

Small hydropower development

In the 1980s and 1990s, ELCOM (now PNG Power) considered small hydropower development for the replacement of diesel power plants in isolated systems. Feasibility studies were completed for Divune (3 MW) near Popondetta and Maum-Danop near Wewak, and reconnaissance studies and river gauging were undertaken for potential sites at Alotau (Gumiini), Fischhafen (Butaweng), Kerema (Murua), Lombrum/Lorengau (Lauls), Vanimo (Daundo) and Kimbe. None materialised due to ELCOM's policy to undertake construction of small hydropower stations only if their financial feasibility was confirmed (WB *et al*, 1992).

Micro hydropower development

In 1985 the DME's Energy Division embarked on an ambitious Diesel Power Replacement Programme (DPRP) with the goal of reducing reliance on imported diesel fuel by designing and constructing small hydro schemes to replace the existing diesel generator sets in C-centres in the interior of the highlands. It was hoped that the DPRP would improve the reliability and quality of electric power and reduce overall costs. Forty-five potential sites were identified near existing diesel-powered C-centres. By 1987, feasibility studies at 14 of the sites had been completed, and between 1988 and 1992 three micro-hydro systems were installed. The 300 kW Tari hydro scheme (Southern Highlands Province) was commissioned in 1988 with the European Union (EU) financing 80% of construction costs and the GoPNG the remainder. The 60 kW Woitape hydro scheme (Central Province) and the 100 kW Telefomin project (West Sepik Province) were completed in 1991 and 1992 respectively, both with GoPNG funds. The cost of the Woitape project (including installation, commissioning and site supervision) was approximately US$1.4 million, or US$23,000 per kW. The estimated cost of completing and commissioning the Telefomin system was US$2.4 million, or US$24,000 per kW (Kopi, 2003).

In 1991 the DPRP evolved into the Micro-Hydro Development Programme (MHDP), a five-year initiative encompassing seven additional small hydro projects, and including training of national engineers (WB, et. al., 1992). Funding for the MHDP was sought from the EU (K8.5 million for equipment procurement) and from GTZ (K2.7 million for training). The EU funding apparently never materialised. The GoPNG has reportedly constructed no further small hydro projects since 1992. GTZ funding for training, however, was approved, and a ForSec-managed hydropower training programme started in mid-1993. ForSec contracted a German firm, Projekt-Consult, to train Energy Office staff in the planning, implementation and operation of small-scale hydropower projects and in solar PV systems. As no counterpart was available, and the GoPNG restructured its ministries, affecting the Energy Division, the training programme and its associated funding was transferred from PNG to the Solomon Islands (Fairbairn, 2004).

4.2.2 Installed and planned capacity: government and commercial auto-producers

The installed hydroelectric generating capacity of PNG Power Ltd. (PNG Power) in 2000 was about 162 MW, about 4% of PNG's estimated economically feasible hydro potential. Ok Tedi Mining Ltd. (OTML) operates a 57 MW facility at Ok Menga plus a 2 MW Yuk Creek plant. The installed hydro capacity nation-wide (2000) is about 220 MW, excluding private hydro installations under 2 MW. Nationwide, hydroelectric in 2000 accounted for 32% of installed capacity as shown in Tables 4-1 and 4-2.

Table 4-1 – PNG Power Hydro Capacity and Generation, 2000

System	Location	MW	GWh	Commissioned
Rouna 1	Central	5.5	2.7	1957 & 1961
Rouna 1	Central	30	108.2	1967 & 1969
Rouna 3	Central	12	59.4	1975
Rouna 4	Central	13.5	41.2	1986
Sirinumu	Central	1.6	1.4	1973
Port Moresby System total		*62.6*	*212.9*	
Ramu	Eastern Highlands	75	248.0	1976 & 1989
Pauanda	Southern/Western Highlands	12	40.3	1983
Ramu System total		*87*	*288.3*	
Warangoi	East New Britain	10	26.7	1983
Ru Creek	West New Britain	1.5	1.8	1982
Lake Hargy	West New Britain	0.9	2.0	1989
Gazelle System Total		*12.4*	*30.5*	
	PNG Power Total	*162*	*531.7*	

Source: PNG Power

PNGP has prepared a list of nine mini/small hydro projects to replace diesel systems for funding consideration by the World Bank. Pre-feasibility studies have been completed (Hairai, 2004). Table 4-3 shows the five hydro schemes which are scheduled by PNG Power for implementation by 2010.

Table 4-2 – Estimated Hydro and Thermal Generation Capacity in 1998 (MW)

Energy	PNG Power		Self production		Total	
	MW	%	MW	%	MW	%
Hydro [a]	162	73	59	27	221	32
Thermal [b]	135	29	335	71	470	68
Total	297	43	394	57	691	100

Source: PNG Power
Notes: % refers to percent of total hydro + thermal
a) self-produced hydro is incomplete
b) PNG Power thermal includes Kanudi.

4.2.3 Installed and planned capacity: mini/micro hydro systems

Micro-hydro systems have a long history in PNG, with church missions installing them for their own use and sometimes extending supplies to nearby households. Some school and health facilities have installed micro-hydro rather than small diesel or petrol generators. Only three C-centres, the largest consumers of public electricity in rural areas, have hydropower.[30] It is not known how many C-centre hydro schemes are still functioning.

Apart from *ad-hoc* systems established in Bougainville during the civil war, there has been little village electrification using small-scale hydro. Community owned and operated schemes (such as the APACE VFEG model in the Solomon Islands[31]) have not been effective in PNG[32] (Mears, 2004). However, in the last few years at least two grassroots organisations have started or intensified initiatives for hydro-based village electrification.

Table 4-3 – Proposed PNG Power Small Hydro systems, 2004 – 2010

Scheme & Province	Units	KW per unit	Total kW	Date
Luwini, Oro	2	2000	4000	2007
Ru Creek, W. New Britain	2	500	1000	2008
Gumini, Milne Bay	3	1200	3600	2008
Kimadan, New Ireland	4	400	100	2009
Daundo, Sandaun	3	350	1050	2010

Source: PNG Power Development Plan, 2003

Numerous small and mini hydro installations exist in PNG, but documentation is sketchy, and the various reports discussing them often contain conflicting information. A 1984 study identified 55 micro-hydroelectric schemes installed since 1960, of which 40 were operational at that time (Hothersall, 1984). An earlier estimate suggested that there were about 100 small schemes towards the end of 1976 (Woodward, 1977). Ranatunga noted that more than 45 micro-hydro plants had been installed throughout PNG between 1960 and 1989 but that not many were operational, mainly due to poor maintenance (Ranatunga et. al., 1989). In 2003 Kopi estimated that about 40 mini and micro-hydropower schemes were supplying power to rural communities and institutions, over half of which were established by missions and church organisations, and some of which had been in operation for over 25 years (Kopi, 2003). Early in 2004 DPE estimated that 30 or so mini or micro-hydro plants had been installed (Kalimba, 2004). The most recent estimate (Mears, 2004) states that, since the late 1970s, about 60 micro-hydro projects had been constructed in

[30] This is due mainly to GoPNG policies favouring diesel generators but also because of the limited success of the Diesel Power Replacement Programme and the apparent failure of the Micro-Hydro Development Programme.

[31] See the Solomon Islands country report (PIREP report volume vol. 12).

[32] This may be due to the different lifestyles (in many areas of PNG people live in geographically sparse hamlets, exceptions being plantations, missions or government stations) and cultural factors (the need for a clan focus to avoid jealousies and land issues) compared to the Solomon Islands.

rural/remote stations by contract workers and missionaries. Anecdotal evidence suggests that 10-15% are operational, with half of these in Bougainville[33].

The estimates by Kopi and Kalimba apparently do not include the community-owned self- built micro- and picohydro schemes in the vicinity of Arawa in Bougainville during the civil war. There are presently (March 2004) reportedly about 30 such schemes in operation, some of which have run for over six years (Mears, 2004).

Combining the various literature sources, the PIREP mission estimates that there may have been as many as 200 pico-, micro- and mini-hydro systems installed in rural PNG between 1960 and 2004.[34] Of these, perhaps 20-25% are still functioning i.e. 20-25 systems on Bougainville and roughly the same number throughout the rest of the country.

Figure 4-2 – 2.5 kW Microhydro Turbine Displayed at RDS, Port Moresby

Photo: P Johnston, 2004

4.2.4 Recent mini-micro hydro developments

Micro-hydro systems (like solar PV systems) are usually sold (Figure 4-2) to institutions rather than to individual households, although there are signs of an emerging market for the latter. The greatest proponents of small-scale hydro have been missions and agricultural enclaves. Within the resources available for the PIREP study, it has not been possible to compose a complete picture of all mini-hydro initiatives. Some private sector and NGO initiatives are mentioned below. Little data is available on hydro initiatives at churches, schools and health facilities.

4.2.5 Private sector initiatives

- *Porgera Joint Venture (PJV)* at the Porgera mine has assisted local people in the Tari area in the Southern Highlands refurbish a hydro system at Duli. In the Pureni area, PJV is assisting the community to rebuild a dam that was washed away due to floods. When this is completed, a small hydro unit is to be set up using existing equipment and a new alternator. In co-operation with local landowner groups (the Paiam Management and Porgera Development Association), PJV has surveyed the Pongema River where it proposes a 2 MW hydro system to supply Paiam Township, Porgera Station and surrounding areas, if funding can be arranged. The installation would be linked to an existing grid operated by the mine and the company would purchase any excess power generated.
- *Platypus Power (Australia)* has supplied a 30 kW turbine/generating unit to Ok Tedi Mining Limited for the Atemkit village micro hydropower project. The scheme is not yet operational due to design problems, for which OTML is

[33] This assumes a loose definition of "operational" as the Bougainville *ad-hoc* schemes deliver very limited levels of service (essentially lighting only) due to lack of voltage and frequency control.

[34] Woodward mentioned 100 units in the period 1960-1976, Mear estimates 60 units in the period 1984-2004, and the picohydro systems in Bougainville would add another 30-40 units.

reportedly obtaining expert assistance. By early 2004, Platypus had sold 12 turbine/generating units for community facilities in PNG.

- *Rainbow Power Company (Australia)* has supplied micro hydro systems (300 watt AC units) to several organisations in PNG, including the Appropriate Technology and Community Development Initiative (ATCDI) at Lae, the Australian Baptist Missionary Society, Catholic Health Services, Conservation Melanesia Inc. and many others.
- *New Britain Palm Oil Limited (NBPOL)* is exploring the feasibility of mini hydro potential in the Hala area and is interested in taking over PNG Power's existing mini hydro installations at Kimbe Bay.
- The department store *ESCO* markets solar home systems and micro hydro systems in the Western Highlands. ESCO has sold these to the Kudji Nazarene Hospital and the Ambua Lodge near Tari.
- *Rural Development Services (RDS) Ltd* has helped develop several combined rural water-supply projects and two hydropower schemes (Wakunai and Kieta district) in Central Bougainville (Capon, 2004). Funding came from Community Development Services (CDS, an AusAid assistance program), the National Member of Parliament for Central Bougainville, and his constituency development fund. It is understood (Mears, 2004) that implementation of some of the systems supplied by RDS remain to be completed, or were recently re-done by CDS.

Mears (2004) adds that a mini hydro project was commissioned in mid-December 2003 close to the old goldmine near Bwagaoia in Misima. With peak output of 250 kW (average 160 kW), it will, with diesel back-up, replace a much larger 6 MW oil fired power station that was operated by the mine. The Mimisa hydro project will be owned and operated by the landowners. However, arrangements for tariff collection are unclear. The hydro capacity is insufficient to meet present demand, so improved load management and some load shedding will be required. In November 2003 there was reportedly little community awareness of these issues.

4.2.6 Grassroots initiatives

At least two not-for-profit organisations are involved in hydro-based grassroots electrification in PNG. These are ATCDI, located at Unitech, and the Australian APACE VFEG (Village First Electrification Group).[35]

ATCDI has been a principle focus of grassroots PNG hydro activity, having been founded by some internationally well-known small hydropower experts (Adam Harvey, Allen Inversin, and others) and now carried on by Garaio Gafiye and others. ATCDI has constructed or rehabilitated at least six micro hydro schemes, including (ATCDI, 2004):

- Bogo Community School, Simbu Province (design and construction);
- Mapos Community School, Morobe Province (design and construction);
- Mt Gahavisuka Provincial Park, Eastern Highlands Province (design and construction);

[35] This is the successor of *Appropriate Technology for the Community and Environment* (APACE).

- Daulo Pass, Eastern Highlands Province (design and construction but needs upgrading);
- Bena SDA School, Eastern Highlands Province (rehabilitation); and
- Baindoang, Morobe (rehabilitation).

The 6.4 kW Baindoang community hydro scheme in Morobe province, a joint effort of the local community and ATCDI/Unitech, supplies electricity to a community school and a village. It is running at reduced output due to lack of maintenance because poor management has resulted in failed tariff collection (Mears, 2004).

If funding can be secured, ATCDI plans to install at least one new micro hydro scheme and fix two others, as follows (ATCDI website):

- Goglme (Gembogl District, Simbu Province), electrification of a health centre, school and catholic mission (construction);
- Daulo Pass Micro Hydro Scheme (upgrading: installation of GI penstock and power poles); and
- Rongo Lutheran Mission micro scheme (refurbishing, as it is currently non-operational).

Figure 4-3 – 5 kW Agaun Microhydro System, Milne Bay

Photo: Idau Kopi, 2003

APACE VFEG, with two decades of experience in community-based rural hydro development in the Solomon Islands, has assisted grassroots electrification in PNG. In the 1980s and 1990s, its PNG efforts were limited to a single scheme, in which APACE VFEG helped develop and improve a 5 kW scheme at Agaun village, Milne Bay (Figure 4-3). APACE VFEG works through local partners to build technical and institutional capacity. Since 2001, it has mentored PNG community groups, reportedly following the communities' wish to establish a PNG Village Electrification Council (PNGVEC). It is understood (Bryce, 2004) that PNGVEC has been formally registered and that a two-year action plan was in place in early2004. However, (Mears, 2004) no hydro systems have yet been realised. Potential micro-hydro schemes for which APACE VFEG has provided some technical and social assistance include (Bryce, 2004):

- a combined hydro-water supply system to serve the town of Alotau, for which detailed design work has been completed;
- electrification of Arawa township and surrounding settlements of Bougainville, for which a pre-feasibility study was conducted; and
- preliminary work at the Chimbu and Maril rivers (Simbu), the Itnonomata river (Oro), the Ramu river (Madang), the Purnine river (Morobe) and several associated with Kandep village (Enga). There has been correspondence with village representatives and several a site visits.

Micro/pico hydro activities on Bougainville

Figure 4-4 –
200 watt household picohydro, Bougainville

Photograph: Andrew Mears, Arawa, Kieta District

Because of its very distinct features, the hydro experience in Bougainville is discussed separately here. From 1988 - 1997, Bougainville suffered from civil strife, and the island was blockaded by the GoPNG throughout much of the 1990s. There was considerable resourcefulness during this period. Some communities used coconut oil to fuel vehicles and developed tiny hydro schemes (Figure 4-4) to deliver very limited service (essentially lighting only), due to lack of voltage and frequency control. At the end of hostilities, the new international assistance available to Bougainville included pico-hydro development. In 2001, APACE conducted a two-week training programme in Arawa for village operators of existing micro- and pico-hydro systems to improve safety and future design. The 55 participants represented some 40 communities, mainly from central Bougainville, which had established micro hydro during the conflict.

In 2002, an Australian renewable energy expert Andrew Mears, in collaboration with Volunteer Service Abroad (VSA of New Zealand) and OXFAM (NZ), and at the invitation of local grass-roots organisations, ran a pico-hydro forum in central Bougainville. This resulted in initiatives to use a pool of skilled labour (pre-crisis mine trained tradesmen) to provide training and local manufacture of robust hydro turbines. The earlier ad-hoc informal hydro schemes on Bougainville had been constructed from components salvaged from the huge copper and gold mine. They were rudimentary, failure-prone and often unsafe. As a result of the training and forum, there is now a mechanical workshop in Arawa which has produced several quality cross flow and Pelton type pico-turbines.

It is likely that a design from the Arawa workshop will be used for a 4 kW installation planned for Paruparu (Avaipa District, Bougainville) which was surveyed in March 2004) for replacement of an earlier non-functioning hydro system. Financed by AusAID's CDS, it will provide power to the school, a health centre, teachers' houses and the Paruparu Education and Development Centre, where the first of the self-built hydro schemes was developed.

4.2.7 Hydro case studies

In his April 2003 hydro field survey, Kopi included case studies on the Agaun, Woitape and Fane Catholic mission micro-hydro schemes. Abridged and edited versions are attached as Annex 4 (Kopi, 2003).

4.3 Experience with Ocean Based Energy Technologies

As far as the PIREP mission has determined, there has been no experience in PNG with sea wave, tidal, OTEC or other ocean-based energy demonstrations.

4.4 Experience with Wind Energy

Figure 4-5 – PIREP National Consultant, John Wilmot below 500 w Chinese Wind System at DPE, Waigani

Photo: Peter Johnston, Jan. 2004

There are very few wind turbines in PNG, and data are sketchy at best. A few wind turbines were installed in farms in the Markham valley, Morobe Province after Independence but it is not known whether any are still functioning (Puy and Sumanasiri, 2003). PNG Power may consider developing a wind farm at the Port Moresby mountain ridge (Bais, 2004), which is believed to have PNG's best wind resource. However, the utility has not begun any wind monitoring at the location. Commercial companies market and sell small wind generators. However, there is little documentation of these systems.

In 2002, the Chinese Government donated 50 small combined wind/solar generators to the GoPNG, the wind component of which is illustrated in Figure 4-5. These are discussed in Section 4.7 below on PNG's experience with hybrid energy technologies.

4.5 Experience with Solar Energy

4.5.1 Solar energy research and utilisation in PNG

Applied research in solar energy applications has been carried out and reported at the RE seminars (see Section 3) held in 1989 and 1994. There have been more than 25 such projects, of which about twenty were undertaken at Unitech (Uppal and Satter, 1985). Unitech's Department of Mechanical Engineering participated in about 15 solar projects from 1980-1993, many of which focused on solar drying of food crops. Research projects underway in 1995 included: i) solar radiation monitoring for Lae; ii) heat pipe solar collectors and thermal storage; iii) Yazaki solar air conditioner; iv) solar drying for cocoa; v) developing a test facility for solar collectors and domestic solar water heaters; vi) PV medicine refrigerator performance monitoring; vii) feasibility study of PV pumping units; and viii) a solar kitchen. Unfortunately, not much of the Unitech solar energy research has progressed towards practical applications (Puy & Sumanasiri, 2003).

Solar energy can be used in a variety of ways. In PNG, the main applications have been solar drying and cooking, solar water heating, and solar PV power generation, each of which is discussed below.

4.5.2 Solar Drying

The most common use of solar energy in PNG has been for copra, cocoa and coffee drying, particularly by small-holders (PREA, 1992). As the mission has no recent data on solar drying practices in PNG, it is not known whether this is practised as much as in 1987, when it was widespread and studied in detail by Gilmour (GoPNG, 1987). AusAID has supported the development of a solar cocoa drier to potentially replace kiln dryers used by smallholders and plantations relying on fuelwood or diesel for process heat.

4.5.3 Solar cooking.

DPE obtained four solar cookers from China in 2002. One of the units was seen by the PIREP mission in the corridors of the DPE Energy Division; it is uncertain whether they have been tested or used. The units were similar to solar cookers tried by DPE's predecessor, DME, during the 1980s but abandoned, as they were unpopular with users.

4.5.4 Solar thermal

In the early 1980s a sizeable solar water heating (SWH) retrofit programme for commercial users, industry and households was implemented by the GoPNG and the private sector. The largest projects were in 1981-1982 by Bougainville Copper Limited (BCL) for about 1700 company houses and the national government for about 1300 government owned houses in Port Moresby (Kopi, 2003). At the time, GoPNG regulations banned the installation of electric water heaters in new homes and provided tax incentives for retrofitting existing electric installations. For a time ELCOM, the forerunner of PNG Power, provided subsidised household SWHs to its customers. As a result of these initiatives, solar water heaters were adopted in many high-income homes. A joint WB/UNDP energy assessment observed that SWH use flourished and estimated that about 7500 units had been installed, of which 90% were in residences (WB/UNDP, 1983). The 1992 PREA estimated SWH use in 1990 to be the equivalent of 28 mtoe, of which 22 mtoe was in the domestic sector and 6 mtoe in the commercial sector (PREA, 1992). The PREA also observed that there were additional opportunities for SWH, particularly for hotels and hospitals.

Since the solar retrofit programme, more than two decades ago, SWH has steadily increased and is now well established for both residential and commercial use. Currently, at least 7000 homes in the Port Moresby area are probably fitted SWHs, plus a considerable number elsewhere (Kopi, 2003). Supply and installation is mainly through commercial suppliers and building contractors (Puy and Sumanasiri, 2003). Liu reports retail prices of K 3000 for a 180 litre unit and K 4000 for 300 litres. He notes that this price is unaffordable by most households and concludes that new systems are bought primarily to replace old ones (Liu, 14 April 2003; Post-Courier). This was confirmed by a local SWH supplier, who sells 50-60 systems per year as replacement units. All are imported, as SWH are not made locally (Associated Plumbing, 2004).

According to Kopi (2003), current suppliers of SWHs include Associated Plumbing Industries, Barlow Industries, Steamship Trading Company, and Brian Bell. Assuming that the other three firms sell on average roughly the same number of systems as Associated Plumbing, some 200 SWH systems are replaced per annum. Considering a lifetime of 20-25 years it seems likely that the total number of operational SHW systems in PNG is decreasing.

4.5.5 Solar Photovoltaics

PV technology was introduced to PNG no later than 1978 with the arrival of an Arco solar module. Over the next 25 years, solar PV use has spread gradually. Nearly all solar PV systems (like mini hydro plants) were initially sold to institutions. However, since 1997 solar PV home systems have been accepted in PNG as attractive sources of electricity for specific applications in remote locations. They are now marketed by a number of private suppliers, and range from small systems of as little as 10 w to larger units of 480 w or more. Their principal use is for lighting, followed by communication (HF/VHF radios) and, less frequently, TVs and other appliances.

Figure 4-6 – Solar Water Pumping in PNG

Location unknown, probably 2003

The mission has tried to map two and a half decades of solar PV history in PNG and has probably managed to cover the majority of PV systems installed. However, especially for those commissioned before the mid-1990s, data are far from complete. For the period covered (1978-2003), technical, financial, and institutional data could be found for only a few projects. Despite these limitations, a general picture emerges.

From the government side, the departments of energy, health and education and the state-owned telecommunications company have been involved in numerous solar projects, although it has not been always possible to trace which department was involved in a particular project. There was some involvement of the Energy Division of DPE (then called DME) until the mid-1990s, but its role in solar electrification has since been marginal.

Outside government, there are a small number of active companies plus institutions such as the ATCDI in Lae. In the past decade, the largest PV projects have been carried out by the private companies Enertec, TE (PNG) and RDS. The PNG RE/solar industry has designed and installed numerous PV installations throughout the country, and has often benefited from donor funds. A market for individual solar home systems and lighting kits is emerging. Based on interviews with three companies (RDS, EnerTec, and RadTel), Kopi estimates that some 3000 solar home lighting systems were sold to individuals between 1998 and 2002 (Kopi, 2003). Although it is reported that the number of private companies distributing renewable energy systems has decreased in the past several economically-constrained years, interviews by the PIREP mission suggest that PV sales are being maintained or may be increasing, with one thousand or more PV systems being sold per year.[36]

[36] The PIREP mission requested RDS, EnerTec, Radtel and some smaller companies to provide sales data but this had not been received by the time of writing this report.

Chronological listing of solar PV projects

Solar projects identified by the PIREP mission are listed in the remainder of this section in chronological order to the extent possible.

Figure 4-7 – PV Panels at RDS, Port Moresby

Photo: P Johnston, January 2004

The first large-scale user of solar PV seems to have been PNG Telecom which uses the technology to power repeater sites. Kalimba (2004) has recently inventoried 173 sites were solar PV systems have been installed. His findings appear as Annex 5 to this report. For 92 sites, the output capacity is available. Extrapolating Kalimba's data, the mission estimates that at the 173 Telecom sites, nearly 5000 solar PV panels have been installed since 1978, with a combined capacity of over 200 kWp. For the period 1998-2002, Kalimba counted 1430 new PV panels of at least a dozen different capacities, nearly 300 panels per year. The mission extrapolation suggesting 5000 Telecom panels correlates well with this number of annual panel additions. The mission has no data on the performance of any of the Telecom solar systems but it is reported that some have been stolen.

Kalimba (2004) also reports nine large PV systems with a total of 606 panels and a total capacity of about 43 kW. Table 4-4 summarises the systems and the locations where they have been installed. The mission has no further data on these systems.

Table: 4-4 – Additional PV Systems in PNG

Location	Output (Wp)	No. of panels	Panel rating (Wp)
Mt Iusaka	9900	132	75
Tsili tsili	1960	56	35
Mt Albert Edwards	5850	78	75
Gurney	7200	96	75
Kiriwina	5100	68	75
Mt Konokalang	2100	28	75
Mt Mission	1408	22	64
Mt Tangi	3300	44	75
Kikori	6150	82	75
Total	*42968*	*606*	–

Source: Kalimba, 2004

Another early application of PV technology was for water pumping. A range of donors, including the European Community, the Australian High Commission, and a 'Commonwealth Heads of Government Regional Meeting' (CHOGRM, for Asia/Pacific) project financed at least a dozen PV pumping projects in PNG during the 1980s (Table 4-5). It is understood that the DME designed and installed the systems (Wade, 2004). In 1989 the EU was requested to finance another 28 solar PV pumping systems. The mission found no evidence that these eventuated.

In the late 1980s, DME reportedly initiated a small number of PV projects through a GoPNG Rural Energy Development Programme (PREA, 1992). Under the 1984-1994 Lomé II Paciifc regional energy programme, a dozen PV-powered vaccine refrigerators (three 100 litre Alpha FR 160 units and nine 24 litre Electrolux RCW42 units) were installed in 1988. Eleven of these were still functioning in early 1990 (Johnston, 1994). DME also installed solar PV systems for lighting and water pumping at some eight schools and missions (Kopi, 2003).

In 1991 the DME's Energy Division announced a five-year programme to electrify ten coastal villages using PV technology[37]. Funding was sought from the EU national programme for procurement of the equipment procurement. Apparently the funds were not obtained and no village PV systems were installed.

Table 4-5 – Solar PV Powered Pumping Schemes Designed and Installed by DME, 1983-1989

Location	Number of panels	Pump	Motor	Funding or technical support	Installation date (& cost)
Yule Island, Chiria Village	18 panels	Southern Cross 2X3 piston pump	1/2 hp Honeywell 48V DC motor	EC	1983
Geabada , Village,	18 panels	PM20 SPECK piston pump	1/2 hp Honeywell 48V DC motor	EC	1983
Aipeana Village:	28 panels	SPECK PM30 piston pump	1 hp Honeywell 48V DC motor	EC	1983; worked for 6 years
Amoamoa Village	8 panels (Arco M55)	PM20 SPECK piston pump	Baldour 59V, 1/2 hp motor with 300 Watt maximiser	Forum Secretariat.	?
Jesuabaibua:	10 panels (Arco M55)	PM20 SPECK piston pump	Baldour 59V, 1/2 hp motor with 300 Watt maximiser	EC	
Bonecaina, Rigo:	28 panels (Arco M55)	PM40 SPECK piston pump	Baldour 96V, 1 hp motor with 1400 Watt maximiser	Australian High Comm.	
Veifa'a Village, Mekeo:	14 panels (Arco M55)	PM40 SPECK piston pump	Baldour 96V, 1 hp motor with a 900 Watt maximiser	Australian High Comm.	
Eboa Village, Mekeo	15 panels	PM20 SPECK piston pump	Baldour 59V, 1/2 hp motor with 600 Watt maximiser.	EC	
Borea:	21 panels	direct coupled self priming pump	1 hp Honeywell DC motor	??	1980 (Kina 10,000)
Kwalimarupu, Rigo	15 panels	a down bore mechanical pump	Baldour 96V, 1hp motor with 600 Watt maximiser	C.P Gout ?	1988) (Kina 9,000)
Kaparoka:	10 panels (Arco)	Southern Cross bore hole pump	1/2 hp Baldour 58V DC motor	C.P Gout ?	1986
Orepetana:	4 panels (Arco)	Chinese copy of a SPECK pump	1/3 hp motor and 300 W maximiser	Forum Secretariat	
Inawaia Village:	21 panels (BP Solar 38 Watt)	SP4-8 Grundfos pump		CHOGRM	Dec. 1988

Source: Herbert Wade, pers com. March 2004
Note: A CHOGRM funded solar PV pump in Babaga had yet to be installed at the time of the survey. The design of the solar PV pump in Geabada was not satisfactory and it never worked.

Because of insufficiently developed institutional support mechanisms, the DME's Energy Division did not qualify for full-scale participation in the 1991-1994 PV Follow-Up component of the 1984-1994 EU Lomé II regional energy programme. Instead, it received a single solar PV system for demonstration purposes. The equipment (valued at Fiji $66,962) was to be used for practical technical training for rural electrification staff and to support a facility to demonstrate PV for rural electrification for both government officials and potential users. Due to a change in the location of the demonstration site, the original 20-panel design was too large and was divided into two systems of ten panels each. One system was installed in 1994 at a demonstration house at the DME (now DPE) premises. It included a solar refrigerator, seven fluorescent lights, one 15-watt tube light and a 500 watt 240V 50 Hz inverter for powering a video or other small appliances. The other system that was

[37] The solar programme was planned to run in parallel to the Micro-Hydro Development Programme that was aimed at villages in the interior highland regions.

meant for to PV pumping demonstration had not been installed by late 1995 due to financial and organisational problems at the Energy Division (Wade 1994/5).

As far as the mission has been able to determine, the role of the Energy Division in solar electrification has since been marginal, with a single project (installation of a solar vaccine refrigerator at the Moreguina Sub-Health Centre in the Central Province) since 1995.[38]

A project entitled 'Solar Lighting Kits for Rural Primary Schools' was carried out in 1997 by the Education Department in rural areas throughout the country. With a grant of K15.4 million from the Japan International Cooperation Agency (JICA), the project has electrified 320 schools in all 20 provinces. Each system included solar panels, a controller, a battery, four 40-watt lights and power outlets. In addition to lighting, the systems (320 Wp for lowland sites and 480 Wp for highland sites) could power VHF/HF radios, television sets, video players and low-powered FM/AM broadcast stations.

The JICA project was completed in 1998 (Kopi, 2003) but has never undergone a formal review. However, few of the systems were functioning by early 2004 due (Mears, 2004) to several problems including the following:

- lack of access to maintenance and support services. Although they were trained in maintenance, teachers in rural PNG are very mobile. Many who were trained have moved elsewhere so the maintenance capacity was lost. Although maintenance was available on a return-to-base arrangement, the transport costs were prohibitive for rural schools;
- poor quality installation. Some systems had PV panels orientated in the wrong direction; and
- poor security. Rural teachers rarely work in their home village and students are usually boarders. At the term breaks, schools tend to be empty but schools cannot afford security services. Even with strong mounting brackets, solar PV panels are vulnerable to theft and many have been stolen.

EnerTec was awarded a K2 million project for 296 solar and gas-based vaccine refrigerators in health care facilities in selected parts of rural PNG as part of the GoPNG's Women and Child Health Programme (Kopi, 2003). Later Enertec supplied and installed solar vaccine fridge systems and solar powered medical examination lamps to remote health facilities through two projects funded by AusAid (EnerTec website).

Many of the solar vaccine refrigeration projects (especially those of the International Red Cross) have suffered from inappropriate technical design and panel theft. The Department of Health has reported some success at community run health posts by using panels of distinctive orange colour and combining this with an awareness programme.

Working with the Department of Health, the company TE (PNG) installed 140 vaccine refrigerator units in health centres across the country. TE (PNG) is currently working with the Department of Health on a National Health Services Radio Network

[38] This system, installed in 1999, consisted of two solar panels of 75Wp each with battery storage. The project cost K 15,000 (US$5,883 using the 1999 exchange rate) for a 150 Wp installed system. The high cost was due to high materials and freight charges.

project, installing solar powered HF radios at rural health facilities. Those electrified under the project will be powered by one or two 75 Wp solar PV modules. The project will include a Church Health Services Network to be operated by the Anglican and the Catholic Churches (WB, 2004).

RDS has been involved in the solar electrification of one of the compounds of New Britain Palm Oil Co. Ltd. (NBPOL). The PV systems provide power for homes, schools and clinics, mainly for lighting. The solar electrification of two more such compounds is scheduled for 2004. The company has already received orders for 5,000 solar kits for 2004 (Capon, 2004). RDS in partnership with Courts (PNG) Ltd. Plans to market 50-150 Wp solar PV systems on a retail basis to individual users. The 150 w system costs K 3,000 in cash sales and K 3,444 under a six-month instalment scheme. ESCO outlets have also sold small solar home systems to households in villages.

A number of smaller solar PV projects known to the mission are summarised below:

- according to the SPC,[39] the EU funded 12 PV systems, each with five 75 Wp modules. Further details are unknown (SPC, April 2003);
- ATCDI installed one pumping and two village lighting/vaccine refrigeration systems in 2000-2002 (ATCDI, January 2004);
- Japan funded solar systems at Buin High School in Bougainville and in New Ireland Province. The New Ireland Disaster and Emergency Services will reportedly receive US$70,000 to improve its VHF radio communication;
- Rainbow Power (Australia) has supplied PV to several organisations, including ATCDI, the Australian Baptist Missionary Society, Catholic Health Services, Conservation Melanesia Inc. and many others;
- Rainbow is also providing sophisticated ‘gold-plated’ solar home systems to six households on Mali Island in the Lihir group. Financed by Lihir Gold Mines (K164,000), each system will have 8 panels, 12 batteries, 6 fluorescent lights, a 240 volt inverter and a 220 litre refrigerator (LGM, 2003); and
- In addition to ESCO, EnerTec, TE (PNG) and RDS, the PNG Yellow Pages and PNG Business Directory (2003) include a few more companies that are understood to sell solar energy equipment but no information is available on their solar business.

[39] The source is the SPC Rural Energy and Development Unit, draft database on PV systems installed in PICs (April 2003).

A summary of PV projects identified by the PIREP mission is presented in Table 4-6 below.

Table 4-6 – An Overview of PV Projects in Papua New Guinea

Location	Dept/Agency or Company	No. of systems	No. of PV panels	Capacity per panel	Installed cap (kWp)	Application	Year Installed
Throughout PNG	Energy?	>12	> 210			water pumping	1983-1988
Throughout PNG	Missions?	9	606	about 70	43	various	unknown
Throughout PNG	Telecom	173	about 5000	about 53	205	telecom	since 1978
Health care facilities	Energy	3	18			vaccine fridges	1988
Health care facilities	Energy	9	54			vaccine fridges	1988
Schools, missions, etc	Energy	8				lighting, pumping	1988-1992
Demonstration	Energy	2	10			urban demo	1994?
Various	???	12	60	75	4.5	???	
Primary schools	Education	320	about 1600	80	128	lighting	1996-'98
Health care facilities	Health	296				vaccine fridges	
Health care facilities	Health	7				examination lamps	
Nalogwam	ATCDI	1				water pumping	2000
Gain aid post	ATCDI	1				lighting; vaccine	2001
Erop health facility	ATCDI	1				lighting; vaccine	2002
Health care facilities	TE (PNG)	140	???	75		vaccine fridges	before 2003
Health care facilities	TE (PNG)	maybe>1000	maybe>1000	75		HF radio	ongoing in 2003
New Britain	RDS	One compound				lighting	before 2004
New Britain	RDS	two compounds	maybe 5000			lighting	starting in 2004
Moreguina sub-health	Energy	1	2	75	0.15	vaccine fridges	1999
Throughout PNG	Energy	50	50	small		focal point electr.	2002 onwards

Source: missions estimates

4.6 Experience with Biomass Energy

4.6.1 Bio-energy research

Applied research in bio-energy applications has been carried out and reported at several national renewable energy seminars and workshops. Uppal and Satter (1984) reported on four bio-energy research projects twenty year ago: i) charcoal stove-operated refrigeration for vaccine storage; ii) biomass stimulated absorption refrigerator for food storage; iii) fluidised bed burning of coffee husks for the coffee industry; and iv) cassava for ethanol production.

In early 2004, Unitech and the Forest Research Institute (FRI) in Lae are hoping to renew and expand bio-energy research activities. At the initiative of the Agricultural Department, Unitech staff formed a research group in 2003 that is trying to establish a biofuel research and development centre. The initial focus is coconut oil as a biodiesel, perhaps extending to agricultural residues. The group is awaiting a response to a proposal for support submitted to National Planning (DNPRD) in mid-2003 (Puy et. al., 2003 & Komolong, 21 Jan. 2004). In late 2003, Unitech's Civil Engineering Department initiated plans for a Rural Energy Research Group (RERG), whose activities would include research on treatment of wastewater to generate biogas (Fifaia Matainaho, 21 Jan. 2004).

Unitech and FRI plan to collaborate with the Japanese company Nippon Koei Co. Ltd. in a project for reforestation of denuded grasslands and biomass gasification for power generation at Urara village in Eastern Highlands Province (Nippon Koei, 2003; Nalish, 2004).

4.6.2 Fuelwood use

Traditional energy, mainly fuelwood, is the predominant source of household energy use in Papua New Guinea. A 1981 study indicated that woody biomass accounted for 32.4% of national energy consumption (GoPNG, 1981). Table 2-4 of this report summarises a 1996/1997 survey (GoPNG, 1997a) showing that 87.1% of households surveyed (a sample size of 2% of all households) use fuelwood as their primary cooking fuel**.** Unfortunately, information on the supply and quantity of fuelwood consumed in PNG is unreliable. Considering that fuelwood and woody biomass are practically the only sources of energy for cooking in rural PNG even today, and 87% of the population are rural, the 1981 estimate seems to underestimate the role of traditional energy sources in PNG.

Recent World Bank-supported field surveys in five villages (in East New Britain, West New Britain, Western Highlands and Western Provinces) indicate per capita consumption of fuelwood and woody biomass of 642.4 kg per year. Extrapolation[40] suggests possible national consumption of 974 ktoe of fuelwood, more than the final consumption of 867 ktoe of modern commercial energy reported by APEC for PNG in 2000. On this basis, traditional energy would account for about 53% of national energy consumption in 2000, which is consistent with other lower-income developing countries in the PIC region.

There are no records of fuelwood sales in Port Moresby, Lae, Madang, Goroka, Mount Hagen and other areas were fuelwood is, to some extent, commercialised. Elsewhere people gather wood from their own lands or nearby forests where resources are plentiful. In some peri-urban areas (e.g. near Port Moresby), mangroves are being destroyed as wood is used for cooking, with detrimental effects on biodiversity reportedly already noticeable (Veve, 2004). There is reportedly little or no replanting at present. It is understood that sawdust is being used to some extent as cooking fuel (in Lae and Bougainville) but no details are available.

4.6.3 Charcoal

Table 4-7 – Charcoal Production, Lae 1968-1974 (tonnes)

Year	1968	1969	1970	1971	1972	1973	1974
Amount	134.9	379.7	629.8	600.6	704.1	401.9	101.0

Source: Hermescec, 1981. Note: production near desiccated coconut factory

In the late 1960s, charcoal was produced as a cooking fuel on a trial basis by the Public Works Department in Port Moresby. For a few years when coconut shells were available near a desiccated coconut factory in Rabaul, charcoal was produced for export (Table 4-7). Between January 1980 and June 1981, the DME's Energy Planning Unit and the Office of Forests co-operated to establish charcoal production from portable metal kilns (Hermescec, 1981). There were hundreds of charcoal stoves manufactured and sold in Lae in the early 1980s[41] but charcoal production is not mentioned in the 1992 PREA study and the PIREP mission found no evidence of widespread use today. This seems to be substantiated by the 1996/97 health survey (Table 2-5 of this report) suggesting that perhaps 1000 families nationwide cook with charcoal.

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40 This assumes 4.5 million rural people in 2000, 13.5% of the 0.7 million urban people cook with wood (Table 2.5), and 0.33 toe/tonne of wood at 15% moisture content (Annex 2). This is nearly double the 517 ktoe of biomass consumption estimated by PREA for 1990, which included 462 ktoe of rural fuelwood consumption, 31 ktoe of urban fuelwood consumption, and 25 ktoe of agricultural residues consumption.

41 Personal observation by one of the authors (P Johnston).

4.6.4 Solid biofuels

Progress in utilising solid biomass for electricity generation has been restricted mainly to auto production of electricity from oil palm waste in the palm oil industry, and combined heat and power generation from wood waste in the wood processing industry.

4.6.5 Sawmill/logging

Sawmill residues include sawdust, shavings, off-cuts, bark, veneer cores, plywood fines, and condemned timber. According to the 1992 PREA study, none of the timber industries at that time combined generation of heat and power (co-generation). The PIREP mission has been unable to source much information on co-generation in the timber industry. It is understood that PNG Forest Products in Bololo uses biomass to raise process steam but no quantitative data are available.

4.6.6 Agricultural residues

Use of solid biomass to generate heat is common. Agricultural residues from coffee, cocoa and copra processing are used for (smallholder) crop drying, usually supplemented with fuelwood. The final processing of crops, such as coffee husk, in centralised locations offers great potential for energy self-sufficiency in the processing industry, but this potential has apparently not been taken up to any great extent.

The use of heat gasifiers for crop drying was common in the coffee industry in the Eastern Highlands in the 1980s. A New Zealand company, Waterwide, supplied a number of these units to PNG[42]. According to Sanday (1990), there were over 80 Waterwide heat gasifiers in operation in PNG in 1990. The heat gasifiers were generally used to replace diesel fuel burners in the copra, cocoa, coffee and tea industries. While heat gasifiers had significantly penetrated the crop drying market, there were minor problems resulting from improper operation and maintenance reported in 1990. Given the low cost and cost-effectiveness of heat gasifiers, the 1992 PREA mission encouraged their continued use. The PIREP mission is not aware of the current extent of heat gasifier in use in PNG. However, the DME (Kalimba to Laris, 2002) says that *"the coffee Industry for example there are at present 52 coffee processors ... currently operating in PNG with an average of two wood burners per coffee processor processing an estimated 300 tonnes of wood per plant per year"* The mission has no further details.

In the palm oil industry waste is used to generate electricity. NBPOL generates about 2.5 MWh of electricity annually from palm waste for the factory and workers' quarters. The PIREP mission has no information on palm waste use by other palm oil companies.

Ramu Sugar Mills is establishing a plantation to grow fuelwood to supplement bagasse (sugar cane waste) as a fuel. Currently 50,000 trees (about 50 hectares) are being planted) with plans to expand to one million trees (about 1,000 ha) after five years (Wilmot, 2004).

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[42] The Waterwide gasifier is essentially a close-coupled two-stage combustion system. Biomass is first gasified in up-draft conditions and the hot dusty, and tarry fuel gas is immediately burned in a cyclonic combustion system.

4.6.7 Liquid biofuels

The production and use of biofuels from agricultural commodities has been considered in PNG since Independence. Research and implementation projects included the production of bio-ethanol from sugar cane molasses or cassava and the production of bio-diesel from coconuts. The Ramu Sugar Mill produces ethanol for export but currently it is not used in PNG as a fuel. This is also true of industrially produced coconut oil. Except for small experimental or demonstration projects, there has apparently been no recent commercial development in the use of liquid or gaseous biofuels in Papua New Guinea.

4.6.8 Bio-ethanol from molasses

In the early 1980s, the GoPNG considered the production of alcohol (ethanol) from sugar cane molasses at both Ramu and Baiyer River. The Ramu plant was completed in 1983 (UNDP/WB, 1983). Alcohol production at Baiyer River would have required an investment of more than six million Euro’s.

DoC officer Kari McLeod examines the leatherback turtle. The species is high on the worldwide endangered list. Picture / Glenn Jeffrey

24.05.05

By ANNE BESTON

A giant turtle usually found swimming in the warmer waters of the northern Pacific has been discovered dead on a South Auckland beach.

The leatherback, the largest species of turtle and famous for its hatchlings' race to the sea to escape predatory seabirds and its return to breed at the same spot each year, is an unusual visitor to New Zealand.

"It's pretty amazing to find one in the upper reaches of the Manukau Harbour where it's just mud and oyster shells - not a very pleasant habitat," said Department of Conservation spokesman Karl McLeod.

DNA samples would be taken by University of Auckland researchers and sent to the United States to be added to an international database, he said. The head would be kept for "educational" purposes.

But the rest of the carcass would be buried because, unlike other turtles, the leatherback's carapace, or shell, disintegrated after death.

Mr McLeod said the turtle had died shortly before being found on Saturday but it was impossible to know the cause.

"There was no sign of fishing gear injury from set-netting ... It may just have succumbed to age."

The 2m-long turtle had a 2.4m "wingspan" and weighed about 650kg.

"We had to dissect it before we could deal with it," he said.

Leatherbacks, while rare this far south, can restrict the flow of blood to their extremities, allowing a tolerance of colder water. They are high on the worldwide endangered list.

The turtles were once plentiful throughout the Pacific Rim, nesting on beaches in Mexico, Costa Rica, Malaysia and Thailand.

But commercial fishing, particularly for swordfish, and development on coasts where leatherbacks breed have caused numbers to plummet.

Scientists estimate that nesting females have declined 95 per cent over the past 22 years and they fear that the species, which has survived for more than 100 million years, could be extinct within two decades.

THePNG sought co-financing of 714,000 Euro from the Lomé II regional energy programme but this was rejected (Johnston, 1994). The GoPNG also attempted to obtain direct investment by oil companies and others. When no investment funds could be found, the proposed Baiyer River alcohol plant was cancelled.

The 1992 PREA study reported that Ramu Sugar Mill produced four million litres (roughly 3600 tonnes) of ethanol from molasses annually for several years. At the time of the PREA mission (1991), the ethanol was being blended with motor spirit for sale as a fuel, primarily in the Ramu valley. At that time the commercial value of molasses at Ramu was low but the cost of petroleum fuels was high due to poor transportation and roads. The PREA mission anticipated that this situation would not prevail, and that ethanol was unlikely to play a major role in the energy mix in PNG. The PREA prediction has proven to be correct. In 1995 the distillery was upgraded to produce potable-grade alcohol, the bulk of which is currently exported. Alcohol production at Ramu Sugar was 1952 tonnes in 2000, 2042 tonnes in 2001 and 2160 tonnes in 2002 (IPA website). Potable alcohol fetches better prices than fuel grade alcohol; it is unlikely that alcohol produced in Ramu will be used for energy purposes.

4.6.9 Bio-ethanol from cassava

Research in utilising cassava for ethanol production in PNG started in the late 1970s. A GoPNG team, including DME and Agriculture, visited Brazil in the early 1980s to study the Brazilian experience with ethanol from cassava and other feedstock (personal knowledge, P Johnston). A pilot system was built to evaluate the economics of ethanol production but was abandoned due to lack of adequate agronomic data. Subsequent research in agronomic aspects of cassava by the Department of

Agriculture at Unitech confirmed the potential of cassava for ethanol production (Puy & Sumanasiri, 2003).

In August 2003, a memorandum of agreement was signed between the GoPNG and a Korean company to develop cassava as an export crop. Initially, cassava will be sent to Korea for ethanol production with subsequent ethanol production in PNG (Puy & Sumanasiri, 2003). The proposed plant, originally planned for Lae, is apparently now to be built at Kwilila, about 100 km from Port Moresby (Oa, 2004). The mission has been unable to obtain further details. As is the case with the molasses-based alcohol, use of cassava-based alcohol as a fuel is unlikely as long as it fetches better prices as potable-grade alcohol.

4.6.10 Biodiesel derived from coconut oil

Coconut oil was used as fuel on a small scale in PNG in the 1980s. A project under the EU Lomé II Pacific regional energy programme was to demonstrate small-scale production of coconut oil for use in diesel engines for electricity generation and vehicle use at a rural site near Wewak. A tender was issued in May 1985 but the sole bidder was 30% over budget and proposed a process different from that specified: esterified (chemically changed) rather than simple coconut oil. However, the project proceeded and reportedly produced "usable" fuel for a year or so until late 1987 when the project closed (Johnston, 1994).

No evidence of any additional research into coconut-oil based biodiesel in the period 1987-2002 in PNG was found. Recently, interest has renewed with coconut-oil based biodiesel reportedly tested by Unitech in late 2002 (Liu, Nov. 2003).

Coconut oil is produced industrially at several locations in PNG. Official statistics issued by the Bank of PNG dating back to 1990 show that at least 30,000 tonnes of coconut oil was produced per year during the 1990s. In 1997, two new copra oil mills, operated by Coconut Products Limited (CPL) and PNG Coconut Commodities (PCC) respectively, came on stream.

CPL has been producing and exporting premium grade coconut oil since 1997. On average CPL crushes 50-60 kilotonnes of copra per year, producing 30-36 kilolitres of coconut oil (IPA website). PCC operates an oil mill in Madang. The Madang Coconut Oil Mill was shipped from Tonga in the mid-1990s and is owned by GoPNG-owned Kokonas Industri Koperesen (KIK). KIK ran into financial problems in 2002 and the Madang oil mill was put up for sale. Local copra farmers mobilised to buy the mill in 2003 but it was sold in early 2004 to Elan Trading Corporation of Australia who plan to operate the mill under a 60%/40% joint venture agreement with local growers, through Madang Commodities Ltd (Mathob, 2003 and 2004).

4.6.11 Small-scale biodiesel from coconut oil

In addition to the two large mills, coconut oil is made in PNG at a much smaller scale, using Tinytech or DME™ technology. Tinytech (of Rajkot, India) produces small ("tiny") expellers that can produce some 300 litres of oil per day, using either a 10 hp electric motor or 12 hp diesel engine. Tinytech has sold more than a thousand units globally, including thirteen units to PICs, where they are used for copra expelling (Tinytech website, undated). Three units have been sold to PNG, all in late 2003 – early 2004 (private communication, Gopal Desai, Tinytech, 19 March 2004).

On both Buka and Bougainville, people fuelled vehicles with coconut oil during the ten-year civil war. Coconut oil was also used for lighting in low-income households to replace kerosene. Buka Copra Mill/Buka Metal Fabricators, based in Tegese village (75 km from Buka town) opened an oil mill in December 2003. Using Tinytech technology, they produce some 600 litres of coconut oil per eight-hour shift on a small commercial scale. The oil is used as fuel in three of their vehicles, initially 80:20 coconut oil / diesel blend, but now pure coconut oil. They are also trying to use coconut oil for cocoa frying. However, recent interest in coconut oil as a fuel has been driven by efforts of the Village Industries Research and Training Unit (VIRTU) of the provincial Department of Commerce, who are proposing distributed small-scale oil production to provide bio-diesel for the Buka town supply.

A second Tinytech plant has been delivered to the Toma/Vunadidir local level government. By March 2004, it had not been put into operation. The third Tinytech unit supplied to PNG is (March 2004) bound for Madang.

Direct Micro Expelling (DME™) technology, invented and promoted by Dan Etherington of Kokonut Pacific Pty Ltd, is designed to produce coconut oil at a very small-scale village level. The oil is squeezed from semi-dried and grated coconuts in a hand-operated press. No electric power is needed. The capacity is some 30 litres per unit per day, about 10% of the capacity of a Tinytech system. The oil produced is very high grade and suitable for use in cosmetics, cooking or as a diesel substitute. DME technology has reportedly been supplied to Misima Island in PNG but the mission has no information on its performance (Kokonut Pacific website, undated).

4.6.12 Biogas

Biogas, a gaseous fuel mixture of methane and carbon dioxide produced as organic matter decays in the absence of air, can be produced from animal dung and vegetable wastes. During the 1970s-1980s, hundreds of biogas systems were built in a dozen PICs. Biogas systems in PNG included the Lae City Council plant at St. John's school and the Wagimek coffee plantation in Hagen. Due to technical problems,[43] both plants became inoperative. Currently there is only one biogas plant known to be operational, set-up by Hombrum piggery about 22 km from Port Moresby (Kalimba to Lari, 2002). A small biogas plant at a twenty-pig piggery was under construction in Central Bougainville in March 2004 (Mears, 2004).

In the opinion of the PNG Energy Division, there is scope for many household biogas systems and they consider this to be an economically feasible renewable energy application in PNG (Veve, 2004). The PIREP mission confirmed the potential or costs for household biogas generation and application.

4.6.13 Waste incineration and recycling

A Chinese renewable energy consultant working with the Energy Division in early 2004 intends seeking Japanese support for garbage recycling for fuel in Port Moresby (Liu, pers. com., 19 Jan. 2004). Despite various attempts, the PIREP mission was unable to obtain information on this and other reported initiatives aimed at generating

[43] Failure of anaerobic digestion (biogas) systems has not been not limited to the developing world. Many of the systems built in Europe in the 1980s period suffered from technical problems too. Solutions to the major technical problems emerged in the 1990s. Current biogas systems are technologically mature, and more than two thousand systems generating heat or power are operational in Germany. In China tens of millions of small household biogas digesters are in use. These typically provide only a small amount of biogas that is used without further treatment for cooking.

power from Port Moresby's waste. The size of the NCD population might suggest that a landfill-based biogas generation project might be economic. A study commissioned by SPREP concluded that waste incineration was not suitable for Port Moresby, as it involved expensive and complex technology, required complex operation and management of ash residues, and produced emissions to the air. Prior incineration in Port Moresby had not been successful (Sinclair Knight Merz, 2000).

4.7 Experience with Hybrid Wind / Solar Energy Systems

A hybrid wind-solar energy system of unknown size has reportedly provided power to a highlands school (UNESCO website) but no details are available.

China donated 50 sets of wind generators coupled with PV panels, valued at US$ 236,000, to the GoPNG in June 2002. Each includes a 500 watt wind turbine and two 50 Wp solar PV panels and will be installed at provincial centres at coastal locations. Chinese experts have provided training in installation and maintenance (*PNG Post-Courier* website). The first six hybrid systems were installed in East New Britain Province in 2002 (Kalimba, 2002). Further units were installed in rural districts in Central Province at Bereina Health Centre in the Kairuku/Hiri District and at Kapari in the Rigo District. The installation costs were K 4500 per system (Tobia, 2004). It is understood by the PIREP mission that the bulk of the systems remain to be installed (March 2004).

The PIREP mission has doubts about the long-term viability of these hybrid systems, which are provided to users for free and for which reportedly no operational or maintenance mechanism has been put in place (Veve, 2004). The electronics of several of the hybrid systems failed shortly after installation, according to a local RE equipment supplier who repaired the units (Capon, 2004).

4.8 A Summary of PNG's Renewable Energy Experience

It is clear from Chapter 3 that throughout the country, PNG has enormous resources, which can be tapped for local energy production. There has also been a longstanding interest within the two national universities, particularly Unitech, and several government agencies in tapping this resource, especially for use in rural areas. This chapter demonstrated in some detail the quite considerable and varied experience of PNG over the past twenty years with RETs, primarily hydro, solar and biomass. In the early 1980s, PNG was the PIC's regional leader in the use of biomass energy for agricultural processing, with considerable government support. The GoPNG also supported a wide range of initiatives and studies with biogas, biomass gasification, wood and charcoal cooking, ethanol production, solar PV, and assessments of the hydro and wind resource. These efforts dwindled after about 1985.

Since then, the GoPNG, with donors and NGOs (and ELCOM/PNG Power), has continued some development of micro-hydro and solar PV for schools and health centres but recently the private sector has largely driven RE use. The coffee industry apparently uses about 100 wood-burning driers, the palm oil industry exploits wood waste for electricity, and Ramu Sugar plans to plant 1,000 ha of trees for combustion in its bagasse boilers. At least several thousand new solar home lighting systems are expected to be installed in rural PNG during 2004, overwhelmingly through private initiatives. Yet barriers to the successful long-term use of RETs seem to be considerable. The PIREP mission estimates that three-quarters of the mini/micro hydro systems installed during the past several decades are probably no longer in use.

A very large percentage of PV systems have also failed. This is not an issue limited to RETs; the majority of small C-centre power systems run by provincial and local authorities are not functioning and many others operate poorly and intermittently due to inadequate management and lack of finance. Chapter 5 considers some key barriers that may be associated with, or exacerbated, these failures.

5 Barriers Identified in the Development and Commercialisation of RETs

In the previous chapters, a number of barriers to the development, use and commercialisation of RETs in Papua New Guinea have been raised implicitly or explicitly. This chapter brings together the earlier observations and further barriers. These have been identified through various means:

- interviews held by the mission with about 70 people in Port Moresby and Lae, of whom about two thirds were Papua New Guineans, and the rest foreign businessmen, aid workers, diplomatic personnel or NGO workers based in the country;
- e-mail and telephone exchanges with people familiar with development and/or energy issues in PNG;
- a workshop on "Strengths, Weaknesses, Opportunities and Threats" (SWOT) to RE use and development in PNG attended by a small but vocal group of eight and summarised in Annex 6; and
- review of two earlier papers on barriers to rural electrification and rural energy in PNG: a 2003 field study by PNG student Idau Kopi (Annex 7) and the report of a two-day workshop organised by the World Bank in 2003.

This chapter reflects the findings and views of the PIREP mission. All significant barriers found were verified through the SWOT workshop discussions and interviews. However, the writers do not pretend to be experts on PNG development issues and inevitably relied heavily on the views and experiences of local people and others with long experience in PNG.

For convenience, the barriers are categorised into groups. There are numerous overlaps among categories so classifications are to some extent arbitrary. The barriers have not been prioritised and others no doubt exist.

5.1 Fiscal Barriers

Fiscal barriers to RETs can include those for which government fiscal policies (import duties, taxes, charges) raised for public finance are biased in favour of conventional energy or biased against renewable energy. Customs officials were unavailable for discussions during our mission. Accordingly, we were unable to ascertain rules for exemptions to import duties or excise taxes for fuels or energy consuming equipment. Fiscal barriers were not often identified by those interviewed. However, several issues did arise:

- **Exemptions on fuel taxes.** PNG Power has received a temporary exemption from the ICCC on excise tax for distillate used to generate electricity. However, at less than US 2 cents per litre, this is unlikely to be a major barrier although it could be a small disincentive against using locally-produced biofuels. Fuel for rural electrification is reportedly not exempt from excise taxes, thus in principle, not giving diesel or petrol generators a fiscal advantage.
- **Cross-subsidies of urban fuel prices.** The tentative decision by the ICCC to maintain the same fuel prices for Port Moresby, Lae, Madang and Rabaul in effect provides a hidden subsidy (of unknown magnitude) for the three outer

centres relative to Port Moresby. It is not known the extent to which this might create, or maintain, a barrier to the use of biofuels.

- **No incentives for RETs.** There is reportedly no fiscal incentive for assembling, manufacturing or importing RETs (e.g. solar water heaters; 1PV systems, 2 volt lights for PV use) rather than conventional systems as import duties and taxes do not differentiate between them.
- **No incentives or mechanisms for RET loans**. There are no incentives to financial institutions, or specific mechanisms, to promote RE investments through 'green' interest rates, or access to foreign capital for RE through government support.
- **Cross subsidies for PNG Power electrification**. Because there is a single national tariff, the customers of the three large interconnected PNG Power grids subsidise the electricity consumption of consumers at the smaller and more costly PNG provincial systems. The subsidy has not been estimated but could be substantial in some locations and form a barrier to the use of RETs where these might be more expensive to construct than diesel systems, but less expensive in the longer term.

5.2 Financial Barriers

In early 2004, the GoPNG's Energy Division had about seven staff in the Policy and Planning Division[44] and a similar number in the Engineering branch. Although this is far more than most PICs, the ED has considerably more responsibility. The lack of access to adequate funds for staff, surveys, travel (especially outside Port Moresby) and communications form a real financial barrier to effectively overseeing national RE developments.

Despite considerable income from the export of minerals and oil, and in some ways a dynamic economy, PNG has been unable to maintain per capita GDP at 1975 (Independence) level, has significant regional inequalities in wealth, and the lowest HDI in the Pacific. Facing serious development issues, GoPNG finance for rural electrification and RETs has not been, and seems unlikely to soon be, a high priority.

Other financial barriers.

- **Lack of cash in most rural communities**. Despite high rural incomes in some enclaves, there is very limited economic activity in most rural areas of PNG with little money circulating in the community. Even where people living at the fringes of a mission or government station could tap into electricity supply, they generally cannot afford even low connection fees and usage charges.
- **High costs of business**. The very high start up and operating costs of establishing businesses in PNG, particularly for small businesses serving rural areas, are daunting to those who might otherwise set up a renewable energy service company (RESCO) or other RE business.
- **Lack of recent donor support.** Except for a few small wind/PV systems from China, there appears to have been very limited financial support from donors for new RET development in PNG in the past five or six years.

[44] The mission received three inconsistent reports on staff numbers. This estimate includes the four long-term casual research officers but excludes two professional staff who are overseas for study or long assignments and several support staff.

- **High initial costs of RETs.** Most rural people cannot afford the high initial costs of RETs (e.g. household or community solar PV; micro-hydro) but there are no formal mechanisms (e.g. accessible rural banks or credit) to help them.
- **Willingness to pay.** In many cases, teachers and public servants at remote locations who receive solar PV or micro-hydro power, and have the ability to pay, are reportedly unwilling to pay for energy services.
- **Risky investments.** Rural landowners have no equity for RE investments that the banks will accept as they do not 'own' the land (i.e. cannot sell it). There is reportedly a perception among financial institutions that RETs and energy service companies are perceived as high risks.

5.3 Legislative, Regulatory and Policy Barriers

Although there have been numerous drafts over the years, and an issues papers was prepared in early 2004, there is no national energy policy which has been formally endorsed by either the minister responsible for energy or the NEC. There is no clear policy on rural electrification and inconsistent implementation of existing informal policies. In general, there is a lack of transparent policy direction but a widespread belief that the GoPNG does not consider rural electrification as a high priority. The lack of appropriate legislation, approved energy strategies and policies, guidelines and regulations form a significant barrier to the development of renewable energy. Other specific barriers raised in PNG, with which the missions concurs are as follows.

- **Unclear regulatory framework**. The power utility, PNG Power, is monopolist in areas that are close to the grid and could block others from generating electricity. This is not seen a serious barrier today, but rather a potential barrier as PNG Power eventually becomes privatised and the ICCC develops new guidelines on its operations. Some observers feel that future access to the grid (power purchase agreements) is uncertain whereas PNG Power may be reluctant to undertake some investments when the extent of liberalisation of the electricity supply industry is uncertain.
- **Unclear legislation regarding rural electrification.** There may be some concern with DPE, and certainly with its policy adviser, about ambiguities between the Electricity Supply Act, and the Organic Act regarding the respective responsibilities and powers of PNG Power and provincial authorities for C-centre operations. There are uncertainties regarding possible future obligations of PNG Power to provide rural electrification under the Community Services Trust Act.
- **Lack of legislation for RESCOs.** There is no legislation regarding the operation or responsibilities of renewable energy service companies (RESCOs), or their regulatory oversight.

5.4 Institutional Barriers

In general, financial governance within the GoPNG is weak. The GoPNG has not been able to effectively tap existing or potential sources of finance (donor and other) for RE. Specific issues, some of which are closely interrelated are outlined below.

- **National Government: structure of DPE Energy Division.** According to DPE's own studies, the Energy Division does little research or planning and little capacity for planning or survey analysis. There is reportedly limited capacity for project planning and economic analysis of proposed projects. A better organisational structure for the Energy Division of DPE has been proposed with additional staff, clear responsibilities and work plans. A clear structure and clear role for the division should be adopted along with additional financial support so its functions can be carried out.

- **National and provincial governments: lack of support.** Since the transfer of the functions of power stations (C-centres) to the provincial government by the national government, there has been little support from the national government (project planning and planning methodology, training, finance, operating guidelines, financial guidelines) or from provincial governments to local communities and local governments (oversight of C-centres, financial arrangements for operators' wages, maintenance support).
- **Regional organisations: PNG feels left out.** A number of those interviewed, officials government and outside government, feel that PNG is treated as a marginal country by regional organisations regarding energy, and energy/environment issues such as climate change and GHGs. Projects and initiatives are seen as having limited relevance or benefit for PNG. Whether justified or not, the perception is strong and may form a barrier to working effectively with the regional organisations.
- **Lack of institutional development for RE at provincial and community level**. In general, the GoPNG (and some private companies) have assisted with hardware for RE in the absence of adequate institutional arrangements for revenue collection, operation, maintenance, technical support, spare parts, financial accountability, etc. In general, there is a lack of access to ongoing support services.
- **Short-term donor policies.** The donor community tends to have a short-range approach to support for RE, often providing hardware but little or no support to assist the GoPNG develop institutional arrangements for RE, discussed immediately above, to be sustainable after the donor departs.

5.5 Technical Barriers

Most technical barriers in PNG seem to be related with poor knowledge of available RETs and conditions where they are appropriate, rather than technical deficiencies. Key barriers to more use of RE in PNG which are in part technical are listed here.

- **Limited knowledge of renewable energy resources**. Most surveys of the hydro, wind and solar resources are two decades old and were of limited scope even when carried out. Their accuracy and practicality today are questionable. There is little information on the amount of biomass actually available for energy use, its seasonality, geographic locations near areas of energy demand and likely price.
- **Lack of commercial technologies to exploit all renewable resources.** There are no commercially available, proven technologies that can be used to exploit sea waves, ocean current or OTEC resources.
- **Limited support for increasing local technical knowledge**. Unitech had a significant level of financial support and encouragement for its work in RE during the 1980s but very limited support today for its efforts to demonstrate and adapt RETs appropriate for the country.

- **Limited knowledge of biofuel potential**. Although there appears to be considerable potential for displacing a large portion of imported petroleum fuels with biofuels (biodiesel and ethanol), and this potential has been known in PNG for twenty years, there has apparently been limited study since then on practical technical and economic options, for both vegetable oils and ethanol from sag and nipa palm.

5.6 Market Barriers

PNG is very rugged with a small communities, many accessible only by air, dispersed over 600 islands. A large percentage of the population is effectively outside the cash market economy. Among the identified market barriers associated with PNG's environment are the following.

- **Small market size.** Although PNG is far bigger than other PICs, nonetheless the local market is too small for local manufacture of most RETs and too small to attract some suppliers who are willing or able to provide back-up or technical services.
- **Dispersed population, isolation and poor accessibility.** Rural communities in PNG are neither compact nor concentrated, with small villages often more than two hours walking distance from each other. In many ways, not just market access, this forms barriers to development of RETs. The cost of project development, technology, spare parts, training, support, etc. are extremely high. The risks to entrepreneurs trying to serve such a market can also be very high.
- **Lack of productive demand for electricity.** The potential market for RETs is also reduced by the lack of easily identifiable or viable economic that could productively use electricity. High freight charges to transport produce to urban markets discourage farmers. There has been a change away from cash cropping in recent years, exacerbated by a current shortage of agricultural field officers in local centres who can advise people on suitable farming methods.

5.7 Knowledge and Public Awareness Barriers

Key knowledge barriers identified are:

- **Low level of public awareness of RETs.** In PNG, with many hundreds of languages, there is low awareness of RETs and it is difficult to reach much of the population. There have been a number of workshops on energy and climate change issues but was no evidence (in English) of public awareness campaigns on energy or climate change during the mission, although these may well exist.
- **Low level of technical knowledge regarding RETs.** Few people know the practical potential and limitations of specific RETs, e.g. where they are or are not appropriate, what energy demands they can supply economically, how to estimate energy demands in a community, etc. A substantial number of RETs have been poorly installed.
- **Inadequate training resources.** PNG has technical training institutes in most, if not all, provinces and two national universities. Despite some knowledge of RETs, training is inadequate, insufficient numbers of people are trained, and curricula are very weak. There is a lack of management skills needed to plan and manage RETs and the technical skills needed for operation

and maintenance. Those who are trained are highly mobile so training at provincial and community level needs to be regularly repeated and updated.

5.8 Private sector Barriers

There is inadequate experience and knowledge within the private sector regarding technical, institutional, financial and management aspects of RET development.

5.9 Environmental and Social Barriers

For those who wish to develop RETs, long-term secure access to land was considered to be a serious barrier. As elsewhere in the region, traditional landowners are very protective of their rights and it can be very difficult to get access to land for RE, especially if it is believed to benefit government, outsiders, or only a few landowners, or others. In some cases, a few dissident landowners (or those who claim to have land rights) have stymied developments. Environmental issues are covered in more detail in Chapter 7. Several environmental and social barriers identified are the following:

- **vulnerability.** PNG is the most vulnerable of all PICs to natural disaster. For a wide range of RETs, equipment or the resource itself (e.g. biomass) can be quickly destroyed;
- **anti-hydro perceptions**. In some communities, there may be a bias against hydropower because of perceptions of extensive downstream damage associated with mining projects, rather than with hydropower *per se*. The mission saw no evidence that this was likely to be a serious barrier; **land access.** Access to customary land (i.e. most land in PNG) at a cost fair to both landowner and developer is increasingly difficult. Compensation demands are serious obstacles and can continue for years. Crossing land boundaries with transmission lines requires compensation, possibly reducing opportunities for local grids or grid-connected renewable energy;
- **little sense of ownership or responsibility.** People often perceive government-supported projects as public assets and are unconcerned about their long-term operation. Developers are often alienated from the community; there is little sense within the community of ownership or responsibility for RETs on their land. It can be difficult to determine who is responsible for management of an RET scheme;
- **high frequency of theft and poor security.** Related to the above point, there has been a very high degree of theft of PV modules and associated equipment from schools, health clinics and telecommunications facilities. Rural teachers rarely work in their home village and students are usually boarders. Between school terms, the compounds tend to be empty but schools cannot afford security services. Even with strong mounting brackets, solar PV panels are vulnerable to theft and many have been stolen;
- **lack of respect for law and order.** PNG has suffered from a lack of respect for the rule of law in general, at personal and political levels. It is reportedly not unusual for politicians to undermine the work of predecessors, including rural RE installations. There has reportedly been considerable vandalism of RETs at government facilities;
- **continuing social instability.** Although the Bougainville unrest has ended, there are continuing demands for greater autonomy and secession in several parts of PNG; and

- **misuse of ethanol.** A possible barrier to the use of ethanol as a fuel is a perception among some that it will be used for illicit drinking. This could well be a problem with small-scale rural production but could be more readily controlled at industrial scale where dyes and emetics can be added if necessary. The mission does not know the extent to which this may be a serious barrier.

6 The Capacity Development Needs for Removing the Barriers

This chapter examines the capacity development needs of PNG. Addressing these may help to remove or reduce key barriers identified in Chapter 5[45]. These are not prioritised. It is not suggested that those listed are necessarily appropriate for addressing though further GEF support. Many of the suggestions below do not fit exclusively, or even primarily, into one category: issues addressed under, for example, fiscal barriers may be applicable to several others. There is also some repetition with similar issues covered under more than one heading. Finally, it is easier to identify barriers than practical means to remove them (or most would have been removed long ago). The suggestions in this chapter are tentative and incomplete.

6.1 Fiscal Barriers

Section 5.1 identified several possible fiscal barriers to the development and commercialisation of RETs including petroleum fuel pricing and cross-subsidies, electricity tariff policies, and lack of 'green' interest rates or incentives. The following could help to address these issues:

- **Import duties and taxes.** The capacity within government is limited with regards to analysing the effects of interest rates, import duties, energy prices and taxes on the development of RET and EET measures.

6.2 Financial Barriers

Access to finance is a major barrier to RET development in PNG simply because so many people are largely outside the cash economy. Low government budgets are a serious constraint to rural electrification overall (in a country with perhaps 10% electrification overall and 5% in rural areas) and where rugged terrain in isolated islands means that electrification (and rural services in general) are very expensive to provide. The effective use of available – or potentially available – finance is a constraint. Some of the barriers identified under 'finance' are discussed in this section, others under other headings. Some e.g. the general lack of cash and high cost of doing business in PNG, can't be dealt with by energy interventions in isolation.

- **Lack of capacity to develop suitable project documents.** The increasing competition for limited donor funds has made the preparation of high quality, well developed project requests necessary. The GoPNG and NGO sectors have insufficient capacity to prepare the complex documentation required by multilateral finance organisations such as ADB and GEF and the high quality project proposals needed to be competitive for funds from bi-lateral donors.
- **Capacity to collect energy payments.** There is a lack of capacity for collection of rural service payments even as regards salaried government employees. The GoPNG should develop clear rules for public servants (at least those paid by the national government) serving in rural areas regarding payment for utilities and services such as electricity. Perhaps payments could be deducted from their salaries as is done in some PICs (assuming a

[45] Some of the same or similar recommendations are made in other PIREP reports. In some cases, it may be appropriate to carry out similar studies concurrently in several countries, or through a regional effort. This is discussed in volume 1 of the PIREP analyses, the regional overview.

mechanism exists, or can be developed, for payment into an appropriate account).

- **Import duties taxes and energy pricing.** The capacity within government is limited with regards to analysing the effects of interest rates, import duties, energy prices and taxes on the development of RET measures.

6.3 Legislative, Regulatory and Policy Barriers

Section 5.3 concluded that the lack of legislation, approved energy policies, guidelines and regulations form a significant barrier to the development of RE. Donors and lending agencies typically expect a clear policy/legislative/regulatory framework to be in place before approving new energy assistance, or sometimes developed as part of this assistance.

- **Energy Division capacity.** Capacity is lacking at the energy division. in many areas of RET development and project management. A clear vision of the responsibilities and authority of the division needs to be established so a focused capacity development programme can be implemented.
- *Limited capacity to develop policy and legislation*. The Energy Division, the Finance Ministry and NGOs do not have the capacity to develop a comprehensive national energy policy or legislation regarding energy that includes the wide range of issues facing Papua New Guinea.

6.4 Institutional Barriers

Some institutional issues have been considered above. Others include the following:

- **capacity to determine the value of a Rural Electrification Authority.** The DPE has proposed, several times, the creation of a Rural Electrification Authority. There should be development of the local capacity to prepare a neutral, disinterested comprehensive study of the costs, benefits, criteria for success (including training, financial needs, technical support), legislative requirements, tariff policy, its relationship with PNG Power (and RESCOs), and its relationship with provincial and local authorities; and
- **regional organisation capacity development.** It would be appropriate for the GoPNG, with other PICs, to express in writing to the CROP chair any concerns it may have regarding the Energy Working Group or relationships among CROP agencies that it feels needs development to better provide effective RET implementation in the country and the region.

6.5 Technical Barriers

There is an absence of accessible and appropriate technical information on which to make energy choices. Some technical matters relate to the suitability of various technologies for use in PICs in general, and can perhaps best be addressed on a regional level.

- **Capacity limits for measuring the RE resource.** There is a need to develop the local capacity to carry out assessments for wind, biomass and small hydro resources and to clearly understand the processes involved for the assessment of geothermal and oceanic energy resources. There is relatively little information or experience available in PNG regarding the magnitude and accessibility of RE resources. The extensive possibilities for small hydro development need closer examination. It would also be appropriate to seek funding to monitor promising wind sites for a period of 18 months or more. For geothermal, the high cost of exploration suggests that further drilling should be left to proponents and potential investors (including GEF and IFC). If there are regional efforts to assess ocean energy potential, PNG should participate but not put its own financial resources into this.

- **Biofuels.** There appears to be inadequate capacity within government to enable the development of biofuel as a large scale alternative to petroleum. There is need to develop capacity for technical development, for analysing the effects of large scale (up to 200 ML/year) biofuel production on government revenue and determining other financial issues as well as developing the logistics required for large scale production and delivery of biofuels to urban centres.
- **Lack of easily understandable reference materials regarding RETs publicly available in PNG.** Although the Internet has many technical resources for persons wishing to understand RETs, the access to the Internet in PNG is not wide spread, tends to be slow and computer literacy low. Also, the wide range of information available on the Internet and its highly variable quality makes it is difficult for the novice to be able to determine which is appropriate to PNG. There needs to be developed a local repository of information that can be accessed by anyone wishing to gain knowledge about RETs appropriate to PNG, their cost, applicability, operation, maintenance and opportunities for use. Further, the resource needs to be somehow made available country wide, not just in one urban area.[46]

6.6 Market Barriers

Market barriers identified as constraints include the lack of affordable transport to rural communities (generally by air or foot), the small market size, dispersed population, and lack of productive demand for electricity. Incentives for local people to establish businesses to provide RE services have been discussed. Considering that PNG already has a large market for RETs (at least PV systems) by PIC standards, and has installed hundreds of micro/mini hydro systems, a study of the reality and seriousness of market barriers to RETs, and ways to overcome them, is warranted.

6.7 Knowledge and Public Awareness Barriers

No studies have been carried out in the region on the effectiveness of awareness campaigns on energy efficiency or renewable energy but studies in developed countries suggest that impacts are generally both very limited and temporary. In PNG, it may be appropriate to include materials on energy efficiency and RETs in school curricula but it is probably not an effective use of public funds to prepare public awareness materials on RE unless focused specifically on the implementation of an RET project..

Training in RETs to date has focused on government officials. There is a large demand for more information and training for NGOs and the private sector.

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[46] SOPAC published a number of technical reports in 2001 and 2002. Issues covered include: hydrogen fuel cells (report MR0416, 2001) OTEC (report MR0417, 2001), space solar power (MR0418, 2001) and geothermal (report MR0452, 2002). No coverage of solar PV, solar thermal, wind, hydro or biomass. It may be worthwhile exploring whether existing materials could be adapted/extended to cover specific PIC needs.

6.8 Private sector Barriers

There is clearly a demand in both the private and public sectors for relevant and practical training for local persons in various aspects of RETs for designing, marketing, installing, operating, maintaining, and repair of RET systems. However, the team had no opportunity to assess the extent and effectiveness of the range of RE training already carried out by regional agencies, donors, NGOs and others. During 2004, the UN's Economic and Social Commission for Asia and the Pacific (ESCAP) is developing a regional RET training programme, in cooperation with regional organisations, specifically for PICs. No specific suggestions are offered here, except that private sector and NGO staff should be included in RE training; thus far it has concentrated overwhelmingly on government officials.

6.9 Environmental and Social Barriers

The key barriers to RETs most frequently described as serious in PNG, are: i) access to land with secure arrangements for the long term; and ii) the lack of law and order and associated theft of, and damage to, RETs. There is a need to develop the capacity to deal with landowners in a manner which gives them incentives to allow the use of their land for RETs and to keep them operating over time.

6.10 Hardware investments to Remove Barriers

Table 2-12 indicates that large scale hydropower may offer the most opportunity for indigenous energy development in PNG with the potential for substantially reducing GHG emissions from modern sector energy use, followed by biofuels (both biodiesel and ethanol) and geothermal. To the extent that GHG reduction is a priority, investments for these large scale RETs, where environmentally appropriate (see chapter 7) should be considered. However, the team feels that it is not appropriate to make any firm suggestions based on a short time in country and the necessarily somewhat superficial study of PNG's energy sector issues.

Choices regarding RET development in PNG should not be made solely on the basis of their potential impact on GHG emissions, which in any case are nearly inconsequential on either a global or per-capita basis.[47] For PNG, the development impacts of RETs are likely to be greater through a large-scale programme of community scale investment solar PV and micro-hydro, including the development of appropriate institutions for their finance and operation, than large hydro, geothermal or biofuel. A rural energy initiative based on stand-alone PV, micro hydro, and possibly small wind systems in appropriate locations, should be seriously considered if donor funding is available.

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[47] Papua New Guinea has no legal obligations to reduce GHGs and is an insignificant producer on a global or even regional scale. The *Climate Analysis Indicators Tool* (CAIT) of the World Resources Institute (WRI, 2003) calculates national emissions to the nearest 1/100 of 1% of the global total. PNG's emissions, by far the largest of the Pacific Island Countries, are shown as 0.03 percent.

For GHG emissions and energy production from RETs, Table 2-12 suggests that the biggest impacts in PNG may come from investments in large hydropower, ethanol as a fuel, geothermal, biodiesel and small hydro respectively. Any of these, if poorly planned, could have significant environmental impacts. Each is discussed briefly below.

7.1 Large hydro (Over 10 MW)

The International Rivers Network (IRN), an NGO which lobbies strongly against hydro projects above 10 MW, alleges that major hydro expansion harms: i) efforts to move toward sustainable development, ii) people and ecosystems, and iii) energy security. Among other dangers, they list increased vulnerability to climate change (due to climate and weather changes) and the emission of significant amounts of GHG from large reservoirs (due to rotting organic matter)[48] (IRN, 2003).

> While some feel that IRN is alarmist, there has been a history of poorly designed and implemented large hydropower developments throughout they world. There can be significant and irreversible effects on surface water, groundwater and other aspects of water transfer within the hydrological cycle during project construction, project operation and maintenance, and decommissioning. In some cases, there are impacts during the planning phase, probably indirect off-site effects as materials are mined or fabricated in preparation for plant construction. For hydropower, the area of influence is very wide, extending from the upper limits of the watershed catchment to the valley below the dam and as far downstream as the estuary and off-shore zones. The most severe direct hydrological impacts are likely to result from the impoundment of water, flooding of land to form a reservoir, and the reduction of water flow downstream. Potential indirect effects can be caused by construction and operation of work camps, access roads, and power transmission facilities, for example soil erosion affecting surface and ground water. The potential hydrological effects of the environment on the dam depend on land and water use in the watershed area upstream of the reservoir. Often relocations of population from the inundated reservoir area can increase pressures within the watershed resulting in changed land use patterns which increase erosion and subsequently sedimentation in the reservoir. The main hazard risk is a failure of the dam resulting in a sudden and massive flow of water downstream (Johnston, 1994a).

The World Bank (1991) lists the following potential, and often real, hydrological impacts of large hydro dams:

- decomposition of trees in flooded land, causing nutrient enrichment in the reservoir and increased water loss through transpiration;

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[48] IRN lists 12 reasons to avoid large hydro in three categories. A) A major expansion of large hydro will harm sustainable development: 1. Large hydro does not have the poverty reduction benefits of decentralized renewables; 2. Including large hydro in renewables; initiatives would crowd out funds for new renewables; 3. Promoters of large hydro regularly underestimate costs and exaggerate benefits; 4. Large hydro will increase vulnerability to climate change; and 5. There is no technology transfer benefit from large hydro. B) A major expansion of large hydro will harm people and ecosystems: 6. Large hydro projects have major negative; social and ecological impacts 7. Efforts to mitigate the impacts of large hydro typically fail; 8. Most large hydro developers and funders oppose measures to prevent the construction of destructive projects and 9. Large reservoirs can emit significant amounts of greenhouse gases. C) A major expansion of large hydro will harm energy security: 10. Large hydro is slow, lumpy, inflexible and getting more expensive; 11. Many countries are already overly dependent on hydropower; and 12. Large hydro reservoirs are often rendered non-renewable by sedimentation. The source is IRN (with Oxfam and other NGOs, 2003).

- creation of reservoir dramatically changing water flow (quantity and timing), water quality, and sedimentation within river basin;
- disrupted water flow to downstream communities, initially with greatly increased sedimentation and later reduced quantities of water;
- loss of wetlands downstream of reservoir;
- sedimentation in reservoir reducing storage capacity and lifetime, reducing nutrient-rich silt downstream, increasing riverbed scouring downstream;
- altered water table upstream and downstream plus resulting salinisation;
- reduced flow of water at times to communities downstream;
- reduction in fish production (and catches) downstream;
- increased pressure on upstream land due to resettlement followed by poor watershed control (agriculture in steep areas, grazing, deforestation,) causing erosion and increased sedimentation in the reservoir;
- deterioration of water quality in reservoir;
- sedimentation at reservoir entrance causing waterlogging and flooding upstream;
- decrease in water for floodplain agriculture. Floodplain salinisation;
- chemical contamination of water during maintenance of transmission lines and towers;
- released water from lower portion of reservoir for power is high in pH, low in oxygen, high in hydrogen sulphide and is cold, all affecting animal and plant communities downstream;
- seismic events causing catastrophic dam collapse with sudden massive water flow downstream; and
- conflicting demands for water uses.

Many potential sites for large hydro development in PNG could, and probably would, be developed as run-of-river systems, greatly reducing potential impacts. In general, any large hydro developments in PNG should be planned, built and operated in accordance with the recommendations of the World Commission on Dams (WCD; guidelines, available from www.dams.org and see a Citizen's Guide to the World Commission on Dams, available from www.irn.org).

7.2 Small hydro (Under 10 MW)

The International Association for Small Hydro, the European Small Hydro Association and the International Energy Agency's Renewable Energy Working Party all define small hydro as less than 10 megawatts. The IRN says *"small hydro can, if responsibly implemented, be environmentally and socially low-impact. … To ensure that small hydro projects have low impacts and meet community priorities it is imperative that all small hydro schemes are planned, built and operated in line with the recommendations of the World Bank/IUCN-sponsored World Commission on Dams." (IRN, 2003).*

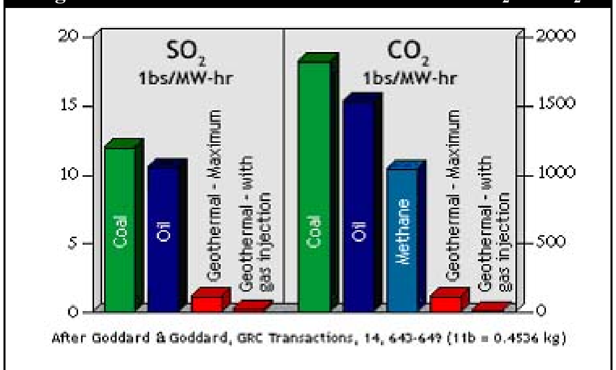
7.3 Ethanol fuel

In section 3.6, it was noted that the G0PNG estimates that 58% of land area is subject to strong or severe erosion, 18% is permanently inundated or regularly flooded and about 200,000 hectares are cleared annually for traditional agriculture. Environmental issues regarding the production of ethanol as a fuel in PNG are essentially those of biomass energy use in general: conversion of forests to biomass plantations, encouraging clear cutting, nutrient draining, use of toxic chemicals, increased erosion, and possibly loss of wetlands.

7.4 Geothermal

Citizens United for Renewable Energy and Sustainability (CURES), a recently formed international NGO network, has defined new renewable energies as including: *"modern biomass, WCD-compliant small (up to 10MW) hydro,* ***geothermal*** *(emphasis added), wind, all solar, tidal, wave and other marine energy. Modern biomass includes improved use of traditional biomass such as 'smokeless' efficient cook stoves as well as electricity generation, heat production and liquid fuels from carbon neutral and low input, sustainable sources of biomass" (CURES website:www.ee-netz.de/cures.html*)

Figure 7-1 – Geothermal Power Emissions of SO_2 & CO_2



Source: www.eere.energy.gov/geothermal/environ_impacts.htm

Although geothermal has not traditionally always been considered renewable (as reservoirs eventually deplete, at least temporarily) or benign (due to hydrogen sulphide – H_2S – and other toxic emissions), it is now considered (Figure 7-1) as an environmentally friendly RET. According to the US Department of Energy *"geothermal power plants easily meet the most stringent clean air standards because they emit little carbon dioxide (fossil-fuel power plants produce roughly 1000 to 2000 times as much), no nitrogen oxides, and very low amounts of sulphur dioxide (SO_2). Steam and flash plants emit mostly water vapour. Binary power plants run on a closed-loop system, so no gases are emitted."* For [plants containing H_2S], the sulphur can be *"separated, dewatered, and recycled as feedstock for sulphuric acid production. Future technology will use microbial processes to extract metals contained in the sulphur, allowing further reuse. At most geothermal hot-water power plants, H_2S is present in such low concentrations that it requires no special controls to comply with environmental regulations. ... A typical geothermal plant requires several wells. Although drilling these wells has an impact on the land, using advanced directional or slant drilling minimizes that impact. Several wells can be drilled from one pad, so less land is needed for access roads and fluid piping." (USDoE website, undated).*

7.5 Biodiesel

The issues indicated in section 7.2 could equally apply here. However, it has been assumed (Table 2-12) that only about 10% of vegetable oil production in PNG might be used for fuel so the impact should be no more severe than current practices.

In terms of use, biodiesel fuels from coconut, oil palm or other vegetable oils are very low in emissions, as they contain almost no sulphur or hazardous materials. In case of spillage to the ground or marine environment, they biodegrade readily and do not cause contamination.

No firm projects were identified as possible co-financing opportunities at this time. The following are recommended as specific studies and co-financing opportunities for capacity development.

- **Biofuels.** A study of the impact of the production of coconut oil-based biofuel in PNG should be carried out at several scales: i) a scale of 20-200 ML per year to replace a large percentage of national distillate imports for power generation and transport; and ii) small-scale production for remote islands and communities to displace distillate for rural electric power and ground transport. The study would consider technical, economic, financial, political, and social issues. It would estimate the effects of various scales of biofuel production on government revenue, including the effect of direct and indirect employment, tax revenues, etc. The report would consider whether it is in the interest of the GoPNG to produce biofuels at various scales and, if so, recommend a strategy to support this development.
- **Import duties and taxes.** A study should be undertaken of the rates of import duties and related taxes, exemption policies, and procedures for establishing duties to determine the extent to which there is a bias for or against the development and use of RETs at small scale (rural, small community) and national scale (grid connected). It would also consider duties and taxes on petroleum fuels and electricity production. The study would recommend changes that encourage the import, possibly manufacture or assembly, and use of RETs, including tools, appliances, and associated monitoring equipment, etc. It would consider the pros and cons (and legality under treaties, conventions and international obligations) of differential import duties on devices that are energy efficient or use indigenous resources.
- **Development of capacity for effective RET project document creation for donor funding.** Though there has been a significant level of support from PNG 's traditional donors for RETs, support has fallen off in recent years and there was no ongoing support found in early 2004. Donor organisations today increasingly require high quality project documents with clear economic analysis components, budgets with realistic justifications, well developed logical frameworks and action plans. In particular, the requirements for preparation of acceptable project documents for GEF and ADB are complex and demanding. The capacity of both the private sector and government to develop clear, logical and adequate project documents is limited and training is needed so donor funding can be accessed on a scale appropriate to the need.
- **Green interest rates.** An assessment should be made of the need for, and practicality of, special interest rates, subsidised by the government, for (majority) locally-owned businesses for the establishment of RE services, including design and installation, operation and maintenance, repair and refurbishing, training local personnel in use of RETs, production of training materials in local languages, etc. If it appears that "green" rates would be a useful incentive, an interest subsidy fund or special government loan arrangements for private RET development should be developed.

- **Energy policy development.** Advisers funded under external development projects and working closely with the GoPNG and the NGO community, should assist in the review of national energy policy and rural energy policy, and prepare practical policy documents for consideration by cabinet. These should include strategic plans with activities, timeframes, priorities, and budgetary requirements. The CROP Energy Working Group's Regional Energy Policy and Plan provides a possible starting point. The DANIDA/UNDP/SOPAC Pacific Islands Energy Policy and Strategic Action Planning project (PIEPSAP), expected to run from about August 2004 for three years, is designed to provide this sort of service but may need co-financing to meet specific capacity development needs.
- **Energy Division**. The functions, authority, and responsibility of the Energy Division should be clarified. If not already done, an up-to-date staffing structure and job descriptions should be prepared and approved at the appropriate level. Any responsibilities of the Energy Division for coordinating energy sector activities overall, providing information to the public and its relationship to other committees or advisory groups with an energy mandate (e.g. NAACC, PIREP, PIEPSAP, etc.) should be included. Once these functions, authority and responsibilities are clearly defined, a focused capacity building effort needs to be launched.
- **Development of a public information resource for RETs**. Financing to develop a library of RET information materials specifically selected and developed for the PNG government, NGO and private users is needed as is selection of suitable repositories for that library. The recent tendency by the donor community to develop such materials for Internet delivery while ignoring the development of traditional library materials is not suitable for PNG due to the low level of Internet connectivity and the slow data rates generally encountered. Without an information resource covering past experience in PNG, other Pacific experience and general issues of economics, technology, management, etc. organisations wishing to develop RETs in PNG may have difficulty developing the technology without a long trial and error period repeating the costly errors already made in other parts of the Pacific and around the world. Entries could include:

- *reports on RETs of immediate relevance to PICs*. There have been a number of technical reports prepared over the years by donor agencies and others on RETs and their potential suitability for the PICs. Some are out-of-date, inaccessible, biased or too technical or academic in style. It may be useful for a series of short but authoritative technical reports to be prepared (by SOPAC, SPREP or the two jointly) and regularly updated which provide an overview of technical, economic, social, and environmental aspects of RETs of particular relevance to PNG and other PICs. These might initially include solar, wind, and biofuel from coconut oil.[49]
- *RETs of potential relevance to PICs*. There has been considerable hyperbole regarding ocean energy for the Pacific. It would be useful to have a series of short authoritative reports which explain the extent to which ocean energy systems are

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[49] SOPAC published a number of technical reports in 2001 and 2002. Issues covered include: hydrogen fuel cells (report MR0416, 2001) OTEC (report MR0417, 2001), space solar power (MR0418, 2001) and geothermal (report MR0452, 2002). No coverage of solar PV, solar thermal, wind, hydro or biomass. It may be worthwhile exploring whether existing materials could be adapted/extended to cover specific PIC needs.

commercially proven and suitable for adoption by PICs in the near future. Perhaps even more useful in the short term would be a critical (in the positive sense) assessment of hybrid energy systems (e.g. wind/solar; RETs/diesel), experience in the Pacific and elsewhere, and their suitability for use in remote areas of PNG and other Pacific islands.

The team notes that in the 1980s, a technical resource library on renewable energy, the 'Commonwealth Regional Renewable Energy Resources Information System' (CRRERIS), was developed by Australia and located in Canberra specifically for the use of the PICs. The effort was somewhat unsuccessful because of inconvenient access, communications problems and the complexity of searching for useful documents. Also the collection was largely academic in nature, all in the English language and not always pertinent to the needs of the PICs. To be useful in PNG, the team believes that it will be necessary for a similar information library to be locally based in several locations around the country, to be carefully fitted to PNG's needs and provided in both print and electronic formats conveniently accessible to public and private users.

- **Provision of Support for Unitech RET activities**. Unitech has a wealth of experience that is not being adequately used. It may be a suitable institution to support for national and regional training on the practical management and use of RETs and can assist in the preparation of a national RET library focused on PNG appropriate technologies and PIC experience.
- **Assistance in resource assessment capacity development.** A programme to assist the Energy Division and other appropriate agencies to develop the capacity to locally perform wind, hydro, biomass and solar resource assessments is needed. Also, assistance in increasing the local capacity to specify and select contractors for geothermal and ocean energy resource assessments is needed.
- **Development of a local capacity to prepare RET operation and maintenance training and manuals in the local languages.** Developing the capacity of rural technicians to install, operate and maintain RET systems requires local language training. This will require external assistance to develop the manuals and training in a metropolitan language then assist local language experts to develop a standard vocabulary for the technical terms and procedures that have to be expressed in the local language as well as translate the documents into the local language.
- **Assistance in understanding market structures for RETs.** Market barriers identified as constraints include the lack of affordable transport to rural communities (generally by air or foot), the small market size, dispersed population, and lack of productive demand for electricity. Considering that PNG already has a relatively large market for RETs (at least PV systems) by PIC standards, and has installed hundreds of micro/mini hydro systems, a study of the reality and seriousness of market barriers to RETs, and ways to overcome them, is warranted if large-scale private sector development is desired.
- **Vandalism and theft.** The extent of this vandalism and theft problem, and the degree of success of the PV panel painting and awareness campaign, should be ascertained. Guidelines for protection of the systems should be prepared and

disseminated (along with appropriate training and awareness) for any new PV systems and similar preventive measures designed for other RETs.

- **Land Access study.** A study with follow-up recommendations for action should be carried out on options and opportunities to involve landowners as potential partners rather than opponents in the development of RETs both small scale (for community, health centre, school, etc. applications) and larger scale (feeding to a grid). This should include case studies of successful and failed approaches in PNG and elsewhere.
- **Preparation of guidelines for village scale hydro development**. Existing international guidelines for hydro development are for much larger scale implementations than useful for village hydro development in the 5-20 kW range for which there are a large number of opportunities in PNG and Melanesia in general. Financing is needed for the development of guidelines for technical assessment, environmental impact assessment, economic analysis, technical design, institutional possibilities, operational requirements and maintenance requirements.

8.1.1 Hardware investments for co-financing

The following investments have the highest short-to-medium term potential for reducing GHG emissions from petroleum energy nationally..

- **Biofuel**. By far the largest potential impact on GHG emissions of new RE investments based on known resources in PNG would be from large scale use of coconut oil as a biofuel. This could eliminate up to two-thirds of the 2003 level of national GHG emissions from petroleum fuel use.
- **Geothermal.** The second largest impact would be from construction of the proposed Efate geothermal plant, which could displace the equivalent of 15% of 2003 emissions initially, more if a second plant were added later. The mission has no information on the likely emissions of sulphur dioxide (SO_2), a major pollutant from some geothermal schemes, or other potentially negative environmental effects of geothermal development in PNG.
- **Hydro.** The third largest impact would be from mini and micro hydro, which could displace 13% of current CO_2 emissions from petroleum, assuming that the sites identified are all practical and capable of producing the energy estimated during preliminary investigations. (There are also likely to be many more sites not yet assessed, see the resource assessment entry above.)

If finance is available to PNG to develop relatively large scale RETs, all of the above should be seriously considered for support. However, choices regarding RET development should not be made solely on the basis of their potential impact on GHG emissions, which in any case are inconsequential on a global or comparative per-capita basis.

9 ANNEXES

Annex 1 – Persons Interviewed by Local and International Consultants for PIREP

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APEC Expert Group on Energy Data and Analysis, Institute of Energy Economics, Japan	http://www.ieej.or.jp/egeda/database/	PNG (and other member country) energy data
ATCDI website	http://www.unitech.ac.pg/ATCDI/index.html	Hydro and solar projects
European Forest Institute (EFI)	www.efi.fi/cis/english/creports/papua_new_guinea.php	Forestry data
Forum Secretariat	www.forumsec.org.fj	Economic data; investment climate
Food and Agriculture Organization (FAO)	www.fao.org/DOCREP/003/X6900E/x6900e0q.htm & www.fao.org/DOCREP/003/X1576E/X1576E05.htm	Asia and Pacific National Forestry Programme updates for PNG
IEA International Small-Hydro Atlas	www.small-hydro.com/	Hydro data
Investment Promotion Authority	www.ipa.gov.pg/sugar_farming.htm	Sugar an molasses
Kokonut Pacific	www.kokonutpacific.com.au	Coconut oil expelling technology
Papua New Guinea Post-Courier/PINA Nius Online	www.pacificislands.cc/pina/pinadefault.php?urlpinaid=4688	Chinese hybrid equipment
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Annex 3 – Solar PV Installations in PNG

This annex is a reformatted and slightly amended version of a table prepared by Mr Colin Kalimba (Policy and Planning Branch, Energy Division; Department of Petroleum and Energy) and is taken from his report *Information on New and Renewable Energy in PNG* (DPE, Report 1/04, GoPNG, January 2004).

Location	Output size (kW)	No. of panels	Panel rating (W)	Panel rating (V)	Panel manuf.	Panel type	Date installed	No of batteries	Battery type	Battery capacity (AH)	Remarks
Mt Iusaka	9.9	132	75	12	BP Solar	BP Solar		36		3303	OCA
Tsili tsili	1.96	56	35	12	SPC612-361	SPC612-361		39		1500	Unserviceable OCA
Mt Albert Edwards	5.85	78	75	12	SPC612-362	SPC612-362		78		1500	OCA
Gurney	7.2	96	75	12	BP Solar	BP Solar		96		4404	OCA
Kiriwina	0	68			Solar Arco	Solar Arco		52		2640	OCA
Mt Konokalang	2.1	28	75	12	BP Solar	BP Solar		48		4404	Decommissioned OCA
Mt Mission	1.408	22	64	12	BP Solar	BP Solar		24		2202	OCA
Mt Tangi	3.3	44	75	12	BP Solar	BP Solar		48		4404	OCA
Kikori	0	82			Solar Arco	Solar Arco		64		2700	Unserviceable OCA
Alupia	0.675	15	45	12	Solarex	LX100GT	.	1	2G560	560	Telicom
Alupia	0.27	6	45	12	Solarex	LX100GT		1	2G560	560	Telicom
Alupia	0.81	18	45	24	Solarex	LX100GT		2	2G560	560	Telicom
Alupia	0.18	4	45	12	Solarex	LX100GT		1	2G225	225	Telicom
Karoma	0.27	6	45	12	Philips	BPX47		1	2G560	560	Telicom
Karoma	0	80		24	Tidelands			2	2G560	560	Telicom
Karoma	0.192	6	32	12	Solarex	SX45		1	2G560	560	Telicom
Kaimunga	0.99	22	45	24	Solarex	LX100GT		3	2G560	560	Telicom
Kaimunga	0.96	30	32	24	Solarex	SX45		2	2G560	560	Telicom
Kaimunga	1.35	30	45	24	Solarex	LX100GT		3	2G560	560	Telicom
Kerewa	9	120	75	24	BP Solar	BP275	25/05/95	6	2P1101	1100	Telicom
Kegum	0.504	12	42	36	Solarex	LX100GT		4	P2425	225	Telicom
Kegum	0.588	14	42	12	Philips	BPX47		?	2G560	560	Telicom
Burges	0.168	4	42	12	Philips	BPX47		1	2G225	225	Telicom
Burges	0	9		36	ARCO			1		183	Telicom
Pumi	4.5	60	75	24	BP Solar	BP275	25/06/94	3		0	Telicom
Ogasumba	0	9		36	Philips	BP47		1		183	Telicom
Ogasumba	0	6		12	Philips	BPX47		1	2G560	560	Telicom
Ialibu	9	120	75	24	BP Solar	BP275	25/06/95	6	2P1101	1100	Telicom
Albowagi	2.52	56	45	24	Solarex	LX100GT		3	BP779	799	Telicom
Albowagi	1.26	28	45	25	Solarex	LX100GT		2	BP779	799	Telicom
Albowagi	0.45	10	45	12	Solarex	LX100GT		1	BP779	799	Telicom
Albowagi	0	6		12	Philips	BPX47		1	BP779	799	Telicom
Albowagi	0.81	18	45	36	Solarex	LX100GT		3	BP779	799	Telicom
Ambunti	3.15	42	75	24	BP Solar	BP275		2	BP1101	1100	Telicom
Ambunti	0	52		24	BP Solar	BP275/ LX100GT		2	BP1101	1100	Telicom
Ambunti	0.54	12	45	36	Solarex	LX100GT		1	BP425	425	Telicom
Ambunti	0.405	9	45	36	Solarex	LX100GT		2	BP425	425	Telicom
Sapau	0	8		24	Tidelands			1	2G560	560	Telicom
Sapau	0	124		24	Tidelands			3	2G560	560	Telicom
Muse	0	136		24	Tidelands			6	PVST0R	1100	Telicom
Muse	0	4		12	Philips	BPX47		1	2G225	225	Telicom
Opwin	0	112		24	Tidelands			2	2G560	560	Telicom
Bewani	0	124		24	Tidelands			2	2G560	560	Telicom
Imonda	0	124		24	Tidelands			2	2G560	560	Telicom
Green river	0	124		24	Tidelands			2		430	Telicom
Nuku	0	124		24	Tidelands			2		430	Telicom
Takamanda	0	48		24	Lucas			3	2G560	560	Telicom
Mission	1.35	30	45	24	Solarex	LX100GT		2	2G560	560	Telicom
Mission	0.32	10	32	24	Solarex	SX45		1	2G560	560	Telicom
Mission	0	10		12	Solarex			2	2G560	560	Telicom
Mission	0.99	22	45	24	Solarex	LX100GT		3			Telicom
Mission	0.09	2	45	24	Solarex	LX100GT		1		90	Telicom
Mission	0.99	22	45	12	Solarex	LX100GT		1	2G255	225	Telicom
Oomsis	0.32	10	32	12	Solarex	SX45		1	2G560	560	Telicom

Location	Output size (kW)	No. of panels	Panel rating (W)	Panel rating (V)	Panel manuf.	Panel type	Date installed	No of batteri es	Battery type	Battery capacity (AH)	Remarks
Oomsis	0	78		24	Arco			4	2G560	560	Telicom
Oomsis	0	54		24	ARCO			3	2G560	560	Telicom
Oomsis	0	6		12	Philips			1	2G560	560	Telicom
Oomsis	0.9	20	45	24	Solarex	LX100GT		3		500	Telicom
Oomsis	0.09	2	45	24	Solarex	LX100GT		1		90	Telicom
Oomsis	0.18	4	45	12	Solarex	LX100GT		1	2G225	225	Telicom
Nambamati	0.9	20	45	24	Solarex	LX100GT		2		500	Telicom
Nambamati	0	44		24	Lucas	LG12		2	2G560	560	Telicom
Nambamati	0.18	4	45	12	Solarex	LX100GT		1	2G225	225	Telicom
Nambamati	0		45	24	Solarex	LX100GT				90	Telicom
Mutzing	2.25	50	45	24	Solarex	LX100GT		2	2G560	560	Telicom
Wideru	0	9		36	ARCO			1		183	Telicom
Menyamya	0.135	3	45	12	Solarex	LX100GT		1		183	Telicom
Menyamya	0.405	9	45	12	Solarex	LX100GT		1		0	Telicom
Aseki	0.384	12	32	12	Solarex	SX45		2	2G560	560	Telicom
Lablab	0	9		36	ARCO			1	2G560	560	Telicom
Tangi	0	9		36	ARCO			1		183	Telicom
Tangi	0	6		12	Philips			1		183	Telicom
Andewa	0.384	12	32	36	Solarex	SX45		2	2G560	560	Telicom
Andewa	0.16	5	32	12	Solarex	SX45		1		210	Telicom
Lokave	0	9		36	Arco			1		120	Telicom
Liapo	0	9		36	Tidelands			1		183	Telicom
Oto	0	6		12	Philips	BPX47		1	NICAD	220	Telicom
Oto	0	9		36	Arco			1	2G560	560	Telicom
Kandrian	1.47	35	42	24	Solarex	LX100GT		2		183	Telicom
Bialla	0.405	9	45	36	Solarex	LX100GT		1	NICAD	566	Telicom
Northson	0	18		36	Arco			1	2G560	560	Telicom
Bainings	0	18		36	Arco	ARCO		2	2G560	425	Telicom
Konokalang	0	88		24	Tidelands	TIDELAND		1	BP 425	183	Telicom
Ambitle	0	84		24	Tidelands			1	2G560	560	Telicom
Nissan	0.45	10	45	12	Solarex	LX100GT		2	P2779	0	Telicom
Nissan	0.72	16	45	24	Solarex	LX100GT		2	2G560	550	Telicom
Nissan	7.05	94	75	24	Tidelands	BP275		2	2G560	560	Telicom
Una pasaba	0	6		12	Philips	SX		1		0	Telicom
Una pasaba	0	104		24	Tidelands			2	2G560	560	Telicom
Lemeris	0	52		24	Tidelands			2	2G560	560	Telicom
Maragu	0	12		12	Arco			1	2G560	560	Telicom
Maragu	0	6		12	Philips	SX45		3	2G560	560	Telicom
Maragu	0.448	14	32	24	Solarex	SX45		2	2G560	560	Telicom
Maragu	0	80		24	Tidelands			2	2G560	560	Telicom
Maragu	0.18	4	45	12	Solarex	LX100GT		1	2G560	560	Telicom
Lihir	0	4		12	Philips			1	2G560	500	Telicom
Lihir	0	10		12	Philips			2	2G560	560	Telicom
Buyang	0.288	6	48	12	Philips	BPX47		1	2G560	560	Telicom
Bogia	1.976	52	38	24	BP Solar			1	2G560	560	Telicom
Tarite	2.604	62	42	24	Solarex	LX100GT		2	2G225	225	Telicom
Tarite	0.45	10	45	12	Solarex	LX100GT		2	2G560	560	Telicom
Dibun	0	6		12	Philips	BPX47		2	2G560	560	Telicom
Dibun	0	58		24	Lucas			2	2G225	225	Telicom
Dibun	0	50		24	Lucas			1	2G560	560	Telicom
Hanseman	0	4		12	Lucas			2	2G560	560	Telicom
Hanseman	0	48		24	Lucas			3	2G560	560	Telicom
Hanseman	0.32	10	32	24	Solarex	SX45		2	2G561	560	Telicom
Otto	0		45	12	Solarex	LX100GT		2	2G90	90	Telicom
Otto	0.18	4	45	24	Solarex	LX100GT		2	2G225	225	Telicom
Otto	0.18	4	45	12	Solarex	LX100GT		1	2G225	225	Telicom
Otto	0	9		36	ARCO			1	NICAD	0	Telicom
Otto	0.9	20	45	36	Solarex	LX100GT		1		500	Telicom
Kerigomna	0							1		0	Telicom
Kerigomna	1.35	30	45	24	Solarex	LX100GT			2G560	560	Telicom
Kerigomna	0.99	22	45	24	Solarex	LX100GT		3	2G560	560	Telicom
Kerigomna	0									0	Telicom
Kulsimau	0.18	4	45	12	Solarex	LX100GT		1	2G225	225	Telicom
Kulsimau	0.768	24	32	24	Solarex	SX45		3	2G560	560	Telicom
Okapa	1.26	28	45	24	Solarex	LX100GT		2	2G560	560	Telicom
Gosopomofc	0								2G560	560	Telicom
Gosopomofc	0									0	Telicom
Gosopomofc	2.43	54	45	24	Solarex	LX100GT		2	2G560	560	Telicom

Location	Output size (kW)	No. of panels	Panel rating (W)	Panel rating (V)	Panel manuf.	Panel type	Date installed	No of batteries	Battery type	Battery capacity (AH)	Remarks
Yangutega	1.26	28	45	24	Solarex	LX100GT		2	2G560	560	Telicom
Hoskins	1.8	24	75	48	BP Solar	BP275	1.11.95	2	N120	120	Telicom
Hoskins	1.8	24	75	48	BP Solar	BP275	1.11.95	2	N120	120	Telicom
Favenc	0	4		12	Philips	47CF	10.11.84	1	2G560	560	Telicom
Favenc	0	4		12	Philips	47C4	10.11.84	1	2G560	560	Telicom
Favenc	0	72		24	Tidelands		25.10.84			0	Telicom
Favenc	0	8		12	Philips	BPX	06.01.88			0	Telicom
Favenc	0	4		12	Philips	BPX	10.10.84	1		370	Telicom
Favenc	0	72		24	Tidelands		10.01.84			0	Telicom
Purari	0				Tidelands		06.04.84			0	Telicom
Kapeminga	0.405	9	45	12	Solarex	LX100GT	18.06.87	3	2G225	225	Telicom
Kapeminga	0	136		24	Tidelands		03.02.84	4	BP779	770	Telicom
Yule	0.27	6	45	12	Solarex	LX100GT	23.01.88	1	2G560	560	Telicom
Yule	0	4		12	Philips	BPX47	27.11.84	1		370	Telicom
Yule	0	4		12	Philips	BPX	10.11.84	1		370	Telicom
Yule	0	4		12	Philips	BPX47	26.11.84	1	2G560	560	Telicom
Yule	0.54	12	45	24	Solarex	LX100GT	30.05.88	1	2G560	560	Telicom
Yule	0	168		24	Tidelands		04.03.84	4		0	Telicom
Yule	0.27	6	45	12	Solarex	LX100GT	27.05.88	1	2G560	560	Telicom
Yule	0.162	18	9	36	Arco		24.07.81	2	2G560	560	Telicom
Yule	0	4		12	Philips	BPX47				0	Telicom
Balimo	0.588	14	42	24	Solarex	LX100GT			2G560	560	Telicom
Fala	0	6		12		PVM4000		1	2G560	560	Telicom
Fala	0.36	8	45	24	Solarex	SX45	02.11.89	2			Telicom
Fala	4.725	63	75	36	Tidelands	BP275	23.12.82	2	BP452	425	Telicom
Fala	0	6		12	Philips	PVM4000		1	2G560	560	Telicom
Fala	0	4		12	Arco					0	Telicom
Fala	0	4		12	Arco		24.12.84	1	2G215	215	Telicom
Strong	0		45	12	Solarex	LX100GT	06.06.88	1	2G225	225	Telicom
Strong	0.09	2	45	24	Solarex	LX100GT	31.12.98	1		90	Telicom
Strong	1.8	40	45	24	Solarex	LX100GT	06.06.88	2	2G560	560	Telicom
Scratchly	0.18	4	45	12	Solarex	LX100GT	12.12.98	1	2G225	225	Telicom
Scratchly	2.25	30	75	24	BP Solar	BP274	20.04.97	4	BP425	425	Telicom
Scratchly	0.09	2	45	24	Solarex	LX100GT	24.11.88	1		90	Telicom
Boregoro	0	4		12	Philips	47CF	02.01.88	1	2G560	560	Telicom
Boregoro	0	12		36	Arco	ARCO	11.04.88	1	2G560	560	Telicom
Boregoro	0	12		36	Arco		11.01.88	1	2G560	560	Telicom
Boregoro	0	4		12	Philips	47CF	02.01.88	1	2G560	560	Telicom
Danio	0.18	4	45	12	Solarex	LX100GT	05.01.88	1	2G560	560	Telicom
Danio	1.35	30	45	24	Solarex	LX100GT	14.01.87	4	2G560	560	Telicom
Doigi	0	12		36	Arco		23.11.89	1	2G560	560	Telicom
Doigi	0	4		12	Philips	47CF		1		120	Telicom
Doigi	0	12		36	Arco		23.11.89	1	2G560	560	Telicom
Wori oro	0	18		36	Arco		09.08.89	2	2G560	560	Telicom
Naura	0			36	Arco		11.11.89	2	2G560	560	Telicom
Dimodimo	3.3	60	55	24	BP Solar	BP255		6	2G560	560	Telicom
Donadona	0.675	15	45	24	Solarex	SX45	06.10.88	3	2G560	560	Telicom
Donadona	0.675	15	45	24	Solarex	SX45	06.06.88	3	2G560	560	Telicom
Sisa	0.765	17	45	32	Solarex	SX45	06.06.88	2	2G560	560	Telicom
Sisa	0.135	3	45	12		SX45	06.06.98	1	2G560	560	Telicom
Sisa	0	30		24		SX45	08.06.88	6	2G560	560	Telicom
Kikori	0.42	10	42	24	Solarex	LX100GT		1	BP779	779	Telicom
Alotau	0.032	1	32	12	Arco			1		100	Telicom
Bobo	0.27	6	45	12	Solarex	LX100GT		1	2G560	560	Telicom
Bobo	3.6	80	45	24	Solarex	LX100GT		5	2G560	560	Telicom
Bobo	0.27	6	45	24	Solarex	LX100GT		2	2G560	560	Telicom
Bobo	3.6	80	45	24	Solarex	LX100GT	06.01.88	5	2G560	560	Telicom
Bobo	0.09	2	45	24	Solarex	LX100GT	06.01.88	1		100	Telicom
Dimo dimo	3.3	60	55	24	BP Solar	BP255		6	2G560	560	Telicom
Bereina	0.6	8	75	12	BP Solar	BP275		2	Enrylite	50	Telicom

Annex 4 – Barriers to Rural Electrification and Renewable Energy in PNG: 2003 Kopi Study

This annex summarises the key barriers that hamper rural electrification and the use of renewable energy in PNG that emerged from a study by Idau Kopi 'Field Trip Report on Rural Electrification' (prepared with SOPAC support in May 2003) of three small hydro projects in remote areas of PNG. This has been abridged and substantially edited.

- **Isolation (Accessibility):** Difficult access to remote rural sites in PNG, maybe accessible only by air, is clearly a significant barrier to project development. Poor access greatly increases costs of technology and spare parts, which have to be transported from main centres. The two related barriers of cost and accessibility were documented in a 1988 PEDP report as the two major constraints to micro- hydro in Papua New Guinea.
- **Dispersed population.** Rural communities in PNG are neither compact nor concentrated, with small villages often more than two hours walking distance from each other. This creates a low level of understanding about choices of locally appropriate possibilities of electricity-based development.
- **Lack of productive demand for electricity.** There were no economic activities at any case study sites that could productively use electricity. Villagers who were once keen farmers of coffee, spices (cardamom) and vegetables have abandoned production for sales in recent years because of high freight charges to transport produce to urban markets. Husking coffee beans and helping dry cash crops are areas where electricity could be put to productive use. The change away from cash cropping has been exacerbated by the lack of agricultural field officers in local centres in recent years to advise people on farming methods.
- **Lack of cash.** There is little economic activity in many rural areas of PNG (including the case study areas) so there is no money circulating in the community. People living at the fringes of a mission or government station can tap into the electricity supply but cannot afford the connection fees and usage charges.
- **Poor management.** The presence of good local government management is important. The absence of an official government representative at one station has resulted in a state of disarray. At other sites, a well-managed mission or government station contributes a great deal to RE project success.
- **Correct construction procedures ignored.** At one site, the original project report revealed that the design did not follow the recommendations of original geological survey and the project has been technically unacceptable.
- **Lack of follow-up visits**. After original operational were resolved, there was no follow-up visit to the hydro plants at any of the sites. The lack of visits creates a feeling of neglect and carelessness on the part of the operator.
- **Lack of government support.** Since the transfer of the functions of power stations (C-centres) to the provincial government by the national government, there has been little support from the provincial government to local communities and local governments, particularly funds for operators' wages and maintenance.
- **No revenue collection.** Only one community hydro committee was successful in collecting revenue from government workers. The *wantok* system makes revenue collection difficult due to traditional reciprocal exchange of goods and services among the clan members.
- **Ownership issues.** People see government projects as public assets and do not care about their long-term operation. Internal social strains arise from impact of the technology; e.g. government workers at one site do not want to pay for electric services which they feel is their right.
- **Standards of rural housing.** Industry electrical standards and safety codes preclude connection to most forms of customary dwellings (grass huts), based on wiring practices designed for urban areas. In all sites visited, only permanent and semi-permanent dwellings were connected.
- **Lack of specialist skills.** The lack of specialist skills (e.g. electromechanical equipment repair) in PNG created problems for the sites visited. At one site, replacement generator exciter windings had to sent from overseas to restore power. At another site, a voltage control board failed and replacements had to be obtained from Australia. At a third site, a failed governor component had to be sent overseas for repairs, resulting in at least four months with no power from the turbine.

Annex 5 - Barriers to Rural Electrification in PNG, 2003 World Bank Workshop

In early 2003, 34 people (Papua New Guineans and others) participated in a World Bank workshop that discussed barriers to rural electrification. The information below is summarised and edited from the WB report, Papua New Guinea Rural Electrification Policy and Strategy Development: Rural Electrification Workshop Report (Port Moresby, 22-23 April 2003). Some categories have been modified slightly or combined.

Policies / National Priorities

- Lack of policy direction from government; there is no policy on rural electrification
- Lack of political will
- Government does not consider rural electrification as a priority
- Developers are alienated from the community; there is no sense of ownership

Capital Financing

- Lack of funding to start small electrification projects in community
- Lack of project financing
- Lack of capital funding for electricity generation

Operation and Maintenance financing

- Lack of funds for operation and maintenance (O&M)

Skills

- Lack of technical skills for basic maintenance and repairs
- Local level governments find it very hard to plan; lack of skills and experience
- Lack of technical training to sustain and maintain facilities

Land Ownership

- Acquiring land is difficult, time-consuming and costly
- Crossing land boundaries with transmission lines requires compensation
- Compensation demands can be ongoing; they never end

Awareness

- Lack of awareness among all people of renewable energy resources
- Human development neglected; therefore no demand for electricity
- Lack knowledge / information about technology in communities
- Lack of technical knowledge for solar and hydro development among villagers

Management and knowledge

- Lack of ongoing management of assets and infrastructure
- Limited management capacity (facilities, operation, generation, distribution)
- Human factor (people who are responsible should be responsible)

Planning

- Poor co-ordination of project funding, especially capital versus O&M costs
- Inadequate project planning
- Lack of data for planning (including lack of information on energy demand)

Logistics and High Cost

- Transportation access to remote rural villages is difficult; cost is too high
- Difficult to get spare parts; takes a long time
- Physical isolation of many communities

Sustainability and Ownership

- Difficult to identify who manages the project for sustainability purpose
- Users do not pay for electricity (Willingness to pay and ability to pay issues)

Security

- Vandalism of existing infrastructure

Annex 6 – Micro Hydro Case Studies in PNG

This annex summarises the findings of a survey of three remote micro hydro sites carried out by Idau Kopi as part of his MSc studies. It is abridged and edited from his paper 'Field Trip Report on Rural Electrification' (prepared with SOPAC support in May 2003).

Case 1: Agaun Micro Hydro Power Scheme

Location. Agaun Micro Hydro Power (MHP) Scheme in Milne Bay Province. Agaun Station is the Sub-District headquarters of the Daga speaking people. There are no road links into Agaun and all access is by light aircraft. The MHP Scheme is operated by the Daga Rural Local Level Government Council.

System. It is a run-of-the river scheme, owned and run by the Amania clan of Paiawa village, with its intake at the Jura River. The turbine generates about 6 kVA (5 kW), supplied to the Agaun government station properties, a mission, numerous street lights, several Paiawa village houses and teachers' houses at a community school. The hydro plant operates 24 hours per day. Surplus power is dissipated in dump loads (open air heaters) in a room nearby. Use of the heaters for cardamom drying was attempted but was not successful.

History. The initial feasibility study and assessment reconnaissance visit was undertaken in May 1986 by the Foundation for the Peoples of the South Pacific (FSP). A further feasibility study undertaken by the Appropriate Technology and Community Development Institute and Unitech in October 1986. APACE was approached to assist with project implementation and visited the site in November 1987, with support from AusAID (then called AIDAB) with in-country assistance from FSP. Construction and installation took place in 1989.

The original turbine (according to Father Bateman, one of the mission staff, a "guinea pig" unit) was an experimental Mitchell cross flow turbine, designed and commissioned by APACE and manufactured at NSW Institute of Technology. It lasted only two years. With additional donor funding a twin-jet Turgo Impulse Turbine was purchased from Tamar Designs of Tasmania. The new turbine was installed by the Milne Bay Provincial Works Department with the help of local people in 1992. In 1996, the Governor of Milne Bay Province formally opened the Agaun Scheme. Since then, there have not been any major problems or breakdowns. In 2002 a minor fault appeared in the dump load control and the control was sent to APACE in Sydney where it was repaired. A few drive belt changes were all that was needed to keep the plant running.

Conclusion. Although there were considerable problems during original implementation, the Agaun scheme has been a success. It is owned and operated by the villagers. It is built on their land and uses their water (river) and other resources. Since it is a clan "*wantok*" thing, there have been no demands for land compensation and every one associated with the hydro has been proud of taking care of it and maintaining it. The success of the system can be attributed to the combined efforts of the church staff, aid donors, an enthusiastic NGO (APACE) and the efforts of the local people.

(Also see the description of the Agaun system prepared by APACE at the end of this annex)

Case 2: Woitape micro hydro project

Location. Woitape is the Sub-District Centre of the Guari Local Level Government. It has a population of around 2000 and is situated in the Goilala District of the Central Province. Woitape is a remote and isolated government centre and the nearest commercial and business centre is Port Moresby some 100 km away. The only means of access to Woitape is by light aircraft.

System. The Woitape microhydro is a run-of-the river scheme with its stream bed intake located at the Lilimo creek. A single nozzle Pelton turbine generates 62 kW and a 77.5 KVA generator supplies Woitape Station and Fatima Mission via a 3 km 11 kV transmission line. An electronic load controller governs the speed of the unit. Surplus power is dissipated in dump loads submerged in a water tank.

History and conclusion. In 1985, the Energy Planning Unit of the Department of Minerals and Energy initiated the project a reconnaissance study by "Beca Worley International" and geo-technical investigations by the Geological Survey of PNG. The project encountered substantial delays and was finally commissioned in September 1991. During the first five years the plant hardly operated due to breakdowns which took a long time to fix. After as little as two months of operation, the generator exciter winding burned out which took six months to repair. Around July 1993 a major landslide in the headrace canal disabled the system. It was not until September 1996 that power was finally restored. Since then, the plant run without major physical breakdown. Tariffs collected for electricity used from the Woitape MHP lasted for two years only, from 1997 - 1998. Since 1998 there has not been a Sub-District Manager or agricultural extension officer in the community. The District Office and the Agricultural Office have been ransacked with all electrical cables and fixtures removed. Locals from the area have occupied four agricultural extension staff houses and the Sub-District Manager's house.

Case 3: Fane Catholic Mission

Location. Fane is situated in the Goilala District of the Central Province at an elevation of 1600 m. The Catholic mission has an airstrip and associated villages of around 1500 persons (within one hour's walk), located on a small plateau, which is surrounded in all directions by high mountains. The only means of access is by small light aircraft.

System. The Fane MHP is an 8 kW run-of-river scheme utilising water from the Ane Creek. It is very compact and of simple design and layout. A cross-flow turbine (made at the Ossberger-Turbinenfabrik,Weissenburg/Bavaria,Germany) produces about 10 kW of hydraulic power. The output power from the 10 KVA generator is transformed to 600V and transmitted via 2.4 km overhead transmission line to a distribution shed near the mission office. The distribution line is placed in conduits and buried underground. The hydro supplies power for the mission station properties only and is not currently available to villagers.

History. Father Dominic, one of the mission Fathers, first considered using hydro in the mid-1970s. The idea was acted on in 1982, when a French engineer (UN volunteer) designed the small run-of-river hydro plant. The project took less than a year from the initial site survey to final commissioning, and was completed in 1982. Local labour, provide for free, was used throughout the duration of the project. ELCOM carried out the associated installation and commissioning of the 600volt overhead transmission and underground distribution network. The Catholic Church in France and the Catholic Arch Diocese in Port Moresby supported the project financially.

Current status. The hydro scheme has been in operation for more than 20 years. There have not been any major faults or social problems with the resource owners. The system, however, experienced an outage in 2002 due to a relatively minor failure of the speed control governor. The outage lasted for more than six months as the failed governor part could not be fixed in Port Moresby and had to be sent to the German manufacturer for repair. The hydro scheme was expected to return to operation during 2003. The current status is not known.

Problems. Because of continuing social unrest in the area, all mission staff except Father Dominic and two trainee priests have moved out.

Addendum: The Agaun Micro Hydro Power (MHP) Scheme

(Edited from material at the APACE website: www.apace.uts.edu.au/docpublish/agaun.html)

The Daga-speaking people of Milne Bay Province in PNG live in a remote region east of Moresby in the easterly end of the Owen Stanley Ranges. There is no road access, and the several hundred villagers in the area have little opportunity for cash generation through usual products such as fish, vegetables or copra production, since transport makes the economics unsustainable.

APACE was asked in the late 1980's to help develop the use of the Jura river flowing past Agaun village. After a decade of local hard work from Agaun people, from APACE volunteers, APACE members and donors, support from the Canada Fund, the Australian NGO cooperation scheme, the Milne Bay Province and Chris of Masurina Ltd at Alotau, a hydro plant was in place.

Andrew and John of Agaun village are employed in maintenance of the APACE-designed micro hydroelectric system that generates power for household lights and limited electric power. The village enjoys a tariff from the Agaun station provincial employees [at times when the Province has funds to pay their employees] since the village-owned hydro exports power to the Government station. Clement, from Agaun village, transmits weather reports each morning and evening using a hydro-charged battery radio set. The hydro also supplies electricity to heating coils inside a clay-insulated oven that dried local cardamom seeds for export.

The Agaun village hydro system consists of a Tamar turbo wheel turbine assembled with a Stamford self-excited synchronous alternator. The power from this assembly is monitored by an APACE/UTS designed fail-safe frequency detector and gravity-operated flapgate, that ensures power is cut off when overspeed or underspeed conditions are sensed. The Agaun community, and particularly Clement and Andrew, keep regular maintenance and cleaning checks of the flapgate and forebay area, since the basic long-term reliability of a small village hydro system lies in ensuring that water entering the turbine is clean.

Water feeds to the forebay via a locally made headrace, constructed over a 300-metre length. The headrace transmits a small percentage of the Jura River over an almost level channel lined with local rocks and pebbles, sometimes through a tunnel of rock and masonry constructed to protect the headrace from rubble that occasionally slides down the steep mountain slopes in times of earth tremors and heavy storms. The Jura River flows abundantly, and a small portion is diverted into the headrace via a rock barrier, a simple line of loose rocks about 15cm high. The original locallymade barrier was more substantial, but was washed away in a flood. The current solution is based on maintainability and replicability rather than longevity. As in all APACE micro hydroelectric systems, there is no storage of water, and hence no prospect of environmental changes that accompany large hydro operation.

Power from the turbine-generator unit is fed over the grassland plain and up a steep slope to the village, via 16 sq. mm aluminium cables operating at 3300 volts. The power is stepped down to 240 volts AC at a transformer station mounted high above Father Clement Bateman's workshop on the perimeter of the village. Here a switchboard and control room house an APACE/UTS electronic load governor that keeps voltage and frequency levels stable within the distribution system. In a nearby room, the locallyfabricated cardamom ovens are being fed through APACE heater/blower fans to provide a high grade exportable spice seed.

Annex 7 – PNG SWOT Workshop

A SWOT workshop was held on 22 January 2004 at the Department of Conservation and Environment in Port Moresby. Other than the PIREP consultants, there were only eight attendees (see annex 1) at the workshop that assessed the strengths, weaknesses, opportunities and threats facing the development and commercialisation of RETs in PNG. The low number was due to the unavailability of advance financial support from SPREP and thus late arrangements for the workshop. Nonetheless, the workshop was effective, with lively discussions and a good deal of information. All participants were civil servants, with the exception of one from PNG Power.

Strengths	
General and miscellaneous	Very large potential resource of largely untapped hydro, wind, solar and other renewable energy sources. Fairly widespread interest within PNG in utilising RETs.
Fiscal andfinancial	A large amount of money is available for energy development through some private sector groups and donors.
Institutional	A large number of technical training institutions throughout PNG at secondary, vocational and tertiary level. A number of institutions with manpower, knowledge and experience of RE (PNG Power, GoPNG's Energy Division, ATCD, private sector). GoPNG has skilled (although unmotivated and under-resourced) staff. Strong NGO / CSO and quasi-government institutions in PNG.
Legislative, Regulatory and Policy	None identified by participants.
Technical	Extensive past experience in PNG with RETs, particularly in 1980s.
Market	None identified by participants.
Knowledge and Public Awareness	Reasonably good knowledge of the resource and RETs in PNG (e.g. at UNITECH, UNPG, private sector) and necessary skills to advise on RETs. Considerable onshore knowledge and skills generally within PNG.
Weaknesses	
General and miscellaneous	Serious lack of respect for the rule of law in general: 'Law and order'. Poor governance and leadership at the political level. A high degree of indifference among public officials and the public about energy in general. Big oil and big power set the agenda and they don't really care about RE. The land tenure system (i.e. inability of planners to deal with land issues and tendency of some landowners to exploit land issues) are a serious weakness restricting RETs. Personal agendas may destroy RE (e.g. a new MP disavows good projects of his predecessor).
Fiscal and financial	Generally poor financial management within government. Widespread inability of the GoPNG to effectively tap existing sources of finance (donor and local) for RET development. Import duties and taxes are sometimes biased against RETs or inconsistent (e.g. same duties for efficient and inefficient equipment). Most rural people cannot afford the high initial costs of RETs (e.g. solar PV) and there are no mechanisms (e.g. rural banks, credit) to help them. Many government investments lack proper cost / benefit analysis so the financial and economic viability is not properly assessed. No financial incentives for government to provide rural electrification. RETs are too expensive. Rural landowners have no equity for RE investments which the banks will accept as they do not 'own' the land (i.e. cannot sell it).
Institutional	Lack of clear responsibilities, and overlapping responsibilities, for energy within government. The Energy Division of DPE requires a better organisational structure, a clear role and financial support. Poor management skills in general and business management specifically. Lack of skills within government to prepare high quality proposals for RET technical assistance. No 'vision' by government of what our energy goals are or should be. The CROP EWG does not effectively serve the countries but fights for their own narrow interests, e.g. getting funds from donors which does not benefit PNG. In general, PNG gets left out by the regional agencies.. The donor community has inconsistent policies toward RE and a short time frame, then their priorities change.
Legislative, Regulatory and Policy	There is no national energy policy and this is needed before donors will support government officials' requests for RET support. Where there are policies (e.g. rural electrification), these are not implemented effectively. The DPE has no legal power or mandate to demand data on energy production (e.g. electricity generation by private companies) or consumption (e.g. sales by oil companies).
Technical	Despite some knowledge of RETs, training is inadequate, insufficient numbers of people are trained, and curricula are very weak regarding RETs. Lack of up-to-date reliable data in general about energy resource: very little surveys or studies since mid-1980s. In PNG, we tend to be weak at impact assessments in general, including RE projects which should be assessed.

Market	The PNG market is too small for local manufacture of RETs and too small to attract some suppliers Due to small market, suppliers will not establish local presence or back-up services or technical services Much of PNG is an informal non-cash economy and cannot afford RETs or modern energy services in general
Knowledge and Public Awareness	Young Papua New Guineans tend not to care for assistance and do not take care of equipment; they have a No Care Attitude. In general, very little public awareness about RETs. DPE does not have up-to-date knowledge on energy use (e.g. to consider substitution options) as most companies to not respond to requests fro data.
Opportunities	
General and miscellaneous	Large number of prefeasability and feasibility studies have been undertaken on RETs and RE resources (although not all were completed and many are outdated). If PNG economy takes off, it will be due to rural economy and rural development requires rural energy services.. The poor rural energy services in PNG at present mean we can 'leapfrog' old technologies and make some wise decisions. Our RE potential is so vast that there are many opportunities if we just seek them. World Bank, ADB, AusAID and others are willing to provide advice or investment in RE, and we can build on that.
Fiscal and financial	A large amount of money is available for energy development donors. There are numerous attractive opportunities to invest in RETs and energy efficiency in PNG which are technically viable, cost effective, can reduce capital investment needs and can benefit consumers. Better import duties and tariffs can nudge PNG toward more rational energy use and in favour of RETs. There are opportunities to tap financial resources (e.g. GEF and EU) if PNG puts some effort into it. The budgetary process is being reformed which may be an opportunity for funds to be used more wisely for energy and RE. There are investors willing to establish joint venture for RE (e.g. the Korean proposal for ethanol from cassava). Carbon credits could reduce the cost of some RE projects in PNG.
Institutional	Potential (and actual) support from APEC EWG, SOPAC, UN system and others to understand & develop RETs. There may be an opportunity for DPE to take over 'c' centres and provide better rural electrification services. The new regional energy programmes (e.g. PIREP, PIEPSAP, REEP) offer opportunities to us if we actively participate.
Legislative, Regulatory and Policy	A national energy policy, approved by Cabinet, may help us to obtain more donor support for RETs. Moves toward commercialisation and competition in energy sector may open new opportunities for RE companies, sales to the PNG Power grid, etc.
Technical	Rapid changes and improvements in RE technologies
Market	Relatively large rural population which wants better energy services Modest RET exports possible to other countries
Knowledge andPublic Awareness	Aus AID has introduced education through national radio and renewable energy could easily be added to the curriculum Lots of good information is available through the Internet and from advisers.

Threats	
General and miscellaneous	'Law and order' issues may not be resolved or may deteriorate further Poor governance, vested interests and bribery are common in PNG at all political levels and this could result in bad decisions regarding RE A large percentage of RET systems (e.g. Telecom PV) are stolen or damaged by the public. The government is not stable, ministers and policies are likely to change at any time Access to customary land at a cost fair to landowner and developer is increasingly difficult and compensation demands are serious obstacles. Our culture may reject RE or it may have a negative impact on our cultures The interests of developed countries differ from those of PNG that may reduce our chances of getting RETs at fair prices as conventional systems may have subsidised loans or pressure from rich countries to use them. Natural disasters are a very serious threat in PNG to any infrastructure Our economy or other forces could result in closure of large projects (e.g. mines) and less government revenue for renewable energy.
Fiscal and financial	The high start up costs to set up an RE business or an energy efficiency services business or a RESCO can scare away those who may be interested and capable.
Institutional	Our institutions may not be sustainable and projects they promote may fail If we pursue RETs, there could be a duplication of efforts within government rather than cooperation among agencies
Legislative, Regulatory and Policy	We may not implement the new policies and laws which we develop
Technical	Failure of rich countries to approve Kyoto Protocol and further measures to reduce greenhouse gases and thus less incentive to develop RETs overseas
Market	None identified by participants.
Knowledge and Public Awareness	None identified by participants.