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ENERGY MISSION REPORT
KIRIBATI

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East-West Center
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PACIFIC ENERGY PROGRAMME
MISSION REPORT

KIRIBATI

1982

SOUTH PACIFIC BUREAU FOR ECONOMIC CO-OPERATION

AUSTRALIAN NATIONAL UNIVERSITY

EAST-WEST CENTER

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

EUROPEAN ECONOMIC COMMUNITY

UNITED NATIONS DEVELOPMENT PROGRAMME

Pacific Energy Programme
Mission Report

KIRIBATI

PREFACE

This report is one of the products of a cooperative programme in which a number of organisations have worked together in helping Pacific countries to assess their situation and needs in the development and management of energy resources, leading to the formulation of regional programmes for assistance to the countries in this field.

With the South Pacific Bureau for Economic Co-operation (SPEC) acting as general coordinator, the other bodies involved throughout the programme were the Australian National University (ANU: Centre for Resource and Environmental Studies), the East-West Center (EWC), the Economic and Social Commission for Asia and the Pacific (ESCAP), the European Economic Community (EEC), the United Nations Development Programme (UNDP), and the United Nations Development Advisory Team (UNDAT).

The mission to Kiribati was comprised of the Team Leader, Dr. Ken Newcombe, who prepared the report, and Dr. Tony Weir of SPEC. Assistance in writing the report came from Stephen Meyers with contributions from Tony Weir and invaluable support services have been received from the typists and research assistants of CRES, ANU, and EWC.

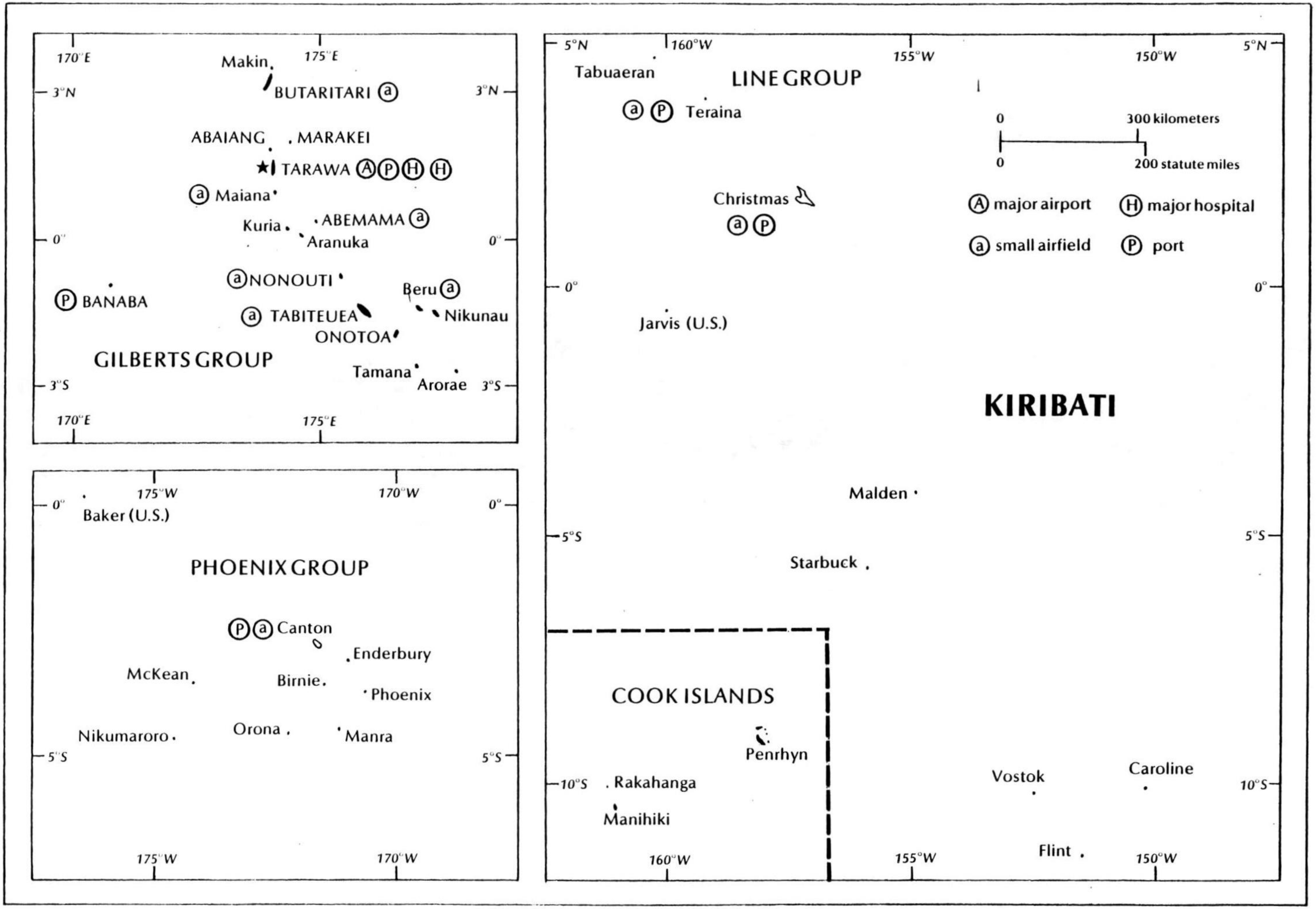
Due to constraints of time and staffing, no attempt has been made in this report to project present day energy demands to 1990 nor to consider the economic implications of the proposed reforms by that time. It is possible, however, to gather a reasonable impression of the likely economic impact from the material contained herein.

EDITORIAL NOTE

The attached report on the energy situation in this country is the result of a regional survey mission which visited 11 Pacific nations during 1982. The findings of this mission were presented in draft form to representatives of participating governments at a meeting held in Suva, Fiji in September 1982. During the process of editing the reports, it became obvious that a great deal of the information and analysis might be of general interest, but was not necessarily contained in every report. As a result, it was decided that a single outline of topical subjects should be developed and that the individual country reports should be standardised and organised around this general structure.

The result of this reorganisation has been to resequence a few sections in each report. In addition, where a country report omitted information about a particular subject, or where a subject had already been merged with a related topic, the designation "N.A." may appear after a paragraph or section number (e.g., 4.2.10 N.A.). The purpose of the "N.A." designation is to alert the reader to the fact that there may be information of general interest on this subject available in other country reports. A set of survey reports is available in your country from the planning authorities.

By the common agreement of the sponsors, the content of the country reports is unchanged from the text agreed subsequent to the Suva meeting. No substantive changes have been made in the editing of these reports. Other than the numerical structuring of sections, the only changes have been revisions to wording and syntax designed to improve the readability of the reports.



The dashed lines on this map do not constitute recognized boundaries; they group islands under the same political jurisdiction.

Base map compiled from World Outline Plotting Maps, U.S. Army Map Service, 1966.

1. SUMMARY AND RECOMMENDATIONS

1.1 Summary

For an atoll island system, Kiribati is in the surprising situation of being able to displace a large proportion of its imported petroleum demand with local energy sources during the next decade. Excluding aviation fuels, for which no near-term prospect of substitution exists, between 45 percent and 50 percent of petroleum fuels can be economically displaced by renewable sources of energy. Fully one-half of this contribution can come from woody biomass used in power generation on Tarawa and is substantially composed of senile coconut trees harvested on a 60-year rotation schedule. These woodfuels, including charcoal produced on the outer islands, can substitute for perhaps one-half of the kerosene and LPG (liquified petroleum gas) now used for cooking, and most of the diesel used in heat raising. Coconut oil can displace up to one-half of road transportation fuel use within ten years. The use of coconut oil for transportation is the only truly speculative interfuel substitution forecast in this projection. The transition away from petroleum will take place slowly, gaining momentum between four and ten years from now, and is contingent upon the close integration of agriculture, forestry, and energy sector development. The benefits that can flow to primary industry from development of a local demand for woodfuels are considerable and include rehabilitation of the national coconut crop.

In the short term, the most substantial gains will result from rational electricity pricing, more effective petroleum supply contract negotiation, and petroleum price contol. Reform here is essential and will prepare the ground for the initiatives to follow toward the greater use of local energy sources.

No lasting beneficial change can result unless there is strong and decisive decision-making and control by government given the unique situation in Kiribati of almost complete government dominance of the economy.

1.2 Main Recommendations and Conclusions

1.2.1 Indigenous energy resources: Prospects for development

Energy resources

- Coconut trees that have become unproductive could provide two-thirds of the fuel required for power generation on Tarawa. Cash flowing from the purchase of these trees can assist with replanting and upgrading overall coconut production.

- Centralised drying of copra in the far northern islands will release useful quantities of husk and shell. If fingercutting is more practical, coconut shell charcoal can be produced providing substantial additional income.

- Charcoal production from coconut shell and wood on the outer islands for sale and use on Tarawa could become an important source of rural income. The government is encouraged to pursue this option with the Kiribati Co-operative Wholesale Society (KCWS).

- The government is advised to review the development of the Temaiku bight area. The mission proposes that this reclaimed land be used for a national fuelwood plantation and the site of a wood- and waste-fired power station. (Aid assistance is available for evaluation and design.)

- There is justification to improve the record of solar insolation in Kiribati (Gilbert Group) for energy planning and solar equipment design considerations.

- Wind may constitute an attractive long-term source of power on Christmas Island (Kiritimati). The mission recommends precise and detailed monitoring of the wind resource near to the demand centres on the island. (Aid assistance is available.)

- Urban refuse on Tarawa may prove a valuable source of combustible residue for power generation. The Department of Works and Energy (DWE) is urged to survey this potential as part of the further evaluation of a wood- and waste-fired power station.

Medium- to large-scale power sources

- The mission recommends that the agriculture division confirm the data relating to the coconut population on Tarawa, the practicality of transporting logs from North Tarawa, and the close integration of coconut replanting and log harvesting on

Tarawa. Should these findings be positive, it is advisable to proceed immediately to design and cost both the Temaiku bight power station and the fuelwood plantation there in place of the coconut crop. (Note that the existing coconut crop on the Temaiku bight is itself a fuelwood resource.)

- Coconut oil will be an economic alternative to diesel for power generation provided that the copra meal by-product has a local value as a stockfeed of A$170/te and that blends of coconut oil and diesel of up to 50/50 prove technically viable.

- Small steam turbines or engines are believed to be economic and practical alternatives to diesel generation on Christmas Island. The mission recommends the use of EEC funds to install a 100 kVa steam turbine system at Banaba during 1983/84.

<u>Small-scale power systems</u>

- Solar electricity is a cheaper and more reliable source of household and general lighting than kerosene in areas away from the grid supply of electricity. The mission advises the government to waive the duty on solar PVC (photovoltaic cell) lighting kits and accessories and to mount a small loans scheme through the National Loans Board (NLB) to facilitate their wider use.

<u>Industry and Commerce</u>

- Industrial-scale solar water heating is far cheaper than using diesel-generated electricity and will only be surpassed economically by small wood- and waste-fueled water boilers. Where the latter are not practical, the installation of solar water heating is recommended.

- There is no economic justification for the use of electricity for cooking at present power production costs. The government is encouraged to convert all institutional cooking to solid-fueled slow combustion stoves incorporating water heating. Charcoal is an ideal fuel for such stoves; hence this conversion offers the opportunity to initiate an outer island charcoal industry.

- Small hot-air generators are likely to be available for adapting diesel-fired ovens to wood fuels during the next three years. The government is advised to follow the development of this technology in Western Samoa during 1983/84.

Transportation

- o Coconut oil could prove a viable diesel extender should the use of blends in smaller diesel engines become manageable. The government is advised to persist with the trial of coconut oil blends in larger diesel engines for power generation before pursuing their use in road vehicles.

- o The mission endorses the government's acquisition of a wind-powered ship for the Marine Training School and encourages further investigation into wind assistance for trading and other marine vessels.

Households

- o Slow combustion stoves are recommended in place of electric and gas cookers for all government upper-level homes. These stoves should incorporate water heating, and kitchens should be slightly modified where necessary to ensure ventilation. Charcoal is the favoured fuel as in (m) above. (Aid assistance is available for demonstration.)

- o Small modular wood and charcoal stoves of Fijian design are recommended for local production and use to replace kerosene cooking and to enhance the convenience and utility of cooking with woody materials. (Aid assistance is available.)

- o Solar water heating is provided for use wherever wood stoves incorporating water heaters are not practicable.

1.2.2 Petroleum. N.A.

1.2.3 Electricity

Planning

- o An economist-financial analyst and a system planning engineer are needed to improve the Public Utility Board's (PUB) capacity to plan for system development and to enhance its financial management.

Management

- o A simple set of guidelines for financial management is necessary to improve the productivity of the Public Utilities Board (PUB), to increase its financial independence, and to allow the government to forward plan any major expenditure or debt raising on its behalf.

- o The board of the PUB could be assisted with additional directors with the direct experience of utility management and engineering, although these will prove difficult to find in Kiribati. In any case, the board should request a detailed work plan for the financial year, and for agreed periods beyond, to enable a regular and precise review of performance of the PUB in achieving its planned objectives.

- A more exact allocation of costs between the power and sewage and water sectors of the PUB is necessary to ascertain the true costs of power production. Ideally, power generation should be operated as a separate and fully commercial entity.

- In the longer-term, the PUB should become the sole authority responsible for power supply on Kiribati.

Pricing

- At the time of the mission, electricity prices were below the direct cost of production, although pricing was being reviewed. The mission estimated the full marginal cost of production and proposed an economic tariff with "life-line" block. A tariff with a first block of 20 kWhs at 20cents/Wh and the remainder at 35cents/kWh was proposed. (The mission was informed that a similar tariff has now been adopted.)

Rural electricity

- No government involvement in power supply to the private sector in outer islands is proposed until the cumulative load at the particular demand centre can be met more cheaply by a centralised government supply.

1.2.4 Energy conservation and management

- PUB, DWE, and KCWS should interact to define and market the most efficient fluorescent and sodium vapour lighting for both domestic and commercial/industrial use.

- Building costs should be amended to ensure that better use is made of natural ventilation and lighting and that, where air conditioning is required, buildings are appropriately designed.

- The government is advised to ban air conditioning except in special places such as libraries, hospital surgeries, and the like. Where air conditioning is deemed necessary, minimum temperatures of 24°C-25°C should apply and buildings should be modified for maximum insulation and shading. Rooms to be de-air conditioned should be modified to achieve thermal comfort.

- o Regarding cooking and water heating, the following steps are recommended:

  1. Banning the installation of electric stoves.

  2. Banning the use of electricity as the prime or sole source of water heating.

  3. Replacing faulty electrical cooking and water heating systems in government homes with wood and/or solar systems.

  4. Eliminating the duty on all renewable energy conversion devices.

- o In order to stabilise the future supply of woodfuels, the government is encouraged: to regulate the felling of coconut trees, to set a fair price for wood in accordance with its energy value, to consider the establishment of a government woodfuel yard, and to engage KCWS in charcoal trading.

1.2.5 <u>Energy administration and planning</u>

- o The mission commends the President's action in seeking the appointment of an energy planner and verifies the need for a person to occupy this post as soon as possible. A national trainee is needed to work with this officer.

- o A "Working Group on Energy" is needed to oversee the work of the energy planner and the implementation of energy programmes by the respective implementing agencies. This group could be comprised of the Secretary of DWE, the Director of Works and Energy, and the key development planning officer in the Finance Department. The group should be chaired by the Minister of Communication and Works and have as its executive officer the energy planner.

2. COUNTRY BACKGROUND

2.1 Land. Kiribati consists of several groups of low-lying atolls scattered along the equator over some five million square kilometres (sq. km) of the central Pacific between longitudes 155° and 170° west. Total land area is 740 sq. km, of which about one-half is Christmas Island. From the Gilberts Group in the west (17 islands) to the Line Group (8 islands) in the east is a distance of nearly 4,000 km. Soil on the atoll terrain is scanty; there are no rivers but most islands enclose a lagoon.

2.2 People. Kiribati has a population of about 60,000 (mid-1982 estimate), of which over 90 percent live in the Gilberts Group. Tarawa, the most populous island, has about 21,000 inhabitants in an area of only 25 sq. km. Population density in South Tarawa is even higher at about 2,000 persons per sq. km. The population of the other atolls ranges from 800 to 4,000. The national population growth rate is about two percent per annum (p.a.).

2.3 Government. Kiribati received its political independence from Great Britain in July 1979. Formerly, the Gilbert Islands had been joined with the Ellice Islands (now Tuvalu) in a joint colony. A parliamentary form of government prevails, with a single chamber legislature and a President elected by the people who serves as Head of State and Head of Government.

2.4 Economy. Since cessation of phosphate mining on Banaba in early 1980, economic production in Kiribati is almost entirely agricultural, both for subsistence and for rural cash income. On South Tarawa, a cash economy prevails, supported largely by government remuneration. Copra is the only export of consequence, with earnings in 1980 of A$2.2 million from 6,000 tonnes, although exports of fish are growing. With the loss of phosphate exports, a large trade deficit has resulted; imports in 1980 were seven times export earnings (see Table 2.1). The major impact categories in 1980 were food and machinery and transport equipment. GDP (Gross Domestic Product) was estimated for 1980 at A$41.2 million (factor cost), about A$700 per capita.

Table 2.1

Selected Indicators

(million A$, unless indicated)

	1977	1978	1979	1980	1981
GDP	35.1	39.2	38.6	41.2	...
Exports f.o.b.	18.2	21.4	21.2	2.4	...
Imports c.i.f.	11.7	14.1	15.5	16.8	...
Balance of trade	+ 6.5	+ 7.3	+ 5.7	-14.4	...
Key exports:					
Phosphate	15.7	17.8	18.0	nil	nil
('000 te)	419	856	446	nil	nil
Copra	2.4	2.5	3.1	2.2	...
('000 te)	...	...	5.7	6.0	11
Inflation rate (%)	11.7	4.3	...	...	...
Exchange rate (US$/A$)	1.109	1.145	1.118	1.140	1.149
Population ('000)	55	56	57	58	59

Notes: (1) Population is mid-year estimate based on 1978 census.
(2) GDP is at factor cost.
(3) Source for exchange rate is the IMF.
(4) Source for trade figures in $ value is SPC.

2.5 Relative Economic Conditions. N.A.

2.6 Role of Energy Imports. The share of total imports accounted for by petroleum fuels imported for domestic consumption has probably nearly doubled from 1978 to 1981. (This assumes 1981 total imports of A$ 18-20 million.) The drop in 1980 is due to the cessation of mining on Banaba.[1]

	1978	1979	1980	1981
Fuel imports (mn A$)	1.48	2.26	1.90	3.30
% of total imports	10	15	11	....
% of total exports	7	11	79	....

[1] Official trade statistics on mineral fuels imports appear to understate 1980 imports; thus, adjustments have been made based on oil company sales figures. The 1981 imports have been estimated using an average c.i.f. value of 30 A cents/litre.

2.7 Development Plans. Limited natural resources, geographical isolation, and the small size of the domestic market constrain Kiribati's options for ecomonic growth. Primary attention is being given to development of marine resources: both deep-sea fishing and lagoon farming. In the agricultural sector, coconut replanting is to continue, and new planting on Christmas Island is planned. Development of vegetable and meat (poultry and pigs) production for import substitution is a further aim.

3. PATTERNS OF ENERGY SUPPLY AND USE

3.1 Petroleum Fuels

3.1.1 Overview. Petroleum fuels are supplied to Kiribati from storage in Fiji by coastal tankers by Mobil and British Petroleum, the latter selling aviation fuels on Tarawa only. (See section 5.1 for details on petroleum fuel supply and marketing.) Internal use of imported petroleum fuels in 1981 amounted to 11 million litres (Ml). About 30 percent of this is jet fuel sold to Air Tungaru, the national airline. Nearly one-half is distillate fuel used mainly in electricity generation and shipping.

3.1.2 Prices. Prices have risen considerably in the last few years. Compared with prevailing prices at the beginning of 1980, the wholesale price of diesel as of May 1982 is 73 percent higher; kerosene is 66 percent higher; and petrol is 43 percent higher:

	Petrol	Kerosene	Diesel
		(A cents per litre)	
January 1980	46	29	30
July 1980	53	35	37
January 1981	55	36	40
July 1981	59	42	44
January 1982	62	43	47
May 1982	66	48	52

Retail prices as of May 1982 were 76 cents/litre for petrol and 60 A cents (Australian cents)/litre for kerosene.

3.1.3 Trends in demand. Annual sales of petroleum fuel in Kiribati since 1973 as reported by the suppliers are shown in Table 3.1. The increase seen in 1981 for petrol and distillate may reflect larger shipments to Christmas Island, though actual sales of petrol from the fuel depot in Tarawa show a rise of about 10 percent. Distillate sales on Tarawa rose only slightly. Kerosene use appears to have declined in 1981. Jet fuel demand has grown considerably since the beginning of operations of Air Tungaru, which now accounts for most of the jet fuel market.

Table 3.1

Demand for Petroleum Fuels

	1973	1974	1975	1976	1977	1978	1979	1980	1981
				(kilolitres)					
Distillate	...	...	...	8608	5253	8745	9937	4590	4848
Petrol	1050	1009	1273	1132	1109	1558	1289	1299	1610
Kerosene	573	536	841	674	774	891	699	741	700
White benzine	8*	8*	9	4	4	5	3	2	3
LPG	5*	5*	5*	15*	15*	19*	22*	25*	28
Total Ground Products	...	...	...	10433	7155	11218	11950	6657	7089
Avgas	377	400*	450*	498	500*	500*	500*	515	630
Jet Fuel	668	700*	750*	800*	853	452	1160	3181	3961
Total All Fuels	...	...	...	11731	8508	12170	13610	10353	11680

Note: (1) Data are annual sales as reported by suppliers, except for distillate use 1976-79, where Mobil data omit sales to Banaba. For these years, the data shown are imports. For 1980 and 1981, sales of ground products as reported by Mobil have been adjusted to reflect corrected sales from the Tarawa fuel depot. An asterisk (*) indicates an estimate made in the absence of reliable data.

3.1.4 Patterns of use. Domestic use of petroleum fuels in Kiribati in 1981 is described in Table 3.2 according to the purposes for which the fuels are used. Fuel used in inter-island shipping and air transport (estimated) is included, as is all fuel purchased by Air Tungaru and domestic shipping. (See Appendix 3.1.4)

Table 3.2

Use of Petroleum Fuel in Kiribati, 1981

	Household uses	Trans- portation	Heat/Steam raising	Electricity generation	Other	Total
			(terajoules)			
Distillate	—	77	8	69	29	183
Motor spirit	—	55	—	< 1	—	55
Kerosene	28	—	—	—	—	28
LPG	1	—	—	—	< 1	1
Jet fuel	—	120	—	—	—	120
Avgas	—	21	—	—	—	21
TOTAL	29	273	8	69	29	408

Note: (1) See Appendix 3.1.4 for derivation of the above breakdown.

3.1.5 Transportation sector. Transportation accounts for just over two-thirds of Kiribati's petroleum fuel consumption. Air transport (jet fuel and avgas) claims one-half of the sector's consumption, while the rest is probably split fairly evenly between land transport and marine transport (shipping and small boats). Approximately ten percent is claimed by the local fishing fleet.[2]

3.1.6 Electricity sector. Electricity generation is the next largest consumer of petroleum fuel at about 17 percent.

3.1.7 Household sector. Household uses (primarily lighting and cooking using kerosene) account for under 10 percent.

3.1.8 Heat and steam raising. There is apparently little or no use for petroleum fuel for heat or steam raising.

2 This fish "harvesting" activity is strictly speaking not transportation.

3.2 Electricity

3.2.1 Supply. Public electricity supply in Kiribati exists on South Tarawa, under the Public Utilities Board (PUB) and on Christmas Island under the Ministry of Line and Phoenix Islands. The former consists of a centralised diesel-powered generating station of 2.4 MW installed capacity and high-voltage distribution system giving full-time service. The latter is a distributed system with about seven separate generating sites and gives part-time service only. Some statistics on the 1981 PUB operations are shown in Table 3.3.

Table 3.3

PUB Electricity Supply in Kiribati, 1981

	South Tarawa
Installed capacity (kW)	2400
Firm capacity (kW)	1650
Generation (MWh)	4920
Fuel consumption (kl)	1486
Generating efficiency (%)	31.5
Capacity factor	0.23
Peak load (kW)	900
Load factor	0.62

Notes: (1) Firm capacity reflects outage of largest single unit.
(2) Capacity factor is the ratio of average load (assuming continuous operation) to installed capacity.
(3) Load factor is the ratio of average load (assuming continuous operation) to peak load.

The number of households connected to the PUB system is about 15 percent of the population in the Gilberts Group.

3.2.2 Households connected to the grid. The number of households connected to the PUB system is about 15 percent of the population in the Gilberts Group.

3.2.3 Tariff. The PUB tariff is a flat rate for all consumers. As of June 1982, the rate per unit, which has been in effect since January 1981, was A$0.24.

3.2.4 Trends in electricity demand. Generation in South Tarawa declined slightly in 1981 after growing at an average rate of 12 percent p.a. from 1977 to 1980. The main reason for the downturn was that tariffs almost doubled toward the end of 1980.

Table 3.4

Trends in Electricity Demand, South Tarawa

	1977	1978	1979	1980	1981
Generation (MWh)	3590	3700	4310	5070	4920
Peak load (kW)	...	700	790	900	900
Sales (MWh)	2970	3110	3540	4180	...

3.2.5 Patterns of use. Government offices, enterprises, and services account for 60 percent of South Tarawa electricity use (based on July 1981 to March 1982 sales). The largest users are telecommunications services and the main hospital. Approximately 35 other government consumers use over 1,000 kWh per month. Private commercial customers account for 13 percent of sales. The largest user is the supermarket (13,978 kWh); 10 other consumers use over 1,000 kWh per month. Domestic consumers account for 27 percent of total sales. Of the 1,380 consumers, 39 percent use less than 20 kWh per month, and an additional 21 percent use between 20 and 50 kWh per month.

3.2.6 Rural and urban use. N.A.

3.2.7 Largest consumers. N.A.

3.2.8 Peak demand. N.A.

3.3 Biomass Fuels

3.3.1 Cooking. Most outer island households and perhaps one-half of Tarawa households use biomass residues (primarily dried coconut husk and shell) for cooking. There is apparently little use of wood. Other Tarawa households probably supplement kerosene with biomass. We assume also that most households make an umumu* on the weekend. We roughly estimate total biomass consumption in cooking as 22,500 ODte, or 425 terajoules. (See Appendix 3.3.1 for details.)

(*Note: An umumu refers to cooking in a pit or cooking with a bon oven over a pit fire.)

3.3.2 Copra drying. As Kiribati has a generally sunny climate, most if not all of the copra is sun-dried. This energy input is not included in our energy balance.

3.3.3 Other. N.A.

3.4 Summary of Energy Use

3.4.1 Breakdown of total energy consumption. A breakdown of total energy consumption in Kiribati in 1981 is shown in Table 3.5. Imported petroleum fuels account for about one-half of the estimated total energy use of 833 terajoules. If husk and shell were used in copra drying as in other Pacific countries, the share of petroleum fuels would be somewhat less. The domestic sector accounts for over one-half of total consumption due in large measure to the relatively inefficient use of biomass fuels in cooking. However, at present there is no shortage of biomass fuels in the outer islands. Transportation accounts for most of the rest of energy consumption.

Table 3.5

Energy Use in Kiribati, 1981

	Imported Petroleum Fuels Direct	Imported Petroleum Fuels Indirect	Indigenous Biomass	Total
		(terajoules)		
Domestic	29	20	425	474
Transportation	281	nil	nil	281
Primary industry	27	<1	--	27
Manufacturing	<1	<1	nil	<1
Services	<1	49	nil	49
Other	2	nil	nil	2
TOTAL	339	69	425	833
	(49%)		(51%)	

Notes: (1) Indirect use: energy used in electricity generation is distributed among the sectors according to their electricity consumption.

(2) Services include private commerce as well as government services.

4. INDIGENOUS ENERGY RESOURCES: PROSPECTS FOR DEVELOPMENT

4.1 Indigenous Resources

4.1.1 Overview. Kiribati is unique in the ratio of sea to land in its territory, and this, of course, greatly influences the nature and extent of the indigenous energy resources that are available for commercial exploitation. It is surprising to find that despite this tiny land area, biomass fuels are already fundamental to the domestic economy and have a greater role to play in future economic development. This is related to the remarkably versatile coconut tree, although other prospects do exist. Both solar and wind energy are creditable resources and can play a minor role this decade in deplacing the demand for imported petroleum, although some development and inventory work will be needed in the case of wind. This review will indicate that, contrary to expectations, Kiribati has many promising options for the use of locally available renewable energy sources that can benefit more than just the energy economy.

4.1.2 Biomass resources. Biomass takes the form of the standing biomass of the coconut crop, the annual fall of coconut plant residues and husk and shell from harvesting copra, meat, or milk, and the trees interspersed with coconuts, or forming dominant stands in some parts of the nation (e.g., saltbush on Christmas Island). Apart from the existing biomass resource, there is the prospect of developing planned fuelwood and timber plantations of selected species over areas of a size significant to the local energy economy.

4.1.3 Coconut energy resources. Coconuts are ubiquitous in the Gilberts Group and other parts of Kiribati. Even though roads, houses, and public buildings and facilities interrupt the plantation, their dominance is not in dispute. The estimated area of the crop here is 26,345 ha. There are large old coconut plantations on Christmas Island which are estimated to well exceed 2,000 ha. On Fanning and Washington Islands in the Line Group, there are large coconut plantations, some of which are now up for repurchase by the government (the area of Fanning Island is 3,373 ha). The average density of planting in the coconut "woodlands" of Kiribati is 197 trees/ha. All newly established plantations are at 215 trees/ha. There has been an official government replanting programme in operation since 1970 which achieved 990 ha when completed by 1978. The present replanting scheme aims at 200 ha/yr of new plantations and the only use of the wood from the old trees that is currently envisioned is for timber. There is a small mobile sawmill processing coconut logs now on Nonouti Island although it is probably processing no more than 2,000m^3/yr whereas the replacement of 200 ha/yr could generate 40,000 m^3/yr total solid volume of coconut palm stem.

The sustainable resources of coconut wood from the bole or stem of the unproductive trees is a vital statistic in planning for the full and efficient utilisation of the resource. While coconut trees may remain in production for 70 to 80 years, in most circumstances there is a marked decline in productivity after 60 years, and in some harsher environments, decline may occur after 40 to 50 years. Even despite this rapid decline in productivity at old age, there may be justification for culling existing trees much earlier if the guaranteed productivity of new hybrid varieties is much higher. In Kiribati, a rotation of 60 years for the coconut plantation would be conservative and reasonable. In the Gilbert Islands group, the standing recoverable volume that we estimate is 2.42 million oven dry tonnes (ODte): an annual availability of 40,300 ODte (see Appendix 4.1.3(a)). For our very preliminary estimate for Christmas Island, we have given 2,390 ODte p.a. The national replanting programme implicitly adopts a rotation of 130 years, thus harvesting about 46 percent of the coconut wood available annually. It is realistic to allow for recovery for timber of 15 percent by volume of the trees harvested under the replanting programme, leaving about 15,800 ODte/p.a. for fuelwood. On Tarawa, where the great majority of the population and the energy demand is located, under the replanting programme about 950 ODte p.a. are available on South Tarawa, including the urban areas, and about 900 ODte p.a. from North Tarawa. However, it is practical to apply a 60-year rotation harvesting plan to Tarawa, and this would yield about 2,500 ODte and 2,300 ODte on the South and North of the island, respectively. This quantity of wood on Tarawa is 67 percent of the current electricity generation requirement if steam boiler turbines of 12 percent overall efficiency are used.

Nationally, the annual net woodfuel yield of the replanting programme and that of a 60-year rotation of the crop is 0.7 and 1.8 times the gross energy value of all the petroleum products now imported annually to Kiribati. Of course, in most circumstances, woodfuels cannot be used with the same efficiency and cannot yet replace liquid petroleum transport fuels at the same level of ease and convenience. The use of coconut wood resource as a fuel should greatly complement the agriculturally-oriented replanting programme by providing additional cash for old trees.

In the course of copra production, the husk and shell are either burned as a drying fuel or become available for the other fuel users depending on the form of drying practiced. This varies in Kiribati from north to south, as rainfall declines and solar drying can be practiced. In Appendix 4.1.3(b), we have estimated the present annual production of husk and shell in the south at 6790 ODte. Although there may be very little, if any, husk and shell now available in the north depending on just how much hot air drying is done. It is possible to centralise drying on each of the islands in production centres of 200-500 te copra per year and use whole nut harvesting. Low-cost technology is now available enabling copra drying to be completed with only half a tonne of husk and shell per tonne of finished copra, leaving 2.4 te in surplus. In this circumstance, the northern group can generate 2,350 ODte husk and shell each year for other fuel uses. The quantity of husk and shell is expected to grow steadily this century as new higher yielding palms come into production as a result of replanting. It is unclear just how much of the present available husk and shell is now used for cooking from place to place in Kiribati and, therefore, how much, if any, of this husk and shell fuel is available outside of domestic use. The resource cannot in any case be regarded as transportable due to its low bulk density but it may be considered a fuel for future power generation or small industrial end-uses, on an island by island basis. The partial exception to this general rule is the production of charcoal from coconut shell, which is a dense and readily transportable commodity.

The costs of transporting low-density and low-value fuelwood over distances up to 600 km by sea are clearly prohibitive, even for the islands within 50 to 100 km of Tarawa. It may, however, prove feasible to convert the denser materials--the coconut shell and lower bole wood--into charcoal and backload trading vessels bringing essential supplies of copra, and passengers, to and from the islands. The present freight rate for copra is A$55/te, which is a bearable charge on charcoal (see 4.6). There is also the basis here of a smallholder industry integrated with the present copra production on outer islands. The maximum resource from the estimate made in Appendix 4.1.3(c) is 3,472 te of wood charcoal, based only on carbonising timber harvested in the replanting programme and 615 te of coconut shell charcoal. It is assumed here that charcoal production will not be undertaken on Tarawa since all the residues available there will more profitably be burned as is.

4.1.4 Other combustible residues. There is no forest resource by any acceptable standard of timber quality and quantity. Nevertheless, the few patches of trees that there are, other than coconuts, and the potential that there is to grow more must be regarded seriously as a resource in Kiribati. On Christmas Island, there is likely to be a good potential for some adaptable fuelwood species. Already large acres of robust saltbushes could constitute a renewable energy source with careful ecosystem management. Nevertheless, trees on Christmas Island are of value as a fuel only there. It is the centre of national energy demand, Tarawa, that is the prime concern. There are two prospects worthy of close evaluation. The first is the deliberate and managed cultivation of Casuarina equisetifolia on all open roadsides, fishpond borders, causeways, and other vacant land in thin coastal windbreaks whenever practical. Casuarina does particularly well in fairly harsh saline environments. The occasional slow growth is compensated to some extent by extremely dense wood (800 kg/m^3) of higher calorific value (possibly as high as 24 MJ/ODkg c.f. 20 MJ/ODkg for most other woodfuel). Surprisingly, the Kiribati population makes little use of Casuarina as a fuel, the mission observed its use only in western style barbeques. Casuarina that is well tended should produce 10-15 ODte/ha/year although this is subject to confirmation locally. It is not possible to determine the land area in the above categories which might be available without detailed mapping. For the purposes of this crude evaluation, we will assume that an additional 5 percent of total area is available and that existing coverage is 2.5 percent. A total of 7.5 percent of land area on South Tarawa, other than the Temaiku bight, is 190 ha, which would yield 1900-2850 ODte/yr. The second prospect is the use of the Temaiku bight as a woodfuel reserve.

In the early 1970s, the Temaiku bight area came under controlled management through the construction of a causeway and channels to enclose 300 ha of very shallow, poorly drained sand and sediment. Up to 100 ha of this area is now, or will become, occupied by fish ponds, accessways, and other dead space. The original concept of growing coconuts on this reclaimed government land appears to have floundered due to the harsh and variable environment (intermittent flooding, nutrient imbalance). The majority of the coconuts are chlorotic and are narrowing at the apex indicating that low to nil productivity can be expected. At the same time there are numerous examples of both planted and self-seeded Casuarina that have grown vigourously. The mission observed growth to 8-10 m height and DBH (diameter at breast height) 14 cm within these years on higher bunds. The deliberate plantings of Casuarina equisetifolia in 1973/74 had mixed success, although the reasons either for the failure of some plantings or for the good success of the remaining stands have not been evaluated. Both uneven drainage and nutrient distribution can be suspected. Allowing for this uneven performance, it is unwise to anticipate more than 10 ODte/ha until a scientifically-determined management strategy is developed. Therefore, the resource will be assigned at 2,000 ODte/yr: the equivalent of about 1.5 GWh p.a. The mission strongly recommends to the government a review of the development strategy for the Temaiku bight area to examine the establishment there of a national fuelwood plantation and the site of a new wood-fueled power station. It is unlikely that income from coconuts on the bight will exceed A$200/ha (gross) compared with a minimum of A$400/ha for fuelwood plantations.

The Department of Works and Energy reported to the mission their difficulty in disposing of waste materials on Betio and Bairiki, including leafy matter, paper, plastics, and the like. We presume that there is also waste lubricating oil. These materials are, in fact, fuels which can be economically utilised given appropriate collection, preparation, and conversion equipment. Serious consideration should be given to densifying, by simple means, combustible residues for use in steam generation, and the use of waste oil there or in the new baking ovens.

4.1.5 Charcoal production. See section 4.1.3.

4.1.6 Hydropower. N.A.

4.1.7 Geothermal. N.A.

4.1.8 Wind. In the Gilbert group, windspeeds are low and non-persistent. There is an anemometer recording windspeed at 35 m height on Betio, although there is some potential for subjective judgement in the establishment of the record. Since the cost of electricity is so high, even in the capital, windspeeds which could not yield economic power elsewhere may prove viable on the outer islands of Kiribati. Some records should be established then for appropriate locations in the more populous but remote centres. On Christmas Island, wind speeds are reported to be consistent over much of the year. The mission was given a huge range of average wind speeds from different sources within which the actual average must lie: 4.3 M/sec to 11 m/sec. Wind electric generation systems have so far failed on Christmas Island after two to three years due to the extremely corrosive humid saline atmosphere and poor maintenance. However, this is a material science and management problem. The wind resource may well constitute a long-term power source for the island. The mission has therefore recommended the use of UNDP funds for the purchase of an anemometer and related monitoring for Christmas Island to establish the wind record in detail.

4.1.9 Solar. There is considerable scope for the economic use of solar radiation in Kiribati. Already solar energy is used for copra drying, and the solar salt industry in Christmas Island is shortly to be expanded to full commercial scale. Also, advanced solar drying of copra occurs at the coconut oil facility at the Ambo fish ponds. The commercial potential is limited for the use of solar electricity in remote stand-alone systems for communication, lighting, and medical refrigeration. Solar water heating to 70° C is already economical. There is a need then for continued monitoring of solar in the Gilbert Islands group. The present record covers only two years. To date, the mean daily average ranges from 18 MJ/m^2 to 25 MJ/m^2. UNDP funds have been made available to improve the quality and extent of the solar record on Kiribati in cooperation with the New Zealand meteorological service.

4.1.10 OTEC and wave energy. N.A.

4.2 Medium and Large Power Systems

4.2.1 Overview. Here power systems above 5 kW peak demand are considered. By this classification, all power systems on Christmas Island are included as well as the main power generation station on Tarawa. The range of indigenous energy sources with economic potential for displacing imported diesel fuel include wood, agricultural residues, coconut oil, and wind. Based on the mission's present understanding, the economic use of wind is restricted to Christmas Island, although this bears confirmation. Biomass power resources can be produced and converted throughout the islands.

4.2.2 Hydropower. N.A.

4.2.3 Combustible resources. The first impression of a coral atoll is that any large wood-fueled production system is out of the question for land that is both very scarce and, in the case of the capital, densely populated. However, the impression is influenced by the convention that forests are the basis of woodfuel production. It overlooks the coconut woodland completely.

In 4.1, it has been established that the sustainable yield of the coconut plantation on Tarawa is 4,861 ODte p.a., that coconut husk and shell may be available there up to 940 ODte p.a., and that there is potential for growing fuelwood despite land constraints. The proportion of the present power demand on Tarawa that these resources can meet is partly a matter of the technology deployed and the pattern of its use. Two major options exist: steam power or gasification. Although the lower capital costs and the higher fuel efficiency of wood gasification are very appealing in the circumstance of Kiribati, not enough is known of the sustained operation of gasifiers in response to typical utility demands to recommend their use with confidence.

4.2.4 Gasifiers. The mission is not prepared to endorse the use of large gasifiers where they are to be relied on to serve vital demands and where superior economic performance is dependent on a greater than 50 percent plant factor with efficient operation. For the moment, the efficient use of gas fed into a diesel engine not made with dual fuel capacity is not guaranteed. The purchase of dual fuel engines--generators and matched gasifiers--does not bring significant savings over the steam power alternative. However, it can be relied upon for sustained generation with a wide range of feedstocks. The mission has therefore chosen only to analyse the steam power option, and on the basis of costs and availability, has selected steam turbines rather than reciprocating engines for the Tarawa size of operation.

The mission advised the DWE not to proceed with small (10-20 kW) wood gasifiers in the outer islands until further experience has been gained in the region as a result of the present regional energy aid programs. Small systems (10 kW/25 kW) that have reputedly been proven in their country of origin (the Philippines and New Zealand) have not operated well where they have been tested in the Pacific (Papua New Guinea and Vanuatu) and cannot be regarded yet as commercial or reliable. There is merit in persisting with small charcoal gasifiers for outer island communities since this feedstock can be readily made homogenous in size, moisture content, and composition and solve many of the problems of small wood gasifiers. It is likely that an aid donor will mount the longer-term field trials of improved small gasification technology in 1983, and Papua New Guinea is now proceeding at the 25 kW level with modern German gasification technology. The mission therefore advises the government to maintain a watching brief on the progress of these demonstrations of very small gasifiers and will also host a UNDP regional workshop on gasification for 1985 to review the performance of this technology to that time.

4.2.5 Steam power systems. The mission proposes the parallel development of a new steam power station of the Temaiku bight reclamation area, as well as an expanded and accelerated coconut replanting and wood and waste collection system for Tarawa as a whole. In Appendix 4.2.5(a), the economics of generation from a simple 1 MW (2 x 0.5 MW) low-pressure steam turbine power system are provided. Units of 0.5 MW have been nominated because 75 percent of the energy can be generated with a firm capacity of 0.5 MW; and with good maintenance scheduling, the peak load of 800 kW will be able to be met for up to one-half of the time with the two units on-line. Thus this power system should meet about 85 percent of the demand for energy, with the diesels providing peaking and stand-by capacity as required. A third 0.5 MW unit can be installed to provide 1 MW firm as it becomes economical. Although if correct pricing is applied to the electricity in this short term and if appropriate measures are taken to use electricity more efficiently (see 4.4, 4.6 and 7.2), power demands should not grow substantially before 1985. (Indeed, the peak has fallen 100 kW since 1980.) The total installed cost of the installation is A$1.58 million and the present value unit cost of production is 13.3 cents/kWh. This compares with a fuel cost alone for diesel generation of 18.6 cents/kWh. Fuel handling equipment will not include chipping or logging since bulk lumpy material is proposed as fuel with only semi-automated loading (a large surge-bin). The cost of this fuel handling system should cover the cost of barges to bring coconut logs from northern Tarawa as well as by road from southern Tarawa, as well as for the appropriate system of docking, splitting, and conveying required in the fuel yard. The cost of production includes a price for coconut logs of A$20 delivered, which should not be substantially less than A$10/tree clear. Even at A$5/tree to the owner, this would be a substantial boost to a replanting program. It should be noted that in order to satisfy 85 percent of the current energy needs with a wood- and waste-fired steam turbine-alternator system, all of the senile coconuts harvested annually for a 60-year rotation will be required, as well as 2,565 ODte of Casuarina sp, with or without surplus husk and shell. Casuarina wood of this order could be obtained from Temaiku bight if 15 ODte/ha/yr yields were obtained or at 10 ODte/ha/yr yield (which is very low for short rotation fuelwood plantations in the tropics) from Temaiku bight. A total of 57 ha of additional leasehold land should achieve this level of fuel production. The important finding is that old coconut stems from Tarawa alone could provide 55 to 60 percent of the present electrical energy demand.

The mission therefore strongly encourages the government to:

(a) confirm with the Agriculture Division the data relating to the coconut population on Tarawa, the practicality of transporting logs from northern Tarawa, and the close integration of coconut replanting and log harvesting on Tarawa,

and should these findings be positive to:

(b) proceed immediately to design and cost both the Temaiku bight power station and the fuelwood plantation there in place of the coconut crop. (Note that the existing coconut crop is itself a fuelwood resource.)

It is the view of the mission that the steam power station is likely to be a practical alternative with attractive side benefits and that funding should be available from bilateral donors. The mission has arranged with SPEC for the funding of a review of the timber availability needed for (a) above and of the Temaiku bight and public lands fuelwood prospect. This was to proceed during October 1982.

Steam engines are renowned as a robust and simple technology even if relatively inefficient. The mission believes this technology to be ideally suited to remote power production, provided there is ample cheap fuel and a reasonable level of technical back-up and skilled maintenance.

The power system on Christmas Island is remarkable in its diversity of both standards and equipment dispersed between Paris, London, Banaba, the airport, and other generation centres. The island has at least 2,200 ha of very aged coconut plantations, and at least some part of the copra harvesting produces centralised piles of surplus husk and shell. In 1978, Merz and McLellan, consulting engineers completed a report on the power supply system for Christmas Island. The option for future power system development that the government accepted was for a combination of centralised and decentralised generation, acknowledging the high cost of connecting very remote loads at Poland and Artemia. In the first instance, the cost of transmission to London and Decca is also too expensive, although the connection of their load is the logical first extension. Thus the mission has addressed a level of 80-100 kVa maximum coincident demand at the Hotel, Banaba, and the airport. One-half of the hotel load has been, or will soon be, reduced through conversion of water heating to solar. Further reductions in demand can result with more efficient air conditioning, thermostatic control, and insulation. Sensitive use of cross ventilation, roof insulation, and shading should alleviate the need for air conditioning in the new room units planned for the hotel. In this circumstance, the mission considers a 100 kVa steam engine generator to be adequate to meet the near-term load, with a second unit to be added as demand grows. The maximum annual wood fuel use of the steam engine system is 1200 ODte compared with the sustained yield of the coconut plantation of 2390 ODte p.a.

The mission therefore recommends the use of the funds for the purchase and installation of a steam engine or turbine generator set to feed the hotel-Banaba-Airport grid. The nominal size is 100 kVa, although design studies will be initiated as soon as formal approval for the aid is obtained. The costs of production of this system are estimated in Appendix 4.2.5(b) as 28 cents/kWh for the steam turbine system and 29 cents/kWh for the steam engine. It may be advisasble to use the steam-turbine system to gain direct operating experience for the larger units planned for Tarawa.

4.2.6 Coconut oil in diesel engines. The other potentially attractive option for power generation on Kiribati is the use of coconut oil in a blend of up to 50/50 with diesel in the slow revving diesel engines at the Betio power house. The basic economics of coconut oil production on Betio are outlined in Appendix 4.2.6. Using the mission's estimate of the economic price for copra on Betio of A$191.60/te, the production costs for oil are 52 cents/litre at the scale of 48,000 litre/yr. Small reductions in price occur if cheaper Chinese or Indian oil expelling equipment and up to four shifts are engaged to expand the level of production; however, the price of copra dominates the economics. Should this option prove technically viable, it is recommended that whole nut harvesting be investigated for oil production, whereby oil is produced from green meat and a credit is available for surplus husk and shell which can be sold for power production and thereby lower the overall price further. Oil at 52 cents/litre requires a by-product credit of A$170/te of copra meal to break-even in financial terms. We are impressed by the prospect of achieving a true local value for copra meal of this level based on its use for poultry and pig production in efficient modern, though small-scale industries. Research staff at the Centre of Resource and Environmental Studies, Australian National University, have undertaken a desk study of a "minimum cost--minimum import" balanced high quality diet for poultry and pork production using copra meal as the basis. The results will be included in the regional overview of the energy mission's findings. The mission urges the government to give serious consideration to small intensive pig and poultry industries in parallel to the copra meal/fish food industry at Ambo ponds integrated with coconut oil fuel production. Finally cooperation has been arranged between SPEC, USP, and the Public Utilities Board (PUB) to supervise and monitor the use of blends of coconut oil and diesel in the old 300 kW (NPR), 750 rpm, English electric diesel generators on Betio, and recommends the assistance of the Department of Works and Energy (DWE) in ensuring satisfactorily long and carefully monitored trials.

4.2.7 Wind energy. In the resource overview (4.1), we commented on the potential for wind-electric generation on Christmas Island being clouded by lack of knowledge of the true resource. In Appendix 4.2.7, the costs of production of wind power are shown for the range of 4.3 m/s to 11 m/s, the extremes of which the mission was appraised. Only a five-year life has been given to the 10 kW system analysed due to the experience of the probably poorly tropicalised wind system applied there in the 1970s. The present value unit costs range from 13 A cents to A$2.26 per kWh, attesting graphically to the importance of a good resource assessment and the sensitivity of wind power resources to only small differences in average wind speed.

4.2.8 Geothermal. N.A.

4.2.9 Biogas. N.A.

4.2.10 Alternative petroleum fuels. N.A.

4.3 Small Power Systems

4.3.1 Overview. Here we report on the local alternatives to imported communication technology, medical refrigeration, and other small motorised appliances.

4.3.2 Photovoltaic cells. The use of sunlight to produce electricity through photovoltaic conversion has become economical in comparison with the quite extreme cost of equivalent kerosene or benzine lighting in communities well away from the main ports of petroleum supply where kerosene costs more than 50 A cents/litre. For example, in the Cook Islands at Raratonga, the cost of kerosene is 54 A cents/litre retail (June 1982), and the cost per night of two large lamps used for four hours each is A61cents compared with 33 A cents for the same lighting from a PVC kit of battery, panel, regulator, and 2 x 13 W fluorescent tubes providing equivalent lighting (see Cook Islands report). The price of kerosene retail on Tarawa is 60 A cents/litre and on the outer islands 20 A cents to A$1/litre, clearly justifying the use of lighting systems. A PVC communication system of 100 w (average) is being installed under aid for the Kiribati Government ground-to-air, air traffic guidance systems; and the government already has in its store PVC kits with a 33 W (peak) panel, 120 ah battery and regulator, and fluorescent lights for A$618. This is less than 10 percent above the Cook Islands price, provided the government does not change the 30 percent duty which is the levy under the present policy on electrical goods. The mission urges the government to waive this duty and to mount a programme through the National Loans Board (NLB) to finance, over five years, the purchase by villagers who are remote from the grid supply of PVC lighting systems. The mission regards this step as a means of improving the quality of life in the outer islands as well as reducing, in a small way, petroleum imports. It is obvious both from the records of supply and from reliable sources that kerosene, other petroleum products, and dry cell batteries are frequently unavailable on the outer islands and that unofficial prices reach extremes since supplies are short. PVC lighting will alleviate this problem. Finally, the mission endorses the use of EEC funds for a demonstration PVC-powered medical centre on a remote island including small refrigerators, lights, and communication.

4.3.3 Wind energy. While the wind resource may be marginal by most standards, it is clear that PVC electricity is very expensive even if cheaper than kerosene lighting. Costs per kWh (delivered) of A$3-A$4 can be expected of small PVC systems for the next four to five years in Kiribati. Against these costs, small wind-electric systems of 100-300 watts' peak using local diurnal sea breezes may be economical. It is with this prospect in mind that the mission has provisionally allocated funding under the UNDP Regional Energy Programme for the Cook Islands and USP to further refine and commercialise wind-electric generators of up to 300 w peak during the 1983-86 period. It is recommended that the DWE follow this project performance closely.

4.3.4 Hydropower. N.A.

4.3.5 Gasifiers. N.A.

4.3.6 Coconut oil in engines. N.A.

4.4 Industry and Commerce

4.4.1 Overview. Industrial development in Kiribati is very limited and, apart from fishing, is certainly not energy intensive. Here we are concerned with heat and steam raising including water heating and cooking. The government is either directly or indirectly the owner of all substantial energy users in the commercial-industrial sector, such as the hotel, the boarding schools, and the hospital, and the activities of the Kiribati Co-operative Wholesale Society (KCWS) which may soon include a large bakery on Betio. In this rather simple energy economy, the government can act to greatly influence the more economically rational use of local energy sources since the opportunities for, and benefits of, change are clearly established. Surprisingly, opportunities for the use of cheaper locally available energy forms are considerable.

4.4.2 Gasifiers/hot air generators. N.A.

4.4.3 Food industries. N.A.

4.4.4 Solar water heating. There is no justification for the use of electric or gas water heating in large institutions such as the local hotel, hospital, and boarding school. While the design of effective and reliable industrial-scale solar systems may be somewhat complex, the benefits are huge with paybacks of between one year and three years depending on the installation. The key factor in deciding to outlaw fossil fuel-based systems is whether wood or solar should be the fuel of future hot water systems. If, as we recommend below, wood or charcoal-fueled slow combustion stoves are installed, it is logical for them to have water heating incorporated and to distribute the hot water as far as possible. However, there are certainly detached hotel rooms, wards, and other accommodation blocks where solar water heating would be the most convenient alternative. In the Kiribati climate, the mission sees no need to provide for electrical heating of solar systems. If boosting is required, a small wood-water boiler stove can be incorporated in the system to cover excessively cloudy days. The mission has arranged through UNDAT/ESCAP for the detailed design and costing of a solar hot water system to meet a large industrial/commercial demand on Kiribati. Work was to proceed on this project during November/December 1982.

4.4.5 Wood and charcoal stoves. Cooking is currently with electricity in the boarding school on South Tarawa and at the hospital and these are, repectively, the first and second biggest consumers of PUB power in Kiribati. There is no economic justification for the use of electricity for cooking at costs of 36 A cents/kWh. We estimate that the fuel cost of cooking in a solid-fueled slow combustion stove is 13 percent to 15 percent that of electricity and one-quarter that of LPG for cooking. Charcoal produced on the outer islandds from coconut shell and wood and retailed in Tarawa for A$250/te is about one-quarter the cost of electricity and 40 percent of the cost of LPG for cooking. Charcoal can be used in solid fuel institutional cookers designed for coal. One such charcoal stove and oven, including a hot water system, costs A$2,900 FOB Melbourne and is rated as catering for 100 persons per meal for bulk cooking and 50 persons individually. The daily fuel consumption for this stove is 30kg charcoal for full service including water heating. A simple demonstration of the financial savings of this alternative would be the conversion of KGV (King George V) school kitchens. If one-half of the April 1982 electricity bill for KGV was for cooking, if this rate of consumption is maintained for ten months of the year, and if the true cost of electricity is used, the DWE could purchase, install, and operate these four solid-fueled slow combustion stoves on charcoal at A$250/te for one year for about one-half the fuel cost of electric cooking and provide the bulk of the school's hot water requirements for the same cost. The mission urges the government to convert all institutions within its control over to solid-fueled stoves as soon as is financially possible. This will involve some redesign of the kitchens for improved ventilation and fuel handling, although the radiant heat load from modern slow combustion stoves is not excessive since heat is directed carefully to cooking surfaces which can be damped when not in use. The mission has recommended the use of UNDP funds to provide a demonstration modern industrial size slow combustion stove with water heating. These funds will be available early in 1983 as part of the Kiribati component of the regional fuelwood, charcoal, and solid-fueled stove program adopted by UNDP.

Charcoal as an industrial cooking fuel is well suited to the situation that the mission sees as emerging in Kiribati and its production may be of unique benefit to rural development. We see a steam power system as viable in Tarawa and have urged an immediate start to refining that option. Its development will mean, logically, the use of all cellulosic residues and wood for power generation, including urban refuse. Power generation will become the prime economic use for this material. The vast coconut and other wood resources of the outer islands are not economically accessible to the Tarawa market unless they are concentrated. Carbonization can achieve this concentration for at least some portion of these biomass fuels.

There is vastly more dense woody materials such as coconut shells than can be utilised as charcoal in Tarawa. Even so, the urban charcoal market, both for commerce/industry and for households, is a significant and potentially growing market which could provide a useful income for outer island communities. In Appendix 4.4.5, we have estimated the cost of charcoal production on the outer islands against a desirable retail price of A$250/te in Tarawa and have found it to be a financially viable proposition. Charcoal is already produced in the outer islands for domestic ironing. In 1981, KCWS arranged for the shipment to Tarawa of several container loads of coconut shell charcoal, although this charcoal did not sell since no market had been prepared. It was, nevertheless, a useful demonstration that the produce is available on demand. Apart from slow-combustion stoves specifically designed for charcoal (in fact for coal), most slow-combustion stoves can take both wood and charcoal. In addition, the Papua New Guinea Energy Planning Unit has developed excellent charcoal-fuel boilers and large charcoal grills. Samples of these technologies can be purchased for Kiribati under the UNDP Regional Energy Programme, if desired. The mission has also arranged in 1983 for a specialist to demonstrate more efficient techniques of production of good quality charcoal using 200 l oil drums or larger kilns since for the present pit method is very inefficient and produces charcoal of low quality.

The only significant heat-raising industry apart from the above is in commercial bakeries such as the one to be re-opened within the year on Betio with KCWS as the proprietors. Standard diesel-fired ovens should be able to be fitted with efficient wood-fired hot-air generators producing clean burned gases at 1,300°C, for exchange with oven air. Diesel-fired ovens are universal in the Pacific; hence the mission has mounted a programme under UNDP funding to match existing small hot-air generators to bakeries in Western Samoa and Tonga during 1983/84. Kiribati will be a beneficiary of this hot-air generator program should it live up to expectations.

4.4.6 Crop drying. N.A.

4.4.7 Other. N.A.

4.5 Transportation

4.5.1 Overview. The mission is here concerned only with locally available energy sources which might conceivably provide an economic substitute for ground and marine transport fuels. Coconut oil offers the only real substitute for liquid petroleum fuels in either sector, although sail-assisted marine transportation is an important consideration. Other prospects exist on a small scale, such as the use of producer gas in road vehicles, as is now being promoted on a commercial scale in the

Philippines. Here the mission recommends simply for the Kiribati energy planners to keep ahead of promising and well proven developments with the assistance of the regional energy agencies of SPEC and UNDP.

4.5.2 Ethanol fuels. N.A.

4.5.3 Coconut oil in diesel engines. The economies of coconut oil production have been established in broad outline in Appendix 4.2.6. The financial viability of the alternative is dependent largely on the sale of copra meal by-product at a fair price, almost double the export price. The mission will try to establish the economic price of copra meal in Pacific countries, although it seems likely that it equals or approaches the financial break-even price required in Kiribati. Fortunately, Kiribati has good operating experience with an oil expelling system which can comfortably produce up to 100,000 litres of oil per year (on a shift work basis). Scaling up this technology and coupling the meal production with intensive animal production, in addition to fish farming, would be the next phase of development required. The use of coconut oil as a road or marine diesel transport fuel should await the outcome of trials on the 750 rpm, 300 kW diesel engines in the Kiribati power house now being promoted to PUB by SPEC and USP. Success with these trials can lead to the use of blends of up to 50/50 oil and diesel in larger trucks and marine vessels, again monitored closely, in this instance by DWE. There is some optimism that the use of blends in larger slow-revving engines will prove technically viable. Hence, the mission urges the government to press ahead with the PUB power station trials and to undertake preliminary planning with the agriculture division regarding the organisation of the coconut oil production and copra meal animal feed industry.

4.5.4 Biogas. N.A.

4.5.5 Producer gas. N.A.

4.5.6 Wind energy. Wind power for marine vessels is already established as the basis of traditional communication and trade in the Pacific. Small fishing canoes still rely heavily on wind power in Kiribati. More recently, the Kiribati marine training school has purchased an all-sail vessel for training purposes which is a commendable move away from total preoccupation with diesel powered vessels. This mission believes there is a good prospect for sail assistance on large inter-island craft and recommends the use of UNDP funds for a brief review of the state-of-the-art in the design and commercialisation of modern sail power in commercial use. It is difficult to imagine a more economically favourable location for wind power than Kiribati, with both high costs of diesel and moderate sea breezes in major trade routes out of the island group to other centres. It is recommended that the energy planner seek the assistance of the marine training school staff in examining further the prospect of commercial utilisation of wind power in marine transportation.

4.6 Households

4.6.1 Overview. In this section, we deal with cooking, water heating, and ironing. Lighting is either with electricity or kerosene. Electric lighting is clearly cheaper and is gradually becoming available to all village areas in South Tarawa as a result of more extensive reticulation between main centres of consumption between Bairiki and Bikenibeu.

4.6.2 Patterns of energy use. Cooking fuels vary depending on the quality of the house and cooking facilities that were installed at construction. Upper-income families, basically the expatriates in the government or quasi-government service, and a very few I-Kiribati, cook with electricity or gas with the occasional wood barbeque as the exception. On the basis of the class of government homes served by electricity and the average monthly consumption, it is likely that about 100 to 150 houses have electric stoves and ovens.

A further 150 or so more probably have occasional use of other electrical appliances for cooking, such as frypans, electric jugs, and the like. However, these households appear to use kerosene as their main cooking fuel. It is possible that up to another 400 families cook with kerosene much of the time, but use coconut residues for longer cooking sessions and feasts. The remaining 2,000 or so households on southern Tarawa use coconut residues exclusively for cooking fuels. Kerosene cooking is used from time to time in the outer islands, although mostly as a status symbol and a novelty. Kerosene is mostly used for lighting in these locations and the total volumes delivered are so small as to make kerosene cooking insignificant in proportion to total fuel use in cooking. Cooking in the houses that use wood or coconut fuel only is exclusively with open fires.

The main fuel sources are leafy matter and the calyx of the coconut palm and the husk and shell of the coconut. Coconut wood is rarely used as a fuel since it presents difficulty in processing without mechanisation. It is worthy of note, however, that coconut wood appears to dry quickly on Tarawa and can be adopted as a fuel if required.

4.6.3 Wood and charcoal stoves. Modern slow-combustion stoves are certainly able to replace electric and gas cooking in the higher standard houses of Kiribati. The range of prices, including built-in hot water systems and ovens, that the mission has obtained is A$800-A$2,200 depending somewhat on size, sophistication of controls, finish, and distribution of heat solely to the cooking surface. Very sophisticated, attractive, and compact slow-combustion stoves with the above features are available for A$1,300 FOB Sydney. These stoves are compatible with the cooling and water heating requirements of upper-income families. Modern electric stoves cost from A$600-A$1,000, and electric hot water systems cost A$300-A$400 for a 200-300 litre capacity. When built into new homes, then, the cost of a solid-fueled stove system is not much more expensive than an electric stove, oven, and water heating system. Obviously, the kitchens of existing homes will have to be remodelled to maximise ventilation and to exhaust the additional heat load. Also, convenient fuel storage and handling bins should be provided. Slow-combustion stoves have been used in the Pacific for decades and were standard prior to widespread electrification. In appropriately designed homes, they are perfectly acceptable appliances. Appendix 4.6.3 provides a comparative cost of LPG electric, wood, and charcoal cooking to serve as a guide. Fuel for a slow-combustion stove will, in fact, be one to two tonnes of wood per year costing A$40-$80, or A$75-$150 for charcoal, all of which would go to a smallholder firewood or charcoal entrepreneur and stay in the Kiribati economy.

Given the freight and installation cost (total A$1,800) of a high class slow-combustion stove and 60 percent of the average monthly power bill for class A and B government housing (160 units/month) at full cost, a simple payback of three years is expected on the basis of electricity savings alone. The mission recommends that slow-combustion solid-fuel stoves be built into all new government homes and that faulty stoves or water heaters be replaced as they break down. Depending on the capital available in the government works programme, a longer-term programme of replacing electric stoves over, say, 5 to 10 years should be planned. In addition, the importation of electric stoves should be discontinued. New kitchen and utilities designs will have to be created soon. To facilitate this and to demonstrate modern slow-combustion stoves, the mission recommends the use of UNDP Regional Energy Programme funds in 1983 for a sample installation in a typical high-cost home. All such homes in Kiribati are owned by government or quasi-government agencies; thus a government policy decision in line with the above will be very effective in bringing forward the substitution of electricity with wood fuel in cooking and water heating in Kiribati.

If it is assumed that 150 homes will be involved in this wood stove conversion over a 5- to 10-year period, the ultimate new demand for wood fuel will be a maximum of 300 te (as received) wood or 90 te charcoal. The mission favours the use of charcoal in these stoves for reasons expanded in 4.4.4, although it is obvious that wood and waste materials of all kinds will be burned since many such materials will be free and have no opportunity cost in respect of displacing woody materials as fuel for power production.

Lower-income households already using wood may have some preference for the Fiji-type ME II and III wood stoves. These concrete slab and steel modular stoves provide a constant water boiling facility with, in the case of ME III, an oven. The larger stove/oven should be able to be built and retailed for less than A$100. There appears to be no pressure on most of southern Tarawa to have more efficient wood stoves for the sake of saving fuel since coconut residues adequately meet the cooking fuel demand. On Betio, the fuel supply is clearly marginal, making fuel efficiency a more realistic objective. For the most part, though, the use of these wood stoves will be welcomed, if at all, for convenience and novelty. Their energy-conserving characteristic is a longer-term bonus from a strategic standpoint. The local construction and use of these stoves will be demonstrated in Kiribati in 1983 as part of the UNDP Regional Energy Programme. Charcoal stoves and ovens are a substitute for kerosene stoves in most circumstances. They are cheap and portable and cook cleanly and quickly if well made and managed. The appearance of modern charcoal stoves of Fiji design is attractive, and local assembly is simple. Should the 500 to 600 households on Tarawa now using kerosene for cooking switch to charcoal, the demand for charcoal will be about 200 te p.a. The demonstration of production and use of these stoves is part of the above UNDP Regional Energy Programme for Kiribati in 1983.

4.6.4 Other cooking aspects. N.A.

4.6.5 Solar water heating. Solar water heating will take second place to all wood cooking and water heating on the basis of cost. However, there may be homes where wood stoves are impractical and the cheaper alternative of LPG must be applied. In these circumstances, solar water heating is highly desirable. No more than 200 litre systems with 2 m^2 collector panels need be installed. It appears that the demand for hot water is not great in any case so that the economics of supply will be less favourable than in more variable Pacific climates. The installed cost of a system will be about A$800 and the payback period between two and four years at Kiribati electricity consumption levels and fuel costs. The life of solar systems is at least 10 years. The decision as to installation of solar or wood-based water heating will depend on physical, economic and, to some extent, social factors (which may slow the adoption of wood stoves). It is recommended that DWE (Department of Works and Energy) review the high-cost housing sector with these decisions in mind, since it is likely that aid monies can be found for either or both of the wood and solar conversion programmes as a package.

4.6.6 Charcoal irons. Ironing clothes with heavy cast-metal irons fueled with charcoal is being reviewed in some parts of the Pacific and is known still to be practiced in Kiribati. The quality and design of charcoal irons varies greatly. It is desirable to have KCWS (Kiribati Co-operative Wholesale Society) survey the market and for the energy planner to arrange tests of the models available to obtain clean, durable, and effective irons for retailing in Kiribati.

5. PETROLEUM FOSSIL FUELS

5.1 Supply and Storage

5.1.1 Present supply patterns. Most petroleum products are supplied at Kiribati by coastal tanker from storage tanks in Fiji. These products originate in refineries in Singapore and Australia (near Melbourne). Mobil Oil is the sole company supplying ground products (except for small quantities of LPG imported in bottles from Fiji), while British Petroleum (BP) supplies aviation fuel for Tarawa. Mobil supplies jet fuel and small amounts of other fuels to Christmas Island. Tarawa receives shipments from Mobil four to five times a year; Christmas Island, two to three times. The Tarawa trip generally does not include any other stops, whereas shipments to Christmas Island are usually combined with a stop in Western Samoa.

5.1.2 Future supply. The mission sees two clear possibilities for alternative and cheaper supplies of petroleum products: (1) the use of a mother ship in the shipping fleet for backloading products from American Samoa to Tarawa and for on-ship power generation for storage freezers and (2) the purchase of a small second-hand tanker to procure supplies directly from Fiji, Samoa, or other favourable markets. This tanker could also supply outer islands direct in bulk. The key product traded in this fashion would be diesel. Aviation fuels, kerosene, and motor spirit would still be marketed, under re-negotiated agreements, to Kiribati by major oil companies. Regarding the first option, the present voyage pattern of the mother ship (of 350 te) is to visit Pago every six to eight weeks to deliver fish. It could return with approximately 200 te of diesel each trip, supplying other Kiribati diesel consumers 1-1.5 Ml/yr. This is equivalent to the present PUB (Public Utilities Board) consumption. The present price in Pago is about 60 percent of the equivalent price in Tarawa. Even if the Pago price is not significantly below the FOB price in Fiji in the longer term, the freight cost (which is truly marginal for the mother-ship arrangement) is significant for oil company supply. Maximum savings at present from this arrangement would be A$300,000 p.a. Clearly, the government should examine this option closely.

In the case of the "captive tanker" option, the government is urged to carefully weigh the relevant costs and benefits before any commitment is made. Owning and operating major ocean going vessels is not unfamiliar to the government.

A careful plan of vessel deployment and a related risk analysis are required for decision-making, and the government is urged to consult widely in making its analysis of this and other options. Both are attractive as a means of increasing the government's capacity to take advantage of favourable open market conditions as they arise.

5.1.3 Fuel storage. Bulk storage facilities on Tarawa are owned by Mobil in the case of ground products and by BP in the case of aviation fuels. Total tank capacity and demand coverage (based on 1981 sales from the depot) are as follows:

	Tonnes	Demand coverage
Motor spirit	305	98 days
Distillate	855	81 days
Kerosene	200	132 days
Jet fuel	380	141 days
Aviation gas	155	129 days

5.1.4 Future arrangements with fuel storage. As long as an oil company owns the oil storage facility for Kiribati outright, the government's capacity to negotiate a fair and equitable price for petroleum products will be in jeopardy. From November 1980 to April 1982, the world oil market has eased considerably, and there are signs that real competition for product sales will prevail for some years to come. However, the government will not be able to take advantage of these favourable market conditions until it owns its strategic oil storage and can dictate the terms of supply accordingly. Following the deployment of the UNDP/UNDAT specialist on petroleum pricing and supply arrangements, the situation of the oil storage on Betio has been clarified, and a forward plan can be devised for government action. The storage was built in 1964 and is almost fully amortised. Only A$34,000 remains to be written off. The storage has also been poorly maintained by the oil company in recent years. First, the government is advised to purchase the storage facility at book value, compulsorily if need be. The oil company has adequately recovered capital charges and maintenance costs on the facility as part of the pricing formula over the years and has no basis, financial or moral, to reject this move. Second, the government can retire the lease for storage facility land and have the land revert to its control. The remaining life of the storage facility is about only four years, depending on maintenance, and the final step is for the government to have built, under aid, a major new oil storage incorporating the most convenient offloading facility, possibly incorporated in a new deeper water port.

5.1.5 Local marketing and distribution. All motor spirit, distillate, and kerosene are sold by Mobil directly to the government, which acts in the capacity of agent. Fuel for use in the islands other than Tarawa is shipped by drum; this amounts to less than 5 percent of total demand.

5.2 Pricing and Price Control

5.2.1 Price composition. The price of ground products to Kiribati is determined by the contract with the supplier; at present, Mobil. Prices for private users are, then, a result of duty and markup collected by the government. The main elements in the buildup of the price of motor spirit and diesel fuel from refinery to retail consumer, based on the shipment of April 1982, are shown below.

A similar buildup applies for kerosene.

	Motor spirit	Diesel
	(A cents/litre)	
FOB Singapore	25.98	25.85
Freight to Fiji	1.79	2.03
Freight Fiji-Tarawa	5.14	5.83
CIF Tarawa	33.31	34.13
Distribution expenses	0.95	0.95
Agency fee	1.04	1.04
Duty	13.70	0.50
Oil company margin	5.22	4.08
Price to government	54.49	40.97
Markup	11.51	11.03
Wholesale price	66.00	52.00
Markup	10.00	10.00
Retail price Tarawa	76.00	62.00

5.2.2 Duty. Duty assessed is a flat rate of 13.7 cents/litre for motor spirit, 0.5 cents/litre for diesel fuel, 0.7 cents/litre for kerosene, jet fuel, and aviation gas. For LPG, duty is 20 percent of the C.I.F. value.

5.2.3 Price control. The Minister of Trade, Industry and Labour sets retail prices for benzine (motor spirit) and kerosene. These prices vary according to remoteness from the fuel depot, with a current range (for benzine) of up to 16 cents/litre from Tarawa to the farthest island. Kerosene has been subjected to price control since before independence, whereas benzine has only been controlled since late 1981. Neither of these products is covered under the freight levy scheme for outer islands. Banaba prices are contolled from Tarawa, and the Christmas Island petroleum price is the responsibility of the price controller in the Line and Phoenix Islands administration.

5.2.4 Price monitoring and negotiation. Through no fault of their own, the staff of the government responsible for negotiations with oil companies on supply and pricing, and the price controller, have little training or experience in management and negotiation of oil industry contracts or in the technical aspects of petroleum price control. This lack of experience is typical of the region and has to date ensured the oil companies the best possible deal for themselves in most cases. The concern of the mission is that the balance be redressed. Countries must quickly assume an equal negotiating strength for the savings that can result from fair and equitable contracts of supply and from close and knowledgeable scrutiny of petroleum price movements that are very considerable. These are perhaps the most significant savings that are available to Kiribati through any other change in the energy sector in the short term. The mission thus recommends the use of UNDP funds for workshops and training sessions on price control methodology over the 1982-85 period to improve the skills of local price controllers and negotiators.

5.2.5 Local marketing and distribution. N.A.

5.3 Resource Development. N.A.

6. ELECTRICITY

6.1 Institutional Arrangements

6.1.1 Overview. Prior to independence, the colonial government administered power supplies to Kiribati as part of the Gilbert Island Development Authority functions. On 1 July 1977, the Public Utilities Board (PUB) was established under an act of Parliament to generate and distribute power and to take charge of water supply and sewage disposal. A board of directors is appointed according to the provisions of the act, with six commissioners and the General Manager as an ex-officio member.

Both the Undersecretary of the Department of Works and Energy and the planning officer of the Finance Department are members. All board members are local citizens. The Minister responsible for the PUB is the Minister responsible for the Department of Works and Energy. The PUB has authority for power generation on Tarawa only. Generation on Christmas Island is maintained directly or indirectly by the DWE (Department of Works and Energy) in cooperation with the Ministry for Line and Phoenix Islands. The generation facilities on the outer islands of the Gilbert Group are small and mostly in private hands. The financial arrangements for the PUB have been established with broad terms under the act. The PUB is permitted to set aside reserve funds from its revenue for replacement and new developments. Tariffs are to be devised by the PUB although they must be agreed by the Cabinet. The government believes that the PUB should be a "commercial" organisation, that is, revenues should meet costs and generate sufficient equity to replace worn and damaged equipment and provide an equity contribution sufficient to cover the debt portion of future distribution and generation development.

At independence in July of 1979, the cost at completion of the new power station on Betio (A$674,000) was constituted as a debt to be paid back to the government interest-free over 25 years with a five-year grace period. Repayments should therefore have begun on 1 July 1982. Currently, the Finance Department is asked to meet almost all expenses for capital items of any kind, including tools and spare parts. Major projects are funded by the Finance Department through the budget or directly from overseas aid (for example, the South Tarawa Village Electrification Scheme and the new Betio-Bairiki causeway cable). However, the PUB is not obliged to have its budget, capital or recurrent, approved by the Finance Department nor to have capital projects approved as part of the national budget.

6.2 The Power System

6.2.1 Generation system. Generation of power is entirely fueled by diesel for the main public power supply system on Tarawa and Christmas Island. Very small PVC power production has begun for aircraft navigation beacons, and a small wind electric system has been used on Christmas Island. On Tarawa, there are power stations at Betio, Baraiki, and Bikenibeu. The main generating station is in Betio, the extreme west of transmission. The diesel sets are 4 x 300 kW, 750 rpm, English Electric, one of which is permanently out of service with an oval crankshaft and a 140 kW ruston set. These sets were probably made in 1954, although they have not yet reached the end of useful life. There are also two English Electric 750 kW, 750 rpm sets installed in 1976. These machines bear the bulk of the load. Site rating and age adjustment reduces individual firm capacity of the smaller 3 x 300 kW sets to 250 kW; thus with one out of service, the firm capacity at the Betio power station is 1,640 kW. The peak load on the system has actually dropped 100 kW in the past two years. In 1976, the maximum demand was 730 kW; in 1978/79 it exceeded 750 kW; and in October 1980, 910 kW. Load curves available for selected months in 1981 and the April, May, June 1982 load curves show the peak at 800 kW. To the converse, the minimum demand has grown from 200 kW in February 1979 to 425 kW in May 1982. This overall improvement in load factor is extremely fortunate, making more efficient utilisation of the larger diesels and delaying to the late 1980s or beyond the need for investment in a new diesel plant. The decline in growth has clearly resulted from doubling tariffs over the 1978 to 1981 period and quite likely through a decline in economic activity during the immediate post-independence and "post-phosphate" period. Additional emergency generators of 300 kW (250 kW site rating) are stationed at both Bairiki and Bikenibeu power stations, although these cannot be operated in parallel with one other or the main power station at Betio.

The generation capacity on Christmas Island is mostly in small and very old sets. In 1978, there was 255 kW (NPR) in four sets at London and 35 kW in three sets at Banaba, all of which were 1,000 rpm. At Poland there was 37 kW installed of 1,500 rpm sets. All the above generate at 415 V or 240 V/60 HZ. The more modern sets at the hotel of 100 kW each and those at Artemia and the airport of 10 kW each generate at 208 V or 120 V/60 HZ. These sets are 1,800 rpm and of short life.

6.2.2 Transmission and distribution. Transmission and distribution on Tarawa is at 11 KV and 415/240 V/50 HZ. An 11 KV feeder line crosses underwater from Betio to Bairiki and from there, it is laid underground through to the Bonriki airport and beyond to the Tanaea agriculture and fisheries establishment (32 kms total length). About 35 transformers "none bigger than 200 kVa" step voltage down to 415/240 V for distribution to consumers throughout the system. Voltage regulation remains a problem with significant voltage drop occurring along the length of the feeder to Bairiki. An automatic voltage regulator has been installed although its effective operation is limited. The prospect of a new power station at Bonriki in the Temaiku bight generating in synchrony with the Betio power station would improve voltage regulation and general system security considerably. Even so, a top quality communication system would have to be installed between the new power station and the Betio power station.

6.3 Planning Issues

6.3.1 Overview. It is acknowledged that during the past five years, planning with any certainty for the future has been difficult. The end of the phosphate revenue, the arrival of independence, and the general downturn in copra prices have made the production of economic growth and hence power demands almost impossible. Even so, there are some basic requirements for system planning which could have been attended to, especially because the local economic situation was in flux. These include: (1) establishing in some detail the nature of the demand within and between the industrial/commercial, government, and household sectors and (2) monitoring the changing patterns of demand occasioned by price. These have been significant and can shed light on the future level and composition of demand. Electricity is now priced at a level, which though below cost, is above that for LPG, solar, or fuelwood for some applications; and with national pricing, the pattern of demand will change significantly yet again. Furthermore, at the true cost of electricity today, there are opportunities for alternative power sources to be brought into economic production. This entirely alters the complexity of planning and demands quite close attention not only to new fuel resources and new technology but also to the equipment which will serve to integrate the old and new systems together for a stable and high standard power supply.

6.3.2 Options and recommendations. Financial planning is essential in attaining an orderly system development. This takes many dimensions. Currently, a deficiency exists in knowledge of costs throughout the system. This arises partly because of the integrated accounts of the sewage, water, and power sectors of the PUB. (However, within the power sector alone, the costs of supply to various classes of consumer are poorly documented.) This deficiency affects the timeliness and ultimate level of tariff increases and, in the event of delays and underestimates, reduces the PUB's ability to attain self-financing status. Forward planning for system development includes the formulation of detailed capital budgets and matching revenue statements specifying the level of tariff that will be necessary to finance the capital program. One cannot proceed without the other. In other words, demand projections, generation, and transmission/distribution expansion plans and costs are needed to establish the financial plan. Neither of these exists today although they are an essential tool in utility management. Having pointed to these problem areas, we must immediately acknowledge that the present staff numbers are too low to cope with this additional workload; and in fact, the PUB has been doing well to manage as it has during a period when two highly skilled expatriates have left its employ. The mission urges the PUB, the Finance Department, and the DWE to rebuild the staff of the PUB to cater for the period of system transformation, both economic and technical, that lies ahead. A system planning engineer is needed to work with the present Chief Engineer; and an economist-financial analyst is needed to work with the present Financial Manager. Their most urgent task is to develop several scenarios of system expansion over 10 to 20 years, employing the options for the new power sources we have outlined, and the existing diesel system, to meet demand under each scenario, and to detail the capital, recurrent, and revenue budgets for the same period.

6.3.3 Other planning aspects. A natural outcome of the transition to wood power would be the need for close and sustained cooperation with the Agricultural Division, the DWE, and transport to ensure that coconut trees are being harvested (and replanted) and delivered to the fuelyard at the power house and that every opportunity is taken both to further develop the fuelwood resource and to assemble and deliver all combustible residues. The day-to-day management of fuel supply will be a significant task, and long-term plans widely agreed among agencies will be critical to success. At the same time, this mission proposes a number of measures by the government which would significantly reduce both maximum demand and total energy demand on the power system.

The PUB planners will need to be aware of the initial review of these prospects and be well informed about the formulation of firm plans and the progress of their implementation so as to modify their own system planning accordingly. All of this needs close and enthusiastic cooperation between government planning and utility planning, a matter which will be further discussed in Section 8.2.

6.4 Management Issues

6.4.1 Overview. The mission was able to spend only little time with the PUB management in reviewing, accounting, and understanding the nature of the government/PUB relationship. Here we present our findings on several issues which influence the performance of the operation and which may be subject to some reform.

6.4.2 Financial management. Several issues are embraced here. The first is the relationship between the Finance Department and the PUB. As stated in 6.1.1, the government expects the PUB to: (1) repay the cost of the Betio power house as transferred as a debt to it from the former authority at independence and (2) raise sufficient revenue to meet some of the future capital as well as the generating costs. The mission finds this arrangement too vague to ensure effective financial management. Also, it is in contradiction to the control that the Finance Department and the Cabinet maintains over tariffs (although the government's attitude to tariff levels will be tempered by the information on costs supplied by the PUB, and this is deficient as stated). The mission believes that a new and simple set of guidelines for financial mangement is essential. As a basic premise, we believe that it is vital for the PUB to function as a fully commercial enterprise, with the full costs of production reflected in the price of electricity to the consumer and with every reasonable measure being taken to have the PUB generate, from its own tariff, sufficient revenues both to renew and to expand the system. To achieve this, the government must determine a rate of return objective for the utility in respect of its power sector operation which is in line with the maximum return the government might reasonably expect from investment in fishing, coconut rehabilitation, salt manufacturing, and the like. To expect less is to reduce the general level of economic productivity, and to subsidise electricity consumers who, in this case, are largely higher-income public servants, or privileged groups, without direct accountability for the costs of their consumption (see 7.0).

Second, the government should nominate what proportion of the cost of new projects in the power system is to be raised as equity by the PUB. Normally, 40 to 60 percent as equity is expected of such enterprises, although rarely is this achieved. Finally, there must be some guideline established as to debt servicing and borrowing limits, determined on the basis of agreed debt service coverage ratios. These financial guidelines are essential in determining appropriate tariff levels, both now and in respect of financial planning to finance the development plan. There is the parallel requirement to keep an accurate record of the funds employed in the system and the extent to which they have been repaid. Ledgers of both the historical value and the replacement value of the system must be maintained up-to-date and in detail.

In the absence of these tools of financial management, the utility finds it hard to determine adequate tariffs and the Finance Department cannot judge the adequacy of those proposed. Since costs are already very high, there is a natural reluctance to find that they are indeed higher and to press for increased tariffs without an absolutely clear basis on which to argue the case. Consequently, the present tariff does not even cover generating costs, let alone capital charges and reserves.

There are currently no renewal reserves and no reserves to finance system development. Even the more sundry of capital items, such as tools, are requested of the Finance Department out of the national budget and in an ad hoc manner as the need arises. It is obviously impossible for the government to receive payments on their initial loan, no matter how soft the terms, while keeping the tariffs so low. And furthermore, the government will continue to be plagued with requests for capital expenditure for equipment without advance warning unless system planning, then financial planning, and finally tariffs are constructed, reconstructed, or reformed.

6.4.3 Other management issues. Management of aid to the power sector. Consistent with the above, the government should pass aid funding on to the PUB on agreed commercial terms and not on the terms of supply by the donor. The government should control the allocation of resources to the economy directly (and with full knowledge of the support it provides sector by sector) to achieve its development goals. This does not mean excluding electrification from government assistance, but it does mean that such assistance will be through the budget in direct consideration of other expenditures. Equipment grants would be valued at open market prices to determine the cost of the aquisition and the financing arrangement as between the Finance Department and the PUB. Loans received on soft terms would be passed on at commercial rates with the government accruing the difference for general development expenditures. Again, it is fundamental that tariffs are set and applied at the levels implied by this commercial approach to utility management.

6.4.4 Recommendations. The present board of commissioners is appropriate in structure even though perhaps in need of further depth in technical and financial expertise. This is, of course, difficult to obtain in Kiribati although the government is asked to carefully consider further strengthening of these areas. The new government energy planner should be appointed to the board ex officio to guarantee liaison between the energy administration and the utility, as well as to help the board monitor the forward planning of the utility. A natural corollary of a new planning and economics division of the PUB is the production of a timetable for system development and renewal, with both financial and manpower resource implications. This will provide the board and the management with a means of monitoring the performance of the utility and the management. Government representatives on the board should seek, and the management should provide, a detailed work plan each year, and an outline for the medium and long term, which identifies all significant activities, their importance to power supply and costs, and the resources allocated for their implementation. This detailed work plan can be reviewed at any regular board meeting. The annual work plan should be derived from the rolling ten-year development and financial plans. By using this mechanism of management, the government should only have to address requests for additional capital expenditure for genuine emergencies, and only then in the interim before sufficient reserves are established within the PUB.

After defining the level of expenditure which constitutes a major project, the government should include such projects in its own budget for approval. The source of funds may partly be the PUB, although the debt portion must be raised by the Finance Department and its source and terms registered accordingly. Major capital projects in the power sector will frequently be among the biggest projects in the economy and should be handled in that light.

The mission is concerned that there is not an adequate partitioning of costs as between sewage/water supply and power production activities in the PUB. The association of these activities already creates problems for the concept of "commercial" operations unless a similar approach is taken to the management of the water and sewage systems. The mission would ideally like to see the power sector managed as a separate entity, leaving water and sewage under the DWE or another authority, although with centralised billing and revenue collection. Without this, we recommend the reconstruction of the accounts to more clearly discriminate between overhead and expenditures incurred in respect of each of their functions.

In the longer term, the government should be looking to have all power supply established by, or under, the supervision of the one authority. The main reasons are: to nationalise planning of power supply, to standardise equipment, minimise overheads, improve safety and efficiency, and in the ultimate, to reduce costs. Of course, until the PUB is properly and fully staffed, increasing its jurisdiction and responsibility will be to no advantage. Adequate staffing is already appreciated by both the PUB and the government as a priority.

The PUB must currently go through the government's supply office to obtain spare parts. This is a frustrating and cumbersome arrangement. The PUB should be allowed to procure and stock its own spare parts independent of the government service, but in accordance with possibly varied board and management approval to ensure that only absolutely necessary stocks are maintained. Over-ordering and inappropriate purchases can become a major burden on a small utility and must therefore be subject to close management supervision.

It is critical to a proper understanding of the level and pattern of sales and the efficiency of generation and transmission to maintain records for consumption for exactly the same period as that for powerhouse records: preferably the calendar month. Currently, the meter reading is for irregular periods and for a different period in each district. Every attempt should be made to have meter reading done within one week of the beginning of each month and in a regular pattern.

6.5 Electricity Pricing

6.5.1 Overview. The mission has attempted to establish the full costs of production in the very limited time available to it in the field. While we have doubts about the accuracy of the capital charges due to the lack of a complete register of equipment installed in the system, the estimate here is more likely to be conservative than excessive. Once having established an estimate of the full costs, we demonstrate an alternative tariff structure that, in our view, best serves both the financial and energy management objectives specified in this section (6.0).

6.5.2 Present tariffs. The full marginal cost of production is estimated for the southern Tarawa power generation system of the Public Utilities Board. By applying a 10 percent discount rate to capital charges, we estimate this cost at 37.7 cents/kWh (see Appendix 6.5.2), and can be compared with the present tariff of 24 cents/kWh which is 4.3 cents/kWh, or 15 percent, below the direct costs of production per kWh (delivered) on the system. There is no doubt that a tariff increase is urgently required. The only question is the absolute level and form the tariff should take. The costs of under-pricing electricity are severe. It is obvious that the incentive for consumers to turn to more economic forms of energy in certain applications will be very much greater, and the transition very much faster, if the full costs rather than the present price were applied to electricity. The fact that government is, for all intents and purposes, the consumer, means that there will be a large transfer from a number of government departments, quasi-government agencies and companies, to the government's PUB--should a tariff increase occur. For example, 3 percent of consumers, all to some extent government, use 53 percent of the electricity. In passing on the full costs of production, as it must, the government must simultaneously ensure that all its agencies are brought to be more directly accountable for their electricity consumption and that every step is taken to utilise cheaper forms of energy (see 4.4 and 7.2). It is in the domestic sector that problems of a political nature might arise.

6.5.3 Other tariff issues. Three-quarters of the consumers are households, and they consume 30 percent of the power. However, 570 consumers, mostly domestic, but some commercial and industrial, use less than 20 kWhs per month. Their gross consumption is 97 MWhs or 2.3 percent of total consumption. It can be assumed without fear of contradiction that the great majority of this electricity is used for lighting and that even at the cost of 20 cents/kWh, there is no cheaper means of producing this light on Tarawa. In effect, the government could reduce the price of electricity to their consumers without impairing the rational use of local energy sources and without losing very much revenue. More to the point, the provision of cheaper electricity to a large number of low-income earners would be a means of ensuring some social equity in energy pricing while increasing the overall price to meet the desired revenue objective and signalling the full marginal cost of electricity to consumers.

6.5.4 Recommendations. The mission proposes the use of a "life-line" block tariff with a full marginal cost last block. A "life-line" block is a small amount of electricity deemed to be essential to maintain the minimum quality of life desirable in a particular environment. This is, of course, a subjective judgement, even though economic considerations are still important. If the "life-line" block were set at 20 kWh/month, and the 21st and all additional units were charged at the full rate of 38 cents or more, there would be a strong incentive not to exceed 20 kWh/month unless it was truly worthwhile or unavoidable. Ultimately, very efficient use of the cheaper power would also be ensured. The mission thus proposes for Tarawa a tariff which for all consumers has a block of 20 kWh priced at, say, 20 cents/kWh and the next and final block at, say, 35 cents/kWh. These levels are chosen as a first step. Once the government has decided which rate of return it would like to see applied and has determined its revenue objective, the cost of the "marginal" units can be re-assessed. For example, a discount rate of 7 percent rather than 10 percent would reduce capital charges by about 1.5 cents/kWh, and there may be a desire to subsidise the electricity utility to some smaller extent allowing time for the populace to adjust to higher tariffs in steps rather than in one move. To indicate the general impact of such a tariff, some general statistics are useful:

A 20-35 cents/kWh block tariff with 20 kWh/month in the first block will give:

- 570 consumers a 20 percent reduction
- 350 consumers an average increase of only 10 percent
- the remainder, about 900, an increase up to a maximum of 45 percent for the largest consumers (all government).

The revenue implications of such a tariff are, of course, quite positive. There is currently a deficit between revenue from sales and direct operating costs of the order of A$185,000. This would be made up and a reserve of A$150-$200,000 would be established annually depending on the elasticity of demand. The mission strongly encourages the government to proceed with tariff reform immediately in parallel with a number of other measures for electricity savings, discussed elsewhere in this report, which are directly under its control.

6.6 Rural Electrification

6.6.1 Overview. In this section, we deal briefly with issues surrounding the sale of electricity on outer islands. The technology for remote small-scale power generation, as well as the government's role in promoting its use, is discussed elsewhere (4.3). Since the PUB does not supply power other than in Tarawa, the issue is simple. The mission recommends no government involvement in power supply to the private sector in outer islands until a significant load exists in each demand centre which can be met more cheaply by a centralised government supply than by a series of small private generation systems. Christmas Island is the exception.

Christmas Island supply. The mission believes that it will be to the advantage of future power development in Tarawa, and to efficiency of supply generally, for the PUB to assume control of the operations of the proposed steam power generation facility on Christmas Island. The experience that the PUB will gain from maintaining this installation will be very useful for later management of the proposed Tarawa steam power station.

6.2.2 Recommendations. N.A.

7. ENERGY CONSERVATION AND MANAGEMENT

7.1 Opportunities for Energy Savings

Kiribati has many opportunities for saving energy. Indeed the most economic energy is the energy not used. The mission has observed wasteful practices which require little more than political willpower and bureaucratic resolve to prevent. And the savings will be significant. Here we will focus on a very few of the most obvious and wasteful practices, although most will be within the ambit of "government measures" (7.2) and will be dealt with there.

7.1.1 Households. N.A.

7.1.2 Lighting is commonly regarded as a low priority because it is such a small user of electricity. However, in 6.5 we observed that more than 500 consumers probably use electricity for little else and thus to them the saving will be significant. It was very common to see incandescent bulbs in houses along the roadway and in public places. It is worth noting that at the present selling price and for lamps used six hours per day, it costs per year A$31.50 to power a 60 watt lamp. Yet the same light is available from a fluroescent tube of 18 W for 30 percent of the cost, more than enough savings to pay for the cost of the fitting in one year and with five times the life for the tube over the bulb. The PUB and the new energy planner could encourage the use of efficient lighting both through appropriate wiring of new government homes and through public literature on savings. Simply connected 18 W fluorescent fittings should be made available cheaply through KCWS.

There are clear opportunities for using less lighting together with more efficient lighting. Sodium vapour lamps can be used for all street lighting. Low-pressure sodium vapour lamps of 18 W and 100 lumens/watt are now available. The cost of the fitting is the same as for 2 x 20 W fluorescent and the pay back time at current electrticity costs is about 15 months. The easiest saving is achieved by physically removing or disconnecting unnecessary lamps. Throughout government offices there are lights shining beside windows which already provide excellent natural illumination. In the Finance Department, however, lighting was not used at all, and with no apparent discomfort to the office staff. Clearly, this is another simple matter for the energy planner to attend to which will be rewarded with immediate benefits. This raises the more general question of building design.

7.1.3 Refrigeration and cooling. Refrigeration is among the highest user of electricity in Kiribati. Large bulk stores and fish freezers provide a constant base load. Heat exhausted from large refrigeration systems can be used for food drying and for hot water production and must be considered as a cheap local energy source.

However, it is not clear that the most efficient refrigeration cycles are in use in the Pacific, let alone Kiribati, and it is known that the efficiency of systems now marketed varies greatly, a factor accentuated sharply where electricity costs are so high. The mission has therefore proposed the use of UNDP funds for a review of all major refrigeration systems in use by a specialist in refrigeration engineering to provide detailed technical advice to the countries of the region, both on procurement and design. The variation in efficiency in household refrigeration and freezers is up to four-fold for appliances now marketed. Japanese equipment is renowned for its efficiency although it is not common in the Pacific. A further refrigeration consultancy has been budgeted for domestic sector appliances, the objective of which is to supply government procurement agencies and wholesalers with a detailed inventory of costs and performances of the equipment available globally, ranked in terms of efficiency and longevity.

7.1.4 Transportation. The design of fishing and trading boats and ships in use in Kiribati varies greatly and is by no means optimum for energy efficiency. Nevertheless, the application of an energy saving design to specific purpose vessels is complex. So too is the correct sizing of engines and propellors.

The mission understands that considerable potential exists for harmonising energy saving and functional design and has budgeted UNDP Regional Energy Programme funds for a specialist review of the regional fleet with technical advice for procurement agents and designers in mind. The Kiribati Marine Training School is well placed to contribute to and benefit from this review.

7.1.5 Industry and commerce. N.A.

7.1.6 Building codes. Designing buildings for natural lighting is one of a number of straightforward design matters which can be dealt with through modifications to the existing building code. The newer government buildings are already fairly well designed for ventilation and shading, but the bulk of the infrastructure is grossly inadequate and demonstrates the need for uniformity in design concept for thermal comfort and natural lighting. We will refer to the use of air conditioning below, although if it is to be used at all, quite different design constraints should be applied than to those buildings using cross-flow ventilation for cooling. With the latter, high ceilings with adequate hot-air exhaust and insulation, combined with full shading of the walls and windows are called for (not unlike the Maneaba traditional design). With clever but simple design, it is also possible to use skylights to take advantage of high natural illumination levels. The mission recommends revision of building codes to induce energy conservation in the building environment.

7.1.7 Energy audits. N.A.

7.2 Government Measures

Ideally, government intervention in the energy market place should be limited to information on the potential which exists to save in the face of full and correct energy pricing. In Kiribati, the government is, in most instances, the producer and the consumer, and there are the typically acute problems of public administrations with minimal individual responsibility or accountability for energy spending actions. In effect, lights can be left on, air conditioners can be freezing, and vehicles misused because the individual neither pays nor answers for the costs. In this circumstance, the government must improve individual accountability and, with appropriate action, regulate. Some measures have been discussed in 4.4 and 7.1 above, though there are important additional steps to be considered here.

7.2.1 Energy pricing. N.A.

7.2.2 Legislative controls. N.A.

7.2.3 Other Measures. Air conditioning. It was most noticeable in Kiribati that many top administrators, and even the President himself, deliberately did not use air conditioning and arranged well-ventilated offices, whereas others used air conditioning heavily in rooms with paper-thin walls, no shading, and no insulation. After discussion with the President and senior staff, the mission recommends that the government ban the use of air conditioning except in special places such as libraries, hospital surgeries, and the like. Where air conditioning is legitimate, heavy insulation, shading, and well-sealed full glass windows should be installed along with thermostatic controls. Air conditioning need not be below 25°C for most purposes. Modifications will be needed in offices that are presently air conditioned to make them fully comfortable with natural ventilation and fans.

Cooking and water heating. In line with our review of wood stoves and solar water heaters (4.4, 4.6), the following steps are recommended to government:

- Banning the installation of electric stoves.
- Banning the use of electricity as the prime or sole source of water heating.
- Replacing faulty electrical cooking and water heating systems in government homes with wood and/or solar systems.
- Eliminating the duty on all renewable energy conversion appliances.

These measures may appear dramatic; however, it is clear that it will be difficult to levy the full price of electricity or to make a rapid conversion across to charcoal and woodfuels without them.

Government and the fuelwood supply. It is obvious that government involvement will be necessary both for regulation and supply in the fuelwood business should these alternative fuels be promoted in line with our recommendaitons. There is the need to closely regulate the felling of coconut trees so as to ensure that only senile trees are felled (unless general clearing is desired) and that seedlings are planted after felling wherever practicable. Either direct involvement or guidance in fuel preparation will be needed if coconut wood is to be used as a domestic fuel. Similarly, it may prove useful to apply incentives for gathering or harvesting other fuelwoods such as a guaranteed price at a government fuel yard and free seedlings for the public to plant. KCWS should be engaged in the business of charcoal trading as significant markets develop in the government sector. There are many other considerations for a transition to fuelwoods which suggest, or demand, government assistance. Planning a fuelwood economy is a major task for the new energy planning administration.

8. ENERGY ADMINISTRATION AND PLANNING

8.1 Present Arrangements. Following the last national elections, the President allocated high priority to the energy sector with a view to increasing the use of local sources and economising on imported fuels. The energy portfolio was established combined with the Ministry of Communication and Works and the President called for the appointment of an energy planner as a matter of urgency. The advertisement has already been made and an appointment was expected in late 1982. This planner was to have been in the DWE and responsible to the departmental head.

8.1.1 Overview. N.A.

8.2 Issues and Options

8.2.1 Overview. The mission strongly commends the President's action in appointing an energy planner. A parallel appointment is needed of a national to assist with, and be trained in, energy policy planning. The responsibilities of an energy planner are many, and, as can be seen from this report, so are the opportunities to gainfully use this person's time. It is essential to ensure that two general circumstances apply:

- that all aspects of the energy sector are examined in proportion to their importance (i.e., not to let wood, or conservation, or petroleum activities exclude all others) in an open analytical context to justify the allocation of time and resources;
- that the planner does not become an implementor too, except in special circumstances (the Department of Works and Energy staff, agriculture division, the PUB, and others are the implementors).

Close management of the energy division will be necessary to begin with in order to ensure the careful allocation of priorities and the full cooperation of implementing agencies. This requires a simple administrative structure.

8.2.2 The role of the energy planning unit. In such a small administration, a widely representative energy committee may not be appropriate. A group of four, including the Minister, is probably more effective. We propose the Director of Works and Energy, the key development planning officer in the Finance Department, the Secretary of

Works and Energy, and at his convenience, the Minister of Communication and Works. The energy planner would be the executive officer to the group. This group should meet at roughly two monthly intervals in order to: be appraised of the progress of relevant regional and local projects and programmes; approve new activities at the time of the budget preparation; and assist with interagency cooperation. We repeat our suggestion that an energy planner with suitable experience should be made a member of the PUB board.

8.2.3 A National Energy Committee. N.A.

8.2.4 National Coordination. N.A.

Appendix: 3.1.4

PETROLEUM FUEL CONSUMPTION IN 1981

This appendix refers specifically to the breakdown of fuel use in Table 3.2. Fuel used in inter-island shipping and air transport is included, as is all fuel sold in Kiribati to Air Tungaru or domestic shipping. Total energy use for the various fuels reflects 1981 sales as reported by the suppliers, with adjustments made in the case of petrol and diesel fuel to account for actual sales and from the Tarawa fuel depot.

Household uses

All kerosene and white benzine is allocated to this purpose, though there may be minor miscellaneous uses as well. Nearly all LPG use is estimated as the household share, though the hotel uses LPG for cooking as well.

Transportation

The amount of distillate used in transportation is estimated by subtracting distillate use in electricity generation and heat and steam raising from total use, with the additional subtraction of a small amount used for other purposes (primarily fishing). Nearly all motor spirit (some of which is used in subsistence and small-scale commercial fishing) and all avgas are allocated to this purpose, as is jet fuel sold to Air Tungaru.

Heat/steam-raising

To our knowledge the only use of petroleum fuels for heat or steam-raising is in bakeries on South Tarawa. We have estimated the consumption at 200,000 litres per total though we have no confirmation from the industry owner/operators of this figure.

Electricity generation

This includes diesel fuel used by the PUB on Tarawa in 1981 (1486 kl), plus use in the generators on Christmas Island. The latter is roughly estimated as 300 kl. A small amount (40-50 kl) is added for fuel use in small private diesel generators.

Other

This heading includes estimated diesel fuel use by the fishing fleet (720 kl) and in construction and agricultural machinery.

Appendix: 3.3.1

BIOMASS ENERGY USE

Domestic cooking

The mission did not undertake a survey of domestic cooking. It was evident, however, that coconut husk and shell is the most popular cooking fuel. There is apparently little use of wood for cooking, except perhaps in umumu. We will assume here that 70% of outer islands' households use biomass only, and another 20% supplement biomass with kerosene (75% biomass). On Tarawa, we assume that half of all households use biomass only, and that 25% supplement biomass with kerosene or gas (50% biomass). We also assume that 90% of households make an umumu on the weekend.

The quantity of husk and shell or other residues used in cooking is not accurately known. We estimate consumption of 1 kg/head/day (oven-dry weight) for households using biomass only. For an umumu, we use Fijian survey data for coral atolls of 2 kg/head/umumu.

In our calculation we use a Tarawa population of 21,000 and an outer islands' population of 39,000. Based on the above considerations, we arrive at total biomass consumption of 22,500 ODte, or 425 terajoules.

Appendix: 4.1.3(a)

STANDING BIOMASS OF COCONUT PLANTATIONS IN KIRIBATI

(a) Gilbert group of islands

- Total area assumed 25,345 ha (D.A. Trotman, Agricultural Adviser, 1980).
- Planting density of trees: 80/acre or 197/ha average.
- Assumed recoverable volume based on W. Samoan data: 0.96m^3/tree.
- Average weight of recoverable portion 1059 kg, at 56% m.c.w.b. (Note: there will certainly be a variation from this data for Kiribati, though from observation it is unlikely that the volume of the mature tree will be less).

Thus total stemwood (est.)

- 5.50 million tonnes fresh weight
- 2.42 million oven dry tonnes (ODte)

Annual availability on a 60 yr. rotation: 40,300 ODte.

(b) Christmas Island

- Assume 2200 ha of plantation, and planting density of 140 trees/ha.
- Other parameters as above.

Thus total stemwood (est.)

- 326,000 te (as received)
- 143,000 ODte

Annual availability on a 60 yr rotation: 2390 ODte

2. Volumes of timber released under the national coconut replanting programme

(a) Gilbert group

- Target is 500 acre or 202 ha/year of new plantings
- Assumption is that planting can be done on the basis of selective felling of senile trees and replacement by seedling, rather than interplanting of seedlings and poisoning old trees to rot as they stand when young trees reach productivity.
- All parameters on yield are as above.

Total annual availability of timber from culling senile trees -

- 202 ha x 197 trees/ha x 0.96 m^3/tree recoverable
  = 38,202 m^3/yr.

- Maximum production of good quality sawn timber will be at 15% average recovery for total standing crops (considering bent and twisted trees, and the proportion of dense timber) or 5730 m^3/yr.

Availability of woodfuel net of timber is 32,472 m^3/year
or 15,781 ODte/yr

Availability of woodfuel on South Tarawa.

- Combined total agricultural land area of Tarawa Urban East, West, Betio and Tarawa South is 1650 ha, or 69% of coconut woodland area in the Gilbert Group.

- Thus 0.06 x 15,781 ODte = 947 ODte per year on basis of the replanting programme.

OR on the basis of a 60 yr rotation

1650 ha x 1/60 yr = 27.5 ha/yr
27.5 x 197 trees/ha x 1.06 te/tree = 5743 te (as received)
OR 2527 ODte/yr

Availability of Coconut wood on North Tarawa

Coconut plantation is 1526 ha. Rotation is 60 years.
Annual harvest is of the equivalent of 25.4 ha/yr
= 2334 ODte/yr

Appendix: 4.1.3(b)

HUSK AND SHELL FUEL AVAILABLE SURPLUS TO DRYING (GILBERT GROUP ONLY)

- In the South, including Tarawa copra is mostly solar dried.
- In the Northern islands of the Gilbert group copra is mostly dried conventionally with Samoan type kilns, using about as much husk and shell that is available.
- For the Kiribati coconut it will be assumed that the same surplus of husk and shell applies net of efficient drying (using modern gasifiers) as the Solomon Islands, i.e. 2.4 te husk and shell (at 37% m.c.w.b) per tonne of dry copra (allows losses of 20% of total husk and shell).
- For Solar drying of copra the total husk and shell available with the same allowance for losses is 2.9 te husk and shell (at 11.6 MJ/kg net heating value).
- Copra production in the Northern Islands (Makin, Butaritan, Marakei, Abaiang) is 1552 te (annual average).
- Total annual average 5269 te copra.

Thus husk and shell surplus to drying in the South (incl. Tarawa) is (5269 - 1552 te) x 2.9 te = 10,780 te or 6790 ODte

And husk and shell available from efficient drying in the Northern group (theoretical maximum) is: 1552 te x 2.4 = 3725 te OR 2350 ODte.

Husk and Shell generated on Tarawa

- Agricultural area of 6250 acres = 2529 ha.
- Av annual production (1949-78) : 542 te/yr

or

Thus: 1488 te husk and shell OR 940 ODte/p.a. total.

- Given the greater coverage of public facilities and population in South Tarawa we will assume that only 50% of the residue is available there compared with 37.5% based on land areas.

Thus: 940 x 0.5 = 470 ODte p.a. husk and shell available on Tarawa South.

Appendix: 4.1.3(c)

POTENTIAL CHARCOAL PRODUCTION FROM COCONUT RESIDUES ON OUTER ISLANDS OF KIRIBATI (GILBERT GROUP ONLY)

(a) Coconut Wood charcoal

- Charcoal is produced with kilns; either 200 l drums or $3m^3$ and $6m^3$ mild steel kilns.
- Wood is waste from mobile sawmills, or is old trees cut into 30-50 cm blocks with chainsaws or docking saws on the back of a tractor, and split into billets with an hydraulic splitter for drying.
- Conversion efficiency is 25% wt charcoal per unit oven dry weight of wood.
- It is assumed that on outer islands (other than Tarawa) sawn timber is extracted at rate of 15% (average) of volume of culled trees.
- Rate of tree felling is determined by the replanting programme. On the basis of land area 88% of replanting will occur on other than Tarawa.

Thus:

- Total woodfuel production : 15781 ODte (2 (a))
- That an outer islands: = 15781 x 0.88 = 13,887 ODte
- Charcoal production (Maximum possible) is 13,887 x 0.25 = 3,472 te

(b) Coconut Shell Charcoal

- Production involves changing the copra production method to finger cutting, i.e. dehusking, then splitting the nut and drying in the shell, either by sun in the South, or by conventional drying in the North.
- Ratio of shell to husk and shell combined by weight is 0.25 : 1
- Charcoal production efficiency is 30% recovery by weight of dry shell.

Thus: maximum possible coconut shell charcoal production outside of Tarawa is:

(6,790 te + 2,350) - 940 = 8,200 ODte husk and shell total

8,200 ODte x 0.25 = 2050 ODte coconut shell

and 2,050 ODte x 0.3 = 615 te coconut shell charcoal.

Appendix: 4.2.5(a)

SMALL WOOD-FIRED STEAM TURBINE POWER SYSTEM FOR TARAWA-KIRIBATI

Parameters

- A 2 x 0.5 MW steam turbine power generation system is installed at the Temaiku bight as a base load station.
- Wood fuel is coconut stemwood from North and South Tarawa, and Casuarina wood from the Temaiku bight and public plantation lands.
- Wood fuel will cost A$20/te of coconut log delivered (i.e.about A$20 per tree), and A$30/te of Casuarina delivered. This is approximately $A45/ODte per coconut palm and $A50/ODte Casuarina.
- The steam turbines are assumed to have a firm capacity of 0.5 MW thus producing 75% of the energy firm, and the two 0.5 MW units are assumed to be on line sufficiently to provide an extra 10% of total energy demand. This means that two units are on line slightly less than half of the time. The peak demand currently does not exceed 800 kW.
- Boilers will accept lump material. Ancillaries will consume 10% of production including all power station use and losses.
- Overall efficiency is 12%.
- Coconut wood fuel as delivered will be 50% m.c.w.b. and 8.6 MJ/kg.
- Casuarina wood-fuel as delivered will be 40% m.c.w.b. and 12 MJ/kg.
- Annual energy production will be 4.82 GWhr (1982 est.). Thus 85% net of ancillaries will be 4.51 GWhrs produced and 4.06 GWhrs sent out.
- Cost of plant:

	Sea water cooled, low pressure turbines		A$
(a)	Steam-turbine-generator set	A$500/kW	500,000
(b)	Boiler, furnaces, ancillaries	A$450/kW	450,000
(c)	Cooling and feed water systems	A$150/kW	150,000
(d)	Fuel handling and storage	A$250/kW	250,000
(e)	Civil works, including buildings, yards, drains	A$150/kW	150,000
(f)	Engineering (5% of capital expenditure)		75,000
			1,575,000

- Life of plant is 25 years
- Maintenance is 3% p.a. or A$45,000
- Labour and salaried staff: 4 shift operation

Engineering supervisor		30,000 p.a.
Foreman mechanic	A$8/day 1	8,320 p.a.
Semiskilled staff	A$6/day 2	14,976 p.a.
Labourers	A$5/day 3	18,720 p.a.
		72,016 p.a.

Costs of production

		A$/yr	c/kWh
(a)	Capital charges		
	• Discount rate 10%, life 25 years	173,515	4.27
(b)	Operations and Maintenance		
	• Maintenance	45,000	1.11
(c)	Fuel		
	• Coconut wood at A$20/te (4861 ODte)	194,440	
	• At 4275 te Casuarina wood at A$30/te (2565 ODte)	128,250	7.95
			13.3 c/kWh

Appendix: 4.2.5(b)

STEAM POWER FOR CHRISTMAS ISLAND, KIRIBATI

Parameters

- A 100 kVa steampower system has been designed (conceptual) and costed for Christmas Island as part of the EEC regional energy grant to Kiribati.
- Given appropriate load management and use of solar and wood devices on the Island the loads at the airport, hotel and Banana are believed to be served by a unit of this size. Synchronization with the diesel system is included for back-up and peaking power.
- Plant factor is assumed at a high 80%. Thus energy production of 560 MWhrs gross is assumed with 10% use by ancillaries leaving 505 MWhrs at the busbar.
- Fuel is old coconut trees in billets at 50% m.c.w.b. on average.
- Cooling water is from a very large (400,000 litre) storage tank system, fed from the roof and groundwater pumping.
- Fuel cost will be A$15/te coconut tree delivered.
- Overall efficiency will be 10%.
- Plant costs (EEC contracts quote) A$ '000

Steam boiler	50	
Underfeed firing	75	
Condenser and deaerator	8	
Pumps, motors, ancillaries	13	
Plant control and switchboard		8
Feedwater treatment	8	
Turbine generator set	38	
(Engine generator set)	(83)	
Synchronization with diesels		4
Spares and miscellaneous	21	
Transportation and packaging		21
Installation and commissioning		75
Engineering	46	
Training for operations and maintenance		13
Plus fuel handling (A$300/kW)		24
TOTAL (A$)	404	Steam Turbine
	449	Steam Engine

- Life of plants is 25 years
- Maintenance is 3% of capex OR $9,150
- Labour and salaried staff

Engineering supervisor	30,000	pa
Senior mechanic	4,500	pa
Shift supervisors (4)	14,000	pa
Labourers (1 per shift)	6,240	pa
and 2 extra on dayshift for fuelhandling	3,120	pa
	57,860	pa

Costs of Production

		A$ p.a	c/kWh
1)	Capital charges (or 370,000)	A$ p.a	c/kWh
•	Discount rate of 10% over 25 years	40,774	8.07 (9.06)
2)	Operations and Maintenance		
•	Labour	57,860	
•	Maintenance	9,150	13.27
3)	Fuel		
•	2344 to coconut logs as received at A$15 delivered	35,163	6.96
	Total for steam turbine	132,447	28.3 c/kWh

and with steam engine 29.3 c/kWh

Appendix: 4.2.6

COST OF PRODUCTION OF COCONUT OIL FROM SMALL EXPELLING SYSTEMS: KIRIBATI

Parameters

- Copra produced in the outer islands has a true economic price of A$136.40, as the cost of bringing it to Betio to store and export is A$87.60 (A$55/te freight plus A$20.60 Stevedoring plus A$12 port charges), i.e. the price actually paid of A$224 per tonne may be reduced to the local oil producer by the amount in any case spent by the copra board.

- On Tarawa the only costs avoided by local use are the port charges and stevedoring, hence the local price to the oil producer is $A191.60.

- Expeller is the Hander Copra Oil expeller New Type '52' rated at 40 kg chopped copra per hour; A$3,600 FOB Singapore.

- Power chopper New type 'CA' US$4,090, FOB Singapore.

- Filter press Type 'A' US$3,330 FOB Singapore.

- Power demands of 5hp Chopper motor, 3 hp expellor motor, 1/2 hp filter press motor at 75% load under continuous operation is 4.8 kW.

- Efficiency of oil extraction is 55% (i.e. 0.55 kg oil per kg copra) and 0.6 litres oil per kg copra.

- Maintenance including filters is 3% of capital expenditure (capex) p.a.

- Cost of a kWh on Tarawa is taken at full marginal cost of 35c/kWh. On an outer island it is taken as A$1.00/kWh produced from diesel in 10-20 kW capacity machines.

- Storage of oil and housing and installation of equipment on outer islands is in 200 l drums at A$30 each new or A$750. On Tarawa existing diesel full storage is used. Installation and housing is A$1000.

- Operations are 250 days/year, 8 hrs/day OR 2000 hrs and 48,000 litres/year and 80 te/copra.

- One semiskilled operator A$3000/year.

Cost of Production		Tarawa	Outer Islands
1.	Copra : 80 te	15,328	10,912
2.	Power: 9600 kW	3,456	9,600
3.	Labour	3,000	3,000
4.	Maintenance and consumables	331	331
5.	Capital charges on a) Equipment $A11,020 FOB Singapore plus 15% transport = $12,673 Discount rate 10%	2,680	2,680
6.	Housing, installation capitalised and storage i. outer islands - 20 x 200 labourers and A$750 = $1550 ii. Tarawa: A$100 total	167	252
	TOTAL	24,962	26,775
	per litre at 48,000 l/yr	52 c/l	55.8 c/l
	c.f. diesel CIF to agent	40.47	
	Wholesale	52 c/l	
	Retail	62.c/l	

- By product credit 32.4te copra meal (10% allowance for losses) must be A$5,534 or A$171/tonne to breakeven with the landed price to the government (as agents)

Appendix: 4.2.7

WINDPOWER FOR CHRISTMAS ISLAND, KIRIBATI

Paaameters

Wind speeds on Christmas Island are alleged to reach 11 ms for sustained periods, though no record was sighted by the mission which substantiates this assertion. The lower and marginal level of 4.3 ms is reported by Merz and McLellan (1978). There 4.3, 8 and 11 ms average windspeeds will be analysed simply to indicate the huge economic consequences of the range.

- The generator in use will be an elektro 10 kW (WVG 120).
- Details of costs of installation, maintenance and performance have been discussed with the Australian agent.
- Life will be assumed to be 5 years.
- Equipment costs for 10 KW (9WVG 120) are:

Generator, motor, automatic controls spare parts, packing, insurance and freight. All at retail price.		A$ 12,500
Tower (13 m), delivered	1,000	
Inverter (AC) 2 kw delivered to Betio	2,000	
Batteries: 60 x 2 volt cells (27 kWh storage), including packing and delivery	2,800	

- Installation of the wind generator involves erection of the tower, placement of the generator, and connection of central panel and battery bank. Specialist input is required for two days.

Costs of installation are:

a) Tower base and erection - digging holes and preparing 5 m^2 concrete:

Materials	$500
Labour (4 days x 2 men)	$50
Transportation by air of materials and equipment from Betio, Tarawa to Christmas Island	$3,000
	$3,550

b) Consultant

- 7 days (daily rate of $300) $2,100
(Note: compulsory one
week stay in Christmas Island
due to frequency of flight.

c) Travel and expenses $2,000

TOTAL $7,650

- Maintenance is taken as 3% of capital expenditure per year. It involves twice-yearly grease and oil change, battery top-up and general inspection.

- Generator output is conservatively estimated at 20% efficiency compared with 38-40% in accordance with manufacturers' literature.

- Power produced annually is then:

    - 30,642 kwh at 8 m/s
    - 79,658 kwh at 11 m/s

- Losses through the system are derived as follows:

    - Battery efficiency 70%
    - Cable losses 10%
    - Rectifier losses are regarded as negligible
    - Efficiency of battery mode is then 0.63

- Thus net power out is (kWh)

    19,305 at 8 m/s
    50,185 at 11 m/s

- Present value (PV) unit cost

$$\text{PV unit cost} = \frac{\text{PV total cost of production}}{\text{PV energy generated}}$$

Present value costs per kwh are thus:

13.5 c/kwh at 11 m/s
35 c/kwh at 8 m/s
and $2.26/kwh at 4.3 m/s

Appendix: 4.4.5

COSTS OF PRODUCTION OF CHARCOAL IN KIRIBATI

Parameters

- Philippine kiln method is applied using 200 l drums. Drums will cost $A10 each and last six months or 125 cycles.
- One labourer will manage 10 kilns using coconut shell charcoal as a feedstock, recovery A$5/day.
- Production will be 12 kgs per kiln per day or 600 kg charcoal per week requiring 2.5 to 3.0 te of coconut shell (as received) per week. This is the shell available after the production of about four tonnes of copra.
- Annual production is then 50 wks x 600 kg = 30 tonnes.
- Charcoal will be screened to remove fines. Screen will cost $A50 complete and will last five years.
- Charcoal will be bagged in multiwalled 10 kg bags with attractive labels, and will be sealed with staples. Staplers will cost A$50. Bags and staples will cost A$25/te.
- Other tools will include scales, A$50, spades, hammer, cole chisels and tin snips $A30.

Costs of Production

		Per year ($)	Per tonne
1.	Capital Charges		
	. all tools over 3 yrs (10% d.r.)	72	2.40
	. kilns at A$20/yr each	200	6.67
2.	Operations and Maintenance		
	. Labour	1,250	41.67
	. Bagging	750	25.00
		2,272	$75.74

- Other costs include cartage to the port for shipment to Betio, say $A15/te, and the cost of freight to Betio, A$55 (same as for copra).
- Costs of charcoal landed in Tarawa: A$146/te
- If coconut shells are purchased at A$10/te or A$30 - A$40 per tonne of charcoal, cost in Tarawa will be about $185.
- Wholesale and retail margins of A$65/te (35%) are then allowed to achieve a retail price of $250/te.

Appendix: 4.6.3

FUEL COST OF COOKING WITH VARIOUS LOCAL AND IMPORTED ENERGY FORMS; TARAWA, KIRIBATI

	Price/ Unit	Efficiency (average)	MJ per unit	Cost/MJ delivered	Proportion of cost of electricity
Electricity[1]	36c/kWh	70%	3.6	14.29	1
Liquefied petroleum Gas	$2.28/kg	50%	52	8.77	0.61
(LPG)				6.37	0.44
Kerosene	60c/litre	30%	36.7		
Charcoal (est retail price)[2]					
. locally produced	A$200/tonne	24%[4]	30	2.78	0.19
. from outer islands	$A250/tonne	24%	30	3.47	0.24
Wood[3]					
. Coconut palm trunk wood	$A40/tonne				
a) 30% m.c.w.b.		15%	12.5	2.13	0.15
b) 40% m.c.w.b.		10%	10.3	3.88	0.27
Casuarina equistafolia	A$40/te	15%	14.5	1.84	0.13
30% m.c.w.b.					

FOOTNOTES

1 Full marginal cost assessed by mission; see appendix 6.5.1

2 Coconut shell charcoal is about 33 MJ/kg (HHV), though a mixture of coconut wood and shell is most appropriate, hence a lower figure is used.

3 Calorific value of wood is 19MJ/kg OD coconut wood and 22 MJ/kg OD Casuarina wood.

4 Efficiency recorded for PNG and Fiji charcoal stoves.

5 Efficiency to cooking surface of slow combustion stove; dry and wet wood. No credit for water heating.

Appendix: 6.5.2

COST OF ELECTRIC POWER ON TARAWA, KIRIBATI

(a) Capital charges

Estimated present day replacement values of major capital equipment and capital charges

	'000 A$	Life	Recovery factor (10% dis.rate)	Annual charge
Buildings	100	30	0.106	10,600
Generating Equipment	1980	15	0.131	260,370
Transmission (11kV)	370	25	0.110	40,774
Distribution	345	25	0.110	38,019
. Lines (415 V/240V)				
. Transformers (50-200 kVa)	124	25	0.110	13,665
. Meters	106	25	0.110	11,682
Vehicles and plant	100	5	0.264	26,400
				$401,510

NOTE: Replacement values are based on $500/kW installed capacity of generation plant, $15,000/km 11kV (submarine), $11,000/km, 11kV (ground), $5,000/km 415/240V transmission, $40/kVa transformer capacity, $50/$150 for single/three phase meters.

Sales and Production:

- From the records provided 3,280,275 kWh were sold in the nine months July '81 - March '82.
- The production for the same period was 3,689,910 kWh.

Thus we will use an annual figure of 4.3 GWh sold and 4.9 GWh generated and 12.2% losses.

Thus capital charges per unit sold: 9.34 ¢/kWh

(b) Fuel Costs

- Diesel sold to the PUB was 51.9 c/1 (June 1982)
- Overall fuel efficiency is 31.5%.
- Lubricating oil use is 3% of fuel cost of generation.
- Losses are 12.2%

Fuel cost is: 18.41 ¢/kWh.

(c) Operations and Maintenance costs

These data are derived from the revised 1981/82 budget, and the 1982/83 budget

	c/kWh
• Generation	4.20
• Transmission and Distribution	4.45

(d) Administration

- This information is derived from an arbitrary partitioning of costs between the power and other sectors of PUB operations.

	c/kWh
• Administration	1.25

Total cost per kWh sold: 1982: 37.65 ¢/kwh

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