INDIVIDUAL COUNTRY BIOMASS RESOURCE ASSESSMENT PROFILES FOR FIJI, KIRIBATI, SAMOA, TONGA, TUVALU & VANUATU

Drs Frank Rosillo-Calle and Jeremy Woods[1]
ICCEPT/EPMG
Imperial College London
Department of Environmental Science and Technology

December 2003 SOPAC Technical Report 364

[1]Contributions also from: Drs S. Hemstock & A. Bauen
ICCEPT/EPMG

Prepared for: South Pacific Applied Geoscience Commission (SOPAC)
A Project on Biomass Resource Assessment, Utilisation and Management for Six Pacific Island Countries

Cataloguing in Publication data:

Rosillo-Calle, F., Woods, J. 2003. Individual country biomass resource assessment profiles for Fiji, Kiribati, Samoa, Tonga, Tuvalu & Vanuatu. (SOPAC Technical Report 364)

73 p.
ISSN: 1605-4377

1. biomass 2. Fiji 3. Kiribati 4. Samoa 5. Tonga 6. Tuvalu 7. Vanuatu

I. South Pacific Applied Geoscience Commission (SOPAC)
II. Author(s)
III. Series

TABLE OF CONTENTS

LIST OF ACRONYMS

ADB	Asian Development Bank
ALTA	Agricultural Landlords and Tenancy Act
APO	Asian Productivity Organization
AUD	Australian Dollar
CROP	Council of Regional Organizations
CSR	Colonial Sugar Refining Company
DMAFF	[Department/Division of the] Ministry of Agriculture, Forest and Fisheries
EEZ	Exclusive Economic Zone
EPMG	Environmental Policy & Management Group (ICCEPT)
EU	European Union
EWG	Energy Working Group (CROP)
FAO	Food and Agriculture Organization (UN)
FEA	Fiji Electricity Authority
FHCL	Fiji Hardwood Corporation Ltd
FSC	Fiji Sugar Corporation
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
ICCEPT	Imperial College Centre for Energy Policy and Technology
IFP	Industrial Forestry Plantation
ITTO	International Tropical Timber Organization
LPG	Liquefied Petroleum Gas
LSP	Local Supply Plantation
MDP	Master Development Plan
MSW	Municipal Sewage Waste
MW	Mega-watt
NEMS	National Environmental Management Strategy (SPREP series)
NFP	National Forest Policy (Vanuatu)
NGO	Non Government Organization
PIEPP	Pacific Islands Energy Policy and Plan
PRA	Parks and Reserves Act (Tonga)
PTAF	Productivity and Training Authority of Fiji
PV	Photo Voltaic
RE	Renewable Energy
RESCOs	Renewable Energy Service Companies
SEC	Solar Energy Company (Kiribati)
SIDS	Small Island Developing States
SOPAC	South Pacific Applied Geoscience Commission
SPM	Sustainable Project Management
SPREP	South Pacific Regional Environmental Programme
TEC	Tuvalu Electric Corporation
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

ACKNOWLEDGEMENTS

We are deeply grateful to all of those who gave their valuable time in the region, particularly:

Fiji Devendran Kumaran (Director, Department of Energy; dkumaran@govnet.gov.fj), Mr Taleshul Ghani and Mr Avinesh Naidu (Energy Conservation Engineers, Department of Energy).
Mrs Sobha Devi Kumar – (Forestry Officer, Forestry Department).
Dr Mahendra Kumar (Head, Physics Department, University of the South Pacific).

Tuvalu Isaia Taape (Energy Planner, fititaape@yahoo.com) and Timaio Auega (tauega@yahoo.com), Energy Planning Unit.

Tonga Tevita Tukunga (Energy Planner, preface@kalianet.to) and Krisimas Lutui (klutui@yahoo.com), Energy Planning Unit.

Samoa Sili'a Kilepoa Ualesi (Energy Coordinator, skilepoa@samoa.ws) and Laavasa Malua (Environment Dept: lmalua@lesamoa.net).

Vanuatu Leo Moli (Principal Energy Officer, leomoli@vanuatu.com.vu) and Moli Janjea, Acting Senior Energy Officer, Energy Division.

Kiribati Mautaake Tannang, Energy Planner and Eita Metai, Water Engineer (Ministry of Works & Energy, energy.mwe@tskl.net.ki).

SOPAC Anare Matakiviti, Rupeni Mario and Paul Fairbairn (and the rest of the SOPAC team).

INTRODUCTION

This Report consists of six sections, each providing a biomass resource assessment for each of the island nations that were selected to participate in the project:

- Fiji;
- Kiribati ;
- Samoa;
- Tonga;
- Tuvalu; and
- Vanuatu.

The structure of the Report has been standardised for all countries where possible. The depth and quality of the data varies considerably between the countries assessed and so it has not been possible to develop a detailed standardised accounting methodology for deriving a quantified assessment of biomass resource availability. We assess all the resources that have a direct bearing on the availability of biomass energy, taking into consideration the specific characteristics of each country and the baseline data availability. Both primary and secondary data, but primarily secondary data, have been used. The use of primary data would have required considerable fieldwork, which was beyond the scope of this project.

Forests and agriculture are particularly important potential biomass resources for energy and these sectors are individually assessed for each country. The energy sector and policies relating to energy availability are also assessed where possible and waste streams such as household rubbish and sewage are also included. The overall aim is to identify the underlying biomass resource base for each country. A synthesis of the biomass resources is provided in a separate 'synthesis report'. Because the exploitation of biomass resources is inexorably linked with other important issues for development and is therefore uniquely cross-sectoral in nature, a brief outline of the main issues and concerns relating to biomass energy resources is also provided for each country.

There are a range of biomass energy technologies and supply chains which could be used to address a number of pressing local problems in the six island countries of the South Pacific assessed in this project. These technology and supply chain options are briefly discussed in the individual country sections below and in more detail in the associated 'synthesis and 'master development plan'' reports. In addition to addressing local problems and providing sustainable energy, these biomass energy systems would result in little or no net greenhouse gas (GHG) emissions and provide additional environmental benefits e.g. improved health and water management. However, the successful application of these technologies and their associated supply chains will depend critically on local circumstances, management practices and technical capacity.

Because biomass energy is intrinsically linked to a number of factors, national biomass resources cannot be assessed in isolation. There are social, economic, technological, managerial and political ramifications to exploiting biomass for energy purposes. In addition, land area and limited plant production are major constraints in most of the island countries covered in this study. These countries are endowed with differing biomass resources, which in turn determine their policies towards forestry and agriculture. Policies aimed at rural development, and the forestry and agricultural sectors in particular, are key determinants to the successful development of biomass energy in these islands once perverse energy subsidies are addressed.

Biomass resources are inherently limited in the islands of the South Pacific, and will not be the panacea for solving all energy-related problems; but the contribution of biomass can be much larger than is currently the case, particularly if combined with other renewable energy. There is a considerable potential to promote biomass energy, particularly in small-scale applications.

Four bio-energy technologies are particularly promising:

i) Biogas production from animal and human wastes;
ii) Direct combustion/gasification in Fiji and possibly Vanuatu and Western Samoa;
iii) Bio-diesel from coconuts, for electricity generation and transport; this resource is common to almost all the countries; and
iv) Production and use of charcoal from coconut shells for cooking could displace expensive fossil fuels and provide an efficient use of the waste shell resource. However, both the conversion and combustion efficiencies need to be improved significantly and adapted to local conditions.

In addition to making more efficient and profitable use of existing and under-exploited biomass resources, a number of ancillary benefits can occur from the careful implementation of these modern bio-energy supply chains. For example, in Tuvalu the use of coconut oil derived from copra could displace expensive imports of kerosene and provide a profitable return for copra production and collection, which at the moment is subsidised by national governments. If the economics are demonstrated, this technology would provide a vital stimulus to the local production of coconuts and hence support the valuable ecological services provided by coconut woodlands. Importantly, activities in this area are already occurring in Vanuatu and Fiji.

The development of locally-adapted village-scale anaerobic digesters for the treatment of human and animal waste could provide significant volumes of biogas for cooking and lighting in certain locations, if small cooperatives can be established. Village- and town-scale digesters could provide sufficient volumes of gas to power electricity generators or to be bottled for use as propane/butane replacement. Perhaps, more importantly, it would treat these wastes rendering them harmless to the environment and the human and animal population. Furthermore, the use of biogas in this way avoids the production and release to the atmosphere of the powerful greenhouse gas, methane, produces an excellent soil fertiliser that promotes soil organic matter levels and avoids contamination of freshwater lenses. The production of biogas cannot be seen merely as an economic exercise, but also as a way of solving pressing environmental and sanitary problems.

1. FIJI

1.1 Basic Data

Fiji comprises over 300 islands archipelago (about 150 islands are inhabited), with a total land mass of 18 272 km^2, which is spread over an Exclusive Economic Zone (EEZ) of 1.6 million km^2. The largest island is Viti Levu (Big Fiji), which covers 10 390 km^2 and account for 87 percent of the land area and 90 percent of the population, followed by Vanua Levu (Big Land) with 5538 km^2. Other large islands include Taveuni and Kadavu. The highest peak in the country is Mt Victoria, at 1323 metres, but there are few others mountains of over or close to 1000 metres.

The larger islands, especially Viti Levu, Vanua Levu, Taveuni, Kadavu and the Lomaiviti group, are quite mountainous and of volcanic origin, rising more or less abruptly from the shore to impressive heights. The southeast or windward sides of the islands are covered in dense forests. The smaller islands are largely encompassed in two recognized groups, the Yasawa Group and the Lau Group. The wet eastern sides of the islands support tropical rainforest while the drier western portions support a higher proportion of grass and savannah lands.

Fiji's forest area covers about 815 000 hectares (45% of the land area), about 10% is arable, 4% is under permanent crops, 10% under permanent pastures, and 11% under other land-use categories. While over 60% of the total land area is suited to some form of agricultural activity, only about 16% is suitable for sustained arable farming.

1.2 Forest Resources

Natural resources, such as forestry, are major revenue earners for the Fiji Islands, and will remain so in the future. There are almost 1Mha of forest, including all types (see Table 1.1). The forestry sector contributes about 2.5% of GDP.

Table 1.1. Forest cover in the Fiji Islands, 1995 (hectares).

Area	Dense Natural Forest	Medium Dense Natural Forest	Scattered Natural Forest	Hardwood Plantation	Pine Plantation	Mangrove Forest	Total
Viti Levu	127 338	268 432	107 377	29 641	28 854	23 927	585 569
Kadavu	12 395	13 267	8 298	–	–	1 205	35 165
Vanua Levu	119 970	117 724	30 868	18 627	13 729	16 475	317 393
Tavenni	20 289	7 305	3 992	–	–	n/a	31 586
Other*	4 336	13 746	2 240	–	2 395	857	23 574
Total	284 328	420 474	152 775	48 268	44 978	42 464	993 287

*Koro, Ovalau, Gau, and Lau; (see FAO for forest definitions)
Source: FAO STAT

Three major landforms can be distinguished: flatlands, hilly lands and steep lands. Elevations range up to around 1300 metres and the mountainous topography produces pronounced windward/leeward rainfall effects. Rain forests dominate the windward and summit steep lands. Dry forests on the leeward side, have largely been usurped by grazing and fire, and persist only as remnants. Instead, extensive lowland areas support talasiqa vegetation, extensive degraded areas dominated by grasses and ferns (FAO, Mueller-Dombois and Fosberg 1998).

1.2.1 Vegetation Types

The following is a brief description of vegetation types in Fiji Islands, based on data from FAO STAT and Mueller-Dombois and Fosberg 1998). Broadleaved consists mostly of lowland, cloud, dry, mangrove and coastal forests.

- **Lowland Rain Forest**. This is the most common mixed type of forest in Viti Levu and Vanua Levu, usually 20 to 30 metre tall trees, largely dominated by primary Fijian species on the steep lands, but largely displaced on flatter lands, with a lower limit of annual rainfall of 2500 mm.
- **Cloud Forest**. This unique, stunted ecosystem is restricted to mountaintops and ridges above 600 m elevation near the coast and above 900 m inland.
- **Broadleaved Dry Forest**. Grazing and fire have largely destroyed the leeward lowland primary dry forests in Fiji. These "dry" forests are only seasonally dry and during the warm season they receive as much rain as the wet uplands. On Viti Levu, no primary dry forest remains. Instead, stands of *Casuarina equisetifolia* have taken their place.

- **Mangrove Forest**. The richest mangroves in Fiji occur at the mouths of major river deltas around mud-covered stream banks in the tidal zone, consisting of seven main mangrove species.
- **Coastal Forest**. A zone dominated by pure stands of *Casuarina equisetifolia* or *Pandanus tectorius* is supplanted inland by a mixed littoral forest. A unique coastal forest exists at Sigatoka, on the south-west coast of Viti Levu.

Mixed forests consist primarily of upland rain and mixed dry forests.

- **Upland Rain Forest**. Found above 400 metres near the coast and above 600 metres inland on Viti Levu, Vanua Levu, and Taveuni. A wet-zone forest with more than 3750 mm annual rainfall can be distinguished from an intermediate-zone forest with 2000 to 3750 mm rainfall.
- **Mixed Dry Forest**. Although no longer extant in Fiji except as remnant stands, the typical Fijian dry forest is dominated by the conifer *Dacrydium nidulum var. nidulum* and *Fagraea gracilipes*.

Broadleaved (open forest) comprises primarily fresh wetland vegetation and shrubs.

- **Freshwater Wetland Vegetation**. This is dominated by poorly drained coastal flatlands along major rivers that various native species e.g. *Annona glabra*, *Barringtonia racemosa*, *Fagraea berteroana*. Shrubs are also important coastal vegetation of Fiji dominated by *Scaevola taccada*, along with *Clerodendrum inerme*, *Sophora tomentosa* and *Wollastonia biflora*.

Forest fallow consists mainly of Talasiga vegetation.

- **Talasiga Vegetation**. In Fiji, talasiga ("sunburnt") vegetation covers about a third of both Viti Levu and Vanua Levu. Large grasslands of *Miscanthus floridulus* and *Pennisetum polystachyon* dominate some areas

1.2.2 Planted Area

The principal trend in forest management in Fiji during the past 30 years has been the effort to establish a significant plantation estate as a substitute and complement to natural forest wood supplies, and has already a significant plantation estate, much of which is presently approaching maturity. Fiji has had the most aggressive plantation establishment policy of any of the Pacific Islands. Reforestation together with afforestation has brought some 90 000 ha of long deforested land back into production. A small area totalling about 42 000 hectares is under mangrove forest (see Table 1.2).

The Forestry Department has been undertaking a reafforestation programme, carried out in the fourteen stations across Fiji. The programme had aimed to increase Fiji's hardwood plantation estate to 85 000 hectares by the year 2010 in order to meet local demand for timber and to maintain a sustainable export trade in timber products. The plantation reafforestation programme is now being taken over by Fiji Hardwood Corporation Ltd (FHCL), which aims to establish 2000 hectares of hardwood on an annual basis.

In addition, the Kyoto Protocol could be an important guiding agreement on the trading of forestry products in future. Fiji is an open economy and needs to be fully aware of the implications of the protocol and the trading opportunities it creates. This may create new opportunities for biomass energy as a CO_2 abatement source, both for indigenous and plantation forests.

Table 1.2 shows the estimated forest plantation in Fiji in 2000, based on FAO STAT data. The establishment of new plantations have been estimated at 9200 hectares/year, while the total planted area is 97 200 hectares, primarily for industrial uses. The Forestry Department plans to increase the plantation rate in the future.

No pruning or thinning is carried out, and rotations are every 30-35 years; *Pinus caribaea* is presently grown on rotations of around 17 years. Seedlings are planted at densities of 1000-1500 stems per hectare. On high quality sites, pruning to 6 metres is carried out for saw log production; thinning regimes are still being developed.

Table 1.2. Estimated plantation area in Fiji in 2000.

Species group	Area (hectares)	Percentage	Industrial use (%)
Mahoganies	42 000	43.2	100
Other broadleaved	4 900	5.0	100
Pinus spp	43 300	44.5	100
Unspecified	7 000	7.0	100

(Note: Only those species used for plantations have been included).
Source: FAO STAT

1.2.3 Industrial Products and Production

There are 34 recorded indigenous species of commercial values, with Dakua Makadre, Kauvula, Kaudamu, Damanu and Sacau being the most popular. The hardwood plantations, including mahogany, have enormous value-adding up to US$200 million annually (ADB, 2002).

The industrial sector is important because it generates considerable amounts of residues that are under-exploited (see Table 1.6) and that could provide significant amounts of biomass-based energy. For example, in only January to June 2003, the Fiji forestry industry extracted 124 500 m^3 of round wood but only produced 31 333 m^3 of wood products, leaving an estimated 53 500 m^3 of residues potentially available as an energy supply (Matakiviti, 2003). Table 1.3 summarises forest product production from 1993 through 2001. A particular characteristic is that estimates for fuel wood remain constant raising some doubts about the validity of this data.

Table 1.3. Forest products production in Fiji, 1993 – 2001 (10^3 m^3).

Product	1993	1994	1995	1996	1997	1998	1999	2000	2001
Roundwood	529	559	598	598	496	516	485	486	486
Industrial Roundwood	492	522	561	561	459	479	448	449	449
Wood Fuel	37	37	37	37	37	37	37	37	37
Sawnwood	111	112	102	102	133	131	64	72	72
Wood-Based Panels	16	16	16	16	16	21	11	12	12

Source: FAO STAT

1.2.4 Forest Management

Good management practices and policy are key factors in the provision of energy from forests. The principal elements of Fijian forest policy have remained largely unchanged during the past half-century. The principal piece of forestry legislation in Fiji is the Forest Decree 1992, which replaced the Forest Act of 1953 (amended in 1990). The Forestry Decree 1992 largely legislates to support the objectives specified in the Fijian Forestry Sector Review 1988, namely:

> *To maximise the sustainable contribution of the Sector to the development and diversification of the economy whilst bringing the Fijian people into fuller and more active participation in sectoral development of all levels and stages and, at the same time, protecting and enhancing the effectiveness of the country's forest in environmental conservation.*

Eighty three percent of land in Fiji is under customary (mataqali) ownership, with 10 percent alienated freehold land and the remaining 7 percent of land under government ownership. Almost 90 percent of the unexploited production forests and 84 percent of all Fijian forests are in mataqali ownership. Fijian mataqali do not have any corporate authority to deal in land and all negotiations for the use of timber grown on mataqali lands must be conducted through the Native Lands Trust Board.

The Code of Practice requires the preparation of detailed logging and management plans. Planning infrastructure has been strengthened by the implementation of a Forest Resources Tactical Planning Project, which assisted in the provision of mapping data and training to help establish a practical and effective process for the preparation of environmentally-sound coupe-level logging plans, hardwood plantation plans, and management plans. Management responsibility for Fiji's plantation resource is vested in the Fiji Hardwood Corporation and Fiji Pine Ltd; both corporations have detailed management plans in place.

It is estimated that around 150 000 hectares of natural forest has been systematically harvested on Fiji. To harvest timber on native land, a Forestry Right License is required under law, which are negotiated through the Native Lands Trust Board. There are four categories of tenure for timber cutting rights in the natural forests:

- Timber concessions (15-30 year period)
- Long term licenses (10 years)
- Annual licenses; and
- Other licences and prepayment licenses (usually for land clearing)

Fiji's protected areas network comprises a range of forest and nature reserves covering more than 37 000 hectares. Nature reserves provide full protection to flora, fauna, soil and water resources. Conversely, Forest Reserves provide only a limited degree of protection status. Activities in these forests are restricted by a requirement to obtain a written consent from the Conservator of Forests. Several other communally-operated parks have been established.

Cyclones are a frequent occurrence in Fiji, with the country being struck by 21 cyclones between 1980 and 1997. For example, Cyclone Kina in 1992 damaged almost 12 000 hectares of plantations, of which 3000 hectares were written off. Thus, wind-firmness is an important property in plantation species selection. Natural forests also sustain periodic heavy damage during cyclones. Wildfires cause significant losses as well. Escapes from burning of sugar cane are a major source of forest fires. In 1989, almost 1000 hectares of plantation were burned in a wildfire.

1.2.5 Policy[1]

The Fijian government's principal forestry agency is the Department of Forestry, a part of the Ministry of Agriculture, Forest and Fisheries (DMAFF). The Department of Forests has a primary role in enforcement of logging regulations. It also has a significant role in management in natural forests, particularly to support management decision-making by assembling a database for the natural forest resources including maps, inventories, and GIS.

The large area of Fijian forests under customary ownership ensures a high degree of, at least de facto, people's participation in forest management. However, the government has accorded priority to ensuring greater landowner participation in all aspects of forestry sector development. An objective is to have landholder participate more as shareholders or owner-operators in forestry activities.

Government has over the years put in place a number of initiatives one of which is the development of a Native Forest Management Pilot Project in Nakavu, Namosi, to assess the impact of different intensities of logging on the regenerative capacity of the forests. Other major initiatives taken towards sustainable forest management include Fiji Forest Sector Review and its incorporation into the National Forestry Action Plan, re-inventory of the indigenous forest, installation of the Geographic Information System (GIS), and Fiji Logging Code of Practice.

---

[1] Main source: Chapter 11 of the country profile submitted to the World Summit on Sustainable Development, Johannesburg 2002. For the full text, see http://www.un.org/esa/agenda21/natlinfo/wssd/fiji.pdf

Fiji has recently become a member of International Tropical Timber Organization (ITTO), which means Fiji is committed to the sustainable management and development of indigenous tropical forests. Fiji has also ratified the International Convention on Biological Diversity and the United Nations Framework Convention on Climate Change (UNFCCC), and this could have positive implications for implementing bio-energy.

1.2.6 Key Issues and Concerns in the Forestry Sector

A priority for Fiji's forestry sector is to get acceptance and support of all stakeholders to utilise forest resources in a more sustainable manner. The land tenure system means that responsibility for natural forest management rest largely with private and customary landowners, except during brief periods while forests are logged. Fiji has also expressed strong interest in the development of an internationally accepted certification system for the Pacific Islands forest products. A major challenge for Fiji is to successfully market its increasing plantation resources while maximising local benefits through domestic processing. These objectives are likely to continue as a focus for the sector for the foreseeable future, with policy designed to facilitate niche marketing and to enhance competitiveness. At the same time, Fiji needs to strengthen its efforts in forest conservation and work with landowners to ensure a satisfactory proportion of representative forest types are accorded adequate protection.

Major constraints facing the sector include lack of proper infrastructure, inadequate skilled personnel, poor timber utilization, and the inability to sustain quality and quantity for domestic and export markets. In recognition of these problems the government allocated in the 2002 budget about US$1.5 million for the construction of a Timber Industry Training Institute and a Forestry Training Centre.

1.3 Agriculture

About 30% of GDP and 70% of exports in Fiji can be attributed to agriculture and natural resources activities. However, the rural sector is stagnant, especially with the difficulties confronted by the sugar industry, which warrants substantial government support, if rural people are to identify alternative livelihoods. One of the key issues affecting the Fiji Islands is the expiry of the Agricultural Landlords and Tenancy Act (ALTA) leases introduced in 1976. Many of the sugarcane land leases granted under ALTA to Indo-Fijian farmers have expired, and are not being renewed. This has particular implications for the sugarcane sector e.g. many small sugarcane growers are abandoning the land. As a result sugarcane production is decreasing and if these trends are not reversed, the planted area will decrease significantly jeopardising new plans for cogeneration. Thus, a new policy is required that will encourage economic growth, diversification, and further reforms, including sugar and other natural resources, tourism, and manufacturing (ADB, 2002). Table 1.4 shows the main crops in Fiji and highlights the importance of sugarcane and coconut production both of which are capable of supplying large amounts of modern biomass energy with the right policies and incentives (see below).

In the agriculture sector, first-class arable land tends to be fully utilized or unavailable for land tenure reasons. That means the expansion of agriculture has been on steeper marginal land. Some agricultural practices, such as sugar cane and ginger production on steep land, are unsustainable as they accelerate the natural erosion rates, which are already high.

Table 1.4. Land use types by major crops, by tonnage, in Fiji Islands (1995).

Crop	Area (hectares)	No. of farmers	Production (tonnes)
Sugar	73 900	22 337	453 000
Coconut	64 953	n/a*	11 003 (copra)
Cocoa	558	2 240	126(dry bean)
Ginger (mature)	24	700	1 140
Ginger (green)	46		1 080
Rice	8 411	11 310	18 888
Pineapple	193	1 428	2 161
Vegetables/fruits		14 320	22 000
Root drop Dalo	2 400	n/a	22 613
Yam	428	n/a	4 401
Cassava	2 610	n/a	40 247
Kumala	1 328	n/a	7 821
Yaqona	2 200	n/a	2 685

Sources: FAO Agricultural STAT; MAFF (1999).

A major constraint to sustainable land use is the conflict between landowners and tenants. Tenants farm under uncertainty with a very short-term perspective and show little interest in sustainable land-use practices. Furthermore, the legislation is not properly enforced so the tenant is not compelled to practice good husbandry and soil degradation continues.

Many agricultural, forestry and fisheries policies are, perhaps, concentrating on specific components of technology, along commodity or disciplinary lines. In future, a more holistic approach is needed with interdisciplinary and usually multi-institutional studies of ecosystem management, biological inter-actions of mixed crop, tree and animal production systems, including aquaculture.

1.3.1 Sugarcane

Sugarcane is thought to be indigenous to the islands of the South Pacific, and it is certain that several of the world's principal commercial varieties of sugarcane were obtained from this origin. Crystallised sugar was probably first manufactured in Fiji in 1862. During the development of the sugar industry, about 35 sugar factories were established, but only four remain today.

These four mills, which crush cane for the Fiji Sugar Corporation (FSC) are: i) The Rarawai Mill in Ba, that commenced crushing in July 1886; ii) the Labasa Mill built in 1894; iii) the Lautoka Mill which commenced operation in 1903 and is the largest mill in Fiji, and iv) the Penang Mill at Rakiraki, that started to crush cane in 1881.

Sugarcane remains a key crop in Fiji's economy; it occupies 50% of arable land, employs 13% of the labour force, contributes directly to 9% of GDP, and generates about 30% of domestic exports. Sugarcane is currently grown in the two main islands of Fiji, Viti Levu and Vanua Levu, in the proximity to the 4 mills (3 in Viti Levu and 1 in Vanua Levu). About 22 000 growers currently produce around 4 million tonnes of cane on approximately 100 000 hectares (74 000 hectares harvested annually over the past 4 years). Initially, all cane was grown on estates, but from the twenties lands formerly leased to planters were returned to Colonial Sugar Refining Company (CSR) and developed into the successful (10 acre) tenant farm system still functioning today.

Several constraints face the future of the sugar industry, including uncertainty over renewal of expired land leases, an inefficient pricing system, and the possible phasing out of sugar support by the European Union (EU). With the ongoing non-renewal of leases, and imminent loss of the EU price premium, about 12 000 displaced sugarcane growers will need to find alternative livelihoods. This adjustment will inevitably require large public investment to counter poverty and potential social unrest (ADB, 2002).

The sugarcane industry in Fiji reached its peak in 1980, when the world market price peaked and together with the establishment of the Lomé Convention in 1975, production reached 4.0 million tonnes (up from 2.2 million ton in 1975), a level which has generally been maintained since then. Domestic consumption has steadily increased from 18 000 tonnes (raw equivalent) in 1970 to around 36 000 tonnes in 1996, reflecting mainly population growth, and remains more or less constant

Cane production is almost entirely rain-fed, and yields are subject to wide annual fluctuations depending on weather conditions. Average national yields of cane per hectare have increased only slightly over the longer run, from 50 tonnes in 1973-75 to 52 tonnes in 1990-95; in 1996 yields reached 59.2 tonnes per hectare.

Major capital investments have been made over the years to modernize equipment and improve efficiency, although much remains to be done. For example, new equipment included the installation of a diffuser at the Lautoka Mill, to increase crushing capacity; vertical crystallisers at Rarawai and Labasa Mills (installation at the Lautoka Mill and Penang Mill, also planned). This is designed to improve extraction of sugar from molasses; the installation of boilers and turbo generators at the Lautoka Mill in 1995, enabling the FSC to supply power to the Fiji Electricity Authority during harvesting, and at the Labasa Mill in 1996, providing that town's electricity needs during crushing.

A major concern for Fiji is the quantity of sugar sold to the EU under the Sugar Protocol of the Lomé Convention. The EU is currently revising its policy and the outcome could largely determine the future of Fiji's sugarcane industry. In addition, it is known that there is considerable scope for the sugar industry to improve its sugar production efficiency in particular, through improved cane agronomic practices and follow the example of Mauritius in bagasse electricity export. Fiji, like Mauritius, has no fuel of fossil origin and relies significantly on hydropower (80-MW installed capacity), which meets 80% of its energy requirements. There exists potential for cogeneration using bagasse complemented with forestry residues and crop residues (e.g. coconut) and this merits particular attention. Further, there is also considerable social value in that it is associated with significant carbon emission credits potentially trade-able under the Clean Development Mechanism of the Kyoto Protocol (see Appendix). If the sugarcane industry can respond positively to the challenges it now faces, it may have a much brighter future.

1.4 Energy

With light industries and tourism acting as the main engines of economic growth, the energy requirements of Fiji have been growing rapidly. Currently 80% of the power requirement is met from the 80-MW hydroelectricity project at Monasavu on the Viti Levu, the main island. There are a few isolated micro and mini hydroelectric power projects as well. The increasing demand for imported petroleum products for the growing fleet of vehicles and motorboats, and for electricity generation on the outer islands has been straining the foreign exchange reserves. The Emperor Mine alone has a diesel-based 30-MW installed thermal-electric project. Liquefied Petroleum Gas (LPG) is commonly used in the household and commercial sectors to meet cooking and heating requirements.

Non-conventional sources of energy are being popularised in Fiji to tide over the energy constraint. A notable example is the Fiji Sugar Corporation using bagasse for most of its energy requirements. The Fiji Industries Ltd, a cement factory, fires its kilns with electrical energy from imported coal, while the steel rolling and fabrication industry meets part of its requirements through waste oil. These industries could be using biomass (bagasse and agro-industrial residues) to meet most of their energy requirements. Several isolated power projects use coconut oil, biogas and biomass as alternative fuels. A 10-kW photovoltaic installation has been set up at Lautoka; but the high cost of the photovoltaic cells places a constraint on the introduction of similar projects elsewhere, at least in the short term.

Wind offers a considerable energy potential in Fiji, and could play a major role in providing electricity to the 40% of the Fijians who still do not have access to electricity. Hybrid power systems that use renewable sources of energy along with fossil fuels (wind/solar with diesel/coal) are currently being assessed for their viability in Fiji and other Pacific countries. Geothermal energy is another renewable source of energy that could be exploited, to further the goals of sustainable development in Fiji. Efficiency in production, transmission and consumption is essential to optimise available energy sources while new avenues are explored (SOPAC).

Various projects have been undertaken to assess the potential of indigenous energy resources, and to develop a regulatory framework to provide the legal and economic guidelines required for the establishment of sustainable renewable-energy-service-companies (RESCOs) for the rural sector. The aim was to establishing the financial, technical and information infrastructure required to remove implementation barriers, and to create in-country capacity to provide reliable and sustainable renewable energy services to the rural sector.

1.4.1 Combined Use of Sugarcane and Forestry Residues

Cane residues (bagasse and barbojo) together with forestry/crops residues (coconut) are the natural resources with greatest potential in Fiji, and hence merit particular attention. A particular problem that the sugar industry has to face when re-orienting itself to co-produce crystalline sugar and electricity for sale to the grid is that of seasonality. The ability to produce electricity all year round is critical to a successful electricity producer; however, if off-season electricity is produced by burning fossil fuels (e.g. coal) then the low-carbon renewable benefits of sugarcane-based electricity production are largely negated. Therefore, innovated sugar mills and estates are looking at ways of supplying off-season electricity from renewable sources which could include other agricultural residues, forestry residues and or dedicated energy crops. As can be seen from the sections above, Fiji is well endowed with both sugarcane and forestry residues and so year-round biomass electricity production could be a valuable potential to pursue in this island nation.

Kroes (2002) has evaluated the potential of waste in the sugar industry in Fiji (see Table 1.5). Significantly, only 11% of the cane is converted to the intended product, sugar, the remaining 89% is considered as a by-product.

Table 1.5. Material transfer for a typical sugar factory that crushes one million tonnes of sugarcane per season.

Constituents of Cane		**Products and by-products**	
Fibre	125 000 t	**Sugar**	110 000 t
Sucrose	125 000 t	**Molasses**	45 000 t
Impurities	25 000 t	**Bagasse (~50% moisture)**	250 000 t
Water	725 000 t	**Water**	590 000 t
		Mill Mud	5 000 t
TOTAL	1 000 000 t		1 000 000 t

Source: Kroes (2002).

Currently in Fiji, mill mud is returned to cane fields to add much needed nutrients to the soil. Commercially, mill mud could also be used for the production of compost e.g. the Labasa Mill is investigating the viability of manufacturing organic fertilizer in conjunction with the Productivity and Training Authority of Fiji (PTAF) and the Asian Productivity Organization (APO). Trial productions and evaluations are planned over the next three years.

While not considered a core activity of FSC, molasses could also be considered a product rather than a by-product, as globally there is a demand for molasses. In fact, because of the sweetness of the Fijian molasses, it is quite highly valued particularly for the distillation of spirits and as a cattle feedstock supplement.

In Fiji, as is typical around the world, bagasse is mostly used to provide the power required for the processing of cane to produce sugar e.g. for much of the crushing season, Labasa Mill supplies enough electrical power to meet the entire demand of Vanua Levu. Until the last decade or two, excess bagasse was considered a major waste problem to sugar factories. As a matter of fact, most sugar factory boilers were designed to be inefficient or had the ability to incinerate to avoid excess bagasse. Today excess bagasse is considered to be valuable and modern boilers are designed and operated to be as efficient as possible to maximise excess bagasse.

The proposed power plant in the Ba area, would use the excess bagasse from the Rarawai sugar factory and waste from the timber industry to supplement the Fiji Electricity Authority (FEA) grid. The benefits of the power plant would be a reduced cost for the power production and reduction of greenhouse gas emissions as compared to that produced by the existing diesel generators. With the existing power demands of Fiji, coal would be required to supplement the biomass, however, with a revitalised sugar industry and expansion of the timber industries it is possible to reduce the need for coal.

There is also the possibility of further reducing the amount of coal required through community management of domestic waste, and by expanding the co-generation capabilities of the Labasa Mill. Utilisation of waste from the neighbouring timber industry and appropriately separated and prepared municipal waste may provide the extra fuel required to allow co-generation to the grid during FSC maintenance season.

The current direction of the FEA is to use wind power and there are, certainly, some advantages but the option of utilizing agro-forestry residues (bagasse, sawmill, etc) should not be overlooked to generate electricity. The combustion of waste for electricity also provides a good social value through the disposal of waste.

1.5 The Biomass Resource

It has not been possible to prepare a detailed assessment of all biomass resources, not only for Fiji, but all the other islands, because: i) there is not enough data available and to collect such data will require considerable field work; ii) such an analysis is beyond the scope of this study.
The role that biomass energy may be able to play in Fiji, as well as the rest of the Pacific islands under consideration, will depend on many varying factors, as stated in the Master Development Plan (MDP) document also developed through this project (see MDP; 2003). These range from the locally available biomass resources, conversion technology used, availability of human resources, local capital, know how, financial support, etc. It is also dependent on the existence of

other energy alternatives and in particular its competitiveness with other renewable energy options and fossil fuels.

A particular challenge will be to make the necessary cultural and social changes, in addition to techno-economic ones, to ensure that biomass energy is used in its modern forms to ensure better utilisation of existing resources and the provision of modern services that the population wants.

Table 1.6. Promising biomass sources and technologies for Fiji Islands.

Resource	Technology/Process & Product	Remarks
Agricultural Residues	Combustion- could be better used in cottage industries	Potential is limited; costs may be high; domestic uses. This could be combined with other RE
Sugarcane/ Bagasse	Cogeneration & gasification (electricity)	Already used, but potential much higher. Production of ethanol should be considered
Forestry Residues	Combustion (heat and power)	Poorly used; there is much greater potential with good management practices; fuel wood; land tenure problems
Coconut	Bio-diesel + charcoal (electric, transport, combustion)	Good possibilities. This could have significant impacts on the local economy
Municipal Sewage Waste (MSW) & other waste	Biogas	Various projects

Table 1.6 is based on the data collected during the in-country missions, feedback from the training course, and visits to Fiji by Drs Jeremy Woods, Sarah Hemstock and K. Deepchand. It seems clear that Fiji has a considerable potential for increasing biomass energy. Making more efficient use of these resources will provide not only greater supply of domestic energy, but will also stimulate the local economy e.g. the sugarcane industry.

1.6 Main Energy-related Concerns

The major concerns include:

- Better utilization of agro-forestry residues e.g. for energy uses
- Major constraints facing the forestry sector include: lack of proper infrastructure, inadequate skilled personnel, poor timber utilization, and the inability to sustain quality and quantity for domestic and export markets

- Growing dependence on imported fossil fuels
- Poor utilization of biomass resources, particularly bagasse
- Serious difficulties in the sugarcane industry. Need to find alternatives. Increase cogeneration and ethanol fuel production is a realistic alternative

1.7 References

1. ADB (2001). Fiji Islands-Economic and Asian Development Bank operations update, Asian Development Bank (ADB).

2. ADB (2002). Country Strategy and Program Update (2003-2005): The Republic of Fiji Islands, Asian Development Bank (ADB).

3. Briguglio, Lino. Small Island Developing States and Their Economic Vulnerabilities. World Development 23(9): 1615-1632. 1995.

4. Brown, C.; 1997; Regional Study - The South Pacific; Asia Pacific Forestry Sector Outlook Study, Working paper No. 1; FAO; Rome.

5. Bureau of Statistics, Annual Report, Government of Fiji. 1998.

6. Daly, B.K., Wainiqolo, J.L., Chand, K. and Hart, P.B.S. The use of microbial biomass carbon for monitoring organic matter dynamics under cropping and agroforestry in two Fiji soils. Fiji Agricultural Journal, 52(1), 35-41. 1996.

7. Donnelly, T. A., Quanchi, M. and Kerr, G. J. A. Fiji in the Pacific: A Geography and history of Fiji. 4th Ed., Jacaranda Wiley Ltd, Australia, 1994.

8. FAO 1995; National Forestry Action Programmes NFAP Update 32; FAO, Rome.

9. FAO 1998; Asia and the Pacific National Forest Programmes Update 33; FAO Regional Office for Asia and the Pacific; Bangkok.

10. FAO Forestry STAT and FAO Agriculture STAT Database. Fiji Statistics Bureau, Suva, Fiji

11. Hasni S., (1997) Country Profile- Fiji, Tropical Forest Update

12. Jiko, L.R.; 2000; Fiji Country Report; in Proceedings of regional consultation on implementation of Codes of Logging Practice and directions for the future; 12-16 July, 1999, Port Vila, Vanuatu. Field Document No. 3; RAS/97/330, Pacific Islands Forests and Trees Support Programme.

13. Kroes, S., (2002). The Waste Pay-off- Adding value to the Sugar Industry, Fiji Sugar Corporation Ltd.

14. Matakiviti, A. Forestry residue arising in Fiji in 2003. 2003. e-mail received 11th November 2003.

15. Ministry of Agriculture, Fisheries and Forests, Annual Report. Government of Fiji. 1996.

16. Ministry of Agriculture, Fisheries, Forests and ALTA. Annual Report for the Year 1996. Parliament of Fiji. Parliamentary Paper N0. 79 of 1999. Government Printer. Fiji. 1999.

17. Mueller-Dombois, D. and F. R. Fosberg (1998). Vegetation of the tropical Pacific islands. Springer-Verlag, New York. 733 pp.

18. Oliver, W.; 1999; An update of plantation forestry in the South Pacific; RAS/97/330 Working Paper No. 7; SPC/UNDP/AusAID/FAO.

19. Sugar Cane Research Centre, Annual Report 1998/99. Fiji Sugar Corporation Limited. Lautoka, Fiji.

20. Swarup, R.; 2000; Country Report – Fiji; Report to Regional Heads of Forestry Meeting 08-12 May 2000; Nadi; Fiji.

21. UNDP/FAO; 1998; Proceedings of Heads of Forestry Meeting 23-28 September 1996; RAS/92/361; South Pacific Forestry Development Programme.

22. World Conservation Monitoring Centre; 1992; 1992 Protected Areas of the World: A review of national systems: Solomon Islands.

23. The following web sites:

www.fao.org/forestry/include/frames/english.asp?section=/forestry/FON/FONS/outlook/Asia/APFSOS/01/APFSOS.htm

www.cia.gov/cia/publications/factbook/geos/fj.html

www.efi.fi/cis/english/creports/fiji.html

www.fiji.gov.fj/

www.fiji-online.com.fj/aboutfiji

www.fiji-online.com.fj/aboutfiji/land.shtml

www.un.org/esa/agenda21/natlinfo/wssd/fiji.pdf

www.wcmc.org.uk/cgi-bin/pa_paisquery.p

2. KIRIBATI

2.1 Basic Data

Kiribati archipelago consists of 33 coral islands, of which 21 are uninhabited. Kiribati lies in the South Pacific Ocean between 1°25' N and 173°00' E. It is composed of three island groups; Gilbert Islands, Line Islands and Phoenix Islands, with a total land area of approximately 810 km^2 (81 000 ha) over 50% of which is the Kiritimati Atoll.

There are three main administrative units in Kiribati; Gilbert Islands, Line Islands and Phoenix Islands. There are 6 districts within these administrative units; Banaba, Central Gilberts, Line Islands, Northern Gilberts, Southern Gilberts and Tarawa and 21 island councils – one for each of the inhabited islands.

Kiribati has a warm, humid, tropical oceanic climate, with annual rainfall ranging from about 1000 mm in the southernmost islands to 3000 mm in northernmost islands. However, many soils are infertile and this limits vegetation, as they consist mostly of low-lying atolls surrounded by extensive reefs. Agriculture employs an estimated 71% of the labour force, and key primary food crops produced are coconuts and bananas.

Contamination of ground water resources due to human activities (e.g. agriculture) is having a significant negative effect on land use. Being a remote country of 33 scattered coral atolls, Kiribati has few natural resources.

2.2 Forest Resources

Data on forest is limited and is based largely on FAO STAT data. It is estimated that about 3% of the land is covered by forests (1966 hectares and a further 185 hectares of mangrove forests). In addition, there are approximately 26 000 hectares of coconut plantations. Kiribati has developed an intensive agro-forestry system based on coconut, breadfruit, bananas and native figs. The system resembles more natural forests than plantations (FAO, 1997).

The main vegetation types in Kiribati are:

- Coastal stand vegetation

- Limited areas of mangroves and costal marsh vegetation
- Relic stands of inland forest.

The main secondary and cultural vegetation types are:

- Coconut palm-oriented agricultural lands, including giant taro or babai pits, under various stages of cultivation and fallow. The dominant tree species is the coconut palm, which covers most of the country, farming naturally generating open woodland.
- House yards and villages gardens.
- Extensive and variable areas of ruderal vegetation (Thomson, 2002).

2.2.1 Forest Management

Kiribati does not have any forestry-specific legislation but forestry is covered under other general legislation. For example, the management objectives of the forests are specified in broader environmental and development planning policy. The Constitution of Kiribati specifically states "*the natural resources of Kiribati are vested in the people and their government".*

Groups (Catholic and Protestant churches, and extended families living in small scattered villages) own most of the land and forests in the most densely-populated islands, except in the case of the Line and Phoenix Islands, which is owed by the state. Land reform will be a key element for further development of forestry and agricultural practices.

There is no significant contribution of forestry and trees to the economy, but trees make a considerable contribution to the subsistence needs of the people. The three most important features of forest and trees in Kiribati, according to Thomson (2002) are:

- Protection of land from sea erosion, sea spray, wind and water.
- They are the primary sources of food, shelter and medicines.
- They produce biomass to improve soil fertility.

Kiribati has few special programmes designed to promote sustainable forest management. For example, trees and coconut palms are harvested on an ad hoc basis to meet subsistence requirements for building, fuel wood, etc. Forest management is primarily limited to agro-forestry systems and it is unlikely that any major change will occur in the near future. There is a lack of public awareness together with scarce resources for any major new undertaking.

The key issues affecting Kiribati's forests are:

- Potential impacts from global warming which could inundate much of the country's land area.
- Population pressure, particularly on South Tarawa, which is creating major problems for sustainable development.
- Land degradation through harvesting for fuel wood, building material, etc.
- Habitat pollution through dumping of rubbish.
- Land fragmentation arising from the customary inheritance law, which leads to continuous subdivisions of holdings (www.fao.org/forestry/fo/country/).
- Need to develop a long-term agro-forestry plan.
- Need to replace ageing coconut palms – the majority of coconut palms on plantations in Kiribati are over 50 years old.

2.3 Agriculture

Agriculture employs an estimated 71% of the labour force, and the primary food crops produced are coconuts and bananas. The largest agricultural exports (in value terms) in 1997 were mangoes, fish and copra with a total value of AUD$10.7 million. The agricultural sector of the economy accounts for almost 14 percent of GDP.

There is no land resource survey of Kiribati which would be needed to provide information on the land area occupied under each land system (Thomson, 2002), estimates, through observations, are indicated in Table 2.1.

Table 2.1. Estimated land use in Kiribati.

Type of land use	Percentage
Coconut trees, taro,+ other food crops	47
Mixed inland forests and under-story species	20
Marginal shrubs and barren land	8
Airstrips, sport grounds, roads	8
Coastal strand vegetation, mangroves & marsh vegetation	7
Backyard gardens and village gardens	5
Villages, schools, hospitals, offices	3
Fish ponds	2

Source: Thomson (2002)

There are some specific areas within the agricultural resources of Kiribati that pose the greatest challenges towards the practice of sustainable agriculture; these challenges include poor soil problems, land degradation, land use issues, water use issues, and pollution of the environment.

2.4 Energy

Kiribati relies totally on imported fossil fuels for its electricity generation, and the country faces serious energy difficulties. The costs of technologies are high and the ability to install and maintain them is currently underdeveloped. However, a new copra mill has been built (funded by the Government, costing approx. $4.2 million). The mill is capable of processing 5 tonnes of copra per hour – producing approximately 26 000 litres of oil per 8-hour day. To provide copra for this production, the plant will require approximately 2500 hectare of coconut plantation to be harvested annually with an average planting density of 254 palms/ha. Only 926 hectare of high density (350 palms/hectare), well managed plantation would be needed, however, 1700 hectare would be necessary if only poorly managed, low density (150 palms/hectare) plantation were available. The plant is expected to be fully operational by the end of 2003. Currently, the coconut oil produced by the mill is expected to be exported for use in the cosmetics industry. However, the oil could also be used as a substitute for imported diesel.

The need for agro-forestry management is essential as the majority of coconut trees in Kiribati are over 50 years old, and are likely to produce a low copra yield in future which may mean that locally produced copra will not be enough to supply the copra mill. A coconut palm re-planting scheme is therefore urgently needed.

Despite relying on imported diesel for the production of electricity, the data on electricity consumption is poor, making the forecasting of load demand difficult. SOPAC programmes and other donor contributions have assisted Kiribati with the supply and installation of a number of solar photovoltaic (PV) systems, which provides a secure, reliable and cost-effective source of electricity for the outer islands. Installation of these systems is ongoing in collaboration with the Kiribati Solar Energy Company (SEC), which was established in 1985.

The Government of Japan funded the installation of 55 solar PV systems in Kiribati in 1992. In 1994, 250 additional solar PV systems were installed, funded by the European Union, 95% of these were still working 5 years later. Users have to pay a fee (around AUD$15 per month), while the systems themselves are property of the electric company. 13 full-time and 14 part-time jobs have been created in Kiribati as a direct result of this project. PV systems have been so successful here as the focus has been on delivering a service rather than on selling a technology.

SOPAC has also undertaken training workshops to strengthen human capacity in Kiribati to evaluate new and renewable energy projects, for the collection and use of energy sector data, and to plan and manage the energy sector. A national energy supply/demand database is also currently being set up. Investigation into other alternative energy sources for Kiribati has also been carried out. For example, a series of studies on the wave energy potential has been conducted by SOPAC at a regional level. The outcome of SOPAC's research was published in a brochure called "Ocean Wave Energy in the South Pacific" which provides extensive information on the results, status of wave energy internationally and avante-garde technology in the field.

A regional energy programme design workshop was also convened in Nadi, Fiji by SOPAC in 1998. This workshop helped to outline the energy sector priorities of the Pacific nations and drew up a programme for the period 1999-2004. Wind, geothermal energy, biomass and hybrid power systems were identified as energy sources of the future for the islands.

- SOPAC realises the need to assist Kiribati in:
- Development of electrification policies and guidelines
- Modification of energy databases
- Strengthening of human resource base in energy sector
- Identification of renewable energy sources.

2.5 Water and Sanitation

The use of biomass for energy is closely coupled with water use and availability. In addition, a number of potential biomass energy provision pathways could have a positive impact on water quality issues. For example, the use of anaerobic digestion systems to treat human and animal sewage also results in the production of a methane rich gas. This gas is used around the world for cooking lighting and even electricity production. Over exploitation of biomass resources or extensive planting of deep-rooted trees can over-exploit fresh-water tables and cause saltwater infiltration with resulting problems of soil salinisation and freshwater contamination. Therefore, careful planning is required for bio-energy schemes with regard to water issues.

Indeed, the availability of fresh water has been a long-standing problem throughout Kiribati. Natural sources of permanent potable water are limited to groundwater in freshwater lenses. These freshwater lenses are floating on the higher-density seawater beneath the atolls. Other sources of water include hand operated pump wells, roof catchments and galleries.

Groundwater resources in Kiribati can be easily contaminated from human and other solid wastes. This arises from inadequate use of proper toilet facilities and lack of infrastructure in the sanitation sector. Due to the shallow water tables, seepage of waste into the fragile groundwater system is a common occurrence in Kiribati.

Several workshops have been organised by SOPAC to evolve strategies on water resource management and development e.g. water and sanitation issues through field surveys, assessments and capacity building through training programmes and workshops.

SOPAC's efforts in water and sanitation problems in Kiribati include the following:

- Development of policy and legislation;
- Water sector action plans for Kiribati;
- Undertaking of pilot projects, research and feasibility studies to address water and sanitation issues; and
- Infrastructural improvement within the water and sanitation sector e.g. proper maintenance of toilets.

Global climate variability may be responsible for increasingly more-frequent and more-severe storms, interspersed with scorching droughts. The impact of this variable climate has been harsh on the ecosystems and coastal, terrestrial and marine biodiversity. Economically, the impact has translated into decreased agricultural yield, death of livestock, and decrease and loss of marine biodiversity. This has caused loss of revenue that can have detrimental effects on the social and economic systems of SIDS and developing economies. The majority of the people dependent on these sources of income are poor, and the poverty implications of variable climate are high.

Possible effects of variable climate comprise the inundation of low-lying atolls, saltwater contamination of freshwater lenses, increased coastal erosion and the loss of already limited and valuable land. While the actual impact of climate change at the local level has not been assessed, the issue of global warming and sea-level change and its possible impact on the environment is of critical concern to the government and people of Kiribati. Little or no attention has previously been given to the possible linkages between biomass energy provision, fresh water supply and climate change. However, there are important linkages between these sectors and opportunities that may arise that require further detailed evaluation.

2.6 The Biomass Resource

Table 2.2 summarises the main potential for the exploitation of biomass resources in Kiribati and is based on the data gathered from the country visit by Dr Sarah Hemstock in May 2003 and from feedback during the associated Training Course (see project web site for more details). Generally, the country is small and the biomass resource base is poor since both the agricultural and forestry sectors offer few realistic possibilities, except for bio-diesel production from coconut.

Table 2.2. Promising biomass sources and technologies for Kiribati Islands.

Resource	Technology/process & product	Remarks
Agricultural residues	Combustion	The country has few natural resources; agriculture is too small to offer any real alternative except in the coconut plantations.
Forestry residues	Combustion	Forest plays a small role but may have a larger future role (see also coconut below)
Coconut	Bio-diesel, charcoal	Good possibilities (see coconut case study)
MSW & other waste	Biogas	No current projects identified

2.7 Main Energy-related Concerns

The main energy concerns in Kiribati, include:

- Soil fertility, which is among the most infertile in the world.
- Shortage of water and water contamination. This is a major concern in Kiribati that overshadows many others issues.
- Land ownership is based in customary inheritance law. This has resulted in land fragmentation to the point that often plots consist of just a few trees.
- Remoteness from world markets.
- Climatic variability e.g. long droughts and exposure to cyclones. These impacts are being translated into decreased agricultural yields, death of livestock, loss of biodiversity, etc.

2.8 References

1. Sekula S et al (1998). A Preliminary Listing of Tuvalu Plants, Fishes, Birds and Insects, Atoll Research Programme, University of South Pacific, Tarawa, Kiribati.

2. Thomas L., (2000) ed., State of Forest and Tree Genetic Resources in the Pacific Islands, and Sub-Regional Action Plan for their Conservation and Sustainable Use, Country Report: Republic of Kiribati. (Conference Proceedings).

3. Thomson L (2002). Thomas L., (2000) ed., State of Forest and Tree Genetic Resources in the Pacific Islands, and Sub-Regional Action Plan for their Conservation and Sustainable Use, Country Report: Republic of Kiribati. (Updated version), SPRIG-2 Project, CSIRO Forestry and Forest Products, Canberra, Australia.

4. The following web sites:

www.fao.org/forestry/fo/country/

www.cia.gov/cia/publications/factbook/geos/kr.html

3. SAMOA

3.1 Basic Data

Part of the Samoan archipelago, the independent state of Samoa is comprised politically of the largest two islands in the group (which also includes six islands comprising American Samoa): Savai'i is 1820 km^2 and 'Upolu is 1110 km^2. The main island of 'Upolu, is home to nearly three-quarters of Samoa's population and its capital city of Apia.

The islands are in the Southeast, about halfway between Hawai'i and New Zealand, in the Polynesian region of the South Pacific. The climate is tropical, with a rainy season from November to April. Savai'i is still active volcanically, while 'Upolu is extinct or at least dormant. Vegetation types include littoral, mangrove, and swamp forests, and a range of rain forest types.

The primary sector (agriculture, forestry and fishing) employs nearly two-thirds of the labour force and produces 17% of GDP. The economy as a whole is highly dependent on agricultural exports, tourism, and capital flows from abroad.

3.2 Forest Resources

Total forest cover has been estimated by FAO at 104 790 hectares; while deforestation has been calculated at about 2500 hectares annually in the 1980s until mid 1990s, though this rate has now subsided. The main cause was land clearing for taro plantations. Other sources (Leavasa & Pouli, 2000) put it at 106 600 hectares (see Table 3.1) this represents about 36% of the total land area of Samoa, although estimates can vary significantly, depending on the forest cover estimation.

Table 3.1. Latest available data on forest in Samoa, 2000.

Type of forest	Hectares
Productive forest	15 923
Non-productive forest	87 396
Plantation	3 277
TOTAL	**106 596**

Source: Leavavasa & Pouli (2000)

Roughly, 75% of Samoa total forest area is on Savai'i Island, comprising merchantable indigenous forests (15%), non-merchantable indigenous forests (83%), and plantations (2%).

The forests of Samoa are mainly humid tropical rainforests, differentiated by elevation into lowland, foothill and upland forests. Common species include *Pometia spp.* and *Terminalia spp.* in the lowland and foothill forests. Substantial areas are under coconut, and smaller areas of mangroves are also present. Deforestation is a serious problem in Samoa; heavy exploitation of the indigenous forests started around mid 1970s. In the subsequent period most of the commercial forest has been cleared firstly for the valuable timber and then for agriculture or damaged by cyclones. Currently, more than 80 percent of the forest is regarded as non-commercial.

Table 3.2 shows estimated plantation areas of the main species according to FAO data. The main species is *mahoganies* (83%), which is used in its entirety for industrial applications. Planting began in the late 1960's, and reached about 5100 hectares by 1990, but the forests were severely damaged by Cyclones Ofa in 1990 and Cyclone Val in 1991, which destroyed over 60% of the plantation areas.

Plantation forests presently comprise approximately 4500 hectares, mainly of *Swietenia macrophylla* with smaller amounts of *Eucalyptus* spp, *Tectona grandis*, and a variety of minor species. Until 1988, the focus was on fast-growing species such as Eucalyptus.

Planting of most species is carried out at 10-metre intervals in rows spaced 2 metres apart. At present, weeding is the principal silvi-cultural treatment. Pruning of some species has been done on a trial basis, and many stands are in need of thinning, but none is currently performed. In 1991, the Government set an annual allowable cut for commercial harvesting at 29 000 m^3.

Table 3.2. Estimated plantation areas in Samoa, according to main species.

Species	Hectares	Industrial uses (%)	Non-Industrial uses (%) *
Acacia	10		100
Eucalyptus	180	40	60
Mahoganies	3 770	100	
Teak	110	100	
Terminalia	160	100	
Other broadleaved	310	40	60
TOTAL	4 540		

* Percentage of wood used for non-industrial applications such as fuel wood
Source: FAO STAT

Samoa faces a major environmental threat from deforestation. Agricultural change is the major culprit although logging has played its part in disturbing the delicate ecosystem. During the past few years, the annual rate of forest clearance has accelerated, primarily for agriculture. Deforestation due to fuel wood acquisition is also considerable and increasing, due to increasing population and increasing prices for fuel wood and fuel wood substitutes.

3.2.1 Forest Management

The key legislation guiding the development of forestry in Samoa is the Forests Act of 1967 and the Forest Regulations of 1969. The Forests Act 1967 established the Forestry Division of the Ministry of Agriculture Forests and Fisheries (MAFF) to administer the conservation, resource management and exploitation of forests. A variety of other legislations incorporate environmental aspects pertaining to forests e.g. the National Parks and Reserves Act of 1974, and the Division of Environment and Conservation.

The evolution of forest management in Samoa has largely centred on traditional Polynesian agro-forestry systems. These are largely subsistence agricultural systems, although trading capacity has developed for some products such as copra, cocoa, and bananas. The harvesting of Samoan forests for commercial timber is a recent occurrence. Since 1980, more than 50 percent of the merchantable, and about 30 percent of the non-merchantable, forest has been cleared.

3.2.2 Policy

A National Forest Policy was introduced in 1995, although this is still to be fully implemented. This prescribes a sustainable management regime for all Samoa's forest resources. Currently, the main silvi-cultural activities on Samoa relate to plantation establishment and maintenance.

Current Government policies related to the effective and efficient planning and management of forest resources in the country include:

- Ensuring protection and conservation of the environment
- Production of wood and non-wood forest products
- The provision of recreation and tourism opportunities
- Ensure sustainability of natural forests and plantations

- Forest management plans

Large-scale commercial timber harvesting in Samoa started in the mid-1970s. Within a few years, much of the remaining lowland tropical forest, and foothill forest on Savai'i and 'Upolu, had been cleared or highly modified. Forest clearance has continued up to the present time, and approached 3.5 percent per annum from the mid-1980s to the mid 1990's. The clearance included even the steep land resulting in severe erosion problems. Significant cutting and in-filling of mangroves has also taken place. Table 3.3 summarizes forest products production in Samoa from 1992 through the year 2000. The fact that all figures remain constant over the years, indicates that the data have extrapolated and hence must be considered as rough estimates only.

Table 3.3. Forest products production in Samoa, 1992-2000 (10^3 m^3).

Products	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Roundwood	131	131	131	131	131	131	131	131	131
Industrial roundwood	61	61	61	61	61	61	61	61	61
Woodfuel	70	70	70	70	70	70	70	70	70
Sawnwood	21	21	21	21	21	21	21	21	21
Total	283	283	283	283	283	283	283	283	283

Source: FAO STAT

A variety of programmes have been implemented to support sustainable forest management including those mentioned above relating to logging practices, plantation establishment, and community forestry and plantation establishment.

The principal trends relating to forest management derive from the rapid acceleration in forest clearance since the mid-1970s. More recently, rates of deforestation have slowed as areas of accessible forests have become increasingly scarce, along with the development of conservation awareness. This reduction in forest resources has seen a shift in development focus from production to increasing application of sustainable management principles and the encouragement of greater participation by local communities, farmers and other stakeholders. Plantation development, as a source of alternative wood supplies, has also been highly significant.

3.3 Agriculture

Despite the increase in services and in industrial activities, agriculture still remains a major area of economic activity, particularly coconut production. This is particularly so after the collapse of the taro exports in the mid 1990s.

The collapse of taro exports in 1994 forced some diversification of Samoa's export products and markets. Prior to the taro leaf blight, Samoa's exports consisted mainly of taro (US$1.1 million), coconut cream (US$540 000), and "other" (US$350 000).

Samoa agriculture also suffers considerably from the vagaries of nature. For example, two major cyclones hit Samoa badly at the beginning of the 1990s. Cyclone Ofa left an estimated 10 000 islanders homeless in February 1990; Cyclone Val caused 13 deaths and hundreds of millions of dollars in damage in December 1991. As a result, GDP declined by nearly 50% from 1989 to 1991. These experiences and Samoa's position as a low-lying island state punctuate its concern about global climate change, which will affect particularly hard agricultural activities. Table 3.4 summarizes land use in Samoa according to major crops.

Another major problem, both for the development of agriculture and forests, is land tenure rights, which is a rather complex issue in Samoa. For administrative and regulatory purposes, land is divided into customary land, freehold land and public land. Almost 80 percent of land is under customary title. The basis for customary land ownership is the extended family, in which the Matai (family head) allocates the use of the family’s land. In addition, there are communally-owned village lands, which are typically firewood gathering areas, beach landings, or unused lands which may be claimed by families by establishment of use. Finally, there are district lands claimed by traditional Samoan district councils. District lands are high mountain lands used primarily for hunting and gathering.

Table 3.4. Land use in Samoa according to major crops (1990).

Crop	Area (hectares)
Coconut	23 310
Cocoa	6 556
Taro	14 771
Ta’amu	3 278
Bananas	2 266
Yam	243
Other vegetable crops	607
Total	51 033

Source: FAOSTAT Database

3.4 Energy

Samoa is confronted with the urgent need to introduce both supply and demand-side management programmes to attain efficiency in the power sector. The import of fossil fuels for electricity generation in the country is placing an increasing strain on the economy of these islands. Therefore, the need exists in Samoa for the exploitation of renewable energy sources such as biomass and solar energy for the sustainability of the energy sector.

SOPAC has been providing continued assistance to the Government of Samoa in order to identify and develop renewable energy sources in the country. This has been done through:

- Field studies to help with the identification and the use of low-emission technologies and native energy sources e.g. the development of wave energy, which has a high resource potential and is considerably steady throughout the year
- Assistance to carry out a feasibility assessment for the construction of a wave-energy plant on the southern coast of Savai'i
- Advice towards the development of rural electrification
- Design and installation of a hydrological network

3.5 The Biomass Resource

Table 3.5 presents a summary of the main potential of biomass energy sources based on field data, visits, feedback from the training course, etc. Samoa Islands could make much better use of its natural resources whilst at the same bringing potential environmental and socio-economic benefits. Both the agricultural and forestry sectors offer realistic possibilities for sustainable increase of biomass energy resources.

Table 3.5. Promising biomass sources and technologies for Samoa Islands.

Resource	Technology/Process & Product	Remarks
Agricultural Residues (general)	Combustion	There are various crops (coconut, copra waste, cocoa). These residues offer some additional potential, both for domestic and small industrial applications
Forestry Residues (general)	Combustion	Samoa has a large forest cover by 80% could be classified as economically unproductive. About 70,000 m3 of fuel wood are used annually. Forests are not expected to play a major role in energy supply.
Sawmill waste	Combustion	With better management practices this offers good possibilities. Currently it partly wasted.
Coconut	Bio-diesel, charcoal	Good possibilities for small applications
MSW & other waste	Biogas	An innovative anaerobic digester has been installed in Apia under the management of SPM International. Unfortunately, this scheme appears to have run into management problems and is currently stalled.

3.6 Main Energy-related concerns

The main energy concerns in Samoa include the following:

- Deforestation, arising chiefly from an expansion of agriculture is a major concern, although commercial logging has also played a very significant role;
- Environmental problems posed by deforestation include watershed degradation, erosion and soil depletion, and loss of biodiversity;
- A shortage of financial resources to implement forestry programmes. Shortages of professional manpower, and a shortage of human resources in general, are ongoing concerns for the Samoan forestry sector, and for the implementation of renewable energy technologies;
- Land tenure issues and uncertainties over the future direction of core forestry programmes; and
- Poor utilization local natural resources, particularly biomass.

3.7 References

1. Brown, C.; 1997; Regional Study – The South Pacific; Asia Pacific Forestry Sector Outlook Study, Working paper No. 1; FAO; Rome.

2. FAO, 2000. Asia and the Pacific National Forest Programmes. Update No.34. FAO Regional Office for Asia and the Pacific, Bangkok. http://usa.samoarealty.ws/land_tenure/index.htm

3. Leavasa, A. & Pouli,T. 2000. Country summary report-Samoa. FAO Workshop-Data Collection for the Pacific REgion

4. Mueller-Dombois, D. and F. R. Fosberg (1998). Vegetation of the tropical Pacific islands. Springer-Verlag, New York. 733 pp.

5. Oliver, W.; 1999; An update of plantation forestry in the South Pacific; RAS/97/330 Working Paper No. 7; SPC/UNDP/AusAID/FAO.

6. UNDP/FAO. 1995. Samoa,Tonga,Kiribati and Tuvalu: A review of uses and status of trees and forests in land use systems with recommendations for future actions. Thaman, R. & Whistler, W. Technical Support Services at Programme Level. UNDP/FAO Work-Programme 1992-1993. Project: RAS/92/T04

7. The following web sites:

www.fao.org/forestry/fo/country/

www.fao.org/agriculture/country/

4. TONGA

4.1 Basic Data

The Kingdom of Tonga comprises about 150 islands with a total land area of 649 km^2, of which Tongatapu with 257 km^2 representing over a third of the total land area. Agriculture has been the primary sector of the economy, representing the main source of livelihood for two-thirds of the population. Agricultural activities in Tonga are, however, very limited and mostly confined to coconut production, and food crop for the local population. In the early 1980s, agriculture provided more than 50% of GDP and currently provides about 25% of GDP. However, the increase in services (e.g. industry, and tourism), have reduced the traditional socio-economic role of agriculture.

4.2 Forest Resources

According to FAO data, Tonga has moderate forest cover, with only a small area of closed natural forests remaining, about 4000 ha, mostly of hardwood, of which about 1700 ha are in Tongatapu.

Secondary forests are the dominant type of forest in Tonga, a mixture of native and imported plant species. Tonga current major timber resources are coconut palms (the main resource in Tonga), although the country is trying to establish commercially viable plantations, particularly *Pinus caribaea*.

At present, there about 900 hectares of plantation forest are established in Tonga, with *Pinus caribaea* and *Toona australis* as the predominant species. Plantation trials commenced in the 1940s, and more than 50 species have been introduced, and tested. Around 80 hectares of plantations are targeted for establishment each year, and line planting is used for all species. Weeding is carried out in the 5 years, after plantation establishment, and some low pruning is carried out during weeding operations, but no high pruning has been performed. Thinning in the *P. caribaea* plantations is just beginning, with a tentative schedule suggesting thinning to waste at age 8, and a production thinning at age 12, down to 450 stems per hectare. Thinning can represent a considerable potential supply of low quality and low value biomass, which is suitable for bio-energy schemes. Tonga's objective is to establish 1500-2000 hectares of plantation forest and efforts have concentrated on the island of ’Eua. Projections show that this plantation estate would be adequate to sustainably meet 80 percent of Tonga’s sawn timber needs.

Table 4.1. Estimated forest products production in Tonga, 1993-2000 (10^3 tonnes).

Year	1993	1994	1995	1996	1997	1998	1999	2000
Roundwood	5	5	5	5	5	4	2	2
Industrial Roundwood	5	5	5	5	5	4	2	2
Sawnwood	1	1	1	1	1	2	2	2

Source: FAOSTAT

Logging has exhausted all the most accessible forest and those that remain are primarily in uninhabited islands, in very steep or inaccessible areas, swamps or mangrove areas. Fuel wood is the main source of energy in Tonga. Also, most of the food products are cultivated under tree canopies, in particular coconut palms. Table 4.1 shows rough estimates of forest product production in Tonga, according to FAO data. This data must been seen as indicative only.

4.2.1 Forest Management

The Forest Act 1961 (amended in 1991) controls the use of forests and includes protection and conservation measures including the establishment of forest reserves and the protection of water catchments. A 1988 Parks and Reserves Act (PRA) provides for "the establishment of a Parks and Reserves Authority and for the establishment, preservation and administration of parks and reserves". The Preservation of Objects of Archaeological Interest Act 1969 provides for the protection of a number of historical, cultural and archaeological sites, many of which are also protected by traditional law. A recent Environmental Protection Act contains provisions relating to forest management, though some of these overlap with Division of the Ministry of Agriculture and Forestry (DMAF) responsibilities and may be a source of confusion.

National forest management is the responsibility of the Forest and Conservation DMAF. Its responsibilities include policy and planning, forestry research, plantation forestry, agro-forestry and conservation. A separate committee exists within the DMAF to coordinate all agro-forestry activities. The Ministry of Land, Survey and Natural Resources administers the Environment Act, and an Environmental Unit within the Ministry is responsible for environment and conservation matters. The Constitution of Tonga provides that: *All the land is the property of the King and he* *may at pleasure grant to the nobles and titular chiefs or matapules one or more estates to become their hereditary estates.*

It is hereby declared by this Constitution, that it shall not be lawful for anyone at any time hereafter whether he be the King or any one of the chiefs or the people of this country to sell any land whatever in the Kingdom of Tonga but they may lease it only in accordance with this Constitution and mortgage it in accordance with the Land Act.

Until recently, all male taxpayers were entitled to an 8-acre allotment, which made landholding subject to fragmentation. More than 60 percent of the country's land area is held in allotment and this system appears to limit forestry development to only small scattered woodlots (www.fao.org/forestry/fo/country/is).

4.2.1.1 Management Objectives

Tonga does not have a formal national forest policy. National forestry objectives are included in the five-year Government development plan. This recognises the need to maximise the contribution of forestry to sustainable national development. The Ministry of Agriculture and Forestry has a rolling three-year Forestry Plan, reviewed and adjusted annually. The three priority areas for development are the implementation of an agro-forestry development programme, plantation establishment (including sandalwood), and conservation and research.

In the medium to longer terms, a commercially viable and sustainable plantation estate is intended to replace the use of indigenous forest for domestic wood supply and to ultimately achieve self-sufficiency. One of the primary objectives of the Ministry of Agriculture and Forestry's development programme is the continued development of agro-forestry. This is seen as being the most effective means of promoting tree planting in a situation where land for timber plantations is limited. The Government is particularly interested in promoting planting of species for timber and fuel wood, planting improved varieties of fruit trees and nitrogen-fixing trees, coconut rehabilitation and replanting, and commercial intercropping.

An Environmental Management Plan was prepared in 1989, and revised in 1992 to become the National Environmental Management Strategy (NEMS). The NEMS activities focus particularly on wildlife conservation and management and the institutional and legal framework for ensuring environmental management.

Around 65 percent of Tonga's land area is under coconut plantations or agro-forestry systems. Under traditional agro-forestry systems, food crops (predominantly coconut) are cultivated under a canopy of trees. Tongan agro-forestry systems have a base in slash-and-burn agriculture, with a principal land clearing strategy consisting of felling, or ring-barking large trees and clearing the underbrush, usually through burning. At the same time selected tree species may be protected or allowed to regenerate along with deliberately planted ground and tree crops. Trees that are preserved are usually slow-growing timber species, fruit or nut trees, and trees of medicinal or other cultural importance. Often, domesticated or indigenous trees, are deliberately or accidentally planted, so that valuable trees are scattered throughout, as the gardens return to fallow.

4.2.1.2 Forest Harvesting Practices

Tonga's timber harvest is almost entirely comprised of coconut. Domestic production depends on the extensive coconut agro-forestry resource, with most of the remaining indigenous hardwood forests either inaccessible or in protected areas. Coconut timber makes up more than 80 percent of the total domestic cut. Commercial harvesting in Tonga mainly relies on the use of small portable sawmills. These are able to deliver timber at a lower price than imported timber. Logs are purchased from farmers at stumpage value, and small volumes are being harvested from the forestry plantations (mainly thinning) at an "at roadside" price. Timber processing and trading is considered to be mainly the responsibility of the private sector.

Consistent with this, the main commercial coconut timber-processing complex at Mataliku, comprising one sawmill, treatment plant, and joinery factory, has been privatised. Several other small fixed mills operate on 'Eua, Ha'apai and Tongatapu, processing coconut and some hardwoods, but their production of sawn timber is very small. These mills represent a major potential focus of future bio-energy schemes in Tonga.

The unique land tenure system in Tonga and the evolution of land-use systems means that opportunities for public participation in forest management on Tonga are less direct than in many other Pacific Islands countries. All Tongan land is, ultimately, owned by the Crown, but is divided into four categories:

- The Queen's hereditary estates;
- Royal family hereditary estates;
- Hereditary estates for the nobles and matapule; and
- Government.

Tonga has implemented a number of relatively small-scale programmes that promote sustainable forest management. These include the establishment of the 'Eua National Park, and plantation establishment programmes mentioned above. Other initiatives include the development of a National Agro-forestry Programme, a Watershed Areas Management Programme on 'Eua, and a Coastal Protection and Rehabilitation Project on Tongatapu. A number of other forestry projects are being implemented with bilateral or multi-lateral donor assistance.

Fuel wood collected from large hardwood trees remains the main source of energy in Tonga, but natural hardwood forests supply an ever-decreasing part of domestic fuel requirements and future fuel wood shortages are a concern. The establishment of 'Eua National Park and the development of Forest Conservation Agreements show clear evidence of a major shift in commitment to forest conservation. Efforts to establish a commercially viable plantation estate and promote agro-forestry support these trends.

4.3 Agriculture

Agriculture has been the primary sector of the Tonga economy, and still remains, the main source of livelihood for two-thirds of the population. In early 1980s, agriculture provided more than 50% of GDP and now it is down to about 25% of GDP.

In recent years, tourism, fisheries and industry are becoming increasingly important. Agricultural activities in Tonga are very limited, mostly confined to coconut production, and food crop for the local population. Agriculture as such, except to coconut production, offers few realistic alternatives.

Coconut is a major activity in Tonga. Annual productivity is about 120 nuts per palm; coconut row spacing is generally between 18 metres (60 feet) to a minimum of 14 metres (45 feet) and 6 to 12 metres between palms, lower densities are also common.

Cassurina (Iron Wood) is also widely grown for fuel wood use, as well as *Terminalia* and *Parangtonias*. Coconut timber is the prime source of material for construction, which takes about 60 years to reach maturity. Coconut wood is difficult to work with and needs tungsten carbide saw blades because it is very hard, especially around the outside-bark. The sawdust is used to fill swampy areas and the slabs/chips are one of the best woods for the 'umu' (underground stoves), that requires about 2 tonnes to fire. Tonga Timber has only recently started importing timber from New Zealand.

Other major crops are yam and taro, coffee, coco, cassava (export crops) and sweet potato. Kava (a medicinal shrub) used to produce medicines and export market to Germany; vanilla, and vegetables (tomatoes, capsicums, pepper, carrots, watermelon, and papaya).

There is a need to concentrate on improving cropping systems and practical methods to accommodate multiple crops and to maintain soil organic matter. They call this sequential relay cropping with a 5 year-cycle. There is a problem with decreasing fallow periods and therefore need to introduce *Leucena* and other leguminous crops to recondition the soil more quickly.

Timber trees are planted along the boundaries of the allotment called the 'tax allotment'. Pines are grown (like *Pinus carribea*) which bring in microrhyza to regenerate the soils.

4.4 Energy Policy

Following is a short summary of the main issues concerning energy in Tonga, with specific reference to RE and more specifically biomass. This rather detailed summary is included to show that it is possible to have a clear policy, which can also serve as an example to the other islands. The reader is strongly recommended to consult Tonga National Energy Policy (Anon 2002) for a detailed discussion of energy policy in Tonga.

Energy has a vital role in achieving sustainable development in Tonga. Responding to energy issues within the context of sustainable development involves many complex and interdependent factors addressed by this policy statement. Tonga faces a unique and challenging situation with respect to energy for sustainable development:

- Demographics vary slightly between districts, but often feature small, isolated population centres;
- Markets are very thin, difficult to serve, and with limited significant economies of scale;
- 10% of the total population is with limited access to electricity (Tonga Population Census, 1996);
- Tonga comprises a wide range of ecosystems, predominantly influenced by marine systems that make infrastructure development difficult and environmental impacts significant; and
- Tonga does not have indigenous petroleum resources and most power is produced from diesel.

Tonga has special concerns arising from its situation that have motivated the development of its national policy:

- Environmental vulnerability through climate change and sea level rise is very high, particularly for small islands and low-lying atolls;
- Environmental damage, habitat loss and pollution resulting from development and use of conventional energy sources have significant effects on fragile island ecosystems;
- Energy supply security is vulnerable, given the limited storage for bulk petroleum fuels, which are sourced over a long supply chain at relatively high prices;
- The development of renewable energy resources has been limited by the availability of appropriate technology, poor institutional mechanisms, and the challenges of developing systems for small remote markets at reasonable cost;
- There is limited scope for market reforms considering the variation in size and density of markets; therefore, appropriate alternatives are necessary for Tonga; and
- Tonga has limited human and institutional capacity to respond to these challenges.

In response to these challenges and their concerns, a National Energy Policy has been developed as a means of co-ordinating the energy programmes in the national and regional organisations and development partners, in areas where international co-operation is required. It is also intended to offer guidelines for adaptation to the circumstances of Tonga in areas for domestic implementation (Anon, 2002).

The National Energy Policy is structured around ten sub-sectors with the following goals in each area:

- *Regional Energy Sector Co-ordination*: Maximise the impact of regional resources and capabilities through a co-operative approach to sector co-ordination;
- *Policy and Planning*: A sustainable energy sector;
- *Power*: Increase reliable, safe and affordable access to power for people in all rural and urban parts of the country;
- *Transportation*: Increase the sustainability of transportation within the country;
- *Renewable Energy*: Increase the proportion of the region's energy use supplied provided by renewable energy;
- *Rural and Remote Islands*: Increase the availability of reliable, cost-effective, and sustainable energy supplies for the social and economic development of rural and remote islands;
- *Petroleum*: Improve the safe, reliable, and affordable supply of fuel to Tonga including rural and remote islands;
- *Environment*: Reduce the negative environmental impacts of the development and use of energy sources within the country;
- *Efficiency and Conservation*: Reduce the country's dependence on imported energy sources in particular the production and consumption per unit product for electricity generated using fossil fuels; and
- *Human and Institutional Capacity*: Develop adequate human and institutional capacity to plan and manage the national energy sector.

To achieve these goals, policies are stated and supported by a detailed strategic plan, organised as follows:

- Policies are stated for each goal, intended to set the rules by which specific strategies and actions will be designed to achieve the goals. They are long-term, but may be reviewed and changed every 3-5 years if necessary;
- The strategic plan consists of strategies for each policy, intended as the general means by which the goals will be reached. They are medium-term, but may be reviewed and changed on a 1-3 year cycle as required; and
- Activities under each strategy in the plan are the specific means by which strategies are implemented. They should be monitored continually and modified annually if needed. Each activity has an identified actor(s) and a proposed time line or milestone.

It is anticipated that the policy and strategic plan should undergo regular review. The Energy Planning Unit is the appropriate body to organise a suitable review process through energy stakeholders' governing bodies.

Another important area is regional co-operation in energy policy and planning that can help to overcome the disadvantages faced by the region, particularly in relation to its small size, dispersed communities, fragmented markets, environmental vulnerability, and limited institutional and human capacity. A regional co-operative approach to co-ordination will allow Pacific countries to share expertise, take advantage of economies of scale, harmonise policies and regulations, and mobilise increased official development assistance from international sources. The goal for regional energy sector co-ordination is: "*maximise the impact of regional resources and capabilities through a co-operative approach to sector co-ordination*" (Anon, 2002).

Tonga energy consumption during 1991-2000 relied very much on fossil fuels and biomass with a little contribution from other renewable energy sources. Policies are aimed at ensuring:

- that sufficient, affordable and appropriate sources of energy are available to promote the economic, social and political development of the people of the Kingdom; and
- that energy sector policy and planning addresses social, economic and environmental issues.

Despite past efforts to promote widespread use of renewable energy, progress in general has been rather slow. This is due to a number of issues including policy, technical, financial, management, institutional and awareness barriers. Renewable energy sources in the form of hydropower, wind, solar, bio-fuel, geothermal and ocean thermal hold a lot of potential to be used to promote sustainable social and economic development, particularly in rural and remote areas, while reducing the dependence on fossil fuel for power generation and in transportation. The major concerns and difficulties are:

- A lack of technical expertise and weak institutional structures to plan, manage and maintain renewable energy programmes;
- The absence of clear policies and plans to guide renewable energy development;
- A lack of successful demonstration projects; a lack of understanding of the renewable energy resources potential;
- A lack of confidence in the technology on the part of policy makers and the general public; and

- A lack of local financial commitment and support to renewable energy; and continuing reliance on aid-funded projects.

The goal for these renewable energy policies is to:

- Increase the proportion of the nation's energy use supplied provided by renewable energy;
- Promote the increased use of proven renewable energy technologies based on a programmatic approach and as a mean to an end;
- Support the renewable energy resource assessment and research and development activities;
- Promote the management of stand-alone renewable-based power systems based on the utility concept;
- Evaluate and document renewable energy developments and issues in and outside of the region and keep countries, donors, NGOs and other stakeholders regularly informed;
- Promote the adoption of a levelled playing field for both renewable and non-renewable energy sources and technologies;
- Increase the number of successful renewable energy installations;
- Increase the number of externally funded renewable energy initiatives; and
- Improve the awareness and understanding of their renewable energy resources and their potential.

4.4.1 Strategy Plan

For planning and policy development purposes, the energy sector is organised and analysed according to the following six themes:

i Planning;
ii Energy Policy;
iii Power (Electricity);
iv Transport;
v Renewable Energy; and
vi Petroleum.

These six themes are the standard classifications for integrated energy planning. Four cross-cutting issues are also identified as follows:

i Environment;

ii Remote or rural nature;
iii Efficiency; and
iv Capacity.

In totality, these ten themes correspond to the sections of the Pacific Islands Energy Policy and Plan (PIEPP), which was developed and implemented through the Council of Regional Organisations (CROP) Energy Working Group (EWG).

Almost uniquely to the South Pacific region, photovoltaics have been successfully implemented in many of the island nations as briefly summarised below and from which biomass energy projects must learn lessons.

Solar Systems. PV have been partially successful partly due to a combination of factors: villagers pay a Tala$50 deposit and then Tala$6 per month for their systems. The oldest PV system was installed 11 years ago and is still running well. This is mainly because the owners of the PV systems do not pay for any of the maintenance costs apart from the light bulbs and equipment repairs (but not labour), which is all, paid for out of their Tala$6 per month fee. The Energy Department pays for all other costs.

4.5 Water Resources

About 85% of the population depends on groundwater resources and 15% on rainwater, mostly collected by roof catchments systems. Because the volcanic bases of most of the islands are well below sea level and seawater percolates through the porous limestone. The fresh water that floats on top of the salt water within the limestone is Tonga's most important water resource. As in most other Pacific Islands the availability of water is a major conditioning factor in socio-economic development, including energy and particular biomass energy.

4.6 The Biomass Resource

Table 4.2 summarises the main possibilities of biomass energy in Tonga. This information has been compiled from visits and feedback from the teaching course. Coconut is a major crop in Tonga and offers good possibilities for bio-diesel production and other applications such as combustion.

Table 4.2. Promising biomass resources and technologies for Tonga Islands.

Resource	Technology/process & product	Remarks
Agricultural Residues (general)	Combustion	Agricultural activities are very limited. Most residues are already utilised.
Forestry Residues (general)	Combustion	The forestry sector is too small to play any significant role in Tonga. A major function of forests is preservation, or is commercially inaccessible.
Coconut	Bio-diesel + Charcoal	Good possibilities for small applications. Coconut is major activity; a lot of waste is generated.
Sawmill Dust	Combustion	Large amounts are generated; often used to fill swampy areas; could be used for energy.
MSW & other waste	Biogas	Any projects?

4.7 Main Energy-related Concerns

The principle forestry concerns in Tonga relate to deforestation and forest degradation – and an associated need to conserve much of the remaining forest-land in the face of continuing demands for consumption. Most areas of lowland forest have been cleared, and this raises concerns over loss of biodiversity, as well as increased incidence of soil erosion and the spread of anthropogenic grasslands. Other issues include:

- The increase in commercial farming of short term crops instead of the traditional agriculture practices is the main cause of forest loss on private lands and remains a key land-use issue in Tonga. Some Tongan islands are vulnerable to the adverse impacts of climate change and sea level rise;
- The country lack of experience in environmental management, together with limited funding, remain major constraints to achieving sustainable resource use. In terms of managing the forest resources these have negatively impacted on forestry training and the availability of qualified forestry staff;
- Solid waste disposal is also a serious problem in Tonga, particularly in Nuku'alofa where the main rubbish dump for household waste and other non-hazardous waste is situated in the mangrove area;
- Energy supply security is vulnerable, given the limited storage for bulk petroleum fuels, which are sourced over a long supply chain at relatively high prices; and
- The development of renewable energy resources has been limited by the availability of appropriate technology, poor institutional mechanisms, and the challenges of developing systems for small remote markets at reasonable cost.

4.8 References

1. Anon (2002) National Energy Policy of Tonga

2. Brown, C., (1997). Regional Study - The South Pacific; Asia Pacific Forestry Sector Outlook Study, Working paper No. 1; FAO; Rome.

3. Burrows, L.E. and Douglass. R., (1996). Inventory of the Coconut Palm Resources. Kingdom of Tonga; Report to the New Zealand Ministry of Foreign Affairs and Trade; Landcare Research NZ Limited.

4. Desloges, C., (1995) Tropical Forests Action Programme Information Mission to Pacific Island Countries; TFAP Coordinating Unit, FAO, Rome/ South Pacific Forestry Development Programme/UNDP, RAS/92/361, Working Paper 2.

5. FAO (1998). Asia and the Pacific National Forest Programmes Update 33;

6. FAO Regional Office for Asia and the Pacific; Bangkok.

7. FAO (2000). Asia and the Pacific National Forest Programmes Update 34;

8. FAO Regional Office for Asia and the Pacific; Bangkok.

9. SPC Forests; A Review of Uses and Status of Trees and Forests in Land-use Systems in Samoa, Tonga, Kiribati and Tuvalu with Recommendations for Future Action.

10. UNDP/FAO, (1998). Proceedings of Heads of Forestry Meeting 23-28 September 1996, RAS/92/361; South Pacific Forestry Development Programme.

11. The following web sites:

www.fao.org/forestry/fo/country/is

www.fao.org/forestry/include/frames/english.asp?section=/forestry/FON/FONS/outlook/Asia/APFSOS/01/APFSOS.htm

www.spcforests.org/Library/usestatus/usestatus.htm

5. TUVALU

5.1 Basic Data

Tuvalu's total land mass consists of just 26 km^2, spread over 750 000 km^2 that comprises its exclusive economic zone. It consists of 9 island groups with Funafuti containing the capital and Vaitupu the main educational and agricultural centres. The nation is populated with just under 11 000 people but it has been rising rapidly as shown in Table 5.1.

Table 5.1. Population & Land Areas of Tuvalu by Island Group.

Island Group	1991	2002	Km^2
Nanumea	155	883	3.87
Nanumaga	157	733	2.78
Niutao	139	757	2.53
Nui	116	704	2.83
Vaitupu	197	1531	5.60
Nukufetau	145	791	2.99
Funafuti	499	5049	2.79
Nukulaelae	60	474	1.82
Niulakita	15	48	0.42
Total	**1483**	**10970**	**25.6**

Source: Tuvalu Statistics Office, Funafuti, 2002.

Tuvalu consists of a large number of relatively small islands with the largest island covering only 520 hectares and the smallest 42 hectares. The nation is regarded as exceptionally vulnerable to rising sea levels and increased storm activity as the maximum height above sea level is a mere 5metres.

The climate is sub-tropical, with temperatures ranging 28 to 36^{o}C, uniformly throughout the year. There is no clear marked dry or wet season. The mean rainfall ranges between 2700 to 3500 mm per year in Tuvalu, but there are significant variations from island to island.

5.2 Forests/Flora Resources

The soil of Tuvalu is generally of poor quality, and only supports limited flora and vegetation, which is dispersed unequally through the islands. Table 5.2 summarises the main vegetation cover in Tuvalu. As can be observed, coconut woodland is the main form of forest cover, occupying about 54% of the land area, followed by mangroves, which cover about 17%. Altogether, there are approximately 200 different plant species, both indigenous and introduced from outside the country.

Table 5.2. Vegetation by class in Tuvalu and percentage of land covered, c1998.

Type of vegetation	Area (ha)	Percentage
Coconut woodland	1619	53.9
Broadleaf woodland	122	4.1
Coconut & broadleaf woodland	51	1.7
Scrub	419	13.9
Pandanus	10	0.3
Mangroves	515	17.1
Pulaka pits & pulaka basins	65	2.2
Village, buildings	172	5.7
Others (i.e. low ground cover)	33	1.1
Total	**3006**	**100**

Sources: McLean & Hosking (1991) and Seluka *et al* (1998).

5.3 Agriculture

In total, approximately 18 km^2 (1800 hectares) are classified as potential agricultural land, however, this potential area is highly fragmented between the islands. In addition, agricultural land is unequally divided among the 9 islands, the largest of which (Vaitupu) covers 520 hectares and the smallest 42 hectares; also, there are 89 islets with less than 5 hectares. The small size of these islands poses serious difficulties to the development of a modern agricultural system based on conventional cropping. Innovative solutions are clearly needed if agriculture is to play a role in the future development and security of the nation. Maintaining soil organic matter levels and containing salinisation are the main problems.

The agricultural services headquarters is based in the island group of Vaitupu, which has the largest continuous area of agricultural land. Despite being the capital, Funafuti is only serviced by a branch of the agricultural service, reflecting its much smaller area of agricultural land. As a result of the small land areas and the even smaller areas of soil of sufficient quality to sustain agricultural activities there is a lack of real commercial agriculture on the Tuvalu Islands. Vegetable production does occur in household plots and surpluses are often sold in local markets. All common vegetables are grown e.g. tomatoes, cucumbers, cabbage, etc. However, imports dominate food supplies in urban areas.

One of the most important influences on land use and agriculture development is the system of land ownership. The ‘Native Lands Act’, with all land being owned under customary laws, governs land use. The Government leases back land under ‘Native Orders’ for development purposes. The traditional land-tenure systems, which are based on the principle of subdivision and inheritance, have resulted in:

- Fragmentation of land pots;
- Disputes over land boundaries; and
- Multiple ownership.

These problems have arisen as a result of a strictly limited land resource and continued population growth. The types of land ownership can be categorised as follows:

[a] Communal land (or common land) relates back to the times when the land was under the management of chiefs;

[b] Village land, usually administered by the Island Council;

[c] Crown land, usually comprises foreshore and sea-bed land;

[d] Acquired land; land acquired by the government for specific purposes;

[e] Leased land; and

[f] Private land, held by separate individuals or land groups (Mclean & Hosking, 1991).

The Agriculture Department runs an annual ‘day to plant trees’. On this day people are encouraged to carry out a general clean up and to plant 'Fetau' (Alexandrian laurel, *Callophyllum Insphyllum*), to help stabilise the shore line. There is also a coconut replacement scheme to replace dead and aging coconut trees but this is no longer active due to a lack of funds.

Under the National Waste Management Scheme, the recycling of organic matter is encouraged and a central composting plant is active on Funafuti; this could be another potential source of energy. Villagers can buy compost at AUD$2.00 per kg and are encouraged to use compost when growing crops and trees. Careful management of soil organic matter is essential to sustained production as the soils are so poor and easily damaged.

5.4 Energy

The main sources of energy use are diesel, gasoline, electricity and gas (bottled), and fuel wood use. There is also an active household and community PV programme.

Energy data collected by this project for Tuvalu includes:

i. Petroleum Products. Kerosene imports by Month from Jan 1998 to June 2002 (including costs) – Tuvalu Statistics Office (Funafuti, 2002). The kerosene is used for electricity generation and as a transport fuel. Note: there are problems with the Kerosene data though which seriously distort the total energy inputs.

ii. Electricity plays a major role in Tuvalu. For example, in Funafuti (Fogafale Electricity Generation Station) electricity is supplied to a local grid and used in most households for lighting and increasingly for air conditioning. Total sales in all islands (2002) amounted to AUD$1 217 981. Current (2002) electricity tariffs on Funafuti are AUD$0.34/kWh and on the outer Islands AUD$0.30. Actual electricity production costs are around AUD$1/kWh, which is expensive primarily as a result of the high diesel costs and low generation efficiency. This year and next year the Energy department will pay the Electrical utility (TEC, government owned) AUD$1.2 (check) million to cover the shortfall between costs and revenue.

iii. Bottled gas is also used for cooking and some lighting. Some fridges may also be run on gas. A gas storage and bottle refilling facility is located on Funafuti.

Practical exploitation of these resources needs careful evaluation of the scope and reliability of the resource and technology base for its exploitation. Data on solar radiation and wind has been collected by the project and is available on request. Some of this data will also be posted on the project web site: www.iccept.ic.ac.uk/research/projects/SOPAC/index.html .

5.5 The Biomass Resource

Although land area and plant production are extremely constrained in Tuvalu there are a range of biomass energy technologies which could be used to address a number of pressing local problems in Tuvalu and at the same time result in little or no net greenhouse gas emissions.

Table 5.3. Promising biomass sources and technologies for Tuvalu Islands.

Resource	Technology/Process & Product	Remarks
Agricultural Residues (general)	Combustion	Agricultural activities are very limited, but some examples of higher efficiency coconut charcoal production and use exist.
Forestry Residues (general)	Combustion	Only residues from coconut plantations could play a significant role.
Coconut	Bio-diesel (electricity & transport) + charcoal from coconut shells	Good possibilities for small applications. Copra production is a major activity; waste is generated which could be more efficiently utilised and these activities are currently highly subsidised.
Municipal Solid Waste (MSW) & other waste	Biogas (pig + humans, sewage)	A stalled central piggery project with combined AD pig sewage treatment on Funafuti deserves further investigation.
Others		Some composting and recycling activities may allow integrated bio-energy project to be developed.

From the country visits carried out by project personnel (Drs Woods (September 2002) and Hemstock (June 2003)) it is clear that there is considerable potential in Tuvalu to promote bio-energy technologies as summarised in Table 5.3, above. In addition to making more efficient and profitable use of existing and under-exploited biomass resources and number of ancillary benefits are expected to occur from the careful implementation of these technologies. The use of coconut oil derived from Copra will displace expensive imports of kerosene and provide a profitable return for copra production and collection, which at the moment is heavily subsidised. If the economics are demonstrated this technology would provide a vital stimulus to the local production of coconuts and hence support the valuable ecological services provided by coconut woodlands. More details of the potential environmental and economic benefits are provided in the Tuvalu coconut case study located on the project web site. The production and use of charcoal from coconut shells for cooking would displace expensive fossil fuels and provide an efficient use of the waste shell resource.

The development of locally adapted to village scale anaerobic digesters for the treatment of human and animal waste would provide significant volumes of biogas for cooking and lighting and perhaps more importantly it would treat these wastes rendering them harmless to the environment and the human and animal population. Furthermore, the production of biogas in this way avoids the production and release to the atmosphere of the powerful greenhouse gas, methane, produces an excellent soil fertiliser that promotes soil organic matter levels and avoids contamination of freshwater lenses.

Currently, Tuvalu does not have specific environmental legislation, or any National Environmental Management Strategy e.g. there is not any regulations on housing standards or sewage disposal. There is not a waste management strategy, although it is a key issue. However, new waste management legislation is currently being submitted to parliament. There is a strong emphasis on recycling of the organic fractions of household and industrial waste, currently sent to a central composting facility near the airport on Funafuti.

There is piggery on the northern edge of the airfield, intended to digest the pig manure, but it is unclear if it is being implemented. The piggery was built by Golder Associates, (A. Boase, Water Resources Market Leader) where Tuvaluans can rent out places for their pigs, the manure is collected and goes through a couple of treatment ponds. In theory, biogas should be produced but no evidence could be found that this was happening.

5.6 Main Energy-related Concerns

- Lack of a functioning waste management policy;
- Concern with climate change and the potential implications for Tuvalu of raising sea levels;
- Depletion of natural resources, already becoming over-exploited; for example, the Funafuti Town Council has a new policy to prohibit the cutting of trees for use as fuel wood;
- Over fishing, which is a major problem especially on the reefs;
- Population growth and thus effects on natural resources;
- Land ownership (e.g. large number of very small plots);
- Perhaps, too much dependency on coconut (e.g. about two-third of land comprises coconut woodland of various densities); and
- Difficulties posed by the large distances between the islands.

It is clear that should Tuvalu decide to proceed with exploiting their biomass resources, they would not be resource constrained, at least during the initial phases of development and the country could address rural development and health issues at the same time. Biomass energy also affords Tuvalu with the opportunity to do some proactive to demonstrate that Tuvalu is taking an active role to abate greenhouse gas production, which will make its case to the industrialised world even stronger that they should act themselves.

5.7 References

1. FAO (1987 & 1991) 'Land Resource Survey for Tuvalu'; UNDP. University of Auckland publication AG:TUV/80/011, Auckland, New Zealand.

2. Malona, S. Tuvalu Energy Import and Population Statistics. Tuvalu Statistics Office, Funafuti, Tuvlau.

3. McLean R F., Hosking P L., (1991). Tuvalu Land Resources Survey – Country Report (FAO) AG; TUV/80/011

4. Prasad, R., Kumar,M. and Narayan,C., (1999). Coconut Oil as Substitute for Fossil Fuels: A sustainable resource for the South Pacific; South Pacific Journal of Natural Science Vol. 17, (Special Edition).

5. Seluka S., Panapa T., Maluofenua S., Samisoni, Tebano T., (1998). A preliminary listing of Tuvalu Plants, Fishes, Birds and Insects' by The Atoll Research Programme, University of the South Pacific, Tarawa, Kiribati.

6. Woods J., (2002). Notes on south Pacific Island country visits. Country visits carried out during September 2002. Personal communication; Imperial College London.

6. VANUATU

6.1 Basic Data

Located at the eastern Melanesian archipelago, Vanuatu is made up of more than 80 islands (of which 70 are uninhabited), some large e.g. Espiritu Santo (3900 km^2), Malakula (2000 km^2), Erromango (1000 km^2), Efate (900 km^2) and Ambrym (665 km^2). Anatom (150 km^2) is the southern most islands in the group; and many small atolls. Around 80 percent of Vanuatu's population still lives in rural villages, where subsistence agriculture, based around shifting cultivation, is the principal means of livelihood for the majority of the population. Land distribution is shown in Table 6.1.

The islands of Vanuatu generally consist of a narrow coastal plain rising through broken foothills to a steep mountainous interior.

6.2 Forest Resources

Much of the interior is forested and large tracts of these interior forests have been preserved from clearance, because the terrain is too steep and rugged to make agriculture or logging economically viable. These forests generally perform soil and watershed conservation roles, though grazing or burning has degraded some areas. In the lowlands, however, forests have been extensively logged, or cleared for agriculture. In the early 1990s, Vanuatu imposed short-lived log export bans, as well as seeking to implement an annual allowable cut of 25 000 cubic metres.

Forest land (all types) covers about 75% of the total land area, and include dense tropical rainforests and exotic plantation forests. Much of the natural forest is on steep inaccessible sites and the limited accessible sites contain few species of commercial use. In the islands' interior much of the natural forest has primarily a protective role. Some of these forests have been degraded by conversion to grazing and in places by burning. In some areas, erosion and soil degradation are significant problems (FAO STAT; FAO 1997).

Table 6.1. Land area and land distribution in Vanuatu, 2000.

Total land area	1 219 000 (ha)
Total forest cover	447 000 (ha)
Percentage of land area covered by forest	36.7 % (1993)
Other wooded land	39.3 % (1993)
Other land types	24.4 % (1993)

Source: FAO STAT

The woody vegetation of Vanuatu includes lowland rain forest, mountain cloud forest, seasonal rain-shadow forest, mangrove forest, littoral forest and secondary forest.

Broadleaved forests are dominated by *Casuarina equisetifolia* and *Pandanus* spp.; and lowland rain forests, which form the natural plant cover up to 600 m elevation on the windward South-eastern side of the islands above the coastal zone. There are a various subtypes e.g. lianas, high-stature forest on old volcanic ash, complex forest scrub densely covered with lianas, alluvial forest found along lowland river courses; mixed-species forests; montane microphyllous/cloud forests on the high islands above 500 m elevation. On the high island of Espiritu Santo (1879 metres elevation), microphyllous forest extends up to 1000 metres, characterized by matrices of trees of the genera *Ascarina*, *Geissois*, *Metrosideros*, etc.

The broadleaved category also include seasonal forest and scrub of which there are_three main variants: i) semi-deciduous transition forest-transitional between dry and rain forest, common in north-west and central Malakula and throughout north-east-central Espiritu Santo, ii) *Acacia spirorbis* forest, locally called gaiac forest, widely distributed, somewhat open forest; iii) *Leucaena* thickets, found in the driest habitats on the west and north-west sides of the islands. Mangrove forests that are found on some of the islands in localized areas in sheltered coasts; secondary forests which have developed in response to disturbances such as shifting cultivation or hurricane damage, and dominated by secondary forest species such as *Antiaris toxicaria*, *Castanospermum australe* and *Kleinhovia hospita*. Primary local uses of these forests are as tree gardens and bush fallow.

Mixed lowland rain forest is restricted to the southern islands of Erromango and Anatom. This forest ranges from 100 to 500 m elevation on older, more acidic volcanic soils with 2 000 mm or more annual rainfall. A wide range of genera are present in the sub-canopy, and there is a rich ground layer of ferns, as well as many epiphytic ferns and orchids (see Corner et al. (1975) and Mueller-Dombois and Fosberg (1998).

6.2.1 Products & Trade

Over the past decade, Vanuatu has operated a log export ban. There are no large-scale forest industries in this country; there are several small sawmills and a number of chainsaw mills. Wood is a moderately important source of fuel in Vanuatu, although this has increased in recent years (Table 6.2). Although data is scant, most of this increased activity appears to be partly linked increased utilization of plantations.

Table 6.2. Forest products production Vanuatu, 1993-2001 (10^3 m^3).

Product	1993	1994	1995	1996	1997	1998	1999	2000	2001
Roundwood	63	63	63	63	63	63	132	131	131
Industrial Roundwood	39	39	39	39	39	39	41	40	40
Wood Fuel	24	24	24	24	24	24	91	91	91
Sawnwood	7	7	7	7	7	7	18	18	18

Source: FAO STAT

6.2.2 Forest Management

The main legislation governing forest management in Vanuatu is the Forestry Act of 1982, which provides a framework for forest management and for development of the forestry sector, including the provision of a legal basis for preparation and implementation of the Code of Logging Practice, provisions for restrictions on the export of unprocessed logs, and provisions for the creation of forest reserves.

The Vanuatu Government endorsed a new National Forest Policy (NFP) in 1998. The NFP recognises the broad scope of forestry activities and stakeholder interests and contains strategies to guide the work of the Department of Forests, in relation to national policy issues and on an operational basis. Responsibility for implementing the government's forest policies and programmes rests with the Department of Forestry in the Ministry of Agriculture, Forestry and Fisheries (DFMAFF).

Vanuatu has operated two plantation development programmes over the past 25 years and has established small areas of *Cordia alliodora* and *Pinus caribaea* plantations. The annual plantation area is about 180 hectares; commercial plantation (unspecified) occupies about 3300 hectares, but the most important plantation is coconut with 96 000 hectare (FAO STAT; FAO 1997).

Vanuatu has operated both Local Supply Plantation (LSP) and Industrial Forestry Plantations (IFP) programmes. The LSP programme commenced in 1974 and established around 1000 hectares of mainly *Cordia alliodora*. Plantations were line planted in areas of logged over natural forests at stockings of around 300 stems per hectare. *Cordia alliodora* has proven susceptible to disease, and much enthusiasm for plantation establishment has abated. The IFP programme has also established around 1200 hectares of *Pinus caribaea var. Hondurensis* plantations. These are intended to produce high quality saw and veneer logs for export. These were generally placed on grasslands at a stocking of around 1100 stems per hectare.

Vanuatu's steep terrain means only about 20 percent of the country's forest resource is economically accessible for harvesting. The commercial quality of the country's natural forests is low, relative to other Melanesian countries, with the forests characterised by species with low density, poor form, low durability and low strength. Logging has been carried out on both a large scale, to supply markets for export logs and wood processing facilities on Vanuatu, but also on smaller scales in tandem with portable sawmills. The average commercial saw-log yield is around 15 cubic metres per hectare. The sustainable yield from natural forest is presently estimated to be 68 000 m^3 per annum

6.2.3 Policy

The key trends in forest management in Vanuatu are encapsulated in the NFP, and the various initiatives that are supporting its objectives. During the past two decades, there has been a shift from largely unregulated logging to the use of logging bans as a means of controlling deforestation and forest degradation. More recently, Vanuatu has made decisive moves towards implementing a more holistic approach to forest management based on principles of sustainability. A range of initiatives (e.g. NFP, Code of Logging Practice, and Sustainable Forest Utilisation Project) is demonstrating the country's commitment to sustainable forest management.

The objectives for forest management in Vanuatu are articulated in the country's NFP of which the principal features include:

- A strong national commitment to sustainable forest management;

- Forest-based rural development leading to greater significance on forestry in the economy;
- Comprehensive land-use and forest planning;
- Increased national forest resources through improved natural forest management and plantation establishment; and
- Improve awareness of the values of forests and trees and greater participation by ni-Vanuatu in the development, management and conservation of these resources.

If such objectives are achieved, this could increase significantly the amount of biomass available for energy purposes.

6.3 Agriculture

The total landmass of Vanuatu is estimated at 1 212 440 hectare[2] of which 41% is cultivable as shown in Table 6.3. Agriculture is the main resource, with about 80 percent of Vanuatu's population still living in rural villages, where subsistence agriculture, based around shifting cultivation, is the principal means of livelihood for the majority of the population. The most important crops in Vanuatu are coconut (the backbone of the rural economy), cocoa, cattle, kava, and to a less extent, garden plots, coffee, etc.

Table 6.3. Land resource availability and utilization in Vanuatu.

Island	Total Land Area (hectares)	Cultivated Land		Land Utilized	
		Hectares	Percentage	Hectares	Percentage
Banks/Torres	89 430	31 300	35	6 464	21
Santo/Malo	425 810	183 100	43	50 445	28
Ambae/Maewo	70 770	27 600	39	13 021	47
Malekula	120 300	83 600	41	29 984	31
Pentecost	50 000	18 500	37	9 495	51
Ambym	67 500	13 500	20	7 826	58
Paama	6 000	2 400	40	1 627	68
Epi	44 350	17 300	39	5 622	32
Shephards	8 850	5 900	69	4 162	71
Efate	92 310	60 000	65	29 219	49
Tafea	163 330	53 900	33	10 064	19
Vanuatu	1 212 440	497 100	41	164 583	33

Source: Anon (1994), Table 1.1

[2] Note that Table 1 shows a total land area of 1,219,000 ha.

6.3.1 Coconut

The coconut sector has been the mainstay of economy since the turn of the 19th Century e.g. the export of copra has been the main foreign exchange earner, in addition of providing the basic needs to a large part of the population. Considerable efforts have gone to improve the coconut industry over the last two decades since this industry has been, and will continue, to be the backbone of the rural economy. For example, about 70% of the rural households own coconuts. Table 6.4 provides some insights on the coconut sector in Vanuatu.

The coconut industry in Vanuatu faces serious challenges, including:

- High transportation costs among the islands, due to long distances to markets
- Small markets due to the small population, scattered along a large geographic area
- Coconut is overwhelmingly produced by a very large number of smallholders and it remains the backbone of the rural economy, not only to satisfy subsistence needs but also to provide the means for cash income. However, hardly any new investment goes into coconut production.

There are some particular aspects that need further attention including:

- The industry needs to be modernised and innovate but the nature of coconut production makes it very difficult;
- Financial inefficiencies need to be removed, or streamlined, so prices reflect more market costs; and
- The industry need to diversify e.g. soup production for the local markets could be encouraged more, better use of residues for fuel wood, etc.

Table 6.4. Coconut and the rural household in Vanuatu, years 1983 and 1993.

	1983	**1993**
Average area smallholding coconut per rural households	3.4 (ha)	–
Percentage area of trees too young to produce coconuts	11%	24%
Percentage with trees bearing coconuts	78%	76%
Percentage area with trees too old to produce coconuts	11%	n/a
Average annual planting rate (ha)	800 (ha)	2763(ha)
Average annual planting rate per household	0.04 (ha)	0.58 (ha)
Average consumption per household/day (human consumption)	6 nuts	6 nuts
Average consumption per household/day (animal use)	9 nuts	3 nuts

Source: Anon (1994)

There is not question that coconut production has been, and will remain the backbone of the rural economy; coconut palms are very adaptable to Vanuatu climatic conditions. The coconut sector offers considerable potential if modern agricultural techniques can be applied.

6.3.2 Cocoa

Cocoa production has been mainly confined to central Vanuatu since it was introduced early last century e.g. 80% of cocoa production is located in Santo/Malo, Ambae/Maewo and Malekula. Cocoa has expanded rapidly as can be observed in Table 6.5, and is currently one of the major crops of Vanuatu. For example, in 1993 over 7400 households were producing cocoa in more than 12 400 plots, with an average of 269 trees per plot. However, despite the rapid expansion of cocoa during 1980s and 1990s, there are serious problems, including:

- Competition from other producing countries such as Malaysia and Ivory Coast that produce cheaper and better quality cocoa and are closer to the main world markets
- Poor quality and high costs are important barriers. It is of paramount importance to increase quality and reduce production costs.
- Particular attention is needed to extension activities in cocoa management and provision of planting material.
- Better utilization of residues generated by the industry e.g. use as fuel wood.

Table 6.5. Cocoa plantations in Vanuatu, 1983 and 1993.

Item	1983	1993
Number of smallholders growing cocoa	2 537	7 414
Number of smallholder plots of cocoa	3 905	12 414
Average area smallholding rural household	0.7 ha	0.4 ha
Number of trees recorded in plots	1 297 988	3 343 700
Percentage holdings operated on single household basis	87%	86%
Average number of plots per holding	1.5	1.7
Average number of trees per plot	297	269

Source: Anon (1994)

6.3.3 Cattle Ranching

Cattle ranching have been a major success in Vanuatu, achieving self-sufficiency while at the same time increasing export. In 1993 there were about 82 000 cattle owned by smallholders, with an average of 57% of household owing 9 cattle (Table 6.6). Despite the considerable advances of recent years, the industry is facing serious challenges and need to improve productivity considerably. This industry might offer a good opportunity to produce biogas is some kind of cooperation among cattle producers.

Table 6.6. The cattle sector in Vanuatu, 1983 and 1993.

	1983	**1993**
Number of smallholders owing cattle	5700 (27%)	9420 (43%)
Total Number of cattle in smallholder sector	31 918	82 140
Average Number of cattle per house holding	14 (44% of total)	9 (57% of total)

Source: Anon (1994)

6.3.4 Others

There are other crops e.g. coffee, and kava (*Piper methysticum* forest), which could also contribute or influence the amount of biomass energy. For example, kava (a local beverage crop) has increased dramatically largely stimulated by increase in urbanization. It has become a major cash crop for many smallholders e.g. in 1993 53% (with 3 695 000 plants) of smallholders were reported to own kava plantations, compared to 25% (3 310 000 plants) in 1983. The remarkable growth of this industry has been attributed to a number of factors:

- Existence of a large domestic market;
- Uniqueness of the community;
- Improved returns to the producers as compared to copra, cocoa, etc; and
- Active participation of the private market, chief responsible for this industry (Anon, 1994).

This market has considerable potential for further expansion. The implications for energy are that such expansion will, probably, be at the expense of other crops such as coconut.

6.4 Energy

Vanuatu is a net importer of energy e.g. 1994 it imported about 400 bbl/day; electricity generation is from an 11 MW thermal plant. Vanuatu economy is highly vulnerable to oil supplies. The government has a policy of achieving 100% renewable economy (***www.vanuatu.gov.vu/energy.html***). RE in Vanuatu has been reasonably successful, particularly in rural electrification (see **www.spc.org.nc/preface/press/**). Undoubtedly, biomass energy has an important role to play in achieving these objectives.

6.5 The Biomass Resource

Vanuatu, together with Fiji, offers one of the greatest potentials for the provision of biomass energy services in the countries covered by this study. Of particular interest are agro-forestry residues and coconut. A major challenge will be how to achieve the transition from traditional to modern applications so that these resources can used more efficiently and to provide modern services.

Table 6.7. Promising biomass sources and technologies for Vanuatu Islands.

Resource	Technology/Process & Product	Remarks
Agricultural Residues (general)	Combustion	Agricultural activities are limited. Most residues are only partly utilised. Some crops e.g. cocoa, offers some good possibilities.
Forestry Residues (general)	Combustion	About 75% of Vanuatu is covered by forests but are largely "economically inaccessible". Fuel wood consumption has increased in recent years (90,000m3). With good forest management this potential could increase substantially.
Coconut	Bio-diesel (electric + transport)	Coconut is major activity; a lot of waste is generated.
Cattle ranching	Biogas	There are good possibilities; but given its nature (i.e. grazing animals) it would not be easy.
MSW & other waste	Biogas	Any projects?

6.6 Main Energy-related Concerns

A major concern in Vanuatu relate to deforestation and forest degradation. Large areas of lowland forest have been cleared, and this has lead to severe erosion and has raised concerns over loss of biodiversity. Other issues include:

- Coastal erosion is a significant problem in some areas;
- Overgrazing and burning of forests in the uplands is a significant cause of soil and watershed degradation. The country's lack environmental management experience, together with limited funding, has been identified as major constraints to achieving sustainable resource use;

- Concerns over the capacity of the Department of Forests to adequately monitor logging operations and fulfil roles envisaged in the Reduced Impact Logging guidelines once current donor-funded projects end; and
- The focus on only a few timber species promotes high-grading of forests, and consequent degradation, is also another serious concern.

6.7 References

1. Anon (1994). Vanuatu – National Agriculture Census 1994. Main Report, Statistics Office, Port Vila.
2. Asiapoint Network; 1997-1999; Vanuatu Profile; Vertiko International LLC.
3. Brown, C.; 1997; Regional Study - The South Pacific; Asia Pacific Forestry Sector Outlook Study, Working paper No. 1; FAO; Rome.
4. Corner, E. J. H., F. R. S. Lee and K. E. Lee (co-ord.) (1975). A discussion on the results of the 1971 Royal Society - Percy Sladen Expedition to the New Hebrides. Philos. Trans. Royal Soc. (London), B, 272: 267-486.
5. FAO 1995; National Forestry Action Programmes NFAP Update 32; FAO, Rome.
6. FAO 1998; Asia and the Pacific National Forest Programmes Update 33; FAO Regional Office for Asia and the Pacific; Bangkok.
7. FAO. 1997. Regional Study The South Pacific. Asia Pacific Forestry Sector Outlook Study. By Brown, C. Working Paper Series, FAO. APFSOS/WP/01, Bangkok.
8. Gerrand, A.; 2000; Country Profile – Vanuatu; Tropical Forest Update; Vol. 10, No. 4; 2000/4; International Tropical Timber Organization; Yokohama.
9. Leo Moli (Principle Energy Officer, Energy Unit, Private Mail Bag 067, Rue Winston Churchill, Port Vila, Vanuatu. T: +678 23584 F: +678 23586 E: leomoli@vanuatu.com.vu (Personal communication)
10. Mueller-Dombois, D. and F. R. Fosberg (1998). Vegetation of the tropical Pacific islands. Springer-Verlag, New York. 733 pp.
11. Pacific Energy News (PEN) Various issues
12. UNDP/FAO; 1998; Proceedings of Heads of Forestry Meeting 23-28 September 1996; RAS/92/361; South Pacific Forestry Development Programme.
13. UNEP; 1998; Country Profile – Vanuatu; Website
14. University of the South Pacific School of Law; 2000: Laws of the Republic of Vanuatu: University of the South Pacific: Vanuatu.

15. The following web sites:

www.fao.org/forestry/include/frames/english.asp?section=/forestry/FON/FONS/outlook/Asia/APFSOS/01/APFSOS.htm

www.insight.asiapoint.net/pacific/profile_vanuatu.htm

www.spc.org.nc/preface/press/

www.vanuatu.gov.vu/energy.html

www.vanuatu.usp.ac.fj/paclawmat/Vanuatu_legislation/Indices_English/Consolidation_General.html#F

APPENDIX

SUGAR CANE BAGASSE ENERGY COGENERATION CASE STUDY IN MAURITIUS AND POTENTIAL FOR REPLICATION IN FIJI

1. The sugar cane crop has been occupying a prominent position in the Mauritian economy over the years since its introduction by the Dutch in the seventeenth century. After trials on a number of crops, it has been found to be the best crop suited for the agroclimatic conditions in the island, which includes frequent visit of cyclones. Sugar production has increased over time to reach a plateau of around 600 to 650,000 tonnes, export markets and arable land area putting a limit to this production. The sugar industry is a major net foreign exchange earning sector but its relative contribution in the economy has been declining with the development of the tourism and manufacturing sectors. However, the agro-industrial nature of the sugar cane gave Mauritius an industrial base that enabled the island to become a semi-industrial society. It is recognised by all stakeholders (Government and the industry at large) that a viable sugar industry is essential to continued economic growth and social stability.

2. Mauritius, as a member of the ACP countries, enjoys a ready market for its sugar under the Sugar Protocol of the Lomé Convention. Around 506,000 tonnes (or 90%) of sugar produced are exported under this trade agreement. 7% of the production is sold to the United States and 4% to other markets. 85% of the price is obtained for around 40,000 tonnes of sugar sold under a special preferential sugar agreement as from 1995 with the entry of Portugal into the European Union.

3. The island of Mauritius has an area of 1,860 km^2 and a population of 1.3 million with a per capita income of US$3,710 in 1998. Two distinct groups of growers own the total area under cane. The miller-planters, having a majority share in the milling companies hold 55% of the cane area, the individual size varying between 700 to 5,500 hectares and this group produces 60% of total sugar. The other group comprises of around 35,000 independent growers holding around 200,000 plots whose area varies between 0.1 to over 400 hectares. 90% of this group own less than 2 hectares and are part-time farmers. The independent growers and the miller-planters are entitled to 78% of their sugar and the totality of the molasses and filter mud. The millers obtain 22% of the sugar as payment for milling.

The Sugar Sector Action Plan

4. Until the year 1975, sugar production grew steadily to meet rising demands in the guaranteed market, which was also associated with rapid price increases. In the subsequent years prices start to fall and the industry profitability and even its viability were threatened. The major cause of this threat was due to Government policies, in particular, the increase in sugar export tax in 1979 coupled with climatic conditions (cyclones, and drought). These developments became a matter of concern and, as a consequence, Government in consultation with the private sector worked out a Sugar Sector Action Plan to restructure the industry targeted at maintaining its viability and at modernising production both at field and factory levels. Industry operations were also rationalised at a national scale. This plan provided for export duty relief and rationalisation cane milling activities (two small mills were closed in1985). These measures impacted positively on profitability of the industry and investments were made to modernise production both at field and factory levels.

5. Additional policy initiatives were designed by Government in 1988 to bring further improvements in the viability and efficiency of the sugar sector. However, while Mauritius had an assured export quota under the Sugar Protocol, price paid by the EC countries were linked to developments in the EC Common Agricultural Policy. Price decreased to the tune of 2% yearly since 1988 and it was difficult to predict the rate of price declines over the ensuing period. Under these circumstances, the industry was already adjusting to those developments. For example, more emphasis was laid on:

(i) production of speciality sugars which fetches a price premium;

(ii) increase in yields through introduction of improved irrigation techniques, adoption of mechanisation and derocking of lands;

(iii) centralisation of cane milling activities involving concentration of sugar manufacturing in mills with higher capacity;

(iv) research to increase productivity in field operations coupled with introduction of high yielding varieties; and

(v) last, but not least, improved use of by-products such as bagasse and molasses which will help to diversify revenue basket sources and reduce industry's vulnerability to sugar price shocks.

The Sugar Industry Efficiency Act (1988)

6. Further incentives were provided to the industry in 1988 in the Sugar Industry Efficiency Act whose objective was to provide for an efficient and viable sugar industry while seeking to promote agricultural diversification and diversification within sugar. The Act essentially brought about the reduction of the nominal export duty rate and an increase in the exemption limit on the duty. A system of performance linked export duty rebate was introduced wherein incentives were provided for improved sugar recovery, enhanced use of bagasse for electricity production and use of marginal cane lands (interline and inter-cycle rotational land) for the production of crops other than sugar. Amendments to the Income Tax Act provided incentives to produce speciality sugars save energy in cane processing and use bagasse to produce electricity.

7. Government in partnership with the private sector initiated a bagasse energy development programme to address the Sugar Section Action Plan's agenda on use of by-products in the sugar industry. A high-powered committee on bagasse energy development, chaired by the Minister of Agriculture was set up and it included the Ministers for Energy, Economic Planning and Development, Environment and Land Use, and Cooperatives and the Financial Secretary. This Committee also guided the work of a Technical Committee chaired by the Financial Secretary, with representation from relevant Government Ministries and agencies, the sugar industry and local research organisations. The setting up of this committee in 1991 also coincided with events in the Gulf area threatening supply of fuel derived from fossil resources.

Energy Status

8. Mauritius has limited renewable energy resources and no known oil, gas or coal reserves. Its main locally available energy resources are hydropower and sugar cane biomass (bagasse and cane tops and leaves). Hydropower is almost fully exploited with its nine hydro stations including one with 10 MW installed capacity. The other resource, sugar cane bagasse that represents 30% on cane was being generally used inefficiently to meet internal power requirement for cane processing. Hydro power and power exported to the grid from sugar factories amounted to 22% and 13% of power supply to the public grid in the year 1990. The remaining 65% was met from imported fossil fuels (diesel, coal and gas). It was felt that a rapid increase in fossil fuel import could be prevented by a more efficient exploitation of bagasse energy for electricity generation.

Evolution in Energy Demand

9. There had been a sharp increase in energy consumption associated with high levels of economic growth involving the rapid expansion of the export-processing zone and the tourism sector. Power demand in the residential sector also increased as indicated by marked rise in sales of household appliances. In the period 1985-1990 annual increases in electricity consumption and maximum demand averaged over 11 and 9.5% respectively. The average economic growth was 6% but the EPZ and tourism sectors were expanding at a much higher rate so much so that the Ministry of Energy had to revise the forecast in energy consumption to 10% for the period 1988 – 1992.

10. In order to meet the increase in demand of electricity, three investment options were available. Firstly, the utility could add 2 units of 24 MW each to its existing 4 units. Secondly, it could invest in a 40-50 MW coal plant. The third option would comprise of bulk purchasing of power from 2 x 22 MW bagasse cum coal plants, to be privately operated by sugar companies at 2 regional sugar factories. This third option would displace public sector investment. This third option was the economically preferred option.

Linking Bagasse Energy with Sugar Production

11. This project of bagasse energy development was a logical extension of Sugar Sector Action Plan wherein Government and the private sector participated in the restructuration process of the sugar industry given that enhanced use of by-products, including bagasse for electricity production was a key objective in the plan. Furthermore, the active participation of the private sector with Government in formulating all the policy measures coupled with appropriate enactments enumerated brought about an improved business environment for the sugar sector. In 1990, the industry presented a programme of investment of the order of US$130 million for sugar factory rehabilitation and modernisation, irrigation and diversification of this amount, around US$27 million

was meant for bagasse saving and handling operations, expansion of the industry's capacity to generate electricity and pollution abatement.

Objectives of Bagasse Energy Development

12. A bagasse energy development programme was formulated by Government in partnership with the private sector over a 6-month period in 1991 on the basis of the recommendations of the High Powered Committee on Bagasse Energy. The programme had two main objectives:

(i) to optimise the use of bagasse for electricity generation and export to the grid. Over the 5-year period to expand electricity generation using bagasse from 70 GWh and 120 GWh, that is a 22 MW bagasse-and coal;

(ii) to investigate into uses of other fractions of the sugar cane biomass (cane tops, leaves and dry trash) for electricity generation which would further add to amount of electricity export to the grid with the concurrent reduced dependance of fossil fuel.

This programme aimed at maintaining the long-term viability of the sector, increasing investment in rehabilitation and modernisation and rationalising the industry operations on a national scale. It was meant to ensure the continued viability of the sugar sector and sustainability of production to meet industry's commitment under the preferential sugar market.

13. The national objective was to develop other sectors of the economy – EPZ and tourism which are energy intensive activities. As a consequence energy demand was to increase. Inefficient use of bagasse implied import of fossil fuels. Alternatively efficient use of bagasse for energy export to the grid will bring additional revenue to the industry. At the same time, the industry will save on the investment on boilers and turbo alternators, which represents almost 50% of the investment of the sugar factory.

14. The project required investment to the tune of US$80 million (1991 prices) in:

(i) erection and commissioning bagasse cum coal fired power plants at 2 sugar factories;

(ii) modernisation of sugar factories to improve the efficiency of bagasse use in sugar cane processing;

(iii) bagasse transport from cluster of sugar factories to a regional sugar factory located power plant; and

(iv) investments in transmission lines from sugar factories to the national grid.

15. The investments were geared towards promoting regional bagasse/coal fixed power plants. The coal as a complementary fuel would ensure power export to the grid year round in that bagasse supply is limited to the crop period normally 5-6 months duration. The regional location of power plants was the preferred option in that bagasse costs are minimised, the sugar factory benefits from the advantages of co-generation and the activities of a number of large sugar estates in the main cane growing areas are diversified with positive impacts on the social stability of the sugar sector.

Funding of Energy Projects

16. The project comprised essentially of three components totalling around US$55 million as capital investment of which US$24 million is for one 22 MW power plant, US$18 million for investments in energy efficiency in cane processing, Rs1.6 million for studies on use of cane field residues and bagasse transport and finally US$1.3 million for institutional support for bagasse energy development to include the Coordination Unit.

17. Out of the US$55 million, US$40 million would be foreign exchange. US$15 million was earmarked for improvements in mill efficiency as a loan from the World Bank (IBRD). It was planned that Government would make available to the Bank of Mauritius the US$15 million which would, in turn, sell to sugar companies requiring foreign currency to import sugar equipment and machinery. This facility would be available over a 5-year period on the basis of application for foreign exchange on a list of eligible items related to energy conservation and use in cane processing.

18. For the investment in power plant, the US$23 million would be from foreign sources and Government would assist the company, which will arrange for the foreign financing.

19. US$3.3 million would be funded as a grant by the Global Environment Facility Fund of the World Bank.

Institutional Set up and Project Strategies

20. In the implementation of the project, a regulatory framework was set up to promote private sector investments in power production and sugar factory modernisation and to encourage an efficient market in bagasse. The key element of this framework were energy pricing and contracting, involving electricity, bagasse and coal. The institutional implementation arrangements addressed the integration of policies and programmes for bagasse energy development with the Government's overall energy production strategy. It also included project management, coordination, monitoring and evaluation. An ad-hoc technical committee was set up in lieu of the regulatory framework at the Ministry of Energy was set up to carry out the above activities and it comprised of representatives from the Mauritius Sugar Authority, the Ministries of Finance, Economic Planning and Development.

21. A Management Committee with representatives from the Government and Industry was set up to undertake detailed planning of programme implementation, to ensure the Government's policy directives related to the BEDP are followed and to effectively integrate Government's policies affecting the sugar and energy sectors. The Management Committee occasionally needed to review and revise policies and, through the Minister of Agriculture, sought the approval of the Economic Sub-Committee of the Cabinet. BEDP coordination was established at the Mauritius Sugar Authority to assist the Management Committee in the tasks of planning and monitoring the implementation of the BEDP and its project components.

22. All the parties, relevant Government Ministries and agencies, the Utility, the private sugar industry stakeholders fully participated in the project right from inception through all stages right from project conception and to implementation through constant interaction and participation. The other specific strategies used by the project management to guarantee achievement of project objects were mainly through incentives provided in enactments by Government, which were devised all along the various stages of the project.

Implementation of Bagasse Energy Projects

23. The project duration was 5 years as from 1991/92 (for the initial slice of BEDP) but there was delay in the implementation and the effective start date was in 1994. However, it was envisaged that use of bagasse would be optimised by the year 2000.

24. The project stages were as follows:

- (i) Government policy defining clearly the bagasse energy option as a means to promote a renewable energy resource available locally.
- (ii) Sugar industry to evaluate its energy requirement and optimisation of same through proper investments in measures for energy conservation and use.
- (iii) Public utility to spell out its energy demand based on reliable forecast in order to establish its base load requirement over time.
- (iv) Memorandum of understanding between utility and sugar company;
- (v) Conduct of feasibility study.
- (vi) Signing of formal Power Purchase Agreement (PPA) between utility and the private investor.
- (vii) Raising of funds for investment in power plant using PPA as the bank guarantee.
- (viii) Conduct of a detailed design of project.
- (ix) Carry out a tendering exercise for supply of items of equipment.
- (x) Evaluation of tenders.
- (xi) Award of contract.
- (xii) Erection and Commissioning.

(xiii) Operation.

Constraints to Bagasse Energy Development

25. In spite of all the above measures, it was observed that investments in bagasse saving in the satellite factories were slow. Only 40% of the total amount (US $15 million) of the Sugar Energy Development Plan Loan was disbursed and the rest (US$9 million) was cancelled. In addition investment in the bagasse cum coal plant was not forthcoming. A number of factors was identified which has influenced this state of affairs.

Price of Bagasse

26. The progress in the implementation of the power plant at Union St Aubin (USA) sugar factory was slow due, inter alia, to the fact that the plant had to rely on a huge amount of bagasse from the satellite factories. These factories were pricing their bagasse on the price of coal and at the condensation mode of operation during which the efficiency of conversion of steam into electricity is higher compared to that of a condensing-extraction mode of operation which is the usual industrial set up for energy cogeneration in the sugar industry. This price had a negative impact on the financial viability of the project. This issue was resolved through consolidation of cane milling activities whereby the totality of cane was processed in lesser and lesser number of sugar factories whose cane crushing capacity was increased and which invested in power plants.

Funding and the fiscal framework

27. The energy projects require a relatively huge investment cost that made it not attractive. Hence Government introduced several enactments which allowed investors to raise tax free debentures for the generation of electricity from bagasse and the modernization of sugar factory; to enable them in cases of segregated activities, growing companies to offset losses incurred by millers in respect to the capital expenditure in energy production from bagasse and in the revamp of sugar factories. Furthermore, the performance-linked rebate on export duty was extended to producers of firm electricity who saved and used their own bagasse and also to millers selling bagasse to continuous power stations. A proportion of capital expenditure incurred in the installation of efficient equipment used to enhance bagasse saving and energy generation therefrom was entitled to a refund of export duty payable.

28. Cane growing and cane milling are undertaken by two distinct companies and in most cases the majority shareholder of the milling company is the growing company. Hence the milling company undertaking a cogeneration project is allowed to transfer in any income year any unrelieved loss to the growing company. Moreover, accumulated unrelieved losses attributable to investment, initial and annual allowances in respect of qualified plant and machinery acquired after the effectiveness of the SIE Act 1988 could be transferred to a related planter. Production of electricity from bagasse is one of eligible plant and machinery.

29. Any amount of bagasse used for purposes other than manufacture of sugar is priced at Rs100 (or US$3.7) per tonne and this money is credited by the CEB mainly to a bagasse transfer price fund. The distribution of the proceeds from that fund was modified wherein millers or sugar factory based power companies exporting electricity to the CEB became entitled to benefit from the Fund. This Fund had previously been accruing to growers only.

30. In 1994, the export duty was abolished and concurrently the sugar companies had, as per a Memorandum of Agreement with Government, to segregate growing and milling activities and set up public milling companies. A Sugar Investment Trust (SIT) was created and 20% of the equity shares in the milling companies were sold to planters and workers. Two directors on the Board of the Milling Company would be from the SIT.

31. In 1995, provisions in the new Income Tax Act, which were in favour of bagasse energy, were retained and, in addition, tax on milling companies was brought down to 15%. The foreign exchange control was removed. All these fiscal measures created investment friendly environment and the decision to invest was left to individual operators.

Centralization of Cane Milling Activities

32. Consolidation of cane milling activities through centralization is one of the means of reducing cost of production. 19 sugar factories were in operation in 1993 and their cane crushing capacity ranged between 55 to 250 TCH.

33. In 1997, Government came up with a Blue Print on Centralization of Cane Milling Activities (Ministry of Agriculture and Natural Resources, 1997), which, besides setting guidelines and conditions to be adhered to in any request and implementation of such closures, emphasizes the need to link such closures with energy generation from bagasse. Three requests for closures have been considered subsequent to the publication of this Blue Print and were generally in conformity with the provisions of this document, where energy generation occupied, inter alia, a prominent position.

The kWh price

34. Government set up a Technical Committee was at the Ministry of Energy to address the issue of energy pricing and power purchase agreement. In the price setting mechanism, the Committees worked on the basis of the cost of diesel plant of 22 MW capacity proposed by the CEB to arrive at the avoided cost for the firm power plant. The World Bank provided support to the Committee to work out the principles and the guidelines. This Committee determined the avoided costs and recommended the kWh price for coal and bagasse.

Evaluation of Project Implementation

35. The activities related to the project were undertaken as planned but there was a delay in its date of completion. It was mainly due to the fact the investors to finance the Union St Aubin plant decided not to go ahead with their project. At the initial stage, an in-house feasibility was carried which indicated that a 22 MW plant would be economically justified and its cost would be US$23 million. Subsequently the services of a design firm was hired using the investor's own fund. The firm presented a design and its cost was twice that of the initial proposal (about US$51 million or US$2318 per kW installed). This was on the high side for a steam power plant. The consulting firm was requested to improve the viability of the plant and in 1994 it came with a proposal for a 30 MW capacity plant at a cost of US$59 million. This was equivalent to US$1967 per kW installed. In 1995 the design firm recommended re-designing major components such as the boiler and the turboalternator, to take account of future capacity of the factory, and improvements in the thermodynamic cycle of the plant. This new design brought about 30% increase in cost of the previous 30 MW plant design. Under the circumstances, the overseas bank, which was interested in funding the foreign exchange, decided not to fund the project. The promoters of the project decided not to go ahead with the project.

36. Almost immediately after, another company in the North of the island drawing itself on the experience and studies undertaken at Union St Aubin started negotiations for the erection of a 70 MW (2 units of 35 MW each) for firm power export to the grid. After successful negotiations for a power purchase agreement with the utility and funds from foreign banks, the company, Centrale Thermique de Belle Vue (CTBV) erected and commissioned the power plant in April 2000. This plant required an investment of US$90 million.

37. The other component of the project related to improvements in mill efficiency thereby to produce surplus bagasse that could be provided to the planned power plant. At the time when the loan was negotiated foreign exchange was a constraint but subsequently Government lifted exchange control thus decreasing the need for World Bank funds right from the start of implementation. At the request of Government, the World Bank cancelled US$9 million of the US$15 million.

Bagasse Energy Projects

38. Table 1 shows the status of the energy projects and it includes technical details on the 10 bagasse based power plants are given. The three firm power plants operate year round using bagasse during crop season and coal during the off-crop period. The so-called "continuous" power plants operate during the crop season only and use bagasse as combustible.

Table 1: Bagasse based Power Plants in Mauritius up to year 2000.

Factory	Tonnes cane per hour	Power	Start Date	Units from Bagasse (GWh)	Units from Coal (GWh)	Total Units from Bagasse & Coal (GWh)
FUEL	270	F	Oct 1998	60	115	175
Deep River Beau Champ	270	F	April 1998	70	85	155
Belle Vue	210	F	April 2000	105	220	325
Médine	190	C	1980	20	-	20
Mon Tresor Mon Desert	105	C	July 1998	14	-	14
Union St Aubin	150	C	July 1997	16	-	16
Riche en Eau	130	C	July 1998	17	-	17
Savannah	135	C	July 1998	20	-	20
Mon Loisir	165	C	July 1998	20	-	20
Mon Desert Alma	170	C	Nov 1997	18	-	18
Total		3 F 7C		360 GWh 235 GWh F 125 GWh C	420 GWh	780 GWh

F = Firm or Bagasse during crop and Coal during intercrop
C = Continuous or Bagasse during crop season only

Progress on Bagasse Energy Evolution

39. The outcome of the project has been satisfactory in that its key strategy was to set up an investment plan, the institutional framework and the policies to encourage private investment in bagasse/coal power plants. This was achieved under the project and more bagasse units have been projected. As at the year 2000, the bagasse cum coal power plants accounted for 220 MW installed or more than 50% of the total (425 MW). Two additional firm power plant projects have already been formulated and is awaiting an audit which will establish the power demand, more particularly evolution of baseload over the next decade prior to implementation.

40. The project related to investments in mill efficiency had a positive outcome in that significant improvements were made in energy use and conservation in cane processing. The tangible result on this project is in the amount of surplus bagasse generated from the sugar factories. This evaluation is shown in Table 2.

41. It is seen that the amount of bagasse saved and sold to firm power plants increased from all the factories until factory closure (e.g. Constance in 1998 and Beau Plan in 1999) or the factory increased its capacity and invested in a power plant (e.g. Deep River Beau Champ and Belle Vue) to generate firm power. The other factories invested in continuous power plants as an interim measure pending centralisation and concurrent firm power generation.

Table 2: Evolution of Bagasse (in tonnes) saved and sold to firm power plant.

Factory	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
DRBC	6844	2120	1633	6605	13650	15914	7955	18257	15364	0	0
Beau Plan	0	0	0	277	0	54	72	303	3897	4155	6106
Belle Vue	90	-	-	248	7688	6457	7081	42962	43768	40916	28524
Constance	8506	12810	9875	7281	14980	18495	20219	20904	23841	24906	0
MDA	897	0	15808	2342	7992	4012	9687	19618	15355	0	0
Mon Loisir	0	0	132	1160	8749	10377	26632	20546	6676	13405	0
Britannia	0	0	158	10	0	1742	644	596	48	1101	1239
Riche en Eau	0	0	0	1384	3995	223	0	0	0	0	0

Table 3: Evolution of Cogeneration (1988-2000).

Year	Cogeneration			Total		Bagasse %		Bagasse + Coal %
	Bagasse		Coal					
	IC	GWh	GWh	IC	GWh	IC	GWh	GWh
1989	42	56	68	270	589	15.6	9,5	21,0
1990	42	53	45	270	668	14.3	7,9	14,7
1991	42	70	54	294	738	14.3	9,5	16,8
1992	42	85	43	284	808	14.8	10,5	15,8
1993	43	71	40	308	870	14.0	8,2	12,8
1994	43	77	46	308	945	14.0	8,1	13,0
1995	43	84	41	332	1047	13.0	8,0	1,9
1996	43	119	-	332	1151	13.0	10,3	10,3
1997	53	125	23	370	1252	14.3	10,0	11,8
1998	90	225	62	397	1365	22.7	14,2	18,7
1999	90	184	155	425	1424	21.2	12,9	23,8
2000	160	274	327	478	1527	33.5	17,0	39,4

42. It can be seen from Table 3 that by the year 1996, 119 GWh of electricity was exported from bagasse, which is almost the 120 GWh target specified in the project objective. This was achieved through investment mostly by private sugar mills using cogeneration technology with their own private fund. By the year 2000, cogenerated energy increased significantly with investment in more efficiency bagasse-to-electricity processes and in a greater number of units so much so that the electricity exported to the grid from bagasse increased to 274 GWh from the 160 MW installed (or 33%) firm installed capacity: 10 out of the 14 sugar factories operating bagasse units and contribution to the total.

Factors Inducing Bagasse Energy Development

43. The sugar industry future is at stake. In the local context, the cost of production is increasing and in the international scene, sugar prices are decreasing. These factors will impact negatively on the industry if measures are not taken to mitigate these effects. Factory modernisation, centralisation and exploitation of the by-products for more value added products are measures that will ensure long-term viability of the industry.

44. Bagasse energy projects are linked with sugar factory modernisation in that boilers, turbo alternators and other energy efficient equipment represent a major proportion (up to 50%) of the cost of a sugar factory. Investing in an energy project ensures that this part of the investment (useful life of 25 years) crucial to sugar processing, is financed independently of sugar activities. In addition, the sale electricity adds to the revenue of sugar companies. Furthermore, linking energy projects to centralisation brings about reduction in cost of production. In 1985, 21 sugar factories were in operation and the number has decreased to 14 in year 2000. 10 of these factories export energy to the grid and only 3 of them are firm power plants. It has been projected that by year 2005, only 7 sugar factories will be in operation through the process of centralisation and it is likely that each one of them will be equipped with a firm power plant which are generally more efficient in energy cogeneration and export to the grid.

The Cane Sugar Industries in Fiji and Mauritius

45. The Fiji sugar industry has known almost similar development over the years since its first crystal sugar production in 1862. Like Mauritius the number of sugar factories have kept on decreasing to reach four currently. The mills in Mauritius are privately owned in contrast to Fiji where Government is the majority shareholder under the Fiji Sugar Corporation.

46. In Mauritius, sugar cane land is privately owned by corporate planters owning between 700 to 5,500 hectares and by around 35,000 independent growers owning between 0.1 to 400 hectares. In Fiji, cane is grown on 50% of the arable land on two main islands. The farms, each 10-acre, are cultivated on a tenant farmer system. Mauritius produces 5.8 million tonnes of cane, which are processed over the period June to December in 11 sugar factories whose crushing capacity varies between 1,600 to 7,000 tonnes cane per day. Fiji produces 4 million tonnes cane, which are processed in 4 sugar mills.

47. Sugar cane fibrous fraction in the form of bagasse is the main, if not the only, energy resource used for the recovery of sugar from cane. It is normally burnt to generate steam which in the traditional mills drives the prive movers in the milling tandem and the turbo generator. The exhaust steam from these equipment is used to heat and evaporate the juice in juice heaters,

evaporators and vacuum pan resulting in crystal sugar formation. The electricity requirement of the sugar factory is met from the turbo generator.

48. Over the years, cane sugar factories worldwide, and more particularly those in island countries like Hawaii, Mauritius and Réunion devoid of any fossil fuel resources, have invested in energy efficient equipment and adopted energy conservation measures with the objective of reducing energy demand in cane processing and maximising energy export in the form of electricity to the public grid.

49. In Mauritius, one factory with a cane crushing capacity of 300 tonnes cane per hour is equipped with 2 x 140 t/h boilers producing steam at 82 bars 525^{0}C which is fed to 2 x 35 MW condensing-extraction turboalternator. The net electricity export is 110 kWh/tonne cane. In such a state-of-the-art technology is implemented in the Fiji sugar factories, the 4 million tonnes of cane produced on an annually renewable basis has the potential to generate 440 GWh of electricity exportable to the public grid. A cane sugar factory processing around 1 million tonnes of cane can accommodate a power plant similar to the one outlined above.

50. Such electricity normally priced between 7 to 8 US cents/per kWh paid by the utility to the sugar/power company constitute an attractive source of revenue to the cane sugar industry particularly in the context of threat to price and quatity reduction in the preferential sugar market in the EU. Both Fiji and Mauritius are members of the ACP Sugar Supplying countries to the EU.

Technology Transfer Opportunities and Sustainability of Bagasse Energy

51. With the successful demonstration of the bagasse energy projects in Mauritius, opportunities are now offered to other cane sugar producing countries to replicate or adapt such projects and Mauritius is well positioned to share its experience given the wide range of technical options available. These options include continuous power plants, seven in number using boilers operating at pressures between 24-31 bars to generate steam fed to condensing-extraction turboalternators in a variety of set-up taking into consideration energy requirement of sugar cane processing and existing infrastructure, the efficiency of energy use and energy generation in the most financially beneficial manner. In addition, there is a wide range of firm power plants (3 in number) based on boilers generating steam at pressures of 44 bars and 83 bars and equipped with matching condensing-extraction turboalternators. All these plants are located within an area of around 1,850 km^2 and are thus easily accessible.

52. The kWh/tonne cane processed in 1988 was 13 and even after implementation of the projects by the year 2000, the value reached 60 kWh per tonne of cane. This is well below the 110 kWh/tonne cane obtained in Réunion where only two factories are in operation, each processing around 900,000 tonnes of cane annually, each factory is equipped with 2x30 - 35 MW power plants operating at around 82 bars. Only CTBV has a similar output.

53. With further centralization of cane milling activities, improvement in exhaust steam in cane processing, upgrading the efficiency of the power plants by adopting operating pressures of 82 bars and use of cane field residues as supplementary fuel, it can be safely said that 800 GWh of electricity can be exported to the grid from sugarcane biomass on an annually renewable and sustainable basis. This is more than twice the current amount. Such a development is achievable in the Fiji sugar industry as well. There is a significant potential for additional power generation and export to the grid if current R and D efforts on biomass gasifier/gas turbine combined cycle become a commercial reality.

Lessons Learnt and Recommendations for possible Consideration in Fiji Context

54. The main lesson learnt from the BEDP is that development of bagasse based electricity generation in Mauritius requires a stronger linkage between developments in the sugar industry and those in the power sector, as well as a greater emphasis on multipurpose benefits of baseload power from bagasse/coal plants.

55. Government's strong support clearly defining its policy with respect to bagasse energy development is critical to the successful achievements of set objectives of substituting bagasse for imported fossil fuels.

56. Conditions must be created to as to enable all the stakeholders to participate fully in the whole process as well as transparent flow of information among them. In this case the World Bank played a key role in providing the necessary support in areas in which the local stakeholders had little or no experience.

57. Prior to start of a bagasse power plant, it is of utmost importance that a detailed feasibility including a reliable cost estimate for a bagasse coal plant and an agreement on a financing plan from the private entrepreneur are made available. This would avoid delays in project implementation.

58. The bagasse coal power development has multipurpose benefits in that it is associated with environmental advantages, offers a diversified alternative and secure source of power from locally available and renewable resource when compared to imported fuel oil and finally brings additional revenue to the cane sugar industry.

59. At the project conception stage, it was envisaged that the bagasse power plants would be located on a regionwise basis whereby that plant would use its own bagasse and that obtained from a cluster of sugar factories. This concept was abandoned in favour of a new approach with centralisation of milling activities through consolidation of operations in most efficient plants for the dual production of sugar and electricity.