INDIVIDUAL COUNTRY BIOMASS RESOURCE ASSESSMENT PROFILES FOR:

FIJI
KIRIBATI
SAMOA
TONGA
TUVULU
VANUATU

Prepared for:

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BIOMASS RESOURCE ASSESSMENT, UTILISATION AND MANAGEMENT FOR SIX PACIFIC ISLAND COUNTRIES

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INTRODUCTION

This Report consists of six sections, each providing a biomass resource assessment for each of the island nations that requested participation in the project i.e.:

- Fiji
- Kiribati
- Samoa
- Tonga
- Tuvalu
- 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. WE use both primary and secondary data, but primarily secondary data. The use of primary data would have required considerable field work 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-sectorial 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 bioenergy 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) biodiesel 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 coops can be established. Village and town scale digesters could be 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 island archipelago (about 150 islands are inhabited), spread over a land mass of 18,272 km^2, with an Exclusive Economic Zone (EEZ) covering 1.6 million km^2. The largest island is Viti Levu (Big Fiji), which covers 10,390 km^2, followed by Vanua Levu (Big Land) with 5538 km^2, and account for 87 percent of the land area and 90 percent of the population; other large islands include Taveuni and Kadavu. The highest peak in the country is Mt Victoria, at 1,323 m, but there are few others mountains of over or close to 1,000 m.

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.

The total land area of Fiji is 1,827,000 ha, of which 815,000 ha are forests (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. FORESTS 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. The hardwood plantations, including mahogany, have enormous value-adding potential TO WHAT? of up to US$200 million annually (ADB, 2002).

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 Vanua Levu	12,395 119,970	13,267 117,724	8,298 30,868	- 18,627	- 13,729	1,205 16,475	35,165 317,393
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

*Karo, 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 1,300 m 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.

Following is brief description of vegetation types in Fiji Islands, based on data from FAO STAT and Mueller-Dombois and Fosberg 1998).

- Broadleaved
- Lowland Rain Forest. This is the most common mixed type of forest in Viti Levu and Vanua Levu, usually 20 to 30 m 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 2 500 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. The leeward lowland primary dry forests in Fiji have largely been destroyed by grazing and fire. 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.
- Upland Rain Forest. Found above 400 m near the coast and above 600 m inland on Viti Levu, Vanua Levu, and Taveuni.. A wet-zone forest with more than 3 750 mm annual rainfall can be distinguished from an intermediate-zone forest with 2 000 to 3 750 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).
- 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.
- Talasiqa Vegetation. In Fiji, talasiqa ("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 ha 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 CO2 abatement source, both for indigenous and plantation forests.

Table 2 shows the estimated forest plantation in Fiji in 2000, based on FAO STAT data. The establishment of new plantations have been estimated at 9,200 ha/yr, while the total planted area is 97,200 ha, 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 sawlog production; thinning regimes are still being developed.

Table 1.2: Estimated plantation area in Fiji in 2000

Species group	Area (ha)	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 production

There are 34 recorded indigenous species of commercial values, with Dakua Makadre, Kauvula, Kaudamu, Damanu and Sacau being the most popular. The industrial sector is important because it generates considerable amounts of residues that are underexploited (see Table 1.6) and that could provide significant amounts of biomass-based energy. Table 1.3 summarises forest product production from 1993 through 2001. A particular characteristic is that estimates for fuelwood remain constant raising some doubts about the validity of this data.

Table1.3: Forest products Production in Fiji, 1993 – 2001 (10x3 m3)

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 3 000 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 1 000 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, and Fiji Logging Code of Practice.
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 is also committed to the effective implementation of the outcome of UNCED, having signed and ratified the International Convention on Biological Diversity and the UN Framework Convention on Climate Change.

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

[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

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 plated 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 (ha)	No. of farmers	Production (tons)
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
Yagona	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 1903and 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 Vanna Levu, in the proximity to the 4 mills (3 in Viti Levu and 1 in Vanna Levu). About 22 000 growers currently produce around 4 million tonnes of cane on approximately 100 000 ha (74 000 ha 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 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 ha/yr.
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 (installation at Lautoka and Penang, also planned). This is designed to improve extraction of sugar from molasses; the installation of boilers and turbo generators at Lautoka in 1995, enabling the FSC to supply power to the Fiji Electricity Authority during harvesting, and in Labasa 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 hydro power (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 Case Studies). 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 requirements is met from the 80 MW hydroelectricity project at Monasavu on 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. (See Case Studies).

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 cane + 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 which crushes one million tonnes of cane 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 FNTC 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 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 factory. 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 be 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. 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 islands under consideration, will depend of many varying factors, as stated in the Master Development Plan 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 RE 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.

The following table (Table 1.6) is based on the data we have collected, feedbacks 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 fro 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.

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; fuelwood; land tenure problems
Coconut	Biodiesel + charcoal (electric, transport, combustion)	Good possibilities. This could have significant impacts on the local economy
MSW & other waste	Biogas	Various projects
Others		

1.6. GENERAL MAIN ENERGY-RELATED CONCERNS

- 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

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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^o 25' N and 173^o 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 of 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 national resources.

2.2. FORESTS

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 ha and a further 185 ha of mangrove forests). In addition, there are approximately 26,000 ha of coconut plantations. Kiribati has developed an intensive agroforestry 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 babi 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 that "*the natural resources of Kiribati are vested in the people and their government*".
Most of the land and forests in the most densely populated islands is owned by groups (Catholic and Protestant churches, and extended families living in small scattered villages), 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, fuelwood, etc. Forest management is primarily limited to agroforestry 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 fuelwood, 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 agroforestry 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 $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 mainly on imported fossil fuels for its energy 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 26,000l of oil per 8 hour day. To provide copra for this production, the plant will require approximately 2,500ha of coconut plantation to be harvested annually with an average planting density of 254palms/ha. Only 926ha of high density (350 palms/ha), well managed plantation would be needed, however, 17,00ha would be necessary if only poorly managed, low density (150 palms/ha) 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 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 are poor, making the forecasting of load demand difficult. SOPAC has assisted Kiribati with the development of a photovoltaic scheme, which provides a secure, reliable and cost-effective source of electricity for the outer islands. Installation of the project was completed 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 Aus$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 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 & 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 bioenergy 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 are 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. As the majority of the people dependent on these sources of income are poor, 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. KEY ISSUES AND BIOMASS RESOURCES

Table 2.2 summarises the main potential for the exploitation of biomass resources in Kiribati as 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 biodiesel 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	Biodiesel, charcoal	Good possibilities (see coconut case study)
MSW & other waste	Biogas	No current projects identified

The main issues affecting agriculture 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.

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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 1 820 km2 and ´Upolu is 1 110 km2. 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 Hawaii 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. FORESTS

Total forest cover has been estimated by FAO at 104,790 ha; while deforestation has been calculated at about 2,500 ha 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 ha (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

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 specie is *mahoganies* (83%) which is used in its entirety for industrial applications.

Forest planting began in the late 1960's.The planted area reached about 5,100 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 4,500 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 silvicultural 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 fuelwood
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 fuelwood acquisition is also considerable and increasing, due to increasing population and increasing prices for fuelwood and fuelwood substitutes.

3.2.1. Forest management

The key legislation guiding the development of forestry in Samoa are the Forests Act of 1967 and the Forest Regulations of 1969. The Forests Act 1967 established the

Forestry Division of the Department of the Ministry of Agriculture Forests and Fisheries MAFF) to administer the conservation, resource management and exploitation of forests. A variety of other legislation incorporates 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 agroforestry 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 silvicultural 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 (10x3 m3)

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

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A variety of programmes have been implemented to support sustainable forest management including those mentioned above relating to logging practices, plantation establishment, 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 ($1.1 million), coconut cream ($540,000), and "other" ($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 (ha)
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 energy 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. BIOMASS RESOURCE POTENTIAL

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 socioeconomic 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 fuelwood 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	Biodiesel, 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.*7. GENERAL ISSUES AND CONCERNS

- 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
- Poor utilization local natural resources, particularly biomass

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4: TONGA

4.1. BASIC DATA

The Kingdom of Tonga comprises about 150 islands with a total land area of 649 km2, of which Tongatapu with 257 km^2 represents 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. FORESTS

According to FAO data, Tonga has moderate forest cover, with only a small area of closed natural forests remaining, about 4,000 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 bioenergy 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.

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. Fuelwood 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.

Table 4.1: Estimated forest products production in Tonga, 1993-2000 (10x3 ton)

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

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 DMAF responsibilities and may be a source of confusion.

National forest management is the responsibility of the Forest and Conservation Division of the Ministry of Agriculture and Forestry (DMAF). Its responsibilities include policy and planning, forestry research, plantation forestry, agroforestry and conservation. A separate committee exists within the DMAF to coordinate all agroforestry 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 matabules 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).

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 agroforestry. 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 fuelwood, 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 agroforestry systems. Under traditional agroforestry systems, food crops (predominantly coconut) are cultivated under a canopy of trees. Tongan agroforestry 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.

Forest harvesting practices. Tonga's timber harvest is almost entirely comprised of coconut. Domestic production depends on the extensive coconut agroforestry 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 bioenergy 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 Agroforestry Programme, a Watershed Areas

Management Programme on ‘Eau, and a Coastal Protection and Rehabilitation Project on Tongatapu. A number of other forestry projects are being implemented with bilateral or multilateral donor assistance.
Fuelwood 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 fuelwood shortages are a concern. The establishment of Eau 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 agroforestry 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 major activity in Tonga. Productivity is about 120 nuts per palm; coconut spacing now is about 60 feet max and min 45 between rows and between palms is between 20 to 40 feet, lower densities are also common e.g. among land owners. *Cassurina* (Iron Wood) is also widely grown for fuelwood 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 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.
- 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.
- 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
- 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.
- 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 stakeholder's governing bodies.

Another important area is Regional co-operation in energy policy and planning 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).

4.4.1. A sustainable RE sector

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

- Ensure that sufficient, affordable and appropriate sources of energy are available to promote the economic, social and political development of the people of the Kingdom.
- Ensure 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 policy, technical, financial, management, institutional and awareness barriers. Renewable energy sources in the form of hydropower, wind, solar, biofuel, 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.

Key issues in renewable energy include:

- 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;
- 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
- Improve the awareness and understanding of their renewable energy resources and their potential

4.4.2. STRATEGIC 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
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
iv. Capacity

In totality, these ten themes correspond to the sections of the Pacific Energy Policy and Plan which is being developed and implemented under the auspices of SOPAC (www.sopac.org).
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 T$50 deposit and then T$6 p.m. 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 T$6 p.m. fee. The Energy Department pays for all other costs. (See Case Studies).

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 bellow sea level, 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 4.3 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 Toga and offers good possibilities for biodiesel production and other applications such as combustion.

Table 4.3: 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 are commercially inaccessible
Coconut	Biodiesel + 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. GENERAL ISSUES AND 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.
- 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.

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5: TUVALU

5.1. BASIC DATA

Tuvalu total land mass consists of just 26 km^2, spread over 750,000 km^2 across 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 ha and the smallest 42 ha. 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 5m.

The climate is sub-tropical, with temperatures ranging 28 to 36^oC, uniformly throughout the year. There is no clear marked dry or wet season. The mean rainfall ranges between 2,700 to 3,500 mm per year in Tuvalu, but there are significant variations from island to island.

5.2. VEGETATION AND FLORA

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 vegetational 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	1,619	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	3,006	100

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

5.3. AGRICULTURE

In total, approximately 18 km2 (1,800 ha) 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 ha and the smallest 42 ha; also, there are 89 islets with less than 5 ha. 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 HQ 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. Land use is governed by the 'Native Lands Act' with all land being owned under customary laws. 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.
- 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.
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 A$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 fuelwood use. There is also an active household and community PV programme. Energy data collected by this project for Tuvalu includes:

i. Petroleum Products:
    a. Kerosene imports by Month from Jan 1998 to June 2002 (including costs)- Tuvalu Statistics Office (Funafuti, 2002). The kersosene 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 A$1, 217 981. Current (2002) electricity tariffs on Funafuti are A$0.34/kWh and on the outer Islands A$0.30. Actual electricity production costs are around A$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) A$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. BIOMASS RESOURCES

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 green house 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	Biodiesel (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.
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 bioenergy 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 bioenergy 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 ancilliary 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 Tuvalan's can rent out places for their pigs (at A$70 per year- need to check figure), the manure is collected and goes through a couple of treatment ponds. In theory, biogas should be being produced but no evidence could be found that this was happening.

5.6. MAIN PROBLEMS FOR TUVALU INCLUDE:

- 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 fuelwood
- 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)
- 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 green-house gas production which will make its case to the industrialised world even stronger that they should act themselves.

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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 (3 900 km^2), Malakula (2 000 km^2), Erromango (1 000 km^2), Efate (900 km^2) and Ambrym (665 km^2). Anatom (150 km^2) is the southernmost island 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 in some areas they have been degraded by grazing or burning. 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

6.2.1. Vegetation (Corner et al. (1975) and Mueller-Dombois and Fosberg (1998).

The woody vegetation of Vanuatu includes lowland rain forest, montane 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 (1 879 m elevation), microphyllous forest extends up to 1 000 m, 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.

6.2.2. 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 ($10x^3$ 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

6.2.3. 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 ha; commercial plantation (unspecified) occupy about 3,300 ha, but the most important plantation is coconut with 96,000 ha (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 1 000 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 1 200 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 1 100 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 sawlog 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

6.2.4. 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) are 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 land mass of Vanuatu is estimated at 1, 212,440 ha[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 mass (ha)	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

6.3.1. Coconut

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

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

Coconut remains the backbone of the rural economy, not only to satisfy subsistence needs but also to provide the means for cash income. However, few new investment goes into coconut production
The industry needs to be modernize 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
The industry need to diversify e.g. soup production for the local markets could be encouraged more, better use of residues for fuelwood, 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)	2,763(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 7,400 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 fuelwood.

Table 6.5: Cocoa plantations in Vanuatu, 1983 and 1993

Item	1983	1993
No. of smallholders growing cocoa	2,537	7,414

No. of smallholder plots of cocoa	3,905	12,414
Average area smallholding rural household	0.7 ha	0.4 ha
No. 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 tree per plot	297	269

Source: Anon (1994)

6.3.3. Cattle ranching

Cattle raising has 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
No. smallholders owing cattle	5,700 (27%)	9,420 (43%)
Total No. cattle in smallholder sector	31,918	82,140
Average No. 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 a 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 owe kava, compared to 25% (3,310,000 plants) in 1983. The remarkable growth of this industry has been attributed to a number of factors:

- Existence o a large domestic market
- Uniqueness of the community
- Improved returns to the producers as compared to copra, cocoa, etc
- 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 SECTOR

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. BIOMASS RESOURCES

Vanuatu, together with Fiji, offers one of the greatest potential 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 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". Fuelwood consumption has increased in recent years (90,000m3). With good forest management this potential could increase substantially
Coconut	Biodiesel (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. KEY ISSUES

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.
- The focus on only a few timber species promotes high-grading of forests, and consequent degradation, is also another serious concern.

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