Aspects of the Use of Biomass as an Energy Source for Cooking in Fiji

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Abstract

Energy from biomass is used extensively throughout the developing world for cooking, heating space, electricity generation, producing steam and hot water for industries and homes, cremation, etc. Developed countries also use biomass for large scale steam and electricity generation. For many developing countries, including many island nations of the Pacific, energy from biomass accounts for over 50% of their total energy consumption. Forms of biomass in Fiji include firewood, coconut husks and shells, paper and cardboard, crop waste, and biofuels derived from biomass. This paper discusses various aspects of use of biomass for cooking in Fiji.

Introduction

Since the dawn of the human civilisation, biomass has provided humans with food, shelter and energy which are widely regarded as the three basic necessities for life. In terms of energy for cooking and providing warmth, biomass continues to provide energy for a large number of developing countries and even in the rural areas of many developed countries. Rural and remote communities in the developing world rely quite heavily on biomass as an energy source. In many communities, it is sometimes the only viable choice. Such communities are usually quite poor; they are quite a distance from towns and cities; they do not have access to grid electricity or even other forms of electrical power supply, and its people subsist on agricultural practices and are quite vulnerable to poverty and poor health. Because of increasing pressure on land for agricultural produce and livestock, the supply of biomass is increasingly getting more and more difficult. This results in quite a lot of abuse of biomass resources, including the indiscriminate cutting of trees from around the villages, stealing of wood from forests and natural reserves, and the use of inappropriate forms of biomass for cooking, leading to increased health and environmental problems.

The island countries of the Pacific region are no exception. There is a heavy reliance on biomass, particularly coconut biomass, in the atoll islands. Many Pacific countries depend on biomass; sometimes exclusively for cooking needs in villages and remote areas. Anything people could get hold of, including cardboard, paper, coconut husks and shells and other wood, are used for cooking, usually on open-fire stoves. Such stoves are inherently quite inefficient; efficiencies as low as 3% are not all that uncommon. Moreover, it is quite a common sight to see such open-fire `stoves' emitting a lot of smoke.

The Social and Economic Context

The small island countries of the South Pacific region have a lot in common, apart from their generally small size and vulnerability to external factors. These include relatively high population growth rates; weak economies; generally poor governance; weakness of the private sector; breakdown of traditional support systems; unequal sharing of the benefits of modernization between the urban and rural populations, and significant poverty levels in many countries. These and other factors lead to a situation where energy issues are not given a high enough priority.

Some of the development challenges for these countries include improving the economic performances, reducing poverty, better governance, reducing environmental degradation and improving the lifestyles of the rural population.

Energy supply plays a crucial role in the social and economic development of any community. A stable and affordable energy supply, including electricity supply, can benefit the rural and remote communities enormously. Apart from the people enjoying the usual benefits from regular supply of electricity, there can be developments such as cottage industries, facilities for storage of food and agricultural produce, access to information technology through access to computers and, perhaps, a slowing of the internal migration of people from the poor rural areas to the perceived richer urban centres.

An Overview of Energy Supply and Demand

Essentially, most of the PIC's rely on a mix of imported and indigenous energy sources. While the larger countries such as PNG, Fiji, Samoa and the Solomon Islands are fortunate in having considerable hydropower potential and actual systems in operation, smaller nations rely almost exclusively on imported petroleum products for commerce. Renewable energy resources include biomass, hydro, wind and solar. The latter two make a tiny contribution and yet are important to list here; there are quite a number of small to medium demonstration power systems using solar and wind resources.

Reliance on fossil fuel (mainly petroleum) ranges from 32% (PNG) to 92% (Cook Islands). Countries which use oil to a level of 75% or more include FSM, Kiribati, Marshall Islands, Nauru and the Cook Islands. These are all small island nations with no indigenous fossil fuel resource. Fiji's reliance on petroleum products is between 25 and 30% of the total energy consumption.

All Pacific countries rely on the use of biomass for cooking and heating water. In some countries, steam and electricity generation from biomass for industries including for small businesses such as bakeries and restaurants, also takes place. Some examples of the use of biomass for steam and electricity generation in Fiji include the sugar mills, copra oil mills, soap factories, several large and small sawmills (Malau, Drasa) and some small power generation systems, such as the one in Wainiyaku in Taveuni. Biomass contributes between 1.5% (Palau) and 63% (Fiji) of the total energy used in these countries. Several countries have energy from biomass making up over 50% of their total annual energy use; these include PNG, Fiji, Samoa, Solomon Islands and Vanuatu.

The per capita energy use in these countries is quite small in comparison with that in developed and industrialized countries such as the USA, Canada, Australia and Germany. In many rural communities across the Pacific, a 5-10 kW diesel power plant is sufficient for meeting the basic energy needs of the community (mainly lighting and some appliance use). Thousands of people do not have access to electricity and rely on biomass, kerosene and/or gas for their energy needs.

Biomass Energy Use

As an energy source, biomass energy is renewable only if it is used sustainably. That is, it must be continuously replenished, by replanting or via re-growth. Its advantages include its generally ready availability, its multiplicity of uses, the low sulphur and ash content for most forms of biomass, and its cost relative to other commercial fuels. Its disadvantages include its high cost of harvesting and transportation, the need to clean the fuel thoroughly for its use to generate electricity and heat, storage problems and the emission of smoke and particulate matter for cooking and heating applications.

Biomass is the most important energy source for most of the Pacific Island Countries, with its contribution to the total energy supply ranging up to 63%. Fiji, PNG, Samoa, Solomon Islands and Vanuatu depend heavily on biomass for over half of their total energy needs. Fiji's high energy use from biomass is due partly to its four sugar mills, which generate their steam and electricity requirements by burning bagasse.

Energy Conversion Processes

The energy contained within biomass can be converted to useful energy such as heat, electricity and other fuels (biofuels) by a variety of conversion processes, which are classed into two major categories.

Thermochemical Conversion

Thermochemical conversion includes processes such as direct combustion, gasification and pyrolysis. In these processes, biomass is heated or combusted to form other energy-rich products or to release heat directly. Direct combustion is the process through which people cook food, by burning the wood directly in some kind of stove. The other two processes involve the partial combustion of biomass by limiting the amount of air supplied to the combustion process. For the gasification process, the products include a mixture of gaseous materials including carbon monoxide, carbon dioxide and water.

Pyrolysis yields a range of solid, liquid and gaseous products, the most important one being charcoal.

Biological Conversion

Here, the two conversion technologies include fermentation and digestion. Fermentation involves the breakdown of the biomass into sugars and then into ethanol and methanol. This process has been used with mixed success in countries such as Brazil and Zimbabwe, where the ethanol produced via this process has been used, mixed with diesel or petrol, to power vehicles. Some forms of biomass are more suitable for this pro-

cess than others and include sugarcane, cassava, sugar beet and other sugar-rich biomass.

Digestion of biomass, in the absence of oxygen and with suitable bacteria, is used to produce a mixture of gaseous products, the main constituents of which are carbon monoxide and hydrogen. The gaseous product is called `producer' gas and, after it is cleaned sufficiently, can be used directly for lighting and heating or as a fuel for running engines for electricity generation.

Energy Efficiency and Conservation Issues

The burning of any fuel results in energy being released from the fuel in the form of chemical energy into thermal energy or heat. The thermal energy is in the form of the combustion products which are at some high temperature. Clearly, heat can be lost from the combustion process itself, from the gaseous stream of the combustion products and as a result of the processes of conduction, convection and radiation from all parts or stages of the entire system. Then there is the problem of incomplete combustion, as indicated by the presence of carbon monoxide and tiny particles of uncombusted fuel inside the gaseous product stream. Finally, quite a lot of heat can be lost due to the gaseous stream exiting from the system. The useful energy obtained from the combustion process is the energy that actually goes into cooking food, for example, the ratio of this useful energy to that of the fuel that was burned in a given time is the energy efficiency of the combustion process or the efficiency of the device used to obtain useful energy.

Thus, even with the best of design, a sizeable amount of initial energy inside a fuel can be lost due to heat losses. In the case of open-fire stoves, the conversion efficiency is quite low, simply because most of the energy from the fuel is lost via the processes listed above. The major loss is the energy that is carried away by the wind before it reaches the pot, placed atop the stove.

From studies on the efficiency of wood-fuelled stoves of various types carried out by students at the University of the South Pacific supervised by the author, open-fire stoves have efficiencies ranging from 3% to 15% for a range of conditions. Thus, even for the best of conditions, some 85% of the energy inside the fuel is carried away and is wasted. Well-designed stoves, with good insulation and with chimneys used to carry the exit gaseous stream, have efficiencies of over 40%. There are some designs which yield efficiencies of the order of over 60%.

Therefore, open-fire stoves are inherently inefficient and, in the case

of their use in rural villages, extremely so. A huge amount of firewood is, thus, simply wasted. With an average consumption of around half a tonne of firewood per person per year in a typical rural village in Fiji, a family of 6 uses some three tonnes of firewood annually. The typical open-fire stove efficiency would be around 5%. If stoves having an efficiency of, say, 15% are used, the same family would use only one tonne of firewood, with an annual saving of two-thirds of the firewood used for open-fire stove. This is obviously a huge saving in firewood.

Therefore, stove efficiency is an important consideration in the study of biomass use for cooking and for any energy conversion process. For Fiji, the annual use of firewood could easily be halved, by adopting some fairly simple measures in terms of stove design and the cooking process itself. Unfortunately, for the vast majority of firewood users, the concept of efficiency is totally alien.

This leads us to the issue of energy conservation, which is, simply expressed, the use of energy in an efficient manner so that any source of energy can last longer. A simple example is that of using an energy-efficient lamp. An ordinary light bulb, the incandescent type, rated at 60 watts, wastes over 90% of its energy as heat. Only 10% of the energy supplied to the bulb is providing the useful output, which is the actual light. An energy-efficient lamp, using fluorescent tube, can supply the same amount of light with a rating of only 10 watts. The ordinary light bulb uses six times more energy to deliver the same amount of light as does the energy-efficient tube. Even with the higher cost of the tube light, it is much better to use this as a light source. The quality of light is also better with the energy-efficient lamp.

Thus, a lot of the energy that is presently used for all kinds of things, can be conserved if more efficient appliances are used. This will ensure that the energy sources, whether fossil fuel or biomass or others, will last longer. This also has the added advantage of reducing the amount of wastage, which is directly linked to the amount of greenhouse gas emissions, which are now proven to cause all kinds of climatic changes and changes in sea levels, to name just two.

Biomass for Cooking and Heating

There is widespread use of biomass for cooking, mainly in the rural areas. However, a significant portion of the urban population also uses biomass for cooking and heating water. Most of the communities use biomass extensively during weekends to make the *lovo*. Quite a significant amount is used for cremation by the Indian Fijians. Heating refers to the

practice of heating water for showers, for washing clothes or for parboiling rice. Processes for food preservation or handling of agricultural produce are also included in this category.

The general practice is that biomass is collected or bought; it is then dried, split and stored for use. Energy for cooking is obtained by burning the firewood in open fires, a practice which is highly wasteful of the firewood as this particular method of using biomass is highly inefficient and also gives off a lot of smoke. Some starter fuel, usually kerosene, is used to start the fire.

The following section uses the data collected from the 1996 Fiji census and through a brief questionnaire designed to gain information on energy sources and uses in a few rural areas in the western part of Viti Levu in Fiji.[1] These areas include Vakabuli village in Drasa; Drasa Dam and Johnson Road, all from Lautoka. The survey was conducted by Surendra Prasad and Anirudh Singh.

The 1996 Census Data

The 1996 Census of Population and Housing in Fiji generated data on types of energy used in households, by province and by the two major races. The survey on housing determined whether households had access to electricity, energy sources used for lighting, cooking fuel, appliances and dwelling adequacy, amongst others. As shown in Table 1 firewood is used in over 56% (ITaukei) and 44% (Indian Fijian) households respectively, average 50% of households using it nationally. Open-fire stoves make up 53% and 36% of the cooking appliance used by ITaukei and Indian Fijian households respectively. The next most common fuel for cooking is kerosene for Itaukei households (22%) and LPG for Indian Fijian households (33%).

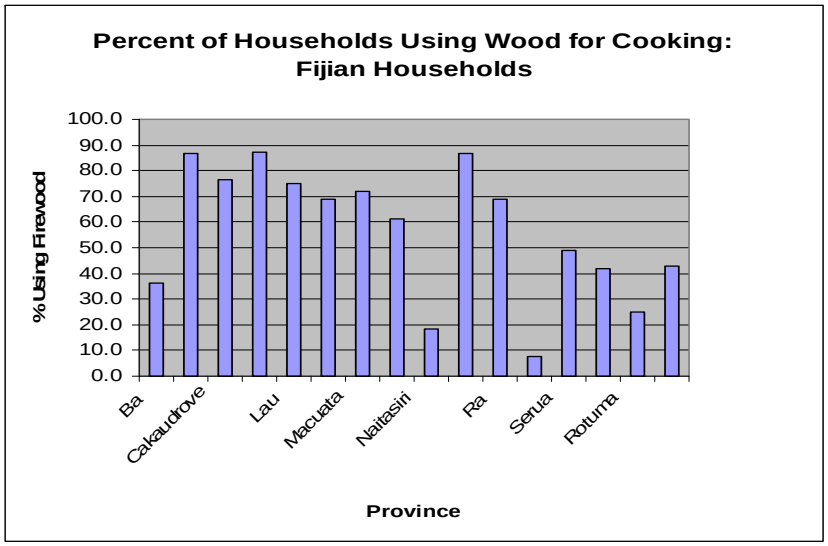
Figure 1 shows the use of wood for cooking in Itaukei homes by province. It is noted that wood, LPG and kerosene are the three dominant fuels used for cooking. For the ITaukei households, there is considerable variation in the percentage of households across the provinces that use firewood for cooking - from a low of 7.5% in Serua to a high of 88% in Kadavu. These figures reflect the urban/rural nature of these households and generally the economic situation which further is an indication of the lifestyles and the energy sources used.

[1] Results of the 2007 Population Census are not available yet

Table 1: Energy Source for Cooking in Fiji Households

Source	Fijian	%	Indian	%	Total	Percentage
Electricity	1556	2.3	1548	2.2	3104	2.3
LPG	12737	19.0	23081	33.4	35818	26.3
Kerosene	14863	22.2	13766	19.9	28629	21.0
Wood (stoves)	2194	3.3	5412	7.8	7606	5.6
Wood (of stoves)	35431	52.9	24874	36.0	60305	44.3
Other	217	0.3	366	0.5	583	0.4
	66998	**100.0**	**69047**	**100.0**	**136045**	**100.0**

(Based on 1996 Fiji Census Report)



Firewood for Crop Drying and Preservation

Firewood is also used, often quite inefficiently, to dry and preserve crops and to preserve certain food types. The copra industry uses a lot of coconut biomass (husk, shell, frond and trunk) to dry copra, the meat of the coconut which is used to make coconut oil and coconut feed. Usually, huge amounts of the biomass is used; often efficiency is not a prime con-

sideration. Other types of firewood is also used to supplement the coconut biomass. Copra and oil mills use large amounts of biomass, usually coconut biomass supplemented by wood, to generate steam for their processes as well as for electricity.

Biomass is also used for rice parboiling, fish smoking, and tobacco curing. Rice parboiling is a common practice among the Indian Fijian families in rural areas. This takes place in open-fire stoves; parboiling takes place in large drums. Again, the process consumes a lot of firewood. Fish smoking and tobacco curing, also done using firewood, is mostly a rural and remote area phenomena.

Firewood Types

For Fiji (and most of the developing nations in the Pacific region), the biomass fuel types include firewood from natural and plantation forests, crop wastes and residues (such as coconut husk and shell), waste timber from sawmills and other industries and wood sold in markets and on roadsides. The type that is used in the domestic sector for (mainly) cooking depends very much on what is available locally. People collect whatever is available, from around their homes, from local forests, river banks; sometimes they travel significant distances - even up to 20km - to get firewood. Common types include nokonoko, mango, guava, raintree, vaivai, pine species, jackfruit, and breadfruit; scientific names of the common species are listed in Appendix 3. People prefer to use firewood that is easy to burn, that is heavy, and that does not emit much smoke. Local knowledge on this is passed from generation to generation. The highest preference is for *nokonoko* and guava as both these types burn well and emit little smoke. Pine, raintree and eucalyptus are avoided if possible because they burn poorly and give off relatively large amounts of smoke.

Firewood is collected in a variety of ways using a range of transportation systems. The most common method is collection by individuals, both males and females, from forests, riverbanks, and coastlines. Depending on the distance from the collection point to the homes, the firewood is transported either by the collector (on his/her back or head), by horse or bullock cart, or by a vehicle. People also use buses to transport wood.

A majority of the households surveyed obtained the firewood from around their residences, usually within a radius of a kilometre. Usually, firewood is collected daily or a few times per week. Others obtained the firewood from within a 10 kilometre radius. In the case of local area collection, it is gathered by hand and taken home manually. For the other

cases, a vehicle, usually a van or small truck is used; normally quantities that last at least a week or more are transported in this way.

There is an interesting pattern to the collection of firewood in the two dominant communities in Fiji. For the Indian-Fijian families, with some exceptions, the collection of firewood remains the task of males whereas it is the opposite for the case of Fijian families.

From the limited survey, it was found that, generally all members of a family above a certain age (usually 6 years) are involved to some extent in collecting firewood. People who hold regular jobs help to collect firewood during the weekends or after they finish work. People who stay home collect it daily at various times. The job of splitting logs, cutting long sticks to manageable sizes and stacking the firewood falls usually on the males. However, in households where females outnumber the males or where the husband has passed away, it is the mother who carries out all these tasks.

Wherever there is a limited supply of firewood within the local area (as is the case for many Indian Fijian cane farms in the west), people resort to purchasing firewood. The two most common sources for the purchase are the local hardware shops and any nearby saw and timber mills. Firewood is bought by the truckload; the cost varies between $10 and $30 per load, depending on the size of the truck or van. Sometimes people grab whatever waste wood they can get and transport this via their cars or vans. In the Tavua and Rakiraki areas, many people buy waste timber from the Vatukoula gold mine.

Some companies, such as Punjas in Lautoka, buy firewood from the landowners for their industrial boilers. The landowners are paid by the truckload.

Storage and Use of Firewood

Given the increasingly difficult situation with respect to the availability of firewood, due to pressures of land clearing, population growth, land lease problems and poverty, the storage of firewood becomes an important consideration. This varies widely among the users of firewood in rural areas and is inter-related to other factors, such as the type of dwelling, storage area, mix of fuels used and the season. While most people would like to store the firewood so that it is dry and readily available for use, the plain fact is that many households do not have adequate space for this. In many households, the wood is stored wherever it is possible or safe to do so. In quite a few cases, people worry that their firewood would be stolen if left outside without some kind of protection.

Thus, one finds that the firewood is stored in:

- Open places, close to the house or the kitchen,
- Inside the kitchen, usually under the stove area if the stove is on a raised `platform',
- Inside the dwelling itself,
- Under some kind of cover such as a tarpaulin, plastic sheets, roofing irons,
- Under the overhang of a dwelling,
- Inside a special building made for firewood storage, and
- Inside empty drums or other containers.

The use of firewood for households which have more than one source of energy for their cooking depends a lot on the weather conditions and on the urgency of the cooking. During fine conditions, people prefer to use firewood, as it would be mostly dry and convenient to use. During rainy periods, people use either kerosene or gas for their cooking, usually inside the kitchen. Many households (as many as 50% of all firewood users for cooking) have a main kitchen and an `outside' kitchen, which is just an extension to the building, usually not fully walled. The latter is often used during fine weather.

Another aspect of the use of firewood is the necessity, at times, of cooking quickly - mostly for sudden demand (for example unannounced visitors). For these occasions cooking is usually done using more than one source - some on a gas stove, some using a kerosene, and some using firewood. In rural communities, there is a marked preference for using firewood during religious, social or ceremonial functions. During weddings, for example, all the cooking is carried out using firewood using quickly made open-fire stoves. Huge amounts of firewood is consumed in these functions as the main objective is to cook food in bulk and little, if any, attention is paid to the efficiency of the stove.

Some Concerns on the Use of Biomass for Cooking

There are some practices with regard to the use of biomass energy for cooking and heating that give rise to problems or concerns. This is the case from the point of view of various players involved: scientists, conservationists, sociologists, economists, forestry workers, government officials and the users of biomass themselves.

The main concern relates to the practices on the collection of biomass energy forms and those relating to the actual use of the firewood. In terms of the collection of firewood, and particularly from areas that are

outside the legitimate boundary of the collectors, there is a tendency to `collect whatever, wherever and in any way'. Thus, little heed may be paid to exercise care when collecting dead or dying wood. In fact, quite often, there is indiscriminate chopping of trees, even live and healthy trees for collection in the future. De-barking of healthy trees to prepare for future collection is also widespread. There is grave danger of clearing the forests, causing soil erosion and related problems like flooding.

In terms of the actual use of firewood, open-fire stoves are wasteful of huge amounts of energy, thus inefficient. Enormous volumes of firewood are, thus, wasted. Moreover, firewood is burnt as it is obtained, frequently without drying adequately. Wet firewood generates a lot of smoke, which is harmful to health and well-being of persons doing the cooking. Because the people who do the cooking are mostly ignorant about energy and efficiency issues, their methods do not change. Cultural practices also feature into the equation, for example, keeping the pot open for `better taste'. This leads to a decrease in the energy efficiency and to an increase in the amount of firewood needed for a given amount of cooking.

According to the 1996 Census report for Fiji, 44.3% of households use open fire stoves. Most of the cooking is done by women who use the method of blowing air on to the firewood to get it to burn properly. They either blow air directly onto the fire or use some kind of a pipe to do so. Using such devices is highly dangerous, as the pipe blower sucks in the smoke which is full of noxious gases and particulate matter. This has an impact on their health.

There are health risks due to the combustion of low-grade fuel which includes certain species of firewood and firewood which has a high moisture content. The principal risk to public health arises from exposure to pollutants formed during the combustion process. These pollutants include various solid, liquid and gaseous products formed during the combustion process like carbon monoxide, carbon dioxide, sulfur dioxide, nitrous oxides, various hydrocarbons, flyash, trace metals and radionuclides. Without proper ventilation and especially if the stove is lacking a chimney (flue), high levels of CO, CO_2, water vapour, SO_x, NO_x and particulate matter can accumulate in the homes. Major health effects are thought to be similar to the effects of passive and active tobacco smoke. In addition to the risks of burns, potential problems include acute respiratory infections, chronic obstructive lung diseases, low birth weights, cancer, eye ailments, ENT (ear, nose and throat) problems, and skin problems.

Our survey showed that many firewood users agree about some if not

all of the risks to their health posed by the smoke-emitting stoves. The women in particular nod their heads when we talk about the smoke from the stoves getting into their eyes and inside their lungs. However, they also state that they have no choice but to continue to use firewood and the open-fire stoves. If they had the choice, a vast majority of those who were surveyed would like to switch to gas for cooking. They also have absolutely no knowledge about stove or combustion efficiency and about the vast amounts of heat loss from such stoves. All they know about is the need to cook the food using as little firewood as possible.

Almost all of the households surveyed agreed that food cooked using firewood tastes better, and in some cases, much better, than that cooked from other energy sources. Because of this, some of the users of firewood don't mind the smoke and the inconvenience of using firewood, even though some of these people can afford to use gas and usually have the gas and gas stove available in their houses.

In the matter of using the firewood for cooking, it is the mothers or wives who perform this important function. Women choose the types of firewood to use and do almost all the cooking. They also suffer from the unhealthy practice of being cooped up in a tiny kitchen for long periods of time and suffer smoke inhalation as part of this duty.

The Changing Role of Firewood as an Energy Source

The pattern of biomass use keeps changing with time. This is explained by the access to and price of alternative fuels such as gas, electricity and kerosene, the cost of biomass itself, changes in the socio-economic status and the extent and cost of rural electrification. There have been some profound changes in the lifestyle of many people who have been forced to move from rural areas to urban or peri-urban areas. These changes include a drastic change in their energy sources, particularly for cooking. In rural areas and on their farms, these farming families had greater access to firewood. On their move to a non-farming situation, with most of the husbands working on day jobs, in many cases, firewood use drops significantly; reliance on kerosene stoves and gas for cooking becomes strong alternatives.

But even in rural and remote areas, where people do not normally have full-time day and/or cash paying jobs, there are trends emerging that indicate that other energy sources are taking on increasingly important roles. These sources include electricity, kerosene and gas.

In Vatusui in Ba, there have been profound changes in the pattern and sources of energy use. Since the electrification of the village in the late 1980's, most of the households have resorted to electrical appliances for boiling water and making rice. Since the early 1990's, LPG was made available at a local shop, thus many households included gas in their portfolio of energy options.

Conclusions

Biomass is the single most important energy source for many of the small island countries in the Pacific region. Even in households that are relatively well-off, biomass sees significant use, particularly for weekend cooking, for *lovos* and BBQs, and for special functions such as birthdays, weddings and parties. People actually purchase firewood (from shops, markets, and timber mills) for this kind of special cooking.

The vast majority of the households in rural areas use open-fire stoves. Most people acknowledge that there are health problems associated with the use of such stoves. If they had the choice, most people who were surveyed would like to switch to gas for cooking. The cost of gas compared to that of firewood is the single most important factor in determining their choice of fuel for cooking.

Firewood is getting more difficult to obtain. People have to travel longer distances to collect firewood as sources are getting scarcer. This is a direct result of, on the one hand, land clearing operations, increasing population, and large squatter population, and the greater use of forest biomass for timber and for commercial fuel and land-lease problems on the other.

Biomass for cooking is the affair of every person in a household. However, with modernisation and urbanisation, while biomass will continue to be the most important supply for domestic cooking in rural areas for a while yet, major transition to non-traditional sources are rapidly occurring. Cash incomes, multiple family members in full-time employment, connections to electricity grids, availability of electrical cooking appliances, and wider supply network of kerosene and gas, has seen an increasing reliance of these sources in place of biomass.

There is a vital role for the users and for government, through its energy agencies, to focus on two key areas in regards to the use of biomass for cooking. These include the design of stoves which are energy efficient and health friendly, and re-afforestation, particularly with those species which are biomass energy efficient. A policy on biomass for cooking needs to be developed for officials to keep this matter in focus.

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Appendix 1: Photographs

An Open-Fire Stove in the Fijian village of Vakabuli, Lautoka (30/10/04)

Open-fire wood stove, used by an Indian Fijian Household in Drasa, Lautoka (30/10/04)

A very smoky open-fire wood stove in use: Indo-Fijian Household, Drasa Dam, Lautoka (30/10/04). Note the flames outside of the stove.

Firewood outside an Indo-Fijian Rural Household: Johnson Road, Drasa, Lautoka (October 30, 2004).

Appendix 2: Fiji's Biomass Energy Use Situation

Biomass Energy Use in Fiji: 1981-1992

Year	Fuel-Wood	Fw To Elect.	H/Hold	Agri.	F/Wood For HH	Bag.	Bag. To Elect.	Tot. Biom.	Bio. To Elect.
	TJ	TJ	TJ	TJ	%	TJ	TJ	TJ	%
1981	4021	40	2903	1078	72.20	9440	9440	13461	70.43
1982	4073	21	2956	1097	72.58	9714	9714	13787	70.61
1983	4220	89	3013	1117	71.40	5201	5201	9421	56.15
1984	4240	32	3071	1138	72.43	10137	10137	14377	70.73
1985	4380	112	3115	1153	71.12	7108	7108	11488	62.85
1986	4430	91	3167	1171	71.49	9689	9689	14119	69.27
1987	4382	6	3196	1181	72.93	7402	7402	11784	62.86
1988	4526	111	3224	1191	71.23	7488	7488	12014	63.25
1989	4482	29	3252	1201	72.56	9917	9917	14399	69.07
1990	4529	39	3280	1211	72.42	10185	10185	14714	69.48
1991	4537	9	3308	1221	72.91	8573	8573	13110	65.46
1992	4576	10	3335	1231	72.88	9123	9123	13699	66.67

Notes: Column 2: Total energy from fuelwood in Terajoules (1 TJ=10^{12} J); Column 3: Electricity generated using fuelwood in TJ; Columns 4 and 5: Fuelwood used in the domestic and agricultural sectors; Column 6: Percent of fuelwood used in households; Columns 7 and 8: Bagasse used in the sugar mills for steam and power generation; Column 9: Total energy from biomass; Column 10: Percent of total biomass converted to electricity.

Appendix 3: Scientific Names of Some Common Fuelwood Species

Common / Local Name	Scientific name	Common / Local Name	Scientific name
Nokonoko	Casuarina equisetifolia	Tamarind	Tamarindus indica
Mango	Mangiferea indica	Breadfruit	Artocarpus incisus
Raintree	Samanea saman	Jackfruit	Artocarpus heterophyllus
Pine	Pinus caribaea	Wild tamarind	Leucaena glance
Coconut	Cocos nucifera	Fiji Kauri	Agathis vitiensis
Guava	Psidium guajava	Loaloa, Qumu	Acacia richii
Vaivai	Leucaena leucocephala	Queensland kauri	Agathis robusta
Monkey pod (raintree species)	Albizia saman		