Enhancing Household Biomass Energy Use in the Philippines

Excerpt from Chapter 2: Strategies for Enhancing Biomass Utilization in the Philippines

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General Overview of Biomass Energy Utilization in the Philippines

Biomass largely provided energy requirements for the Philippines when tropical forests covered the islands and the population was modest. At the beginning of the 21st century, biomass energy still plays a vital role in the nation's energy supply. Nearly 30 percent of the energy for the 80 million people living in the Philippines comes from biomass. Most is used for household cooking by the rural poor. More than half of Philippine households have an income level under 5000 pesos per month (Department of Energy 1995) and will probably have little choice but to continue using biomass fuels in the future. There is an urgent need to assess and develop new options for modernizing the role of biomass in the Philippine energy economy. With rising fossil fuel prices, demand for both forest and agricultural biomass resources will increase. To lessen the environmental impact from overexploitation of these resources sustainable utilization strategies need to be explored.

The Philippines is among the most vulnerable nations to climatic instability and experiences some of the largest crop losses due to violent climatic events. As a result the country has strong self-interest in the advancement of GHG-friendly technologies such as biofuels. The Philippines could become a model for other developing nations to follow, with a broad portfolio of renewable energy sources.

Enhancing Biomass Energy use in the Household

The role of biomass in cooking at the household level

To optimize biomass fuels for household cooking, it is essential that the social and economic aspects are understood. The types of foods being cooked, where cooking occurs (rural and urban areas), family economics, and health risks all play a significant role in fuel use. It is also important to consider available fuels, how these fuels are procured, recent trends in fuel use, factors people consider when choosing cooking fuels, and the availability of biofuel sources and cooking systems that can provide more economical and environmentally friendly energy for household cooking.

Photo 1. Native forests have been depleted by using wood for household cooking and by its conversion to charcoal (as shown in the above photo). Inefficient production systems and inefficient charcoal stoves mean that only about 5% of the wood energy is recovered as useful heat for cooking. There is a large, illegal charcoal trade that persists in the Philippines. Modernizing the charcoal industry and developing new cooking systems would reduce this trade.

Cooking Habits in the Philippines

The traditional Philippine diet revolves around rice, fish and vegetables. The preferred staple food is rice, but maize is also widely eaten in the upland regions. This is particularly true for the Central Visayas and Mindanao. Meals are generally prepared in a large aluminum pot over a biomass stove. Rice or maize are cooked first followed by vegetables which cook more quickly. Fish and meat are commonly cooked in the same pot as vegetables. Dried and fresh fish are pan-fried in oil, and fresh fish and chicken are also grilled over charcoal. Maize roasting over biomass stoves is also popular. Baking is uncommon at the household level, though Filipinos enjoy purchased baked snacks. Coffee is also very popular, and water is boiled several times per day or stored in thermoses to make instant coffee. Filipinos in urban areas and towns often purchase their noon meal at a Carenderia. These small cafeteria style restaurants usually are found in urban areas where people gather or work and can also found at rest points on rural transportation routes.

School starts early in the Philippines (often about 7:20 am) and time is valuable in the morning, particularly in rural areas where transportation time is lengthy. The weather also has an important influence on cooking as gathering dry fuewood is difficult in the rainy season. Families often supplement wood cooking with charcoal and/or use more kerosene as fire starter. Open wood fires are generally made underneath pots and are supported by steel rails (photo 2). Relatively simple firewood and charcoal clay stoves are also common (photo 3).

Exposure to smoke from fuelwood stoves is high for women and children. Chimney systems are often absent or of very poor design.

Photo 2. Open wood fires commonly used for household cooking have approximately 10% conversion efficiency, and are wasteful of energy during periods when low heat is required since there is no control of the oxygen supply. More efficient wood stoves are uncommon in rural households. Wood use per household is approximately 2 tonnes/year. Cooking with firewood has a tremendous impact on the landscape ecology of the nation.

Photo 3. Simple clay stoves for charcoal and firewood are available in markets in the Visayas

Main fuels used in the Philippines

The main cooking fuels used in the Philippines include agricultural residues, fuelwood, charcoal, Liquefied Petroleum Gas (LPG) and kerosene.

Agricultural residues are defined as any agricultural byproducts such as coconut husks and shells, rice hulls, or maize cobs and stalks. These materials are often dumped into waste areas, left to rot or burned in the fields. Increasingly, these residues are being used for cooking fuels as wood supplies tighten and fossil fuel prices increase.

Fuelwood refers to any wood product directly burned. Wood is the backbone of the rural energy economy and is still used in urban areas in surprisingly large quantities. The main source of fuelwood was once tropical forests, but this land is now used for agriculture. Frequently trees such as leucaena and gliricidia are grown on farms for fuelwood purposes and branches and prunings of gemelina trees and fruit trees are also widely used. In 1998, fuelwood comprised 16.1% of the total fuel used in the Philippines, which equates to 38.3 million barrels of fuel oil equivalent (MBFOE).

Charcoal is a wood or plant product burnt into a porous carbon mass. In the Philippines, it is now mainly produced from leucaena in upland sloping areas. Charcoal is more easily transported than wood from remote hill areas. It is widely used in grilling of certain foods and is preferred in urban areas as it emits less smoke than wood.

Liquid petroleum gas (LPG) or propane is becoming a more popular fuel choice, especially in countries with large urban areas and rising income levels. It is popular with middle and upper income families because it is a clean burning, and quick cooking compressed gas with an adjustable heat output.

Kerosene is commonly used as a cooking fuel by the urban poor. It is also widely used in rural areas for lighting and fire starting. As a cooking fuel it has a relatively flexible heat output and is fast cooking, but is less user friendly because it gives off more noxious fumes than LPG.

Photo 4. Rice hulls are an unused residue at most rice mills that can be recycled for household cooking. About 1.5 million tonnes of rice hulls are available in the Philippines.

Present Use of Cooking Fuels at the Household level

The Philippines is typical of many developing countries where the majority of the population has a low income and the middle class is small. In 1995 there were 12,821,000 households in the Philippines, with 57% in the lowest income bracket (less than 5000 pesos/month) (Table 1). Unfortunately, the 1995 Philippine household survey combined 57% of the population into one income category, limiting a more detailed understanding of fuel choice relative to income level. Nonetheless, the household survey provides some valuable insights into the fuel choices made by the general populace.

Table 1. Number of households in the Philippines by income class (1995)(Philippine Energy Plan: 1999-2008)

Monthly Income Class (pesos/month)	Total Number of Households ('000)	Percentage of Total Population
Total population	12,821	100
Less than 5,000	7,263	57
5,000-9,999	3,238	25
10,000-14,999	1,173	9
15,000-24,999	666	5
More than 25,000	466	4

Rural Household Cooking

In the rural sector, the greatest use of fuelwood is among households with incomes lower than 5000 Philippine pesos (Figure 1). Considering that the number of members in the average rural household exceeds the national average, the low cost of fuelwood makes it the most viable energy source. Fuelwood is also extremely popular among the higher income rural households, which can be attributed to its availability and higher quality of food taste.

The use of other fuels varies greatly among the differing income brackets. As they are readily available and inexpensive, agricultural wastes are popular for households earning less than 5000 pesos. The majority of these low-income households have little income for purchasing fuel and rely heavily on gathering firewood and biomass residues. Currently, the fuel requirement of 55% of the rural poor is supplied by firewood, with another 25% of the requirement met through biomass residues. As the Philippine landscape is becoming increasingly agricultural in nature (deforestation and land conversion have become more widespread), the rural poor will likely be driven to rely more heavily on agricultural residues for their fuel supply instead of firewood and charcoal. Biomass residues seem to be quite popular across all income brackets in rural areas due to their availability.

In terms of more modern cooking fuels, LPG seems to be predominant in those households earning more than 10,000 pesos per month with about 20-25% of households using the fuel. LPG burns cleaner than kerosene. Charcoal is not used as a principle fuel, and like kerosene, is considered a 'dirty' fuel. However it is widely used for grilling. The rural poor use the least amount of charcoal because it is expensive and they rarely have the opportunity to enjoy fresh fish and chicken. Rural charcoal consumption is about half that found in urban areas.

Photo 5. A typical LPG cooking stove with bottled gas, a system used in more than 4 million households in the Philippines.

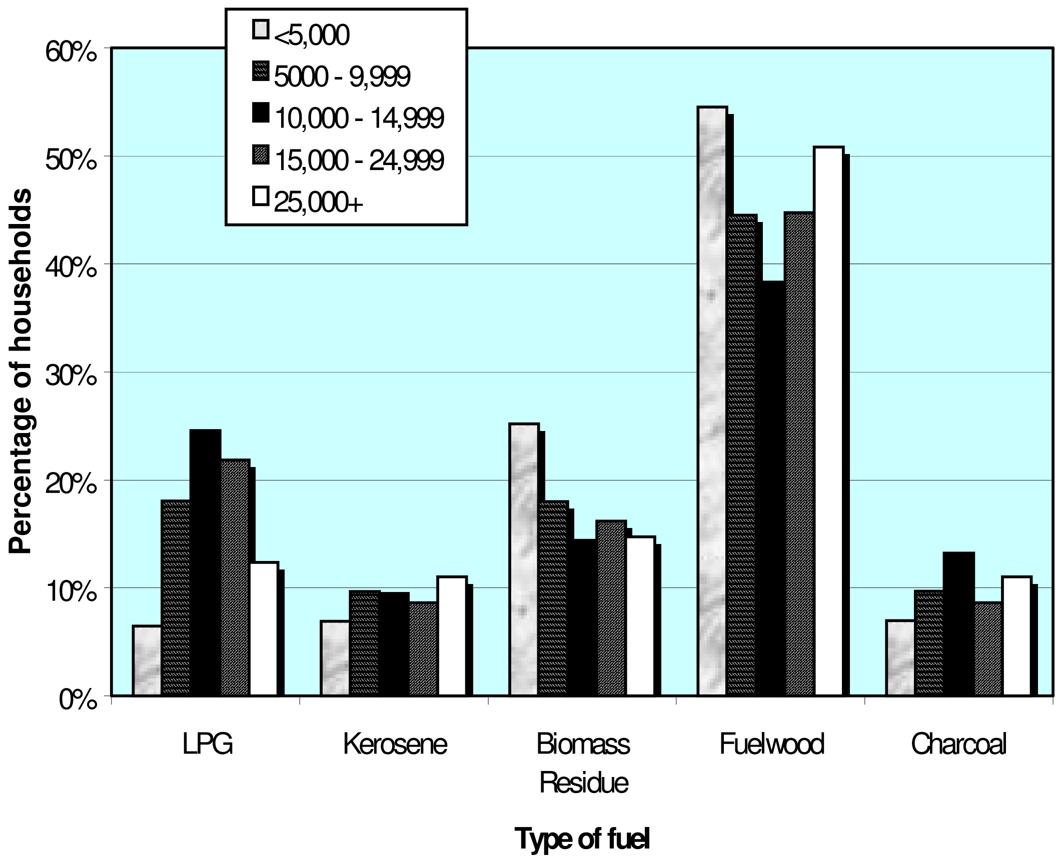

Figure 1. Percentage of rural households using fuels for cooking by monthly income (pesos): 1995 (Philippine Energy Plan 1999-2008)

Urban Household Cooking

Cooking fuel use in the urban sector differs greatly from that of rural areas for several reasons (Figure 2). The primary reason is the lack of biomass available. For example, fuelwood is not as readily available in the urban market and is more expensive. However, low-income urban households rely on fuelwood and biomass residues for over 50% of their cooking fuel. A surprising 74% of these urban fuelwood users collect all of their own fuelwood. This involves scrounging for wood at construction sites, obtaining old crates at markets, and collecting any other available wood scraps. Low income households supplement their fuelwood and biomass residue use with kerosene and charcoal. All other incomes use LPG as their main cooking fuel source with over 40% of urban households (earning 10,000 pesos or more per month) using the fuel. Charcoal and fuelwood remain a popular secondary fuel source for all income brackets, which can be attributed to the preference for grilled foods.

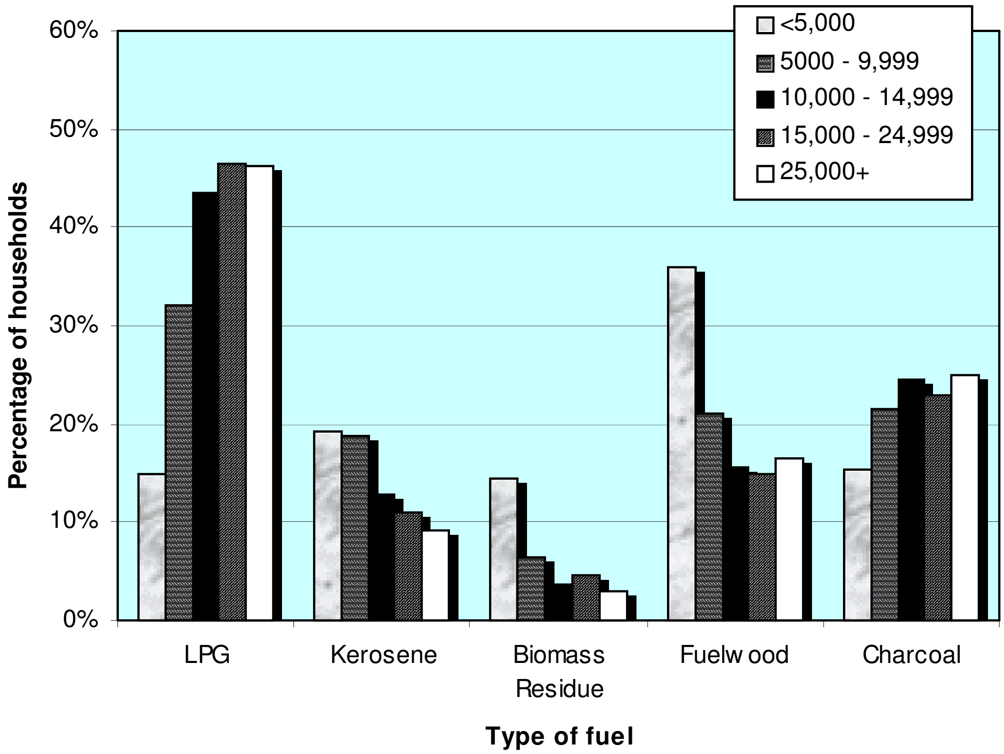

Figure 2. Percentage of urban households using fuels for cooking by monthly income: 1995 (Philippine Energy Plan 1999-2008)

Recent Trends in Household Fuel Cooking

Overall trends

Household surveys were conducted in the Philippines to explore fuel choice in 1989 and in 1995 (Table 4). The surveys suggest that increasing agricultural land base, ongoing deforestation of the uplands, and population urbanization have an important influence on household fuel use patterns. The surveys indicate an increasing trend of LPG users and LPG consumption, and an overall decline in biomass use. Kerosene consumption also rose between the two surveys, although the number of users remained somewhat constant, and the use of kerosene for direct cooking applications comprised only about 1/3rd of its total use. In the biomass sector, fuelwood use declined by 20% between 1989 and 1995, charcoal fuel consumption declined by 51%, and biomass residue use increased by 43%. Overall biomass use decreased by 15% on a tonnage basis over the 6 years. The more widespread availability of electricity in the Philippines appears to have had minimal impact on cooking fuel choice to date.

The main reason people switched their primary cooking fuel was that new fuels were more convenient (70%) and more widely available (56%). Urban users also reported that changes in income (47%) and higher prices of fuels (44.9%) were also important factors. Technology for biofuels must be modernized if biomass is to remain a primary cooking fuel in the future.

Specific Fuel Use Trends:

Firewood

Firewood consumption declined from 18.3 million tonnes in 1989 to 14.6 million tonnes in 1995 (Table 2), while the number of users increased from 7.5 million households to 8.1 million. Average household consumption of fuelwood for cooking showed a decline in per capita consumption from 342.7 kg in 1989 to 327.6 kg in 1995. Fuelwood was used almost exclusively for cooking in the home. Based on the 1995 household survey, dedicated rural firewood users were consuming 2.0 tonnes/household per year. This translates into an average 10% conversion efficiency if 3.17 GJ of delivered heat were required for cooking per household.

Photo 6. Charcoal is made by poor, small-scale upland farmers by carbonizing leucaena wood. Generally, the wood is gathered, dried and split, and placed in a shallow pit. The woodpile is wrapped with banana leaves and covered with soil or sand prior to ignition.

Charcoal

During the 6 year period charcoal consumption dropped dramatically by 51 percent. However, the total number of users increased by 41%. Overall household consumption, therefore, dropped from an average of 445 kg per year to 156 kg/yr. Clearly charcoal use is becoming less common as a primary cooking fuel. However, more people use charcoal as a secondary fuel, mainly for grilling. Overall, charcoal is not a fuel for the poor, but a product produced by poor upland farmers for moderate to upper income families mainly in urban areas. Only 60.8 percent of the charcoal used in 1995 was for cooking. Other uses were for ironing and, to a lesser extent, water heating.

Biomass residues

According to the surveys, approximately 90.6% of biomass residues used for fuel are self-collected or gathered. The annual consumption of biomass residues per capita rose from 46.4 kg (1989) to 53.9 kg (1995).

Table 2. Household fuel use in the Philippines

Type of fuel	1989			1995		
	Number of households (‘000)	percentage of households (%)	Bulk Weight (‘000 tonnes)	Number of households (‘000)	percentage of households (%)	Bulk Weight (‘000 tonnes)
Electricity (GWh)	7,236	64.7	6,845	10,760	83.9	8,134
LPG (‘000 MT)	2,449	21.9	321	4,236	33.0	503
Kerosene (‘000 m^3)	8,332	74.5	496	10,245	79.9	776
Fuelwood (‘000 MT)	7,504	67.1	18,317	8,142	63.5	14,557
Charcoal (‘000 MT)	3,509	32.1	1,565	4,941	38.5	770
Biomass residues (‘000 MT)	5,189	46.4	2,570	3,744	29.2	3,668

Source: Department of Energy, Republic of the Philippines 1995.

Fossil fuel Use Trends for Cooking

Electricity, LPG and kerosene are becoming more popular fuel sources in the Philippines. Between 1989 and 1995 the household utilization and the amount consumed of each of these fuels rose significantly (Table 2). On a household scale, the use of both LPG and kerosene increased 26% per year between 1989 and 1995.

LPG

In 1995, 491.3 million kg of LPG was consumed almost entirely for cooking. About 74% of the total LPG was used by urban dwellers. These same households used LPG as their primary cooking fuel source and, to a lesser extent, as a fuel for water heating. LPG has become somewhat of a household status symbol, and its increasing popularity is largely due to the characteristics of the fuel. People view it as very convenient and clean burning relative to biomass fuels. The unpopularity of LPG in rural communities is accounted for by the lower average income and its limited availability compared to other fuel sources (i.e. fuelwood, agriwastes, charcoal). Another drawback is that initial equipment costs are quite high.

Kerosene

In 1995, total consumption of kerosene on a household scale exceeded 750 million litres. Some 4.2 million households, or about half of all firewood users, reported an average use of 58 litres per year. Two thirds of the total kerosene consumed was for heating related purposes (i.e. bath water heating, cooking, and fire starting).

The use of kerosene differs between urban and rural populations (Figure 3). Lighting (lamps) in rural areas accounts for 49% of the kerosene due to the lack of electricity in these communities. Fire starting accounts for 40% of the kerosene used as a result of the long rainy seasons. Rural areas generally use fuelwood, not kerosene, as their main cooking fuel. Urban use of kerosene is strongly biased towards cooking applications. Of the 400 million litres of kerosene used by the urban sector, 53% was for cooking. Lighting and fire starting accounted for 23% and 24% of use, respectively. Overall, households reported kerosene to be a somewhat unsafe, dirty fuel, but convenient to use as it accelerates fuelwood cooking.

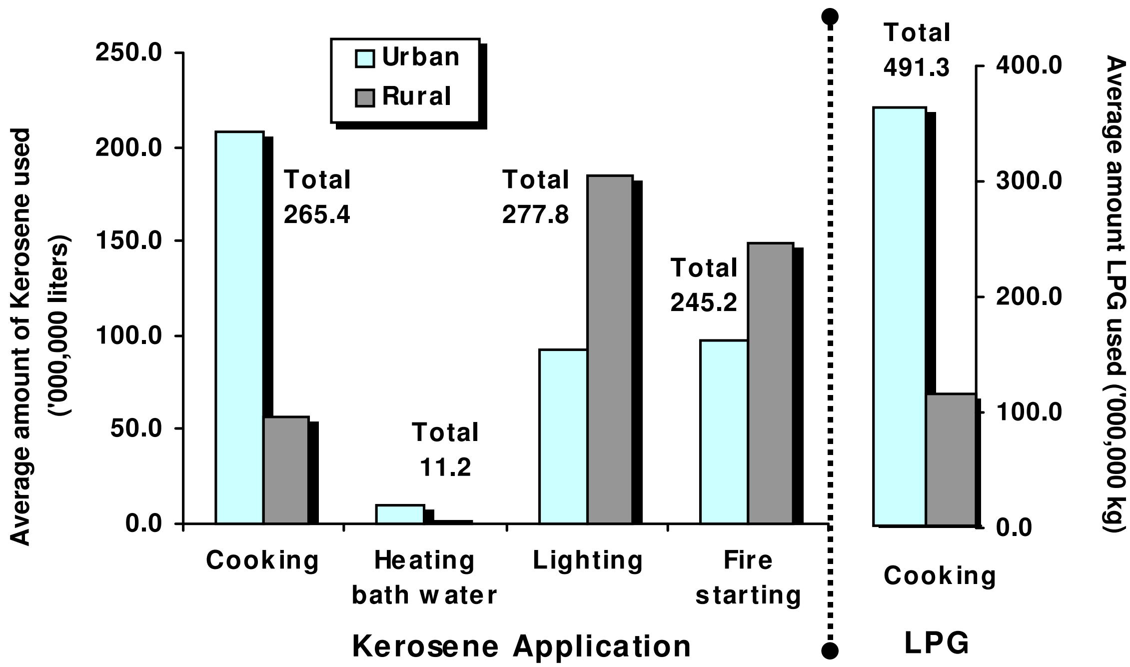

Figure 3. Use of kerosene and LPG in urban and rural areas.

Overall outlook for Kerosene and LPG

In 1986, LPG and kerosene consumption in the Philippines was 2.46 million barrels of fuel oil equivalent (MBFOE) and 2.27 MBFOE respectively. By 1998, kerosene use had increased 220% (approximately 18% per year). The 445% rise in LPG use (approximately 37% per year) by 1998 is even more remarkable. Based on 1995 calculations, virtually all of the kerosene consumed in the Philippines is used at the household level. Similar calculations for LPG show that approximately 50% is used in households. LPG use in the Philippines has been steadily rising for approximately 12 years (Figure 4). Electricity should reduce the use of kerosene for lighting applications in the future, but the continuing trend towards urbanization will likely increase the demand for convenient fuels. Biomass could play a larger in household cooking and displace fossil-based fuels like LPG and kerosene use if more convenient systems were available.

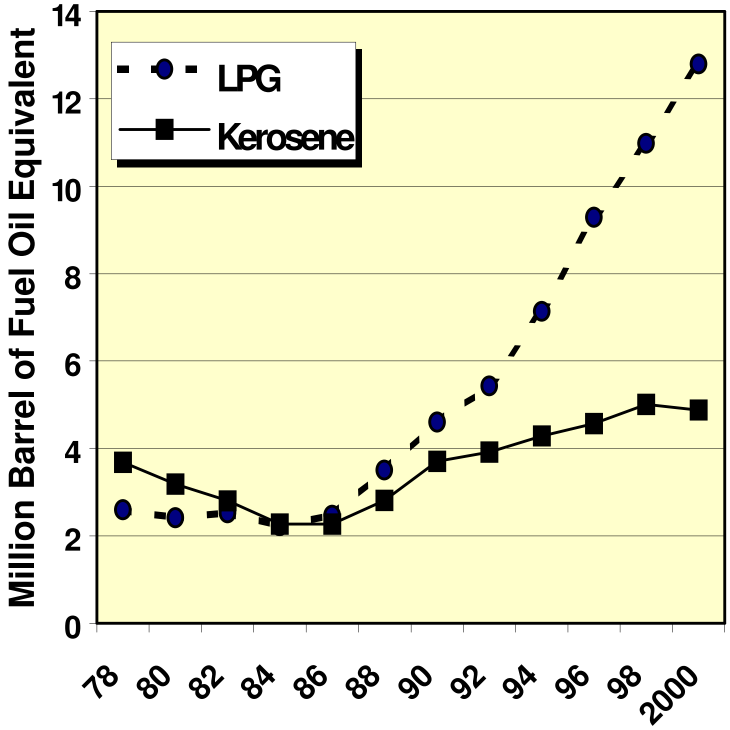

Figure 4. LPG and kerosene use in the Philippines (1978 – 2000)
Source: Inquirer Philippine Daily 2000, Philippine Energy Plan 1999-2008.

Economic analysis of Cooking Fuels

Financial analysis

Two main factors affect the cost of household cooking. First is the purchase cost of cooking equipment (Dutt and Ravindranath 1993), which usually represents a lump sum payment that acts as an obstacle for low-income households. The second factor is the annual cost of operating the fuel stove (Dutt and Ravindranath 1993). This is composed of the annual consumption of fuel plus the annualized cost of the cooking equipment. From a financial point of view, the annual cost of operating a fuel stove is a better parameter than the purchasing cost of the cooking equipment when comparing across different fuel stove alternatives.

Purchasing cost

The purchasing cost of cooking stoves was determined as the market price of the stove. The market price of LPG, fuelwood, kerosene and charcoal stoves was obtained through marketing research in the Island of Negros, Philippines. The market price of the LT-2000 Multi-Fuel stove was calculated as the cost of producing, selling and distributing the stove plus a commercial margin (Table 3, Figure 5).

Table 3 LT-2000 Multi-Fuel Stove Cost Breakdown	
	Philippine pesos
Labour	P115
Materials	P163
Fixed	P20
Contingency	P35
Marketing & margin	P67
Total	*P400*

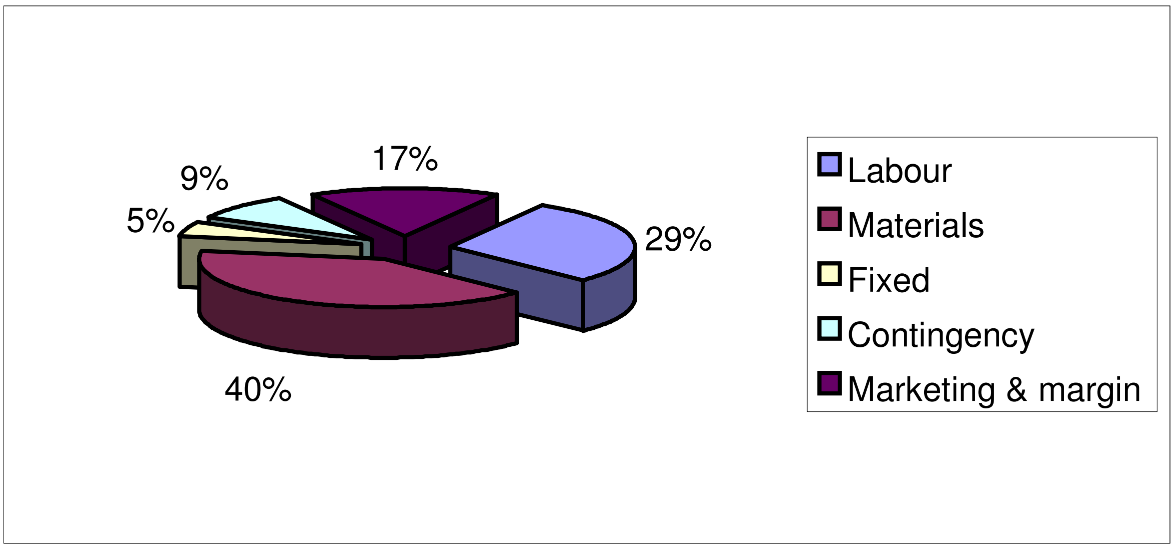

Figure 5: LT-2000 Multi-Fuel Stove cost breakdown

Table 4 and Figure 6 show that the LT-2000 Multi-Fuel stove is cheaper than most alternatives. LPG[1] and kerosene stoves are three to seven times more expensive than rice hull stoves. Low efficiency stoves that use fuelwood and charcoal however are significantly cheaper (20-75%) than the rice hull stove. Low-income households usually cannot afford to buy (or cannot access) the most efficient biomass stoves, so they use low-efficiency ones. Rice hull stoves are available at a modest cost and allow low-income households to access a more efficient cooking system that does not require a large initial investment in equipment.

[1] The cost of a LPG stove includes the cost of buying one gas bottle.

Table 4. Purchase cost of cooking equipment										
Fuel	LPG	Kerosene	Fuelwood	E-FW	H-E-FW	Charcoal	E-Charcoal	HE-Charcoal	Rice Hull	Pellet
Cost (Pesos)	2800	1200	115	315	800	115	315	800	400	1000

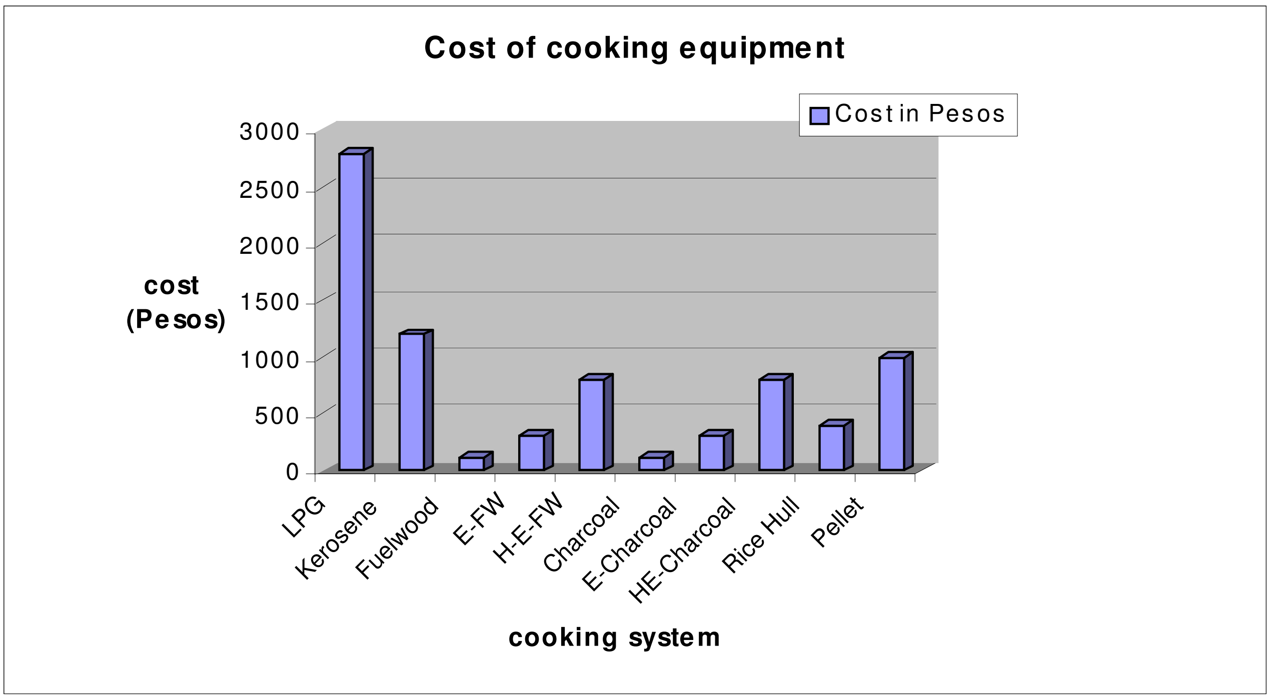

Figure 6. Purchase cost of cooking equipment

Annual cost of operating cooking stoves

The annual cost of operating a cooking stove has two components. The first is the cost of the fuel consumed during one year of regular use. The second component is the annualized cost of the initial investment required to purchase the cooking equipment. The cost of fuel is determined by multiplying the quantity of fuel consumed by the price of the fuel to the consumer. Fuel consumption per year by a household was only available for LPG and fuelwood (Dept. of Energy, Republic of the Philippines 1995).

Kerosene, charcoal and rice hull consumption was determined analytically, using data on energy used by a household per year, energy content and thermal efficiency of the corresponding fuel, and the following equation[2]:

$$\text{Fuel consumption} = \frac{\text{Energy used per year}}{\text{Thermal efficiency x Energy content}}$$

The price to the consumer of the different fuels was obtained from statistical reports (Dept. of Energy, Republic of the Philippines 1995) and from marketing research in the Island of Negros.

The type of stove and energy content of the fuel directly affect the amount of fuel consumed by a cooking system (Table 5). The type of stove determines the heat efficiency range and the flexibility of heat output control. Higher heat efficiency or broader capacity to control the heat output of the stove is associated with lower fuel consumption. In the Philippines rice is simmered after boiling, and lack of heat control makes fuelwood-cooking systems energy inefficient. LPG, kerosene and charcoal stoves allow better control of heat output, thereby improving efficiency. Programs to improve cooking stoves have been widely implemented outside of the Philippines and have in many cases successfully increased the heat efficiency of cooking systems, thus decreasing the amount of fuel consumed in cooking.

The cost of an energy source per unit of energy delivered takes into account the efficiency of the cooking system as well as the fuel's energy content (Table 6). Fuels that have high energy content and are generally used in efficient cooking systems (LPG and kerosene) are usually more expensive than fuels with a lower energy content used in less efficient stoves (fuelwood and agricultural residues). Electricity presents a high cost per unit delivered energy because the savings due to increased efficiency and energy content are offset by higher prices. Rice hulls are a cheap alternative per unit of delivered energy because of the low cost of acquisition. Charcoal represents the most expensive fuel choice because it has a low efficiency and a high price.

[2] It is assumed that an equal amount of delivered heat energy (3.17 GJ/year) is required to cook a typical meal for a typical household using different fuels and stoves.

Table 5. Energy Content, fuel cost and cost / unit energy of various cooking fuels						
	Electricity	LPG	Kerosene	Charcoal	Fuelwood	Rice Hull
Energy Content (*MJ/unit*)	3.6 MJ/kWh	45.5 MJ/kg	35 MJ/L	28 GJ/tonne	16 GJ/tonne	14.7 GJ/tonne
Cost (*Philippine pesos-p/unit)*	3.1 p/kWh	25 p/kg	15 p/L	7380 p/tonne	2290 p/tonne	500 p/tonne
Cost per unit energy *(pesos/GJ)*	850 P/GJ	549 P/GJ	400 P/GJ	264 P/GJ	143 P/GJ	34 P/GJ
Heat efficiency range (*%*)	*55 - 75%*	*55 - 65%*	*45 - 55%*	*15 - 35%*	*10-25%*	*10 - 25%*
Cost per unit *delivered* energy - (*pesos/GJ*)	1133-1545 P/GJ	845-998 P/GJ	727-889 P/GJ	754-1760 P/GJ	572-1430 P/GJ	136-340 P/GJ

Source: Department of Energy, Republic of the Philippines 1995, Inquirer Philippine Daily 2000 (see Appendix 2.3).

The annual cost of equipment was estimated using the function PMT in an Excel spreadsheet. The function PMT in Excel can be applied to calculate an annuity, given a present value, an interest rate and a period of time for the investment. In this case, the present value is the purchasing cost of the cooking equipment and the period of time is the life span of the cooking equipment. The interest rate used is an average of the lending interest rates published by the Central Bank of the Philippines over the period 1996-2000 (14.4%).

Table 6. Comparative Economics of cooking stoves and fuels										
	LPG a	**Kerosene** b	**Fuelwood** c	**E-FW** d	**HE-FW** e	**Charcoal** g	**E-Charcoal** h	**HE-Charcoal** I	**Rice Hull** f	**Pellet** j
Annual equipment cost	728	520	115	192	347	115	192	347	173	434
Cost of fuel per year	2900	2534	4431	2592	1816	5572	3343	2384	720	2095
Total Cost in Pesos	**3628**	**3054**	**4546**	**2785**	**2163**	**5687**	**3535**	**2731**	**893**	**2529**

Considering the annual cost of operating a cooking stove using purchased fuels, the LT-2000 stove is the cheapest alternative available (Table 4, Figure 7). Operating the stove costs about 33-42% as much as operating the cheapest fuelwood and charcoal stoves, and 25% as much as operating an LPG stove. The main reasons for such a large difference are that the LT-2000 stove is cheaper than most alternatives, and that rice hulls are largely available for free. The only cost to households is the cost of transportation from the mill to the house.

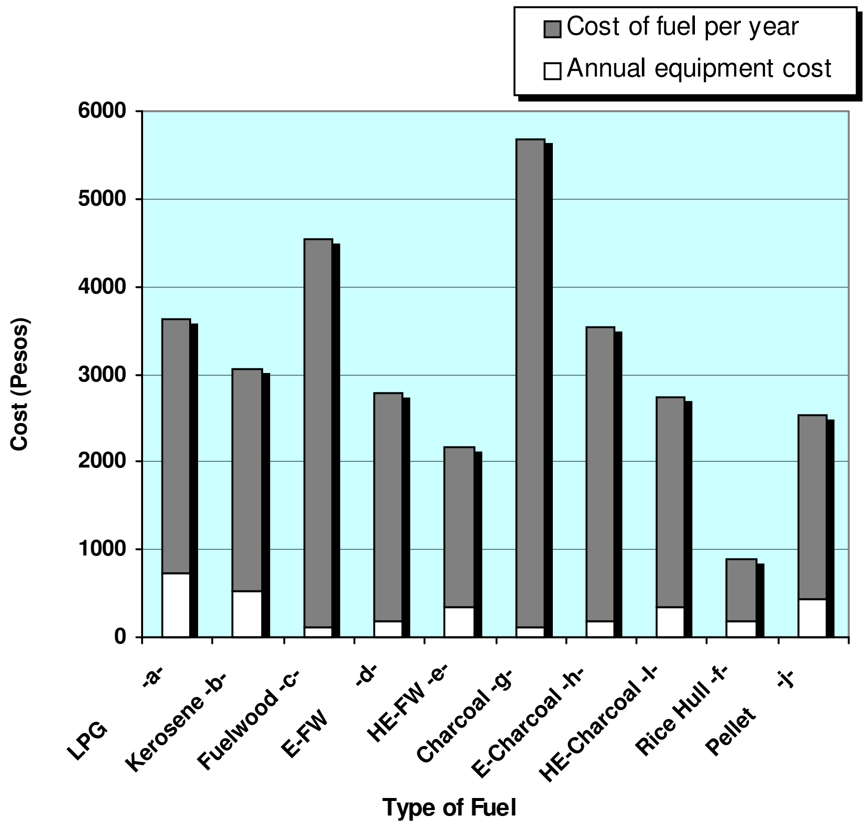

Figure 7. Annualized cost of cooking equipment

Other economic components

Financial aspects do not constitute the only factors considered by households when making a decision on which cooking system to adopt. Other important characteristics include convenience, aesthetics, time requirements, smoke emissions and health risks.

Convenience refers to availability/accessibility of fuel supply, the adaptability of the cooking stove to local food preferences and cooking habits, and installation and maintenance requirements among others. Time requirements refer to the time spent acquiring or gathering fuel, and time spent cooking. Smoke emissions are important when using biomass fuels as they generate considerable dirt and respiratory problems. Health risks are associated to the chemicals released in the combustion process and present in the fuels and their ashes. Aesthetics may also play an important role, as cooking systems can be seen as a symbol of status.

Characteristics of the LT-2000 Multi-fuel stove identified during a pilot field-testing program on the island of Negros in 2001 by REAP-Canada are summarized in Table 7. These and other characteristics have an influence on the economic value of the stove. Thus, considerable effort has to be devoted to quantifying the stove's economic value and how this affects households acceptance of the cooking system. Previous experience with stove programs has shown that inconvenience, poor aesthetics and smoke or health problems can offset the financial advantages provided by a new cooking system (Leach and Mearns 1988).

Barnes et al (1994) suggested that efforts be directed at:

1. Marketing research and surveys to assess market potential
2. Alleviating smoke and health problems
3. Adapting stove design to consumer tastes, preferences and cooking habits
4. Engaging local artisans in the design and production processes
5. Creating local institutions and developing local expertise
6. Setting up mechanisms for obtaining credit

Table 7. Characteristics of the LT-2000 Multi –Fuel Stove

Advantages	Disadvantages
• Rapid cooking speed • High heat output • Modest emission of pollutants compared to fuelwood stoves • Safe use in the house compared to fuelwood • Reduce labour requirement for wood collecting • Capable of burning other fuels (coconut husks, maize cobs, pieces of wood), which saves the user to buy other stoves and resolves concerns about rice hull availability	• Handling of ash may present a health risk for users, because of the high content of silica in rice hull ash which can cause health problems. • Somewhat tedious requirement for tapping during the cooking process to control fuel burning and heat output.

Opportunities for using the LT-2000 Multifuel Stoves

In the Philippines there are approximately 1.5 million tonnes of rice hulls produced that are recoverable on an annual basis (Chapter 1). This source of biomass energy could be effectively harnessed by using the LT-2000 in rural areas and agricultural towns where rice is processed. This stove could have a significant impact on cooking systems and bioenergy utilization if large quantities of stoves were available. Burning rice hulls in this stove represents a high value application: for example, as a substitute for LPG, 1.44 tonnes of rice hulls saves $58 US in LPG fuel purchases. This end use application provides a much higher value than other bioenergy uses including crop drying and power generation. In addition to rice hulls, the stoves are capable of burning large volumes of maize cobs, chopped coconut fronds and coconut husks identified in Chapter 1. These fuels improve the convenience of the LT-2000 as they reduce the amount of care needed to maintain the heat output relative to rice hulls. Additionally, the use of multiple fuels eases seasonal supply concerns of rice hull availability. Advantages of the LT-2000 include its rapid cooking speed (the stove boils water in 5-7 minutes, comparable to LPG), its high heat output, its reduced emission of pollutants compared to fuelwood stoves and its relatively safe use in the home. It also enables rice hull ash to be recycled efficiently back into farming systems or gardens. More complicated rice hull combustion systems are available and can be used successfully. Overall, the LT-2000 appears to be a promising means of utilizing rice hulls and other agricultural residues.

More research is needed on stove design, cost and production. In particular, efforts should be directed towards reducing emissions, improving user convenience and reducing stove production costs. Marketing studies should be conducted to assess the potential of the stove as well as to determine the need for credit mechanisms that can alleviate the financial burden to potential buyers, especially low-income households.

Photo 7. Communities in the Philippines are extremely interested in the LT-2000 stove. Fueled by residual hulls from rice production, this low-cost stove produces modest levels of smoke, is simple to start, and has a high heat output. Rice hull has the lowest annualized cost of the purchased fuel systems in the Philippines (Figure 7)

Photo 8. High efficiency stoves completely burn the fuel being used and effectively transfer the heat to the pot, thus reducing the amount of fuel needed for cooking. An important fuel saving feature is an adjustable heat output, for boiling then simmering rice. Sufficient energy is needed to replace heat losses during the latter part of the cooking cycle. Greater control of heat output would improve user acceptance of improved biomass cooking stoves.

Opportunities for using the Pellet Fuel Stoves

Pellet fuel stoves are one of the most promising approaches to modernizing biomass-cooking systems, especially as a substitute for fossil fuel and charcoal cooking in urban areas. The rising price of fossil fuels could encourage the success of pellet stoves in many developing countries where wood resources are increasingly limited and fossil fuels prohibitively expensive. Pellet fuel cooking has already begun to be more widely used in some developing countries such as Ethiopia. Napier grass (Chapter 1), sugarcane trash and wood wastes could be used as potential feedstocks to fuel these stoves. Pelletized biomass enables more efficient combustion relative to other biomass forms and makes fuel convenient to transport and store for consumers. Significant improvement in pelleting technologies (Samson *et al.,* 2000) and small cook stoves suitable for burning these fuels are under development (Reed and Larson, 1996, Drisdelle, 2000). Advances in pelleting technologies will significantly enhance the potential for the widespread introduction of pellet fuel stoves, as well as larger stoves and furnaces. Pelleting studies and commercial experience indicate that herbaceous biomass sources such as grasses have higher throughput rates and are less expensive to pellet than wood fuels, as they have a more pliable fiber. Unlike other biomass processing systems, the production of fuel pellets is not energy intensive. An energy analysis of grass production, pelleting and delivery indicated a 14.5:1 energy output to input ratio for fuel pellets made of perennial grasses (Samson *et al.,* 2000). The stove has the potential to greatly reduce the exposure of women and children to air-borne pollutants, reducing respiratory illnesses. A stove with an efficiency of 45 to 50% and a cost of 1000 pesos appears to be an achievable target with the current understanding of pellet stove manufacturing and pellet combustion.

Photo 9: Prototype CPC Turbo (Wood-Gas) Stove suitable for burning pellets (Reed and Larson, 1996)

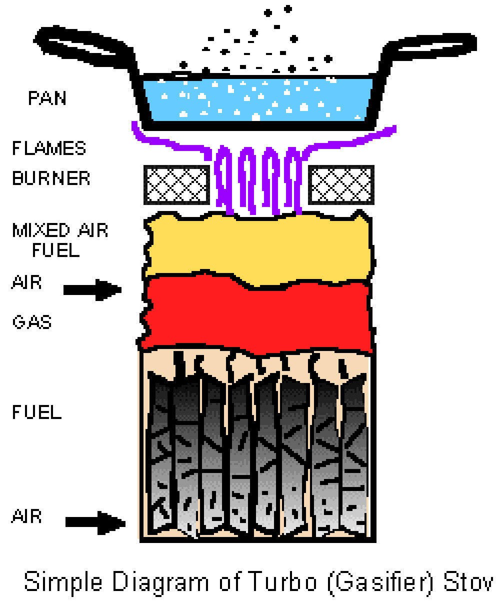

Figure 8: Simple Diagram of Turbo (Gasifier) Stove

Health Issues

Petroleum products produce far less smoke and suspended particulate matter within the home than biomass fuels. The combustion of biomass can produce carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_x), fluorine, suspended particulate matter, and other products of incomplete combustion. Within the home, these compounds are often many times more concentrated than health standards recommend, and can exceed pollution levels of the most polluted industrial cities. Inhalation of these products can lead to serious respiratory problems, including silicosis-related diseases, and birth defects. In densely populated areas it is essential that efficient combustion stoves are introduced to avoid air pollution problems.

Respiratory diseases

Respiratory diseases such as chronic bronchitis and lung/throat cancer are a common health problem in cultures that rely heavily on biomass as a fuel source. In many developing nations, young children are especially vulnerable to lower respiratory tract infections (RTI). A 1980 study in Indonesia showed that respiratory illness caused 28.8% of the deaths in children aged 1-4, second only to diarrhea (36.9%) (Achmadi, 1992). Investigators in Nepal found a strong relationship between the incidence of acute respiratory infections in children and the number of hours spent by the fire (Pandy, 1992). A study in Gambia involving

500 children under the age of 5 showed that in confined huts, young girls carried on their mother's backs were 6 times as likely as other children to suffer from acute respiratory illnesses (Smith, 1987).

Adults are also susceptible to respiratory illnesses. Because women are largely responsible for meal preparation in developing countries, they are exposed to particularly high quantities of indoor air pollution. For example, the quantity of benzo-alpha-pyrene (BAP) to which the average rural woman is exposed to in a day is equivalent to smoking 450 non-filter cigarettes (Sims and Kjellstrom, 1992). Exposure to carcinogenic poly-aromatic hydrocarbons (PAHs) contained in smoke significantly increases the risk of lung cancer. Studies in China have shown that for women over 45 years of age, the incidence of various respiratory problems is higher for those who cook with coal instead of gas (Hong, 1991) (Table 8).

Silica and its health risks

Silica (SiO_2) is a constituent of the ash produced by the combustion process. Different types of biomass fuels contain different quantities of silica. The International Agency for Research on Cancer has classified silica as a human carcinogen. Long term inhalation of airborne silica particulates can cause lung cancer or other related health problems. As rice hull ash contains high levels of silica (~15%), its use as a biomass fuel presumably increases the risk of developing silicosis-related illnesses, and care should be used in handling the ash.

Table 8. Respiratory diseases/symptoms in women using different cooking fuels (age ≥45)

Disease/symptoms	Coal users (%)	Gas users (%)
Cough	40.1	17.7
Productive cough	25.6	12.9
Shortness of breath	25.6	9.7
Chronic Bronchitis	24.6	11.8
Emphysema	10.1	2.2
Bronchodilatation	6.2	1.6
Asthma	7.3	3.3

Photo 10. In the Philippines, many women are frequently exposed to indoor air pollution from inefficient firewood cooking and poorly designed chimneys, resulting in chronic respiratory problems that can lead to early mortality.

Birth defects

More recent studies in China have shown that children born into homes that use coal for cooking or space heating have higher rates of birth defects. Furthermore, there is a strong correlation between the time of conception and the rate of birth defects. Children conceived in coal-heated homes during the winter months (when indoor air pollution is highest) have increased rates of birth defects. Unborn children are also at a greater risk of suffering birth defects if their mothers spend long periods indoors (Hong, 1991).

Other possible health effects

Studies in India have suggested that indoor smoke could increase the risk of ailments such as tuberculosis, blindness, and perinatal effects (stillbirth, low birth weight, and death during the first two weeks following birth). Strong evidence points to the danger of acute respiratory infections in children under 5 years of age, chronic lung disease in women, and lung cancer in women who cook with coal (Smith, 1998).

Improving the safety of biomass stoves

Improvements in cooking stove design can reduce the health implications associated with biomass fuels. Stoves that burn fuelwood and agricultural residues efficiently require less fuel and emit fewer pollutants. Additionally, stoves that are equipped with a chimney system and an ash trap or holder can reduce pollutants in the home. It is not possible to completely eliminate all pollutants, but the combination of an efficient burning stove and a proper chimney system can significantly decrease indoor air pollutants and reduce health risks in the home.

2.7 Environmental Issues

Recently, improved cooking stove programs have been viewed as a possible means to reduce greenhouse gases emissions. Approximately 75% of biomass fuel used in the Philippines is consumed by households for cooking purposes (ARREEC 1996). A substantial portion of the total GHG's emitted is from biomass fuels. Thus, there is great potential for cutting down emissions through the improvement of cooking stoves.

Multi-fuel stoves represent an alternative to the burning of biomass fuels and can reduce emissions of greenhouse gases. The LT-2000 Multi-fuel stove is designed primarily for rice hulls as a fuel, but is also capable of burning other crop residues, such as coconut husks, maize cobs, sawdust, etc. In the Philippines, rice mills produce approximately 1.5 million tonnes of rice hulls per year that could be recovered for biomass applications (Chapter 1). Rice hulls are usually treated as an unusable residue and commonly disposed of by burning in fields (Chapter 1), and as a consequence, greenhouse gases are released into the atmosphere. The use of this residue as a fuel for cooking stoves would capture the energy that would otherwise be lost to the atmosphere, while at the same time replacing other fuels such as fuelwood, charcoal, kerosene, and LPG. Thus, the use of rice hulls as a cooking fuel would not increase the emission of greenhouse gases, and the replacement of other fuels decreases net GHG emissions.

One of the potential benefits from developing the LT-2000 is the reduction in land use required per household for cooking. With the introduction of the LT-2000, 1.4 tonnes of rice hull replace almost two tonnes of gathered fuelwood. The current production of leucaena firewood is approximately 10 tonne/ha/year, thus 7 tonnes of rice One 1 ha of napier grass converted into fuel pellets, could provide cooking fuel for 50 families. This is because of the high yield (20 ODT/ha) and a high end-use conversion efficiency (45% in the pellet cooker) so only 400 kg of fuel are required per family. Approximately 100,000 ha of napier grass converted into pellets could replace 50% of all LPG imports for fuel cooking and one third of all fuel wood requirements (5 million tonnes) in the Philippines.

Conclusions and Recommendations

Although the use of petroleum based cooking products such as LPG and kerosene is increasing in the Philippines, biomass fuels will always remain popular. The annualized fuel costs of LPG and kerosene systems are well above the economic means of the majority of the populace, and rising costs are making them more inaccessible. Cheaper alternatives such as fuelwood and biomass residues still remain viable solutions for the households with lower income. Although these fuels are not as clean burning as LPG, improvements in fuelwood stoves and innovations in residue stoves could provide efficient alternatives. The promotion of such technologies would help alleviate the burden of purchasing expensive imported fuel products and reduce the impact of fuelwood demand of fuelwood harvesting.

Improvements in biomass cooking must:
- Decrease cooking time
- Reduce smoke and suspended particulates in the atmosphere, providing a healthier environment within the home.
- Be designed with traditional cooking methods in mind
- Be cost effective over their life span.
- Minimize fuel consumption, and hence reduce fuel purchases
- Be aesthetically pleasing to the user and not offend others in the community.

This analysis indicated that the LT-2000 and a high efficiency pellet stove are promising options for providing economical, convenient and environmentally responsible cooking options. A significant research and development effort is required for these systems to facilitate rural development, poverty alleviation, community health and climate change mitigation.

References

Achmadi, U. F., 1992. "Health Aspects of Biomass Fuel Use in Households: The Indonesian experience". Working paper from Indoor Air Pollution from Biomass Fuel, World Health Organization.

ARREEC (Asian Regional Research in Energy, Environment and Climate). 1996. "Status of Biomass Energy Technologies: Philippines." p.15.

Barnes, Douglas, Keith Openshaw, Kirk Smith and Robert van der Plas. 1994. What makes people cook with improved biomass stoves?. World Bank Technical Paper Number 242, Energy Series.

Department of Energy, Republic of the Philippines. 1995. *1995 Household Energy Consumption Survey*. Main Report and Annexes. p. 192.

Drisdelle, M. (2000). Personal communication. Also refer to www.pelletstove.com.

Dutt, Gautam S. and N.H. Ravindranath, 1993. Bioenergy: direct applications in cooking. In Renewable energy: sources for fuels and electricity, Ed. Thomas

Hong, C.J. 1991. "Health aspects of Domestic Use of Biomass Fuels and Coal in China". Working paper from Indoor Air Pollution from Biomass Fuel, World Health Organization, 1992.

Inquirer Philippine Daily, 2000. http://www.inquirer.net/issues/nov2000/nov11/news/news_15.htm, visited on November 11 2000.

Leach, Gerald and Robin Mearns, 1988. Beyond the woodfuel crisis: people, land and trees in Africa. London, UK: Earthscan Publications Ltd.

Pandy, M. 1992. *Health Aspects of biomass use in Nepal and interventions implemented or under consideration.* Working paper from Indoor Air Pollution from Biomass Fuel, World Health Organization.

Philippine Energy Plan. 1999-2008. Republic of the Philippines: Department of Energy. http://www.doc.gov.ph/PEP-Demand.htm

Reed, T. and R. Larson. (1996). "A wood-gas stove for developing countries." http://www.ikweb.com/enuff/public_html/TI.htm

Samson, R., P. Duxbury, M. Drisdelle and C. Lapointe. 2000. "Assessment of Pelletized Biofuels." PERD Program, Natural Resources Canada, Contract 23348-8-3145/001/SQ.

Sims and Kjellström, 1992. "Biomass Fuel and Indoor Air Pollution: Underlying Issues from a Social Perspective". Working paper from Indoor Air Pollution from Biomass Fuel, World Health Organization.

Smith, K.R. 1987. "Biofuels, Air Pollution and Health: A Global Review". Plenum Press.

Smith, K.R. 1998. "Overview of the Indian National Burden of Disease from Indoor Air Pollution". Prepared for Conference on Health and Environment, July 7-9, 1998.