Mitigating Greenhouse Gas Emissions through Energy Supply and Demand Options for Cooking in Developing Areas

R. A. Samson, Resource Efficient Agricultural Production, Box 125, Glenaladale House,
Ste. Anne de Bellevue, Quebec, Canada, H9X 3V9, reap@interlink.net

T.A.Lawand and R. Alward, Brace Research Institute, Macdonald Campus of McGill
University, Ste. Anne de Bellevue, Québec, Canada H9X 3V9

INTRODUCTION

In rural areas, cooking is one of the largest energy consuming activities in less developed countries. In fact, about one half of the total population cooks with biofuels. Firewood and charcoal from forests has been the major source of this energy. From a greenhouse gas standpoint, cooking with biofuels causes no net increase in atmospheric CO_2 as long as a renewable supply of plant material is maintained to recycle the CO_2 back into the landscape. This closed carbon loop biomass fuel systems differs from that of fossil fuels, where carbon from long-term stored sources is burned and no system is available to reabsorb it. Unfortunately forests in less developed countries are, for the most part, not manged in a sustainable way. In less developed countries, forests continue to be devastated through a combination of factors, such as land clearing for subsistence food production, plantation agriculture and forestry, as well as use of forests for timber and pulp extraction, and fuelwood and charcoal production. However it has been identified that the use of firewood does not necessarily or frequently lead to deforestation and that other factors are primarily responsible. (ERG, 1986).

Deforestation has been identified as a major source of increasing CO_2 into the atmosphere in several ways:

Directly

Carbon dioxide levels in the atmosphere have increased because of a reduced standing biomass in the landscape. Also as biofuel sources of energy disappear or become prohibitively expensive, people in developing areas are often forced to use fossil fuels, such as kerosene or liquid petroleum gas (LPG) for cooking which increases atmospheric CO_2 emissions compared to closed loop biofuels.

Indirectly

Deforestation also increases energy costs as a result of reduced water supply, which requires greater use of fossil fuels for irrigation and/or reduces food production per area.

As well, deforestation reduces fish catch, through siltation and increased damage due to flooding.

FUTURE OUTLOOK

Much of the developing world now suffers from the lack of an affordable and sustainable fuel supply. The current situation can be best described as one where developing areas are gradually fuel switching from unsustainable biomass systems to unsustainable fossil fuel systems. In poor countries the deforestation problem is particularly troublesome as the rural poor often cannot afford to switch to fossil fuels, and switch to burning crop residues and dung, which leads to degrading soil fertility.

The general trend for fuel consumption by income is summarized in Table 1 (although there are regional exceptions). The lowest cost fuel for cooking is generally wood, followed by charcoal. When incomes rise, consumers switch to higher cost liquified petroleum gas (LPG) and kerosene cooking because of greater convenience and less household pollution. Greatest convenience and cost is associated with electrical cooking. Similarly, when economies collapse (as recently occurred in south- east Asia) or environmental situations deteriorate, fuel switching can be a backward process (e.g. firewood to dung). It is evident that a more convenient biomass fuel could develop a market between the charcoal and liquified petroleum gas cooking systems. Another problem with the higher priced fuels is that as higher grades of energy are used, higher CO_2 emissions are generally associated with the fuel. For example, charcoal has more CO_2 emissions than wood and increases the forest land requirements per household (Dutt and Ravindranath, 1992). Similarly, most country grids of electricity have more emissions associated with them than direct cooking with kerosene or LPG. A convenient, mid-cost, closed loop C biofuel could play an important role in contributing to the creation of a sustainable rural energy supply system. It could also possible play an important role in urban areas if sufficient biofuel production could be achieved.

Table 1. Range of Fuels and Relative Costs

Fuel	**Relative Cost and User Preference**
Electricity	high
Liquified petroleum gas (LPG)	
Kerosene	
	medium

Charcoal	
Wood	
Crop residues	low
Dung	

Adapted from Dutt and Ravindranath (1992)

Overall, two main options can be considered to create a more greenhouse gas friendly means of meeting energy for rural cooking needs:

- reduce demand of biomass fuel through more efficient stoves
- increase the biofuel supply

REDUCING ENERGY DEMAND FOR COOKING IN RURAL AREAS

Surveys of rural energy demand were not consistently undertaken until the 1970's. In fact, in some Government Five-Year Plans at that time, the use of fuelwood (by far the largest energy source consumed in most rural developing areas) was not even taken into account. In Sénégal a survey of rural energy consumption was taken which showed that four-fifths of the energy in rural developing areas was used for food preparation and cooking (BRI, 1976). This was and still is particularly true for villages which do not have a lot of agricultural based industry. Given this preponderance of energy used for cooking, it was obvious that to have any impact on reducing the energy demand in a rational and sustained manner in rural areas, one would have to reduce familial and communal energy consumption.

There have been many measurements in the subsequent two decades of the actual consumption of energy used for cooking by traditional means. It should be remembered that even the classical 3-stone approach to cooking, using firewood as a fuel, produces a wide variety of energy consumed per person per day. Tchinkel et al, working in Tunisia in the mid 1970's, estimated that the daily consumption of dry firewood was in the order of 1.5 kg/person/day (Lawand, 1979). Makhijani at that time quoted studies in Gambia and India in which the fuel consumption varied from 0.7 to 1.0 kg/person/day for slow burning fires. (Lawand, 1979).

When one considers that in this time period in many African and Asian countries, often more than 90% of the population was using either fuelwood or charcoal, it was evident that significant savings could be affected if stoves were developed that reduced the consumption by 30 to 50% (BRI, 1976).

SOME ENERGY SAVING DEVICES

Over the intervening decades, considerable effort has led to the introduction and development of improved fuelwood and charcoal stoves. This has been primarily aimed at the development of individual family cookstoves which were able to, in most cases, reduce the biomass energy consumption by half compared to traditional open fires (Brunet and Kandpal, 1987). Stoves were typically the ceramic/pottery type such as in Thailand (BRI, 1992) or sheet metal (Brunet and Kandpal, 1987). The objective has always been to develop a locally based industry for the production of fuel efficient cookstoves, thus reducing total biomass energy demand while upgrading local skills and employment opportunities.

As well, a reduction in biomass energy demand results in a reduction of the amount of trees that are removed from the environment. The advantages of this are:

- Enhancement of local water resources
- Reduction of soil erosion particularly in hilly areas
- Reduction in the amount of particulate matter in the areas where the cooking is being undertaken thus enhancing the living environment of the local population (in particular women who generally undertake most of the cooking)
- The additional presence of trees increases the absorption of carbon dioxide from the environment

There are also other financial and socio-cultural benefits to maintaining forests in the local environment, such as the continuance of the diverse use of these forests by the local communities. The development of more efficient stoves has not been without concerns however. Care must still be taken to utilize these cookstoves in reasonably well-ventilated environments to avoid exposure to noxious fumes emanating from improved cookstoves.

Some specific biomass energy saving devices are discussed below. In arid and semi-arid areas, where the availability of biomass fuel is considerably reduced, the use of solar cookers can and should be given serious consideration.

RECENT DEVELOPMENTS

Community Fuelwood Stoves

The Brace Research Institute, amongst others, has been instrumental in working with collaborators in Argentina, in addressing the need for community fuelwood stoves. In the larger urban areas, there are comedores or community kitchens located in different suburbs, to assist lower income families to have a decent noon-time meal. Money is provided by the municipalities to community groups in each barrio where meals are prepared and served to 100 to 150 children as well as older community residents. The women in the community primarily provide the labour and the cooking fuel. In order to reduce the effects of deforestation in the local areas around Salta, in Northern Argentina, community based fuelwood stoves were developed (BRI, 1997). A diagram of one of these stoves is shown (see Figure 2). The principle of operation of these stoves is simple – the fire is concentrated in a firebox located immediately below the cooking chamber where a large 50-litre pot is placed inside a cylindrical outside wall. The heat from the firebox rises and impinges directly on the base of the cooking pot. In addition, exhaust gases from the fire travelling in the annulus between the cooking pot and the outside wall, also transfer heat into the sides of the pot. As a result, the efficiency of use of the energy from the fire is greatly enhanced resulting in quicker cooking times and a reduction in the quantity of fuel used.

For example, studies in Argentina using these large community cookstoves, showed a mean specific fuel consumption of 100 grams of wood per kilogram of food cooked in-situ in the community kitchens. This compared to 700 grams of fuel per kilogram of food cooked at parallel studies in the same community kitchens using the 3-stone fire traditionally used at these locations (BRI,1997). As a result, community cookstoves were fabricated and distributed to 32 community kitchens (in the period 1994/1995). A recent survey of the performance of these community cookstoves has been undertaken in 1995 indicating that a good number of them are still in use (Stoll and Giroux,1999).

The advantage of this type of stove is that very small sizes of wood can be used, such as twigs and branches, again reducing fuel consumption when compared to traditional open fires (figure 2).

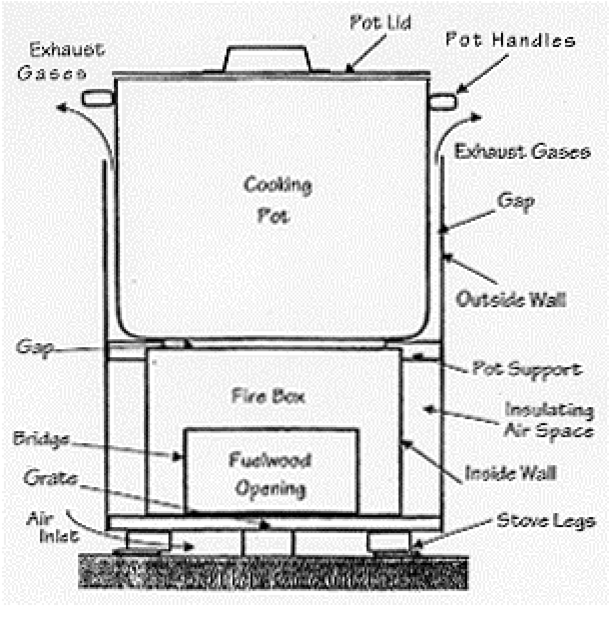

Figure 2. Cross section of improved community sheet metal cookstove

Pellet Stoves

A recent development has been the biomass pellet cookstove, which can be used in developing countries. Waste products from sawmills often have to be disposed of through site burning, burying or trucking elsewhere. This sawdust and woodchips can be compacted on-site into briquettes or pellets, which can then be used as fuel for cookstoves or industrial heating purposes. Both briquettes and pellets are comparable to charcoal in their heat content, their ability to burn with low smoke and ash residuals, and can be easily and conveniently transported and stored. However, they are a more efficient use of the entrained energy in forest biomass since, unlike charcoal, the original mass and energy in the wood is retained for later use to produce heat. Charcoal, typically, retains only 20 to 40% of the original mass and energy, the remainder being used in the carbonization process. The net result is an increase in demand for forest biomass and hence land mass requirements per household.

Brace Research Institute has developed a pellet stove, based on earlier fuel-efficient fuelwood stove designs, that can be used as both a cookstove and a space heater. This was a co-operative effort between the Institute and Quebec industry, financed by the Ministère de Ressources Naturelles, Gouverenement du Québec, to produce a stove design that could be useful in remote and non-permanent hunting, fishing and camping cabins in Canada, and for family use in developing areas of the world where sawmill wastes are available.

The stove resulting from this effort is illustrated in Figure 3. It has an optional chimney, which is necessary for operation indoors and when used as a heater. It's fuel consumption, in the cooking mode without chimney, is comparable to the community cookstoves in Argentina, described above.

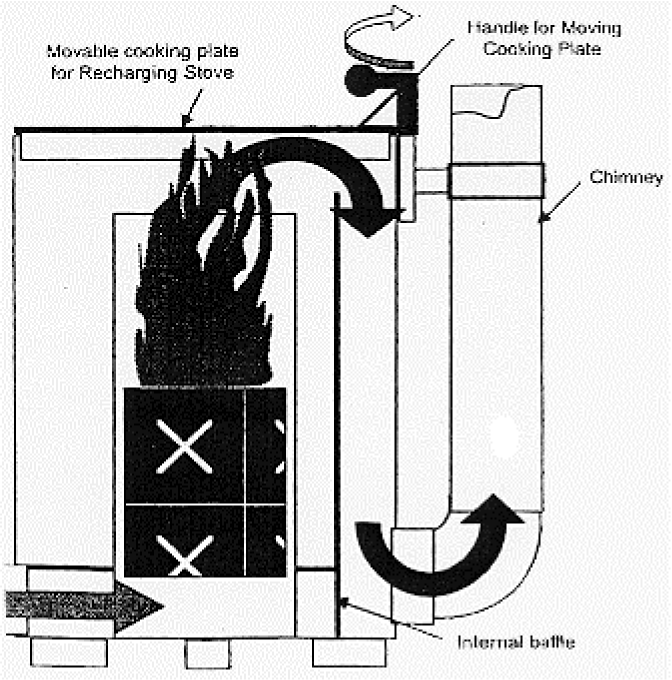

Figure 3. Pellet cookstove designed by the Brace Research Institute

Another recent development in Canada has been the introduction of a close coupled gasifier pellet stove that burns agricultural fuels or high ash wood wastes such as bark for home heating (Samson et al., 1999). The device was built by Del-Point Technolgies of Blainville, Quebec, along with the Advanced Combustion laboratory at Natural Resources Canada as a high efficiency space heating device capable of burning high ash agricultural fuels. This device could offer major opportunities for increasing the supply options for biomass fuel for developing areas if a low cost unit could be constructed for meeting rural energy demands. While this would not be affordable for the poorest families, it could provide a practical option for families of middle incomes instead of switching to liquified petroleum gas as discussed earlier.

Solar Cookers

In arid and semi-arid areas or in regions with extended dry periods and abundant sunshine, the use of simple solar box cookers properly integrated with a comprehensive program of reforestation and the use of improved woodstoves can reduce the production of greenhouse gases and enhance the local environment. The Brace Research Institute has been working in this field for the past 30 years and in the last 5 years has come out with a series of lightweight (5 kg), portable solar box cookers (Figure 4). This unit is family-sized and can cook a considerable amount of food if properly used over the entire day. It is particularly well adapted to use in warmer and sunnier climates. As it is making use of incident solar radiation, once the cooker is built, there is no loss of effort and time, as is the case with biomass cookers in collecting, transporting and preparing (chopping, splitting, etc.) the fuel.

The use of solar cookers will undoubtedly increase in the course of time due to the expanded world population and the rise of greenhouse gases. Its use must be very carefully integrated into the socio-cultural and economic infrastructure of the local community. Unlike biomass stoves, the use of solar cookers is novel for most rural dwellers in developing areas. In order to be successful in a developing area context, the use of solar cookers must be preceded with careful planning and animation of the local population.

Error! Unknown switch argument.

Figure 4. Portable Solar Box Cookers

INCREASING BIOMASS SUPPLY FOR COOKING IN RURAL AREAS

Planting fast growing trees as a means of supplementing forest derived fuelwood is increasingly practiced. Species used vary by region but commonly include leucaena, gliricidia and eucalyptus. Fast growing trees are generally planted for multiple purpose use on farms, uses include building materials, livestock fodder, and green manure for fertilizing fields. Further investment in breeding programs to enhance productivity and reduce pest and disease incidence would help encourage planting and improve livelihood opportunities for farmers growing them.

However, new approaches to greatly increasing the supply of biomass need to be developed if the fuel crisis is to be fully resolved. The main options, after tree planting are harvesting agricultural residues, or growing dedicated energy crops specifically for biomass production.

Crop Residues for Energy

In developing areas, the main residues available in large quantities are residues from annual crops, such as rice, corn and wheat, as well as sugar cane. In the case of wheat and corn, much of this residue is best to be incorporated back into the soil for nutrient conservation purposes, as significant problems with soil erosion can result from their removal. For example, in China, major problems are being experienced with siltation of rivers from soil erosion due to residue removal for rural energy needs and paper manufacturing (Stoskopf, 1998). In the case of rice and sugar cane, there is good potential for removal of some of this material for bioenergy purposes which would help prevent field burning of the material. In the Philippines, it was estimated that 8 million tonnes of rice straw and 3 million tonnes of sugar cane are burned annually representing the equivalent of more than 30 million barrels of oil/yr (Mendoza and Samson, 1999). In comparing the two materials, sugar cane residue has the better potential as a biofuel. Rice straw is very high in silica and consequently has an ash content of 16-18% (Misra, 1987). This results in a relatively low energy content biofuel that is not conducive to easy processing, and is not user friendly because of the high ash component. Nonetheless, some potential exists for using rice residues, for example rice husks are commonly used as fuel in rice growing regions and stoves have been designed specifically for its use. Sugar cane as a warm season (C_4 photosynthetic cycle) grass, has a lower ash content than cereal crop residues, and has a range of 3-6% ash content (Samson and Mehdi, 1998). Rice residues represent a large disposal problem as almost 100% of fields are burned in countries such as the Philippines (Mendoza and Samson, 1999). Densification of the residual field material and bagasse into fuel briquettes or pellets could produce a moderately priced and convenient fuel for home cooking where sugar cane residue is available.

High Yielding Perennial Grasses for Energy

In areas where sugar cane residue is not available, it may be viable to plant dedicated biomass crops for energy purposes. This strategy is currently the thrust of a major research program in North America examining fast growing perennial grasses (McGlaughlin et al., 1996). The biggest effort is on warm season (C_4 grasses) such as switchgrass (Panicum virgatum), which have high solar radiation conversion efficiencies. In less developed countries, high yields have been obtained with C_4 species such as napier grass (Pennisetum purpureum) and guinea grass (Panicum maximum). For example, in Puerto Rico and El Salvador yields over 80 od (oven dried) t/ha have been obtained with napier grass in small plot yield trials (Watkins and Severen, 1951; Vicente-Chandler et al. 1959). Yields of 30-50 odt/ha have also been achieved with napier grass in subtropical regions (Woodard et al., 1993). These grasses could greatly expand the energy supply for producing biofuels. In Florida, yields of four grasses ranged from 37-53 odt/ha and were found to contain the energy equivalent of 106-145 barrels of oil per hectare (Woodard and Prine, 1993). These grasses would be best harvested infrequently to optimize biomass accumulation and minimize nutrient extraction from the soils (as mature material has a lower nutrient content). The economic viability of these biomass crops and residues appear promising compared to fossil fuel use. In Canada, it was assessed that perennial grass biofuel pellets would be more economical than electricity or propane as a home heating fuel (Samson et al., 1999.) There is no reason to anticipate that pelleted biomass could not be a lower cost option than cooking with electricity, kerosene or liquified petroleum gas in less developed countries. Further analysis of this opportunity is a high priority research area.

SUMMARY

The combined use of enhanced agroforestry systems, judicious harvesting of crop residues and planting of perennial grass energy crops could greatly increase the biomass supply in developing areas for cooking and other energy applications. If this was combined with energy efficient conversion systems for cooking such as improved fuelwood, charcoal and pellet stoves, it could make a major contribution to resolving current energy problems experienced in developing areas. Consequently, major benefits would take place on natural ecosystem restoration in these areas. As a greenhouse gas abatement strategy, it would have direct benefits by enhancing carbon storage in the landscape and enable a moderate cost, modernized fuel cooking system to be developed, which greatly minimizes greenhouse gas emissions compared to fossil fuel use.

BIBLIOGRAPHY

BRI, 1976. "A Study of the Feasibility of Establishing a Rural Energy Centre for Demonstration Purposes in Sénégal", by Brace Research Institute, Report No. I.116, 380 pp., August 1976.

BRI, 1992. "Rural Renewable Energy, Thailand – Final Narrative Report, August 1987 to March 1992", by Brace Research Institute, Report No. I.319, 221 pp., February 1992.

BRI, 1997. "Renewable Energy Development and Rational Use of Resources – Argentina – Final Report, October 1991 to February 1997", by Brace Research Institute, Report No. I.363, 181 pp., March 1997.

BRI, 1999. "Conception de Poêles Multifonction à Biomasse Densifiée en Granules pour Usages Domestiques et Communautaires", by Brace Research Institute, Report No. I.376, 98 pp., March 1999.

Brunet, E. and T.C. Kandpal, 1987. Design, Fabrication and Laboratory Performance Evaluation of Improved Charcoal Cookstoves, by, Brace Research Institute Report No. T.167, 40 pp., August 1987.

Dutt,G.S. and N.H. Ravindranath. 1992. Bioenergy: Direct Applications in Cooking. In Johansson, T.B., H. Kelly, A.K.N. reddy and R.H. Williams. 1992. Renewable Energy: Sources for Fuels and Electricity. p. 653-697. .

ERG, 1986. Energy research:directions and issues for developing countries, IDRC-250e, Energy Research Group, International Development Research Centre, Ottawa, Ont. Canada.

Lawand, T.A. 1979. "A Brief Overview of the Fuelwood Crisis". Paper presented at the Inter-Energy 1979 Symposium, Winnipeg, Manitoba, 18-19 October 1979. Brace Research Institute Report No. R.138, 19 pp.

McLaughlin, S.B., R. Samson, D. Barnsby and A. Wiselogel. 1996. Evaluating physical,chemical, and energetic properties of perennial grasses as biofuels. Bioenergy 96: Proc of the 7th National Bioenergy Conference. Vol 2. pp1-8.

Mendoza, T. C. and R. Samson.1999. Strategies to avoid crop residue burning in the Philippine Context. Prepared for Frostbites and Sunburns: Canadian International Initiatives Toward Mitigating Global Climate Change, April 24 to May 2, 1999, San Salvador, El Salvador.

Misra, D.K.1987. Cereal straw, In Hamilton, F. and B. Leopold, Pulp and Paper Manufacture, Vol. 3: Secondary Fibres and Non-wood pulping, p. 82-93.

Samson, R., P. Girouard, B, Mehdi, M Drisdelle, C. Lapointe, R. Braaten and S. Hall. 1999. The combined use of perennial grass biofuels and gasifier pellet stoves and furnaces as a greenhouse gas offset strategy. Prepared for Combustion Canada 99, May 26-29, 1999, Calgary, Alberta, Canada.

Samson, R. and B. Mehdi. 1998. Strategies to reduce the ash content of perennial grasses. Expanding Bioenergy Partnerships, Bioenergy 98, Great Lakes Regional Biomass Energy Program, Chicago, Illinois; pp. 1124-1131.

Stoll, D. and J.F. Giroux, 1999,"Sondeo Acerca Del Uso De Estufas de Biomasa en Varias Cocinas de la Comunidad en Salta, Argentina", Brace Research Institute Report No. I.377, 5 pp., February 1999.

Stoskopf, N. 1998. Professor, Dept of Plant Agriculture, University of Guelph, Guelph, Ontario, Canada (Personal communication).

Vicente-Chandler,J., S.Silva and J. Figarella. 1959. The effect of nitrogen fertilization and frequency of cutting on the yield and composition of three tropical grasses. Agron.J. 43: 291-296.

Watkins,J.M., and M.L. Severen. 1951. Effect of frequency and height of cutting on the yield, stand and protein content of some forages in El Salvador. Agron.J. 43:291-296.

Woodard, K.R. and G.M Prine, 1993. Dry matter accumulation of elephantgrass, energycane and elephant millet in a subtropical climate. Crop Sci. 33: 818-824.

Woodard, K.R., G.M. Prine and S. Bacherin. 1993. Solar energy recovery by elephantgrass, energycane and elephantmillet canopies. Crop Sci. 33: 824-830.

Home Page