Home grown power plants

The Case for Wood-Based Energy Systems in Sri Lanka

In Sri Lanka there is an urgent need to identify alternative energy pathways by which the country can provide for all its power needs in a manner that is sustainable, uses local resources, and is economical. Wood-based gasification or "Dendro-thermal" energy as it is commonly called in the country seems to hold promise of providing energy in this way in Sri Lanka given local resources and skills already in place due to the huge tea, rubber and tobacco industries in the region. Kamal Kapadia provides an overview of this promising future energy source for Sri Lanka.

The energy sector in Sri Lanka is currently a hotbed of activity and change. A reform process is underway in the power sector, and the debt-ridden state-owned electricity utility - the Ceylon Electricity Board (CEB) - will soon be broken up into separate generation, transmission and distribution entities that will function on a commercial basis, under the watch of a regulatory agency. The reformed system, it is hoped, will provide for the growing power needs of the country more efficiently and effectively than the current system allows.

Indeed, there is an urgent need to reinvent the structure of the electricity sector in this small island country in South Asia. The country's current installed power capacity, which stands at 1835MW, is woefully inadequate to meet the demand for power, which is growing at an annual rate of 8-9%. 60% of the power comes from large-hydro facilities, however, almost all large hydro potential in the country has now been used up. For the last twenty years, the Ceylon Electricity Board has been trying to get a 900MW coal-fired power plant built; this plan, however, has faced considerable environmental and social protest within the country, and has been stalled by the government. In essence, there is already a large generation shortage. Further, only 60% of the country's 18 million people have access to grid-based electricity, and the average electrification rate in rural areas is actually 47%, much lower than the national average (Ministry Of Power and Energy, 2002).

The power sector reform may address some inefficiencies in the current structure, and allow for the sector to function on a more commercial basis, in a way that is at least partially free of the political interference that currently bogs the CEB down. However, there are two key issues that the proposed reform process has failed to address to date:

1. If all additional generation capacity is to be installed on a purely commercial, least-cost basis, this implies that the country will be tied in to a largely coal-based electricity future (in spite of all the protest against coal power by strong environmental lobby groups). Indeed, this is exactly what is being projected by the CEB. Not only does this bear significant negative environmental consequences, but also, as Sri Lanka has no fossil fuel resources of its own, the country will be tied into a rapidly growing dependency on imported fossil fuels. According to Dr. Ray Wijewardene, one of the foremost proponents of biomass-based energy in the country, "it is observed that within about ten years, the (foreign exchange) cost for such generation will absorb ALL of Sri Lanka's net foreign-exchange earnings from its major agricultural exports (tea, rubber and coconut). Leaving very little for other vital imports such as for food and fuel for transportation." (Wijewardene and Joseph, 2002).

Environmental considerations aside, while coal itself is a cheap fuel (from a narrow, short-term financial view-point), under the new reformed electricity structure, private sector power developers will attempt to recover their capital costs within the first ten years of the project. This will result in a higher electricity tariff than people are currently paying.

2. Under the reformed structure, it is unclear how the electricity needs of the off-grid rural population will be met. There is a World Bank/GEF funded program in place that intends to provide for off-grid power needs with renewable energy technologies like solar PV, micro-hydro, wind and biomass, but this program intends to reach only 10% of the off-grid population (World Bank, 2002). As things stand, the means and mechanisms for extending power services to rural areas has yet to be clearly identified. This is especially relevant under the reformed power sector structure, as extending the grid to the vast majority of off-grid regions cannot be justified on a purely commercial basis.

In the face of these issues, there is an urgent need to identify alternative energy pathways by which Sri Lanka can provide for all its power needs. Further, this needs to be done in a way that is simultaneously environmentally, economically and socially sustainable, and by means that foster energy security, as opposed to creating import dependencies. This situation is not unique to Sri Lanka alone, indeed, most developing countries (and indeed, many developed nations) are struggling to provide for their electricity needs in a manner that is sustainable, uses local resources, and is economical.

Energy-bearing trees

Wood-based gasification, or 'dendro-thermal' energy could provide one such alternative pathway and is one that seems to hold the promise of promoting both sustainability and energy security in an economical way. Wood-based energy systems involve the cultivation of energy plantations, which feed wood-based power generating units. These units could be connected to 33kV grid lines, feeding the main grid-based system, or connected to mini-grids for those regions that are currently off-grid.

By no means is this a new technology; indeed, there is considerable experience in energy plantation development, and wood-based gasification in both developing and developed countries. The Philippines, Brazil and India have been experimenting with gasification systems for several decades. In the USA, wood based electricity generating capacity is in the range of about 6000 – 7000 MW, and Scandinavian countries have large-scale wood based power plants.

Sri Lanka is an ideal place for the large-scale deployment of this technology. The country is blessed with a wet tropical climate, which makes it ideal for cultivating fuel wood plantations. Further, the country possesses a wealth of plantation management experience; it is one of the world's leading producers of tea, and a large producer of rubber and tobacco. Indeed, most of the country's energy needs are already from biomass sources. The domestic sector accounts for most of this biomass use for cooking purposes (which represents 36% of total energy use in Sri Lanka in 2000), followed by the agriculture and industrial sector, which uses biomass for heating needs. However, the use of biomass for electricity generation has not been pursued in any significant way in Sri Lanka (Energy Forum, 2001).

Over the last two decades, a small but dedicated band of individuals and organizations have been steadily working on researching the technology, and documenting the results of various studies and experimental projects and plantations. And the results are indeed heartening. All studies point to the fact that biomass, and especially wood-based systems, hold much promise for both on- and off-grid applications on a large scale. Mr. Joseph, Director of Alternative Energy, at the Sri Lanka Ministry for Economic Reform, Science and Technology, is a very active member of the Sri Lanka Biomass Association, and an ardent and committed proponent of wood gasification systems. He qualifies (and quantifies) his enthusiasm with some staggering facts:

"One-third of land in Sri Lanka is either degraded or under-utilized and can very effectively be utilized for energy plantations (Figure 1). If all this land were to be converted to energy plantations, this would represent a total energy capacity of 4,000 to 5,000 MW. Further, the government has, in the last few years, spent SL Rs. 2 Billion (US$ 20M) on just the feasibility studies for locating and establishing a coal plant. Had that money been invested in dendro-thermal power, we could have 300,000 acres of energy plantation and 300MW of dendro-thermal power in our system would have been commissioned by the private sector today." This last statement is particularly relevant in view of the fact that the intended, but yet to be built coal-plant would have been a 300MW plant in the first phase.

Other renewables?

Other RE technologies can also contribute to meeting the energy needs of the country (In recognition of this fact, the World Bank and GEF have instituted a program called 'Renewable Energy for Rural Economic Development (RERED)', which supports the deployment of solar home systems (SHS), wind energy, micro-hydro, and biomass systems). However, this project is limited in its scope in that it only intends to provide for 10% of the off-grid power needs of the country by 2007. However, with the exception of biomass-based systems, all the other technologies are limited in their scope. This is especially relevant if power has to be provided in a manner that is simultaneously sustainable, local and low-cost. Technologies like SHS are very high cost, delivering very small amounts of power at significantly high costs to the end user. No doubt solar home systems offer considerable quality of life benefits, but if the primary purpose of rural electrification is economic development, solar PV is probably the least cost-effective way to pursue rural electrification. Both wind and micro-hydro energy are promising options; they have lower costs than solar PV, and provide more power services, but these are limited on account of their site-specific nature. For example, small hydro capacity in Sri Lanka is estimated to be approximately 97.4 MW (This figure is based on surveys carried out at 257 sites in the country) (Fernando, 2002). Wind capacity is also very limited due to resource constraints – wind is very seasonal in most parts of the country.

Benefits of biomass/ wood energy

The systems are environmentally sustainable, so long as the energy plantations are harvested sustainably, and no natural forest is cleared to plant fuelwood monocultures. Carbon dioxide that is emitted during the combustion of wood, is fixed by the continuous growth of the fuel wood trees. Fast-growing tree species could lock up 50-15 tons of carbon per hectare per year (Energy Forum, 2002). Further, establishing plantations on degraded lands can help regenerate forest cover, especially if mixed species are cultivated. Other benefits include the prevention of soil erosion. The species of trees used are also nitrogen fixing.

Local, low-cost fuel source:

For Sri Lanka, wood and biomass is the only abundant fuel source that could be locally made available at very low costs on a large scale. With no significant large-hydro potential left, the only other alternative for the country is to start importing fossil fuels, spending a huge amount of their precious foreign exchange for the same.

Employment and rural development benefits:

Biomass gasification systems can provide for both power and heating needs (for agricultural and industrial uses, for example, tea factories could benefit greatly from biomass-based cogeneration units), as well as generate considerable rural employment in the management of plantations and the operation of power plants.

If 1/3 of total degraded/under-utilized land were converted to energy plantations, this would provide employment for 150,000 rural families, which is about 1/20th of the country's population (Wijewardene and Joseph, 2002).

Table 1: Costs of a wood-based (gasification) power system in Sri Lanka.

Cost	Wood
Capital (US$/kW)	500
Life span (years)	15
Annuity (US c/kWh)	1.0
Fuel (US c/kWh)	1.5
Operational (US c/kWh)	2.5
Transport & Distribution (US c/kWh)	1.0
Total (US c/kWh)	6.0

Source. Wijewardene and Joseph, 2002.

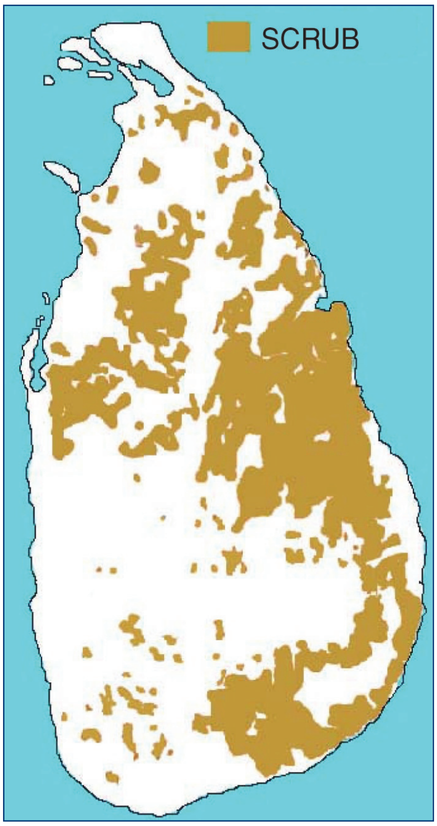

Figure 1: Scrub map of Sri Lanka. A third of land in Sri Lanka is degraded or under-utilized scrub land. Source: Compiled by Joseph P. (2002) based on Sri Lanka Survey Dept. studies

How does it work?

Based on research and experimentation with a number of trial plantations in Sri Lanka, it has been established that the best method for sustainable fuel wood cultivation is Short Rotation Coppice (SRC) farming. In this method, fast growing nitrogen-fixing trees such as Gliricidia or Leucena are planted (densely), and harvesting can begin within fifteen months from planting, with regeneration time for branches harvested being as little as six months. 'Coppicing' refers to the process by which the side branches of trees sprout after older branches are periodically harvested, leaving the main stem intact and growing. The 'coppicing' cycle of re-growth, lopping and re-growth again could extend to at least twenty-five years. Fertilizer needs are minimal, and returning the ashes after combustion to the soil would further reduce fertilizer usage. Gliricidia and Leucena also fix nitrogen.

Power plants

The wood produced from these energy plantations is used as fuel to run either direct combustion systems, or gasification systems, which generate electricity. Direct combustion systems function largely like conventional power plants, where wood is burned in a furnace to raise steam, which drives a turbine, generating electricity. These systems tend to be expensive, especially on smaller scales (<50MW). Wood gasification involves the conversion of wood into a combustible gas (commonly termed producer gas – a combination of carbon monoxide and hydrogen gas), which is then burnt in an internal combustion engine, or in a gas turbine. Gasification is much better suited for smaller systems (around 500kW capacity). There are various different technological options in wood gasification systems, depending on the type of gasification process (fixed or fluidized bed), and type of power generation technology (diesel engines, combined cycle gas turbines, steam injected gas turbines). Wood gasification units that use wood as the only fuel source are more expensive. However, if the fuel source is a combination of agriculture waste and wood, or even diesel and wood[3], costs can be reduced substantially (While this option has obvious environmental disadvantages, a system that uses 30% diesel fuel can be installed at half the cost of one that runs on 100% wood, and still be a far more sustainable option than a 100% fossil fuel-based power plant) (Figure 2).

Management and operation

The management scheme for such an energy system can take several forms, ranging from community-based management, as is currently in practice for micro-hydro installations, to complete private sector management. For grid-connected systems, Mr. Joseph proposes a scheme that is a combination of the two:

- The government will lease out plots to a plantation company, which, will establish and cultivate a wood plantation, and sell the wood to a privately owned gasification plant. The gasification plant will be run and operated by the private sector, which sells power to the utility at a fixed tariff.

- Off-grid systems can be managed cooperatively by the community, or by the private or NGO sector, and can be funded by the government, and/or with donor, or carbon-offset funds.

Costs and economics

Based on experimental systems, and economic and financial modeling, the costs of a complete wood-based power system have been worked out (Table 1). Let us compare this with the other energy path being currently promoted by the Ceylon Electricity Board – a coal-based future: A study carried out by Japanese consultants in July 1993 show that costs of establishing a coal-fired plant can range from $2112 to $2279 (in 1993 US$) per kilowatt of capacity (Vamakulasinghe, Kulatange et al, 2002). The range is based on variations in construction costs resulting from ecological and geographic differences in the locations studied. At the low end, cost of power generated from the coal plant will be around US $ 0.04-0.045/kWh. However, the price to the end user is much higher (US $ 0.078/kWh) as both transmission and distribution costs and losses (which alone stand at $0.01/kWh) have to be factored in (Siyambalapitiya, 2002). Further, under the reformed electricity sector structure, all these costs will be passed on to the end-user, and capital cost recovery will operate on much shorter time frames than are currently in place.

Wood gasification systems, in comparison, are located closer to consumers, and would connect to low-voltage or 33kV lines, avoiding significant transmission and distribution costs, as well as losses. The foreign exchange savings, and employment generated should also be factored in to any economic comparison. If to all this, we quantify and factor in carbon benefits, wood-based systems are clearly the most economically sound and sustainable option. Wood-based systems for off-grid areas could have a slightly higher cost. This could be funded either through CDM-type mechanisms, and/or through cross-subsidies for off-grid electrification.

Biomass potential

Based on several experimental plantations and trials carried out by the Department of Agriculture at the University of Perediniya, as well as by the Ministry of Science and Technology, there is concrete evidence that one hectare of SRC-farming could yield over 25 tonnes of dry matter per year. According to Dr. Ray Wijewardene, who owns and manages an SRC plantation, "considering just 500,000 hectares, (one third of the total scrub terrain) this land could conservatively produce 10 million tonnes of fuel-wood annually and on a continuing basis. This quantity of wood, when used to generate electricity could generate 10,000 GWh of electricity annually and equivalent to nearly twice our known hydropower potential, and the equivalent of over 1,700 MW of power station capacity while operating for only 67% of the available time (`plant factor') (Note: this is still from just one third of the underutilized land available!)" (Wijewardene and Joseph, 2002). Indeed, the biomass energy association has projected that these "dendro-thermal" power systems could easily meet all 100% of the country's thermal energy needs by 2006.

Figure 2: Dendro-thermal flow chart
A: The wood is sun-dried before being fed to the gasification unit.
B: A view of the 35kW down-draft solid biomass gasifier with water scrubber and filters, installed at Lanka Transformers. Sapugaskanda, Sri Lanka.
C: The wood is fed in from the top and the unit is fired up.
D: The producer gas generated runs through a series of filters.
E: The gas is combusted in an internal combustion engine, and the energy generated is used by Lanka Transformers in their factory next door.
F: A view of the compact housing unit for the dendro-thermal gasification system.

So what's holding them back?

There are several issues that need to be addressed, and hurdles to be overcome before wood-based energy technologies can be deployed on a large scale:

While there is considerable experience, documentation and pilot studies in the area of energy plantation productivity, economics and management, there is very little experience in the establishment and management of an entire system, including the power plant, and no experience in providing power to the grid in Sri Lanka (although valuable and relevant lessons can be learnt from systems already established in countries like India, Brazil and the Philippines). However, two developers are in advanced stages of commercial preparation of an 8 MW co-generation facility as part of an existing production facility for coconut-based charcoal, and a 500 kW gasification facility with a 200-hectare Short Rotation Cropping (SRC) plantation. There is also a 35 kW downdraft solid biomass gasifier with a water scrubber and filters, installed by Lanka Transformers in Sapugaskanda, near Colombo. This of course, is the situation of the chicken and the egg. It has been hard to raise funds for pilot projects, although this is now changing. There is a new World Bank/GEF funded project in Sri Lanka (Renewable Energy for Rural Economic Development project), which includes a biomass component. Also, the Biomass Energy Association is pursuing discussions with the Ceylon Electricity Board with a view to establishing a power purchase tariff for grid-connected wood gasification systems. For off-grid options, the Energy Forum, has conducted a detailed study, and identified a village and community for establishing a pilot project. Energy Forum is a Sri Lankan NGO that works to promote and disseminate the use of renewable energy technologies for rural energy applications.

The issue of the power purchase tariff is a significant stumbling block. For the wood gasification plants to be economical, they must function at a high plant factor, and therefore be included as base load, feeding the grid continuously. Further, for the systems to be commercially viable, the tariff must be at least \$0.07/kWh. The Ceylon Electricity Board, however, currently pays \$0.055/kWh for base load power (mostly large hydro), and so far has been unwilling to pay the slightly higher costs of wood-based power. No doubt there are various ways in which the difference could be funded – either through CDM funds, or by a cross-subsidy on fossil fuel-based power. To pursue this, however, calls for a political commitment that is currently lacking.

Uncertainties and unknowns

The biggest concern associated with large-scale cultivation of wood plantations, is that, should a thriving market develop for fuel wood, in the absence of sufficient regulation or control, existing forests would become threatened. If the private sector is to operate the gasification units, it is unlikely that companies will discriminate against wood that has not been harvested sustainably, in the absence of strong controls and disincentives. While 1.7 million hectares of land is deemed to be barren or underutilized, no doubt some portion of this land is being used for shifting cultivation, and perhaps for other small-scale productive purposes. The Ministry of Land is currently carrying out a detailed assessment of land use in the country.

There are also concerns about the large water demands of fast-growing tree species, and changes to soil chemical properties on large scales. These can all be controlled, however, by effective plantation management practices. Other environmental issues are related to emissions controls – currently, most systems use water-based filtration systems, and the water effluent carries away a number of toxic compounds that need to be treated and disposed suitably. There are ways to convert the scum that is produced in the effluent tank to solid fuels for domestic cooking fuel. However, liquid effluents need to be properly disposed of. Also, the prolonged application of wood ash to the plantations could result in accumulation of heavy metals such as cadmium, and mercury. Although the quantities involved are very small, this should be monitored. Compared with the impact of coal fly ash on the environment, however, the wood ash problem is extremely small.

In off-grid areas, as there is very low power demand at night, the overall plant factor is very low (i.e., the plant only runs for a few hours everyday, as opposed to 24 hours). This could make the unit cost of power significantly more expensive, by a factor that would depend on local electricity demand. The Government of Sri Lanka is, in principle, supportive of renewable energy technologies. However, they are yet to commit any funds, or set up any real program to back up the rhetoric of support. Political commitment has to move beyond words to concrete steps if wood-based energy is to become a significant contributor to Sri Lanka's electricity supply mix.

Conclusions

There is little doubt that wood-based energy systems hold much potential for meeting the energy needs of Sri Lanka. They are a low-cost, local and sustainable alternative to all other energy paths being currently considered and pursued by the country. However, current impediments to the pursuit of this path include inadequate political support (in terms of real programs and funding). Further, concerns about potential deforestation and waste issues in the context of large-scale biomass gasification need to be addressed. Potential next steps could include:

1. Setting up a number of pilot projects consisting of different technologies, and plantation management systems. This should be well monitored and evaluated for financial, technical, economic, social and environmental impacts.
2. Based on the results of these projects, a large-scale plan for wood, and other biomass-based energy systems could be drawn up for the country.
3. All this needs to be accompanied by awareness campaigns, training and capacity building.
4. Simultaneously, regulatory and control systems must be put in place that ensure that all wood that is used in gasification systems is harvested sustainably, and effluent treatment systems meet certain standards.

While the promise of renewables for developing countries is now a part of mainstream energy discourse, this promise is far from being realized. The contribution of renewable energy to meeting developing country energy needs continues to be a mere drop in the ocean, and if one looks at energy plans of government and utilities, renewables play a very minor role. Sri Lanka has the opportunity, with wood-based energy, to demonstrate to the developing world how a relatively cheap and sustainable energy regime can be established using a renewable fuel that is abundant in most tropical countries. The challenge is to overcome the chasm between the supporters and practioners and the political system, and get them working together to establish an energy future that is simultaneously sustainable, economical and secure.

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