

FARMING WOOD FUEL FOR SUSTAINABLE ENERGY IN RURAL AREAS IN CAMBODIA

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PART I – PILOTING LEUCAENA TREE FARMS IN NORTH-WEST CAMBODIA

1. Introduction

The Cambodian economy and population is currently growing at an increasing rate. The globalization of trade and commerce adds further demands on Cambodia's natural resources. These resources include tropical rainforests, fresh water lakes, fisheries and mineral deposits (gemstones). Some are already becoming over exploited and polluted. Cambodia's primary rainforest cover decreased from over 70% in 1970 to about 20% today. The country has only about 17.3 million acres (7 million ha) of forested area remaining. Most of the logging is conducted to satisfy the international demand for tropical timber. Logging rates accelerated dramatically during the 1990's when unprecedented numbers of lumber mills were constructed. In early 1996, Cambodian leaders signed 30 contracts with foreign, mostly Asian, logging companies to log 16 million acres (6.5 million acres) of rainforest, over 92% of Cambodia's remaining rainforest (country index from www.mogabay.com). Deforestation is becoming a serious problem in Cambodia, as well as globally, especially in light of global warming, floods and erosion.

Besides cutting forests for the export of timber, cutting pressure on forests also exist to satisfy the growing demand for energy. Fuel wood is the number one source of energy in Cambodia and is widely used for cooking. For electricity Cambodia relies entirely generation equipment using import of fossil fuel, mainly diesel oil. The combination of high world prices of fuel oil and high importation taxes (>100%) results in very expensive electricity, especially in rural areas (often \$0.60 to \$0.90 per kWh). The high cost of fuel cost of diesel generated electricity are major obstacles to developing local businesses in rural and provincial areas of the country where 80 % of the population reside. Increasing prices of imported fossil fuel directly affects economic growth and the competitiveness of Cambodian products for export.

Fortunately, there are alternative solutions to these problems. This includes a strategy combining reforestation of harvested areas and the introduction of renewable energy technologies that utilize and transform locally available biomass (from farmed trees and agricultural residues) into less expensive electrical energy. Technologies such as biomass gasification can convert fuel wood into producer gas, that can be used in either 100% gas engines or dual fuel diesel engines that drive electricity generators.

To avoid increasing fuel wood cutting pressure on local natural forests such electrification schemes must be coupled with the establishment of tree farms to provide continuous ("coppiced") supply of wood biomass. It is recommended that these tree farms grow one or several of the species of fast growing tropical legumes that are available in the Cambodia ecosystem. These include, Leucaena, Gliricidia, Accacia and several others. Selection of species will depend on soil acidity and moisture conditions at the farm site. Leucaena is a multipurpose leguminous tree that originates from central America but is now found in the tropics of S.E Asia having probably been transported to first the Philippines by the Spanish in the 1500s -1600s.

Leucaena was introduced into Cambodia during the French colonial era as a shade tree for coffee plantations and has spread wildly on the better soils. Leucaena is now commonly grown in rough hedgerows around village houses and is well accepted as a fuel wood, live fence, and poultry, pig and cattle feed source. Leucaena groves and rows also help prevent soil erosion and restore or stabilize soils.

In summary, Leucaena offers a combination of benefits as a source of fertilizer, animal feed (high Urea content leaf), and fuel energy (wood). It can also be allowed to grow larger and in 3-5 years provide usable timber for building and furniture manufacture.

2. Method of Planting Utilized in Cambodia

In February 2004, SME Cambodia began a program of planting *Leucaena* and encouraging farmers to establish large scale production. with the objective to plant fast growing Nurseries were set up to provide trees at interested farmers. The goal of encouraging increased production was to establish energy plantations which can provide fuel wood biomass for local communities for both electricity generation and to reduce fuel wood cutting pressure on local natural forests.

2.1 Selection of seed

Seed Source

Leucaena was re-introduced into Cambodia during the 1990s by the Cambodia Australia Agriculture Extension Project (CAAEP), however the extension process was weak and the overall impact on local farm families low. To determine the best choice of tree species SME Cambodia sought the advice of an Australian agro-forestry consultant (Mr. Alan Robertson), the provincial Department of agriculture staff at Battambang and the CAAEP advisor (Mr. Lex Freeman) . The consensus was that the best results in terms of both wood and leaf production would be achieved by choosing *Leucaena* rather than *Gliricidia* and that a new hybrid from Australia would perform better than collecting seed from mixed varieties found in the local forests. Application was made to the Ministry of Agriculture to import *Leucaena* seeds and 100kgs of (*Leucaena Leucocephala*, Tarramba) from Australia was imported in January 2004..

Seed treatment

Leucaena has a very hard, impermeable waxy seed coat which must be broken before the seed will imbibe moisture and germinate. Mechanical scarification was applied 50 kgs of the commercially purchased seed from Australia. Seed subsequently, collected in Cambodia was treated with hot water before planting. The hot water treatment includes immersing the seed in hot water at 80°C, by first boiling water then letting it stand for 5 minutes. The water is then, poured into a container containing the seed and after ten minutes, spreading the seed on a dry clean surface to dry.

Inoculation of *Leucaena* was completed using commercial peat-based products. Some legume species will nodulate very effectively with *Rhizobium* (bacterial culture) providing plentiful nodulation, nitrogen fixation and achievement of its nitrogen producing potential.

2.2 Land preparation

Leucaena is best planted in deep, well drained fertile soils of neutral to alkaline acidity. Through experience, the recommended soil acidity for growing *Leucaena* in Cambodia ranges from pH 6 to 7.5. However, *Leucaena* can be grown successfully in slightly more acidic soils with pH above 5.2. Below this pH, *Rhizobium* bacteria do not survive well and *Leucaena* does not extract the amount of food nutrients required for better growth.

Leucaena does not tolerate water logging so planting sites must not pond water and must be internally drained. Its deep tap root allows the plant to reach moisture deep in the soil profile. This allows the production of new leaf material after shallow rooted grasses have run out of moisture (*Leucaena* in Cambodia, Lex Freeman, 2005).

2.3 Planting Recommendation

Leucaena can be planted by direct seeding, or transplanted from nurseries (using Bare Root - Bare stem method), or as poly bag seedlings.

Direct Seedling

With reference to the *Leucaena* Production Handbook (by Dr. Carol Cross), the direct seeding method requires following certain procedures very carefully in order to develop a good *Leucaena* plantation.

First of all it requires good land preparation. The method used to prepare the land depends on whether it is flat land, shallow sloped or steep sloped. Equally important to know is the type of soil, the amount of rainfall and in which months the rain falls.

The second step involves the preparation of the seeds. In order to get the seeds to grow well, they may need to be treated. Seed preparation includes:

- Proper seed selection;
- Scarification of the seed;
- Inoculation of the seed.

The third step involves selection of direct seeding method:

- using the auger hole method;
- broadcasting;
- spot cultivation

Direct seeding is the least expensive method of planting *Leucaena*.

Nursery Planting

The nursery beds are well prepared with fertilizer and rice husk ash turned over to 0.5 m. depth. The planting density used by SME Cambodia is 400 seeds per sq meter planted in rows across beds 2-3 meters wide and 20 to 50 meters in length. Close spacing (5.0 -7.0 cm) within the nursery seed bed allow the seedlings to grow thin and tall which is desirable for most transplanting situations. The nursery beds are irrigated / watered either with gravity fed micro spray nozzles or by hand held sprinklers twice a day. The 3-4 month nursery period begins with seeding during the dry season in early February and growing until May/June. Following this planting schedule results in the seedlings being at optimal transplanting size at the beginning of the rainy season (June-July).

Transplanting

There are two ways to transplant *Leucaena* seedlings:

Bare Root – Bare Stem Method

Leucaena seedlings may be transplanted out when they have reached a height of 1 - 1.5 meters. Organize uprooting/transplanting only when there is adequate soil moisture within the nursery bed and at the planting site.

- Strip off all leaves and trim the top 15-20 cm (immediately cut and do not delay planting);
- Carefully uproot the seedling and shake off any loose soil (without disturbing the Rhizobium nodules);
- Transplant seedling quickly (keep weeding and protect seedling from livestock).

Poly Bags Seedling

Poly bag seedling transplantation can be performed but is less used than those produced by the bare root - bare stem method. The disadvantage of the poly bag method of transplanting includes poor tap root development and coiled tap root, increased labor and nursery management costs, and more heavy transportation to plantation sites. The main advantage is less shock and disturbance of Rhizobium nodules. Overall, this method is not recommended nor is it necessary to establish successful tree farms.

2.4 Transplanting Arrangement

Hedgerow Establishment

Hedgerows involve planting *Leucaena* hedges on contours or rows at intervals of 3-5 meters in between rows. Alley cropping of *Leucaena* is where cash crops are grown in between the rows of *Leucaena* trees.

- Prior to planting, sites must be well cultivated by ploughing twice and harrowing once. Fallow to store adequate subsoil moisture down to 30 cm. by hand weeding, machine

cultivation or by using of herbicides. Eliminating weeds is critical for the success of transplanting since *Leucaena* seedlings are initially highly susceptible to weed competition, in the first growing season. Deep ripping of the planting rows will help moisture and root penetration in hard clay sub soils.

- Transplant at the beginning of the wet season.
- Spacing between plants in rows should be a minimum of one (1) meter.
- Spacing between rows will depend on soil type, cropping system and type of machinery used, but generally the range is 3-5 meters.
- Dig narrow hole just wide enough to insert plant. Plant bare-stem cutting into moist soil taking care that the tap root is straight (tip of tap root can be cut shorter to facilitate planting) and compress soil around the seedling.
- *Leucaena* can be established by direct seeding into the cultivated field. This may suit some local management situations where field security to control animals and adequate labor is available.

Leucaena on Fence Lines

Fence row planting can be used as a source of fodder, a windbreak or as a live fence.

- Spacing between plants in a row can be reduced down to 0.5 meter.
- Other planting procedures and conditions are the same as for hedgerow planting.

Leucaena in Backyard Plots (Cut and Carry)

Intensive planting of closely cut *Leucaena* could form the basis of a smallholder cut-and-carry forage plot in conjunction with plantings of selected grass and legumes mix. Grass species might include Napier/Elephant (*Pennisetum Purpureum*) and Gamba (*Andropogon Gayamus*).

The system requires farmers to grow trees and fodder in one area, maintain their animals in another and cut-and-carry fodder to the animals.

Cut-and-Carry has the following advantages:

- It can result in maintenance of animal live weight or live weight gain, even when using pure forage crops with no concentrated supplements.
- Animal waste, manure and urine mixed with rice straw, can be collected and used to fertilize intensive crop production or for top dressing to the backyard forage crops.
- Crop damage from livestock feeding and trampling is avoided.
- The vegetation is able to grow back more easily and more quickly.

Inter-row-alley cropping

Alley cropping is a system of fallow improvement in which food, cash crops or fodder grasses are grown in alleys between hedgerows of *Leucaena* trees. Hedgerows are spaced at 3-5 meters between rows and are kept pruned during the cash crop season to prevent shading and reduce competition with the crops. The hedgerows should be established in the first season and the cash crop introduced at a later date when the *Leucaena* is well established.

3. Benefits of *Leucaena* for Rural Economic development

3.1 Growing *Leucaena* for Energy

Energy demand in rural Cambodian villages is dominated by the energy requirements for cooking and heating. These account for almost 100% of the total energy needs. Fuel wood and crop residues are the main sources of fuel to provide this energy. Day by day farmers spend their time cutting and collecting fuel wood from the forest, facing the threat of landmines and

inadvertently destroying the environment. Farming fast growing tropical trees, such as *Leucaena*, as a source of fuel is a good way to reduce deforestation of community and local natural forests.

Leucaena Leucocephala is a fast growing tropical tree that gives high yields of woody material which can be used for energy purposes. At the same time the leaf material it produces can be used for feeding livestock. About 12 to 18 months after transplanting, preferably at the start of the monsoon (in Cambodia around June), *Leucaena* trees can cut (coppiced) for the first time. Initial cutting takes place at waist height, a height at which the new branches that will grow back can be easily harvested in the future. After cutting, the harvested branches are spread and dried under the sun till the moisture content decreases to 15-20 percent. Branches may be cut to smaller pieces for quicker drying. When using the woody material in a biomass gasifier, branches (2.5cm in diameter) are cut into 5-8cm lengths, then dried to a moisture content of <15%.

The gas produced for burning in a gasifier consists of CO (19±3%), H₂ (18±2%), CO₂ (10±3%), CH₄ (up to 3%) and N₂ (50%). This "producer" gas is cooled and filtered before it is fed into a 100% gas engine, or into a "dual fuel" modified diesel engine.

In order to reduce deforestation, an education program should be implemented and alternative energy resources need to be identified. In rural Cambodia, education of farmers is being undertaken gradually by local NGOs and Agriculture Extension officers. These efforts raise awareness of the problems related to deforestation and explain the possibilities of farming trees for fuel wood. This way, farmers can earn additional income to their seasonal crop (usually rice) by growing and selling wood for fuel (which can be harvested every 4-6 months) and leaf for animal feed supplement.

Besides using fuel wood directly for cooking purposes, charcoal is also often used for cooking. Farmed *Leucaena* can also be used for making charcoal. For this purpose it is best to let the *Leucaena* tree grow older and bigger, before drying it and partially combusting it in pits or kilns to obtain charcoal. For methods of making charcoal from *Leucaena* wood reference is made to the *Leucaena Production Hand book* by Dr. Carol Cross.

3.2 Growing *Leucaena* for Feeding Livestock

Leucaena leaves are very palatable to ruminants including cattle, buffalo and goats. It can be fed as fresh/green leaf, or dried. Often *Leucaena* leaves are fed to cattle as a protein supplement to grass or rice straw. Sometimes feeding *leucaena* leaves improves the intake of the basal diet but generally it improves the total intake of dry matter, protein and digestible nutrients. The extent of the improvement depends on the amount of *leucaena* that is fed to the animal.

In the rice production areas of Cambodia, rice straw and stubble grazing constitute the major fodder supply. However, quantities are typically inadequate for the number of livestock fed, and this problem will be exacerbated with any shift to planting new rice varieties with lower straw yields. Rice straw is collected during harvest time and stacked near the farmer's house. Nutritional improvement in the feeding value of rice straw can be made by adding and mixing *Leucaena* leaf before feeding out to the animal. Cattle and buffalo utilize grasses and weeds growing on roadsides and communal grazing areas.

In cut-and-carry systems, *Leucaena* trees are cut back to about 1.0 meter height, branches harvested every two months during the growing season and fed fresh to animals. The frequency of cutting depends on the main purpose of the *leucaena* hedgerow, being either forage (leaf and fine stems) or wood. Long intervals between cuttings will favor wood yield, shorter intervals will favor leaf yield.

In larger production systems such as those for fuel wood production, the branches and leaves are sun dried on a rice drying slab, plastic sheeting or woven mats to allow the dry leaflets to drop. The dry leaf pieces are swept up and bagged for safe storage.

Table 1. Feeding Leucaena to cattle.

Animal	Base diet	Voluntary Intake of Base Diet only		Voluntary Intake with <u>Leucaena</u> Supplement				Fresh leaf equivalent (Kg)	Expected live Weight Gain (Kg/day)
		%body weight (approx)	Kg DM/day	Base diet		Leaf meal			
				% body Weight (approx)		% body weight (approx)			
Cattle (250 Kg Live Weight)	commune grazing and rice straw	3%	7.5	2.75	7.0	0.25	0.5	3.0	live weight maintained
Cattle (250 Kg Live Weight)	commune grazing and rice straw	3%	7.5	2.5	6.25	0.5	1.25	6.25	0.3 Kg/day
Cattle (250 Kg Live Weight)	commune grazing and rice straw	3%	7.5	2.0	5.0	1	2.5	12.5	0.5 Kg/day

Assumptions:

- Starting live weight of cow is 250 kg.
- Leucaena leaf meal yield, from PD AFF-Bek Chan plot in Battambang province, are 3,000-3,500 kg DM leaf/hectare per year. This equals to about 150 kg DM leaf / 100 meal hedgerow per year (Leucaena leaf is cut 3-4 times per year).
- From the above table, 150 kg leaf meal is sufficient to supplement feed of one cow for 60 days with an expected weight gain of 30 kg.
- 8 kg of Leucaena fresh leaf yields about 1.6 kg leaf meal (DM).
- DM = dry matter of leaf meal. This is plant material without water content following sun drying.
- The quality of the basal diet will affect overall performance of the animal. For example, if communal grazing is poor or nil, then additional Leucaena feeding would be required just to maintain current live weight. Rice straw has poor digestibility and contains about 3% total protein, compared to leucaena leaves with approximately 25% protein content and high digestibility (70%).
- Mimosine should not present any problems with this level of supplementation.

3.3 Reforestation

Another purpose of growing Leucaena is for reforestation. In Cambodia, the amount of forested area has decreased rapidly in the last 15 years because of an increased demand in the national and international market for tropical wood for furniture. Farmers often cut ('slash and burn') forest to access land for cultivating their subsidiary crops such as chili peppers, corn, peanuts and mung beans. The result of these practices and resulting deforestation are drought, global warming, land erosion and floods. In order to protect the environment and restore forested areas, fast growing trees such as Leucaena can be used.

Farmers can develop their own Leucaena plantations intercropped with corn, chili peppers, beans, and tea. As a result of such intercropping, farmers will not have to cut forest trees for fuel wood. Together with the positive impact on forests, farmers can benefit from planting Leucaena by improved soil conditions (through nitrogen fixation), better crop yields of crops that grow inter-row with Leucaena, additional income due to selling of access Leucaena and having livestock feed bank for their animals.

4. Results of Leucaena Harvest at Selected Sites Planted by SME Cambodia

During May 2005, 1 year after transplantation of seedlings from the SME Cambodia nursery, destructive sampling was conducted in order to determine the growth rate of the planted Leucaena (*Leucocephala Tarramba*). Four sites with a total harvesting size of 266m² were selected from over 50 different planting sites, all in the same village of Anlong Tamei, Bannan District, Battambang province. A total of 176 trees were harvested. Stems, branches, leaves and fruit were weighed. Site 4 is a plot where Leucaena trees are “intercropped” with fruit trees. This site was irrigated during the dry season (from October/November till May). Biomass production on an individual tree basis for this site was visibly higher (taller trees, larger diameter stems) than for the other 3 harvesting sites. However, since Leucaena trees on site 4 are planted widely spaced between orange trees, biomass production per unit area (square meter) is low.

In order to determine the amount of dry matter produced, samples of stems, branches, leaves and fruits were oven dried to constant weight at 70 degrees Celsius.

As can be seen from Table 2, branch biomass production (harvesting height 1 meter above ground) ranged between 3.1-5.1 t/ha, oven dried. This amount sounds rather small but the total above ground biomass (including stem, foliage and fruits) reached about 10 t/ha, within the first year. The branch production expected over the next year will likely reach well over 10 t/ha (dry matter basis).

Table 2. Leucaena growth rate during year 1.

		Site 1	Site 2	Site 3	Site 4
Surveyed plots		4m x 4m x 3plots	5m x 5m x 2plots	4m x 4m x 3plots	20m x 3m x 2plots
Area surveyed (m ²)		48	50	48	120
Number of planted trees		48	41	52	47
Number of survived trees		45	34	52	45
Planting method and spacing		1 x 1m, pure stand	1 x 1m, pure stand	1 x 1m, pure stand	1m x 3m, orange and guava trees are planted between the Leucaena rows
Irrigation		No	No	No	Yes
Previous status of the land		Abandoned orange garden. No fruit production for previous 3 years. Mango trees were planted with Leucaena but all died.	Abandoned orange garden. Back yard of a farmer's house. Disturbance by cows and children?	Abandoned orange garden. Chili was planted with Leucaena and grew well.	"Intercropping" with orange and guava.
Planting period		May/June 2004	August 2004	August/September 2004	June 2004
Age		12 months	10 months	10 months	12 months
Branch (> 1m) biomass	Fresh (t/ha)	10.3	7.8	6.4	6.7
	Oven Dried (t/ha)	5.1	3.8	3.1	3.3
Stem (0-1m) biomass	Fresh (t/ha)	6.8	5.5	5.9	3.8
	Oven Dried (t/ha)	3.8	3.0	3.2	2.1
Total oven dried woody biomass (t/ha)		8.9	6.8	6.3	5.4
Oven dried woody biomass per tree (kg)		0.9	1.0	0.6	1.4
Foliage	Fresh (t/ha)	6.1	5.5	4.9	5.4
	Oven Dried (t/ha)	2.0	1.8	1.6	1.7
Fruits	Fresh (t/ha)	0.1	0.7	0.8	1.4
	Oven Dried (t/ha)	0.0	0.3	0.3	0.5
Oven dried total above ground biomass (t/ha)		10.9	8.9	8.2	7.7

PART II – COMMUNITY BASED VILLAGE ELECTRIFICATION PROJECT USING BIOMASS RENEWABLE ENERGY, A CASE STUDY

5. Cost comparison of wood fuel versus diesel fuel for rural village electrification

In Cambodia today, less than 10 percent of rural households are connected to electricity grids. Most rural villages utilize various energy sources for lighting and cooking including, oil lamps, candles, charcoal, wood, rice husk and batteries (charged by diesel generator sets). Where available, electricity services in rural areas are supplied by Rural Electricity Enterprises (REEs). These enterprises are operated by local entrepreneurs using diesel generator sets that distribute electricity through stand-alone grids that the REE owner has constructed from available materials. Often the equipment condition and quality are deficient.

Households not connected to local electricity grids have either no access to electricity services or must use (12 volt) car batteries to power fluorescent lights, radios or TVs. Lighting for households that have no batteries is limited to kerosene lamps and candles. The REEs are severely limited in their ability to expand services to more distant villages and households due to lack of capital for modern generation and transmission equipment.

System inefficiencies and the high fuel cost of imported diesel oil result in electricity rates in rural villages that are among the highest in South-East Asia, ranging from \$0.40 to \$0.95 per kilowatt hour. The high electricity rates are a major obstacle to developing local businesses, that can compete with those in urban areas. Reducing the cost of fuel and dependency on imported fossil fuels will be critical to improving the economic status of rural residents.

Costs of fuel for operating biomass gasification, village electrification system

An alternative for rural electricity services using increasingly expensive, imported fossil fuel is the utilization of renewable energy technologies that transform locally available biomass into cheaper electrical energy. Using biomass gasification technology, 1.2 to 1.5 kg of wood (with a moisture content of less than 20%) is required to produce 1 kWh of electricity (ref: Ankur Scientific Energy Technologies). One ton of wood therefore can be converted into about 714 kWh of electricity. Presently, in Cambodia, the price of Leucaena fuel wood (dry) is around \$25 USD per ton. Therefore the fuel costs for operating a biomass gasification, village electrification system in Cambodia are only 0.035 USD per kWh.

Cost of fuel for operating a diesel generator set for village electrification

A reasonably efficient diesel generator set consumes about 0.3 liter of diesel fuel to produce 1 kWh of electricity. In practice, for rural electrification in Cambodia, the consumption will be higher than this because of the use of old and inefficient equipment. Presently in Cambodia, the price of diesel fuel is about 0.66 USD per liter (retail price on 24 July 2005). Therefore, the fuel costs for operating a diesel generator set for village electrification in Cambodia are 0.20 USD per kWh.

Comparing the above calculations, it can be concluded that the fuel costs for operating a biomass gasification, village electrification system are 6 times lower than the fuel costs for operating a diesel generator set. The cost of the initial investment and maintenance of a biomass gasifier is however somewhat higher than for a diesel generator set. In terms of economic comparison biomass fuelled systems result in much lower electricity production costs than comparable sized diesel fuelled systems.

6. Pilot project of renewable Energy at village level in Cambodia

6.1 Project goal, objective and idea

In March 2004, SME Cambodia, utilizing grant fund support from the Canada Fund and US-AID, implemented a pilot-project, to test 100% biomass gasification technology managed by a community energy cooperative. The goal of the project is rural economic development and improved competitiveness of rural businesses by setting up a high quality, low cost, community owned electricity service using locally produced fuel (woody biomass from leucaena trees).

Project objectives are to:

- Increase farmer income through growing and selling fuel wood to the community energy cooperative and selling leaf material to local animal feed markets;
- Increase employment and income generation through creation of new commercially productive activities utilizing the lower cost electricity;
- Improve quality of life of rural residents through household electrification;
- Establish tree plantations or “energy reserves” sufficient to provide a continuous supply of wood biomass fuel, required to power the village electricity system;
- Improve village public security through introducing outdoor lighting of public pathways, roads and commercial areas.

The project is intended to also:

- introduce and demonstrate the member-owned electricity utility model to rural Cambodia;
- introduce and demonstrate biomass gasification, an alternative renewable energy technology, that can supply electricity to village households at rates that are 50% below the rates currently charged in surrounding rural villages using diesel generation systems;
- demonstrate the feasibility of creating community energy reserves (tree farms), that provide a locally grown renewable fuel source that substitutes for the environmentally damaging, economy draining imported fossil fuels, and
- reduce fuel wood cutting pressure on local natural forests.

6.2 Village Energy Cooperative Model

The village of Anlong Tamey, in Bannong District, Battambang Province was selected for the pilot project implementation. This village is comprised of over 200 households and did not have an electricity supply system. A community based energy cooperative, registered at the Ministry of Interior, was formed to own, operate, maintain and manage the electricity generation and distribution system. During construction, villagers provided all labor free of charge to construct the village electricity distribution system. The initial cost of equipment required for setting up a biomass gasification, electricity generation and distribution system pilot was covered by a grant provided by the Canada Fund. After completing the initial preparation, construction and operational testing period in January 2005, the Community Energy Cooperative began operation and has provided electricity services to 75 households on a non-subsidized, sustainable basis since February 15, 2005.

Daily operation of the system is managed by 3 permanently employed, local staff. Management of the village electricity service is supervised by a member-elected, management team. In April 2005, the Anlong Tamei Community Energy Cooperative was granted a 5 year operating license from the Electricity Authority of Cambodia. The first member owned cooperative to receive this license.

6.3 Biomass Gasification, electricity generation and distribution

Biomass gasification technology, developed and widely used in India, and other developing countries in Asia has proven to be a reliable and efficient alternative to technologies dependent on increasingly expensive fossil fuels. Biomass gasifiers using wood fuel are easy to operate and maintain, and can power a modified engine to run on 100% producer gas, eliminating the need for expensive, imported fossil fuel. SME Cambodia staff supervised cooperative members during installation of the 9 kWe biomass gasification, electricity generation system and during construction of a 1 kilometer long, 3-phase, electricity distribution system serving 75 cooperative members homes. The biomass gasification technology used was developed by Ankur Scientific Energy Technologies Pvt. Ltd., Baroda, India. The fuel source used is wood harvested from farmed *Leucaena* tree planted by local farmers for the purpose of providing biomass to the energy cooperative.

Customers are charged on a per kWh rate, based on metered individual customer consumption. Rates charged for the electricity consumed are established such that all system operation and maintenance expenditures plus equipment replacement (“depreciation”) costs are included. The tariff of \$0.30 per kWh is 1/2 to 1/3 of the tariffs currently charged in nearby rural communities, and similar to the rate charged by the government owned electricity provider in the provincial capital (\$0.25 per kWh). The system also provides 20 streetlights on the main road through the village at no extra charge to the members.

6.4 Tree Plantation - “Community Energy Reserve”

The installed biomass gasification system operates on 100% biomass from locally farmed trees. Around 6 hectares of leucaena trees were planted in the village, distributed over land owned by more than 50 farmers. Initial “coppicing” of the tree stem, at a level about 1 meter above the ground, took place after 16-18 months. Farmers then periodically (every 4-6 months) harvest the branches at a diameter of 2-3 centimeters, dry and sell the wood to the Community Energy Cooperative to provide biomass fuel for the gasifier.

7. Socio-economic survey and preliminary results of village electricity service operation

A socio-economic survey was conducted in Anlong Tamei village, with the objective to establish a baseline of social, economic and energy-use parameters. Follow-up surveys are planned at a later stage to determine changes in these parameters as a result of the electrification project. The initial socio-economic survey was conducted through the use of household surveys covering 20 electrified and 20 non-electrified households, and through key informant interviews from among key individuals in the village, by an independent consultant. The survey took place over a period of 1 week from May 26 to June 1, 2005, 4 months after commissioning of the biomass gasification village electrification system.

The study indicates the following conditions in the village:

- The village is generally agricultural where majority of households rely on agriculture as the primary source of income with crop production occurring over the entire year;
- Across all household types, fuel cost is low at about 1.40 USD and contributing to about 4% share of the total household expenses;
- Trees are cut for firewood for individual home use and for selling purposes. According to the village chief, cutting of trees is more than what is available/ growing in the village;
- Household income is generally greater than expenditures across all households and ownership of land and household assets is common;

Fuel and energy use prior to improved electricity services

The fuel and energy sources available for use among villagers are firewood, charcoal, kerosene, LPG, car batteries, private diesel generators, dry cell batteries, candles and agricultural residues (e.g. rice husks and stalks, coconut husks). However, the main fuel and energy sources are firewood, kerosene, car batteries, and candles.

Firewood is mainly used for cooking purposes, while kerosene, car batteries and candles are generally used for lighting. For appliances, car batteries are the main source of energy.

Impact of Electrification

After 4 months of electrification in Anlong Tamei village, impacts to work and income, quality of life, perceptions on future use, and its importance to everyday life can be seen among the villagers.

The most noticeable impact of electrification in the village is in the improvement of villagers’ quality of life. This change is generally brought about by their use of household appliances that lessen workload, provide convenience and ease, and gives them access to entertainment and information. There is also a feeling of security especially at night with the street lights in the main road and continuous lighting at homes. Households also feel that they have more time for family gatherings e.g. eating/ being together when watching television programs.

A few villagers have utilized electricity by establishing new businesses or extending their business hours to night time hours. This is evident in the new coffee-shop/ karaoke, and small stores businesses and with the motor-repair shop and water vending business. Electricity is generally used for lighting purposes in the businesses although there are those that run appliances to attract customers i.e. video player at coffee-shop, and karaoke machine. This change is positively coupled with lesser expenses associated with such fuel types as kerosene, battery-charging cost, and diesel for private generators.

Emerging positive attitudes revolve on night work and children's ability to study at night. Although, so far, only a few engage in night work (rice-cake making and rice/corn grinding), the start of this trend at an early stage of the electrification service is encouraging. Some 35% of those interviewed wanted to open their own stores, and of equal percentages, laundry services, water/ice vending, karaoke shop, and selling deserts were also the given choices of possible income-earning activities.

Key findings from the survey are:

- Utilization of electricity is mostly for home convenience and entertainment but there are emerging productive uses in the service sector;
- Available electricity has reduced use and cost of kerosene, car batteries and diesel; and
- Impact of electrification revolves around quality of life benefits, satisfaction with the current electricity service is good, and willingness to pay for electricity is very high.

The findings also indicate that the managing beneficiary, the Community Energy Cooperative, is capable of operating and maintaining the biomass gasifier system, and is a viable organization.

8. Conclusion / Recommendation / Future development

The recent increase in oil price is slowing down the world economy. Therefore alternative sources of energy are becoming more and more important to decrease dependency on fossil fuel and to restore the economy. In the case of Cambodia, where all fossil fuels are imported, and highly taxed, biomass renewable energy technology, in combination with the creation of tree farm 'energy reserves' are a means of improving the living standard of impoverished, rural residents. This model of village electricity service can improve the quality of life of rural residents and enhance the local economy thereby creating urgently needed jobs. The technology of biomass gasification has proven to be reliable and suitable for operation in rural areas in Cambodia.

Farming fast growing tropical legume trees such as *Leucaena*, in order to establish a sustainable energy supply in rural areas, contributes to local socio-economic development, trade mechanisms, and provides additional income for farmers selling fuel wood and leaves. In addition, growing trees such as *Leucaena* will help restore poor soil conditions, improve the atmosphere by absorbing CO₂, improve soil fertility due to its fast growing root system, fixing nitrogen to the soil, and through the high urea content of the leaves.

To have better understanding of the use of wood fuel, more research needs to be done on exploring the new high yield varieties of trees, to be used as a new energy resource for replacing fossil fuel. This will also have a good impact on our environment, such as decreased global warming, erosion, floods.

Besides farming trees for energy, SME Cambodia is currently working on the introduction in Cambodia of biomass gasification technology using agricultural residues such as rice husks, peanut shells and cashew nut shells. Application of this technology has enormous potential in an agricultural based economy where large amounts of agricultural residues are under-utilized, and can be used as a substitute for increasingly expensive, imported fossil fuel.

9. References

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