Cambodia Village Agroforestry:
A Pilot Project for Sustainable Energy Resources, Income Generation, and Gender Equity

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Acronyms and Abbreviations

C	Carbon
CDM	Clean Development Mechanism
cm	centimeters
CO_2	Carbon dioxide
DBH	Diameter at Breast Height
dm	dry matter
FA	Forestry Administration, Royal Government of Cambodia
FAO	Food and Agriculture Organization
GERES	Renewable Energy and Environment Group
Ha	Hectare
hh	household
JICA	Japan International Cooperation Agency
kCal	kilo calories
Kg	kilogram
LPG	Liquefied Petroleum Gas
m^3	cubic meters
MAFF	Ministry of Agriculture, Fisheries, and Forestry, Royal Government of Cambodia
MJ	Mega-Joule
mm	millimeters
NGO	Non-Governmental Organization
NPV	Net present value
NTFP	Non-timber forest products
OECD	Organisation for Economic Co-operation and Development
pH	Hydrogen Ions concentration
RGC	Royal Government of Cambodia
RWEDP	Regional Wood Energy Development Program
SME Cambodia	Small and Medium Sized Enterprises Cambodia
SNV	SNV Netherlands Development Organisation
t	ton
tCO_2e	tons of carbon dioxide equivalent
TJ	Tera-Joule
US$	United States Dollar
yr	year

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Abstract

Cambodia is a least developed country located in Southeast Asia, where 85 percent of the population depends on woodfuel for their domestic energy consumption. This large demand and Cambodia's momentus population growth will place an even heavier demand on woodfuel sources because alternative, more modern sources of energy are currently out of reach for the rural poor. The conventional views of woodfuel supply and demand suggest that if there is woodfuel scarcity, it can be alleviated by planting trees. Addressing woodfuel scarcity is more complex than just planting trees and the programs that address this problem must be carefully planned to address site-specific data and provide the appropriate incentive scheme for villagers to justify planting trees.

This paper analyzes the various forest management options present in Cambodia for their suitability in achieving the following development objectives: (i) allow villagers to have free access to sustainable fuelwood and other non-timber forest products; (ii) allow villagers to have the opportunity to generate additional income, and; (iii) strengthen the role of women in the village. Based on the data that is available and after analyzing the various forest management regimes, the paper puts forth a development proposal for a pilot project for village level agroforestry that will allow tree planting on farms and in public spaces through out a village. Workable farmland is at a premium and farmers use space to grow crops economically. With fast growing multi-purpose leguminous tree species that can grow in a wide spectrum of soil conditions, farmers can intercrop their agricultural crops with these tree crops or plant the tree crops as fencing or shade on land that is not able to support rice production. Data shows that the average subsistence farmer works one hectare of land. The results of this paper's

analysis is that one hectare of farmland would be enough to not only cultivate enough rice to meet a household’s demand, but also allow them to plant multipurpose tree crops to generate enough fuelwood to allow them to meet their own fuelwood consumption levels and allow an equal amount of fuelwood to be sold to the market in order to generate additional income. Plus, through the pilot project proposed in this paper, the bundling of such tree planting efforts throughout the village could provide a viable carbon offset project through the avoidance of deforesting natural forests.

1 Introduction

The significance of this paper derives out of an urgent need to find alternative solutions for rural household energy consumption that will enable the rural poor to meet their energy needs without degrading the environment. Cambodia's rural poor have very limited access to other alternative forms of energy and with momentous rural population growth, the dependency on fuelwood for their energy needs will continue to increase. The results may have devastating effects on Cambodia's environment and rural economy.

This paper analyzes the existing domestic energy trends for Cambodia's rural population and examines existing forest management regimes for their suitability of achieving the following development objectives: (i) allow villagers to have free access to sustainable fuelwood and other non-timber forest products; (ii) allow villagers to have the opportunity to generate additional income, and; (iii) strengthen the role of women in the village. The second half of this paper proposes a development project that seeks to achieve the above objectives.

2 Domestic Energy Background

Cambodia is one of the poorest countries in the world[1] with an overwhelming majority of its population depending on biomass fuels such as firewood and charcoal for their energy needs. Overall, the national energy consumption in Cambodia in 2005 was calculated to be about 138,500 Tera-Joule (TJ) of which 77 percent was covered by various types of biomass including firewood, charcoal, dung, and agricultural residues (Table 1).

[1] Ranked 130, Human Development Index, UNEP 2003; and among the countries on the UN's list of Least Development Countries (LDCs)

Table 1. National Energy Demand from 1994 to 2010 (TJ) (MIME, 2005)

Type of Fuel	1994	2000	2005	2010
Wood	77,721	89,616	103,552	106,344
Charcoal	1,097	1,213	1,367	1,357
Other biomass	1,754	1,600	1,559	1,351
LPG	103	421	729	1,050
Gasoline	6,006	10,765	15,288	20,284
Kerosene	1,323	1,678	2,081	2,430
Jet Fuel	725	881	1,125	1,435
Diesel Oil	4,580	7,521	10,539	14,783
Fuel Oil	65	102	158	249
Electricity	777	1,308	2,066	2,962
Total	94,151	115,105	138,464	152,245

Firewood and charcoal are often referred to as traditional fuels, yet they remain the dominant source of energy for cooking within the domestic sector and are used extensively by industry and the service sector[2].

At a conservative price of US$ 0.04 per kg at the village markets and a consumption of more than 7.5 kg/household/day, the cost of fuel is a substantial daily burden for the average rural household. Biomass remains the cheapest and most accessible source of energy used for cooking. The price of charcoal, depending on the location, is 600 - 800 Riel per kg or around US$ 0.15 to US$ 0.20, while the price of kerosene is 1,800 Riel per liter or around US$ 0.45 (exchange rate US$1 = 4,000 Riel). Though the efficiency of devices to burn firewood and charcoal is quite low, the cooking cost for each useful unit of energy (MJ/kg) is still lower than the same cost of kerosene or Liquefied Petroleum Gas (LPG) burned in a high efficient stove (JICA, 1999).

Energy needs of rural areas are not likely to be met through access to electricity or petroleum products in the medium-term. Even if the Government of Cambodia is able to meet its target of increasing access to electricity (from current 7 percent to 70 percent

[2] Wood is used in pottery production, bakeries, tobacco drying kilns, charcoal kilns, tile kilns, wine factories, rattan drying factories, sugar and palm sugar factories, smoked fish factories, wrought iron production, and restaurants (Burgess, 2000).

in 25 years), it would not address the problem of lack of access to modern cooking fuels in rural areas (MIME, 2005).

As the population of Cambodia continues to increase, it is most likely that the consumption of firewood will continue to rise because 40 percent of the population still lives below the poverty line and the affordability and availability of modern cooking fuels such as LPG, will remain out of reach for many people, especially in the rural population.

2.1 Woodfuel Supply and Demand

Biomass energy consumption is often times stated in international donor reports, such as Japan International Cooperation Agency's (JICA) *Country Profile on Environment: Cambodia* (JICA, 1999), as a major cause of deforestation; however, there is limited data supporting this claim. Groups such as the United Nations Food and Agriculture Organization's (FAO) Regional Wood Energy Development Program in Asia (RWEDP) state that the exploitation of forests for woodfuel use contributes little to deforestation of natural forests because most woodfuel comes from non-forested land such as shrublands. Statements such as these debunk the "fuelwood gap theory" that was very popular leading up to the 1970's when data on forest cover was not very abundant. In short, the "fuelwood gap theory" states that woodfuel is being used on an unsustainable basis and that demand for woodfuel outpaces the supply and regeneration of woodfuel (Arnold et al, 2006). RWEDP's statement may be true on a national or provincial level but could also be false when spatial limitations are applied, i.e. at the village level, as in the next example.

In woodfuel supply and demand studies performed in Kampong Thom Province, it was concluded that the supply for woodfuel is much higher than demand; therefore, the use of forest resources for woodfuel is sustainable (Top et al, 2004a, 2004b, 2006). The study claims that villagers collect firewood from trees with a DBH of less than 30 cm from mostly non-forested lands, re-growth forests, and from trees along the roadside. These findings are somewhat in contrast with the other studies and the opinions of many natural resource managers in Cambodia. It is important to note that results vary upon the spatial scales that are measured within the study because at the provincial level, the supply seems sustainable relative to demand but the same study shows that in some villages within the province, demand does outweigh sustainable supply and that forest resources are becoming degraded; however, the majority of villages have a balanced supply and demand. For the villages that are balanced, the study acknowledges that if population continues to grow and demand for woodfuel increases then the forests within those areas will not be able to meet demand resulting in natural resource degradation.

Although the study somewhat contradicts other wood flow studies by determining the woodfuel sources as being sustainable, the end result of the studies are complementary in that they each stress the importance for sustainable forest management interventions in order to ensure a sustainable supply of woodfuel to the population.

If firewood and charcoal production are not a major cause of deforestation, one main issue is whether firewood and charcoal are renewable or not. If not, then at what point will non-renewable firewood and charcoal production become a major cause of deforestation?

Data is limited in determining the origin of supply of firewood and charcoal in Cambodia other than the Kampong Thom study previously described. Only two other wood flow studies were available both of which are for the city of Phnom Penh. One performed by the FAO's Renewable Wood Energy Development Program in Asia (RWEDP) in 1998 and the other by a French NGO, Renewable Energy and Environment Group (GERES) in 2006 as part of a wood energy baseline study for the Clean Development Mechanism (CDM)[3] in Cambodia. Both studies agree that the main supplies of charcoal and firewood are transported to Phnom Penh using National Highway 4. According to GERES, 99.6 percent of charcoal and 70.6 percent of firewood are transported to Phnom Penh using this road (Van Mansvelt, 2006b). From this road the woodfuel originates in different areas. According to GERES, most of it comes from Kampong Speu Province leading into the Aural Wildlife Sanctuary, about 90 kilometers west of Phnom Penh. The GERES study confirms that the charcoal and firewood production is evidently causing deforestation, converting primary evergreen forests into degraded shrub-lands.

Although there is an increase in LPG use in Phnom Penh and a decrease in charcoal for household cooking, taking into account the population growth, the total amount of charcoal consumed per year is relatively the same. Thus, the supply from Kampong Speu will still need to generate the same amount of charcoal it has been doing for the past several years. This is becoming more difficult to do as primary forests are continuously being depleted and the wood is not as abundant and needs to be gathered further and further away from the road as well as further into the Aural Wildlife Sanctuary, jeopardizing the integrity of a protected area and the biodiversity that inhabit it. The RWEDP study claims that as recent as 1990, forest areas were found along the

[3] The Clean Development Mechanism (CDM), defined in Article 12 of the Kyoto Protocol, provides for Annex I Parties (industrialized countries) to implement project activities that reduce emissions in non-Annex I Parties (developing countries), in return for certified emission reductions (CERs). The CERs generated by such project activities can be used by Annex I Parties to help meet their emissions targets under the Kyoto Protocol. Article 12 also stresses that such projects are to assist the developing country host Parties in achieving sustainable development and in contributing to the ultimate objective of the United Nations Convention on Climate Change (UNFCCC). Source: UNFCCC (http://unfccc.int/kyoto_mechanisms/cdm/items/2718.php)

roadside of National Highway 4 and now the forest has receded a great distance, and firewood collectors spend a whole day going to the forest.

In another CDM baseline study that GERES performed for the Cambodia National Biodigester Program, they set out to determine whether the woodfuel used in the 6 provinces targeted by the program was renewable or not. In order for the National Biodigester Program to be eligible for the CDM, the woodfuel would have to be established as non-renewable in order to show that there is net carbon loss and the proposed project activity would offset that loss. A total of 300 households were surveyed, 50 in each province. The result of the survey shows that 67 percent of the respondents collect firewood near or around their house of which they indicated that the amount of trees and shrubs are decreasing (Van Mansvelt, 2006a) and it was determined that this biomass is non-renewable. The results further show that the woodfuel that is purchased originates from rubber plantations. The rubber plantations are mostly in Kampong Cham Province and are approximately 15 years old and will be cut in the next 1-2 years. With these clear cuts, other sources of woodfuel will need to be harvested in its place, leading to a net loss in carbon stocks; therefore, the biomass that originates in these areas can be considered non-renewable as well. In all, the average household that was surveyed in the study consumes 8.9 kilograms of wood per day and 77 percent of that amount is determined to be from non-renewable sources.

2.2 Gender Issues

Decades of conflict and the genocide from 1975-1979 that killed approximately 1.7 million people have left Cambodia with a disproportionate male/female, young/old population. The conflict continues to have an impact not only in the economic realm and on the physical infrastructure of the country but also on the social infrastructure. The ramifications of the war have changed the gender dynamics as women in rural and industrial areas represent over half of the workforce, contribute substantially to the national economy, endure most of the workload in rural areas, yet hold less than one percent of the power in government.

Cambodia's population is approximately 14 million of whom 80 percent live in rural areas (NIS, 2004). Women make up 52 percent of the population. Rural women are responsible for 80 percent of food production, and more than 65 percent of women are farmers. Half of women farmers are illiterate or have less than a primary school education (compared to 29 percent for men), and 78 percent are engaged in subsistence agriculture (World Bank, 2004). Most farmers till small plots of land to satisfy the family's need for rice and vegetables. The quality of the arable land is mostly poor; the average rice yield per hectare is 1.3 tons compared to 3 tons in the neighboring countries (Lam & Boers, 2005). Low agricultural productivity and increasing pressures on land are making it extremely difficult for most small farmers to survive. Access to agricultural extension services, market information, and financial services are very limited for all farmers and especially difficult for women farmers (World Bank, 2004).

Time studies show that women have less leisure time than men, and the intensity of their work remains constant throughout the year, whereas the intensity of men's work fluctuates (Gorman et al, 1999). Women tend to align their own interests with those of the family by doing housework in addition to the other responsibilities for the family's food and income. In 66 percent of the rural households, research indicated that women are responsible for collecting the wood either alone or shared with the children and husband.

By providing villagers with local supplies of fuelwood for cooking, women and children will spend less time collecting cooking fuel which will allow women to use their time more productively and allow children the time to attend school. Per household the workload of (mainly women and girls) could be reduced by approximately 2-3 hours per day if local sources of fuelwood were available or if other modern forms of energy could be used. This is caused considerably by reduced time for firewood collection.

2.3 Cambodia's Forests and Ecology

Cambodia's forests comprise a variety of evergreen, deciduous, mixed and mangrove forest types. There has not been a national forest inventory in Cambodia since 1969 (World Bank, 2003). Since then, forest statistics have been established by interpreting satellite imagery which lead to many different estimates of deforestation rates and forest cover. The Royal Government of Cambodia (RGC) estimates that the current forest cover is approximately 60 percent of the total land area, decreasing from roughly 73 percent in 1969 (Bottomly, 2000). Global Witness, a non governmental organization (NGO) who closely monitors forestry issues in Cambodia, has estimated forest cover could be as low as 30 percent and that the RGC used a high estimate in order to justify allocating more forest land to concessions (Global Witness, 1996).

The size of Cambodia's land area is 176,250 square kilometers which converts to 17,652,000 hectares (ha). Statistics from a Cambodian Department of Forestry and Wildlife[4] report divide Cambodia's forestry estate into 1.346 million ha of protected forest, 3.273 million ha of protected areas, 3.874 million ha of valid forest concession areas, 3.001 million ha of cancelled forest concession areas since 1999, and a negligible 56,528 ha of tree planting stations (Barney, 2005). This breakdown shows that 22

[4] The Department of Forestry and Wildlife is now known as the Forestry Administration.

percent of the total land area of Cambodia is under forest concessions, and another 26 percent of the total land area is under some type of protection, leaving a remaining 17 percent of total land area as forests with no designated use.

There are a number of root causes of deforestation of natural forests in Cambodia, none of which are attributed to woodfuel consumption. Major deforestation has been caused by civil war, corruption, political rivalry, military control, and the demand of neighboring countries (Bottomly, 2000).

3 Comparative Analysis of Forest Management Types for Sustainable Woodfuel Production

The livelihoods of the majority of rural Cambodians are dependent on access to forest products, especially for food, fuelwood, small-scale timber harvesting (for building and household materials), resin tapping, fodder, traditional medicines and other non-timber forest products. However, in many rural areas, forest resources are heavily degraded or have been lost entirely, leading to access constraints in terms of distance, increasing population pressure, and exclusion from forest areas (DFW, 2003).

The objective of the following analysis is to determine the most appropriate forest management type that will: (i) allow villagers to have free access to sustainable fuelwood and other non-timber forest products; (ii) allow villagers to have the opportunity to generate additional income, and; (iii) strengthen the role of women in the village.

According to the Royal Government of Cambodia's (RGC) Forestry Administration[5] and the Cambodia Tree Seed Planting Project[6], there are basically five

[5] http://www.forestry.gov.kh

forest management types present in Cambodia today that are potentially suitable for fuelwood production.

1) Forest Concessions
2) Community Forestry
3) Private Plantations
4) Agroforestry / Farm Planting
5) Planting on public communal / village lands

This section will review each forest management type for the feasibility of meeting the above three objectives. A comparison table of the forest management types is located in Table 2 of Section 3.6.

3.1 Forest Concessions

Forest concessions are granted to private logging companies by the RGC. According to the FA website, there are approximately 3.4 million ha of forest land under concession and another 3.5 million ha of cancelled forest concession areas[7]. Forest concession areas are typically closed off to the public; therefore the collection of fuelwood and other non-timber forest products are not allowed. There is also much scrutiny over the government granting forest concessions on land that the rural poor depend on for their livelihoods. Thus, the closing off of this land to them is a serious threat to their livelihoods.

There is potential for forest concession reform where the Government of Cambodia could mandate that forest concession areas are to be open to the rural poor for fuelwood and other non-timber forest product collection, which should be encouraged by the Concession holder to show good corporate responsibility. The villagers that

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[6] http://www.treeseedfa.org
[7] http://www.forestry.gov.kh/Statistic/Forestcover.htm

collect from these areas could be free to sell these products in order to generate additional income.

3.2 Community / Village Forestry

Community or village forestry is the devolution of forest management responsibilities to local communities under the authority of the federal and local governments. The majority of community forest activity in Cambodia is the management of existing primary or degraded forest rather than reforestation by planting (JICA, 2005).

The land designated for community forests in Cambodia is typically a bottom-up approach that is initiated at the local level. The request is sent from local organizations to the local government to the provincial government up to the Forestry Administration (FA) under the Ministry of Agriculture, Fisheries, and Forestry (MAFF). The forest area that is requested to become a community forest is public land under management authority of the government. Once approval is granted, community forestry projects are managed by a committee that usually consists of the commune chief, village chief, and other elected citizens.

Community forestry programs are donor driven because there are typically limited to non-revenue generation activities to self sustain the operations and maintenance of the community forest. Although the majority of community forests provide free access to villagers to collect fuelwood and other non-timber forest products which may or may not be enough to generate additional income, the community forestry itself is fully subsidized and runs the risk of not being sustainable in the long run.

According to FA's web database[8], there are approximately 179,000 hectares of Cambodia's forest designated as community forests. This is approximately 0.02 percent of all Cambodia's forests. The main objectives of the majority of the community forests in Cambodia are to increase the supply of wood and non-timber forest products for local consumption, ensure forest resources for future generations and to ensure the equitable benefit sharing from forest resources among the local community.

3.3 Privately Owned Plantations

There is insufficient data providing evidence of private energy plantations in Cambodia. They would seem beneficial if managed in an ecologically sustainable manner. For example, planting a mixture of species to promote biodiversity, enrich soil conditions, and generate revenues from non-timber forest products. Private energy plantations could be appropriate to supply fuelwood for charcoal production in markets where demand is high such as peri-urban and urban areas. Otherwise, an energy plantation that provides free access to villagers for fuelwood collection alone is not financially viable and not self-sustaining unless it can generate income from other activities such as timber sales.

Also, it is speculated that the government is allowing foreign investors to purchase large tracts of land to establish energy crop plantations where fuelwood and biofuel from Jatropha plantations is being exported to Europe and other countries and not for domestic consumption.

[8] http://www.forestry.gov.kh/CFWeb/CFbyProvince.asp

3.4 Agroforestry / Farm Planting

Many rural families plant trees in areas where tenure is perceived to be more secure than forestlands, especially on agricultural land and home gardens. The World Agroforestry Centre defines agroforestry systems as "a land-use system in which woody perennials (trees, shrubs, palms, bamboos) are deliberately used on the same land management unit as agricultural crops (woody or not), animals or both, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic interactions between the different components[9]."

Agroforestry systems aim to gain a continual harvest with many purposes such as the harvest of forest products from these crops such as fodder, firewood, and other non-timber forest products and to improve soil fertility or prevent soil erosion. Tree species that have been identified by the Cambodia Tree Seed Planting Project[10] are *Leucaena leucacephala*, *Sesbania bispinosa*, and *Moringa oleifera*. These species are fast growing and can grow in poor soils with limited irrigation. A detailed species chart for these tree species and other potential tree species that are appropriate for agroforestry systems in Cambodia is located in Annex III.

The planting of tree crops on agricultural land that is owned by farmers can potentially sustain a household's daily requirement for fuelwood and may possibly generate enough fuelwood and other-non timber forest products to market to local businesses or other villagers that are in demand for such products; thus, generating additional income for the household.

[9] http://www.worldagroforestrycentre.org/InformationResources/A-B.asp
[10] http://www.treeseedfa.org/publications.php

3.5 Planting on Public Communal / Village Lands

There are several benefits to planting multi-purpose tree crops on public communal/village lands. These include fuelwood production, live fences, windbreaks, shade, beautification, and preventing soil erosion among others. Planting activities are summarized in the Table 3. However, the coordination of planting activities would require a local management office to oversee a planting, maintenance and surveillance program. The sharing of benefits derived from such a tree planting effort would need to be carefully planned out and decided by the community; therefore it would be difficult to say whether there would be free access to villagers to collect fuelwood or if they would have to purchase the fuelwood. If the community management office charges for fuelwood, the proceeds could go towards supporting the community management office and social programs such as schools and health services and other services that are needed in rural Cambodia.

Table 3. Planting Activities on Communal / Village Lands

Tree Planting Activity	Benefits	Recommended Species*
Boundary of large fields, homesteads	Live fences, windbreaks	*Leucaena leucacephala*, *Pithecellobium dulce*, *Sesbania bispinosa*, *Casuarina equisetifolia*), *Acacia*, *Hura crepitans*, *Azadirachta indica*, *Eucalyptus camadulensis*
Public places, such as hospitals, schools, pagodas and public gardens	Shade and beauty	*Hopea odorata*, *Dipterocarpus alatus*, *Delonix regia*, *Albizia saman*, *Cassia siamea*, *Cassia fistula*, *Casuarina euqisetifolia*, *Afzelia xylocarpa* and *Pterocarpus macrocarpus*.
Forest cover along waterways	Prevent erosion and banks from collapsing	*Barringtonia asiatica*, *Pithecellobium dulce*, *Bambusa spp*, *Psidium guajava*, *Nauclea orientalis*, *Acacia*, *Eucaliptus camadulensis*, *Crateva andansonii*, *Ficus spp*., and vines (*khtum*)
Fodder for raising animals	Food for animals, fencing, and beautifying the homestead	*Leucaena leucacephala*, *Moringa oleifera*, *Hura crepitans*, and *Sesbania bispinosa*
*Cambodia Tree Seed Planting Project (Partnership with the Forest Administration)		

3.6 *Lessons Learned*

The objective of the comparative analysis is to choose the most appropriate option to allow the rural poor at the village level to have (i) free access to sustainable fuelwood and other non-timber forest products; (ii) to have the opportunity to generate additional income, and; (iii) to strengthen the role of women in the village.

Table 2. Comparison of Forest Management Types

Forest Management Types	Land Ownership	Regulatory Requirements (Oberndorf, 2006)	Access Rights to Public	Income Generation for Rural Poor
1) Forest Concession	State Owned/Leased by Private Company	Forestry Law, Law on Environmental Protection and Natural Resource Management (requires an Environmental Impact Assessment on Areas greater than 10,000 hectares or logging on areas over 500 hectares)	None	None
2) Community Forestry	State Owned/ Managed by Community Board	Forestry Law, Community Forestry Sub-Decree, Law on Environmental Protection and Natural Resource Management (requires an EIA on Areas greater than 10,000 hectares or logging on areas over 500 hectares)	Membership based	None
3) Private Plantations	Private (owned by company)	Law on Environmental Protection and Natural Resource Management (requires an EIA on areas greater than 10,000 hectares or logging on areas over 500 hectares)	None	None
4) Agroforestry /	Private (owned by	None	None	Yes

Farm Planting	villager)			
5) Plantations on Communal Lands	Commune Owned / Managed by Community Members	None	None	Yes

After analyzing the options above, the most appropriate option(s) to meet the development objectives seem to be a combination of both agroforestry on farm land owned by villagers and planting trees in public communal / village lands. The agroforestry option will allow farmers to generate enough fuelwood to meet their demand and potentially more which can be marketed along with other non-timber forest products that are generated. The public planting option will also provide fuelwood for public gatherings and meet any fuelwood gap that villagers may have if they are unable to harvest enough on their own to meet their demands. It could also potentially generate income for the village that can in turn provide for social programs as well as the beautification of the village and protection from natural elements. Planting trees in degraded areas will also reduce soil erosion and improve soil nutrient levels.

Villagers should be encouraged to use the most appropriate species based on soil and climatic conditions in order to maximize yield and to economize land use planning with other crops. For example, if a portion of a farmer’s farmland is degraded with poor soil conditions and workable land is limited, the farmer most likely needs all the land he can use to grow rice, therefore intercropping tree species may not be an option. In this case, the farmer could plant a tree species that can tolerate poor soil conditions on the degraded lands and that can also fix nitrogen into the soils, so over time, this land can be reclaimed for rice and other agricultural production. The farmer may also choose to plant multipurpose tree species in other areas of his/her property to provide specific services such as live fences, windbreaks and shade as shown in Table 2. With a sustainable rotation and depending on the household's fuelwood needs, the farmer may be able to maintain the trees to continually provide these services as well as harvest enough fuelwood to meet the households fuel requirement.

3.7 Carbon Offset Projects

Another benefit of the project is the potential revenue stream from the sale of carbon credits from avoiding the deforestation of natural forests and woodlots which would otherwise occur if it was not for agroforestry planting. Carbon sequestration from the above ground biomass from the agroforestry trees would be negligible if they are continually harvested which would typically be the case if the objective of planting them is to supply fuelwood. The type of carbon offset project envisaged would be a small-scale project that would require an intermediary that bundles such small-scale projects together in order to reach the economy of scale to market such projects to potential buyers of carbon credits. The Clean Development Mechanism (CDM) allows for small-scale afforestation and reforestation projects on degraded lands as a project type; however, the transaction costs for preparing a CDM compliant project for such as small-scale project are still too high. Plus, the CDM does not allow ‘avoided deforestation" as a project type because, according to the rules of the CDM, net increases of carbon pools compared to what would occur in the absence of the project activity should not be taken into account in the accounting of emission reductions.

The best option is to promote the project to purchasers of voluntary carbon credits where the carbon credits do not need to meet stringent criteria like that of the CDM. Buyers of voluntary carbon credits are in many cases corporations that want to "green" their image or offset their travel miles, or electricity consumption, or they are intermediaries such as carbonfund.org[11] and The Carbon Neutral Company[12] that purchase voluntary carbon credits from projects and broker them to corporations or individuals. However, a monitoring and verification system for the project must be in place to prove the carbon offsets are real, but again, it is not as stringent as a CDM project; therefore, could be more cost effective.

In the case of a village level agroforestry project, it would be beneficial to develop a village level program office to record who is planting in the village, how much is being planted, monitor the tree growth, and keep record of all necessary data required to determine the amount of emission reductions generated by the program. This program would include all private tree growers and public trees being grown. Carbon revenues would be paid out to individuals and to the communal groups based on the respective amount of trees that are planted.

A similar example of this type of project is the International Small Group and Tree Planting Program or “TIST”[13]. The TIST program introduced improved farming and land use techniques to isolated subsistence farmers in Tanzania, Uganda, Kenya, and India Using a combination of Small Group development and training programs and providing small stipends to groups, TIST helps local farmers meet their economic needs, even during severe dry seasons. TIST also is selling carbon offsets on eBay[14] to generate revenues for the program in order to sustain the stipend that is granted to farmers for growing trees.

[11] http://carbonfund.org
[12] http://www.carbonneutral.com/
[13] http://www.tist.org/
[14] TIST eBay store: http://stores.ebay.com/TIST-GHG-Boutique

Another example of a local tree planting project is the Scolel-Té Project[15] in Mexico. Small-scale farmers in Mexico's poorest state, Chiapas, switched from swidden agriculture to agroforestry activities such as the planting of live fences, shade grown coffee plantations, enrich degraded soils, and the intercropping of tree species with agricultural crops. A local trust arranges the sale of carbon credits, which allows the farmers to earn substantial income that can cover the costs of implementing new farming systems, and provide for other livelihood benefits such as food and medicines.

The two examples above present local, small-scale, tree planting projects that generate income for the farmers through the sale of carbon credits. However, the objective of these two projects is not fuelwood production, therefore the harvesting of trees is not in the interest of the farmers. In this case, carbon credits are generated from the carbon sequestration of the above ground biomass of these trees. If the objective of a project is fuelwood production, then the carbon revenue strategy would need to be changed to gaining credits through avoided deforestation, of which there are very little data on project examples in the carbon market to date.

4 Development Proposal

This paper has analyzed the various forest management options present in Cambodia for their suitability in achieving the following development objectives: (i) allow villagers to have free access to sustainable fuelwood and other non-timber forest products; (ii) allow villagers to have the opportunity to generate additional income, and; (iii) strengthen the role of women in the village. Based on the data that is available and after analyzing the various forest management regimes, the paper puts forth a

[15] http://www.eccm.uk.com/scolelte/

development proposal for a pilot project for village level agroforestry that will allow tree planting on farms and in public spaces through out a village.

4.1 Development Objectives

The objectives of this pilot project are (i) to meet the village level energy demand through the sustainable supply of fuelwood; (ii) to provide opportunities for villagers to generate additional income from the sale of non-timber forest products, and; (iii) to strengthen the role of women in the village by creating agroforestry related entrepreneurial activities.

The objectives would be met through the following three components: (i) preparatory and support activities; (ii) sustainable woodfuels supply management; and (iii) entrepreneurial activity development for rural energy suppliers.

By successfully demonstrating this pilot project, there could be great potential to replicate it across thousands of villages of Cambodia.

4.2 Project Overview

The project seeks to demonstrate the planting of multipurpose tree crops intercropped on farmland and unproductive degraded lands located in public areas such as pagodas and schools and village perimeters. The project will provide a sustainable supply of fuelwood and non-timber forest products as well as improve the soil nutrients and erosion control on those lands.

The project is envisaged to be undertaken by local NGOs such as SME Cambodia or GERES and financed by multi-lateral development organizations such as the World Bank[16] and/or the Asian Development Bank[17], or through bilateral aid from OECD[18] countries. An explanation of organizational arrangements is presented in Section 4.5.

The project will encourage villagers to plant fast growing, multipurpose tree crops that are suitable for fuel on their farms and in public areas, such as *Leucaena leucocphala* trees. *Leucaena* is a legume tree species that fixes nitrogen and grows well in relatively nutrient poor soil and has generally positive effects on soils. Their branches resprout vigorously after cutting. There is experience with *Leucaena* in Anlong Ta Mei community, in Battambang Province, where it is grown in woodlots in order to supply fuelwood to an energy cooperative for rural electrification. Villagers can start to harvest branch wood one year after planting and they expect to be able to harvest twice a year for approximately 10 years. Annual wood production of the project site is about 20 tons per hectare according to the project sponsor, Small and Medium Enterprises Cambodia (SME Cambodia). The green leaves are also sold to farmers at Riel 300/kg ($75/t) for feeding animals.

The pilot project will take place in an average sized rural village that has distant or limited access to forest resources. The estimated village size for this project is approximately 100 households with an average of six people per household. It is assumed that for both households and small businesses, the majority of the fuelwood is collected by users, with a small proportion purchased from vendors.

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[16] http://worldbank.org
[17] http://www.adb.org/
[18] OECD refers to the Organisation for Economic Co-operation and Development, which is a group of 30 industrialized member countries that share a commitment to democratic government and the market economy. Source: http://www.oecd.org

The average per capita consumption of fuelwood for Cambodia's rural population is 455 kilograms per year. The average household demand for fuelwood then equals 2,730 kilograms per year. The average yield for *Leucaena leucocphala* is 19.25 dry tons per hectare per year. Assuming that a household can coppice branches after 6 months of growth and then every 6 months for over 10 years, the amount of land required to furnish enough wood to sustain the household's domestic energy consumption plus allow an equal amount to sell to the market is 0.3 hectares. According to the FAO, the average rice consumption per person per year is 151.2 kilograms. Multiply this times 6 people with an average national rice yield of 1.3 tons per hectare, and the required land to feed the household is 0.7 ha (see Annex II for analysis).

Planting multipurpose tree crops on farms can have a significant positive effect on the household's income whether the household collects fuelwood or purchases it from a market, especially for the poor in the lower quintiles of the poor population. A household of six would spend up to US$110 per year for their own fuelwood consumption or spend several hours a day in collecting fuelwood. This is a significant savings for poor families. For households that collect fuelwood, the time saved and health benefits from no longer collecting it could potentially be significant. Since women and children are the ones that mostly collect fuelwood, the time saved could be spent on education, leisure activities, or for other productive uses to benefit their livelihoods.

For a project to be self sustainable, it must be financially viable. A one time subsidy may be granted to the project for start-up costs, but operations and maintenance over time should be viable based on the revenues generated from the project which include non-timber forest products such as fuelwood, fruits, and nuts, and from carbon credits.

In this scenario, the revenues that are generated from sequestering carbon from the above ground biomass are negligible due to the continuous harvesting of nearly 99 percent of growth every 6 months (see analysis in Annex II). There is a net effect between carbon stored and carbon emitted from harvesting and burning for fuelwood. However, there are emission reductions that derive from implementing such a project if you compare it to what is happening in the baseline scenario. The emission reductions are generated from the deforestation that is avoided in natural forests and woodlands that would otherwise be degraded if it wasn't for the agroforestry crops that were planted and managed sustainably and used as fuelwood in their place. If carbon credits could be derived from avoided deforestation, although they are currently not eligible, then this would provide much more revenues to the farmers because the sequestration from the entire crop yield would be counted and not what is left over after harvesting.

4.3 Project Description

Component I – Preparatory and support activities component would last approximately thirteen weeks and would finance technical assistance to carry out the following activities:

Table 3. Component I Activities

Activity	Objective	Timeline
A.1 Rapid Feasibility Study of Project Area	Determine viability of project area	Week 1
A.2 Consultation with Village Leaders	Determine interest and support of local leadership	Week 2
A.3 Consultation with Villagers	Determine the needs and concerns of the villagers and incentives that would drive their interest in planting trees	Week 3
A.4 Establishment of village	To provide local management	Week 4 & 5

level management office	and coordination	
A.5 Training of Management Team	To develop local management capacity	Week 6 & 7
A.6 Development of Agroforestry Management Plan	To develop strategic, project area specific management plan	Week 8 & 9
A.7 Development of program and tree planting manuals in local language and illustrative posters	To train villagers on technical issues related to planting and maintaining tree crops, create awareness of the incentives to planting multi-purpose tree crops	Week 10 & 11
A.8 Training of Villagers	To properly plant and harvest trees for sustained use	Week 12 & 13

Component II – Sustainable woodfuels supply management component would finance technical assistance, seedlings, nurseries, small tools and field equipment for rural villagers:

Table 4. Component II Activities

Activity	Objective	Timeline
B.1 Technical Assistance for tree planting	Hands on training in planting seedlings	Week 14 & 15
B.2 Seedlings, Nurseries, Planting Equipment	Villagers plant seeds	Week 16 & 17

*Component III – The e*ntrepreneurial activity development for rural energy suppliers component will include the following activity:

Table 5. Component III Activities

Activity	Objective	Timeline
C.1 Access to markets	Train villagers on the sale of	Week 18 & 19

workshops	non-timber forest products	

4.4 Performance Indicators, Monitoring and Supervision Plan

Table 7 presents a summary of the project's key performance indicators and monitoring and supervision plan. The project is based on 100 households with 0.3 hectares of *Leucaena* per household with an average annual yield of 19.25 tons of dry matter per hectare. When measuring avoided deforestation indicators, it is assumed that the density of natural deciduous and evergreen forests is 255 tons of dry matter per hectare. Therefore, there would be 30 hectares of planted agroforestry land in the project scenario multiplied by 19.25 tons of dry matter per hectare per year for *Leucaena* divided by 255 tons of dry matter per hectare in natural forests, equaling 2.3 hectares of natural forests saved per year.

Table 6. Performance Indicators, Monitoring and Supervision Plan

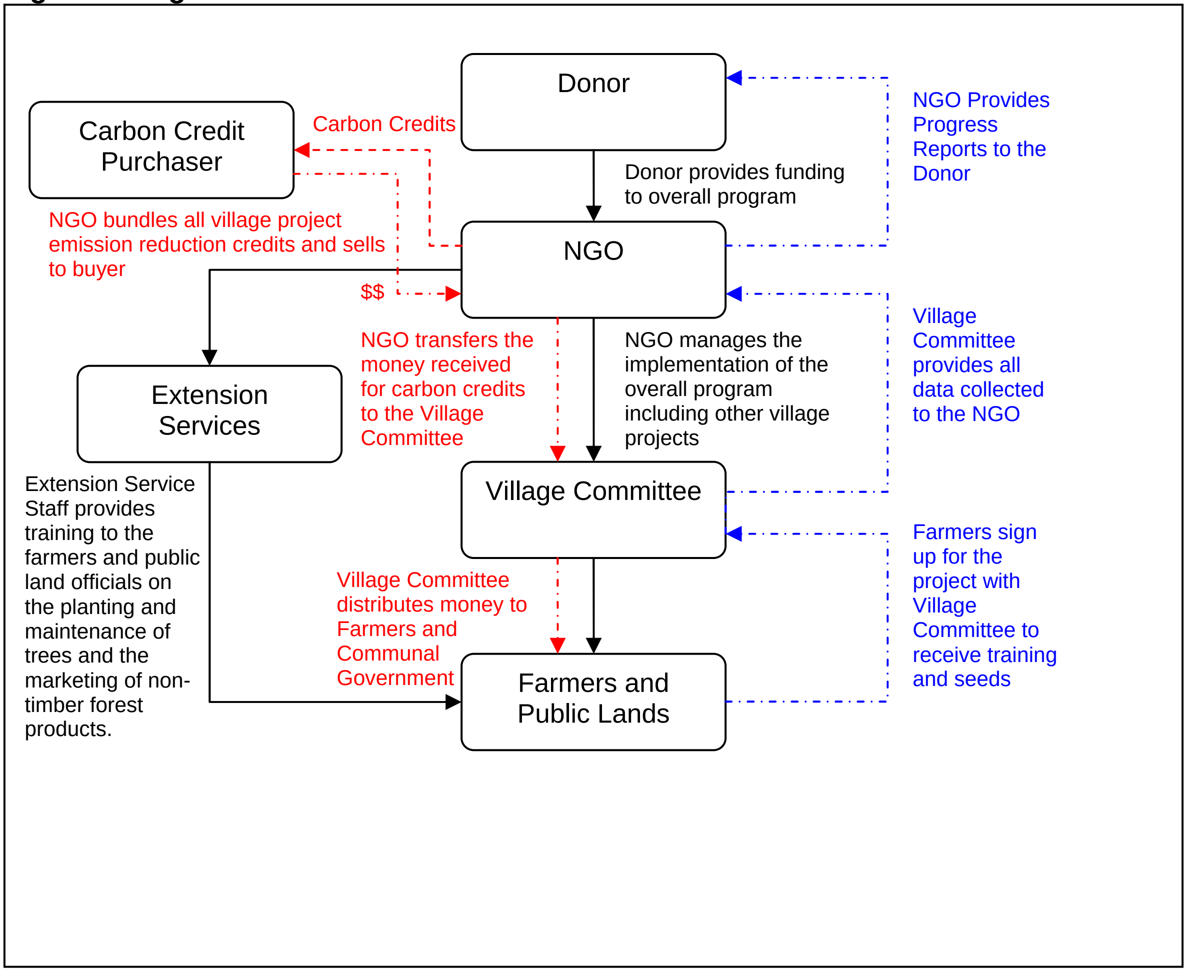
Project Development Objectives	Key Performance Indicators	Monitoring and Supervision
A. Reduce woodfuel related deforestation	A. Reduce deforestation by: Date: Hectares Year 1: 2.3 Year 5: 11.5 Year 10: 23	A. Annual evaluation of forest resource exploitation.
B. Increase income generation for rural population with special attention on women.	B. Generate revenues in village: Date: US$ Year 1:6,000 Year 5: 30,000 Year 10: 60,000	B.1. Annual evaluation of development impacts. B.2. Annual evaluation of participation.
C. Reduce net CO_2 emissions	C. Reduce net CO_2 emissions by: Date: Tons of CO_2 Year 1: 1,000 Year 5: 5,000 Year 10: 10,000	C. Annual climate change assessment.
Project Development Outputs	Key Performance Indicators	Monitoring and Supervision
A. Sustainably produce fuelwood.	A. Annual sustainable production of fuelwood: Date: Tons Year 1: 580	A.I. Bi-annual progress report. A.2. Bi-annual field supervision.

	Year 5: 2,900 Year 10: 5,800	
B. Increase agro-forested land in village	B. Increase Agroforested land by: Date: Ha Year 1: 30 Year 5: 30 Year 10: 30	B.l. Bi-annual progress report. B.2. Bi-annual field supervision.

4.5 Organizational Arrangements

The overall coordination of this pilot project and possibly a larger program including several of these projects is executed typically by a local or international Non-Governmental Organization. However, NGOs require funding from donors to support their overhead and program costs. The NGO would require funds from a donor or donors for the start-ups of this pilot project. The NGO would prospect potential villages and meet with village leaders to ascertain whether the villages would be ideal and willing to host such a project. After consultations with village leaders and villagers, a village level management committee would be established and trained. They would be responsible for the collecting data and coordinating with farmers on tree planting initiatives. The data collected would be sent to the NGO to fulfill their reporting requirements to the donors and to fulfill the monitoring requirements for receiving carbon offset revenues. Working in conjunction with the NGO, Village Committee, and the farmers are the extension service staff that are responsible for training the farmers on tree planting and the marketing of non-timber forest products.

Figure 1. Organizational Chart



4.6 Budget and Economic Analysis

The total proposed budget for this pilot project is approximately US$26,000 (Table 8). The budget is based on the components and activities listed in Tables 4, 5, and 6. The fees for the work that NGO staff perform are based on a lump sum payment to the organization for that activity, and are not on a per staff basis. The fees are competitive with local consultant rates. There are also funds allocated for translation of documents from Khmer (national language of Cambodia) to English. The cost of the seeds are based on 2,500 trees per hectare multiplied by 30 ha (100 households x .3 ha/hh) multiplied by US$0.02 per seed. It is most likely that seeds can be provided free of charge from other *Leucaena leucacephala* woodlots in the country. Fifteen percent is allocated in the "Other Costs" section of each project component for administrative overhead fees and unforeseen expenses.

Table 7. Project Budget

COMPONENTS & ACTIVITIES	Expenditure Category	Quantity	Unit	Unit Rate (US$)	Total Cost (US$)
A. Preparatory and Support Activities					
A.1 Rapid Feasibility Study of Project Area					
(1) Local Staff of NGO (National)	Fees	0.25	months	2,500	625
(2) Translation Services	Fees	0.25	months	300	75
(3) Other Costs (Administrative Overhead)					105
SUBTOTAL A.1:					805
A.2 Consultation with Village Leaders					
(1) Local Staff of NGO (National)	Fees	0.25	months	2,500	625
(2) Translation Services	Fees	0.25	months	300	75
(3) Other Costs (Administrative Overhead)					105
SUBTOTAL A.2:					805
A.3 Consultation with Villagers					
(1) Local Staff of NGO (National)	Fees	0.25	months	2,500	625
(2) Translation Services	Fees	0.25	months	300	75
(3) Other Costs (Administrative Overhead)					105
SUBTOTAL A.3:					805
A.4 Establishment of village level management office					
(1) Local Staff of NGO (National)	Fees	0.5	months	2,500	1,250
(2) Translation Services	Fees	0.5	months	300	150
(3) Office Equipment	Goods				1,000
(4) Other Costs (Administrative Overhead)					360

SUBTOTAL A.4:					2,760
A.5 Training of Management Team					
(1) Local Staff of NGO (National)	Fees	0.5	months	2,500	1,250
(2) Translation Services	Fees	0.5	months	300	150
(3) Workshops	Fees and Materials	10	days	300	3,000
(4) Other Costs (Administrative Overhead)					660
SUBTOTAL A.5:					5,060
A.6 Development of Agroforestry Management Plan					
(1) Local Staff of NGO (National)	Fees	0.5	months	2,500	1,250
(2) Translation Services	Fees	0.5	months	300	150
(3) Other Costs (Administrative Overhead)					210
SUBTOTAL A.6:					1,610
A.7 Development of program and tree planting manuals in local language and illustrative posters					
(1) Local Staff of NGO (National)	Fees	0.5	months	2,500	1,250
(2) Translation Services	Fees	0.5	months	300	150
(3) Printing	Materials	100	manuals	1	100
(4) Other Costs (Administrative Overhead)					225
SUBTOTAL A.7:					1,725
A.8 Training of Villagers					
(1) Local Staff of NGO (National)	Fees	0.5	months	2,500	1,250
(2) Translation Services	Fees	0.5	months	300	150
(3) Other Costs (Administrative Overhead)					210
SUBTOTAL A.8:					1,610
SUBTOTAL COMPONENT A:					15,180
B. Sustainable woodfuels supply management					
B.1 Technical Assistance for tree planting					
(1) Local Staff of NGO (National)	Fees	0.5	months	2,500	1,250

(2) Translation Services	Fees	0.5	months	300	150
(3) Other Costs (Administrative Overhead)					210
SUBTOTAL B.1:					1,610
B.2 Seedlings, Nurseries, Planting Equipment					
(1) Local Staff of NGO (National)	Fees	0.5	months	2,500	1,250
(2) Translation Services	Fees	0.5	months	300	150
(3) Seedlings	Goods	75,000	seedlings	0.02	1500
(4) Nursery Infrastructure	Goods	2	nursery	300	600
(5) Planting Equipment	Goods	50	tools	5	250
(6) Other Costs (Administrative Overhead)					563
SUBTOTAL B.2:					4,313
SUBTOTAL COMPONENT B:					5,923
C. Entrepreneurial activity development for rural energy entrepreneurs					
C.1 Access to markets Training Workshops					
(1) Local Staff of NGO (National)	Fees	0.5	months	2,500	1,250
(2) Translation Services	Fees	0.5	months	300	150
(3) Workshops	Fees and Materials	10	days	300	3,000
(4) Other Costs (Administrative Overhead)					660
SUBTOTAL C.1:					5,060
SUBTOTAL COMPONENT C:					5,060
TOTAL PROPOSAL COST:					**26,163**

An economic analysis is performed to determine the net present value (NPV) for a rural household for both the baseline scenario and project activity. The household economic indicators range dramatically with the different quintiles of the rural poor and there is only aggregate data available that averages the figures across all quintiles. The assumptions in this analysis are taken from the 2005 Global Village Energy Partnership (GVEP) Report for Cambodia. The following assumptions are used: majority of villagers are farmers that typically cultivate 1 ha of rice. A rural household consists of an average of 6 people with a per capita woodfuel consumption level of 455 kg/year. Average monthly income is on average US$68 and the average monthly household expenditure is US$60. Household expenditures include: food, medical care, housing rent, fuel and power, clothing and footwear, personal care and effects, transport and communication, education, household equipment, water charges, and other (Exel, Draft). The retail price for fuelwood is US$.04 per kilogram and the wholesale rate is US$.02. The retail price is used to determine cost savings for a household no longer needing to purchase fuelwood and also to determine the opportunity costs of no longer needing to collect fuelwood. The wholesale rate is used to determine the income generation from the sale of fuelwood to the market. The amount of fuelwood that a household would no longer need to collect or purchase is 2,730 kilograms per year and the amount that is sold to the market is 3,000 kilograms per year.

The net present value at a 10 percent discount rate over 10 years of a household project that plants multipurpose trees on 0.3 hectares of land for the purpose of sustaining their own consumption and for income generation is US$1,630 (without carbon revenues, see Table 8) and US$1,937 (with carbon revenues assuming a price of US$5 per ton of CO_2 equivalent multiplied by 10 tons of CO_2 emissions through avoided deforestation per household per year, see Table 9). The net present value for a farmer under the baseline activity that does not plant multipurpose tree species nor receives carbon revenues is US$590 (see Table 10). The net present value is determined by the following formulae:

$$\mathrm{NPV} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0$$

Where:

t - the time of the cash flow
n - the total time of the project
r - the discount rate
C_t - the net cash flow (the amount of cash) at time t.
C_0 - the capital outlay at the beginning of the investment time ($t = 0$)

Table 8. Cost Benefit Analysis of Project Activity without Carbon Revenues

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Expenditure										
General Household	720	720	720	720	720	720	720	720	720	720
TOTAL Expenditure	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**
Revenues & Savings										
Fuelwood Sales	60	60	60	60	60	60	60	60	60	60
General Income	816	816	816	816	816	816	816	816	816	816
Fuelwood Savings	109.2	109.2	109.2	109.2	109.2	109.2	109.2	109.2	109.2	109.2
Carbon Revenues	0	0	0	0	0	0	0	0	0	0
TOTAL Revenues & Savings	**$985**	**$985**	**$985**	**$985**	**$985**	**$985**	**$985**	**$985**	**$985**	**$985**
NET Balance	**$265**	**$265**	**$265**	**$265**	**$265**	**$265**	**$265**	**$265**	**$265**	**$265**
NPV	10%	$1,630								

Table 9. Cost Benefit Analysis of Project Activity with Carbon Revenues

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Expenditure										
General Household	720	720	720	720	720	720	720	720	720	720
TOTAL Expenditure	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**
Revenues & Savings										
Fuelwood Sales	60	60	60	60	60	60	60	60	60	60
General Income	816	816	816	816	816	816	816	816	816	816
Fuelwood Savings	109.2	109.2	109.2	109.2	109.2	109.2	109.2	109.2	109.2	109.2
Carbon Revenues	50	50	50	50	50	50	50	50	50	50
TOTAL Revenues & Savings	**$1,035**	**$1,035**	**$1,035**	**$1,035**	**$1,035**	**$1,035**	**$1,035**	**$1,035**	**$1,035**	**$1,035**
NET Balance	**$315**	**$315**	**$315**	**$315**	**$315**	**$315**	**$315**	**$315**	**$315**	**$315**
NPV	10%	$1,937								

Table 10. Cost Benefit Analysis of Baseline Scenario

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Expenditure										
General Household	720	720	720	720	720	720	720	720	720	720
TOTAL Expenditure	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**	**$720**
Revenues & Savings										
Fuelwood Sales	0	0	0	0	0	0	0	0	0	0
General Income	816	816	816	816	816	816	816	816	816	816
Fuelwood Savings	0	0	0	0	0	0	0	0	0	0
Carbon Revenues	0	0	0	0	0	0	0	0	0	0
TOTAL Revenues & Savings	**$816**	**$816**	**$816**	**$816**	**$816**	**$816**	**$816**	**$816**	**$816**	**$816**
NET Balance	**$96**	**$96**	**$96**	**$96**	**$96**	**$96**	**$96**	**$96**	**$96**	**$96**
NPV	10%	$590								

4.7 Socio-Economic and Environmental Benefits

4.7.1 Socio-economic Benefits

The project is expected to (i) generate employment and economic development opportunities in rural villages, including women, in the management and marketing of woodfuels and other related income generating activities; (ii) generate during the implementation period more than US$60,000 in direct revenues from the trade of woodfuels, and generate additional revenues to the communities from related natural resource management and exploitation activities (agro-forestry, non-fuelwood forest products, etc.); (iii) generate income from the sale of carbon emission reduction credits from avoided deforestation (iv) strengthen the planning, policy making and implementation supervision capacity of the local village, while increasing the participation of the civil society (private sector, academic institutions, and NGO's community) in the management and operation of the sector.

4.7.2 Environmental Benefits

The project is expected to: (i) reduce deforestation and soil degradation through the implementation of multi-purpose tree planting activities; (ii) contribute to reducing the loss of carbon sequestration capacity that results from non-sustainable exploitation of woodfuels from woodlands and, over time, increase capacity through the extension of sustainable natural resource management practices nationwide.

4.8 Next Steps

The next steps would be to present this paper and project proposal to NGOs working in Cambodia such as SME Cambodia and GERES to gauge their opinion on the feasibility of the proposal and their interest in implementing the project activity. Further investigation is needed in locating potential buyers of carbon credits from avoided deforestation projects. It is important for the carbon market and for the millions of villagers throughout the world that depend on forests for their livelihoods to get a small-scale project of this nature piloted with a proper monitoring and verification system that can be used as best practice and replicated wherever deforestation is occurring due to unsustainable fuelwood demand.

Annex I – Alternative Rural Household Energy Solutions

The following section describes alternative cooking technologies that could replace the use of woodfuel in the rural household. Liquefied Petroleum Gas (LPG) is not listed because it has been proven to be too expensive for rural households to purchase and therefore is not a feasible option at this time. The two technologies explained below: household biodigesters and solar cookers are promising renewable energy technologies but have very little to no market penetration in Cambodia to date.

Household Biodigesters

The anaerobic digestion of fresh animal dung and water into a fixed dome underground digester room of 4m³ (or larger sizes of 6, 8, and10m³) generates biogas because of microbiological action (See Photos in Annex IV). Biogas is comprised of a mixture of methane, carbon dioxide, and small amounts of other gases. In small domestic biodigester units, human excreta is also added through toilet construction. The gas is mainly used for cooking and lighting purposes. The gas produces an odourless and smokeless flame that can be piped into a house for cooking and lighting, therefore replacing fuelwood use for cooking and kerosene for lighting.

The average size (6m³) biogas plant uses about 40 kg of fresh dung and produces gas for about four hours of stove use, enough to satisfy the cooking energy needs of a medium-size family. Farmers with three cattle can operate a 6m³ biogas plant.

Per household the workload of mainly women and girls is reduced by about 2-3 hours per day, caused by considerably reduced time for firewood collection, chopping and cooking time. Female members of households, after starting the use of biogas, report significant health improvements, particularly regarding respiratory, gastro-enteritis and eye diseases. It is estimated that each reactor saves annually on average about 2,556 kilograms of firewood and reduces greenhouse gases to the extent of approximately 5.015 ton-equivalent CO_2/plant/year. The biogas plant also produces quality organic fertiliser for the farm from the slurry that is the by-product of the digester process.

The average digester costs approximately US$300, partly of which is subsidized by the Cambodia National Biodigester Program, a joint initiative between the Ministry of Agriculture, Fisheries and Forestry (MAFF) and Dutch NGO, SNV[19]. Even with the subsidy, the biodigester is too expensive to reach the lower quintiles of the rural poor. Plus, to be eligible for the program, a farmer must own several cattle in order to generate enough dung to properly operate the system, which is not the case for the lowest quintiles of the poor.

Solar Cooker

Solar cookers can be parabolic or spherical dishes or trough collectors, often cheap to make but capable of cooking only small quantities of food at a time. They can also be insulated box ovens with transparent covers, which can be more effective, but more expensive (See Photos in Annex IV). Their use is limited to daylight hours and favourable seasons, and they offer only a limited range of cooking, usually either baking or simmering. Without heat storage systems, they cannot be used to prepare an evening meal unless the meal was prepared during the day and kept insulated into the evening. So far, there has been little demand for solar cookers in Cambodia and their use appears at best as a marginal substitute for wood.

[19] http://www.snvworld.org

Solar cookers, if adapted to local conditions, can play a big role in reducing fuelwood consumption; however, they are inoperable on cloudy days and at night and may not meet the cooking standards for certain popular Khmer dishes; therefore, a dependency on fuelwood would still exist. One issue is that of a donor funded project subsidizing the stove, because the stove would be too expensive for a poor villager to purchase. If the solar cooker breaks or if the subsidy runs out, the solar cooker may be abandoned. If they are too expensive for the rural poor to purchase out right there will be very limited market demand.

Annex II – Carbon Sequestration Potential for Village Agroforestry Project

This project intends to establish 0.3 hectares of multipurpose tree crops on farm lands for each individual household and on idle village land to supply non-timber forest products such as fuelwood.

The lands that will be planted are assumed to accumulate aboveground biomass at an average annual rate of 19.25 t dm/ha-yr or 9.625 t dm/ha-6 months assuming that *Leucaena leucocphala* is planted. A thinning of approximately 99 percent of aboveground biomass stocks will occur every 6 months. It is estimated that in the absence of the project, the farm and idle village land will remain unchanged, and an amount of fuelwood equivalent to the amount produced under the project scenario would be harvested from nearby woodlands, contributing to their degradation.

The proposed project activities impact not only the farm and idle village lands on which the tree crops will be established, but also the woodland area where deforestation will be avoided as a result of the project. Therefore, the accounting of CO_2 impacts of the project should include CO_2 emissions and carbon sequestration on both the planted areas and the woodlands. However, to be conservative with the carbon sequestration estimation, the above ground biomass stocks from planted areas will only be counted.

To calculate annual flows of carbon emissions and sequestration under the project scenario, the following formulas are applied[20].

For years 1 - 10:

Step 1 - Total Project Area (ha) x (Annual Biomass Growth Increment (t dm/ha-6 months) x Biomass Carbon Content (t C/t dm)) x (-1) = Annual Biomass Carbon Sequestration (t C/6 months)

Step 2 - Total Project Area (ha) x (Annual Biomass Harvested/Destroyed (t dm/ha-6 months) x Biomass Carbon Content (t C/t dm)) = Annual Biomass Carbon Emissions (t C/6 months)

Step 3 - Annual Biomass Carbon Sequestration (t C/yr) + Annual Biomass Carbon Emissions (t C/yr) = Net Annual Biomass Carbon Sequestration (t C/6 months)

Step 4 - Net Annual Biomass Carbon Sequestration (t C/6 months) x Molecular/Atomic Weight Ration (t CO_2/t C) = Net Annual CO_2 Sequestration (t CO_2/6 months)

[20] Source of the formulas is the Greenhouse Gas Assessment Handbook, World Bank, 1998: http://lnweb18.worldbank.org/ESSD/envext.nsf/46ByDocName/GreenhouseGasAssessmentHandbook1998PDF953kb/$FILE/GHGAssessmentHandbook.pdf

Figure 2. Carbon Sequestration Calculation per Household

STEP 1.
Total Project Area x (Annual Biomass Growth Increment x Biomass Carbon Content) x (-1) = Annual Biomass Carbon Sequestration

Total Project Area (ha)	0.30
Annual Biomass Growth Increment (t dm/ha-6month)	9.625
Biomass Carbon Content (t C/t dm)	0.50
Annual Biomass Carbon Sequestration (t C/yr) =	-1.44

STEP 2.
Total Project Area x (Annual Biomass Harvested/Destroyed x Biomass Carbon Content) = Annual Biomass Carbon Emissions

Total Project Area (ha)	0.30
Thinning	99.22%
Annual Biomass Harvested/Destroyed (t dm/ha-yr)	9.550
Biomass Carbon Content (t C/t dm)	0.50
Annual Biomass Carbon Emissions (t C/yr)	1.43

STEP 3.
Annual Biomass Carbon Sequestration + Annual Biomass Carbon Emissions = Net Annual Biomass Carbon Sequestration

Annual Biomass Carbon Sequestration (t C/yr) =	-1
Annual Biomass Carbon Emissions (t C/yr)	1.43
Net Annual Biomass Carbon Sequestration (t C/yr)	-0.011

STEP 4.
Net Annual Biomass Carbon Sequestration x Molecular/Atomic Weight Ration = Net Annual CO2 Sequestration

Net Annual Biomass Carbon Sequestration (t C/yr)	0
Molecular/Atomic Weight Ratio (44 tCO2e/ 12 tC)	3.666666667
Net Annual CO2 Sequestration (tCO2e/yr)	-0.041

Under the baseline scenario, the amount of fuelwood collected from the woodlands is equal to the amount of fuelwood harvested under the project scenario. Since no carbon sequestration is assumed to occur in the woodlands, the net carbon emissions under the project scenario are almost equal to the carbon sequestration under the project scenario. By applying the molecular/atomic weight ratio (44 t CO_2/t C), net CO_2 emission reductions under the project scenario are determined to be 0.041 t CO_2 per household.

Although the project hardly generates CO_2 emissions from the above ground biomass sequestration, it does produce a CO_2 benefit by preventing emissions of approximately 96 tons of CO_2 per household over 10 years that would have occurred under the baseline case from the woodlands (see Table 12).

Assumptions:

.3 hectares of multi-purpose tree planting per hectare
Species: *Leucaena leucocphal (*19.25 tons of dry matter yield per year (9.625 tons of dm per six months))
1 household = 6 people
455 kilograms of fuelwood per capita
.5 tons of Carbon per ton of dry matter

Table 11. Data Sheet

Months	6	12	18	24	36	48	54	60	66	72	78	84	90	96	102	108	114	120
6 month Yield (t dm)	2887.50	2894.25	2896.28	2896.88	2897.06	2897.12	2897.14	2897.14	2897.14	2897.14	2897.14	2897.14	2897.14	2897.14	2897.14	2897.14	2897.14	2897.14
Viilage Household 's Own Consumption (t dm)	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
For Sale (t dm)	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Balance (t dm)	22.50	29.25	31.28	31.88	32.06	32.12	32.14	32.14	32.14	32.14	32.14	32.14	32.14	32.14	32.14	32.14	32.14	32.14
Coppicing Percentage every six months	99.22%	98.99%	98.92%	98.90%	98.89%	98.89%	98.89%	98.89%	98.89%	98.89%	98.89%	98.89%	98.89%	98.89%	98.89%	98.89%	98.89%	98.89%
6 month yield (tCo2e) Seq.	5.29	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31
Harvest every 6 month – Emissions (tCO2e)	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25
Net CO2 Sequestration (tCO2e)	0.0412	0.0536	0.0573	0.0585	0.0588	0.0589	0.0589	0.0589	0.0589	0.0589	0.0589	0.0589	0.0589	0.0589	0.0589	0.0589	0.0589	0.0589
Fuelwood Savings ($0.04 per kilogram, Retail)	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60	$54.60
Fuelwood sales ($0.02 per kilogram, wholesale)	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00	$30.00
Carbon Credit ($5 per tCO2e)	$0.21	$0.27	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29
Total # 1 (Agroforestry)	$84.81	$84.87	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89	$84.89
(Avoided Deforestation)	$26.47	$26.53	$26.55	$26.55	$26.56	$26.56	$26.56	$26.56	$26.56	$26.56	$26.56	$26.56	$26.56	$26.56	$26.56	$26.56	$26.56	$26.56
Total # 2	$111.07	$111.13	$111.15	$111.15	$111.16	$111.16	$111.16	$111.16	$111.16	$111.16	$111.16	$111.16	$111.16	$111.16	$111.16	$111.16	$111.16	$111.16
Rice (National average tons per hectare per year) 1.3 tons rice x .7 hectares / 2	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455
Market rice per ton of rice ($114)	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87	51.87

Annex III – Species Chart

Botanic Name	Calorific Value (kcal/kg)	Average Annual Incremental Yield (m^3/ha)	Density (kg/m3) (Default 15% moisture content)	Average Height (m) / diameter (cm)	Products and Services	Soil Conditions	Climate	Rainfall (Ideal conditions) mm
Acacia sp.								
	n/a	n/a	1000*	n/a	n/a	n/a	n/a	n/a
Afzelia xylocarpa								
	n/a	n/a	900*	n/a	n/a	n/a	n/a	n/a
Albizia saman	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=180							
	5200-5600	Average annual wood production has been estimated at 25-30 cubic m/ha per year	950*	18 cm in 5 years	Food, Fodder, Fuel, Timber, Gum or resin, Medicine, Shade or shelter, Nitrogen fixing, Soil improver, Ornamental	neutral to moderately acid soils. It grows on light or heavy soils and tolerates infertile or waterlogged conditions.	Altitude: 0-1300 m, Mean annual temperature: 20-35 deg. Celcius	600-3000 mm
Azadirachta indica	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=271							
	n/a	n/a	930*	n/a	Food, Fodder, Fuel, Timber, Gum or resin, Tannin or dyestuff, Lipids, Poison, Medicine,	grows on a wide variety of neutral to alkaline	Altitude: 0-1500 m, Mean annual temperature: Up to 40 deg. Celcius	400-1200 mm

					Erosion control, Shade or shelter, Nitrogen fixing, Soil improver, Intercropping	soils but performs better than most species on shallow, stony, sandy soils, or in places where there is a hard calcareous or clay pan not far below the surface.		
Bambusa spp								
	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Barringtonia asiatica								
	n/a	n/a	540*	n/a	n/a	n/a	n/a	n/a
Cassia fistula	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=1780							
	n/a	n/a	1050*	10 m tall / 1 m diameter	Food, Apiculture, Fuel, Timber, Tannin or dyestuff, Medicine, Ornamental	n/a	18-29 deg Celcius	480-2 720 mm
Cassia siamea								
	n/a	15	1000*	5 m in 3 years 15 m in 10 years / 15 cm	Firewood, timber, revegetation	Deep, well drained, relatively rich soils	Tropics Lowlands	1,000
Casuarina equisetifolia	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=477							

	5000 kcal/kg	15 cubic m/ha of wood in 10 years	1160*	6-35 (60) m / up to 100 (max. 150) cm in diameter	Fuel, Fibre, Timber, Tannin or dyestuff, Medicine, Erosion control, Shade or shelter, Reclamation, Nitrogen fixing, Soil improver, Ornamental, Boundary or barrier or support, Intercropping	Soils are invariably well-drained and rather coarse textured, principally sands and sand loams. The species tolerates both calcareous and slightly alkaline soils but is intolerant of prolonged waterlogging and may fail on poor sands where the subsoil moisture conditions are unsatisfactory.	Altitude: 0-1 400 m, Mean annual temperature: 10-35 deg. Celcius	200-3 500 mm
Crateva andansonii								
Delonix regia	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=648							

	n/a	n/a	800*	10-15 (max. 18) m high, attaining a girth of up to 2 m	Apiculture, Fuel, Timber, Gum or resin, Medicine, Shade or shelter, Ornamental, Boundary or barrier or support	The species seems to tolerate many types of soils from clay to sandy, but it prefers sandy soils.	Altitude: 0-2000 m, Mean annual temperature: 14-26 deg Celcius.	700-1200 mm
Dipterocarpus alatus	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=1774							
	n/a	n/a	905*	up to 40 m tall (sometimes more), up to 150 cm in diameter.	Timber, Gum or resin, Essential oil, Poison, Reclamation, Soil improver, Intercropping	The tree prefers alluvial soils.	Altitude: 0-500 m, Mean annual temperature: 20-30 deg.Celcius	1100-2200 mm,
Eucalyptus camadulensis	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=760							
	n/a	n/a	700*	20 m tall, occasionally reaching 50 m, with a trunk diameter of 1 (max. 2) m	Apiculture, Fuel, Fibre, Timber, Tannin or dyestuff, Essential oil, Medicine, Shade or shelter, Ornamental, Intercropping	Grows best on deep, silty or loamy soils with a clay base and accessible water table. Tolerates waterloggin g and periodic flooding. It is one of the species found to be	Altitude: 0-1500 m, Mean annual temperature: 3-22 to 21-40 deg. Celcius	250-2500 mm

						most tolerant to acid soils.		
Ficus spp., and vines (*khtum*)								
	n/a	n/a	740*	n/a	n/a	n/a	n/a	n/a
Gliricida sepium	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=912							
	4,900	n/a	800*	10 m / 30 cm	Timber, green manure, fodder, honey living fence, ornamental, shade	Moist or dry soil	22° - 30° Mainly below 500 m, up to 1,600 m	1,500-2,300
Hopea odorata	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=1756							
	n/a	n/a	980*	45 m tall / up to 4.5 m or more	Timber. Gum or resin, Tannin or dyestuff, Medicine Shade or shelter, Reclamation	It is found typically on deep rich soil, usually along the banks of streams and in damp situations.	Altitude: 0-600 m Mean annual temperature: 25-27 deg. C	1,500-3,000 mm
Hura crepitans								
	n/a	n/a	360*	n/a	n/a	n/a	n/a	n/a
Leucaena leucocephala	http://www.worldagroforestry.org/Sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=1069							
	4,200	30 and 40	550*	5 - 20 m	Firewood, Forage, pulp and paper, construction materials, green manure, reforestation on steep slopes and degraded lands	Wide variety, from rock to heavy clay	Tropics / Sub Tropics Lowland areas mainly below 500 m	600-1,700

Moringa oleifera	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=1169							
	4600 kcal/kg	n/a	n/a	8 m high and 60 cm dbh	Food, Fodder, Apiculture, Fuel, Fibre, Timber, Gum or resin, Tannin or dyestuff, Lipids, Medicine, Erosion control, Soil improver, Ornamental, Boundary/barrier/support, Intercropping, Pollution control	Adapted to a wide range of soil types but does well in well drained clay or clay loam without prolonged waterlogging. Prefers a neutral to slightly acidic soil reaction	Altitude: 0-1 000 m, Mean annual temperature: 12.6 to 40 deg. Celcius	At least 500 mm
Nauclea orientalis	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=17928							
	n/a	n/a	690*	a height of 30 m and a diameter of 1 m	Food, Apiculture, Timber, Poison, Medicine, Erosion control, Shade or shelter, Reclamation, Soil improver, Ornamental	Prefers alluvial soils along stream banks	Altitude: 0-500 m Mean annual temperature: 25 deg Celcius	800-3 800 mm
Pithecellobium dulce	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=1314							
	5177-5600 kcal/kg	n/a	690*	commonly 10-15 m, but ranges from 5-18	Food, Fodder, Apiculture, Fuel, Timber, Gum or resin, Tannin or dyestuff,	found on most soil types including	Altitude: 900-1 800 m, Mean annual temperature: 0-	250-1,650 mm

				m. Crown is broad spreading with irregular branches up to 30m across	Lipids, Medicine, Shade or shelter, Reclamation, Nitrogen fixing, Ornamental, Boundary or barrier or support	clay, limestone, and wet sand with a brackish watertable. The tree is rated highly tolerant to soil salinity and impoverished soils. It however grows best on well-drained, deep, fertile loamy agricultural soils.	48 deg. Celcius	
Psidium guajava	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=1375							
	n/a	n/a	750*	generally 3-10 m high	Food, Apiculture, Fuel, Timber, Tannin or dyestuff, Essential oil, Alcohol, Poison, Medicine, Ornamental, Boundary or barrier or support, Intercropping, Pollution control	Soils vary widely, including slightly to strongly acid. It grows well on poor soils with reasonably good drainage,	Altitude: 0-2 000 m, Mean annual temperature: 15-45 deg. Celcius	1 000-2,000 mm

						however growth and production are better on rich clay loams.		
Pterocarpus macrocarpus								
	n/a	n/a	865*	n/a	n/a	n/a	n/a	n/a
Sesbania bispinosa	http://www.worldagroforestrycentre.org/sites/TreeDBS/aft/speciesPrinterFriendly.asp?Id=1516							
	4281 kcal/kg	n/a	500*	(min. 0.6) 1-3 m tall	Food, Fodder, Fuel, Fibre, Gum or resin, Medicine, Shade or shelter, Reclamation, Nitrogen fixing, Soil improver, Intercropping	tolerant of soil alkalinity even up to a pH 10, and grows well under both water-logged or non-irrigated conditions.	Altitude: 0-1 200 m,	550-1 200 mm
*World Agroforestry Centre – Wood Density Database (http://www.worldagroforestrycentre.org/sea/Products/AFDbases/WD/Index.htm)								

Annex IV – Photographs

Leucaena leucocephala

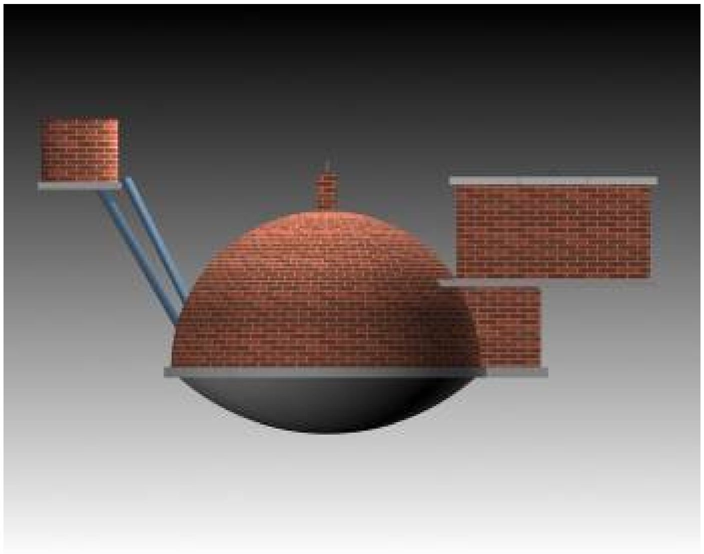
Leucaena leucocephala Nursery, Anlong Ta Mei Village, Battambang, Cambodia (Photo: Jason Steele)

6 month old Leucaena leucocephala, Anlong Ta Mei Village, Battambang, Cambodia (Photo: Jason Steele)

One year old Leucaena leucocephala, Anlong Ta Mei Village, Battambang, Cambodia (Photo: Jason Steele)

Harvested fuelwood from 6 month old Leucaena leucocephala, Anlong Ta Mei Village, Battambang, Cambodia (Photo: Jason Steele)

Biodigester Photos – Source: National Biodigester Programme Office (unless otherwise noted)



Kandal Province, Cambodia: A kitchen that uses fuel wood for cooking.
(Photo: Jason Steele)

Kandal Province, Cambodia: A kitchen that uses biogas for cooking. (Photo: Jason Steele)

Solar Cookers

Parabolic Solar Cooker (Source: Agricultural and Rural Development Association, Ghana, www.ara-ghana.de/internship_programme6.htm)

Solar Oven with Reflectors (Source: Idaho Department of Water Resources, http://www.idwr.state.id.us/energy/solar/solar_history.htm)

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