DETAILED PROJECT FEASIBILITY REPORT

VOLUME I – MAIN REPORT

KWENDIN BIOMASS ELECTRICITY PROJECT

(60 kW)

KWENDIN

NIMBA COUNTY

USAID's Liberia Energy Sector Support Program (LESSP)

STRATEGIC OBJECTVE # 2

To develop hydro capacity and other renewable energy sources

U.S. Agency for International Development
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ACRONYMS AND ABBREVIATIONS

BWI	Booker Washington Institute
CBEP	Cross Border Electrification Project
dB	Decibel
DCA	Development Credit Authority
EPA	Environmental Protection Agency of Liberia
EPC	Engineering Procurement Construction
EMMP	Environmental Mitigation and Monitoring Plan
GHG	Green House Gas
GOL	Government of Liberia
GPS	Global Positioning System
IRR	Internal Rate of Return
KBEP	Kwendin Biomass Electricity Project
kW	Kilowatt
kWe	Kilowatt Electricity
kWh	Kilowatt Hour
LEC	Liberia Electricity Corporation
LESSP	Liberia Energy Sector Support Program
L$	Liberian Dollar
MLME	Ministry of Lands, Mines and Energy
MW	Megawatt
NEP	National Energy Policy
NO_x	Oxides of Nitrogen
O&M	Operation & Maintenance
PLF	Plant Load Factor
RREA	Rural and Renewable Energy Agency
SO_2	Sulphur Dioxide
USAID	U.S. Agency for International Development
US$	United States Dollar
WI	Winrock International

EXECUTIVE SUMMARY

Decentralized renewable energy and energy efficiency technologies are well suited to promote sustainable development in rural and peri-urban areas of Liberia where infrastructure has been left in ruins after decades of mismanagement, neglect and civil war. Sustainable energy solutions meet the priority needs of the rural population, boost local productive activities, contribute to poverty reduction, help create wealth, improve healthcare, create jobs and enhance water supply and sanitation.

As part of USAID's continued assistance to the Government of Liberia (GOL) in building up Liberia's energy sector, USAID is funding the Liberia Energy Sector Support Program (LESSP). Winrock International is implementing this program. The purpose of LESSP is to increase access to affordable and renewable energy services in geographically focused rural and urban areas in order to foster economic, political, and social development. Towards this purpose, LESSP plans to establish power stations that will demonstrate the viability of renewable energy, especially for rural communities. It is intended that the successful operation of these power plants will be replicated by other non-US government donors, the GOL and private sector investors.

Liberia is a country with significant resources of biomass. These biomass resources could be used for power generation in a sustainable manner. One of the commonly available biomass resources in Liberia is rubber wood. Rubber trees need to be uprooted after trees cease to be producing latex. Usually a rubber tree needs to be uprooted in about 25 – 30 years to facilitate replanting. These uprooted rubber trees are a good source of biomass materials. Some rubber smallholders are not proceeding with the required replanting because of the cost involved in replanting. Biomass based power generation would result in establishing biomass supply chains that could be a source of additional income for rubber farmers. Farmers in turn may proceed with much needed replanting. Since LESSP is mandated to construct one pilot biomass power project in Nimba, LESSP was required to identify a location for the pilot plant excluding the towns in Nimba that are to be electrified under the Cross Border Electrification Project.

Having excluded all potential towns that would get electricity under the Cross Border Electrification Project, LESSP identified Kwendin, a small town in Nimba, as the potential location for a pilot biomass project. Kwendin is a town with about 2,300 persons and with adequate biomass resources. The survey conducted by LESSP in Kwendin to ascertain the demand for electricity and the ability and willingness to pay for electricity revealed that a 60 kW power system would be viable for Kwendin with a view to demonstrating the feasibility of a biomass based mini power system. For the given capacity of the power system, the appropriate technology would be gasification where woody biomass resources would be converted to a combustible gas known as producer gas or syngas. The survey revealed that there would be more than adequate biomass resources available in Kwendin for the project.

The estimated project cost is US$ 487,300 inclusive of the electricity distribution system. The land required for the Project is to be donated by the Kwendin Community and the estimated plant cost does not include the land cost. It was assumed that the Project would be operational 5 hours per day in Year 1 and as consumers get used to using electricity they would want to use electricity more and more. Accordingly, it was assumed that the Project would be operational for 12 hours per day and 18 hours per day in Year 2 and Year 3 respectively. Under these sets of assumptions, the Project's financials have been evaluated for different tariff levels from US$0.30 per kWh to US$ 0.45 kWh. According to the base case scenario (five hours daily operation), the Project would need cash subsidies of varying amounts for any initial tariff level between US$0.30 and US$0.42 per kWh. The project would not require any cash subsidy if the initial tariff is set at US$0.45 per kWh. However, if the daily operation period is increased to 6 hours, the requirement of Year 1 cash subsidy would be only if the initial tariff will be set at less than US$0.40 per kWh. Thus, the Project could be operated in a viable manner at initial tariff levels between US$0.30 – US$0.45 per kWh. However, the Project needs to be supported with a cash subsidy only for the initial year.

Biomass power projects will have to follow a stringent routine maintenance program to ensure trouble free operation over a long period of time. Therefore, it is proposed that the equipment supplier be required to operate the gasification plant for at least 3 months so that local Liberian operators will receive adequate training before taking over the responsibility. The proposed Project is expected to create 8 direct employment opportunities and this will be increased to 15 once the Project will be operational for 18 hours a day. Beyond the number of jobs created at the Project, the socio-economic impacts of the project are expected to be positive due to the supply of inexpensive and reliable power to an area which currently has no access to electricity. The availability of electricity will act as a catalyst for residents to establish income generating activities.

The direct environmental impact of the Project is expected to be negligible. Several potential impacts are discussed in this feasibility study, including gaseous emissions and air pollution, greenhouse gas emissions, liquid and solid wastes, water use and water pollution, noise, and aesthetics. It is concluded that due to the size and nature of the Project at its particular location, each potential impact is either de minimis or can be mitigated to be de minimis. The Project will commence construction after obtaining the Environmental Permit from the Environmental Protection Agency of Liberia (EPA) and the clearance from the USAID Bureau Environmental Officer. Additionally the Construction Quality Control Plan will be submitted to USAID before commencing construction. As per USAID requirement, an Environmental Mitigation and Monitoring Plan (EMMP) will be submitted to USAID and as construction and operation begin, EMMP will be implemented. Additionally, care will be taken to monitor for any unanticipated impacts and to implement necessary mitigating measures for such impacts.

The proposed project will be implemented as a community owned and managed project. LESSP will help the Community establish and formalize an electric cooperative society for the purpose of managing the power system. LESSP will develop a comprehensive business plan which is outlined in section 7 as the framework for the Community's management of this power system. LESSP will play a greater attention to the fact that the Community should be able to operate the power system sustainably without incurring institutional failure. The hallmark of prevention of institutional failure is (a) fixing tariff to recover, at a minimum, the O&M costs; (b) timely collection of electricity bills from consumers; and (c) management without malfeasance. LESSP will provide adequate training and guidance to the proposed electric cooperative to manage the power system within the above stated parameters.

One of the objectives of LESSP is to demonstrate the feasibility of using locally available biomass resources for electricity generation in a commercially viable manner. The success of this Project will result in its replication in rural Liberia where rubber wood or any other woody biomass is widely available. This type of renewable energy projects will be an economic stimulus for rural Liberia. More importantly the financial analyses show that the proposed Project is financially viable by pricing the energy to end users at US$0.35-US$0.40 per kWh which is almost 40% cheaper than the cost of electricity in Monrovia, but without causing negative impacts on the environment.

1 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Liberia's infrastructure, particularly electricity, is in ruins after decades of mismanagement, neglect and fourteen years of a brutal civil war. The vast majority of the 3.5 million Liberians do not have access to electricity. Only the capital Monrovia has a grid based electricity supply operated by the Liberia Electricity Corporation (LEC). Less than 10% of the urban residents and only 2% of the rural populations have access to electricity and other modern forms of energy services. The transportation of fossil fuels to remote areas is often very costly and rural communities have to pay higher prices for energy services compared to the population in cities. Low-income groups are particularly vulnerable to price fluctuations such as the recent price increase of petroleum based products. This is considered a major factor affecting the country's social and economic development. In this context, decentralized renewable energy and energy efficiency technologies are well suited to promote sustainable development in rural and peri-urban areas. Sustainable energy solutions meet the priority needs of the rural population, boost local productive activities, contribute to poverty reduction, help create wealth, improve healthcare, create jobs and enhance water supply and sanitation.

The LEC is statutorily responsible for generation, transmission and distribution of electricity in whole of Liberia. However, due to financial constraints, LEC is unable to extend its mandate beyond Monrovia. In this context USAID/Liberia, in consultation with the Government of Liberia (GOL), the donor community and other stakeholders, has identified renewable energy as an underutilized resource that could have tremendous impact on the country's development. The GOL is committed to support rural and renewable energy development and modern energy service provision in Liberia. As fulfillment of the Government's role, the GOL has established an autonomous agency, the Rural and Renewable Energy Agency (RREA), with a view to facilitating and accelerating the economic transformation of rural Liberia by promoting the development and supply of modern energy products and services to rural areas with an emphasis on locally available renewable resources.

As part of USAID's continued assistance to the Government of Liberia in building up Liberia's energy sector, USAID is funding the Liberia Energy Sector Support Program (LESSP). Winrock International has been selected by USAID to implement the LESSP. LESSP will be working very closely with the Ministry of Lands, Mines and Energy (MLME) and RREA in implementing the work program of LESSP. The purpose of LESSP is to increase access to affordable and renewable energy services in geographically focused rural and urban areas in order to foster economic, political, and social development. The ultimate impact of the activity, i.e. the change that is expected in targeted areas upon assessing the completed work, will include:

- increased and sustainable access and affordability of electricity within urban and rural poor communities;
- improved performance of local governments, civil society and the private sector in monitoring, regulating, and managing the use of renewable energy;
- increased percentage of households and businesses utilizing clean energy and a corresponding increase in economic activity;
- policy changes that improve the investment climate for energy sector.

LESSP aims to mobilize public and private sectors in order to develop power projects by using the country's diverse and plentiful renewable energy resources. Towards this purpose, LESSP plans to establish power stations that will demonstrate the viability of renewable energy, especially for rural communities. It is intended that the successful operation of these power plants in a commercially viable manner will result in their replications by other non-US government (USG) donors, the GOL and private sector investors.

As the implementing agency of USAID/Liberia's LESSP, Winrock International is mandated to construct two Hydro Power Systems and two Biomass Power Systems in three Counties: Bong, Lofa and Nimba as part of developing rural and renewable energy. Since the two hydro power systems have been identified in Bong and Lofa Counties, one of the biomass power systems is required to be constructed in Nimba County. This report is about the feasibility of constructing a biomass power system in Nimba.

1.2 POTENTIAL OF BIOMASS AS A RENEWABLE RESOURCE IN LIBERIA

Liberia's electricity generation is highly dependent on imported fuels. This makes the country vulnerable to energy supply disruptions and global price fluctuations. At the same time Liberia is endowed with abundant renewable energy sources – biomass, biogas, mini hydro, solar and wind. Therefore, tapping the potential of renewable energy can increase Liberia's energy security, save foreign exchange, and protect against global price fluctuations of fossil fuel by using domestic energy sources. One of the objectives of LESSP is to develop renewable energy in Liberia.

Currently, the entire power generation in Liberia is based on burning fossil fuel with the exception of Firestone which operates a 4 MW hydro power plant for its captive use. There is no single power project using biomass as fuel although the country has abundance of biomass resources that could be utilized for power generation in a sustainable manner. A study report prepared for USAID in December 2008, "Assessment of Biomass Resources in Liberia" has estimated the extent of biomass resources currently

and potentially available in Liberia for power generation. Some of the biomass resources available in abundance in Liberia include old rubber trees, paddy/rice husks, crude palm oil, food crop residues, cash crop residues etc.

Among these biomass resources, one of the abundantly available solid biomass materials is rubber wood which is a byproduct of rubber plantations. Considering the importance of the Rubber Sector to the economy of Liberia in general, and the availability of rubber wood in a sustainable manner in particular, Winrock International (WI) has determined that a biomass power project using rubber wood chips as fuel will be the most appropriate pilot project for Nimba.

2 PILOT BIOMASS POWER PROJECT IN NIMBA COUNTY

2.1 PRELIMINARY BIOMASS RESOURCE ASSESSMENT IN NIMBA

The Nimba County is known for its extensive rubber plantations which have been developed over the decades of 1950 to 1980. The Assessment of Biomass Resources in Liberia, compiled by the National Renewable Energy Laboratories for the International Resource Group (IRG) (Ref 1) in 2008, provides valuable information on the potential of the rubber plantations in Liberia as a source of biomass. The section on Rubber Plantations is quoted below.

> *"Rubber has been Liberia's principle cash crop since the 1920s. The country ranks third in Africa's production of natural latex after Nigeria and Ivory Coast, with about 117,000 tones in2005 (FAOSTAT). Below is a list of the large-scale rubber plantations established in Liberia over the years and Figure 2 illustrates their locations:*
>
> - *Firestone near Harbel, Margibi County*
> - *Liberia Agricultural Company (LAC) near Buchanan, Grand Bassa County*
> - *Guthrie (also known as Goodrich plantation) near Baha, Bomi County*
> - *Liberia Company (LIBCO) near Cocopa, Nimba County*
> - *Salala Rubber Corporation near Nienka, Margibi County*
> - *Cavalla (initially part of the Firestone concession) near Harper, Maryland County*
> - *Sinoe Rubber Corporation (SRC) near Greenville, Sinoe County*

Some of these plantations were abandoned or taken over by rebel forces during the civil war. As a result, many suffered years of poor or indifferent management and would need significant investment to put them back in production. During this time, a few plantations changed hands, such as Firestone, which sold its interests to the Japanese-owned Bridgestone in 1988, or ceased operation (the government suspended the agreement with LIBCO in December 2007[1], citing poor management). The two largest plantations, Firestone and LAC, remained in good condition after the war, and are currently producing significant quantities of rubber. As of July 2007, the Firestone factory was producing 3,000-4,000 tons of rubber per month, while LAC was producing about 2,000 tons per month (PAC 2007). Two other plantations, Guthrie and Cavalla, reported production of about 4,000 tons each in 2006 (MOA 2007). Because of these companies' operation, many household farmers in Liberia note that rubber is their current most important cash crop. They sell raw rubber to the companies, making the industry a big employment generator as well as a major income earner for the country (FAO 2006).

Figure 1 - Rubber Plantations in Liberia

The study estimates that large-scale rubber plantations in Liberia today cover an area of approximately 58,000 hectares. This type of plantation generates considerable amounts of wood residues from pruning and replanting activities. According to MOA, the tree stock in these plantations is still productive; however, UNEP indicates they are nearing the end of their productive lifespan. The rotation period, when the trees are cut down for replanting, is 25-30

[1] According to the LIBCO, the Ministry of Agriculture suspended the Concession earlier. The suspension was later cancelled in December 2007.

years. Tree trunks and branches become available during replanting and approximately 81 dry tons of wood could be obtained per hectare (about 180 m3 of green wood). Tree trunks are usually used as timber and the small branches (54% of total biomass) are left in the field. If only 10% of the current rubber tree stock (about 5,800 ha) is replanted, it would result in roughly 254,000 dry tons of wood branches. The corresponding energy content is about 4,600 TJ, equivalent to 381 GWh of electricity. Additional biomass resources from rubber trees that could be tapped as an energy source are the leaves. Rubber trees are deciduous—they shed their leaves during the dry season, resulting in a residue resource of about 1.4 tons per hectare. The leaves are often disposed of by burning at the end of the dry period. However, if collected, it would result in approximately 69,000 dry tons of biomass. Some of the leaves should be left on the field to maintain soil quality and control erosion; however, even if only 30% of this biomass resource is collected (~21,000 dry tons), about 31.5 GWh of electricity would be generated.

This analysis doesn't evaluate the residues generated from rubber trees grown on household farms because it is assumed that these residues are already in use as firewood or on farm applications. Additionally, MOA reports that more than 75% of the smallholder farms are newly planted, therefore no significant residue generation is expected in the next 15-20 years".(Ref IRG Assessment of Biomass Resources in Liberia, December 2008).

The most important attribute of rubber wood chips based power generation is that the sustainable availability of fuel wood for continuous power generation. According to industry sources, rubber trees are planted only for their latex. Trees take about 6-8 years from planting to mature and have an economic life of 30-35 years from the time of planting by which time latex flow is steadily decreasing. The old rubber trees, trunks, branches and cleaned roots are an excellent source of biomass fuel for electricity generation. It is estimated that Liberia currently has 125,000 hectares of rubber as per the 2005 data. The tree density is 360 – 370 trees per hectare in plantations and 400 – 500 trees per hectare in smallholdings. Assuming an average density of 400 trees per hectare, Liberia will have annually 2 million trees for uprooting. Most of the rubber growing countries in the world now use treated rubber wood increasingly for furniture manufacture, however, Liberia does not use rubber trees for furniture manufacture. Currently, Firestone is producing treated rubber woods for exports but even if the treated rubber wood industry becomes well established in Liberia, it will not pose a threat to biomass based power generation in Liberia because only 30% of the wood mass is used for treated rubber industry. Liberia must use its own biomass resources for power generation instead of importing fossil fuels for power generation as the country does it now.

2.2 PILOT BIOMASS POWER PROJECT IN NIMBA

Two of the most important factors to be considered in setting up a biomass power project are the potential load centers and the availability of continuous supply of biomass material within a reasonable distance to the power plant. Major cities in Nimba, such as Ganta, Saclepea and Tappita are good

locations for establishing biomass power systems because these cities are commercially active cities with significant business consumers and there are rubber plantations within a reasonable distance from these load centers. There are also many smallholder rubber plantations in and around these cities. Therefore, these cities are very good locations for siting biomass based electricity projects. However, all these commercial cities have been identified as load centers for the Ivory Coast - Liberia Cross Border Electricity Project (CBEP) which is being implemented by the Liberia Electricity Corporation (LEC) in partnership with the West African Power Pool. According to LEC sources, the CBEP completion is anticipated in late 2013.

ECOWAS Lights Up Rural Liberia

> *Eighteen (18) communities in rural Liberia will soon see their cities and towns light up very soon for the first time in a long time since the outbreak of the ended 14 year civil war with the coming into operation of the Cross-Border Electricity Supply project of ECOWAS from Prollo, Cote d'Ivoire through its specialized organization, West African Power Pool (WAPP).*
>
> *The project is divided into three (3) lots for the supply and installation works. Lot 1, Maryland County, Lot 2, Nimba County and Lot 3, Grand Gedeh County. The Maryland County Lot electrification will include Pleebo City, Fish Town, Fish Town City, Rock Town, Harper City, Cavalla, Cavalla Rubber, Graway, and Kablaken with metering point at Poste Frontiere de Prollo, Cote d'Ivoire. Nimba County Lot will link through the Danena Line with metering point at Gbeunta and Poste Frontiere de Prollo to service Logotuor, Saclepea, Duoplay, Kanplay, Ganta, and Sanniquellie. Grand Gedeh County Lot metering point will be at Frontiere Pekan Barrage to connect Toe Town, Blodiala, Zleh Town, Tepeta and Zwedru City.*
>
> *The Cross-Border Electricity Supply project is an initiative of the Economic Community of West African States, (ECOWAS) implemented through its specialized organization, the West African Power Pool (WAPP) established January 12, 2006 after the signing of the article of agreement at its 29th Summit of Heads of State and Government of member states in Niamey, Niger in follow up to that West African regional body decision reached at the 22nd Summit of Heads of State and Government of 1999 in Benin after preliminary work of a Steering committee appointed by that body.*
>
> *(Source: thenewdispensation.wordpress.com/.../ecowas-lights-up-rural-liberia/)*

While selecting a suitable location for establishing a pilot plant in Nimba, LESSP excluded major towns in Nimba that have been earmarked by the proposed cross border electricity supply project as load

centers. Additionally, LESSP has decided to select a location in Nimba for construction a pilot plant based on three criteria:

(a) The location would not get electricity supply from the proposed cross country electricity project within a foreseeable future;
(b) Adequate biomass materials (mostly old rubber trees) are available within a reasonable distance from the power generation point; and
(c) The residents living in the location are willing to pay and are able to pay for electricity.

2.3 PROJECT LOCATION

Having excluded major towns in Nimba for siting the pilot biomass power system, LESSP evaluated two towns to locate the pilot power project, Kwendin and Gbonipea. Kwendin and Gbonipea are located within a 5 mile radius from Tappita. These two potential locations were evaluated in terms of human factors and availability of biomass fuel. Kwendin can be described as a small town and Gbonipea can be described as a small village. Both these locations are similar in nature with the exception of the number of inhabitants living in the two communities. Access to both these locations is extremely difficult. LESSP decided to select Kwendin as the potential location for the biomass pilot project in Nimba because it has a larger population and it is located along the Tappita-Buchanan road. Kwendin has the potential of becoming a major town in Nimba.

LESSP conducted a survey in Kwendin to ascertain the socio-economic status of the Kwendin residents and their primary ability and willingness to pay for electricity if they will be provided with grid electricity. The Survey Questionnaire is attached as Annex 1. The primary survey data are stated in Annex 2. Kwendin is a small town with a population of 2,305, living in 248[2] houses. Almost all the inhabitants are involved in agriculture. This town is an attractive location because it has a mix of residential housing stock and a few institutions. Kwendin also has potential to become a commercial town once a mini electricity grid will have been constructed. Commercial consumers will create a demand for electricity during the day time. This will allow for improved utilization of the generating assets, but more importantly, the availability of electricity will accelerate productive economic activity, which is critical to the sustainability of the project. Kwendin has a school with 350 students, and a health care/clinic. Commercial users include 5 video clubs (entertainment centers) and a couple of small business enterprises. Kwendin represents a typical rural town in Liberia.

[2] Based on the survey carried out by LESSP Staff in August 2012

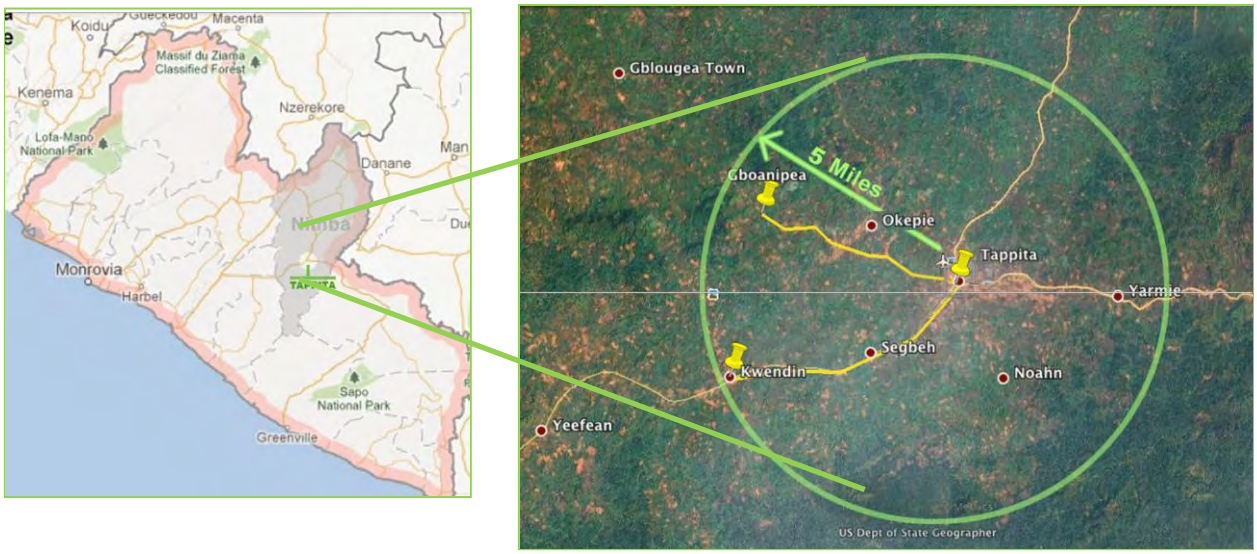

Figure 2 - Project Location

The following is the snap shot of Kwendin Town:

- Kwendin Town is 11 kilometers away from Tappita city;
- This town is accessible by vehicles and motorbikes. The access road from Tapitta is very difficult with 5 culverts in dilapidated conditions. However, the access road is being widened;
- There is a government school building fully in use. The school has an enrollment of 350 students and 8 teachers, 3 trained and 5 untrained;
- No market building. The inhabitants of this town attend the weekly Wednesday market in Tappita;
- Livelihood activities of the people of this town are farming, mostly Rice, Cassava and Oil Palm.
- Rubber is the most predominant cash crop in this area. In fact, there are many unproductive rubber farms that are barely cultivated by the smallholder farmers. The farmers lack capital for re-planting the trees;
- There are 5 functional business enterprises including video clubs and small business enterprises; and
- Health center/Clinic is available in Kwendin.

In terms of biomass availability for power generation, Kwendin has many rubber farms with old rubber trees. Farmers are willing to sell old rubber trees. Moreover, Kwendin has abundance of forest resources such as trees, shells, Bamboo and a variety of plant species that can be processes into produce biomass fuel for power generation. The community is willing to provide land for siting the powerhouse. LESSP carried out a survey as to the community's ability to pay and willingness to pay for electricity and such survey data have been used to ascertain the estimated capacity of the power project. The survey also assessed the extent of rubber plantations owned by individual farmers and the extent of old rubber

trees in these smallholdings. But more importantly, LESSP selected Kwendin because they are archetypical. There are hundreds like them in Liberia, so lessons learned here can be applied efficiently in other communities in Liberia.

3 DEMAND FOR ELECTRICITY AND ABILITY TO PAY FOR ELECTRICITY

3.1 DEMOGRAPHICS

Kwendin town is a typical rural town in Liberia. It is located in Nimba County in the District of Yarulin Mehnsonnoh. It is 11 km away from Tappita along the Tappita-Buchanan road. It has 248 households with a population of 2,305 inhabitants. The main livelihood of the community is agriculture and farmers travel to Tappita for marketing their produce on the Wednesday Market Day.

3.2 COMMUNITY'S ABILITY AND WILLINGNESS TO PAY FOR ELECTRICITY

Kwendin town never had any kind of mini grid electricity. A few households use diesel generators for generating electricity and majority use other types of sources for electricity. The concept of a mini electricity grid for the community is much appreciated by the community members. In order to assess the potential demand for electricity in the community and also to assess community's willingness and ability to pay electricity, LESSP carried out a survey covering all households during August 7th August 20th, 2012. The survey revealed that the every household was willing to have electricity and predominantly the requirement for electricity would be during the evening and early night. This is understandable because villagers use lighting equipment mainly for light during the night. The map showing the locations of households is given in Annex 3.

Table 1 – Kwendin Household's Willingness to Pay for Electricity

	Number of Households	Willingness to Pay per week (L$)	Willingness to Pay per month in US$[3]
	98	Less than 100	Less than 5.87
	68	100 - 149	5.87 – 8.75
	16	150 - 199	8.80 – 11.68
	18	200 - 249	11.74 – 14.62
	08	250 - 299	14.68 – 17.55
	03	300 - 349	17.61 – 20.49
	02	350 - 399	20.55 – 23.42
	02	400 - 500	23.48 – 29.35
	05	500 and above	29.35 and above
	28	No response	No response
Total	248		

The above table was prepared based on the responses of the households to the survey. The table shows that about 98 (around 40%) of the households are prepared to pay less than L$100 (US$1.37) per week or US$ 5.87 per month for electricity. Approximately 10% of the households did not indicate the amount they were willing to pay for electricity. The remaining households have shown their willingness to pay for electricity in various amounts up to L$500 per week.

In the absence of any benchmark for reasonable tariff for a rural mini electricity system, LESSP observed the tariff structure of private electricity providers in Monrovia and in other towns such as Ganta. These private electricity suppliers are in operation in Monrovia and other major towns. Most of these private service providers supply electricity to consumers on a flat tariff, based on the maximum load of electricity connection provided to each household. The standard rate in Monrovia is US$40 per month for 1 Ampere load for 11 hours of electricity supply. The supply is regulated by installing a devise known as miniature circuit breaker (MCB). One Ampere MCB will allow the consumer to draw up to 1 ampere current and if the current flow exceeds 1 ampere, the MCB will trip. Since electricity is distributed at 220

[3] Computed for 30 days at the exchange rate of L$ 73 for 1 US$. The column shows theoretical amounts based on the prevailing conversion rate. Any tariff decision will have to be in terms of the minimum denomination of the respective currencies available in Liberia (Five Liberian Dollars and one US Dollar).

volt, one ampere current limiting devise (MCB) will allow a maximum load of 220 - 200 watts. Accordingly the effective tariff of private electricity suppliers is around US$ 0.55 – US$ 0.61 per kWh[4].

LESSP believes that a biomass based electricity system should be able to provide electricity at a rate cheaper than the rate used for diesel based power generation. Accordingly, LESSP proposes that the proposed pilot plant should charge a tariff of around US$ 0.35 – US$ 0.40 per kWh. This indicative tariff is more than 40% cheaper than the real cost of diesel generation inclusive of amortization and O&M cost. This tariff is also about 25% cheaper than the rate currently levied by private service providers. The proposed power system will supply electricity for 5 hours per day initially. If a household is allocated 100 watts load, the monthly bill of that household would be US$6.00[5]. The households that reported their willingness to pay around L$100 per week could very well afford to have 100 watts of electricity consumption for 5 hours per day paying L$ 440 monthly. The amount reported as "willingness to pay for electricity" by each household had been used to estimate the potential load allocation for each household. Accordingly, each household was allocated the maximum load of electricity as per the data shown in Table 2 below. The households that did not respond to the survey, numbering 28, were lumped together with the group of households that responded their willingness to pay for electricity as less than L$ 100 per week.

Table 2 - Potential Load Allocation

Willingness to Pay for Electricity L$ per Week	Willingness to Pay per Month in US$	Number of Households	Potential Load Allocation (watts)
No response	No response	28	100
Less than 100	Less than 5.87	98	100
100 – 149	5.87 – 8.75	68	200
150 – 199	8.80 – 11.68	16	400
200 – 249	11.74 – 14.62	18	400
250 – 299	14.68 – 17.55	08	600
300 – 349	17.61 – 20.49	03	600
350 – 399	20.55 – 23.42	02	600
400 – 500	23.48 – 29.35	02	600
500 and above	29.35 and above	05	800
Total		248	

[4] A household with 1 Ampere load (200-220 watts) will consume 2.2 – 2.4 kWh for continuous 11 hours per day and the monthly consumption of energy would be 66 – 72 kWh. Monthly fee of US$40.00 will amount to tariff rate of US$0.55 – US$0.66 per kWh.

[5] Five hours of 100 watts per day will result in 15 kWh of electricity consumption. If the tariff is US$0.40 per kWh the monthly electricity bill would be US$6.00. This is around L$438 at the prevailing exchange rate of L$73 per one US$.

3.3 INSTALLED CAPACITY OF THE POWER SYSTEM

Except for 4 households with generator facilities, all other Kwendin households use flash lights for lighting purposes. Accordingly, it is expected that the households' primary use of electricity would be for lighting purposes for the time being. In this context, the potential load allocation as shown in Table 2 would be a reasonable basis for estimating the potential capacity of the proposed power system. Table 3 shows the peak capacity for each household category if the maximum load were to be allocated as shown in Table 2. Thus it is seen that the peak capacity of the entire power system would be 48 kW. Accordingly, the community electricity system will be designed for 60 kW installed capacity by keeping allowances for internal power consumption for running auxiliary equipment such as a wood chipper.

Table 3 - Load Allocation for Households

	Number of Households	Maximum Load per Household (Watt)	Total Load in kW
	126	100	12.60
	84	200	16.80
	26	400	10.40
	07	600	04.20
	05	800	04.00
Total	248		48.00

3.4 ELECTRICITY CONSUMPTION AND POTENTIAL REVENUE

Kwendin is a residential town with little commercial activity presently, and therefore, it is assumed that the demand for electricity will be only for lighting purposes in the night. Based on the interviews LESSP has had with the residents, LESSP believes that this assumption is fairly valid, at least during the initial years of the electricity supply. It is expected that the availability of a mini grid based electricity system for residents in Kwendin would be a catalyst for potential commercial consumers to establish commercial activities in Kwendin. Commercial consumers need electricity mostly during the day time and the proposed electricity system will be able to cater to them without carrying out load shedding for residential consumers. Therefore, the proposed electricity system will operate from 6.30 pm to 11.30 pm daily during the first year of operation. It is estimated that the demand for electricity will increase

during subsequent years and the project would operate 12 hours per day during the second year and the number of operation hours would be increased to 18 hours per day from the third year onwards. It will very well be that the increasing demand for electricity may happen sooner than above stated time period. However, the Project's financial projections would be based on the above stated conservative projections.

Table 4 shows the potential revenue of the project, assuming the daily operation of the power system as 5, 12 and 18 hours for Year 1, Year 2 and Year 3 respectively.

Table 4 - Annual Electricity Consumption

		Year 1	Year 2	Year 3 +
Installed Plant Capacity	kW	60	60	60
Available Capacity	kW	60	60	60
Operating Days	per year	365	365	365
Operating Hours	per day	5	12	18
Maximum Available for Distribution Plant Efficiency of 80%	kWh	87,600	210,240	315,360
Tariff	US$/kWh	0.40	0.40	0.40
Revenue	US$	35,040	84,096	126,144

The proposed power system should be able to operate in a commercially sustainable manner and therefore, there should be an effective way of collecting revenue from electricity consumers. The equitable way of collecting revenue would be to provide metered electricity connections to consumers. The conventional meters do not provide the security required by service providers. Even Liberia Electricity Corporation, with all its resources, finds it difficult to effectively collect revenue from consumers and to prevent theft. LEC is in the process of introducing pre-paid meters to its consumers. It may be not feasible for introducing pre-paid metering systems to small rural electricity systems. However, LESSP is exploring to introduce a metering system that would serve the interests of both the consumers and the service provider. As an interim measure LESSP proposes to introduce a flat tariff regime as practiced by all private service providers in Liberia.

Table 5 below shows the practical way of collecting revenue from consumers if the project will charge revenue on the basis of monthly flat tariff. The unit rate of US$ 0.40 per kWh would be equivalent to a monthly flat fee of US$12.00 per 1 ampere load.

Table 5 - Potential Monthly Revenue in Year 1

	Number of Households	Maximum Limiting Current per HH (Amp)	Monthly Flat Tariff per 1 Amp (US$)	Monthly Revenue in US$
	126	0.5	12.00	756
	84	1	12.00	1008
	26	2	12.00	624
	7	3	12.00	252
	5	4	12.00	240
Total	248			2,880[6]

4 TECHNOLOGY

4.1 BIOMASS RESOURCE AVAILABILITY

Figure 3 - Bamboo Plantation in Kwendin

Biomass based power generation is well suited to remote villages with no access to grid electricity but access to significant amounts of biomass resources. There are various technology options for biomass based power generation, depending on the type of biomass materials and the scale of operation. Various studies had established the fact that Liberia is a country with substantial amount of biomass materials. Nimba also has substantial resources of biomass in the form of old rubber trees from rubber plantations. During the site visit to Kwendin in early August 2012, LESSP team observed a large quantity of unproductive rubber trees in and around Kwendin. Some

[6] The monthly revenue of US$ 2,880 is same as the annual revenue of US$35,040 in Year 1

residents in Kwendin are also rubber smallholders as revealed during the survey carried out by LESSP. Rubber trees have productive life time of 25 to 30 years according to industry sources[7]. The LESSP survey revealed that farmers in Kwendin collectively own approximately 2,166 acres of rubber in and around Kwendin. These smallholders reported that approximately 951 acres of old rubber trees are needed to be uprooted.

As per the rubber plantation norms, the density of rubber trees in smallholder plantation is about 150 – 200 trees per acre. On this basis, the available rubber trees from 950 acres would be sufficient for a period of about 58 years[8] if the plant were to run 24 hours a day at full capacity of 60 kW.

Besides old rubber trees, the project may utilize bamboo trees as fuel for the project. Bamboo is a fast growing tree which has a regeneration cycle of three years. Bamboo trees are abundantly available in Kwendin. Although bamboos are used in construction industry and other industries such as furniture, utensils, fiber & paper in many part of the world, there are no known usages of bamboos in Liberia. Bamboo has been recognized as the fastest growing plant species in the world with very favorable characteristics for gasification. Bamboo has a number of desirable fuel characteristics such as low ash content and alkali index. Its heating value is higher than most agricultural residues, grasses and straw[9]. In addition to old rubber trees, bamboo is suitable as fuel for the proposed biomass electricity project because of its high biomass productivity, self-regeneration, sustainable basis and environmental friendliness. Most importantly, the Kwendin community is willing to provide biomass to the proposed project. Considering the scale of operation of the proposed project such a task would not be a difficult task to the community. The project will seek to establish a biomass supply chain to the project as a community owned activity.

4.2 TECHNOLOGY OPTION

Considering the fuel recommended for the proposed biomass power project and the scale of operation, the most appropriate technology for the proposed project would be Gasification Technology as against Combustion Technology. In the case of combustion, the biomass is fired to generate steam which turns a turbine for power production. In the case of gasification, the biomass is gasified into a mixture of CO and H_2 in a gasifier. This gas is fed to a gas engine connected to an alternator that produces electricity.

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[7] Mr. Bowier, Plantation Manager, Cocopa Rubber Plantation, private discussion in April 2011

[8] Assuming dry wood yield of 300 kg from a tree, the availability of dry wood from 950 acres would be around 45,600 tons. The biomass consumption of 1.5 kg per kWh, the plant would need approximately 789 tons per year for 24 hr. daily operations at full capacity of 60 kW.

[9] Eco Energy Solutions of India, Project Report on "Cultivation of Bamboo and its Bio Energy Production", www.ecoenergysolutions.co.in

Biomass gasification refers to the incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4). This mixture is called producer gas or syngas. Producer gas can be used to run internal combustion engines (both compression and spark ignition) for power production, or can be used as substitute for furnace oil in direct heat applications.

Gasifiers can work at low scales – as low as 20 kW, and works well up to 2 MW, with current technology. Technology uses a combination of gasifiers and gas engines. The technology has been in vogue for decades, but is still evolving. Gasification works best for woody biomass, but latest gasifiers also work reasonably well with non-woody biomass such as rice husk.

4.3 GASIFICATION TECHNOLOGY BASED POWER GENERATION

4.3.1 Gasification Process

Gasification plants consist of several process steps. The solid biomass fuel delivered needs to be adjusted (fuel conditioning and handling) to the fuel characteristics (particle size, moisture content) required for the gasification process. The conditioned fuel enters the gasification process, which produces raw product gas. The raw product gas needs to be cleaned in order to achieve the product gas quality needed for further utilization. The cleaned product gas is used for the production of electric power, heat and fuel based on different technologies.

4.3.2 Components of Gasifiers

Gasifiers consist of three components: Gasifiers, Engines and Power Evacuation Systems. Gasifiers are reactors that heat biomass in a low-oxygen environment to produce a fuel gas that contains from one fifth to one half (depending on the process conditions) the heat content of natural gas. The gas produced from a gasifier can drive highly efficient devices such as gensets, turbines and fuel cells to generate electricity. Gas engines used in the gasification power plants run on producer gas to produce power. These engines have reasonable efficiencies. Producer gas has a very low air to fuel ratio (1.3:1) compared to other gases (Natural gas 17:1). Hence the engine has to be operated with a different carburetor for producer gas and natural gas. Also, the producer gas can be operated in an engine which has a higher compression ratio. Engines used for producer gas have generally lower in efficiency and they are cheaper. The efficiency of these engines is more than 30%. Power evacuation system is the method of transmitting electricity to the grid (if it is grid connected) or to the location where electricity is required (if it is captive).

4.3.3 Types of Gasifiers

There are two types of gasifiers; Fixed Bed and Fluidized Bed. The fixed bed gasification system consists of a reactor/gasifier with a gas cooling and cleaning system. The fixed bed gasifier has a bed of solid fuel particles through which the gasifying media and gas move either up or down. It is the simplest type of gasifier consisting of usually a cylindrical space for fuel feeding unit, an ash removal unit and a gas exit. In the fixed bed gasifier, the fuel bed moves slowly down the reactor as the gasification occurs. The fixed bed gasifiers are of simple construction and generally operate with high carbon conversion, long solid residence time; low gas velocity and low ash carry over. In fixed bed gasifiers, tar removal used to be a major problem; however recent progress in thermal and catalytic conversion of tar has given credible options.

Fixed bed gasifiers are the most commonly ones. These are in turn available under two important categories depending on the direction of the gas flow through the reactor:

- Updraft gasifiers
- Downdraft gasifiers

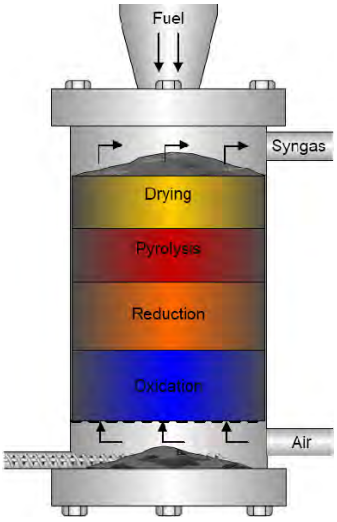

Figure 4 - Fixed-bed Updraft Gasifier

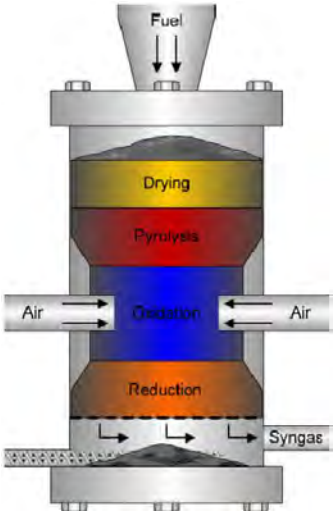

Figure 5 - Fixed-bed Downdraft Gasifier

4.3.4 Updraft Gasifiers

Fuel flexibility is the main feature of updraft multi-fuel gasifiers. These gasifiers can operate on either coal or biomass and fuel switching does not require any changes in the reactor. Updraft gasifiers

tolerate higher ash content, higher moisture content and greater size variation in fuel as compared to downdraft gasifiers.

In updraft gasifiers, gas is drawn out of the gasifier from the top of the fuel bed while the gasification reactions take place near the bottom. As the producer gas passes through the fuel bed, it picks-up volatile matter (tars) and moisture from the fuel. Therefore, the gas from the updraft gasifier contains condensable volatiles. The design and operation of the gasifiers is such that the gas comes out at 200^0-400^0 C temperature. At this temperature, most of the volatile hydrocarbons are in vapor form, which add to the energy content of the gas. It is most appropriate to utilize updraft gasifiers in close-coupled-hot gas mode for direct heating applications. However, if the application warrants, the scrubbing of gas to remove the volatiles/tars is also carried out.

4.3.5 Downdraft Gasifiers

Downdraft gasifiers are fuel specific. Downdraft wood gasifiers can operate on wood like biomass materials and biomass briquettes with a minimum bulk density of 250 kg/m3 and ash content of less than 5%. In downdraft gasifiers, gas is drawn from the bottom of the reactor while the hottest reaction zone is in the middle.

The volatile matter in the fuel gets cracked within the reactor, and therefore, the output gas is almost tar-free. However, the gas, as it comes out of the reactor, contains small amounts of ash and soot. The gas comes out of the gasifier at 250^0-450^0 C. This gas can also be used either in hot condition (after preliminary cleaning) or in cold-clean condition (after appropriate gas clean-up arrangement). The gas from the downdraft gasifiers can be cleaned to very high purity such that it can be used in IC engines or for direct heating applications where purity of gas is a critical requirement.

4.3.6 Fluidized-bed Gasifiers

In fluidized bed gasifiers, the biomass is brought into an inert bed of fluidized material (e.g. sand, char, etc.). Such systems are less sensitive to fuel variations but produce larger amounts of tar and dust. They are more compact but also more complex, and usually used at larger scales. Fluidized bed gasifiers are operated with significantly higher gas flow velocities than fixed bed gasifiers. The fuel bed and a carrier material (e.g. sand) are fluidized by the gas flow (fumigator and recirculated product gas). Thus, the gasification reaction takes place in a fluidized bed but only 5-10% weight of the bed is fuel.

4.4 PREFERRED TECHNOLOGY OPTION

The industry practice is to employ Fixed-bed downdraft gasifiers for gasification plant for electricity generation using woody biomass as fuel for less than 500 kW capacity plants. The major drawbacks of updraft gasifiers are the high amounts of tar and pyrolysis products that occur because the pyrolysis gas

does not pass the hearth zone, and therefore, is not combusted. This is of minor importance if the gas is used for direct heat applications in which the tar is simply burned. But when the gas is used for internal combustion engines, extensive gas cleaning is required before the gas is fed into engines. Syngas from downdraft gasifiers contains little tar and the gas is suitable for running engines. However, high amounts of ash and dust particles remain in the gas because the gas has to pass the oxidation zone, where it collects small ash particles.

During biomass gasification, various pollutants may be produced depending on the type of gasifier and the composition of the biomass material. The pollutants can include sub-micron particulate matter and tars. These pollutants must be removed before the gas is used in internal combustion engines. Various technologies for cleaning and cooling of syngas, like venturi scrubbers using water, diesel or caustic solutions, organic oils and other solvents, wet or dry electrostatic precipitator, ceramic & fabric filters, biomass bed filter, activated carbon filters, paper filters, molecular sieves etc. and combinations thereof have been tried by various gasifier manufacturers. These technologies are being employed by various manufacturers for syngas cleaning. Due to remoteness of the project, the cooling and cleaning system should not generate any waste water and hence the environmental issues of handling waste water. The most common methods used for smaller gasifiers are either wet scrubbers or biomass filters. The filter media used in biomass filters are saw dust, medium size & fine woodchips etc. The advantage of biomass filters is that the system does not create any solid & liquid waste. The used filter media can be mixed with biomass & fed into the gasifiers. The proposed project will employ a Fixed-bed downdraft gasifier as the preferred technology with a dry cleaning system because it reduces the risk of environmental impact as can result from the wet scrubber discharge.

5 KWENDIN BIOMASS ELECTRICITY PROJECT – PROJECT DESIGN

5.1 PROJECT DESCRIPTION

The Kwendin Biomass Electricity Project (KBEP) will be designed with an installed capacity of 60 kW as the pilot biomass power project to be established in Nimba County under the auspices of LESSP. The Project will use rubber wood chips as fuel. The Project is to be located in Kwendin which is located 11 km away from Tappita in Nimba County. The feedstock for the Project is available in abundance in and around Kwendin as observed during the initial survey carried out by the LESSP staff. The Project will establish an electricity generation plant using gasification technology and an electricity distribution system providing electricity to village residents. The Project will serve as a pilot plant demonstrating the use of rubber wood chips as fuel for electricity generation and the viability of establishing such a system in rural Liberia.

5.2 PROJECT PLANT AND MACHINERY

KBEP will employ gasification technology for the generation of electricity. The conventional gasification plants will consist of fuel handling systems, gasification plants, gas cleaning systems and internal combustion engines coupled with generators. Additionally, there will be provision for cleaning producer gas by water scrubbing, accompanied by water treatment facility. These plants operate as one single unit thereby limiting the operational flexibility regardless of the system demand. Such gasifiers are available from 10 kW upwards and will be manufactured as against receiving confirmed orders from customers. There are various manufacturers of gasifiers offering gasifiers from 10 kW upwards, suitable for different fuel types and different applications. One of the components of gasifier is syngas cleaning unit consisting of a water scrubber to clean syngas before syngas entering into engine/generator. This is called wet scrubbing. These conventional gasification plants need highly trained technicians to operate and maintain plants.

There are also compact small gasifiers for small scale applications. They are available with dry scrubbing system with gasifier/engine/generator supplied on a common base as a single module. These gasifiers are fully automated systems, capable of converting woody biomass into electricity in one single compact unit. The entire operation is controlled by an electronic panel. These compact gasifiers are available from 10 kW to 20 kW range and can be operated as individual units independent of one another. The required capacity for the power system could be obtained by adding units in a modular manner. Most importantly, these gasifiers are available as standard units, and therefore, they could be procured with very little lead time. These plants also need trained operators but not as skilled as operators required for conventional gasification plants. However, the disadvantage of these small modular plants is that the generators need to be synchronized before feeding electricity into the main distribution line. Synchronization panels are expensive and they need highly trained technicians. In spite of this drawback these compact units are easy to operate because they come with an electronic Gasifier Control Unit which senses and controls the gasification process by interacting with biomass supply train, gasifier and engine. For rural electrification projects, such flexibility offers greater operation freedom because these units are easy to operate and maintain as individual units. Moreover the power system could be augmented by adding additional units in a modular manner. Since these compact gasifiers are capable of being operated as individual units these are best suited for rural settings. The proposed Kwendin Project envisages using three units of 20 kW gasifiers for a total maximum output of 60 kW. Any increase in demand for electricity could be met with installing additional units.

5.3 GENERATOR CONTROL AND SAFETY SYSTEMS

The generators will be connected to the distribution system through some safety equipment to ensure the isolation of the faults of the distribution system from the generators. Depending on the selection of gasifier/engine, the distribution system will have to be designed. If the gasifier comes with one single engine/generator the electricity distribution system will be designed with one main distribution line capable of transmitting the entire load of 60 kW to consumers. The main line will have feeder lines connecting the consumers to the distribution system. Alternatively, if the gasifier system consists of a multiple units of smaller size generators, then the generator terminals will need to be connected to the distribution line through a synchronization panel. One of the disadvantageous of powerhouses with synchronization panels is that operation of such systems requires a high level of competency on the part of powerhouse technicians/operators. The industry experience suggests that small rural power systems should not have very complicated power systems. It is therefore recommended that the distribution system should avoid power synchronization and the distribution system will be designed with dedicated main lines connecting the each individual generator to a cluster of consumers. Such a distribution system will consist of a number of dedicated main lines and the equal number of consumer clusters.

Regardless of the design of the distribution system, the utility standards provide guidelines on the requirements for safety of switch gear. These will include, as a minimum, a design to ensure that:

1. Faults external to the power plant do not result in a damage to the generator;
2. Any line faults are isolated to the particular phase;
3. The power system will trip at low voltage and high voltage;
4. There will be protection for phase failures;
5. There will be relays for reverse power prevention.

LESSP will employ a competent electrical engineer to design the distribution system that will meet all safety and system protection standards as per international standards. Particular attention will be given to ensure that any faults developed externally do not adversely affect the generation system. The standard protection systems using MCCBs, Lightening Protection etc. provide this type of protection. The individual distribution lines at cluster levels include devices to ensure that generators will not trip due to faults at these levels.

5.4 PROJECT SITE

The Project is to be constructed in Kwendin, located 11 km away from Tappita along the Tappita - Buchanan main road. Tappita is in Nimba County and is approximately 400 km from Monrovia. The

Project site has been selected in consideration of the proximity to source of biomass material and the potential load centers for usage of electricity. The Kwendin community has agreed to provide the land for siting the powerhouse and the extent of the land is about 1.0 hectare which is more than adequate for the Project. The land is currently under no vegetation. The land is high ground with firm sandy clayey soil. The intensity of loading on the foundation by the generators will be well within the bearing capacity of the soil without any need for additional improvements. The pressure transmitted to the soil is not expected to exceed 1 Ton/m^2.

However, some simple geotechnical investigations will be carried out as per the specifications of the plant manufacturer's detailed layout plans and the foundation specifications will be designed once the plant manufacturer will have been selected. The GPS coordinates of identified land are N6^0 27' and W8^0 52'. The Project site is located close to the main Tappita – Buchanan road which is being widened and compacted now. However, there are 5 culverts in very bad conditions and the Kwendin community leaders assured LESSP that the 5 culverts will get repaired or strengthened before the construction works begin. There is no water source nearby and any water requirement for the Project will be obtained from a deep well which will be constructed within the Project site. The Project site is on high ground and it is not subject to flooding. The land is generally flat requiring no major land preparation for the construction of the power plant. The power plant site is not close to any dwelling houses or other institutions such as churches or schools. The nearest dwelling is 77 meters away.

5.5 BUILDING AND CIVIL WORKS

The total area of the building requirement is about 210 m^2 to house the gasifier and engines/generators. The building proposed has overall dimensions of 10 m x 21 m x 4 m high. The construction of this building will be of reinforced cement concrete with structural steel trusses and galvanized corrugated roof sheeting. The provision will be made for office space accommodation for the operators and other staff as well as for a spare parts store and maintenance shop.

Fuel processing and storage building is required to be constructed close by to ensure that an uninterrupted supply of fuel would be made available to the gasifier. The actual size of the storage will be determined by the supply arrangements. However, two week's supply of wood after chipping will be stored indoors. This is estimated to be about 30 tons (when the plant will be working at full capacity for 24 hours) requiring a building with a floor area of approximately 18m^2 with a storage height of approximately 2 meters. A larger outdoor storage will be provided for the wood logs awaiting chipping.

5.6 OPERATION & MAINTENANCE OF POWER PLANT

The operation and maintenance (O&M) is an important function of any power plant. This is more so for biomass gasification plants. Currently, there are no biomass power generation projects in Liberia and there are no competent persons in Liberia with experience in operating gasification plants. The proposed project is structured as a community owned project, to be located in rural Liberia and it would be very hard for the community to carry out O&M functions of a gasification power project without having experienced operators. In order to make the KBEP and also any future biomass projects in Liberia sustainable, KBEP should address technology transfer in an unequivocal manner. In this context, the gasification plant supplier will be required to erect and commission the plant and operate the plant for a period of at least 3 months along with the staff who would be recruited to be employed in the Project by the community. The selection of the gasifier supplier will be made both on the quality and price competitiveness of the plant and the viability of the proposed technology transfer arrangement.

During the first year of the plant operation it would not be realistic to expect the plant to operate more than 5 – 6 hours per day. As consumers get used to consume electricity it is expected that consumers would like to have electricity for a longer period. Also, the availability of electricity in Kwendin will make residents get into commercial/business activities. All these activities will result in the plant operating for a longer period of time both during the day and the night. It is expected that the plant would operate 5 hours per day in Year 1 and it would operate 12 hours per day and 18 hours per day in Year 2 and Year 3 respectively.

The supplier of the gasification plant will be required to provide the following services as part of supplying the gasification plant in three Phases:

(a) Phase (1) – The gasifier supplier would be required to supervise setting up equipment and the biomass supply chain and commissioning;
(b) Phase (2) – The supplier would be required to operate the plant for first 3 months and train community staff to operate and maintain the plant;
(c) Phase (3) – The supplier would be required to provide limited supervision/technical advice over 9 months after the plant commissioning.

LESSP will assist the Community to recruit persons with some technical background and these recruited persons will be required to work along with the gasification plant supplier. The staff requirement is described below in section 5.8.

5.7 UTILITY REQUIREMENTS

There are no specific utility requirements for the compact type of gasifiers. However, for other types of gasifiers there are some utility requirements such as:

- a back-up diesel fuelled power generator for the startup operations since no gird power is available to the Project site;
- water for the open loop syngas cleaning/cooling system, first fill of water for the closed loop engine cooling system; and
- a source of compressed air to operate their control systems (if required by the plant design) or to carry out cleaning purposes.

The syngas cleaning/cooling water is usually re-circulated through a cooling pond with a make-up to balance the evaporative loss plus a blow-down needed to control the concentration of impurities removed from the syngas by the washing process. The proposed Project would seek to employ compact modular type gasification plants with dry scrubbing system, no further evaluation of utility requirements will be carried out in this feasibility study.

The gasifier requires wood chips to be pre-processed to a specified size and also dried to the required moisture content. Simple electricity driven wood chipper would be employed for converting rubber tree logs into wood chips. Rubber wood chips contain moisture about 50-55% by weight as felled and chips need to be dried up to about less than 20% moisture before feeding into the gasifier. This will be achieved by sun drying of wood chips. The plant operators will be required to check the moisture content of wood chips daily as part of daily checks. Unless moisture meters are part of the gasification tool kit, such meters would be procured. Storage space for the chipped wood will be constructed. As there is no water stream closer to the project site, the water requirement will be obtained from a deep well and water pumping and overhead storage system. Gasification plants with dry scrubbing systems do not need water for plant operation. However, a water source is required for safety reasons and for the use of the project staff.

5.8 MANPOWER REQUIREMENT

The project will be operational 5 hours per day in Year 1, and thereafter, it is expected that the number of hours in operation will be increased to 12 and 18 hours per day in Year 2 and Year 3. The manpower requirement will be as follows:

Table 6 - Kwendin Biomass Electricity Project - Manpower Requirement

Manpower Requirement			
Type	Year 1	Year 2	Year 3
Plant Manager	1	1	1
Gasifier Operator	1	2	3
Maintenance Technician	1	2	2
Unskilled Labor	2	4	6
Electrician	1	1	1
Clerk/Book Keeper	1	1	1
Driver	1	1	1
Total	8	12	15

5.9 ELECTRICTY DISTRIBUTION SYSTEM

Kwendin village never had grid electricity and there are a few households equipped with diesel or gasoline run generators. According to the survey data, these households spend between L$ 350 – L$ 860 (US$ 4.80 – US$ 11.78) Sper week for fuel. The LESSP Team carried out a survey in Kwendin with a view to assessing the demand for electricity and consumers' ability and willingness to pay for electricity. That survey data were used as the basis for designing the electricity transmission system for the proposed project. Each household in Kwendin was identified with a reference number and the GPS coordinates of the house were recorded in a GPS meter. Such data were used to prepare the map of the electricity distribution system. The demand for electricity will increase as consumers get used to having electricity and using electrical appliances. For a foreseeable future, the demand from the domestic segment will determine the system limitations. It is expected that the availability of electricity in Kwendin will act as a catalyst for business entities to establish their operations and they will create a demand for electricity during the day time while the domestic consumers will have more demand for electricity during the late evening and early night.

Since the maximum length of the longest spur will be less than 2 km, the power will be distributed as Low Voltage (LV) distribution system. Thus, there are two options for the construction of the distribution system. The two options available are:

- Power distribution via overhead cables along the street using the treated wooden poles/steel tubular poles and exposed or insulated conductors.

- Power distribution via underground cables protected with armor sheathing against possible accidental physical damage.

The first option is the standard mode of construction of distribution lines which would be useful in the event the town is expected to receive central grid connections in the future. The distribution system would be constructed as per the standards adopted by LEC. It is recommended that insulated cabling be used for the distribution system for reasons of safety as well as to avoid possible illegal tapping of the lines for electricity. For the present evaluation, this option is selected. The second option, via underground cables, which can provide additional protection against illegal tapping is likely to cost more, and therefore, may not be affordable within the available funding for the project.

The cables are to be selected conservatively to ensure acceptable voltage drop over the longest spur of the distribution system. The LEC has confirmed that the standard distribution voltage of the LEC system is 400 V phase to phase and 230 V single phase. The project may generate electricity at 400 volt three phase and distribute it at 230 volt single phase so that this system could be connected to any LEC grid system at a later stage. This will permit maintenance of the voltage at the furthest consumer point as close as the LEC system would permit after accounting for the line voltage drops. In addition, provision will be made for several street lights for the town. A detailed power distribution system including standards and specifications will be prepared at the bidding stage.

The proposed project is designed as a 60 kW power system. Such a power system could be established with one single unit of power source or with multiple units of smaller sources. Both systems have their advantages and disadvantages in terms of cost, lead time and operational convenience. However, power generation from one single machine will require designing the transmission system with one major trunk line with a larger conductor size. Power generation from multiple units can use the same distribution system design provided the units are synchronized. The past experience of mini grid designs shows that rural mini grid systems should avoid synchronization because of its operational complexity.

The alternative is to design the distribution system with dedicated distribution lines connected to each identified power source. The Kwendin Project is designed for employing three units of 20 kW compact gasifiers. Thus, the Kwendin distribution system will be designed with three dedicated main lines, connected to each gasifier/engine, providing electricity to three clusters of households. In order to keep the power generation system very simple, it is proposed not to synchronize the three generators. Components such as synchronization panels are not only expensive but they will require higher levels of skills to manage. They are also likely to give problems of nuisance tripping with a small and variable load that usually takes place. It is therefore necessary to carefully manage the loading of the three generators at all times, with each generator being identified with a particular load center. Manual change over among the three generators can be provided to enable transfer of loads among the

generators as needed. The three clusters of households for the proposed Kwendin Biomass Electricity Project are shown below.

Table 7 - Kwendin Load Centers

Load Center	No of Households	Peak Demand (kW)
Cluster 1	87	15.4
Cluster 2	81	14.2
Cluster 3	80	18.4
Total	248[10]	48.0

The three phases of the each generator have to be kept balanced within acceptable levels to ensure the stability of the system. This is primarily done by balancing the loads connected to each of the phases. As such the number of rungs for each village will be determined once the detailed design will have been prepared.

In addition, the project may provide for battery charging facilities at the power plant itself as a load balancing mechanism which will be under the control of the plant operator. The financial analysis will be prepared on the basis of electricity consumption by residential consumers. Thus, the project should consider attracting businesses to create an increasing daytime demand for electricity which will increase the Plant Load Factor.

[10] This is the number of households without 7 institutions such as the school, Church etc. For planning purposes potential demand from these entities were ignored.

Table 8 - Basic Design Parameters - Power Distribution System

Description		Cluster 1	Cluster 2	Cluster 3
Generation Voltage 3 Phase	Volts	400	400	400
Total Number of Consumers	Nos	87	81	80
Estimated Peak Demand	kW	15.3	13.9	18.4
Distance to the Powerhouse from the furthest point	km	0.51	0.88	0.85
Total Load Current	Amp	27.61	25.08	33.20
Maximum Voltage Drop	%	4	4	4
Ideal Minimum Voltage at the End of Line	Volt	384	384	384
Required Conductors – ABC Conductors Main Lines		3x35 mm^2 1x16 mm^2	3x50 mm^2 1x16 mm^2	3x50 mm^2 1x16 mm^2
Approximate Cable Length	km	0.75	1.2	0.9
Extensions				
Service Connection Copper wire 2.5mm^2	km	4.1	2.3	2.0
Projected Voltage Drop	Volts	12.5	15.45	19.86
Projected Minimum Voltage at the End of the Line	Volts	387.5	384.55	380.14

6 FINANCIAL FEASIBILITY

6.1 FUNDAMENTAL CONSIDERATIONS

This section analyses financial feasibility of the proposed biomass power project, to be established in Kwendin. The financial feasibility of the Project has been prepared in a conservative manner. The major cost of operation of the Kwendin Biomass Electricity Project would be the O&M cost. In the absence of any grid electricity in the proposed Project's geographical location, the financial feasibility is evaluated on the basis of the total investment cost of the mini power system that includes generation of electric power, transmission of electricity to load centers and distribution of electricity to consumers and also the commercial operating cost which is mostly the O&M cost.

Gasification technology is widely used in rural settings of Asian countries using agricultural waste as fuel. Biomass gasification plants are being operated in rural settings of these countries without technical and financial constraints because finding O&M capabilities in rural parts of these countries is not difficult.

However, the experience of Liberia would be different because the technology is very new to the country. In this context, LESSP is of the view that there should be adequate donor assistance to this sector during the initial years of introduction of the technology. Such upfront investment support by the donor community would be beneficial to Liberia in the long run because of the abundant availability of biomass resources in the country and the country's ever-increasing needs for electricity. In this context, the proposed Kwendin Biomass Electricity Project should be evaluated in its ability to recover, at a minimum, the O&M cost through tariffs from consumers. Considering the rural location of the Project, it may very well require an operating subsidy in the first year of operation because the demand for electricity from the community may not exceed five hours a day in year 1.

6.2 INITIAL TARIFF

LEC is currently responsible for providing grid electricity to some consumers in Monrovia. After the war, when LEC recommenced its business all new generation and transmission assets have been procured with donor funding. The business model of LEC is to recover the total O&M cost by way of consumer tariffs. LEC currently charges a flat tariff of US$0.56 per kWh inclusive of fuel adjustment charge (July 2012) from its consumers. For those who do not have access to grid electricity, the only alternative is to have individual diesel generators or to obtain power from private electricity suppliers, if such private suppliers operate in their respective areas. Private electricity suppliers sell electricity on a monthly fixed fee as described in section 3.2. The equivalent unit rate of such private suppliers is the range of US$0.55 – US$0.61 per kWh, and could become more if the diesel prices increase. Even though the proposed Project is expected to be funded through donor assistance, the tariff has to be established to ensure that the revenue would be sufficient, at a minimum, to recover the O&M cost. It is also important that the proposed tariff should be within the ability and willingness of consumers. In this context, the financial evaluations were carried out assuming an initial at US$ 0.40 per kWh, which is assumed to be within the capacity of the majority of community residents. In the absence of any community owned/managed power system in operation, it would be a real challenge to define a reasonable electricity tariff to rural populations. However, the financial model, shown in Annex 4, will be used to ascertain the effect of different tariffs on the financial viability of the proposed project under changing scenarios, mostly the Plant Load Factor (PLF). Undoubtedly, the PLF will have a solitary effect on the cost of generation and the viability of the power system at any given tariff level.

6.3 ASSUMPTIONS FOR FINANCIAL EVALUATION

6.3.1 Capital Cost

The land required for the Project is to be obtained from the Kwendin Community as the contribution of the Community to the Project. The installed capacity of the plant will be 60 kW. The total project cost for a 60 kW powerhouse inclusive of the distribution system and providing connections to 248 consumers is estimated to be US$ 487,300 as computed below:

Table 9 - Estimated Project Cost

Estimated Project Cost	US$	Remarks
Project Land Preparatory Cost	2,000	Land – Community Grant
Civil Construction Cost	28,000	LESSP RE Estimate
Total Civil Cost	**30,000**	
Gasification Plant CIF Cost	120,000	Industry data
Spares for two years of operation	7,500	Industry Data
Auxiliary Equipment:		
Wood chipper CIF Monrovia	10,000	Indicative offer from India
Weighting Platform 1 Ton Capacity	2,000	Indicative Local price
Tools and Ancillary Equipment	2,500	Indicative local price
Local Transport & Handling	5,000	Indicative local price
Local Insurance	1,000	Indicative service cost
Installation and Commissioning	15,000	Cost of an expatriate engineer
Total Plant Cost	**163,000**	
Project vehicle	40,000	4x4 Pickup
Office equipment and other ancillary	4,500	Office furniture, safety equip.
Subtotal	**44,500**	
Electricity Distribution Cost		
Smart Meters	30,000	LESSP Estimates
Distribution Network	170,000	LESSP Elect. Engineer estimate
Subtotal	**200,000**	
Working Capital	6,000	
Contingency 10%	43,800	
Total Project Cost	**487,300**	

LESSP sought the appetite of the Liberian private sector to invest in rural biomass based power systems in Liberia with partial funding support from LESSP by way of local press advertisements and direct solicitations with the Liberian Chamber of Commerce. The feedback was that the local private sector believes that rural electricity systems would be too risky an investment for the private sector in terms of being able to collect tariff from consumers. Even two leading commercial banks in Liberia, who are members of the USAID's DCA scheme, are of the view that such infrastructure projects are not within the purview of banks because of perceived risks. In the absence of any biomass power generation projects operating in Liberia, the sentiments of the private sector appear to be within the normal business prudence. In this context, LESSP proposes that the proposed project may be implemented as a fully donor financed project.

6.3.2 Operating Cost

The major cost of a biomass based power project is the cost of Operation and Maintenance (O&M). Unlike other renewable energy projects such as solar and wind power, biomass projects need to incur a substantial O&M cost which consists of the cost of biomass materials, the wages of operating staff and the maintenance cost. In the O&M cost structure, the cost of biomass is not a significant cost. The project will be proposing to pay US$10 per metric ton of green rubber tree branches/trunks delivered to the project site. The consumption of biomass in gasification plants is around 1.2 kg of dried biomass with 20% moisture content for 1 kWh of energy. Assuming green biomass is having a moisture content of 50%, the estimated biomass cost component of the electricity cost is US$0.0192 per kWh[11] which is 5.3% of the diesel oil fuel cost for diesel generated electricity[12].

The annual operating cost and also the annual revenue have been computed on the basis of the annual operating hours of the plant. Based on the demand profile of the Kwendin residents, the power plant will operate 5 hours per day in the initial year of operation. It is expected that the power plant would operate 12 hours and 18 hours daily in Year 2 and Year 3 respectively. The manpower requirement for the generation plant and for the project is shown below. The proposed wages and salaries are the prevailing market rates for comparable positions and will be subject to an annual increase of 2%.

[11] Please see the Financial Model for computation

[12] Assuming the diesel price of US$4.56 per gallon the diesel cost of one unit of electricity is US$0.36 per kWh. (Based on a 20 kW diesel generator running on full capacity. Source: www.dieselserviceandsupply.com.)

Table 10 - Manpower Requirement

Type of Manpower for Generation	Year 1		Year 2		Year 3	
	No	Monthly Salary $	Nos	Monthly Salary	Nos	Monthly Salary
Gasifier Operator	1	400	2	816	3	1,248
Maintenance Technician	1	400	2	816	2	816
Unskilled Labor	2	300	4	612	6	936
Subtotal for the Generation		1,100		2,244		3,000

The other cost component of the O&M cost structure is the consumable for maintenance. This cost will also be increased from Year 1 onwards in keeping with the increasing operating hours. The consumable cost mainly consists of engine oil and oil filters that will be changed/replaced every 200 hours of operation. The other replacement components include spark plugs, air cleaner elements, fuel filters, fuel hoses, radiator hoses and clamp bands. The requirement of these spares for two years of operation will be procured along with the generation plant given the remoteness of the project location. Such costs will be capitalized along with the cost of the plant.

6.3.3 Administration Cost

The Project will be managed by a full time Plant Manager who will be responsible for the overall management of the project from procuring biomass materials to revenue collection and maintaining books of the Project. The electrician will be required to ensure maintenance of the electrical distribution system and tariff collection. The other major administration cost is the vehicle operating and maintenance cost. All these costs have been accounted for the computation of financial evaluations.

Table 11 - Proposed Wages and Salary Structure

Type of Manpower for Project Administration	Year 1		Year 2		Year 3	
	No	Monthly Salary $	Nos	Monthly Salary	Nos	Monthly Salary
Plant Manager	1	500	1	510	1	520
Electrician	1	400	1	408	1	416
Clerk/Book Keeper	1	300	1	306	1	312
Driver	1	300	1	306	1	312
Subtotal for Project Administration		1,500		1,530		1,560

6.4 FINANCIAL INDICATORS

Although biomass electricity projects are a viable option for power generation in rural areas without any public subsidies, as proved in many Asian countries, the specific situation in Liberia requires some kind of donor assistance in the initial years to make biomass power projects to happen. Liberia currently does not have technical capabilities required for establishing and operating biomass electricity projects. The costs of engineering services in Liberia are also extremely expensive. Lack of such local technical capabilities and the extremely expensive service costs will render biomass projects expensive to be established, and thereafter to be operated, without significant subsidies. The proposed Kwendin Biomass Electricity Project needs to be evaluated in light of these factors.

The financial evaluation shown in Appendix indicates that the proposed biomass project can be operated in a commercially viable manner at the initial tariff level of US$0.40/kWh. Even at this tariff level, the project makes an operating loss of US$ 29,192 and a cash loss of US$ 3,992 in Year 1. Accordingly, the project needs to be granted a cash subsidy of US$ 3,992 in Year 1. However, in year 2 the project will earn an operating profit US$ 870 and cash earnings of US$25,200. The profitability of the Project in subsequent years will improve steadily. The reason for the poor cash flow in year 1 is because the Project would operate only for 5 hours a day. This is a very conservative estimate and if the demand for electricity would require the project to operate 6 hours per day in Year 1, the project would still make an operating loss of US$22,521 but a positive cash balance of US$ 2,679 in Year 1. Thus, there would not be any subsidy requirement from LESSP/USAID for Year 1 operation. This demonstrates the importance of the daily operation hours for the commercial viability of the Project. If the Project were to be established in a commercial town, the Project may have been viable from Year 1 onwards, even at a slightly lesser tariff level than currently envisaged in this Project, because of the demand for electricity from commercial consumers.

The Internal Rate of Return (IRR) of the proposed Project was evaluated under two sets of investment scenarios: investment cost for the entire power system (generation, distribution and consumer connection) and the investment cost only for the power generation system (similar to an IPP situation). These evaluations were carried out under different tariff schemes. The results are shown below:

Table 12 – Effect of Initial Electricity Tariff to Internal Rate of Return

INTERNAL RATE OF RETURN (IRR) Hours of Daily Operation: Year 1 – 5 hrs. Year 2 – 12 hrs. Year 3 – 18 hrs.					
Investment Scenario	Initial Tariff US$/kWh				
	0.30	0.35	0.40	0.42	0.45
IRR - Investment in the entire power system including the generation, distribution and consumer connection. (US$ 487,300)	-6,893%	-0.133%	4.635%	6.265%	8.514%
IRR - Investment in only the power generation assets. (US$ 163,000)	5.06%	14.77%	22.26%	24.95%	28.76%
Cash Subsidy Requirement in Year 1	$12,752	$8,372	$3,992	$2,240	None

It is seen from the above table that the Project would make a positive IRR even for the entire investment including the distribution and consumer connection, at the initial tariff of US$0.40 per kWh. However, the Project may still need a cash subsidy of US$3,992 in Year 1. However, if the initial tariff is set at US$0.45 per kWh, the Project IRR would increase to healthy 8.514% and 28.76% for the two investment scenarios respectively while the Project would make a positive cash balance not requiring any subsidy for operating cost.

The financial performance was also evaluated under the increased operating hours in Year 1 from 5 hours per day to 6 hours per day. The results are shown below:

Table 13 - Effect of Increased Daily Operating Hours in Year 1 on IRR

INTERNAL RATE OF RETURN (IRR) Hours of Daily Operation: Year 1 – 6 hrs. Year 2 – 12 hrs. Year 3 – 18 hrs.					
Investment Scenario	Initial Tariff US$/kWh				
	0.30	0.35	0.40	0.42	0.45
IRR - Investment in the entire power system including the generation, distribution and consumer connection. (US$ 487,300)	-6.79%	0.003%	4.806%	6.450%	8.722%
IRR - Investment in only the power generation assets. (US$ 163,000)	5.42%	15.28%	22.95%	25.71%	29.63%
Cash Subsidy Requirement in Year 1	$7,833	$2,577	None	None	None

Thus it is seen from the above evaluation that the performance of the Project would be significantly improved if the operating period in Year 1 is increased from 5 hours to 6 hours per day. At this level of operation, the Project would require an operating subsidy only in Year 1, provided the initial tariff is set below US$0.40 per kWh. Under the initial tariff of US$0.35 per kWh the Project would breakeven if it would operate 6 hours per day. Under all these scenarios the Project would recover the O&M costs by way of tariff. Thus, the proposed Kwendin Biomass Electricity Project would be a viable candidate project to be funded under LESSP. The initial tariff may set at US$0.30 –US$0.40 per kWh by providing appropriate cash subsidy only in the initial year of operation.

7 BUSINESS PLAN

The main purpose of the Kwendin Biomass Electricity Project is to establish the commercial viability of running a biomass power system in a rural area of Liberia. As stated in section 6.3.1, the private sector in Liberia is not yet ready for investing in biomass based power projects especially in rural Liberia. The technology is new and the private sector perceives the revenue collection risk as a risk that the private sector would not be able to take. In the current context of Liberia, it will be very unlikely that a private entity will take an investment risk for such a project. Therefore the proposed Project will be funded as a fully donor funded project and LESSP will construct the Project by utilizing USAID funding allocated to LESSP. As the Project will be fully funded by USAID, it will have to be operated as a community owned and managed project. The LESSP team has had a number of meetings with the Kwendin community with the participation of the District Commissioner, the Clan Chief and town elders describing about potential for a biomass power project in Kwendin. The community was very pleased about the prospects of getting electricity and also about the opportunities for selling old rubber trees to the Project. As the community's commitment towards the Project, the community has agreed to donate a land to the extent of 0.75 hectares for siting the power plant. LESSP will be working very closely with the local community in formalizing a Cooperative that would operate and manage the power plant for commercial operation. LESSP has developed the following Business Plan as the framework for the Cooperative's management of this Project. The proposed business plant will be robust enough to ensure the long term financial and operational viability of the Project once the donor assistance will be no longer available.

a. LESSP will help the Kwendin Community to establish a Cooperative to manage and operate the plant with adequate autonomy and legal authority to carry out the business operations, including charging tariff for electricity and collecting revenues from the sale of electricity.
b. LESSP, subject to receiving required approvals, will construct the power plant and the distribution system.

c. The Cooperative in consultation with LESSP will appoint key staff to operate the power plant. LESSP will provide training to the selected employees.
d. The operators selected for the operation of the plant will be available at the time of installation so that the equipment supplier can provide training to them.
e. The consumer tariff will be determined on the basis of maintaining a positive cash flow that would be sufficient to meet the operational costs (fuel costs and operation and maintenance costs). This is necessary to attract adequate number of consumers to sustain the Project in the initial stages.
f. The Project will establish biomass supply chains with the participation of village farmers. The farmers will be assisted in formal establishment of such supply chains with contractual obligations towards the Project.
g. The tariff collection will be on a prepayment basis to ensure revenue to the Project and to reduce the cost of collection.
h. LESSP will explore providing metered connection to households. If there is going to be a delay in procuring "smart meters", the consumer connections would be through a devise that would limit the maximum load the house could utilize. The consumers will pay a monthly fixed fee to the Project. The flat monthly fee which depends on the maximum load given to households and the electricity supply duration will be determined by taking into consideration the electricity tariff that the Project would need to collect from consumers. If the electricity tariff is set at US$0.40 per kWh, the equivalent flat fee for a household with 100 watts for five hours of daily electricity supply would be US$6.00 per month.
i. In order to prevent illegal connections the distribution system will be via insulated bundle conductors on wooden or tubular galvanized steel poles.
j. LESSP will assist the Community to manage the Power project in a prudent manner during the life of the LESSP. The tariff will be set to maintain a surplus cash flow to ensure the liquidity of the Power project.
k. In consultation with the Rural and Renewable Energy Agency (RREA), LESSP will determine how the surplus funds, if there will be any, could be utilized for replicating similar plants in other rural areas of Liberia.

8 SOCIAL ASPECTS

8.1 OVERALL BENEFITS TO COMMUNITY

Liberia's grid electricity system currently consists of mainly the LEC managed Monrovia power system. Another small grid electricity system is available in Gbarnga, known as the Bong Electricity System (BES).

BES is owned and managed by the Bong County. BES is facing difficult situations due to lack of finances for procuring diesel fuel and this has resulted in unreliable power supply in Gbarnga. Unfortunately, this unreliable power supply has caused the potential consumers to keep away from the BES provided electricity and to rely on more expensive, self-generation of electricity, causing noise and air pollution. There are also private service providers providing electricity to households on a monthly fixed price which is as expensive as the LEC tariff. Therefore, electricity systems for consumers must be reliable, affordable and sustainable. Biomass based power generation will be a viable alternative to diesel power generation if biomass resources are available in close proximity to generation sites. Although Liberia is blessed with abundance of biomass resources, these resources are not yet utilized in a sustainable manner for power generation.

The proposed project area, Kwendin, has no access to electricity of any kind except few households that operate small diesel/gasoline powered generators for their own use. The lighting in the dwellings is by flashlights, oil lamps and candles as reported by households during the survey carried out by LESSP.

The importance of expanding electricity is well recognized by the government of Liberia and is expressly highlighted in the National Energy Policy (NEP) which has as its policy initiatives as:

a. Leveraging enhanced energy access for improvements in education, health and economic development;
b. Providing access to modern energy fuel and electricity for previously neglected rural areas;
c. Securing the long term financial viability of utilities;
d. Establishing affordable access to energy for poor consumers; and
e. Balancing environmental costs and economic benefits.

This proposed biomass electricity Project addresses all these objectives. However, the sustainability of the Project depends on the short term and long term financial viability of the Project. One of the problems associated with biomass based power generation is the sustainability of biomass supply chain. Once a demand for biomass materials will have been established, the owners of biomass resources will tend to request higher prices for biomass. This problem could be addressed by the Project entity by getting into long term supply arrangement with the rubber smallholders and exploring alternative biomass materials such as bamboo trees. However, the cost of biomass is a small percentage of the overall O&M cost of the Project. The Project entity will be required to fix the electricity tariff in relation to the overall O&M cost and to ensure a reasonable cash surplus for future maintenance/refurbishing of the generation assets.

The current electricity generation cost by the LEC is reported as high as US$0.56 per kWh, whereas the cost of self-generation by independent producers is even higher at US$0.75 per kWh. Using these benchmark tariff levels, the electricity tariff of the Project will be set at a level that would recover the

O&M cost at a minimal and that would be affordable to consumers. Based on the estimated cost of generation, the electricity tariff will have to be set at above US$0.30 per kWh in order that the project could remain financially sustainable. However, if the Project would be able to decrease its O&M cost and the cost of staff, the Project would be viable even at tariff level less than US$0.30 per kWh. This has to be viewed in comparison of the alternate of diesel fueled power generation which is reported to cost as much as US$0.75 per kWh and is likely to be higher in the coming years. On this basis, the proposed initial tariff, between US$0.30 and US$0.40 per kWh, being 40% of the alternative appears attractive to consumers in Kwendin.

However, this also needs to be assessed in the context of ability to pay for electricity by the consumers. The monthly cost to a household consuming 100 watts for 5 hours per day would be between US$ 4.50 (@ tariff level of US$0.30 per kWh) and US$ 6.00 (@tariff level of US$0.40 per kWh). At the prevailing exchange rate, the monthly electricity cost (L$330 to L$440) would be easily affordable to about 50% and moderately affordable to 40% of the households. The projected demand for electricity has been calculated conservatively, assuming limited supply of electricity to households mainly for lighting.

8.2 ECONOMIC BENEFITS TO LOCAL COMMUNITY

The proposed Project would bring in economic benefits to the community in many ways. Given the nature of the requirement of the technical personnel required to operate the power plant, the local residents would get limited employment opportunities. If there will be residents who could assume technical responsibilities with some training such personnel would get the preference. More than employment benefits, the major benefit would be the spinoff effects of the availability of electricity in Kwendin. A reliable and regular electricity supply would be a forceful incentive for business men and business women to commence commercial activities in agribusiness, food processing, communication and entertainment etc. Such economic activities will result in employment generation to the community. The Project also would bring in additional cash flows to rubber smallholders who could sell old trees as biomass materials and use such income for replanting activities. All these economic benefits will be further supplemented by the accompanying increased quality of life for residents.

8.3 COMMUNITY INVOLVEMENT IN PROJECT MANAGEMENT

The community will act as the suppliers of the fuel and as the consumers of the electricity generated, and therefore, the community's main involvement of the Project is to manage the Project in a commercially viable manner. Their positive involvement in the Project is already apparent by the

interests expressed and the contribution by the community by releasing the land for the power plant. It is expected that the community will be further involved by the inclusion of the proposed Cooperative in the project management structure. LESSP will help the community establish the Cooperative and train them in the management of the power system before the Project becomes operational.

9 SUSTAINABILITY EVALUATION

One of the biggest challenges of a community owned and managed electricity project is to prevent institutional failure once the donor involvement is withdrawn and to ensure long-term sustainability of the project. It will be the responsibility of LESSP to introduce adequate measures to ensure the long term sustainability of the Project. First and foremost, the plant must be reliable, easy to operate and will not be subject to breakdowns needing expensive repairs. This fundamental issue will be addressed by LESSP at the time of procurement of plant and machinery. Secondly, the community should be able to operate and maintain the power plant without technical problems. LESSP will ensure that the operators of the power system and technicians will be recruited on merit and provide them with technical training under the auspices of the equipment supplier. LESSP will also address the supply arrangements of consumables/spare parts required for the plant. The terms of the procurement of plant and machinery will include a provision for a competent representative of the equipment supplier to be attached to the Project at least for a three months period. Thirdly, the power system will have to recover, at a minimum, the O&M cost by way of consumer tariffs.

LESSP will provide adequate training to the Cooperative and carry out the handholding support to the Cooperative until they become adequately proficient in carrying out these fundamental tasks to ensure the long term sustainability within the life of the LESSP. In addition to the above stated fundamental requirements, the Cooperative will have to carry out some other tasks as listed below in order to ensure the long term sustainability of the Project.

- Maintain uninterrupted biomass supply chains - The current assessment of the availability of old rubber trees in the project area suggests that adequate supplies of rubber wood chips would be made available to the Project. However, it would be prudent to evaluate other types of biomass availability in the region as a backup measure. It is important that biomass supply chains will be established with various farmer groups while addressing their financial interests to ensure sustainability.
- Ensure revenue collection in a timely manner – The Project would seek to install smart meters that have been proven in rural electric systems in a few other countries to ensure smooth

revenue collection. If such a system will not be feasible in Liberia, the consumer connection would be on the basis of monthly fixed fee with appropriate load limiters.

- Ensure consumer penetration – The viability of the Project will depend on, among other things, achieving higher PLF.
- Practice leadership without malfeasance - Another challenge with the community model is that there is a high risk of social conflicts within the community. Disputes of who has paid for what and who should benefit and at what price should be avoided through sociological, technical and economic approaches including the social shaping of the committees and the rules of leadership.

A strong feature of the community cooperatives is that the owners are also the customers, and therefore they have a strong interest in the service and quality of the output. Furthermore, they are often less bureaucratic than public utilities, can create jobs in the local community, and make tailor-made tariffs for the customers. Downsides with the community cooperative are that they often lack the technical skills to design and run the power systems and the business skills to implement a sustainable business plan. Therefore the community owned business model requires substantial technical assistance. LESSP will ensure such technical assistance during the life of LESSP.

10 ENVIRONMENTAL ASSESSMENT

10.1 OVERVIEW

The proposed biomass power project is being funded by USAID under the LESSP and as such this project activity would be commenced only after obtaining both the USAID Environmental Clearance under Regulation 216 and the approval of the Environmental Protection Agency (EPA) of Liberia (which is currently being sought). The project activities, both during the construction and the commercial operation, would adhere to and comply with all environmental guidelines of USAID and EPA of Liberia. The project will particularly adhere to local environmental laws and follow the Environmental Guidelines for Small-Scale Activities in Africa, available at: http://www.encapafrica.org/egssaa.htm, as well as USAID environmental procedures. Furthermore, the biomass sources and systems will be examined to ensure they have sustainable development outcomes.

10.2 DIRECT ENVIRONMENTAL BENEFITS

The construction and operation of the Biomass Power System may cause the following environmental impacts and this section discusses the impacts in more detail along with necessary mitigating measures that would be implemented:

1. Impacts from land clearance and preparation
2. Impacts on water availability
3. Impacts from construction materials and waste
4. Impacts from operation and maintenance waste
5. Greenhouse gas emissions
6. Air pollution
7. Increased vehicle traffic
8. Noise from construction and operation of the plant
9. Damage to aesthetics of the area
10. Impacts along the biomass supply chain

10.3 CONSTRUCTION STAGE

10.3.1 Impact from Land Clearance and Preparation

The site will be about 0.75 hectares. The site has a small slope and so to prepare the land there will be slight leveling activities and some bush clearing (it is not currently vegetated).There are no water bodies in the vicinity so this activity does not pose a risk to surface water and the nearest house is 77m from the site so will not impact homes. The land is currently barren and not use for any community activities. The transmission lines will run about 1.5 km but will be situated along the existing road and so no additional land clearance is needed.

Based on examining satellite images of the proposed project site and nearby environmentally-sensitive areas, the only potentially sensitive areas nearby the project site are Gibi and Gio National Forests. Due to the contained nature of the project it is not expected that this project will impact these national forests, however, this will be examined closer during initial environmental reviews of the project in the coming months.

10.3.2 Impacts from Construction Materials and Waste

Some materials required for construction of the small generator house will be stored on site for a short time before their use, although it is a small amount of materials compared to other construction activities. These will be properly covered to ensure no infiltration into groundwater, so no impact is expected.

10.3.3 Damage to the Aesthetics of the Area

The visual impacts of the plant will be minimal as the project site is less than one hectare. Should more significant aesthetic damage become apparent during construction, the visual impact can be mitigated to some extent by the planting of trees surrounding the power plant area with trees and shrubs, targeted towards both enhancing the aesthetic appeal and also to act as a sound barrier.

10.4 OPERATION STAGE

10.4.1 Impacts from Water Consumption

The only water use will be for drinking purposes and this will be sourced from a deep well constructed at the Project site. The quantities used will be minimal and will not affect water tables.

10.4.2 Impacts from Operation and Maintenance Waste

The selected gasifier technology produces a very small amount of waste compared to other gasifiers. The ash produced (~1kg per 50 hours of operation of a 10kW system) can be used in the system's filters and the other half can be placed on agricultural soils to improve their quality and will not have a negative environmental impact. Prior to distribution, if the ash, and if any other system waste or fuels are stored on site for any amount of time, it will be done so in a contained way such that they cannot runoff or permeate the soil. There is also the possibility of gas leakage during maintenance, so proper maintenance and monitoring measures will be practiced to ensure this does not occur.

10.4.3 Greenhouse Gas Emissions

Although it is often asserted that bioenergy is a carbon-neutral energy source because the greenhouse gases emitted during use are equal to those absorbed during growth, it is now also recognized that there are additional sources of emissions that must be taken into account throughout the bioenergy lifecycle. For rubber wood biomass, these include emissions from land use change, emissions from the fertilizer and other agriculture inputs, and emissions associated with the transportation of the feedstock. The project will not create any increased emissions due to these sources as it uses rubber trees that are already produced and scheduled to be cut down in absence of the project. Furthermore, at Kwendin, the rubber wood production is low emissions as there is no fertilizer use and the trees are within a few kilometers to the energy generation site so the transportation is minimal, especially compared to the distance that the diesel alternatives are transported.

In order for the assertion that the greenhouse gases emitted when consuming the biomass are equal to the emissions absorbed in growth to hold true, it is necessary to ensure continual renewal of the feedstock source. In this case, the trees are scheduled to be cut down with the explicit purpose of replanting them for continued rubber production.

10.4.4 Air Pollution

There will be gaseous emissions associated with the biomass combustion. The exact emissions depend on the system used, and regular maintenance to avoid leaks. The exhaust emissions will consist of CO, NOx, and particulates, which may require treatment to keep within an acceptable limit before discharge. Other sources of air pollution include dust generated from transportation of the feedstock and construction materials, but as discussed in the next section, this is minimal.

10.4.5 Increased Vehicle Traffic

The movement of trucks delivering the fuel wood for the power plant could increase the number of vehicles in the area, which can technically impact air quality and noise. However, the wood requirement of the plant is very small and coming from short distances such that there is not expected to be a noticeable increase in vehicle traffic. In the construction phase it is expected vehicle traffic may increase by one vehicle loads per week.

10.4.6 Noise from Plant Operation

During operation, there will be noise from the wood chipper and from the system itself. The noise from the operation of the generator engine is around 60dB at a distance of two meters. This is to be mitigated by the enclosing of this equipment in covered spaces and further, if needed, by the construction of noise barriers. In addition, the capacity of the wood chipper should be over sized to minimize the number of hours of operation.

10.4.7 Impacts along the Biomass Supply Chain

Although outside of the project boundary, rubber wood production may also have environmental impacts in the feedstock growth stage and collection stages. Some of the most significant environmental impacts of bioenergy can come from the conversion of land in order to produce bioenergy feedstock. Unrestrained land use changes may result in emissions of greenhouse gases, depending on the carbon stocks of the lands converted, biodiversity and other ecosystem services losses, and erosion and flooding.

The targeted source of fuel wood for the operation of the plant is from rubber trees uprooted for replanting. The rubber wood will be sourced from rubber smallholder plantations in and around

Kwendin who collectively own 877ha. The smallholders will bring the rubber wood to the plant site by small trucks or hand carrying. The trees that will be cut are old and no longer producing rubber so they are scheduled to be cut and replanted. If they could not sell the wood to this project, it would likely be used for cooking fuel. Nearly half of the area needs to be uprooted immediately, which is estimated at 152,000 trees or approximately 45.6 million kg of dry rubber wood. The project requirement in the year 1 will be around 135,000 kg and could increase to up to 400,000 kg/year. On this basis, the available rubber trees would be sufficient for a period of about 58 years if the plant were to run 24 hours a day at full capacity of 60 kW. Since there is more than enough rubber wood than needed based on the plantations replanting plans, no additional tree cutting or planting will be driven by this project.

Other environmental impacts from the biomass supply chain can be associated with agriculture management practices, such as the use of fertilizers and irrigation. The smallholders in this area do not irrigate or use agrochemicals so these impacts are considered to be minimal.

11 PROJECT IMPLEMENTATION

The proposed Kwendin Biomass Electricity Project will be implemented in close coordination with the Rural and Renewable Energy Agency (RREA) after obtaining the USAID approval and all other statutory approvals, including the approval of the Environmental Protection Agency (EPA) of Liberia. This Project is implemented as a community owned and managed project, and therefore, before the commencement of project construction, the proposed community management structure, Cooperative, would be established with the concurrence of USAID/Liberia and RREA. The LESSP Team had a consultative stakeholder meeting with the participation of the District Commissioner, and the Clan Chief, elders and all other stakeholders of the community. Such consultative stakeholder meetings will be continued throughout the Project preparatory stages to the completion stage.

LESSP will ensure the selection of quality gasifiers/engines/generators to the Project and also ensure the proper training of O&M staff of the Project. The potential operators and technicians would be selected from the region and provide them with adequate training before the arrival of plant to Liberia. LESSP will coordinate with the Booker Washington Institute (BWI) to train the potential operators with basic training, and thereafter, along with the equipment supplier's technical staff during the installation of the gasification plant and the construction of the electricity distribution system. As part of the procurement process, LESSP would evaluate the feasibility of contracting with the equipment supplier to operate the plant for a predetermined period.

Until the completion of the physical construction of the power system, and thereafter for a period of at least three months, LESSP will have a very close liaison with the Cooperative. During this period LESSP will have regular meetings with the Cooperative officials with a view to implementing a robust management system to the power system.

12 SAFETY AND SECURITY

The power plant will be located on a land owned by the community. The chosen site has access from the main road Tappita – Buchanan and the closet residential dwelling is about 77 meters away. The Community will be required to provide adequate security to the power plant as part of the community's continued contribution towards the Project. No security guards have been included in the manpower structure of the Project with a view to minimizing the Project's overhead cost. The powerhouse will be adequately secured with a peripheral fence/wall. Only the authorized personnel will be allowed to access the powerhouse. Secure storage will be provided for the generation plant, fuel stocks and spares, tools and other materials stored on location.

Basic fire protection equipment consisting of fire extinguishers, sand and water buckets will be made available at the power plant. The powerhouse will have a deep well with an overhead tank for storing water for the consumption of staff. This overhead water tank will also be a water source for firefighting if needed. The O&M staff will be trained in basic firefighting techniques and maintain safety measures at the power plant. Unlike other renewable energy power generation systems, biomass power systems present some hazards to operators. As per the industry norms and gasifier plant supplier's recommendations, operators will be trained to overcome such hazards.

13 PROJECT RISKS AND MITIGATION MEASURES

13.1 TYPES OF RISKS

The Project will be associated with inherent risk factors particular to biomass gasification projects in rural areas. These risks are classified as:

- Technology Risk
- Operating Risk
- Biomass Supply Chain Risk

- Revenue Risk
- Institutional Risk

These risks will be addressed in a timely manner and mitigating measures will be implemented to ensure the smooth functioning of the proposed Project:

13.2 RISK MITIGATION

The following Table shows the each of the potential risk and the mitigating measures to be introduced.

Table 14 - Risk Mitigating Measures

Risk Factor	Risk Mitigating Measure
Technology Risk	• The chosen technology, gasification using wood chips, is currently a well-established technology with a number of manufacturers in Asia, Europe and America. The track record of the equipment suppliers will be an important criterion for the selection of the successful supplier. Provision for a period of monitoring by the equipment supplier can also be included as a further mitigating measure. • Training of the operating staff and an extended commissioning/trail operation period will be included in the procurement contract as further mitigation measures. • Technology provider/plant supplier will be required to undertake the installation of the plant under the supervision of a competent engineer from the gasification plant manufacturer. The local staff will be assigned to work with the installation engineer to ensure the familiarity with the plant.
Operating Risk	• Proper training of the selected operators and ensuring that adequate numbers are trained so that there will always be trained operators to run the power plant. • Monitoring of the operation of the power plant by the manufacturer's engineers until they are satisfied with the competence of the local operators. This requirement will be built in to the EPC contract. • Maintaining a stock of dried fuel wood at least for two days operation under weather proof cover, particularly as a source of fuel for the startup operations until the waste heat is available for the on line drying process. • Adequate stocks of fuel wood for about two weeks operation awaiting

	drying. • Maintaining the stocks of essential spares recommended by the manufacturer. • Strict adherence to the operating and maintenance instructions by the operators and regular checks by the management. • Periodic overhaul of the engines at intervals specified by the manufacturers. • Adherence to the safety instructions strictly and prevention of access by unauthorized personnel, particularly children to the power plant premises.
Biomass Supply Chain Risk	• Biomass projects are as good as their biomass supply arrangements. There will be a risk of breaking down the biomass supply chain due to price sensitivities. This risk is minimal because of the lack of alternative users. Long term contracts with multiple suppliers would be a mitigating measure. • Another biomass supply chain such as bamboo plant would be explored as an alternative.
Revenue Risk	• Revenue risk may arise from not enough consumers obtaining electricity connection and nonpayment by already connected consumers. The first risk is minimal as every household expressed its desire to obtain electricity. The second risk would be addressed by installing pre-paid meters in the case of metered connection. Otherwise consumers would be provided electricity through a load limiting devise based on their capacity and willingness to pay and collecting the payment upfront.
Institutional Risk	• The major risk would be the risk of institutional failure. In the absence of any funding commitment by the community to invest in the biomass project, the proposed Cooperative may not have sufficient incentives to ensure the proper management of the power system without malfeasance. One of the ways of mitigating the risk is to allow the Cooperative to use part of surplus funds for the distribution among the members of the Cooperative. The most potent risk mitigating measure would be the pressure from the Community itself. The Project would provide affordable electricity to the Community and extra cash flows for farmers in the form of biomass supplies. The failure of the Project would result in the Community loosing these benefits.

14 IMPLEMENTATION

14.1 INSTITUTIONAL STRUCTURE

The proposed Project will be implemented as a community owned and managed power system, selling electricity to consumers. Although there is one community owned and managed project under construction in Liberia and a few more have been planned for implementation, there is no existing community owned and managed project in operation. There are a few private generators selling electricity to nearby communities in an ad hock manner and such activities are not in accordance with the existing legal framework which provides the monopoly powers to LEC electricity distribution to consumers. However, in the absence of any private sector investment in the proposed Project, the legal issues would not be an impediment to implementation of this Project. In order to provide institutional structure for implementation of the proposed Project, LESSP will assist the Kwendin Community to form an electric cooperative. This Cooperative will be legally established and LESSP will provide adequate training to the Cooperative officials. Until the formation of the Cooperative, LESSP will work along with the District Commissioner and the village elders/chiefs to carry out the preliminary work.

14.2 PHYSICAL IMPLEMENTAION

The physical implementation of the Project will represent many challenges. This is going to be the first biomass gasifier based power generation project in Liberia, and therefore, there is no relevant engineering experience available in the country. For typical biomass gasification plants, the construction activities will require experienced technicians, welders, mechanical fitters, electricians etc. and also construction management expertise. The lack of this expertise within Liberia represents a major challenge even though the physical implementation is to take the form of an EPC (Engineering, Procurement and Construction) type contract. There are also compact gasification plants available in the market for small plants. These plants are available with dry scrubbing system with gasifier/engine/generator supplied on a common frame. These plants do not require any local fabrication involving highly trained welders/technicians. LESSP will take into consideration the availability of such compact systems at the time of procurement. However, there is adequate local engineering/construction capability for construction of the electricity distribution system of the Project, and therefore, it would not represent a challenge as big as the one for the construction of the biomass gasification plant.

The Project is structured as a community owned and managed project. LESSP will play a major role in the physical implementation of the Project along with the proposed Cooperative that would be formed

once the Project is approved by USAID and the EPA of the Government of Liberia. LESSP will be working very closely with Kwendin Community from the Project planning stage up to the Project implementation stage. The actual construction of the Project would commence after obtaining the environmental approval from the EPA of Liberia and USAID and after the preparation of the EMMP as per the USAID guidelines. Because of the lack of qualified/experienced contractors in Liberia the most preferred way of implementing the Project is by way of an EPC Contract. LESSP will act as the Owner's Engineer.

The Project generation facility consists of fuel handling facility, gasification facility and electricity generation facility. Of these three components, the most technically complex component is the gasification plant. Therefore, the EPC Contractor must preferably be the gasification manufacturer. The gasification manufacturer will have to ensure that he takes the responsibility for the appropriateness of other components of the power generation facility and to offer guarantees and warranties not only for the gasification plant but also for other procured components such as engines/generators. Given the size of the Project, 60 kW, it may very well be that gasification manufacturers may not want to undertake the civil construction part of the Project because the manufacturer may not want install a complex project management structure in a country like Liberia incurring a significant mobilization cost for a smaller project such as the subject Project. On the other hand If the gasification plant will come in the form of a compact single unit, some of these implementation challenges would not be present. LESSP will coordinate civil construction part of the plant with the gasification manufacturer to ensure smooth implementation of the Project.

LESSP will seek prior approval for the selection of vendors from USAID as customary for USAID funded procurements and will present to USAID the Quality Control Plan for construction activities. During the construction, periodic progress reports and EMMP will be submitted to USAID.

14.3 IMPLEMENTATION SCHEDULE

The time schedule for the Project implementation depends on the time taken for obtaining all statutory approvals and making procurement decisions/approvals. For a custom designed gasification plant the time required for project completion is approximately 44 weeks from the date of confirming the order with a prospective manufacturer in Asia to complete the construction of the gasification plant.

Construction of the gasification plant	20 weeks
International shipping	10 weeks
Clearing in Monrovia and local transport	02 weeks

Plant erection/commissioning	12 weeks

The project completion time could be drastically reduced if the gasification plant will be procured as multiple units of a compact plant. The estimated time for completion of the Project would be around 20 weeks from date of confirming the procurement order with the equipment supplier.

15 CONCLUSION

Liberia is an electricity starving country which needs to accelerate generation of electricity as a means of achieving social and economic development. Before the war Liberia had regional small scale grids providing electricity to population centers outside Monrovia. Given the country's geographic structure, distant locations to population centers, and the size of population centers across the country it may be long time before the country will have a national grid connecting the entire country. Therefore, the most viable alternative appears to be the development of regional grids, serving the regional population centers. Such electricity generation will have to be predominantly the renewable energy because fossil fuel based power generation is not only extremely expensive but also environmentally negative.

Fortunately, Liberia is a country with an abundance of biomass materials and such biomass can be utilized for power generation in a very economical manner with minimal environmental impacts compared to negative impacts associated with fossil fuel based power generation. Compared with a conventional fossil fuel-fired power plant of the same capacity, the Project will produce less CO_2. The subject Project is a greenfield project initiated in response to USAID's LESSP.

The proposed Kwendin Biomass Electricity Project is a biomass power project using rubber wood chips as fuel. The Project is introducing gasification technology to Liberia for the first time. Gasification technology is the preferred way of for power generation for less than 1 MW of range especially in rural locations. Gasification technology can accommodate most variety of biomass material as fuel. More importantly the financial analyses show that the proposed Project is financially viable by pricing the energy to end users at US$0.35-US$0.40 per kWh which is almost 40% cheaper than the cost of electricity in Monrovia, but without causing negative impacts on the environment. The viability of the Project could be further improved by increasing electricity consumption during the daytime with an increased PLF. LESSP recommends that the proposed Kwendin Biomass Electricity Project be implemented as a pilot biomass project under LESSP because it is a commercially viable project and similar projects can be replicated in many parts of Liberia.