USAID | LIBERIA
FROM THE AMERICAN PEOPLE

USAID'S LIBERIA ENERGY SECTOR SUPPORT PROGRAM (LESSP)

LIBERIA NATIONAL ELECTRICAL GENERATION DESK STUDY

CONTRACT NO: 669-C-00-10-00059-00

August 29, 2014

This document was produced for review by the United States Agency for International Development. It was prepared by Winrock International under USAID's Liberia Energy Sector Support Program, Contract number 669-C-00-10-00059-00.

USAID'S LIBERIA ENERGY SECTOR SUPPORT PROGRAM (LESSP)

LIBERIA NATIONAL ELECTRICAL GENERATION DESK STUDY

Prepared for:	USAID/Liberia
Submission Date:	August 29, 2014
Award No:	669-C-00-10-00059-00
Contract name:	USAID's Liberia Energy Sector Support Program (LESSP)
COR:	Luis Velazquez, PE

Prepared by: Winrock International
LESSP
Atlantis Beach Hotel Compound
Mamba Point, UN Drive Monrovia
Liberia

Strategic Objectives:

SO1: To extend grid electricity throughout Monrovia and its environs;
SO2: To develop hydro capacity and other renewable energy sources;
SO3: To expand grid electricity to other urban areas and some rural areas; and
SO4: To improve legal, institutional and regulatory framework in the energy sector.

The author's views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

Table of Contents

1 Executive Summary 1

2 Introduction 4

2.1 Liberia's electricity sector 5
2.2 LESSP Background 6

3 Methodology 8

3.1 Study Purpose and Background 8
3.2 General Methodology 8
3.2.1 Monrovia Residential and Commercial/Institutional Survey 9
3.2.2 IPP Monrovia Survey 12
3.2.3 Interview with County Officials: Self-Powered Establishments and IPPs 12
3.2.4 Self-Powered Establishments' Database 13
3.2.5 Analysis of Actual and Extrapolated Data 13
3.3 External Data and Literature Review 14

4 Results 15

4.1 Self-Powered Establishments by Class 15
4.2 Informal Power Providers 17

5 Findings 17

5.1 Total Power Generation Capacity in Monrovia 18
5.2 Cost of Electricity Generated and Sold in Liberia 18
5.3 Provision of Electricity and Coverage in Liberia 21
5.4 Total Electricity Generated and Volume of Fuels Consumed in Liberia through Informal Power Producers 22

6 Conclusions and Recommendations 24

7 Acknowledgements 25

Annexes 27

A. Sample Questionnaires 28
B. Survey Methodology, Maps, and Other Information 32
C. Geographically Stratified Random Sampling 34
D. Definitions 36
E. Challenges 38
F. Works Cited and External Data 40

List of Tables

Table 1: Number of Surveys – Commercial and Public sample frame 10
Table 2: General Assumptions 13
Table 3: Self-powered establishments..... 16
Table 4: IPP analysis results..... 17
Table 5: Monrovia Estimated Generation Capacity 18
Table 6: Cost of electricity generated and sold ($/kWh)..... 20
Table 7: Estimated Electricity Coverage in Liberia 21
Table 8: IPP findings..... 23

List of Figures

Figure 1. LESSP Activity Map..... 7

Acronyms and Abbreviations

$	dollar(s)
a	annum
AFTEG	African Energy Unit (World Bank)
CBO	Community-Based Organizations
CFSNS	Comprehensive Food Security and Nutrition Survey
CLSG	Cote d'Ivoire-Liberia-Sierra Leone-Guinea Interconnection Project
EP	Eagle Power
ESG	Energy and Security Group
FAO	Food and Agriculture Organization
GOL	Government of Liberia
GWh	gigawatt-hours
HH	Household
hr	hour
IFC	International Monetary Fund
IPP	Independent Power Producer
kW	kilowatt
kWh	kilowatt-hours
LCPDP	Least Cost Power Development Plan
LEC	Liberia Electricity Corporation
LESSP	Liberia Energy Sector Support Program
LISGIS	Liberia Institute of Statistics and Geo-Information Systems
MLME	Ministry of Lands, Mines and Energy
MoIA	Ministry of Internal Affairs
MPW	Ministry of Public Works
MW	megawatt
NEP	National Energy Policy
NGO	Non Governmental Organization
Norad	The Norwegian Development Agency
NPHC	National Population and Housing Census (Liberia, 2008)
O&M	Operations and Maintenance
PRS	Poverty Reduction Strategy
RE	Renewable Energy
RREA	Rural and Renewable Energy Agency
SMP	Stella Maris Polytechnic
SP	Self-Powered Generation
SWEL	Society of Women Engineers in Liberia
UL	University of Liberia
USAID	U.S. Agency for International Development
WAPP	West African Power Pool
WB	World Bank
WFP	World Food Programme
WHO	World Health Organization
WI	Winrock International
WTP	Willingness to Pay
yr	year

1 EXECUTIVE SUMMARY

This desk study was sponsored by the United States Agency for International Development (USAID), through USAID's Liberia Energy Sector Support Program (LESSP). Winrock International (WI) implements LESSP on behalf of USAID .

1.1 Introduction and Methodology

At present, the Liberia Electricity Company (LEC) distributes electricity to approximately 26,000 customers (LEC, 2014) within central Monrovia and its environs, at a tariff above $0.50 per kWh. Prior to the civil war, LEC supplied electricity to approximately 35,000 customers (then representing 13 percent of the total population), as well as operated ten isolated power generation and distribution systems within urban centers outside of Monrovia (Fichtner, 2014). Today, almost no formal, regulated electricity distribution companies exist within or outside of Monrovia, and none are under the direct supervision or support of LEC. Due to the limited availability of electricity through regulated LEC or other schemes, several residences and vast quantities of businesses, institutions and industries have turned to self-generation and/or the provision of electricity via non-regulated informal power producers (IPPs) for their electricity needs. An end-user survey, carried out by the Norwegian Development Agency (Norad) in 2010, estimated that approximately 40 percent of households and 58 percent of businesses and institutions in Monrovia had access to electricity via a generator or shared generator. Moreover, some 19 percent of households reported to be customers of an IPP (Norad, 2011). Data for establishments and IPPs outside of Monrovia is even more limited; however estimates put household access to self-generation or IPPs at between two to 10 percent, depending on their relative location (Energypedia, 2014). As such, load demand in MW for 2015 has been estimated at between 34 and 56 MW for Monrovia, and between 41 and 77 MW for all Non-Monrovia areas - totaling to between 97 and 111 MW for Liberia, as a whole (Fichtner, 2014) (Africa Energy Unit (AFTEG), 2011).

As a result of the prevalence of non-LEC sources of electricity, this report estimates and outlines the notional quantities and the average electricity generated per year by categorized self-powered institutions (homes, businesses, institutions, etc.), as well as documents the relative regions, quantities, electricity generation averages, and tariffs of the many IPPs found within Liberia today. Specifically, the goal of this report is to summarize the findings of several targeted surveys, as well as provide a review of available data from sector partners, to ascertain probable figures for the following:

- The quantities and electricity generated by self-powered institutions in Liberia – including residences, businesses, factories, institutions, and large concessions
- The generation capacities, electricity generated, and tariffs by informal power producers in Liberia
- The total power generation capacity in Monrovia
- The total electricity generated in Liberia through informal power providers
- The cost of electricity generated and sold in Liberia
- The provision of electricity and coverage in Liberia
- The volume of fuels consumed for the production of informal electricity

To collect the data necessary to analyze and present the relevant information on self-powered establishments and IPPs, the study employed the following tools:

- A residential and commercial/institutional end-user survey to ascertain the electricity supply and consumption patterns of Monrovia establishments
- An IPP Monrovia survey to acquire data on IPPs' electricity generation and distribution businesses

- A telephone interview survey with County Superintendents or key County representatives to ascertain the quantities, power capacities, among other details, of self-powered establishments and IPPs outside of greater Monrovia
- Data collection efforts from Government of Liberia (GoL) sources (Ministry of Lands, Mines and Energy (MLME), Rural and Renewable Energy Agency (RREA)), Donors, LEC, World Bank, etc. to compile existing information on self-powered establishments and IPPs in Liberia

MLME was consulted, and provided their consent, for the proposed implementation process for this study.

1.2 Results and Findings

1.2.1 Self-powered establishments by class

Within Monrovia, 21 percent of residences and 80 percent of commercial/public/institutional entities are estimated to employ generators for their electricity needs. Outside of Monrovia, approximately 13 percent of urban residents and four percent of rural residents are estimated to utilized self-generation, while approximate 81 to 85 percent of commercial and public entities (in urban and rural areas) employ generators for their electricity needs. Total self-powered generation capacity in Liberia is estimated at 350 MW, with 233 MW (66 percent) found in Monrovia and 63 MW (19 percent) found outside Monrovia. In addition, an estimated 54 MW (15 percent) is installed in larger concessions. Finally, total electricity generation via self-generation is estimated at 1,301 GWh per year for Liberia, as a whole.

Liberian households, businesses and institutions are spending between $1.12 and $0.24 per kWh more than the LEC tariff for distributed electricity access, and between $0.31 and $0.18 per kWh (solely in fuel costs) more for self-generated electricity access.

1.2.2 IPP Results

Average generator capacity for all surveyed IPPs (122 in total) was estimated at 27 kW, with approximately 59,000 kWh generated per year. Tariffs were estimated based upon projected customer electricity usage per month (using residential electricity usage as the basis, and assuming an average of six hours of electricity used per day) and the reported charge per ampere by each IPP. The average tariff across all IPPs was found to be approximately $1.41 per kWh. Monrovia IPPs averaged tariffs of $1.17 per kWh, while Non-Monrovia IPPs averaged $1.66 per kWh. Again, since IPPs do not meter electricity consumption, this tariff is only an approximation.

1.2.3 Total Power Generation Capacity in Monrovia

Within Monrovia, it is estimated that 44 percent of total generation capacity is through self-powered residences, while 25 percent is met by self-powered commercial and public establishments. LEC provides approximately eight percent of the total Monrovia generation capacity. IPPs are thought to provide around 10 percent of Monrovia generation capacity – though this figure is only a notional estimate. Total installed capacity from all sources was estimated at 284 MW.

1.2.4 Cost of Electricity Generated and Sold in Liberia

LEC's cost of generation – for fuel only – was projected at $0.32 per kWh, while IPPs fuel costs were calculated as ranging from $ 0.34[1] to $0.66 per kWh. Of the current known tariffs, LEC's current tariff – shown as $0.54 per kWh – is naturally the most affordable. Within the analysis and research completed under this study, IPP relative tariffs were calculated between $1.40 to $1.17 per kWh, higher than both LEC's tariff and the cost of self-generation.

1.2.5 Provision of Electricity and Coverage in Liberia

Self-generation seems to be the overwhelming largest contributor to national electricity access – estimated to cover 10 percent of Liberian households and 60 percent of Liberian commercial and public entities. These figures drop specific to Non-Monrovia households due to low generator usage; however, increase within Non-Monrovia commercial and public establishments is likely due to the absence of LEC or IPP electric supply. IPPs in Monrovia are estimated to serve approximately six percent of all projected residential, commercial, and public consumers nationally.

1.2.6 Total Electricity Generated and Volume of Fuels Consumed in Liberia through Informal Power Producers

As the total quantity of IPPs is unknown, determining the total electricity generated and volumes of fuel consumed by the sub-sector is not possible at this time. Using the data available, it is estimated that 122 estimated IPPs in Liberia generate approximately 7.2 GWh per year, consuming approximately 940,000 gallons of fuel in the process.

1.3 Conclusions

Though caution must be employed in any concluding statements, as the results shown illustrate only notional ideas of self-generation and IPP effects within the Liberian electricity sector, three main points can be drawn from the study's key results and findings presented herein:

i. Liberian households, businesses, and institutions are spending between $0.24 and $1.12 per kWh more than the LEC tariff for distributed electricity access, and between $0.18 and $0.31 per kWh (solely in fuel costs) more for self-generated electricity access. Clearly, electricity is a desired commodity, especially when considering that Liberian homes and businesses are willing to pay more than double the price per kWh for access. These trends point to the need for, barring faster paced LEC expansion, a more formalized and scaled approach towards reducing the costs of self-generation, as well as IPP generated electricity.

ii. Where LEC electricity is not accessible, the preferred choice is clearly self-generation, for those that can afford it (see Tables 3 and 5). Costs range between $0.72 and $0.85 per kWh for fuel alone. Adding in the costs of equipment replacement, maintenance, etc., this cost can rise to as high as $1.90 per kWh. These high costs point to a need for an expanded array of self-generation options – from small consumer lighting products, to appropriate business scaled solutions. In the medium term, by eliminating or easing a number of economic cost barriers, much could be done to provide alternative solutions - from technology options (solar lanterns, PV kits, etc.) to effectively designed and scaled electrification programs (for urban and rural settings) that address the need and role of self-generation (and distributed generation in a larger sense).

[1] Eagle Power IPP was analyzed in more detail by LESSP; its generation costs were estimated at $0.34 to $0.45 per kWh, while the average cost of generation for the IPPs surveyed was calculated at $0.66 per kWh.

iii. Though they are not legally permitted within the current Energy Law, there is a clear need for more formalized contact and perhaps supervision (in place of formal regulations for the time being) of IPPs. A good first step would be to encourage all IPPs to register with the GoL, and while the legality of their operations is still denied, they could potentially be offered training on safety issues, proper tariff setting, house wiring inspection, generator sizing, etc. A step further would be to encourage them to provide the GoL with a uniform monthly financial and statistical performance report. This would allow for a more patterned, organized utilization of IPPs, and possibly allow for a diversified, professional core set of generation/distribution companies to grow and compete within Liberia.

2 INTRODUCTION

This desk study was sponsored by the United States Agency for International Development (USAID), through USAID's Liberia Energy Sector Support Program (LESSP). WI, on behalf of USAID, implements LESSP. LESSP's purpose and background is outlined in Section 2.2.

This report estimates and outlines the notional quantities, and the average electricity generated per year by categorized self-powered institutions (homes, businesses, institutions, etc.), as well as documents the relative regions, quantities, electricity generation averages, and tariffs of the many informal power providers[2] (IPPs) found within Liberia today. Very little information is presently available relative to these two sources of electricity access within Liberia. Several studies present the results of recent surveys relative to electricity access within households and institutions in Monrovia – namely Norad in 2011- while a number of electricity demand projections have been made for Monrovia, as well as Liberia as a whole – namely the World Bank/African Energy Unit (WB/AFTEG) in 2011, International Finance Corporation (IFC) in 2007, and Norconsult in 2009. In addition, a Least Cost Power Development Plan (LCPDP) is currently under development by Fichtner for the Ministry of Lands, Mines and Energy (MLME) as well as the Liberia Electricity Corporation (LEC), which also projects demand for Liberia into 2033, along with a comparison of previous estimates.

The specific objectives of this report are to summarize the findings of several targeted surveys, as well as provide a review of available data from sector partners, to ascertain probable figures for the following:

- The quantities and electricity generated by self-powered institutions in Liberia – including residences, businesses, factories, institutions, and large concessions
- The generation capacities, electricity generated, and tariffs by informal power producers in Liberia
- The total power generation capacity in Monrovia
- The total electricity generated in Liberia through informal power providers
- The cost of electricity generated and sold in Liberia
- The provision of electricity and coverage in Liberia
- The volume of fuels consumed for the production of informal electricity

The report will provide insights into self-powered generation and IPPs in Liberia through first providing a brief sector background, as well as an outline of the LESSP within Section 2. Section 3 provides an overview of the methodology used for each of the surveys employed, as

[2] IPPs are the term locally given to these entities. They are, in essence, unregulated, small-scale electricity generation and distribution utilities.

well as a review of the external sources consulted. Section 4 presents the results of the surveys, followed by Section 5, which presents the findings of both the surveys and external data review relative to the core goal of this report. Finally, Section 6 presents recommendations relative to the findings.

Load demand in MW for 2015 has been estimated at between 56 to 34 MW for Monrovia, and between 77 to 41 MW for all Non-Monrovia areas - totaling to between 111 to 97 MW for Liberia as a whole
(Fichtner, 2014)

2.1 Liberia's electricity sector

The extent of destruction to Liberia's electricity infrastructure caused during its fourteen-year civil war is well documented. Today, though many efforts are under way to improve electricity supply and access, Liberia still ranks among the world's lowest in terms of electricity access rates – with reportedly less than one percent of the population connected to the national grid managed by the LEC. At present, LEC distributes electricity to approximately 26,000 customers (LEC, 2014) within central Monrovia and its environs, at a tariff above $0.50 per kWh. Prior to the civil war, LEC supplied electricity to approximately 35,000 customers (then representing 13 percent of the total population), as well as operated 10 isolated power generation and distribution systems within urban centers outside of Monrovia (Fichtner, 2014). Today, almost no formal, regulated electricity distribution companies exist within or outside of Monrovia, and none are under the direct supervision or support of LEC.

LEC's expansion is greatly hampered by the limited generation options currently available. Currently, all grid-supplied electricity is generated through several high speed diesel power plants located in Monrovia – with an installed capacity around 22 MW. The Mount Coffee Hydropower plant (64 MW) is currently under reconstruction, while several isolated electricity generation, transmission, and distribution schemes are in progress, including:

- 33 kV interconnection with Cote d'Ivoire at three points within the counties of Nimba, Grand Gedeh, and Maryland for the supply of electricity to various localities;
- The West African Power Pool (WAPP) cross-border transmission interconnection project, namely the Cote d'Ivoire-Liberia-Sierra Leone-Guinea Interconnection Project (CLSG), which was initiated in 2004;
- Construction of LESSP small-scale renewable energy based generation projects (more information on these efforts in found in Section 2.2);
- Medium to micro-hydro plant generation sites including the Mein River Hydropower plant (under construction), Harbel (Firestone-managed) hydro power plant, and the Yandohun community micro hydro plant (rehabilitated and commissioned in 2013).

Due to the limited availability of electricity through regulated LEC or other schemes, several residences and vast quantities of businesses, institutions, and industries have turned to self-generation and/or the provision of electricity via a non-regulated IPP for their electricity needs. An end-user survey, carried out by Norad in 2010, estimated that approximately 40 percent of households and 58 percent of businesses and institutions in Monrovia had access to electricity via a generator or shared generator. Moreover, some 19 percent of households reported to be customers of an IPP (Norad, 2011). Data for establishments and IPPs outside of Monrovia is even more limited; however, estimates put household access to self-generation or IPPs at between two and 10percent, depending on their relative location (Energypedia, 2014).

As such, load demand in MW for 2015 has been estimated at between 34 and 56 MW for Monrovia, and between 41 and 77 MW for all Non-Monrovia areas - totaling to between 97

and 111 MW for Liberia as a whole (Fichtner, 2014) (Africa Energy Unit (AFTEG), 2011). Additional information on these projects can be found via the reports cited, found within Annex 0.

2.2 LESSP Background

The USAID's LESSP contract was awarded to WI on October 4, 2010 under USAID Contract 669-C-00-10-00059-00.

The purpose of USAID's LESSP is to increase access to affordable, renewable energy services in geographically focused rural areas, in order to foster economic, political, and social development. The ultimate impact of the program, i.e. the change that is expected in targeted areas upon assessing the completed work, will include:

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

USAID plays a leading role in building Liberia's energy sector. Its successful collaboration with the GoL and other donors during the Emergency Power Project (EPP) and Liberia Energy Assistance Program (LEAP) has provided a strong platform and valuable lessons for expanding access and improving the affordability of electricity to urban and rural residents.

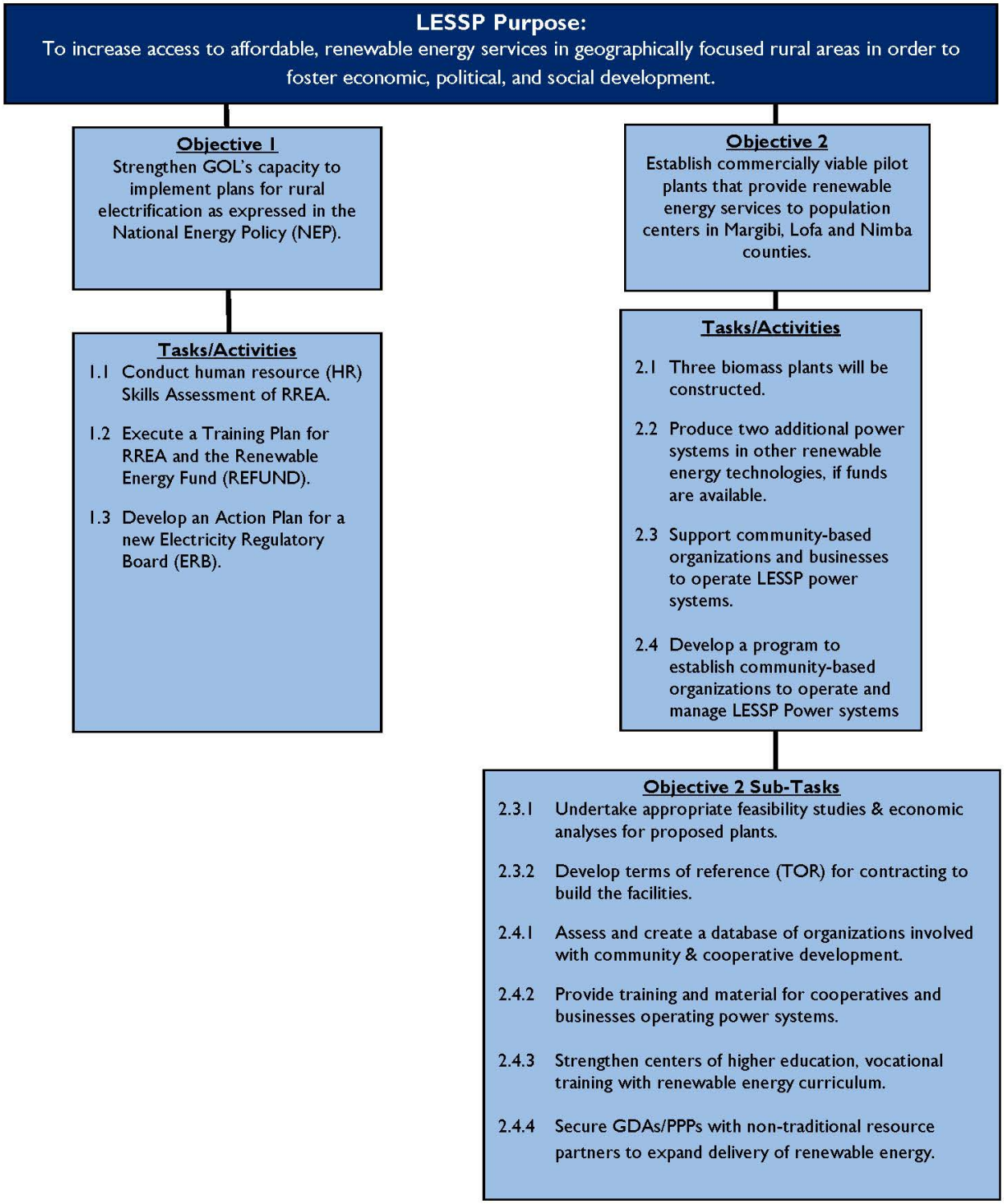
To date, LESSP has focused efforts in three counties: Margibi, Nimba, and Lofa counties. Winrock International (WI) and its partners will continue supporting the Ministry of Lands, Mines, and Energy (MLME) and the Rural and Renewable Energy Agency (RREA) to strengthen institutional capacity.

USAID Liberia, in consultation with the GoL, donor community, and other stakeholders, has identified renewable energy (RE) as an underutilized resource that could have tremendous impact on the country's development. In order to exploit these resources in the most cost-effective and expedient way, LESSP will work with the GOL to implement policies that create an environment conducive to foreign investors and for Liberian entrepreneurs to participate in the growing market for renewable energy technologies (RET) and services.

LESSP will establish power projects that will demonstrate the viability of RET and biomass power technologies for rural communities. LESSP will also assist the LEC with the installation of a utility interconnected solar photovoltaic (PV) power system, the first of its kind in Liberia. The intent is that these types of projects will be replicated by other non-US government donors, the GOL, and private sector investors over time. LESSP's pilot project work will help support the development of a skilled workforce capable of constructing, maintaining, and sustaining infrastructure.

Under the US Foreign Assistance framework's Economic Growth Objective, USAID Liberia's assistance will be leveraged to increase access to modern energy services. USAID Liberia will pursue the objectives shown on the following LESSP activities map, which are consistent with the USG assistance framework, the GOL's Poverty Reduction Strategy (PRS), Liberia's National Energy Policy (NEP), and the USAID-GOL bilateral assistance agreement.

Figure 1. LESSP Activity Map



3 METHODOLOGY

This section presents a detailed summary of the study's purpose and its methodologies – both in terms of the surveys implemented, as well as the data collected from external sources.

3.1 Study Purpose and Background

In October 2013, LESSP produced a Concept Study titled the "Expansion of Eagle Power Generation Capacity Using Renewable Energy Technology and Improvements to the Electricity Distribution System" as part of a public private partnership with Eagle Power (EP). EP is an IPP that supplies between 350-750 customers within specific areas of Monrovia, and operates an installed capacity of 899 kVA. The study brought to light the potentially high quantity of IPPs in existence with significant capacity in Monrovia, as well as other areas of the country. Furthermore, the study's results highlighted the possibility that electricity access within Monrovia is higher than currently reported in most studies on Liberia's energy sector. Results suggest that IPPs may collectively sell electricity to more customers than LEC. Consequently, LESSP conducted similar studies in its counties of operation and found that in Gbarnga, Bong County's urban area, the county-endorsed IPP, Geontia Liberia Ltd., provided electricity to some 100 customers and served as the primary electricity provider in the area.

This desk study is a continuation of these efforts; however, in addition to understanding IPP electricity provision, the study also explores electricity access and generation in Liberia. As such, its aim is to provide a notional understanding of electricity supply, costs, and usage within self-generating establishments, as well as through IPPs. Specifically, as mentioned above, its aim is to summarize the findings of several targeted surveys, as well as provide a review of available data from sector partners, to ascertain probable figures for the following:

- The quantities and electricity generated by self-powered institutions in Liberia – including residences, businesses, factories, institutions, and large concessions
- The generation capacities, electricity generated, and tariffs by informal power producers in Liberia
- The total power generation capacity in Monrovia
- The total electricity generated in Liberia through informal power providers
- The cost of electricity generated and sold in Liberia
- The provision of electricity and coverage in Liberia
- The volume of fuels consumed for the production of informal electricity

The methodology and process followed related to the surveys employed and interviews conducted is found in Section 3.2, while the external data collection and document review process is described in greater detail in Section 3.3.

3.2 General Methodology

To collect the data necessary to analyze and present the relevant information on self-powered establishments and IPPs, the study employed the following tools:

- A residential and commercial/institutional end-user survey to ascertain the electricity supply and consumption patterns of Monrovia establishments
- An IPP Monrovia survey to acquire data on IPPs electricity generation and distribution businesses

- A telephone interview survey with County Superintendents or key County Representatives to ascertain the quantities, power capacities, among other details, of self-powered establishments and IPPs outside of greater Monrovia
- Data collection efforts from Government of Liberia sources (MLME, RREA), Donors, LEC, World Bank, etc. to compile existing information on self-powered establishments and IPPs in Liberia

MLME was consulted, and provided their consent, for the proposed implementation process for this study. Each method utilized is described in further detail below.

3.2.1 Monrovia Residential and Commercial/Institutional Survey

The primary survey conducted under this desk study was designed to gain further insights into the electricity access patterns within residences and commercial/institutional entities of greater Monrovia. A team of enumerators was assembled and survey instruments designed to query sampled respondents of both categories on their sources of electricity, costs, hours of electricity usage, fuel type and consumption patterns, etc. Further details on the survey's methodology are presented below.

3.2.1.1 Scope and Sample Frame

Each survey's scope was defined as any building and/or establishment that is or can be potentially connected to electricity.[3] Buildings or establishments in this sense are: residences or households, hotels, restaurants, churches/mosques/religious establishments, shops, services, embassies, markets and their corresponding stalls, embassies, NGO offices, UNMIL and other army headquarters, stadium, banks, schools, universities, hospitals, clinics, police and fire stations, airport, seaport, concession companies, government offices, and industrial building.

The sample frame for this end-user survey was taken as greater Monrovia's urban administrative areas- utilizing the city's known administrative divisions. For the residential survey, the sample size was estimated using population data generated from the 2008 National Population and Housing Census. Using these estimated household population figures, the sample frame was further stratified into different geographic zones – as shown in Annex b. Furthermore, the final sample frame was again stratified into the various electricity access types within known residential establishments, with each stratum assumed to have 1) a calculated percentage of buildings with access to electricity and 2) a calculated percentage of buildings with access to LEC.

Using this methodology, the total residential sample size was estimated as 384, though, this was exceeded and the actual number of residential samples taken was 392.

A margin of error of $\pm 5\%$ was determined for the stratifications and the residential surveys, with a confidence interval of 95%; however, only overall estimates were calculated.

For the commercial/institutional sample frame, due to a lack of comprehensive information, a set population was estimated for commercial and public buildings. The number of surveys for each administrative region for each type of commercial and public establishment was set as proportionate to the estimated population[4] within each geographically stratified area. Table 1 shows the sample size of each establishment, including both phone and in-field surveys.

[3] Please see annex for more detailed definitions, maps, and survey number divisions.
[4] Population sizes are taken from LISGIS estimates.

Table 1: Number of Surveys – Commercial and Public sample frame

No.	Type	Building	Population	Sample Size
1	Private	Hotels	30	30
2	Private	Restaurants	100	80
3	Private	Shops	500	217
4	Private	Services	10	10
5	Private	Embassies	20	20
6	Private	NGOs (UNMIL, Armies)	900	108
7	Private	Churches	300	169
8	Private	Stadium	2	2
9	Private	Banks	9	6
10	Private	Markets: stall electricity providers	300	169
11	Private	Schools	50	50
12	Private	Universities	5	5
13	Private	Hospitals and Clinics	50	50
14	Private	Industry	50	50
15	Public	Schools	50	50
16	Public	Universities	5	5
17	Public	Hospitals	5	5
18	Public	Police	10	10
19	Public	Fire Station	10	10
20	Public	Airport	2	2
21	Public	Seaport	2	2
22	Public	Government Offices (M, A, D…)	20	20
23	Informal Providers	Electricity Businesses	100	80
24	Private	Concession Companies	5	5
		TOTAL NON-RESIDENTIAL SAMPLE:		**1,155**

Total sample size, including both phone and in-field interviews, is 1499 surveys in Greater Monrovia.

3.2.1.2 Sampling Methodology

Simple geographic random sampling was used to determine suitable houses, businesses, and/or institutions to survey. Visual survey and simple counting were used to execute the randomization process for each surveyed geographic zone. Each zone was divided into districts, within each district, the survey was conduct on every fifth street and fifth residence or establishment until the determined sample size was met for both surveys. This was done for in-person interviews only.

3.2.1.3 Survey Implementation Components

The survey process included several key activities some of which were accomplished prior to the field work, and others accomplished during the survey process. The primary activities included design of the survey instrument; testing the survey instrument; design of the database; design and implementation of a training program for the enumerators; implementation of the survey within the sample frame; error checking the survey forms; transcription of data to the data base; and, analysis of survey results.

The survey team designed two complementary paper-based survey instruments, one to collect data from households and the other to collect data from businesses and institutions. Samples of the survey instruments are found in Annex a. The survey took place over one month, from May 27 to July 30, 2014.

Enumerator training was conducted during the first week prior to the commencement of the survey. This included training on the administrative regions, interviewee selection, discussing the questionnaires for in-depth understanding, introducing the survey, organizations, and purpose and answering interviewee questions, conducting the survey, reporting data, as well as entering data into the database. A pilot survey was conducted for the surveyors' areas for all questionnaires during the training; each was given 10 surveys for all three types of questionnaires. These were revised after the pilot. A supervisor, from Society of Women Engineers in Liberia (SWEL), was also hired to assist in conducting the survey. Finally, the initial three days of the survey were used to pilot survey sites in Central Monrovia and West Point, and to further train the enumerators and test the data collection tools.

When contacting a residence or other establishment, the enumerators asked to speak with an adult (aged 18 or older) who could serve as the respondent. All interviewers carried copies of a permission and introductory letter for the survey, to be read to the respondents before the beginning of the interview. If a relevant respondent was not available, the enumerator asked for contact details in order to conduct the interview at a later time. If details were not provided, the enumerator moved on to the next establishment. The interview was conducted in English and/or Liberian English, depending on the respondent and typically ranged from three to fifteen minutes in length. The type of establishment was determined at the beginning of the survey and was identified on the questionnaire.

For quality control, the enumerators were asked to come every two days to the office to debrief, report findings, drop off surveys, and discuss next steps. These meetings included discussions regarding inconsistencies in data collected, improvements in data collection, estimating the number of IPPs, as well as information on necessary changes to the database format.

For data entry, the last day of the workweek was designated specifically to enter field data into the database. This was done with iPads and direct data entry into the database. Enumerators all came during this time and alternated in two-person teams, depending on the schedule, to enter and facilitate faster and more efficient data entry.

3.2.1.4 Phone and Field Interview Instructions

Due to their location and/or designation, certain establishments were surveyed through phone interviews only. Selected establishments include: concession companies, government offices, seaports, airports, fire station, universities, big private and public hospitals, police station, stadiums, banks, embassies, services

(i.e. water or waste disposal), and certain hotels. Phone interviews are a separate sample and were not included in the geographical sampling.[5]

Contact phone numbers were taken from online registries of establishments and NGOs in Monrovia. All contact information was kept completely separate from the answers provided during the interview.

During the phone interview, the enumerators repeated the same process utilized within field visit survey. Some interviews included asking contact details of relevant persons with better ability or knowledge to respond to the questionnaire. Therefore, some questionnaires were completed and sent by email and some were filled out during the phone call. All Monrovia phone surveys results were then entered into the corresponding database.

3.2.2 IPP Monrovia Survey

A separate survey was designed to gather information on Monrovia IPPs. A pre-determined number of IPPs was used as the population, with the number of IPPs sampled within one geographic zone (similar to the residential and commercial end-user survey) dependent on the population of that area relative to the total population. A census of IPPs would have been the preferred approach, but due to time and budget constraints, this was not possible. No phone interviews were conducted for IPPs.

Each interview consisted of questions critical to the IPP's methods of generating and distributing electricity; specifically the type of fuel used, how many hours generators are used, how much is charged, the number of customers subscribed to different amp subscriptions, and safety concerns. Additional information on safety and community electricity provision (public service) were also posed.[6] A sample of the survey instrument used can be found in the Annex.

IPPs were contacted primarily through word-of-mouth in the areas surveyed; these surveys were done in conjunction with the residential and commercial surveys. The targeted number of IPPs to survey were contacted – 62 IPPs were identified in Monrovia - though, not all contacted IPPs provided answers. Enumerators were instructed not to pursue IPPs who were not willing to provide information. Debriefings showed that enumerators were able to contact one or two more IPPs than targeted, implying that the total quantities of IPPs in Monrovia is larger than the sampled set identified within this study. This again points to the need for a census of IPPs – both in Monrovia and beyond – to fully understand the extent and impacts of their role within the electricity sector.

Data entry also followed the same process as with residential and commercial surveys.

3.2.3 Interview with County Officials: Self-Powered Establishments and IPPs

Telephone-based interviews with County Superintendents or key County Representatives were conducted to ascertain the quantities, power capacities, and other details of self-powered establishments and IPPs outside of greater Monrovia. These Superintendents estimated the number of IPPs, hotels, businesses, homes, and institutions that generate their own electricity, as well as their potential generation capacity. Data was extrapolated for similarly sized institutions with no reliable information on their electricity generation. Contact information for County Representatives was provided by the Ministry of Internal Affairs (MoIA). These phone interviews included asking contact details of relevant persons with better ability to respond to the questionnaire. Therefore, some questionnaires were completed and sent by email

[5] For more information on phone numbers in the event of and/or preparation of future surveys, please contact LESSP.
[6] This information has been excluded from the report. For more information, please contact LESSP.

and some were completed via phone interview. Superintendent surveys were inputted into a separate database.

A field survey approach was preferred, but not possible due to the Ebola outbreak during the time of this desk study.

3.2.4 Self-Powered Establishments' Database

A separate database detailing the generator capacity and load demand of various commercial and public institutions such as hotels, embassies, large industries, banks, government offices, and other larger establishments around Monrovia was provided by USAID. These generator capacities ranged from 15 to more than 2000 kVA, and included one or more generators. These estimates were used for the self-powered generation analysis.

3.2.5 Analysis of Actual and Extrapolated Data

Survey data was compiled and analyzed over the sampled residential and commercial/institutional respondents. Various assumptions were utilized to generalize the sampled data in relation to the estimated total population per consumer category. Caution should be exercised in assuming these results are representative, as the study is notional.

Data used for analysis was extrapolated from the survey mentioned above, as well as other studies' estimates for households, commercial and public establishments, industries, and concessions or other large businesses/institutions. Least Cost Power Development Plan (LCPDP) assumptions were used for estimating for overall residential, commercial, and industrial values in Liberia.

Data cleaning assumptions include the following:

- A power factor of 0.8 was used for all generators
- For the commercial and residential data, "small tiger" generators were assumed to have capacities of either 0.5 to 1.5 kVA (to be based on frequently occurring capacity) where not specified or clear
- For the commercial and residential data, unclear weekly fuel purchase information (i.e. one vs. daily or once per week/day) has been modified and assumed to depend on number of hours of operation
- Conversions from USD to LD are made with an 80LD=1USD conversion rate.

Table 2 shows a summary of general assumptions used in the actual analysis:

Table 2: General Assumptions

Unit	Value	Unit	Note
Residence	6.1	People/HH	
Days for residential electricity generation	30	Days	
Days for commercial electricity generation	20	Days	
Average operation/day	12	hrs	
USD conversion	1	80	LD

Unit	Value	Unit	Note
LCPDP Assumptions			
Monrovia – Commercial and Public Establishment	0.6	100	Households
Non Monrovia Urban - Commercial and Public Establishment	0.66	100	Households
Non Monrovia Rural - Commercial and Public Establishment	0.4	100	Households
Generator Assumptions			
Frequently Occurring kVA Gen (Residential and Commercial Urban)	2.5	kVA	
Frequently Occurring kVA Gen (Residential Monrovia and Rural Residential/Commercial)	1.5	kVA	
Gbarnga WtP Com Genset kW average	4.5	kW	
1L Diesel	2.5	kWh	Large generator, decently loaded
1L Diesel	2	kWh	Small generator, under 50% loaded
1L Gasoline	1.9	kWh	3/4 load
Load factor	0.7		
Voltage	220	V	

These values were used to analyze the data from all sources.

3.3 External Data and Literature Review

To complement the field data collection activities implemented under this desk study, the analysis team also reviewed and utilized external data collected in previous studies, reports, spreadsheets, and on-going program activities from a number of sources, including[7]:

- Africa Energy Unit (AFTEG). (2011). *Options for the Development of Liberia's Energy Sector.* Washington, D.C.: The International Bank for Reconstruction and Development/THE WORLD BANK GROUP.
- Energypedia. (2014, April 11). *Liberia Energy Situation*. Retrieved from Energypedia: www.energypedia.info/wiki/Liberia_Energy_Situation
- Fichtner. (2014). *Preparation of a Government of Liberia Least Cost Power Development Plan (LCPDP).* Monrovia: Government of Liberia - MLME and LEC.
- LEC. (2014, August 7). CEO report August 7 2014.xlsx. Monrovia: Liberia Electricity Corporation.
- Modi Research Group. (2013). *Liberia Power Sector Capacity Building and Energy Master Planning Final Report, Phase 4: National Electrifiation Master Plan.* New York City: Columbia University.
- MWH. (2012). *Evaluatoin of EU energy funding in Liberia and recommendations.* Monrovia: European Union.
- Norad. (2011). *Norwegian support to the Liberian energy sector: Baseline study and RBM system.* Oslo: Norad.

[7] A full documentation of literature and data reviewed can be found in the report's bibliography

- RREA. (2013). *Liberia Investment Plan for Renewable Energy.* Monrovia: Rural and Renewable Energy Agency.
- Liberia 2009. Enterprise Surveys (http://www.enterprisesurveys.org), The World Bank.
- Willingness to Pay survey for the Mien River Hydropower plant service territory, 2013
- LISGIS. (2009). *2008 Population and Housing Census, final results*. Monrovia: Liberia Institute of Statistic and Geo-information Services.

4 RESULTS

The results presented herein were derived mainly from the survey work completed for this study as outlined in the section above. The results are split into the study's two main areas of focus: 1) self-powered establishments and 2) IPPs. Where necessary, external data has been utilized to complement and complete the survey data collected – particularly for the self-powered establishments results. Further analysis and comment on the results is also found within the Findings in Section 5.

4.1 Self-Powered Establishments by Class

Table 3 provides an estimate of self-powered institutions by consumer category, per region. Population sizes of each consumer category were estimated using the National Population and Housing Census (Liberia, 2008) (NPHC) as well as the LCPDP. Estimates on number of total self-powered generation were based on percentages of the survey for Monrovia; the industrial and concessions date are taken directly from the LCPDP. Non-Monrovia urban and rural numbers are estimated from business surveys done for LESSP as well as the percentage findings of self-powered generation in the WB's 2009 Enterprise survey.

Within Monrovia, an estimated 21 percent of residence and 80 percent of commercial/public/institutional entities employ generators for their electricity needs. Outside of Monrovia, approximately 13 percent of urban residents and four percent of rural residents are estimated to utilized self-generation. Approximately 81 to 85 percent of commercial and public entities (in urban and rural areas outside of Monrovia) employ generators for electricity needs.

Utilizing these estimates, as well as average generator capacities, an estimated total self-powered generation capacity in Liberia is projected at 350 MW, with 233 MW (66 percent) found in Monrovia and 63 MW (19 percent) found outside Monrovia. Additionally, an estimated 54 MW (15 percent) is installed in larger concessions. Total electricity generation via self-generation is estimated at 1,301 GWh per year for Liberia, as a whole.

According to these estimates, total residential self-powered electricity generation is higher than commercial and public electricity generation.

Table 3: Self-powered establishments

Monrovia				
	Consumer Category	Number	Electricity Generated (kWh per year)	Total Capacity (kW)
	Residential	50,261	550,360,963	125,653
	Commercial and Public	1,021	312,814,942	71,419
	Industrial	25	157,198,200	35,890
		Subtotal:	**1,020,374,106**	**232,962**

Non-Monrovia Urban				
	Consumer Category	Number	Electricity Generated (kWh per year)	Total Capacity (kW)
	Residential	16,986	111,601,226.61	25,480
	Commercial and Public	581	11,449,613	2,614
	Large Institutions/Commercial	134	23,177,998	5,292
		Subtotal:	**146,228,837**	**33,386**

Non-Monrovia Rural				
	Consumer Category	Number	Electricity Generated (kWh per year)	Total Capacity (kW)
	Residential	16,474	108,231,024	24,710
	Commercial and Public	1,242	24,476,862	5,588
		Subtotal:	**132,707,886**	**30,299**

Other				
	Consumer Category	Number	Electricity Generated (kWh per year)	Total Capacity (kW)
	Other/Large Concessions	3	2,280,960	54,000

Overall Total:	**1,301,591,789**	**350,646**

4.2 Informal Power Providers

Table 4 presents speculative information on the various IPPs surveyed, grouped by region (Monrovia or Non-Monrovia), then assembled by the range of customers each IPP serves. Of the IPPs surveyed in Monrovia, 38 percent serve between 25 and 50 customers, followed by 30 percent serving fewer than 25 customers. Approximately 11 percent of Monrovia IPPs surveyed serve over 75 customers. Likewise, in Non-Monrovia areas, 31 percent serve between 25 and 50 customers, while 51 percent serve fewer than 25 customers.

Table 4: IPP Analysis Results

	Customer Range	Quantity of IPPs	Ave. Generation Capacity	Ave. Electricity Generated	Ave. Tariff
Region	**(Num)**	**(Num)**	**(kW)**	**(kWh per year)**	**(Approx. $/kWh)**
Monrovia	Total	62	28.8	50,808	$1.17
	0-25	19	16.8	22,270	$1.21
	25-50	24	22.2	37,872	$1.11
	50-75	12	45.9	45,845	$1.22
	75-100	3	41.3	34,007	$1.25
	>100	4	65.0	291,462	$1.13
Non Monrovia	Total	60	25.1	67,439	$1.66
	0-25	31	14.0	54,924	$1.53
	25-50	19	29.2	103,963	$1.94
	75-100	10	51.5	36,836	$1.56
Total		**122**	**27.0**	**58,987**	**$1.41**

Average generator size for all surveyed IPPs was estimated at 27 kW, with approximately 59,000 kWh generated per year. Finally, tariffs were estimated based upon projected customer electricity usage per month (using residential electricity usage as the basis, and assuming an average of six hours of electricity used per day) and the reported charge per ampere by each IPP. As shown in Table 4, the average tariff across all IPPs was found to be approximately $1.41 per kWh. Monrovia IPPs averaged $1.17 per kWh, while Non-Monrovia IPPs averaged $1.66 per kWh. Again, since IPPs do not meter electricity consumption, this tariff is only an estimate. If a consumer uses more or less electricity per month than the assumed average, then naturally this tariff will either rise or fall. For example, if over 12 hours of electricity is used per day by a certain customer, the tariff for one amp of service can range between $0.62 and $0.70 per kWh.

5 FINDINGS

Utilizing the survey results presented above, along with available and relevant external data, this section presents the main findings of the desk study, namely:

1. Total power generation capacity in Monrovia
2. Cost of electricity generated and sold in Liberia
3. Provision of electricity and coverage in Liberia

4. Total electricity generated and volume of fuels consumed in Liberia through informal power providers

5.1 Total Power Generation Capacity in Monrovia

Table 5 below shows that an estimated 44 percent of Monrovia's total generation capacity is through self-powered residences, while 25 percent is met by self-powered commercial and public establishments. LEC, meanwhile, provides approximately eight percent of the total Monrovia generation capacity.

Table 5: Monrovia Estimated Generation Capacity

Generation Source	Distributed by	Est. Known Total Generation Capacity (kW)
Paynesville HSD (2 x 0.3 MW)	LEC	600
Congo Town HSD (2 x 1.0 MW)	LEC	2,000
Kru Town HSD (5 x 1.0 MW)	LEC	5,000
Bushrod Island HSD (15 x 1.0 MW)	LEC	15,000
Small to medium diesel or gasoline generators	IPPs - Monrovia	28,889
Small diesel or gasoline generators	Residential Self Powered Generation	125,653
Small to medium diesel or gasoline generators	Commercial and Public	71,419
Large diesel or gasoline generators	Large Concessions/Industrial	35,890
	Total	**284,451**

Self-powered residences, commercial and public establishments, and large concessions/industrial comprise 82 percent of total electricity generation capacity in Monrovia and its surrounding urban environs.

IPP generation capacity was estimated using Norad's energy survey, as data from the end-user surveys was found to be unrepresentative of the IPP population and thus unusable. Using Norad's estimates, IPPs are thought to provide around 10 percent of Monrovia generation capacity – though this figure is likely only a notional estimate.

5.2 Cost of Electricity Generated and Sold in Liberia

The estimated cost of electricity generated and sold within Liberia is shown in Table 6. Data for the table was compiled from a variety of sources (each listed within the table), and shows a variety of estimates for costs of generation ($ per kWh) and relative tariffs (for those entities currently selling electricity). It can be noted that the costs for residential self-generation via diesel or gasoline generators is the highest, estimated at between $0.85 to $1.90 per kWh, depending on what factors beyond fuel cost are included. LEC's cost of generation – for fuel only – was estimated at $0.32 per kWh, while IPPs fuel costs were calculated as ranging from $ 0.34[8] to $0.66 per kWh. Through expanding its distribution network, LEC's lower costs and economies of scale should allow it to easily out compete almost all IPPs for market share. LESSP supported projects employing biomass fuel generators are able to produce electricity at between $0.33 and $0.38 per kWh, while the solar PV grid supported by LESSP in

[8] Eagle Power IPP was analyzed in more detail by LESSP; its generation costs were estimated at $0.34 to $0.45 per kWh, while the average cost of generation for the IPPs surveyed was calculated at $0.66 per kWh.

Gbarnway has an estimated cost of $0.51 per kWh – both of which include the costs of maintenance, deprecation, operation, etc.

As calculated, IPP tariffs are thought to be higher than LEC's as well as the cost of self-generation. Within the analysis and research completed under this study, their relative tariff was calculated as between $1.40 to $1.17 per kWh.

Of the current known tariffs, LEC's current tariff – shown as $0.54 per kWh – is naturally the most affordable. As calculated, IPP tariffs are thought to be higher than LEC's, and potentially higher than the cost of self-generation in some cases. Within the analysis and research completed under this study, IPP relative tariffs were calculated between $1.17 and $1.40 per kWh. No IPP employs electricity consumption meters, hence most tariffs are either based upon the ampere subscription of the client or a rough calculation based upon the number of lights and/or appliances within a customer's establishment.

Table 6: Cost of electricity generated and sold ($/kWh)

Source	Distributed by	Cost of Generation ($/kWh)	Est. Tariff ($/kWh)	Source(s)
Bushrod Island Substation via Monrovia HSD Power plants	LEC	$0.32	$0.54	
Small to medium diesel or gasoline generators	IPPs (Monrovia)	$0.66	$1.17	LESSP survey
Small to medium diesel or gasoline generators	IPPs (Non Monrovia)		$1.66	LESSP survey
Small to medium diesel or gasoline generators	IPPs (Monrovia)		$1.40 to $ 0.90	EU survey and Norad
Small to medium diesel generators	Eagle Power IPP (Monrovia)	$0.34 to $0.45	$0.78	LESSP Concept Paper
Small diesel and gasoline generators	Residences (Monrovia) - Self Powered Generation	$0.85		LESSP survey
Small diesel and gasoline generators	Residences (Monrovia) - Self Powered Generation (*including equipment depreciation, maintenance, etc.)	$1.90		EU survey
Small diesel and gasoline generators	Small Commercial Establishments (Monrovia) - Self Powered Generation	$0.72		LESSP survey
Small to medium diesel or gasoline generators	Medium Commercial and Institutional Establishments (Monrovia) - Self Powered Generation	$0.72		LESSP survey
Large diesel or gasoline generators	Industrial (Monrovia) - Self Powered Generation	$0.72		LESSP survey
Biomass generator	Sorlumba and Kwendin - LESSP	$0.33 to $0.38		LESSP Project
Solar PV array	Gbarnway - LESSP	$0.51		LESSP Project

5.3 Provision of Electricity and Coverage in Liberia

In Table 7, estimates are presented in regard to the calculated consumers per electricity distribution entity (LEC, IPP or Self-Generation), by region, and per consumer category. These figures are then projected over the assessed known total *national* population for that consumer category to arrive at an estimated 2014 electricity coverage percentage.

Table 7: Estimated Electricity Coverage in Liberia

Electricity Distributed by:	Consumer Category	2014 Estimated Consumers	2014 % Coverage vs. Liberia Known Population of Consumer Category
LEC	Residential/Pre-Paid	25,644	3%
	Commercial and Public	285	7%
IPPs - Monrovia	Residential, Commercial and Public	45,474	6%
Self-Generation - Monrovia	Residential	50,261	7%
	Commercial and Public	1,021	27%
	Industrial	25	100%
IPPs - Non-Monrovia	Residential, Commercial and Public	1,889	0.3%
Self-Generation - Non-Monrovia	Residential	16,474	2%
	Commercial and Public	1,242	33%
	Large Institutions/Commercial	134	100%
	Other/Large Concessions	3	100%

The figures for IPP coverage in Non-Monrovia areas are the lowest. This is likely due to the unknown total quantity of IPPs. Through a detailed census of all IPPs, these figures are expected to rise. However, any rise in IPP coverage will likely be limited. Most IPPs charge very high tariffs and cannot distribute electricity over large distances due to the design of their distribution systems and choice of generators. In addition, they are, as of yet, not legally allowed. Conversely, IPPs in Monrovia are estimated to serve approximately six percent of all projected residential, commercial and

Self-generation seems to be the overwhelming largest contributor to national electricity access – estimated to cover 10 percent of Liberian households, and 60 percent of Liberian commercial and public entities.

public consumers nationally, and 19,500 more total consumers than LEC.

Self-generation seems to be, by an overwhelming margin, the largest contributor to national electricity access – estimated to cover approximately 10 percent of Liberian households and 60 percent of Liberian commercial and public entities. These figures drop due to low generator usage within Non-Monrovia households; however, within Non-Monrovia commercial and public establishments the figures increase, likely due to the absence of LEC or IPP electric supply.

5.4 Total Electricity Generated and Volume of Fuels Consumed in Liberia through Informal Power Producers

Similar to Table 5, Table 8 provides an overview of the average kWh per year generated by the IPPs surveyed, as well as their average consumption (in gallons) of fuel per year, followed by the percentage of IPPs using diesel fuel over gasoline.

Again, over the total sample size, assuming the data is relevant enough to provide notional inferences, the average IPP within Liberia generates approximately 59,000 kWh per year, and consumes approximately 7,700 gallons of fuel. Also, approximately 60 percent of IPPs utilized diesel fueled generators for their power generation needs.

As the total quantity of IPPs is unknown, determining the total electricity generated and volumes of fuel consumed by the sub-sector is not possible at this time. Using the data available, it is estimated that 122 IPPs in Liberia generate approximately 7.2 GWh per year, consuming approximately 940,000 gallons fuel in the process.

Table 8: IPP findings

Location/Customer range	Number of IPPs (Num)	Ave. Electricity Generated (kWh per year)	Total Electricity Generated (kWh per year)	Ave. Volume of fuel (gallons per year)	Total Volume of fuel (gallons per year)	Fuel Source (% Diesel)
Monrovia (total)	62	50,808	3,150,072	6,235	386,573	82%
0-25	19	22,270	423,135	2,977	56,561	74%
25-50	24	37,872	908,927	4,957	118,957	75%
50-75	12	45,845	550,141	5,513	66,160	100%
75-100	3	34,007	102,022	4,498	13,495	100%
>100	4	291,462	1,165,847	32,850	131,400	100%
Non Monrovia (total)	60	67,439	4,046,311	9,200	551,993	35%
0-25	31	54,924	1,702,649	7,709	238,980	16%
25-50	19	103,963	1,975,306	13,862	263,387	74%
75-100	10	36,836	368,356	4,963	49,627	20%
Grand Total	**122**	**58,987**	**7,196,383**	**7,693**	**938,566**	**59%**

6 CONCLUSIONS AND RECOMMENDATIONS

A select number of conclusions and recommendations can be drawn from the study's key results and findings, presented above. Caution must be employed in any concluding statements, as the results shown illustrate only notional ideas of self-generation and IPP effects within the Liberian electricity sector.

That said, three main points can be drawn from the information presented.

i. Liberian households, businesses, and institutions are spending between $0.24 and $1.12 per kWh more for distributed electricity access than the LEC tariff, and at a minimum between $0.18 and $0.31 per kWh (solely in fuel costs) more for self-generated electricity access.

   As outlined above, of the current known tariffs, LEC's current tariff – estimated at $0.54 per kWh – is the most affordable. As calculated, IPP tariffs are thought to be higher than LEC's, and potentially higher than the cost of self-generation in some cases - calculated between $1.17 and $1.40 per kWh. However, no IPP employs electricity consumption meters, hence most tariffs are either based upon the ampere subscription of the client or a rough calculation, based upon the number of lights and/or appliances within a customer's establishment.

   Moreover, monthly electricity costs for a household subscribed to a typical Monrovia IPP – if they charged a calculated average of $1.17/kWh for a typical residential consumer – would cost approximately $70 per month for a yearly estimated urban residential consumption of 800 kWh (estimated within the Ficthner's LCPDP, 2013). Whereas when connected to LEC, the monthly fee would be approximately $32 per month – more than double that of a typical Monrovia IPP, per month, for likely less electricity. Again, since IPPs do not meter electricity consumption, the USD per kWh tariff is only an estimate. If a consumer uses more or less electricity per month than the assumed average, then naturally this tariff will either rise or fall. For example, if more than 12 hours of electricity is used per day by a certain customer, the tariff for one amp of service may range between $0.62 and $0.70 per kWh – which is still at least $0.08 per kWh above the LEC tariff. In addition, since IPP consumers do not pay based on metered consumption, their electricity usage can be easily manipulated by the hours of electricity provided by the IPP.

   Clearly electricity is a desired commodity, especially when considering that Liberian homes and businesses are willing to pay above double the price per kWh for access. This trend points to the need for, either faster paced LEC expansion, or a more formalized approach towards reducing the costs of self-generation as well as IPP generated electricity.

   Considering the impact to the projected quantity of total consumers (estimated at 45,000 consumers, including residential, commercial, and public) connected to the estimated IPPs in Monrovia alone – consumers as a group would hypothetically spend more $19 million per year on electricity from LEC (again conservatively assuming 800 kWh per year per consumer[9] consumption at the current tariff of $0.54/kWh). Assuming the IPP estimated tariff is accurate, consumers are paying approximately double their total bill, as

[9] Due to insufficient data on the quantity of consumers per category served by IPPs, only estimates for total consumers were made. Hence conservatively the value of 800 kWh per year estimated for the average residential yearly electricity usage within the LCPDP is used for all consumers. These figures are hypothetical and are mainly used to show the cost to the consumer, and theoretical lost revenue to LEC, for electricity access from an IPP in Monrovia.

compared to if they had access to LEC. Moreover, using Ficthner's estimate for yearly electricity consumption for an established residential electricity consumer – estimated at 1,300 kWh per year – as a group, consumers would hypothetically spend over $31 million per year on electricity from LEC. These projected estimates of the lost revenue to LEC are necessarily hypothetical, as some of the customers may not reside in areas readily accessible to LEC's current or planned medium term network. However, these estimates do represent a sizable level of suppressed energy demand.

It is evident electricity is a desired commodity, especially considering Liberian homes and businesses are willing to pay more than double the price per kWh for access. This trend points to the need for either faster paced LEC expansion or a more formalized, scaled approach towards reducing the costs of self-generation, as well as IPP-generated electricity, which is discussed below.

ii. Where LEC electricity is not accessible, the preferred choice is clearly self-generation, for those that can afford it (see Tables 3 and 5). Self-generation allows households and businesses the flexibility to have electricity when needed and can be sized to fit demand. However, self-generation is expensive - particularly in terms of its up-front capital costs - where costs range between $0.72 and $0.85 per kWh for fuel alone. Adding in the costs of equipment replacement, maintenance, etc., this cost can rise to as high as $1.90 per kWh. These high costs point to a need for an expanded array of self-generation options – from small consumer lighting products, to appropriate business scaled solutions. In the medium term, by eliminating or easing a number of economic cost barriers, much could be done to provide alternative solutions - from technology options (solar lanterns, PV kits, etc.) to effectively designed and scaled electrification programs (both urban and rural) that address the need and role of self-generation (and distributed generation in a larger sense).

iii. Finally, while the surveys conducted did not point to an overwhelmingly large IPP sub-sector, their role is nonetheless important, as they will likely be a continuing and growing factor in the Liberian electricity sector. Though they are not legally permitted within the current Energy Law, there is a clear need for greater contact and perhaps supervision (in lieu of formal regulations, for the time being) of these entities. The IPPs also require guidance. A good first step would be to encourage all IPPs to register with the GoL. While the legality of their operations is still denied, they could at least be trained on safety issues, proper tariff setting, house wiring inspection, generator sizing, etc. An additional step would be to encourage IPPs to provide the GoL with a uniform, monthly financial and statistical performance report. This would allow for a more patterned, organized utilization of IPPs, and potentially allow for a diversified, professional core set of generation/distribution companies to grow and compete within Liberia.

7 ACKNOWLEDGEMENTS

This study was funded through the USAID's LESSP; however it would not have been possible without the assistance and cooperation of the following entities and individuals:

The Society of Women Engineers in Liberia (SWEL) provided technical assistance through their four student enumerators and one senior power surveyor (Engr. Mambiyea Monica Wounuah) to conduct the survey.

The MLME management and their NVE consultants, particularly Mr. Ian Yarp (Senior Adviser), Mr. Edward Konneh (Assistant Director for Alternative Energy), Mr. Henry Kimber (NVE Program Manager), and Mr. Terje Lysford (NVE Consultant) were instrumental in providing assistance in acquiring necessary documents, approval, forms, and

other types of assistance for the survey and overall study. Mr. Konneh was also able to acquire information of contact details from the MoIA.

In the LEC, particularly Mr. Gregory Sylvestre, CEO, was a vital source of technical information and provided documentation used for the study.

LISGIS also provided information, particularly Dr. Ted Liberty, the Director, and Mr. Germue Gbawoquiya, the Assistant Director for Social Statistics, for general population information and exploring potential avenues for up-country surveying.

USAID, in collaboration with MLME, also provided databases and other information used in this study. Luis Velazquez, Engineering Officer, Office of Economic Growth , USAID Liberia, was instrumental in shaping the design of the study and providing review and feedback.

Other resources included the County Superintendents and LISGIS County Officers who provided county-specific information on electricity.

The survey would not have been possible without the participation of its various respondents and the hard work and dedication of the LESSP staff to plan, gather information, analyze, and produce this end report.

8. ANNEXES

ANNEX A. SAMPLE QUESTIONNAIRES

A.I RESIDENTIAL

USAID
FROM THE AMERICAN PEOPLE

Questionnaire Type _____ Survey Questionnaire No _____

Method of data collection _____ Location _____

Name(optional) _____ Date _____ Time Strated _____

Name of Interviewer _____ Time Ended _____

Country _____ City/Town _____ District _____ Area/Street _____

A. SOCIO-DEMOGRAPHIC INFORMATION.

1. Gender ☐ M ☐ F

2. Do you have electricity? ☐ Yes ☐ No

3. How many people reside in your home? _____

B. ELECTRICITY SOURCE

☐ LEC ☐ Self-Powered ☐ Informal Electricity Provider ☐ Other other_source _____

C. USAGE. CIRCLE/LIST ALL ANSWERS THAT APPLY, IN THE YEAR 2013, what best describes your electricity source and use.

1.Liberia Electricity Corporation (LEC)

a. How many hours are you connected to LEC? ☐ 0-1 ☐ 2 ☐ 4 ☐ 6 ☐ 8 ☐ 10 ☐ 12 ☐ 24

b. How long have you been connected? _____ months (record if more than two weeks)

2. Self-powered electricity.

a. What is the capacity of your generator?

☐ 2.5 ☐ 5 ☐ 10 ☐ 15 ☐ 20 ☐ 25 ☐ 30 ☐ 35 ☐ Other

Other_specify _____

b. How many hours do you run it? ☐ 0-1 ☐ 2 ☐ 4 ☐ 6 ☐ 8 ☐ 10 ☐ 12 ☐ 24

c. What type of fuel do you use? ☐ Diesel ☐ Gasoline ☐ Both

d. How many times do you buy fuel? _____ _____

e. How much fuel each time? _____ gal or _____ liter

f. How much do you pay for fuel? Gasoline _____ _____ _____

Diesel _____ _____ _____

g. Is there a noise problem? ☐ Yes ☐ No

h. Is there a smoke problem? ☐ Yes ☐ No

i. Have you had accidents? ☐ Yes ☐ No

3.Independent Service Provider

a. What is your amperage subscription? _____

b. What is the cost per amp? _____

c. How many hours are you connected? ☐ 0-1 ☐ 2 ☐ 4 ☐ 6 ☐ 8 ☐ 10 ☐ 12 ☐ 24

A.2 COMMERCIAL AND PUBLIC

USAID
FROM THE AMERICAN PEOPLE

Questionnaire Type _____ Survey Questionnaire No _____

Method of data collection _____ Location _____

Name(optional) _____ Date _____ Time Started _____

Name of Interviewer _____ Time Ended _____

County _____ City _____

District _____ Area/Street _____

Institution Type

☐ Hotel	☐ Restaurant	☐ Airport	☐ Fire Station	☐ Hospital
☐ Shop	☐ Church	☐ Seaport	☐ Industry	☐ Hospital(Public)
☐ Service	☐ UNMIL,Army	☐ Government	☐ Clinic	☐ University
☐ Embassy	☐ Stadium	☐ Stall	☐ School	☐ University(Public)
☐ NGO	☐ Bank	☐ Police	☐ School(Public)	

Name of Institution _____

A. SOCIO-DEMOGRAPHIC INFORMATION.

1. Gender ☐ M ☐ F _____ 2 Do you have electricity? ☐ Yes ☐ No _____

B. ELECTRICITY SOURCE. Specify Source

☐ LEC ☐ Informal Electricity Provider
☐ Self-Powered ☐ Other _____ _____

C. USAGE. CIRCLE/LIST ALL ANSWERS THAT APPLY, IN THE YEAR 2013, what best describes your electricity source and use.

1. Liberia Electricity Corporation (LEC)

a. How many hours are you connected to LEC? _____

b. How long have you been connected? _____ months (record if more than two weeks only)

2. Self-powered electricity

a. What is the capacity of your generator? (on average, if institution has multiple branches) Specify

☐ 2.5 ☐ 5 ☐ 10 ☐ 15 ☐ 20 ☐ 25 ☐ 30 ☐ 35 ☐ Other _____ _____

b. How many hours do you run it ? ☐ 0-1 ☐ 2 ☐ 4 ☐ 6 ☐ 8 ☐ 10 ☐ 12 ☐ 24

c. What type of fuel do you use? ☐ Diesel ☐ Gasoline ☐ Both

d. How many times do you buy fuel? _____ _____

e. How much fuel each time? _____ Gal _____ Liter

f. How much do you pay for fuel? Gasoline _____ _____ _____

Diesel _____ _____ _____

g. Is there a noise problem? ☐ Yes ☐ No

h. Is there a smoke problem? ☐ Yes ☐ No

i. Have you had accidents? ☐ Yes ☐ No

3. Independent Service Provider

a. What is your amperage subscription? _____

b. What is the cost per amp? _____

c. How many hours are you connected?

☐ 0-1 ☐ 2 ☐ 4 ☐ 6 ☐ 8 ☐ 10 ☐ 12 ☐ 24

A.3 INDEPENDENT POWER PRODUCERS

USAID
FROM THE AMERICAN PEOPLE

Questionnaire Type _____ Survey Questionnaire No _____

Method of data collection _____ Location _____

Name(optional) _____ Date _____ Time Started _____

Name of Interviewer Time Ended _____

Country _____ City _____ District _____ Area/Street _____

A. SERVICE PROVISION.

1. What types of buildings/institutions does your system/generator service? How many of each type are subscribed to your system?

Shops	Residences	Stalls	Restaurants	Churches/Mosques	Clinics	Others

2. What amperage subscription choices do you have? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 Other, specify _____

3. How many people are subscribed for each amperage?

1	2	3	4	5	Other

4. What is your cost per amperage? ☐ $30 ☐ $35 ☐ $40 ☐ $45 ☐ $50 ☐ $55 ☐ $60

5. What is the capacity of your generator? ☐ 2.5 ☐ 10 ☐ 20 ☐ 30 ☐ Other ☐ 5 ☐ 15 ☐ 25 ☐ 35

If more than one, specify number _____ If more than one, specify capacity _____

6. What are your hours of provision? _____ OR ANSWER (9)

7. How many hours do you provide electricity to your customers ☐ 0-1 ☐ 2 ☐ 4 ☐ 6 ☐ 8 ☐ 10 ☐ 12 ☐ 24

8. How long on average are your customers connected to your system? _____ months

9. Do you provide streetlights? ☐ Yes ☐ No If yes how many _____

B. ELECTRICITY SOURCE. Answer the average/usual. List all sources in 2013.

1. What type of fuel do you use? ☐ Diesel ☐ Gasoline ☐ Both

2. How many times do you buy fuel? _____

3. How much fuel each time? _____ gal _____ liter

4. How much on average do you pay for fuel? Gasoline _____ _____

Diesel _____ _____

C. SAFETY.

1. Is there a noise problem? ☐ Yes ☐ No 2. Is there a smoke problem? ☐ Yes ☐ No

3. Have you had accidents? ☐ Yes ☐ No 4. Other problems, specify _____

5. How often do you change your wires? _____

6. What date was this IPP established? _____

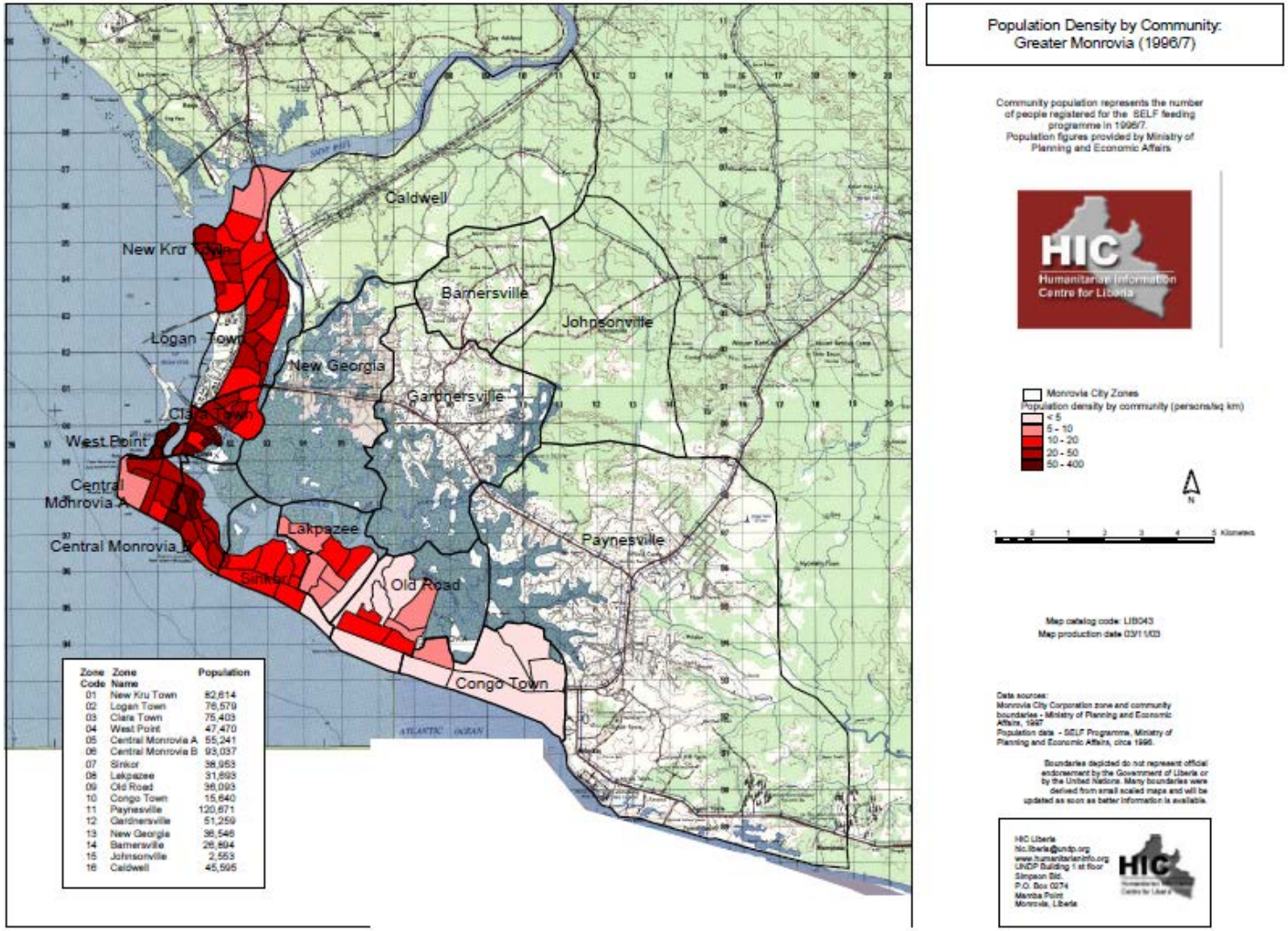
7. How close do you estimate the power lines of national electricity grid one to this IPP ? _____

8. How often does your transmission and distribution system need repairs? _____

Annex B. Survey Methodology, Maps, and Other Information

Survey Methodology Maps and Other Information

To determine the sample size, the study used the following a 1997 Greater Monrovia map for dividing the administrative regions:[10]



[10] Also used in the Comprehensive Food Security and Nutrition Survey (CFSNS) conducted on December 2006 through a joint collaboration of Liberia Institute of Statistics and Geo-Information Systems (LISGIS), Irish Aid, Food and Agriculture Organization (FAO), Unicef, World Food Programme (WFP), World Health Organization (WHO), and World Vision.

Annex C. Geographically Stratified Random Sampling

Geographically stratified random sampling

The 2008 census data on population sizes was used to determine the number of surveys to be conducted in each zone. The following table shows the division of surveys sample sizes:

No	Zone	Zone Name	Total	Surveys	Home	Hotel	Restaurant	Shop	NGOs	Church	Market stalls	School	Hospital/ Clinics	Industry	School	Electricity Business
a	*b*	*c*	*h*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*	*r*	*s*	*t*	*u*	*v*
1	01	New Kru Town	75,191	81	29	2	6	17	8	13	13	4	4	4	4	6
2	02	Logan Town	56,350	60	22	2	5	12	6	10	10	3	3	3	3	5
3	03	Clara Town	56,446	61	22	2	5	12	6	10	10	3	3	3	3	5
4	04	West Point	30,830	33	12	1	3	7	3	5	5	2	2	2	2	3
5	05	Central Monrovia A	44,897	48	18	1	4	10	5	8	8	2	2	2	2	4
6	06	Central Monrovia B	40,922	44	16	1	3	9	5	7	7	2	2	2	2	3
7	07	Sinkor	42,041	45	16	1	3	9	5	7	7	2	2	2	2	3
8	08	Lakpazee	40,753	44	16	1	3	9	4	7	7	2	2	2	2	3
9	09	Old Road	49,012	53	19	1	4	11	5	8	8	2	2	2	2	4
10	10	Congo Town	25,321	27	10	1	2	6	3	4	4	1	1	1	1	2
11	11	Paynesville	304,745	327	119	9	25	67	34	52	52	16	16	16	16	25
12	12	Gardners-ville	81,590	88	32	2	7	18	9	14	14	4	4	4	4	7
13	13	New Georgia	58,958	63	23	2	5	13	6	10	10	3	3	3	3	5
14	14	Barnesville	36,014	39	14	1	3	8	4	6	6	2	2	2	2	3
15	15	Johnsonville	10,180	11	4	0	1	2	1	2	2	1	1	1	1	1
16	16	Caldwell	27,754	30	11	1	2	6	3	5	5	1	1	1	1	2
		TOTAL:		**1053**	**384**	**30**	**80**	**217**	**108**	**169**	**169**	**50**	**50**	**50**	**50**	**80**

Annex D. Definitions

Definitions

Electricity is at a minimum having one to three light bulbs in the house and/or a radio, fan, and other small appliances. A connection is defined as a building or establishment that is or can be connected to the same electricity source though it need not be only one. Buildings or establishments can mean: residences or households,[11] hotels, restaurants, churches/mosques/religious establishments, shops, services, embassies, markets and their corresponding stalls, embassies, NGO offices, UNMIL and other army headquarters, stadium, banks, schools, universities, hospitals, clinics, police and fire stations, airport, seaport, concession companies, government offices, and industrial building. Households are defined as a group of individuals living in the same small house or building with or can have one connection to LEC, an independent power provider, or their own generator.

11

Annex E. Challenges

Challenges

Some challenges faced during the survey included the following:

1. A major challenge was the lack of information on which to base the sample in regards to the commercial and public establishments.
2. Another challenge was that interview skills and consistency filling up the questionnaires in spite of training and supervision. This resulted in extensive review, cleaning, and additional assumptions made for the data.
3. According to the surveyors, survey challenges included:
    a. That commercial loss seemed to be prevalent; these IPPs refused to speak to the enumerators and enumerators did not seek them out.
    b. Some establishments and/or IPPs did not participate for various reasons such as busyness and fear that their competitors or the government will use the information.
    c. Some of the selected establishments and/or residents did not have persons capable of giving information on the electricity or were otherwise unavailable for the survey.
    d. Some residential connections had only women, who did not have full knowledge of the electricity information in their residences.

Prioritizing ease of surveying can lead to non-randomized sampling; however, since the enumerators divided the districts among themselves within each survey zone, each area will be represented in the sample. Non-response bias was probable due to unwillingness of interviewees to participate; phone interviews also had problems of no connection, incorrect phone number, or no response with around 30% response rate.

Annex F. Works Cited and External Data

Works Cited and External Data

Wülbek, Hans-Friedrich. Fichtner. August 2013. Draft Final Report of "Preparation of a Government of Liberia Least Cost Power Development Plan."

Modi, Vijay, Edwin Adkins, Jonathan Carbajal, Shaky Sherpa with contributions from Naichen Zhao. Department of Mechanical Engineering (SEAS) and Earth Institute Columbia University: Modi Research Group, Energy Planning Team
National Electrification Master Plan."

Dr. Cota, Alma and Engr. Michael McGovern. USAID LESSP. October 2013. "Expansion of Eagle Power Capacity Using Renewable Energy Technology and (2) Improvements to the Electricity Distribution System."

Government of Liberia. March – April 2006. "Republic of Liberia: Comprehensive Food Security and Nutrition Survey."

MLME. May 2009. " Republic of Liberia's National Energy Policy: An Agenda for Action and Economic and Social Development."

S. Ulseth, Å. Königson, J. Arntsen, G. Tamm. NORAD (Norwegian Agency for Development Cooperation). March 2011. "Norwegian Support to the Liberian Energy Sector: Baseline Study and RBM System."

MWH (Montgomery Watson Harza), Gaillard, Roger and Laurence Wilhem. March 2012. "Evaluation of EU funding in Liberia and Recommendations."

NORAD on behalf of MLME. April 2009. "A Fast Track Comparative Analysis of the Various Power Generation Options Available to Liberia/Simplified Power System Master Plan – A Decision-Making Primer."

RREA and MLME. 2013. "Liberia Investment Plan for Renewable Energy (IPRE) and Scaling Up Renewable Energy Program (SREP)."

The World Bank Group. 2011. "Options for the Development of Liberia's Energy Sector."

The World Bank and the International Finance Corporation (IFC). 2009. Liberia Country Profile.

The World Bank. June 2011. Map of Liberia's Major Demand Centers.

The World Bank. May 2013. Map of Liberia's Main Population Areas.

USAID. 2013. "Mid-Term Report of the Liberian Energy Sector Support Program (LESSP)."

Dr. Jayjay, Roosevelt D. MLME Possibly 2008. "An Overview of the Investment Opportunities in the Energy Sector of Liberia."

The World Bank. May 2013. "Project Appraisal Document on a Proposed Credit In the Amount of SDR 23.4 Million (US$ 35 Million Equivalent) to the Republic of Liberia for an Accelerated Electricity Expansion Project."

Statistics Canada. 2010. "Survey Methods: Catalogue No. 12-587-X."

Montaquilla, Jill M. and Kristen M. Olson. April 2012. "Practical Tools for Non-Response Bias."

Dewey, Jennifer. NCREL. September 2000. "Guidelines for Interviewing."

The World Bank, Foster, Vivian and Nataliya Pushak. March 2011. Policy Research Working Paper 5597. "Liberia's Infrastructure: A Continental Perspective."

The World Bank, Bhatia, Mikul. May 2013. SREP Pilot Country Meeting. "Defining and Measuring Access to Energy."

LEC. LEC F.Y. 2014 Qtr. 4 Report. April 1st to June 30th, 2014. "Quarterly Progress Report."

LEC. LEC Monthly Report. June 1 - June 30, 2014. "Quarterly Progress Report."

Liberia Institute of Statistics and Geo-Information Systems (LISGIS). May 2009. "2008 National Population and Housing Census (NPHC)."

Liberia Institute of Statistics and Geo-Information Systems (LISGIS). June 2008. "2008 National Population and Housing Census (NPHC): Preliminary Results."

UNDP and WHO, Sustainable Energy Program: Environment and Energy Group. November 2009. "The Energy Access Situation in Developing Countries."

HIC (Humanitarian Information Centre for Liberia). September 2003. Liberia County Maps.

Lutheran Training Institute (LTI). 2011. "Report of Load Demand Assessment and Socio-Economic Survey Conducted in Salayea District." Submitted to USAID LESSP.

USAID LESSP. May 2011. "Load Demand Assessment and Socio-Economic Survey for Proposed Mein River Mini Hydropower Project."

Stroup. June 2009. Catalyzing New Renewable Energy in Rural Liberia: World Bank Mission. "Yandohun: Socio-Economic Characteristics."

USAID LESSP. November 2013. "Program Brief."

USAID Self-Powered Generation Database.

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-000
Fax: (202) 216-3524
www.usaid.gov