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POWER AFRICA
A U.S. GOVERNMENT-LED PARTNERSHIP

ASSESSMENT OF CURRENT AND POTENTIAL FUTURE OFF-GRID PRODUCTIVE USE OF ENERGY PRODUCTS

LIBERIA

OCTOBER 2020

Power Africa Off-grid Project

ABOUT POWER AFRICA

The Power Africa Off-grid Project is a four-year program that launched in November 2018 to accelerate off-grid electrification across sub-Saharan Africa. RTI International implements the project in collaboration with Fraym, Norton Rose Fulbright, Practical Action Consulting, and Tetra Tech. Power Africa is a U.S. Government-led partnership that brings together the collective resources of over 170 public and private sector partners to double access to electricity in sub-Saharan Africa.

Power Africa aims to achieve 30,000 megawatts of new generated power, create 60 million new connections, and reach 300 million Africans by 2030.

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ACRONYMS AND ABBREVIATIONS

AECF	Africa Enterprise Challenge Fund
AfDB	African Development Bank
BGFA	Beyond the Grid Fund for Africa
CBDSPL	Consortium of Business Development Service Providers of Liberia
CBL	Central Bank of Liberia
CDA	Cooperative Development Agency
CLSG	Côte d'Ivoire, Liberia, Sierra Leone, and Guinea
CNFA	Cultivating New Frontiers in Agriculture
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Center for Renewable Energy and Energy Efficiency
ELL	Electricity Law of Liberia
ELR	Electricity Licensing Regulations
EnDev	Energizing Development
EPA	Environmental Protection Agency
EPASES	ECOWAS Programme on Access to Sustainable Electricity Services
EU	European Union
FTF	Feed the Future
GN Bank	*Groupe Nduom* Bank Liberia Limited
GOGLA	Global Association for the Off-grid Solar Energy Industry
GTB	Guaranty Trust Bank Liberia
IDA	International Development Association
IPPs	Independent Power Producers
IPRE	Investment Plan for Renewable Energy
KII	Key Informant Interview
kV	Kilovolt
LACEEP	Liberia Accelerated Electricity Expansion Project
LADA	Liberia Agribusiness Development Activity
LEC	Liberia Electricity Corporation
LEEAP	Liberia Energy Efficiency and Access Project
LEG	Liberia Engineering and Geo-Tech
LEN	Liberian Energy Network
LERC	Liberia Electricity Regulatory Commission

LIRENAP	Liberia Renewable Energy Access Project
LUL	Light Up Liberia
LUOF	Light Up Our Future
MCA_L	Millennium Challenge Account Liberia
MME	Ministry of Mines and Energy
MOA	Ministry of Agriculture
MW	Megawatts
NEPL	National Energy Policy for Liberia
NGO	Nongovernmental Organization
NIC	National Investment Commission
NPA	National Port Authority
PAYGO	Pay-as-you-go
PUE	Productive Use of Energy
PV	Photovoltaic
RDFI	Rubber Development Fund Incorporated
REACT SSA	Renewable Energy and Adaption to Climate Change Technologies in sub-Saharan Africa
REFUND	Rural Energy Fund
RESMP	Rural Energy Strategy and Master Plan for Liberia
REWG	Rural Energy Working Group
ROGEP	Regional Off-Grid Electrification Project
RREA	Rural and Renewable Energy Agency
RTI	Research Triangle Institute
SE4Life	Sustainable Energy 4 Life
SEforALL	Sustainable Energy for All
SHS	Solar Home Systems
SIDA	Swedish International Development Agency
SJEDI	Sustainable Joint Energy Development Initiative
SMEs	Small and Medium-sized Enterprises
TV	Television
USADF	United States African Development Foundation
USAID	United States Agency for International Development
VOSIEDA	Volunteers for Sustainable Development in Africa
WAPP	West African Power Pool
WB	World Bank
Wp	Watt Peak

EXECUTIVE SUMMARY

Power Africa is a U.S. Government-led partnership that brings together the collective resources of over 170 public and private sector partners to double access to electricity in sub-Saharan Africa. Power Africa's goal is to add more than 30,000 megawatts (MW) of new electricity generation capacity and connect 60 million new homes and businesses to power by 2030.

Contributing to this goal, the USAID-funded Power Africa Off-grid Project works to improve off-grid energy policies and regulations; catalyze new investment capital; and facilitate six million new off-grid electricity connections in sub-Saharan Africa by 2022. Power Africa defines "access" as the direct or actual number of new households and businesses connected to electricity via an on- or off-grid solution.

As part of the project implementation process in Liberia to support off-grid solar expansion, a productive use of energy (PUE) assessment was conducted from April to September 2020 to collect, analyze, and present key market information to support the development of the off-grid energy sector in Liberia.

The primary objective of this report is to provide policymakers, off-grid energy companies, investors, and donors with information on Liberia's current and potential future demand for off-grid productive use of energy products to inform strategies for market expansion.

The approach and methodology used in the assessment included:

- Design of the assessment.
- Development of assessment tools.
- Literature review of relevant reports and other publications.
- Conducting stakeholder interviews.
- Data cleaning, analysis, and interpretation of assessment findings.
- Development of this report.

The assessment focused on stakeholders in the off-grid energy sector in Liberia with specific reference to those involved in PUE, including:

- Technology and solution providers.
- Energy product/input supply firms, energy demand firms, and their value chains.
- Supporting services organizations such as banks.
- Public sector agencies and international players such as the World Bank, European Union (EU), etc.

To curtail and prevent the spread of COVID-19, the government of Liberia instituted periods of lockdown during 2020, suspending major socio-economic activities and public gatherings. These measures impacted the implementation of the assessment methodology, because sectors employing the majority of targeted respondents were either not permitted to continue normal operation or allocated limited time for the questionnaire. Stakeholder interviews were conducted via phone calls, email correspondence, and occasional Zoom calls.

Basic productive uses of energy include dryers for food preservation; cold storage for meat, milk, fruit, and vegetables; and solar graters (solar-powered devices that cut agricultural produce such as cassava and plantain into smaller pieces) used in agro-processing. The development of the PUE market especially in the agricultural sector will help to alleviate poverty and support the economic development of rural Liberia.

Table 1 summarizes key assessment findings related to each of the stakeholder sectors assessed:

TABLE 1. SUMMARY OF KEY FINDINGS

STAKEHOLDER SECTOR	SECTOR DESCRIPTION	SUMMARY OF KEY FINDINGS
Energy product and input supply firms	Energy product and agriculture equipment supply firms	Limited availability of PUE products
		Lack of PUE product awareness
		Relatively high PUE product uptake investment cost
		Limited business management and technical capacity
		Limited mobile network reliability
		Poor enabling infrastructure
Energy demand in key agriculture value chains	Organizations including cooperatives that use energy for productive use	High potential PUE demand
		Relatively high cost of PUE products/inputs
		Limited access to finance (loans and grants) to finance PUE products/input acquisition
		Need for more off-grid PUE generation solutions
Supporting services (access to finance)	Companies providing finance and financial technology for energy-agriculture e.g. banks and other financial organizations	Limited PUE project knowledge and awareness
		High PUE investment costs
		Restrictive ownership structure
		Perceived limited ability to pay
		Shortage of skilled PUE technicians
Public sector	Government agencies and programs supporting energy especially for agriculture	Limited policy focus on PUE
		Limited collaboration and coordination
		Slow development of regulations
		High tariff on PUE products
Development partners	Local and international NGOs, programs, foreign governments, donor agencies supporting energy sector development especially for agriculture	Lack of specific PUE support programs
		Limited sectorial progress measurement and oversight
		Need for more effective collaboration
Women	Gender considerations in agricultural value chains	Limited access to land for PUE installations
		Limited access to profitable cash crops
		Low affordability of PUE products/services
		No gender inclusive productive use energy policies/programs
		Limited access to finance and markets

Although the current market for PUE in Liberia is still in a very early stage, there is clearly a high demand and potential growth market for PUE products. Based on the assessment findings, the following key recommendations can be drawn to optimize PUE in Liberia.

Sector coordination

› Strengthen coordination between public entities, international players, supporting service providers, and private sector companies to develop, review, and update relevant PUE policies and regulations.

Policy and regulatory support

› Increase the off-grid standalone duty waiver to include PUE loads above 350 Wp.

› Update existing policies to create, enable, and diversify the power generation, transmission, and distribution for PUE as well as supporting PUE product market development.

› Establish more effective donor oversight, specifically in the measurement of energy sector progress and updating and implementation of energy policies. This oversight could identify gaps in the energy industry such as the lack of focus on PUE development.

Technical assistance to private companies

› Provide business development, capacity building, and technical support to private organizations to grow their capacity to increase sales/distribution and access finance to expand PUE in rural areas of Liberia.

› Provide technical support in terms of training and equipment to private and government owned technical institutions (such as Liberia Opportunities Industrialization Center) to train and develop technicians with specialties in PUE. Such training can also target women to increase gender diversity in a sector traditionally dominated by men.

Access to finance

› Engage financial institutions and the Central Bank of Liberia (CBL) to improve and expand electronic payment platforms needed to increase accountability, transparency, and sustainability for PUE systems.

› Provide support to financial institutions through awareness creation about the PUE sector; linkage to funding opportunities for energy development that can be used for PUE financing; and the development of financial products and services to increase access to finance for PUE product suppliers and for acquisition by local businesses.

Gender mainstreaming

› Develop energy policies and programs for PUE to revitalize the rural economy, including agricultural production, processing, and marketing with a clear focus on the role and participation of women.

› Expand capacity for women's participation in the PUE sector – particularly understanding women's energy needs – to promote the uptake of productive use technologies through policy guidelines, awareness creation, capacity building, provision of business development and funding support targeted at increasing women's involvement in energy businesses.

1 BACKGROUND AND METHODOLOGY

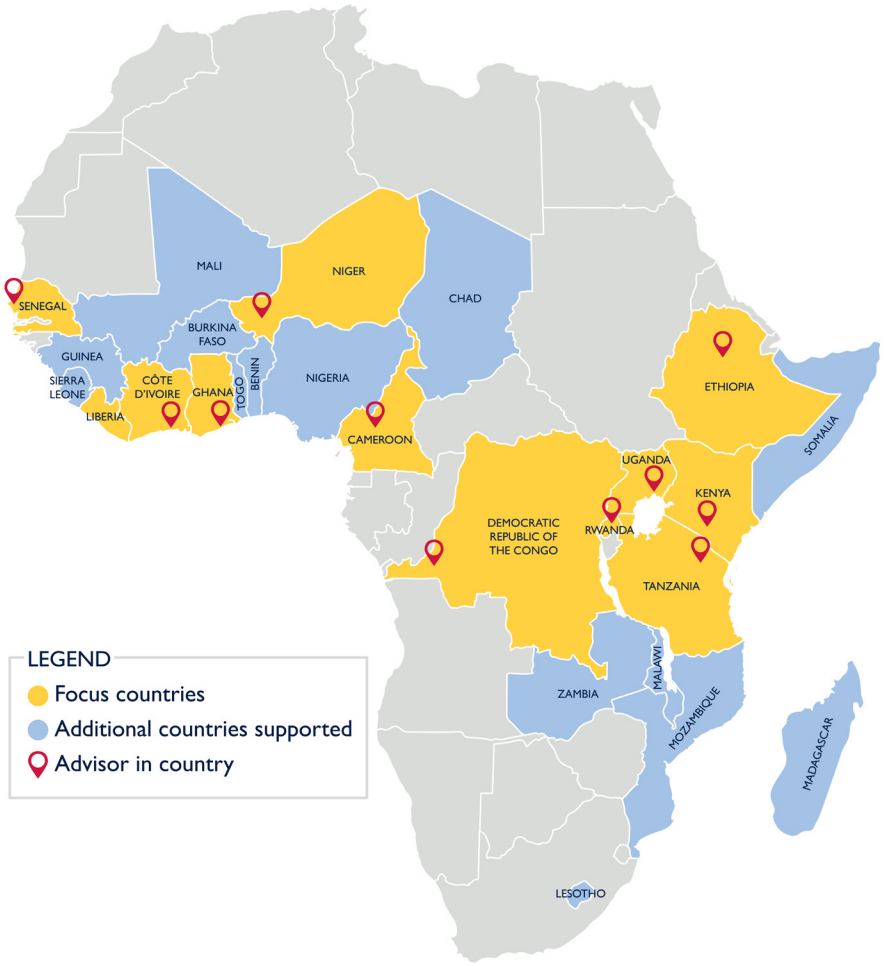
1.1 ABOUT POWER AFRICA AND THE POWER AFRICA OFF-GRID PROJECT

Power Africa is a U.S. Government-led partnership that brings together the collective resources of over 170 public and private sector partners to double access to electricity in sub-Saharan Africa. Power Africa's goal is to add more than 30,000 MW of new electricity generation capacity and connect 60 million new homes and businesses to power by 2030.

Contributing to this goal, the USAID-funded Power Africa Off-grid Project works to improve off-grid energy policies and regulations; catalyze new investment capital; and facilitate six million new off-grid electricity connections in sub-Saharan Africa by 2022.

Figure 1 identifies the countries in sub-Saharan Africa currently receiving support from the Power Africa Off-grid Project, with the Project's focus countries highlighted in yellow.

FIGURE 1. THE PROJECT PROVIDES SUPPORT TO 26 COUNTRIES IN SUB-SAHARAN AFRICA



By improving market and regulatory structures, as well as improving access to private capital for the commercial off-grid sector, the Project substantially increases energy access through off-grid energy solutions and enables better developmental outcomes for those who gain access to these energy solutions.

1.2 SCOPE OF THE STUDY AND METHODOLOGY

This report highlights the findings from an assessment (conducted April to September 2020) of the PUE sector in Liberia. The objectives of the PUE assessment were to analyze and present findings on:

› Off-grid PUE technologies and supply chains in Liberia.

› Current and potential future demand for off-grid PUE technologies.

› The role of supporting services to the energy and agriculture sectors.

› Areas of assistance to support off-grid energy companies with diversifying into the PUE market.

The scope of the assessment included:

› Organize and hold meetings with relevant stakeholders in Liberia, as required, including off-grid energy companies, international organizations with off-grid programs, financial institutions, government ministries (National Investment Commission, Liberia Energy and Regulatory Commission, etc.), and others working in the country's energy sector.

› Interview stakeholders to gather relevant productive use data related to the off-grid energy sector, including technology and solution providers; energy product/input supply; energy demand and their value chain; supporting services; off-grid policies and regulations; and international players.

› Ensure that women's views are included – at the time of the assessment there were no Liberian off-grid energy companies managed by women, but the assessment team held meetings with several women-owned and run agricultural producers and non-governmental organizations (NGOs) that support women.

› Analyze data collected through stakeholder consultations and develop narratives on findings and recommendations to be shared with relevant stakeholders including development partners, the Government of Liberia, and off-grid energy companies in Liberia.

The assessment team appplied a detailed methodology framework to obtain the relevant data (outlined in Annex 2). Table 2 outlines the main sectors assessed, as well as the assessment objectives for each sector.

TABLE 2. ASSESSMENT SECTORS

SECTOR	DESCRIPTION	ASSESSMENT OBJECTIVES
Energy product and input supply firms	Energy product and agriculture equipment supply firms	› Assess supplier strategies and challenges in reaching target markets including market barriers and access to finance › Catalogue technologies available › Highlight the business models in this report
Energy demand in key agriculture value chains	Organizations including cooperatives that use energy for productive use	› Understand the dynamic of the organizations, farmers' cooperatives, and big buyers and how they get access to agriculture devices and energy › Assess value chain and energy needs › Understand women's participation in the value chain
Supporting services (access to finance)	Companies providing finance and financial technology for energy-agriculture e.g. banks and other financial organizations	› Assess organizations that provide supporting services such as finance in support of the energy/agricultural development in Liberia
Public sector	Government agencies and programs supporting energy especially for agriculture	› Assess public sector organizations that support the energy/agricultural development in Liberia › Identify sectorial support at national and regional levels, programs/ projects, and existing policies

TABLE 2. ASSESSMENT SECTORS, CONTINUED		
SECTOR	DESCRIPTION	ASSESSMENT OBJECTIVES
Development partners	Local and international NGOs, programs, foreign governments, donor agencies supporting energy sector development especially for agriculture	› Assess and understand various international players, including NGOs in the sector › Identify projects/programs supporting energy development generation, distribution, and access – particularly for the agricultural sector

1.3 OVERVIEW OF LIBERIA'S ENERGY SECTOR

Liberia has one of the lowest rates of electrification in the world. Roughly 17 percent of the urban population and 2 percent of the rural population have access to electricity.[1] In line with the Sustainable Development Goals, Liberia is working to attain 70 percent electrification of the capital city and 35 percent of rural areas by 2030, but much remains to be done, particularly in rural regions.[2]

Four key government institutions oversee Liberia's state-run energy sector: The Ministry of Mines and Energy (MME), the Liberia Electricity Corporation (LEC), the Rural and Renewable Energy Agency (RREA), and the Liberian Electricity Regulatory Commission (LERC). In addition, the West African Power Pool (WAPP) manages the cooperation of national electricity providers in West Africa.

Of relevance for PUE technologies, the RREA is tasked with expanding access to electricity with renewable energy technologies by supporting the development of the commercial energy sector, facilitating project funding for energy projects, promoting renewable energy, and integrating energy into development planning across rural Liberia.[3] RREA's flagship initiative has been the Lighting Lives in Liberia (LLL) program, which has been importing solar products for distribution to rural communities through private Liberian distributors. RREA also plans to establish a rural energy fund (REFUND) to provide low-interest loans, grants and subsidies aimed to make electricity more affordable for low-income consumers.

Liberia's energy sector is governed by several energy policies and strategies. These include:

› The National Energy Policy (NEP) which establishes the Government of Liberia's goal that all Liberians will have access to affordable modern energy

› The National Renewable Energy Action Plans (NREAPs) outline targets to develop the renewable energy sector of Liberia from 2015 to 2030, based on the goals outlined in the NEP. The NREAP indicates specific targets of 100 percent of the rural population with access to renewable electricity (mini-grids or SHS systems).

› The National Energy Efficiency Action Plan (NEEAP).

› The Pro-Poor Agenda for Prosperity and Development (PAPD). The PAPD is organized around four pillars: Empowering the people, economy and jobs, sustaining peace, and governance and transparency.

Section 1.4 below provides a broader overview of the PUE market in Liberia.

[1] Liberia - SEforALL Africa Hub. se4all-africa.org
[2] Power Africa. Liberia Fact Sheet. https://www.usaid.gov/powerafrica/liberia
[3] Sandikie. National Renewable Energy Action Plans (NREAPs). 2015. http://www.se4all.ecreee.org/sites/default/files/national_renewable_energy_action_plans_nreap_-_liberia.pdf

1.4 OVERVIEW OF LIBERIA'S AGRICULTURAL SECTOR

Agriculture is the primary livelihood for more than 60 percent of Liberia's population and provides sustenance for many households engaging in cassava, rubber, rice, palm oil, cocoa, and sugarcane production, with more households engaged in cassava production than any other crop. However, overall agricultural productivity is relatively low, resulting in Liberia importing more than 80 percent of its rice, making the country vulnerable to global food price volatility.[4] Cassava and rice are the primary staple food crops.

TABLE 3. LIBERIA AGRICULTURE TOTAL MARKET SIZE

LIBERIA AGRICULTURE TOTAL MARKET SIZE	2015	2016	2017	2018 (ESTIMATED)
Total local production	$896.4 million	$882.1 million	$904.1 million	$939.4 million
Total exports	$283.3 million	$279.3 million	$388.8 million	unknown
Total imports	$1,551.4 million	$1,201.2 million	$1,018.2 million	unknown
Imports from the United States	$136.6 million	$87.9 million	$81.6 million	unknown
Total market size*	$2,164.5 million	$1,804 million	$1,533.5 million	unknown

**Total market size = (total local production + imports) – exports. Source: Central Bank of Liberia, Annual Report 2017, Page 38.*

Export crops: The main export crops and foreign exchange earners in Liberia are rubber, cocoa, and timber. Rubber is one of the dominant generators of state revenues, accounting for 17.5 percent of the total export receipts in 2017. An estimated 30,000 people are employed by commercial rubber farms and up to 60,000 smallholder households are involved in growing rubber trees. Firestone Rubber Plantation, covering almost 200 square miles, is the largest single natural rubber operation in the world and the biggest private sector employer in Liberia. Another significant cash crop is palm oil, which has traditionally been produced for the domestic market. Recently, there has been considerable interest from both smallholders and large investors in expanding export production. However, uncertainty regarding land tenure is a significant challenge for potential palm oil farmers and investors. Liberia has the favorable climate and fertile soil for cocoa production and there is increased investment in the rehabilitation of cooperative and smallholder farms in the country.

Local crops: Beside these cash crops, there are market opportunities and potential for agribusiness investment in the development of the value chains of food crops such as rice, cassava, vegetables, fruit, poultry, and fish. Liberia's climate is also suitable for horticulture such as production of peppers, okra, onions, tomatoes, squash, etc., which are in high demand throughout the country all year round.[5] Lowland cultivation and low-cost irrigation could give smallholders an opportunity to increase productivity and expand market share of these valuable crops. Stakeholders in Liberia's main cash crops of palm oil, cocoa and rubber include smallholder farmer cooperatives, individual farmers, large multinational corporations, and concessionaires, as well as individuals playing various intermediation roles such as buying agents and support services, including banks who mainly handle export financing. Liberia has an Atlantic coastline spanning about 580 kilometers, which is endowed with abundant marine fish stocks. The coastline and abundant freshwater resources provide breeding grounds for a variety of marine species including crab, lobster, shrimp, tilapia, tuna, shark, croaker, and barracuda.

Key challenges and opportunities: Some of the key challenges within the agricultural sector in Liberia include poorly integrated commodity value chains; lack of basic infrastructure such as processing machines, farming equipment and tools, farm-to-market roads, fertilizers and pesticides; and food storage facility capacity. Other obstacles include limited access to finance, poor agribusiness management skills, and lack of

[4] SelectUSA. Liberia - Agricultural Sectors. 2019. https://www.selectusa.gov/article?id=Liberia-Agricultural-Sectors
[5] Ibid.

professional expertise to increase farm productivity. However, the sector provides opportunities for private financing of the agriculture value chain of palm oil, cocoa, coffee, and Liberia's staple foods, rice and cassava. Opportunities include development financing, microfinance, business development, and cross-cutting areas such as agro-inputs, agro-logistics, packaging, storage, and aggregators.

Agricultural energy services: Energy access in Liberia represents a significant challenge, as the country has one of the lowest electrification rates in the world. In 2016, an estimated 88 percent of the population – over four million people – did not have access to electricity, with a significant disparity in rates of access between urban (16 percent access) and rural (3 percent access) areas (Energy Outlook 2017). Although the agricultural sector in Liberia is mostly artisanal at present there is a potential high demand for energy services particularly in poorly grid serviced areas. Agro-based concessions, such as rubber and other mechanized activities, produce electricity mainly from generators for their own consumption. Demand for energy in agriculture in the short, medium, and long term will be significant. Energy access and PUE equipment solutions could play an incremental role in developing the value chain of available food crops and bring an added value to existing processes.

This includes a range of solutions for storage, processing and preservation of fish and animal products, vegetables and fruit, such as peppers, okra, grains, tomatoes, banana, mangoes, oranges, and pineapples, which are in demand all year round. There is also PUE potential for the processing of palm oil, cocoa, coffee, and Liberia's staple foods, rice, and cassava. Table 4 provides a broader mapping of potential energy needs and potential renewable energy solutions which could be adopted by some of the key value chains such as cassava, horticulture, palm oil, cocoa, and fishing.

TABLE 4. ENERGY NEEDS AND POTENTIAL RENEWABLE ENERGY SOLUTIONS

AGRICULTURAL SUB SECTORS	FISHING	CASSAVA	FRUIT AND VEGETABLES	PALM OIL	COCOA
Production	Solar lights for fishermen	Solar water pumps for irrigation		Solar water pumps for irrigation, including nurseries	
Post-harvest management/ storage	Cold storage: Cold chambers/containers for refrigeration or freezing Solar refrigerators Solar freezers Ice production machines	Solar dryers	Cold storage: Cold chambers/ containers for refrigeration Solar refrigerators	N/A	Solar dryers
Processing	Solar dryers and smokers	Solar powered cassava graters	Drying: Solar dryers Transformation: Solar powered manufactory	Presses for oil extraction Solar oil presses	Roasting and cocoa butter production; Solar powered factory (commercial and industrial)
Waste valorization for energy	N/A	N/A	Biogas potential	Biogas and direct biomass potential for valorization	Potential biomass valorization of shells
Distribution	Solar powered refrigerated distribution trucks	N/A	Solar powered refrigerated distribution trucks	N/A	N/A

2 ENERGY PRODUCT AND INPUT SUPPLY FIRMS

Nearly 30 companies currently operate in Liberia's solar energy sector, offering a wide range of products and services to both on- and off-grid customers throughout the country[6], including importers, distributors, wholesalers, retailers, NGOs, and end-users. Private Liberian-owned companies and a few foreign companies dominate the energy product market in Liberia. Most private energy companies in Liberia are currently focused on providing power for household lighting and powering appliances for mainly entertainment purposes through the deployment of solar lanterns and standalone SHS. Few companies distribute systems specifically for PUE. The main firms and suppliers of renewable energy products in Liberia that could be applied for productive uses are outlined in Table 5.

TABLE 5. SAMPLE OF KEY ENERGY PRODUCT/INPUT SUPPLIERS

COMPANY NAME	DESCRIPTION OF PRODUCTS/ SERVICES
African Energy	› Solar water pumps › Solar refrigerators › Solar batteries and accessories
EcoPower Liberia	› SHS › Inverters/solar panels › Solar water pump irrigation systems › Solar food dryers › Off-grid customized solar systems
Easy Solar Liberia	› SHS › Solar water pump irrigation systems
Green Gold Inc.	› Bioenergy technologies systems › Bio-briquettes/biogas/biofuel › Improved cook stoves
Integrated services and equipment	› Solar water pumping
Liberian Energy Network (LEN)	› Solar lanterns › Inverters/solar panels › Solar installation and maintenance
LIB Solar	› SHS › Solar refrigerators for small businesses
Malnutrition Matters	› Electric food processors › Food dryers
Oasis Africa Resources Limited	› SHS
SJEDI	› Solar lanterns › SHS › Inverters/solar panels › Efficient cook stoves
Sun Star Green Energy	› Solar lanterns › SHS › Inverters/solar panels › Solar installation and maintenance

[6] World Bank. Regional Off-grid Electrification Project. 2018. http://documents1.worldbank.org/curated/en/705201535029941781/pdf/129620-PSDS-P160708-PUBLIC.pdf

TABLE 5. SAMPLE OF KEY ENERGY PRODUCT/INPUT SUPPLIERS, CONTINUED

COMPANY NAME	DESCRIPTION OF PRODUCTS/ SERVICES
Sustainable Energy for Life	› SHS › Solar PV water pumps › Solar dryers
Union Strong Group	› Inverters/solar panels › Solar batteries and accessories › Improved cook stoves › Solar systems for storage, solar dryers, etc. › Solar, bioenergy, grid, hydro installation, and maintenance
West Coast Energy	› Inverters/solar panels › Solar batteries and accessories › Solar installation and maintenance
Yandalux	› Solar water pumps

2.1 Sectorial Overview

The key solar companies are involved in selling pico-solar and SHS as well as solar hybrid mini-grids, but the latter has very limited capacity. Most firms are distributors of international brands or retailers, typically offering pico-solar or SHS products. A number of these are relatively early stage companies that depend on donor support for (i) technical assistance to develop their management and operational capacity, (ii) revenue generation through the execution of donor and Government project contracts. Sources of funding varies, with Alternative Energy implementing a mini-grid project funded by United States African Development Foundation (USADF), and Mercy Corps recently implementing the Light Up Liberia project funded by the EU.

a) Productive use systems currently available in the Liberian market

As highlighted in Table 5, several companies have recently started selling and distributing productive use systems, although many of these initiatives are still very early stage pilot projects to test the market. Solar pumping for irrigation devices is the most common productive use solution currently being sold by Yandalux, African Energy, Ecopower, Easy Solar, Sustainable Energy 4 Life (SE4Life), and Integrated Services and Equipment. In addition to lanterns and SHS, several companies have started selling cold storage devices to preserve vegetables, fish and meat. For instance, Lib Solar offers a commercial refrigerator (240 L) that is used by women entrepreneurs in rural areas. African Energy distributes Sundanzer fridges and freezers. Malnutrition Matters, Ecopower Liberia, and SE4Life have different models of electric and thermal solar dryers in their portfolios.

To date, no companies have been identified in the distribution of solar milling and processing devices, although there is a large market potential with the transformation of crops like cassava and maize, and potential value-add to the cocoa value chain. Other solar companies, such as SJEDI, West Coast, Ecopower, and African Energy sell solar systems that are capable of powering entire agricultural operations from solar water pumps, to solar-diesel hybrids for powering mills, and other commercial and industrial solutions. Solar systems can also be designed to power small businesses in off-grid settlements, such as for sewing and barber shops and LIB Solar and Easy Solar Liberia are currently diversifying their product portfolio to potentially include a range of PUE devices to meet the needs of a range customers.

As the market continues to evolve new market innovations are emerging, such as pay-as-you-go (PAYGO) systems combined with mobile money transfer technology, biogas institutional stoves, efficient domestic stoves, micro and nano-grid technologies, solar-diesel hybrids, and small hydro-generators. Annex I provides an outline of potential productive use technologies which could be of relevance to the agriculture sector in Liberia. International manufacturers with certified brands are also interested in partnering with national distributors to try and meet the market demand for a range of productive use technologies.

b) Mini-grid and productive uses

In order, to increase energy generation and access to electricity, especially in rural areas, donor agencies and development institutions including USAID, EU, World Bank, etc. have piloted several off-grid mini-grid projects iin Liberia. These mini-grids have mostly been installed and then handed over to local cooperatives, local NGOs, and private operators to manage.

Experience has shown that in such an early-stage market like Liberia, particularly in very remote areas, the cooperative model is not sustainable. Communities often lack the capacity to manage and maintain the systems and collecting payment from one's own neighbors often proves difficult. Additionally, most cooperative mini-grids lack the necessary anchor customers to be sustainable. The limited installed capacity coupled with a lack of efficient management and technical knowledge has not made PUE services viable in many cases, with most systems only providing access to lighting and charging small appliances.

Moreover, this is not only specific to Liberia – continent wide there are similar issues with mini-grids – recent research is starting to prove with data which equipment and best practices can foster the growth of the mini-grid sector, and PUE plays and important role as anchor loads that generate extra income to contribute to the long term sustainability of mini-grids. Without a strong anchor to productive use activities, and income generating activities, mini-grids have often failed to meet their financial viability and therefore the expected socio-economic benefit derived from accessing electricity.

FIGURE 2. GREEN MINI-GRID FIELD IN LOFA, LIBERIA

Source: Renewable Liberia

Box 1 below provides guidance for planning of productive use to ensure mini-grid viability in energy projects.

Box 1. Productive use as key anchor to mini-grid sustainability

Low electricity demand is one of the most frequent causes of the failure of mini-grid projects to achieve financial sustainability and have development impact. However, if properly developed, mini-grids can provide a range of socio-economic benefits for people living and working in underserved communities. Mini-grids enable community uses of energy, providing energy for schools, thereby improving the quality of education, or for health clinics, reducing birth mortality rates and helping maintain cool chains for vaccines. Mini-grids can also enable individuals and local enterprises to increase their agricultural productivity and undertake new employment generating activities, therefore increasing income.

However, low end-user demand jeopardizes the financial viability of mini-grids, and therefore the expected socio-economic benefits derived from accessing electricity. Low energy consumption patterns cause a self-perpetuating cycle whereby operators are forced to charge prohibitive tariffs to cover their costs, leading to poorly performing grids, which are underused by the people they are meant to serve. According to stakeholders interviewed, lessons from recent mini-grids installed in Liberia show that it is not sufficient to provide electricity to communities to stimulate economic development. In most contexts there is need for interventions that stimulate new or improved productive activities which can be undertaken with the new electricity connection. This will increase electricity demand and livelihoods opportunities for the community and ultimately increase the viability of the mini-grid. For example, a grain mill operator on one of the Lab developer's existing sites consumes 300 kWh/month of electricity in a region where the median mini-grid customer consumes 3 kWh/month. This single grain mill operator therefore consumes as much power as one hundred typical customers.[7]

In Liberia, West Africa Renewable Energy Biomass (WAREB) Ltd. provides local technical expertise in operational support of mini-grid electrification projects as well as development of agribusiness activities to increase load demand and stimulate economic development in rural communities. Joint ventures and partnerships have been agreed such as the Sorlumba Community Electric Cooperative Society. As highlighted in the Practitioner Guide released by the green mini-grid facility Kenya,[8] steps to boost productive uses within mini-grid projects might include (and not be limited to):

- Assessment and forecasting to understand current use of energy in local communities, current and future demand, as well as willingness/ability to pay.
- Community involvement to improve business planning, and community participation and ownership (including women and youth) to improve business and financial modeling.
- Activities for stimulating energy demand and strengthening livelihoods by increasing productive uses of energy.
- Identification and promotion of electrical appliances driving industrial and commercial activities.
- Building capacities of businesses on energy usage/consumption.

c) Business models and end-user finance

Most companies have their main offices in the capital city of Monrovia, with smaller offices in major cities like Ganta, and a network of distributors and sales agents throughout the country. To supply communities in peri-urban and rural areas, community-level cooperative engagement is required to acquire new customers and ensure payment collection for products. While several established manufacturers are represented in Liberia, there is currently no local manufacturer/assembler in the country. SJEDI indicated interest in building a local assembly unit in the country.

The main business model deployed by local solar energy companies is cash and over-the-counter sales, while a few companies have started to employ PAYGO sales. Several of those selling SHS provide their

[7] Crossboundary. Study Design: Appliance Financing 3.0 Energy Efficient Productive Use. 2020. https://www.crossboundary.com/wp-content/uploads/2020/02/CrossBoundary-Innovation-Lab-Study-Design-Appliance-Financing-3.0-Energy-Efficient-PU-Anonymized-25-Feb-2020.pdf

[8] Green Mini-Grid Facility Kenya. Milling as a Productive Application in Green Mini-Grid Systems - Practitioner's Guide. 2018. https://infohub.practicalaction.org/bitstream/11283/621153/1/Miling_as_a_Productive_Application_in_GMG_Systems_FINAL.pdf

products through lease-to-own PAYGO models, involving regular instalments supported by mobile payment technologies. Companies such as Easy Solar and LIB Solar offer financing plans through monthly payments to ensure their products are affordable. However, this same model may be challenging for productive use energy products as they have a significant higher upfront cost.

While some companies are selling a wide range of products, others have started to specialize in order to focus on specific consumer segments (Table 6). For most formal solar companies, their target markets are households and large institutional groups such as NGOs and other public institutions. PAYGO is still in its early stages and restricted to a few companies.

However, due to high poverty rates in Liberia – especially in rural areas – the ability to pay for PUE systems remains a challenge. For productive use technologies, such as solar refrigerators with lighting and a fan, businesses are generally willing and able to pay up to $ 90 per month. However, given the high upfront cost of such systems off-grid solar companies consider it too risky for their business to finance products over long loan time periods.

d) Customer target markets

Most energy product and input supply firms target households and businesses in urban, peri-urban, and rural areas, with limited or no access to grid electricity. The main customer segments in each target market are outlined in Table 6.

TABLE 6. ENERGY SUPPLY TARGET MARKETS

TARGET MARKETS	TYPES OF CUSTOMERS
Rural communities	› Smallholder farmers/cooperatives/agricultural firms/agro-processing › Farming householders › Health centers/public schools › Mining and agricultural concession areas
Peri-urban communities	› Cooperatives/agricultural firms/agro-processing › Health centers/public schools
Urban communities	› Banks/automated teller machines › Commercial buildings and residential homes › Gas stations/shops › Hospitals/public and private schools

Off-grid solar power also supports a wide range of connectivity applications, including mobile phone charging, wi-fi servers, banks, mobile money kiosks, and telecommunications towers. The target markets, in particular in peri-urban and rural areas, are characterized by a lack of access to reliable power which is predominantly substituted by expensive off-grid diesel/gasoline-powered generators for productive use. To disseminate their Grundfos solar submersible pumps, SE4Life specifically targets counties such as Lofa, Nimba, Bong, and Maryland as these have the greatest irrigation challenges during dry seasons.
Most rural households operate in the informal sector with no steady income as they are often petty traders, casual laborers, and subsistence farmers with low incomes. Most rural farmers cannot afford the upfront cost of modern PUE products. Primary energy products in use are flashlights, low cost and low quality electric lights, charcoal and/or wood for cooking and heating, and occasionally small petrol-powered generators for keeping businesses running. Although many rural households may have interest in new PUE products, they will likely struggle to afford the systems unless supported through credit.

Companies can consider addressing this challenge by developing agreements with agricultural cooperatives that may be able to negotiate lower and longer payment terms for their members. In addition, as the use of PUE technologies can lead to increased production and value of agricultural products, the use of PUE can increase the ability of rural households to pay for such systems. Cooperatives can help increase access to PUE systems, and support their members to pay on credit over time while the systems are in use. For example,

vegetables cooperatives can support their members to use solar water pumps for irrigation and when the members harvest and sell the vegetables, the cooperative can withhold a percentage of sales to pay for the solar water pump systems provided. Although these strategies do not specifically target women, there are some women's groups and cooperatives managed by women that can support their women members.

Some companies, such as Union Strong and West Coast Energy, are developing strategic partnerships to act as local distributors and resellers for leading international renewable energy manufacturers. As the sector grows, more PUE products may become available through these partnerships.

Other interesting partnerships might involve local finance institutions such as microfinance institutions, or commercial banks to support the upfront financing of productive assets for smallholder farmers or cooperatives. No specific experience could be collected during this assessment, although one potential source of local funding is BRAC, which was identified as a microfinance institution providing credit to SMEs in the energy sector (World Bank/ROGEP, 2017-2022).[9]

e) Distribution/marketing strategies

The distribution and marketing strategies currently employed in the sector include direct retail sales from small shops and raising community awareness through sales jingles and direct marketing and advertisement. Mass media, including TV and radio advertisements, flyers and pamphlets, billboards, and marketing collaboration on renewable energy promotions, has only been carried out with support from donor programs and national agencies such as the RREA, GIZ, and LUL (Mercy Corps) to conduct community awareness activities throughout the country.

Others like SJEDI promote their products in the major cities through advertising and community awareness events. SJEDI uses a "hub-and-spoke" distribution model with main offices in the large cities of Monrovia and Ganta, and a network of distributors and sales agents distributing to smaller towns and communities throughout the country. The leading energy product companies are focused on building field-based sales teams and promoting sales through partnerships, such as with farmer cooperatives. These channels could be leveraged to support the promotion and sale of PUE products.

Distribution activities are supported by further training of the supply chain. For example, SE4Life provides technical support to the retailers that it works with, including training on product knowledge, marketing, and basic installation of systems. There are several challenges hindering marketing and distribution efforts, including the lack of financing capabilities with loan payback mechanisms and poor infrastructure for transportation of materials/products to areas like the southeastern Liberian counties.

Currently most companies in Liberia do not have specific strategies for targeting female customers. However, LIB Solar has been targeting women entrepreneurs and other companies may start to develop similar strategies in future.

f) Policies/government regulations

The electricity sector in Liberia is still largely unregulated, with no specific policies and regulations in place for PUE products. This scenario is quite common as PUE typically falls under PV regulations in most markets in Africa. In Liberia for example, fiscal policy incentives are benefitting the sector with exemptions under the Liberia Renewable Energy Access Program (LIRENAP) program implemented by RREA and off-grid stand-alone products can apply for duty waiver below 350 Wp. There are some PUE products that are small enough in size that could benefit from this exemption under the LIRENAP program and importers could apply to RREA for the waiver. However, most PUE stand-alone off-grid products are sized above 350 Wp and PUE loads for mini-grids will not benefit from this fiscal policy as they mostly have AC loads and are not stand-alone off-grid. The cost of PUE products is relatively high and duties, taxes, and other clearing costs compound this; therefore, increasing the scope of the current import duty waiver under the LIRENAP

[9] World Bank. Regional Off-grid Electrification Project. 2018. http://documents1.worldbank.org/curated/en/705201535029941781/pdf/129620-PSDS-P160708-PUBLIC.pdf

program to include larger PUE loads will foster the economic grow benefits the PUE sector brings into off-grid communities.

2.2 Assessment Findings

Findings from the assessment of energy product and input supply firms indicate the following:

- **Limited availability of PUE products:** While there are obvious needs for PUE solutions in Liberia, especially for agro-processing activities including drying and cooling, the forces of demand and support coupled with the lack of access to finance is hindering the availability of PUE products in the marketplace. Based on information received from energy product and input supply firms, less than 5 percent of these entities currently have PUE products, such as solar irrigation pumps, solar dryers and cold chain store systems, available for sale. However, all of the companies stock solar energy systems with components including solar panels, invertors, solar powered TVs, radios etc. If able to access financing, these companies are positioned to sell PUE systems.

- **Lack of PUE product awareness:** There is currently a lack of awareness of what PUE products and inputs are being demanded by potential PUE technology businesses, such as farming operations.

- **Relatively high PUE product uptake investment cost:** PUE products usually require more power than household systems and hence their initial upfront cost is considerably higher. The lack of local access to finance reduces the ability of energy product and input supply firms to invest in PUE products. In addition, target customers have relatively low incomes and might find it hard to finance high investment cost of PUE products. This further discourages energy product and input supply firms from investing in new PUE products.

- **Limited business management and technical capacity:** Several of the energy product and input supply firms lack adequate access to finance and do not have technical capacity and experience to develop large energy systems that can generate substantial energy for PUE. Internal business and financial management systems and experience are also lacking, coupled with limited qualified local energy technicians.

- **Limited mobile network reliability:** For communities with unreliable mobile network coverage, instalment payments through PAYGO platforms will be a challenge.

- **Poor enabling infrastructure:** The poor state or lack of roads (especially from farm to market), transportation, water supply, technical training schools, information technology, and telecommunication infrastructure are all major hindrances to the development of the PUE market in Liberia. These factors make it very difficult for PUE suppliers and potential users to connect to enable PUE access, especially in rural areas.

3 ENERGY DEMAND IN KEY AGRICULTURAL VALUE CHAINS

Several organizations in Liberia, including agro-businesses and agricultural cooperatives, use energy within the agricultural sector, including those involved in farming, processing, and distribution of tree crops (rubber, cocoa, coffee, and palm oil), cassava, plantains, and horticulture (fruit and vegetables). Table 7 outlines the key stakeholders that use energy within several key agricultural produce value chains in Liberia, and who will likely be the main customers of PUE products in the near future. This sample includes tree crop farmers, horticulture farmers and distributors, and animal husbandry. Other potential customers of PUE products include small businesses like barber shops, traders, restaurants, internet cafes, etc.

TABLE 7. USERS OF ENERGY IN KEY AGRICULTURAL VALUE CHAINS

NAME OF ORGANIZATION	PRODUCE/ VALUE CHAINS	BUSINESS SUMMARY
Atlantic Cocoa Inc.	Cocoa	Private company involved in the cocoa aggregation and export.
AYA Inc.	Cocoa	Private company involved in the cocoa aggregation and export.
Bravo Sisters	Cassava, super gari, plantain flour, cassava flour, cassava bread, etc.	Private company involved in cassava aggregation, processing into local food product known as 'garri', and other by-products for sale.
Bright Farm	Rubber	Private company involved in the planting of rubber, processing to rubber smoke sheets, and export.
Cape Hotel	Fruit and vegetables (lettuces, cucumber, tomatoes, carrots, pineapples, etc.)	Private hotel in Liberia involved in the purchase of large quantities of vegetable produce.
Green Tech	Cocoa	Private company involved in the planting of rubber, processing to rubber smoke sheets, and export.
J Palm Inc.	Palm oil, kernel oil, skin hair collection, soap bars, hair and body butter	Private company involved in the aggregation of palm kernel, processing and extraction of palm oil and manufacturing into soaps, creams, and other personal care products.
Liberia Business Incubator	Cassava, super gari, cassava chips, cassava flour, etc.	Private company involved in cassava aggregation, processing into garri, and other by-products for sale.
Rubber Development Fund Incorporated (RDFI)	Rubber	An autonomous, not-for-profit entity established as a joint public-private partnership corporation by an Act of the Legislature in 2017 with the goal of supporting and guiding the Liberian rubber industry to attain sustainable competitiveness in global markets while retaining the position of leading rubber producer in Africa.
Rubber Planters Association of Liberia	Rubber	Established by an Act, involved in advocacy for policy formulation to protect rubber farmers. It provides linkages, technical assistance, and advisory services to its members. Serves as the umbrella organization for smallholder farmers.
Todee Rubber Farmers and Multipurpose Cooperative	Rubber	Established 2009, core is rubber but also other tree and food crops, registered with Cooperative Development Agency (CDA) in 2013.

TABLE 7. USERS OF ENERGY IN KEY AGRICULTURAL PRODUCE VALUE CHAINS, CONTINUED		
NAME OF ORGANIZATION	PRODUCE/ VALUE CHAINS	BUSINESS SUMMARY
Wulkin Farms	Poultry, animals (chicken, pigs, goats etc.)	Private company involved in poultry, pigs, goat farming, and other agricultural produce for sale.

3.1 Sectorial Overview

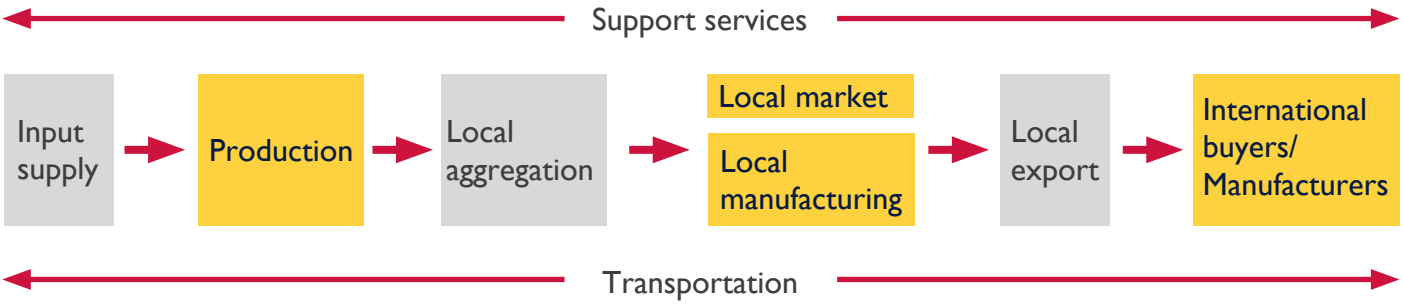
Based on available data, the national energy demand for electricity is forecasted to have a peak load of 311 MW by 2033 with the corresponding energy demand being 1,672 GW.[10] The ability to achieve this level of demand will be a major challenge for the Government of Liberian considering current capacity and financial challenges. According to a report published by SelectUSA,[11] the Liberian energy market comprises of many communities without reliable power, both for households and small businesses, which is significantly impacting income generation and employment potential.

In urban and semi-urban areas, there is significant need of power from small businesses such barbers and hair salons, video clubs (cinemas), bars, restaurants, etc. for PUE products. In addition, more than 60 percent of Liberia's population depends on agriculture as the primary source for their livelihoods and sustenance. Key crops include cassava, rubber, rice, palm oil, cocoa, or sugarcane production. In Liberia, electricity for PUE is needed in many parts of the agricultural value chain, including agro-processing and storage.

Figure 3 provides a general outline of the value chain for a key agricultural product in Liberia, highlighting the many actors involved and the potential need for PUE products throughout the chain.

As an example, the cocoa sector in Liberia is composed of approximately 30,000 smallholders, which accounts for as much as 12.6 percent of total employment in the agriculture sector. Approximately 9,000 tons of cocoa beans are produced from 25,000 hectares annually, with average holding sizes of 1-3 hectares.[12] Much of this production (estimated between 4,000 and 5,000 tons) is exported across the border, mostly via Guinea, Côte d'Ivoire, and Sierra Leone, and onward via export networks into other international markets.

FIGURE 3. GENERIC REPRESENTATION OF THE VALUE CHAIN FOR A KEY AGRICULTURAL PRODUCT IN LIBERIA



[10] Republic of Liberia. Investment Plan for Renewable Energy (IPRE). 2013. https://rrealiberia.org/forest/pg_img/Liberia%20IPRE%2010%2003%202013%20Final.pdf
[11] SelectUSA. Liberia - Agricultural Sectors. 2019. https://www.selectusa.gov/article?id=Liberia-Agricultural-Sectors
[12] The Republic of Liberia. National Export Strategy Cocoa Export Strategy 2014-2018. https://www.moci.gov.lr/doc/Liberia_National_Cocoa_Export_Strategy2014_2018.pdf

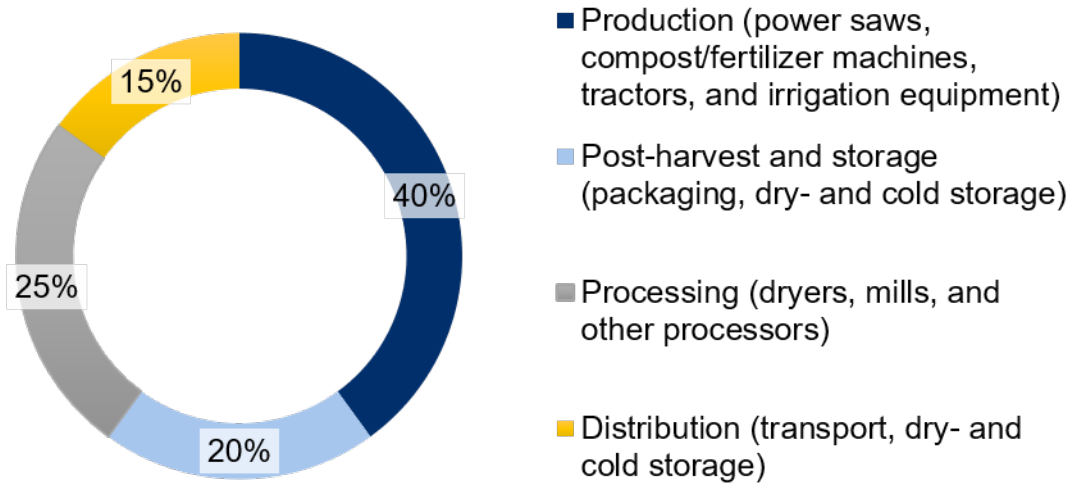
The cocoa value chain and energy demand utilization as outlined in Table 8 below is similar to the value chains of other key agricultural produce such as rubber, coffee, and palm oil. The value chain is currently mostly underdeveloped as minimum processing and value addition, such as basic drying and/or grinding, are carried out. Most local players in these agricultural value chains – in particular producers and local aggregators – focus on selling the product to the next player in the value chain rather than identifying how to best add value. This is due to a lack of processing equipment, high cost and limited access to energy, lack of finance, and poor local market development of PUE products. As a result, without the ability to transform raw materials into semi-finished or finished products, Liberia loses significant value from its produce.

TABLE 8. COCOA INDUSTRY ENERGY DEMAND ALONG THE VALUE CHAIN

VALUE CHAIN SECTION	KEY ACTIVITIES	MAIN PLAYERS	CURRENT OFF-GRID PUE USAGE	POTENTIAL OFF-GRID PUE USAGE
Input suppliers/ Support service providers	› Sourcing of high variety seeds › Farming tools › Fertilizers and pest control chemicals › Processing equipment › Packaging › Seeds/nurseries development › Training and development	› Local input importers/distributors/retailers › International NGOs › International development agencies › Agricultural Development Institute for seeds development	Sales and marketing of PUE off-grid products such a solar dryers, solar lights for lighting of houses and warehouses, etc.	› Product/input diversifications, including PUE products for: » Water pumps for irrigation » Coolers for preservation » Dryers processing and preservation » Lighting systems for warehousing › Provision of PUE technical support for product knowledge/system design, support, maintenance, etc.
Production	› Land preparation › Farming activities › Crop/farm maintenance › Harvesting › Basic processing › Minima storage	› Smallholder farmers estimated at about 30,000 › Large scale farmers, number unknown but estimated to be less than 100 › International NGOs such as GROW, Solidaridad, and Ministry of Agriculture (MOA)	Unknown	› Power tillers for land preparation › Water pumps for irrigation › Dryers for processing and preservation › Lighting systems for warehousing › Harvesting machines
Local aggregation	› Produce collection from farming communities › Individual procurement in small quantities to aggregate › Transportation to warehouse › Processing including drying and cleaning › Packaging into jute bags › Storage/warehousing › Transportation to buyer warehouse usually at the port	› Cooperatives › Registered bing agents › Unregistered individual buyers › International NGOs such as Solidaridad supporting warehousing construction › GROW supports development of cooperatives and buying agents	Solar drying sheets Solar lights for warehouses	› Dryers for processing and preservation › Lighting systems for warehousing
Local processing/ manufacturing	› Agro-processing into local cocoa drinks › Packaging › Storage › Distribution and sales	› Individuals › Small businesses	Unknown	› Solar graters and grinders for processing into cocoa powder › Packaging machines › Coolers for preservation
Local exporters	› Major procurement › Packaging › Limited storage	› Major exporters › Transport companies › Industry regulator (LARCA) › Financial banks providing letters of credit, guarantees, etc. for export processing › Liberia revenue authority › National Port Authority (NPA) › Shipping lines	Unknown	› Dryers for processing and preservation › Lighting systems for warehousing
International buyers/ Manufacturers: not active in Liberia cocoa value chain	› Worldwide distributors › Manufacturing of cocoa product/chocolate › Sales and marketing of finished product to consumers	› Some international buyers have representatives in form of registered Buying Agents to source, aggregate and export produce to their headquarters.	Unknown	Locally, need for PUE is the same with local aggregation.

In the agricultural sector, the assessment highlighted the demand for PUE products in various value chains, with greatest demand in production, followed by processing, storage, and distribution. Processing includes powering machines and equipment such as chain saws, power tillers, water pumps, and composting. In terms of distribution and preservation, electricity is required for storage and preservation facilities, including cold rooms and refrigerated containers.

FIGURE 4. AGRICULTURAL SECTOR VALUE CHAIN ENERGY DEMAND



The survey data also highlighted that the use of these types of machines and equipment is extremely limited due to lack of funding and inadequate/lack of access to electricity.

Women comprise over half of the agriculture labor force and about two-thirds of the trade and commerce labor force in Liberia.[13] Their role in agriculture is important, particularly for food crops, where women are reported to produce over half of Liberia's total output. However, the involvement of women in the production of cash crops is limited.[14] Access to resources and finance is significantly constrained across the entire population of Liberia, but women have particularly limited opportunities.[15] Policies and programs designed to support Liberia's rural economy, including its agricultural production, processing, and marketing, should take the role of women into account.

3.2 Assessment Findings

Findings from the assessment of energy demand in key agricultural value chains indicate the following:

› **High potential PUE demand:** As more than 60 percent of Liberia's population depend on agriculture as their primary source of livelihood and sustenance, energy for productive use technologies are needed for agro-processing and storage, drying of cassava and cocoa beans, milling of rice, extraction of palm oil, processing of rubber, pumping of water for fish farming, and refrigeration of vegetables and poultry, fish and other animal products. As women are involved in many of these agricultural value chains, there is also a strong gender component for such products. Currently, most agricultural operations from production to processing and distribution are performed manually, which is labour intensive, expensive, creates excessive waste, and unnecessary losses. This leads to smallholder famers' inability to expand their farms and agro-based small and medium-sized enterprises (SMEs) to increase their processing capacity. PUE is also needed to support the operational activities of small businesses, such as bars, restaurants, salons, fresh fruit juice manufacturers etc., for refrigeration and powering appliances.

[13] FAO. The Role of Women in Agriculture. 2011. http://www.fao.org/sustainable-food-value-chains/library/details/en/c/265584/
[14] Ibid.
[15] United Nations. Women's Control over Economic Resources and Access to Financial Resources, including Microfinance. 2009. https://www.un.org/womenwatch/daw/public/WorldSurvey2009.pdf

- **Relatively high cost of PUE products/inputs:** PUE products are relatively expensive to acquire and the low-income generating capacity of rural farmers and agro-processors makes it difficult for them to finance the acquisition investment cost of PUE products without finance. To address the barrier, there is a need for innovative end-user financing models such as PAYGO models, leasing models, or partnerships with microfinance institutions.

- **Limited access to finance (loans and grants) for PUE product acquisition:** The lack of access to finance is adversely limiting the development of the PUE market. There are no favourable platforms such as agricultural banks to support the long-term financing required for effective and efficient agricultural production and operation. Over 95 percent of respondents highlighted that the current loan conditions with commercial banks and credit unions offer are short term (usually 6-12 months), with unfavourable payback terms, and high interest rates averaging 13.69 percent base on the CBL mortgage credit interest rates from 2015 to 2020. This is likely to continue to limit the investment in PUE products needed for production and operation.

- **Need for more off-grid PUE generation solutions:** The lack of adequate national and off-grid power transmission and distribution capacity, including poor road networks, significantly contribute to post-harvest losses. This is due to lack of access to markets as well as lack of processing and storage facilities. Since many farming communities are off the national electricity grid, they will require off-grid PUE solutions.

4 SUPPORTING SERVICES

Several organizations provide a range of supporting services including telecommunication, finance, and fintech support to the energy and agriculture sectors in Liberia. These organizations are outlined in Table 9.

TABLE 9. KEY STAKEHOLDERS PROVIDING SUPPORT SERVICES TO THE ENERGY AND AGRICULTURE SECTORS

INSTITUTIONS/ ORGANIZATIONS	BRIEF DESCRIPTIONS
Mobile network operators: Lonestar MTN and Orange Liberia	Lonestar Cell MTN, the parent company of Lonestar Cell MTN Mobile Money Inc. is a member of the MTN Group. Orange Liberia is a member of the Orange Telecommunication Group. Both companies operate mobile networks across major towns and cities in Liberia and are licensed to operate as full-fledged mobile financial services institutions by CBL.
National Investment Commission (NIC)	NIC provides effective business and investor support in Liberia, accompanying investors throughout all phases of their investment plans, facilitating meetings, assisting investors in navigating as efficiently as possible the regulatory and establishment procedures, and maximizing investor opportunities through dedicated programs in business linkages, development of special economic zones, and incentives.
Agricultural development programs and projects	Programs and/or projects that support the agricultural sector to develop agribusiness, increase crop production, and enhance national food security. An example is the Feed the Future (FTF) Liberia Agribusiness Development Activity (LADA), a USAID-funded five-year project implemented in four counties (Montserrado, Bong, Nimba and Lofa) by Cultivating New Frontiers in Agriculture (CNFA). The main goal of the project is to increase the incomes of smallholder farmers through increasing private sector investment in the Liberian agribusiness sector. The project is also involved in cross-cutting interventions such as gender and youth engagement, access to finance, and environmental compliance using a "private sector development strategy" that leverages grants and/ or guarantees, and training.
Financial institutions	Financial institutions in Liberia are characterized by commercial banks, non-banking institutions (funds, venture capital, investments funds, etc.), microfinance institutions, deposit taking and non-deposit taking, village savings, and loan associations. These institutions provide various financial products (loans, debts, equity, investments, etc.) across numerous economic sectors in Liberia, including merchandise and trading, food industry, construction, agriculture, etc.
Business development and training institutions	Business development services and training institutions active in Liberia, including EDUCARE and the Consortium of Business Development Service Providers of Liberia (CBDSPL) that provide business development and support services to energy supply and energy demand companies to improve business, financial, and operational management.

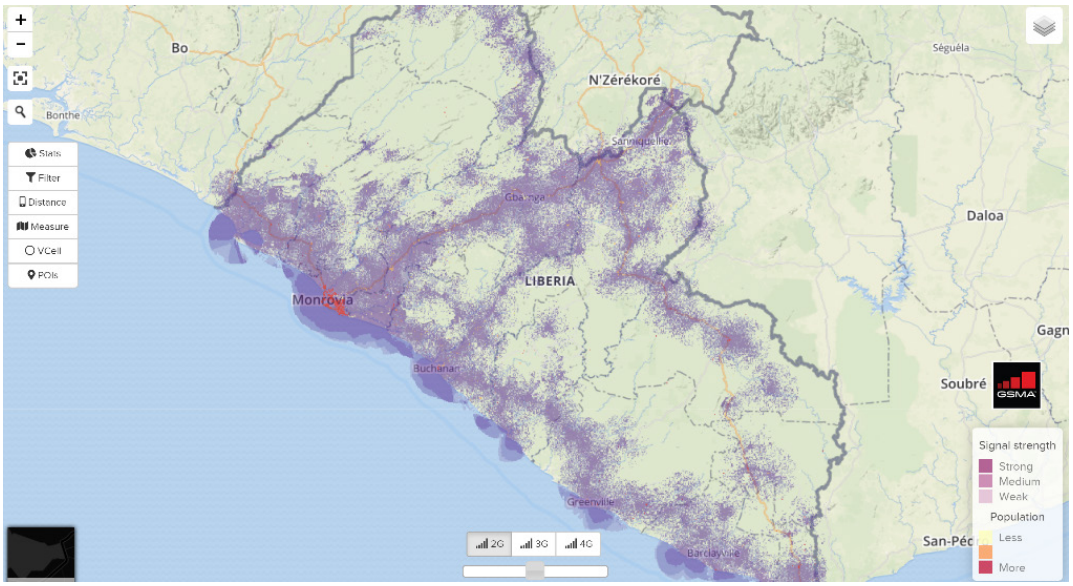
4.1 Sectorial Overview

Based on analysis of the assessment data from respondents, the overview of the supporting services sector are as follows:

› **Telecommunication companies:** Telecommunication companies provide communication services and payment platforms to facilitate smooth and seamless payment for products and services, helping to resolve payment hurdles and difficulties between energy supply and energy demand companies. According to a GSMA Telecommunication mapping analysis, 94 percent of the settlements with a population above 4,000 people are already covered, and the population not covered live in 16,000 settlements with an average

size of 80 people. An estimate of the actual coverage is illustrated in figure 5 below. Telecommunication companies will likely play an important role in rolling out PAYGO for PUE technologies.

FIGURE 5. ACTUAL NETWORK COVERAGE IN LIBERIA



Source: www.gsma.com/mobilefordevelopment/blog/are-mobile-operators-under-investing-in-rural-coverage-in-emerging-markets/

There is a need for support to off-grid entrepreneurs to foster linkages with telecommunications companies and mobile money providers to help roll out technology platforms and PAYGO business models. In the assessment, some companies reflected challenges in cooperating with telecommunication providers. Some of the companies involved in PAYGO revealed that for each mobile money transaction, the mobile company takes a great portion of the revenue. Having thousands of customers, it is a great windfall for these mobile companies with little recourse for the off-grid distributors who already face extreme operating costs and very low margins.

› **Capacity building institutions:** Institutions such as EDUCARE and CBDSPL can provide business development services support to energy supply and demand companies, in particular to enhance effective business and financial management to support uptake of PUE technologies (for farming and processing activities) which are relatively new to the market.

› **Financial institutions:** Financial institutions currently do not make significant direct investment to the energy sector, except through partnerships with donors, or international organizations such as the World Bank, African Development Bank, and the Swedish International Development Cooperation. A World Bank study (2015-2018), conducted in partnership with CBL, indicated that financial institutions see limited viable financial investment opportunities in the energy supply sector and that as much as 66 percent of energy supply firms are viewed as being low level operations with limited investment opportunities. Commercial banks find the energy sector to have a low level of attractiveness due to the relatively high cost of energy generation that requires substantial investment and often lacks the technical capacity to implement such projects. Most investments made by financial institutions have been guaranteed by international donor organizations and NGOs under specific programs to support renewable energy. Support from international donor organizations may be required to increase investment for the PUE sector.

› **Ownership structure:** About 60 percent of energy supply and demand companies are registered as sole proprietorship and partnership organizations, which limits the amount of funding that commercial banks and other financial institutions can lend to them (due to high accountability risk). It may be necessary for these companies to change their ownership structures to attract greater investment to support the uptake of PUE technologies.

4.2 Assessment Findings

Findings from the assessment of Supporting Services Providers indicate the following:

› **Limited PUE product knowledge and awareness:** Financial institutions currently have very limited knowledge about PUE products available in Liberia, including the economic potential of PUE. This lack of awareness hinders the development of appropriate financing instruments for PUE products. This in turn results in limited access to finance for potential PUE customers.

› **Limited payment systems:** While telecommunication network coverage is relatively extensive across Liberia, it is still limited in reach in rural areas. This affects online transactions, including payment options, in particular PAYGO systems for both SHS and PUE products. Improved electronic payment platforms are needed to increase accountability, transparency, and sustainability for solar PAYGO systems, including for PUE systems that typically have higher costs and may require longer payment terms.

› **High PUE investment cost:** The relatively high cost of PUE products is a significant barrier for off-grid rural communities that may be the main customers of such products. Local financial institutions perceive these products as high risk, as they are mostly required in rural areas where there are generally low economic activities to generate the income needed to repay the investment cost.

› **Restrictive ownership structures:** Most energy companies are registered as sole proprietorship and partnership organizations, which are seen as having higher risk of default. These ownership structures limit the amount of funding that support services organizations such banks can lend to the companies. Hence, access to finance is limited for PUE marketplace business expansion and growth.

› **Perceived limited ability to pay:** Financial institutions determine the ability to pay of potential customers based on income generated from the sale of PUE products. However, due to limited data about the PUE market size, the limited business and financial management systems of local PUE supply companies, and the low purchasing power in rural areas, financial institutions perceive loans to the PUE market as having high financial risks. Therefore, financial institutions are generally not willing to lend to PUE supply companies.

› **Shortage of skilled PUE technicians:** While efforts have been made to increase local capacity in Liberia, there is still a storage of a skilled technical workforce which will impede the development of the PUE sector.

5 PUBLIC SECTOR

This section outlines government agencies and programs supporting energy development for PUE, in particular for agriculture. Table 10 highlights relevant government agencies and programs.

TABLE 10. KEY GOVERNMENT AGENCIES AND PROGRAMS SUPPORTING ENERGY DEVELOPMENT

COMPANIES/ ORGANIZATIONS	DESCRIPTION OF SERVICES
Ministry of Mines and Energy (MME)	Administers all activities related to mineral, water, and energy resource exploration, coordination, and development. Primarily responsible for the overall development of the Liberian energy sector and implementation of the 2015 Energy Law.
Liberia Electricity Regulatory Commission (LERC)	An autonomous regulatory body set up to regulate and oversee the electricity sector. Responsible for: › Drafting, implementing, monitoring, and enforcing regulations to drive reforms. › Issuing licenses (for generation, transmission, distribution, import/export, and trading) to operators. › Regulating tariffs and charges for service. › Establishing and monitoring technical standards and norms. › Resolving related disputes.
Rural Renewable Energy Agency (RREA)	Primarily responsible for the development of renewable energy and the implementation of the Rural Energy Strategy and Master Plan for Liberia (RESMP). The agency also coordinates the support of development partners for rural energy development through the Rural Energy Working Group (REWG) and manages the Rural Energy Fund (REFUND).
Environmental Protection Agency (EPA)	The regulatory Institution of the Government of Liberia for the sustainable management of the environment and natural resources. The EPA ensures environmental protection and conservation biodiversity.
Ministry of Agriculture (MOA)	Mandate to develop the agriculture sector calls for putting in place an effective organizational structure. It ensures that its staff and the farmers are trained to cope with the challenges of developing the agriculture sector. MOA ensures that agricultural challenges that impede production are investigated and lasting solutions found, and the farmers are provided with the supportive services and the enabling environment to produce food.

5.1 Sectorial Overview

The 2009 National Energy Policy and its enactment through the 2015 Energy Law, separated the roles of policymaking, regulation, and operation and oversight over the Liberia energy sector. The following are the key policy players:

› MME has overall responsibility for the development of the energy sector and the relevant policies, strategies, and master plans.

› LERC is an autonomous regulatory body responsible for regulating and overseeing the electricity sector through drafting, implementing, monitoring, and enforcing regulations as well as issuing licences (for generation, transmission, distribution, import/export and trading) to operators, regulating tariffs and charges for services, establishing and monitoring technical standards and norms, and resolving related disputes.

› LEC is the national grid utility, that generates, transmits, and distributes electricity across the country.

› RREA is responsible for the development of renewable energy, with a mandate to facilitate and accelerate the economic transformation of rural Liberia through the provision of modern energy services. RREA coordinates the support of development partners for rural energy development through the Rural Energy Working Group (REWG) and manages REFUND. RREA's operations are supervised by MME, who involve RREA in national strategy energy planning initiatives.

The above public sector players, apart from LEC, are responsible for the development, regulation, and implementation of policies for the energy sector in Liberia. However, as the PUE sector is very new, specific policies related to PUE are very limited within the general framework of electricity generation, transmission, and distribution. For example, the National Electricity Policy of Liberia, Action Document for Rural Electrification, Food and Agriculture Policy and Strategy, has not been revised to fully incorporate PUE to meet current realities of the energy sector and agriculture.

In general, while there are policies and law promoting energy development and accessibility, there is a limited focus on the promotion of energy for productive energy use. A holistic policy approach is needed to create an environment that is conducive to PUE business development, including product quality assurance, effective regulations to promote PUE, on and off-grid energy generation and distribution, and gender diversity in a sector traditionally dominated by men.

Although the public sector stakeholders interact with one another, the collaboration and cooperation amongst stakeholders to promote new products such as PUE is irregular and not very effective. Public sector actors led by LERC are developing regulatory instruments to attract private investment in the electricity sector, to increase access, reduce costs, and improve quality of service, including improvement in agricultural productivity. Increasing the access and use of PUE products in Liberia can have important developmental benefits and the public sector has an important role to play.

MME and RREA are the primary contributors in implementing energy projects funded by the World Bank, EU, USAID, etc. Support is needed to increase the awareness of the benefits of PUE products, increase access to finance, and support the companies distributing and retailing PUE. A duty waiver for energy products and related accessories, which should include PUE products, is needed to make products more affordable for low-income consumers in peri-urban and rural areas. Access to PUE will in turn facilitate energy market development, productive use, job creation, and drive social and economic transformation.

5.2 Assessment Findings

Findings from the assessment of Public Sector Stakeholders indicate the following:

› **Limited policy focus on PUE:** Policies related to PUE are very limited within the general framework of power generation, transmission, and distribution. Policies to promote PUE products is lacking and need to be developed.

› **Limited collaboration and coordination:** There is currently limited collaboration among key public stakeholders – in particular MME, LERC, RREA, the Liberia Revenue Authority and the Ministry of Development Finance – which is impeding the growth of the energy sector in Liberia. There is also some overlap in functions between the key agencies. This overlap leads to a lack of clarity on who leads what. The establishment of LERC is expected to resolve some of these conflicting issues and increase better coordination and demarcation of responsibilities. Political interference is also an issue of concern in the sector, especially as it relates to leadership appointments within the key public agencies.

› **Slow development of regulations by LERC:** The development and implementation of energy regulations, including unbundling of the energy industry and promotion of private sector investment, have been very slow. This has implications for developing the PUE market.

› **High tariffs on PUE products:** The cost of PUE products is generally very high, which in a small country with economic challenges, like Liberia, makes it even more difficult for the sector to grow. High import duties and other local taxes present a challenge for import and acquisition of PUE products. Providing tax exemptions could support the growth of the sector.

6 DEVELOPMENT PARTNERS

Several development partners support the energy and agriculture sectors in Liberia. These development partners are outlined in Table 11.

TABLE 11. KEY DEVELOPMENT PARTNERS SUPPORTING THE ENERGY AND AGRICULTURE SECTORS IN LIBERIA

COMPANIES/ ORGANIZATIONS	DESCRIPTION OF SERVICES
United States Agency for International Development (USAID)/Liberia	USAID/Liberia is a development partner currently providing technical assistance support to both grid and off-grid sectors in Liberia. USAID and Power Africa provide business performance improvement technical support to off-grid solar companies, and policy development and implementation support to the government.
World Bank	The World Bank is an active player in the energy sector in Liberia, supporting the national grid expansion and several mini-grids and off-grid projects.
European Union (EU)	The EU has been supporting various energy development programs in Liberia and has contributed substantial funding to several key projects. The EU has been focusing on the development of mini-grid infrastructure projects in the South East of the country and provided support towards access to various off-grid solar energy programs, including provision of SHS.
Economic Community of West African States (ECOWAS) Center for Renewable Energy and Energy Efficiency (ECREEE)	ECREEE is coordinating the implementation of several projects on electricity access in the region, such as the ECOWAS Programme on Access to Sustainable Electricity Services (EPASES) and the Regional Off-Grid Electrification Project (ROGEP) to increase access to sustainable electricity services in the ECOWAS region and four Sahel countries for household, commercial enterprises and public facilities.
GIZ/Energizing Development (EnDev) Liberia	GIZ/EnDev Liberia focuses on strengthening the renewable energy sector in Liberia, bringing in technical expertise for information and knowledge exchange, trainings (installation, lamp repair, stove construction), and networking. EnDev Liberia aims to ensure sustainable and affordable access to renewable energy all over Liberia. This is done by strengthening markets and collaborating with various partners from public and private sector as well as NGOs.
Africa Development Bank (AfDB)	AfDB supports renewable energy for electrification in Liberia including the construction of dams and the development of hydropower. Their current project supports the expansion of the power grids to isolated localities in the north-eastern region and to connect schools, health centers, businesses, and industries to the national grid and increase rural electrification.
Millennium Challenge Account Liberia (MCA_L)	MCAL is the Liberian government agency that manages the compact funded by the U.S. Government and has supported LERC's start up. MCAL is making an investment in materials to help LEC increase connections to the grid including wires, meters, transformers, specialized vehicles, as well as electrical poles. Funds were also used to rehabilitate the Mount Coffee hydropower plant.
Sida (Sweden's government agency for development cooperation)	Through cooperation with civil society, multilateral organizations, public agencies, and the private sector, Sida works for sustainable development and helps to improve the living conditions of people living in poverty and oppression. In Liberia, Sida supports several efforts that increase access to renewable energy: › Africa Enterprise Challenge Fund (AECF): AECF through the program REACT, provides grants and technical support to companies investing in the off-grid sector and in agribusiness. AECF has been engaging RREA to coordinate its support to the sector. › Beyond the Grid Fund for Africa (BGFA): BGFA has an initial funding target of € 48 million and seeks to create sustainable markets for distributed and stand-alone off-grid energy services in rural and peri-urban Africa.

6.1 Sectorial Overview

Most development partners working in the energy sector in Liberia have been working in partnership with RREA, funding several projects. These projects have included support for expansion of the national grid through LEC; construction of off-grid mini-grids; development of electrification infrastructure projects; support for national energy policy development; feasibility studies and funding of project pilots; development of legal and regulatory frameworks; technical capacity building and support for establishment of energy specific agencies such as LERC and RREA.

It is important for development partner projects to link their objectives to support the development of the PUE sector in Liberia. For example, the USAID-funded LADA activity focused on increasing private investment in agriculture input systems, post-harvest handling, storage, marketing, transportation, etc. To achieve these objectives, the utilization of the energy for production and processing is necessary to increase production capacities of the project target groups. However, the effective linkage of other donor projects with PUE products has not been well defined to establish a definite process in project implementation.

RREA's working group and high-level energy sector working group are two key platforms designed to harmonize the interventions of development partners in the energy sector in Liberia and could be very important in the future to support the growth of the PUE sector in Liberia.

6.2 Assessment Findings

Findings from the assessment of International Players in the energy industry indicate the following:

- **Lack of specific PUE support programs:** There are several completed and ongoing energy access projects implemented by a range of development partners, including USAID, EU, World Bank, AdDB, etc. However, none have been developed solely to support the PUE sector in Liberia. Some energy projects and programs funded by different development partners and NGOs have sometimes led to the distortion of the energy market. This is particularly the case when energy products are given away or sold for discounted amounts, making it difficult for private energy product suppliers to sell similar products at reasonable market prices. It is important that these mistakes are not repeated for PUE products.

- **Limited sectorial progress measurement and oversight:** While coordination of energy project activities has improved, measurement of project progress and updating of energy sector development plans are still lacking. Given the extensive donor support being provided, more coordinated sectorial oversight is needed to measure progress and will be very important in effectively supporting the PUE sector in the future.

- **Need for more effective collaboration:** More effective collaboration between stakeholders is needed to avoid overlapping of support and for more effective mobilization and use of much needed investment and support for the PUE sector in the future.

7 GENDER-RELATED ISSUES ON PRODUCTIVE USE ENERGY IN AGRICULTURE IN LIBERIA

In Liberia, gender norms generally define household cooking, subsistence farming, food processing for household consumption, and sales through small scale commercial activities as activities for women and girls. Men are more likely to be engaged in relatively larger commercial activities such as cash crops farming, processing, sales, and basic manufacturing activities. Women are more likely to focus on clean cooking options, lighting, and PUE systems for refrigeration, and food production (such as grating and, or, milling). Men's PUE requirements are more likely to include the use of relatively larger energy systems for irrigation, drying, storage, and manufacturing activities.

In Liberia, it is estimated that women constitute about half of the agriculture labor force and about two-thirds of the trade and commerce labor force[16] which indicates their essential role in agriculture especially in the production of food crops. However, their involvement in major cash crops, including coffee, cocoa and rubber production, is limited. Notwithstanding, women's' involvement in food crop production and their potential need for PUE systems is important and critical for increasing Liberia's agricultural production, and for ensuring overall food security.

TABLE 12. GENDER BREAKDOWN OF SURVEY RESPONDENTS

DESCRIPTION OF THE MAIN ACTIVITIES OF ASSESSMENT ORGANIZATION (N=59)	HORTICULTURE (VEGETABLES & FRUIT)		CASH/TREE CROPS (RUBBER, COCOA, COFFEE AND PALM OIL)		AGGREGATES OF BOTH SUB-SECTORS		
	Male	Female	Male	Female	Male	Female	Total
Producers and processers (tree and food crops)	12	3	12	1	24	4	28
Distributors (wholesalers and retailers)	0	22	3	0	3	22	25
Unions/associations/corporations/ cooperatives	1	0	5	0	6	0	6
Total	**13**	**25**	**20**	**1**	**33**	**26**	**59**

Of the 59 participants from the demand side of the PUE assessment, 64 percent are involved in horticulture while 36 percent are involved in cash crop production. There were 86 percent male respondents and 14 percent female respondents from the producers' sector, and 88 percent female respondents and 12 percent male respondents from the distribution sector. All respondents representing unions, associations, and private-public corporations were male.

[16] World Bank. Liberia: Gender-Aware Programs and Women's Role in Agricultural Value Chains. 2010. https://openknowledge.worldbank.org/handle/10986/18507

7.1 Assessment Findings

Based on data collected from the survey (Table 12), and desk review of several reports, women in Liberia currently experience several constraints with regards to the supply and use of PUE systems in the agricultural sector, which can be summarized as follows:

- **Limited access to land for PUE installations:** Access to land and control over land-tenure security are serious challenges that women face in Liberia. In rural areas, women are traditionally given ownership of the crops they cultivate, but not the title to the land.[17] This hinders women's ability to invest in large scale agriculture and acquire PUE products as they have no title that can be used as security/collateral to access funding for PUE equipment. This often limits farming production to subsistence level for most women.

- **Limited access to profitable cash crops:** Due to traditional society norms and structure, women are prevented from diversifying to higher economic crops which limits their prospects for generating more cash income. The analysis of the survey data indicated that less than 10 percent of the respondents stated that they are involved in the production and processing of cash crops including rubber, cocoa, coffee, and oil palm. This is due to the rigid, gender-based division of labor in crop production that results in women specializing in food crops such as cassava, plantain, and horticulture. The fact that many cash crops, particularly tree crops, are grown under vertically coordinated institutional arrangements to which women have limited access is also a factor.[18] These factors contribute to women's inability to generate more income to invest in PUE products.

- **Affordability of PUE products:** Most households' non-farming enterprises (56 percent) are run by women and most of these enterprises (71 percent) have a monthly gross revenue of less than $ 200.[19] This low financial capacity can affect the ability of women-owned businesses to acquire PUE products.

- **Limited gender specific PUE policies and programs:** Generally, there are very limited policies and programs that are focussed on PUE in Liberia. While existing government policies recognize the role of women especially in the energy demand side, specific programs to develop women's capacity in PUE supply and demand do not yet exist.

- **Limited access to finance and market:** Access to finance and markets are key challenges that face both men and women in Liberia. However, women find it particularly difficult to access finance as they often lack access to collateral such as land rights and property. Limited opportunities to access to finance and to generate adequate financial resources affect women's ability to purchase PUE products.

[17] Republic of Liberia. Pro-Poor Agenda for Prosperity and Development (PAPD). 2018. https://mk0globalnapshvllfq4.kinstacdn.com/wp-content/uploads/2019/01/liberia-national-development-agenda-pro-poor-agenda.pdf
[18] World Bank. Liberia: Gender-Aware Programs and Women's Role in Agricultural Value Chains. 2010. https://openknowledge.worldbank.org/handle/10986/18507
[19] Ibid.

8 CONCLUSION AND RECOMMENDATIONS

The lack of accessible and affordable PUE products in various sectors of the Liberian economy, including agriculture, manufacturing and retail, is a major challenge for the future economic development of the country.

This assessment identified several challenges in various market sectors, including inadequate policy and regulatory guidelines for PUE products; low awareness and availability of PUE products; and a lack of access to finance for PUE products, especially in rural areas where the majority of agricultural activities take place.

The survey noted that many organizations, companies, and local businesses that could be the direct beneficiaries of PUE products are currently struggling with the high electricity costs of their operations. Many firms and businesses indicated that there is an enormous potential demand for PUE products, particularly within the agriculture sector. Machinery and equipment usage requires energy for increasing productivity and value-add of products.

The market for PUE products in Liberia is currently underdeveloped or near nonexistent. However, the assessment findings indicate that there is a strong market potential for PUE products, in particular dryers for food preservation, cold storage for fruit and vegetables, and solar graters and mills for agro-processing to add value to various value chains within the agricultural sector. Employing PUE can lead to increased income and employment opportunities. As many Liberians are involved in the agricultural sector, the development of the PUE market will help to alleviate poverty and support the development of Liberia's national economy if it can be supported in an effective way.

8.1 Key Recommendations

The following are the key recommendations that can be been drawn from the assessment to optimize the future use of PUE products in Liberia.

Key Recommendations for PUE development

Sector coordination

› Strengthen coordination between public entities, international players, supporting service providers, and private sector companies to develop, review, and update relevant PUE policies and regulations.

Policy and regulatory support

› Support the development of regulatory incentives for IPPs to develop capacity off-grid systems to generate, transmit, and distribute energy specifically for PUE in major farming and agro-processing communities to enable the design of larger capacity off-grid systems.

› Update existing policies to create, enable, and diversify the power generation, transmission, and distribution for PUE as well as support PUE product market development.

› Establish more effective donor oversight, specifically in the measurement of energy sector progress and updating and implementation of energy policies. This monitoring will identify gaps in the energy industry such as the lack of focus on PUE development.

Technical assistance to private companies

› Provide business development, capacity building, and technical support to private organizations to increase their capacity to increase sales and distribution as well as access to finance to expand PUE in rural areas of Liberia.

› Provide technical support in terms of training and equipment to private and government-owned technical institutions (such as Liberia Opportunities Industrialization Center) to train and develop technicians with specialties in PUE. Such training can also target women to increase gender diversity in the sector.

Access to finance

› Engage financial institutions and CBL to improve and expand electronic payment platforms that are needed to increase accountability, transparency, and sustainability for PAYGO PUE systems.

› Provide support to financial institutions through awareness creation about the PUE sector; linkage to funding opportunities for energy development and PUE financing; and development of financial products and services to increase access to finance for PUE product suppliers and end-users.

Gender mainstreaming

› Develop energy policies and programs for PUE to revitalize the rural economy, including agricultural production, processing, and marketing with a clear focus on the role and participation of women.

› Expand capacity for women's participation in the PUE sector, particularly understanding women's energy needs, to promote the uptake of productive use technologies by women through policy guidelines, awareness creation, capacity building, provision of business development, and funding support targeted at increasing women's involvement in energy businesses.

9 ANNEXES

Annex 1: Overview of PUE Technologies

Solar water pumps

Solar PV irrigation pumps can improve provision of water and stimulate productivity of agricultural value-chains during dry seasons. This technology is particularly suitable for:

› Large farms for food crop production (fruit and vegetables, cassava, grains, etc.)
› Nurseries and plantations (palm oil, rubber, cocoa, coffee, etc.)
› Other water needs such as drinking water for households and livestock

Solar pumping devices vary:

› Submersible pumps: Adapted for groundwater
› Surface mounted pumps: Adapted for surface water

Innovation offered in some of the systems include:

› End-user financing by integrating PAYGO models, leasing model approach, or partnership with microfinance institutions
› Remote monitoring of devices to allow monitoring of water usage and device maintenance/troubleshooting
› Coupling with efficient irrigation systems such as drip irrigation
› Integrated modular battery allowing smallholder farmers to use the batteries for pumping as well as other energy related needs such as powering a TV, phone chargers, and lights

Agricultural solar sprayers

Solar Village manufactures, distributes, and finances tailored PAYGO-enabled solar solutions boosting agricultural productivity. The commercialized battery stick:

› Replaces disposable batteries as the source of energy for two existing fertilizer/pesticide sprayers (Micron Ulva+ and Handy)
› Powers a range of household applications similar to SHS (light, phone charging, 12 V TV, fan, USB music device, etc.).

Solar refrigerators and freezers

Solar refrigeration and freezer technologies can ensure a continuous flow of goods in the market and protect the quality of perishable and semi-perishable products from deterioration. Several manufacturers offer a range of varied features depending on the purpose of the usage.

Size: Small standalone freezers and refrigerators can vary from 110 L to 450 L with temperature ranges between -18° C and 0° C.

Innovation: An example is an ice thermal storage model in replacement of a solar battery, allowing to considerably reduce the global cost of the system. Using this technology, the system can provide cooling for up to 36 hours. Some bigger systems are in the form of containerized cold chambers from 18 ft to 40 ft in size.

Different end-user financing options:

- Direct cash sales
- PAYGO model
- Cooling as a service (for example in micro-grids settlement, or in communities and remote areas)

Solar dryers for food preservation

Food dryers are generally used for the preservation of food e.g. fruit and vegetables, meat and fish, but also herbs and can be carried out at farm level immediately after harvest.

Food dryers are mostly produced locally and come in different sizes and shapes, often tailored to customer needs. Some are solely thermal, others comprise of a ventilation system powered by a small PV panel.

Solar agricultural processing (e.g. milling, threshing, hulling, and grinding)

A number of early stage companies are proposing highly efficient technologies for flour milling for cereals such as maize and sorghum; husking, threshing and hulling of rice; grating of cassava and coconuts, etc. Although the market for solar powered efficient processing technologies is still in its early stages, there is great potential for additional income generation for smallholder farmers. Milling capacities can vary from 50 kg/h to 80 kg/h.

Solar-powered digital devices for information and financial services

Access to digital devices is essential for rural populations for access to information as well as facilities and opportunities that the online world offers.

Digital devices connected to the internet can offer access to content and financing solutions to meet the needs of local populations. Solar powered information technology devices are designed to offer:

› Educational/training content where the products include a selection of educational applications related to farming practices, market related information or to foster early learning and children's school education.

› Digital cash register that allows business owners to input their sales, manage their inventory and enhance their margins in order to optimize their business performance.

Solar nano- and micro-grids:

A few companies have developed small solar "energy boxes" which offer DC and/or AC solar energy that can be connected to several productive anchor clients to become a very small electrical grid, called a nano-grid. Every client has their own energy meter and is invoiced based on their consumption.

The maximum distance from the energy box, such as from Solergie's Box, to a client is around 500 meters. Customers of these small nano-grids can be micro-entrepreneurs who can connect fridges, sewing machines, irrigation pumps, shavers, televisions, play stations, etc. Business models to disseminate the innovation can be easily adapted to local circumstances.

Overall specifications of several PUE technologies

IRRIGATION PUMPS
Surface water pumps Wattage: 75 W-1.5 kW Head: 6-75 m
Submersible pumps Wattage: 0.45-22 kW Head: 4-310 m

OTHER LIVESTOCK
Poultry incubators Wattage: 75-100 W Capacity: 48-1,000 eggs
Milk machines Wattage: 1.1 kW Capacity: 20 cows/day

COOLING/DRYING
Chilling systems Wattage: 40-200 W Capacity: Up to 45 L of milk/day
Refrigeration Wattage: 40-400 W Capacity: 50-400 L
Freezing/ice making Wattage: 95 W Capacity: 1.2 kg/day
Walk-in cooling units Wattage: 2 kW+ Capacity: 9 tons+
Fan cooling/drying Wattage: <50 W Capacity: 25-100 kg

AGRO-PROCESSING
Flour milling Wattage: 500-750 W Capacity: 25-160 kg/hour
Husking/threshing/hulling Wattage: 100-375 W Rice capacity: 35-70 kg/hour Maize capacity: 250 kg/hour
Grating Wattage: 250 W Capacity: 100 kg/hour
Oil and nut presses Wattage: 1.5 kW Capacity: 20 kg/hour

Annex 2: Assessment Approach and Respondent Profiles

The following approach was used to conduct the assessment:

› Design assessment workplan
› Develop questionnaires for assessment
› Generate: comprehensive list of stakeholders in relevant sectors of the off-grid Industry
› Generate sample size for the assessment: aggregate across the sectors
› Setup and train assessment team: on use of Questionnaire
› Conduct assessment: field work and strategies
› Data analysis of collected data: including data cleaning and organization
› Development of assessment draft report - presentation and review of preliminary findings
› Submission and presentation of final assessment report

Based on the analysis of the assessment data collected, and the following were the key findings.

TABLE 13. DISTRIBUTION OF RESPONDENTS

SECTORS	MALE	PERCENT	FEMALE	PERCENT	TOTAL	PERCENT
Public sector	2	2.6	0	0.0	2	2.6
Support services	2	2.6	1	1.3	3	3.9
Energy product	8	10.4	1	1.3	9	11.7
Energy supply	1	1.3	0	0.0	1	1.3
International players	1	1.3	2	2.6	3	3.9
Energy demand	29	37.6	30	39.0	59	76.6
Total	**43**	**55.8**	**34**	**44.2**	**77**	**100**

TABLE 14. BUSINESS REGISTRATION TYPE

TYPE OF REGISTRATION	FREQUENCY	PERCENT
Cooperative	7	9.1
Sole proprietorship	30	39
Partnership	16	20.8
Corporation	11	14.2
Association/unions	3	3.9
Legislation act	4	5.2
NGO/INGO	6	7.8
Total	**77**	**100**

TABLE 15. RESPONDENT PROFILE SUMMARY

PROFILE AREA	PROFILE DESCRIPTION	PERCENT
Sex	Male	55.8
	Female	44.2
Sectors	Public sector organizations	2.6
	Support services organizations	3.9
	Energy product firms	11.7
	Energy supply institutions	1.3
	International players	3.9
	Energy demand firms	76.6

FIGURE 6. RESPONDENTS' POSITIONS BY GENDER

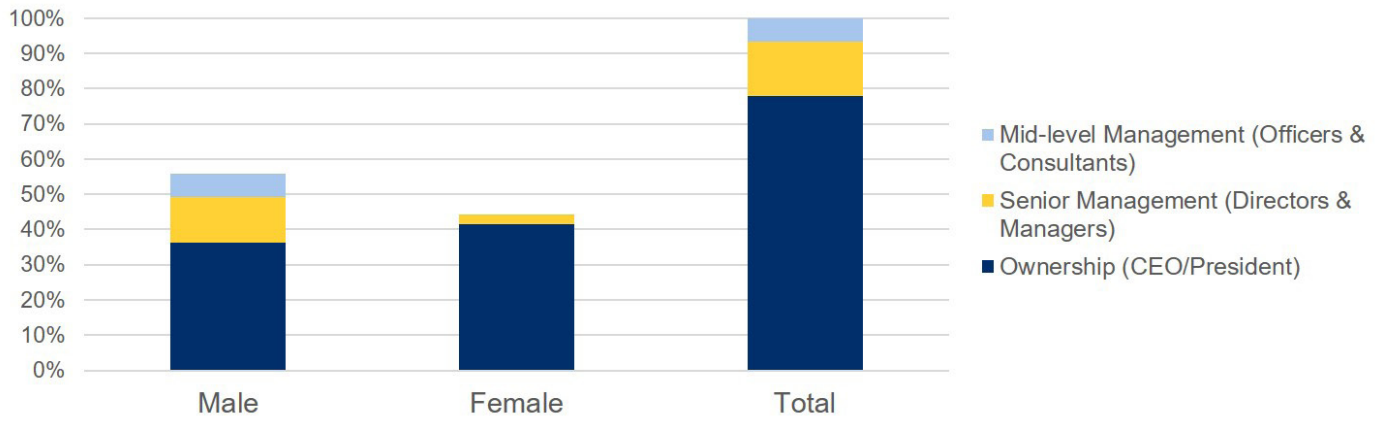


TABLE 16. GENDER REPRESENTATION IN ENERGY DEMAND

DESCRIPTION OF THE MAIN ACTIVITIES OF ASSESSMENT ORGANIZATION (N=59)	HORTICULTURE (FRUIT & VEGETABLES)		CASH/TREE CROPS (RUBBER, COCOA, COFFEE AND PALM OIL)		AGGREGATES OF BOTH SUB-SECTORS		
	Male	Female	Male	Female	Male	Female	Total
Producers and processers (tree and food crops)	12	3	12	1	24	4	28
Distributors (wholesalers and retailers)	0	22	3	0	3	22	25
Unions/associations/corporations/ cooperatives	1	0	5	0	6	0	6
Total	**13**	**25**	**20**	**1**	**33**	**26**	**59**

TABLE 17. ASSESSMENT CHALLENGES AND MITIGATION ACTIONS

LIMITATION	MITIGATION ACTIONS
Global COVID-19 pandemic: The survey was conducted during the period of the coronavirus outbreak when the government announced the suspension of major socio-economic activities and public gatherings to curtail and prevent the spread of the virus. This was a major hurdle in the implementation of the survey, because most of the targeted respondents were either not working at the time or allocated limited time for the survey.	› Formal phone calls and emails to get respondents to agree to participate in the survey. › Multiple interviewers accessed the same respondent, including phone interview, email interview, and in-person visit where possible (mixed mode of interviews).
Delayed and incomplete interviews: Some respondents did not complete the questionnaires in a timely faction, due to reduced office hours and limited or no internet connectivity at home.	Phone calls and emails to collect questionnaire responses in batches.
Low rate of respondents: Most respondents were not comfortable participating in a survey via phone, Skype call, WhatsApp call, etc. Most would have preferred in-person participation.	Considerable time and effort dedicated to convince respondents to participate in the survey, emphasizing that this was the only way possible due to COVID-19 lockdown restrictions.

Annex 3: Current Programs or Projects

TABLE 18: CURRENT PROGRAMS OR PROJECTS

NAME	KEY ACTIVITIES	IMPLEMENTER	REGION	FUNDED BY	DURATION
Regional Off-Grid Electrification Project (ROGEP)	Technical assistance for off-grid market, loans for electricity service providers, support to electrify public institutions	ECREE	19 countries: 15 West Africa (including Liberia), 4 Sahel	World Bank	2017-2022
Liberia Renewable Energy Access Project (LIRENAP)	Hybrid hydropower and diesel plant and grid in Lofa, capacity building, market development of stand-alone solar systems	RREA	Lofa, nation-wide	Strategic Climate Fund Grant, World Bank	Jan 2016-Jun 2021
Energizing Development Liberia (EnDev)	Strengthen renewable energy sector, promotion of solar technologies, pico PV, cocoa solar dryers, improved cookstoves	GIZ/EnDev	Nationwide	Netherlands, Germany, UK, Australia, Norway, Switzerland	2012-2018
Light Up Liberia (LUL)	Curriculum development, market facilitation, financial services, and pico-grid installation	Mercy Corps	Margibi, Lofa, Nimba, Bong, Grand Bassa, Rural Montserrado, Gbarpolu,	EU	2016-2019
Light Up Our Future (LUOF)	Solar electrification of five remote communities	PLAN International, Volunteers for Sustainable Development in Africa (VOSIEDA)	Lofa	EU	2015-2017
Mount Coffee Hydropower Rehabilitation Project	Rehabilitation of hydropower plant (generating units, powerhouse, intake, dam, and spillway) and reservoir, 132/66 kV substation, two 132/66 kV transmission lines, expansion of receiving substations in Monrovia	Manitoba Hydro International, Norplan Fichtner, Voith, Dawnus, Andritz, Ncc, Eltel, Psm Jv, Hydro Operation International	Montserrado	Norway (Ministry of Foreign Affairs), Germany (KFW Development Bank, European Investment Bank), U.S.A. (Millennium Challenge Corporation), Government of Liberia	2012-2017
Renewable Energy, Adaptation and Climate Change Technology sub-Saharan Africa (REACT SSA)	Partial grant and business in 10 countries including Liberia	AECF	Nationwide	Swedish Embassy	2018-2023

TABLE 18: CURRENT PROGRAMS OR PROJECTS, CONTINUED

NAME	KEY ACTIVITIES	IMPLEMENTER	REGION	FUNDED BY	DURATION
Liberia Accelerated Electricity Expansion Project (LACEEP)	Extension, transmission, and distribution of grid; transport and storage of heavy fuel; capacity building in electricity sector	Ministry of Lands, Mines and Energy	Monrovia, Kakata, Kakata Highway	World Bank, International Development Association (IDA)	2013-2020
Liberia Renewable Energy Project	9.34 MW mini-hydro power plant at Gbedin Falls	RREA	Nimba county	AfDB	2018-
Concessions in South East	Technical assistance on how private sector can be attracted to five major settlements in the southeast, first financial pre-feasibility study - Gbanga prioritized	TBD	South East: Cestos city, Greenville, Barclayville, Harper, Pleebo, Fish town, Zwedru, Tappita, and Gbarnga	EU	Ongoing
Power Africa – Beyond the Grid	Rehabilitation of Mount Coffee hydroelectric plant, pilot projects, road rehabilitation	NRECA	Montserrado	USAID	2015-
Technical Assistance for reduction of maternal mortality in Liberia	Telemedicine support for midwives, trainings, solar installations, smartphones	Epos, MoH, GIZ/ EnDev	Grand Gedeh	EU	2017
Liberia Energy Efficiency and Access Project (LEEAP)	Construction of transmission and distribution lines, capacity building	LEC	Montserrado, Bomi, River Gee, Maryland	AfDB, TSF, NTF, EU, GEF, Government of Liberia	2017-2019
Skip the Grid	Health facility electrification (solar)	RREA, ELCA	Liberia	Donations	Started in 2017

Annex 4: Past Development Programs or Projects

TABLE 19: PAST DEVELOPMENT PROGRAMS OR PROJECTS

NAME	KEY ACTIVITIES	IMPLEMENTER	REGION	FUNDED BY	DURATION
Lighting Lives in Liberia (LLL)	Solar electrification, elaboration of regulations, market support for stand-alone solar systems	RREA	Nationwide	Global Environment Facility (GEF) Trust Fund Grant, World Bank.	2012-2017
Renewable Energy Sources to Rural Primary Health Care Facilities	204 health facilities in 15 counties received DC solar installations, 410 health facility staff were trained in maintenance of solar systems	Merlin, Save the Children International-Liberia	Nationwide	EU Energy Facility II and the Government of Liberia	2011-2014
Developing a Rural Energy Strategy and Master Plan for Liberia	Supported RREA to develop into a strong, independent, efficient, and sustainable organization capable of achieving Liberia's target of increasing access to modern energy services in the rural areas	RREA	Monrovia, Lofa, general	EU	2011-2016
Liberia Energy Sector Support Program (LESSP)	Capacity building, four pilot projects electrifying rural communities with renewable energies (biomass, hydro, solar)	Winrock International	Lofa, Nimba, Bong	USAID	2010-2014
Light Every Birth	Solar suitcases for maternity wards	We Care Solar, UNICEF, GIZ/ EnDev, Africare, PHIL	Nationwide	United Nations Department of Economic and Social Affairs, UBS Optimus Foundation, Gilead Foundation, and private donors	2016-2018

Annex 5: Summary of Mini-grid Projects in Liberia

TABLE 20: SUMMARY OF MINI-GRID PROJECTS IN LIBERIA

COUNTY & COMMUNITY	TECHNOLOGY	FUNDER	IMPLEMENTER	OPERATOR	CAPACITY	START DATE	STATUS (BY SEP 2020)
Lofa – Yandohun	Hydro	World Bank	RREA	Local cooperative	60 kW	2013	Operational
Nimba – Kwendin	Biomass (wood)	USAID	NRECA	Local cooperative	60 kW	2016	Operational
Lofa – Sorlumba	Biomass (palm oil)	USAID	NRECA	Local cooperative	25 kW	2017	Almost operational
Bong – Totota	Solar/diesel	–	NRECA	Private operator	25 kW	2016	Operational, plans for extension
Lofa – Kaiha 2	Hydro/diesel	World Bank	RREA	Private operator	2.5 MW	2019	Planned
Bong – Suakoko	Hydro/diesel	USAID	NRECA	–	1000 kW	2019	Planned
Margibi – Robertsfield Highway	–	–	–	–	10 MW	2020	Memorandum of understanding signed
Lofa – Langbemba	Solar	EU	PLAN & VOSIEDA	Local cooperative	31.1 kW	2017	Damaged by fire
Lofa – Taninahun	Solar	EU	PLAN & VOSIEDA	Local cooperative	28.5 kW	2017	Operational
Lofa – Mamikonedu	Solar	EU	PLAN & VOSIEDA	Local cooperative	25.5 kW	2017	Operational
Lofa – Koiyama	Solar	EU	PLAN & VOSIEDA	Local cooperative	22.5 kW	2017	Operational
Lofa – Nyengbelahun	–	EU	PLAN & VOSIEDA	Local cooperative	–	2017	Operational
Lofa – Gbarnway	–	USAID	–	–	24 kW	–	–
Montserrado – Koon Town	Solar	EU	Mercy Corps	Business	–	–	Operational
Montserrado – Karto Town	Solar	EU	Mercy Corps	Business	–	–	Operational
Montserrado – Block Pad	Solar	EU	Mercy Corps	Business	–	–	Operational
Bong – Totota	Solar	USADF	–	Private operator	–	–	Planned

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