Rural and Renewable Energy Agency
Securing modern energy access for all Liberians

Funded by: European Union

RURAL ENERGY STRATEGY AND MASTER PLAN FOR LIBERIA UNTIL 2030

TECHNICAL REPORT

April 2016

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AC	Alternating Current
ADC	Austrian Development Cooperation
ADER	Agence pour le Développement de l'Electrification Rurale
AECID	Spanish Agency for International Cooperation for Development
AEDC	Abuja Electricity Distribution Company
AER	Rural Electrification Agency of Cameroon
AFD	Agence Française de Développement
AfDB	African Development Bank
AfDF	African Development Bank Fund
AfT	Agenda for Transformation
AMADER	Agence Malienne pour le Développement de l'Energie Domestique et de l'Electrification Rurale
ARE	Alliance for Rural Electrification
ASER	Agence Sénégalaise d'Electrification Rurale
BC	Building Capacity
BOO	Build, Own, Operate
BOS	Balance of System
BOT	Build, Operate, Transfer
BTG	Beyond the Grid
CAPEX	Capital Expenditure
CEC	Copperbelt Energy Corporation
CIAT	International Center for Tropical Agriculture
CIF	Climate Investment Funds
CLSG	Côte d'Ivoire, Liberia, Sierra Leone and Guinea
CPO	Crude Palm Oil
DANIDA	Danish International Development Agency
DC	Direct Current
DEG	German Investment and Development Company
DEM	Digital Elevation Model
DFI	Development Finance Institution
DFID	Department for International Development
DG	Decentralized Grids
DG DEVCO	Commission's Directorate-General for International Cooperation and Development
DR	Distribution Royalties
ECG	Electricity Company of Ghana
ECOSOC	Economic and Social Council
ECOWAS	Economic Community of West African States
EDF	European Development Fund
EETC	Egyptian Electricity Transmission Company
EIB	European Investment Bank
EITI	Extractive Industries Transparency Index
EREDPC	Ethiopia Rural Energy Development and Promotion Center
ESRA	European Solar Radiation Atlas
ESRP	Economic Stabilization and Recovery Plan
EU	European Union
EUEI PDF	European Union Energy Initiative - Partnership Dialogue Facility

EVD	Ebola Virus Disease
FAO	Food and Agriculture Organization of the United Nations
FDE	Fonds de Développement de l'Electrification
FDFA	Federal Department of Foreign Affairs
FDI	Foreign Direct Investment
FDSEL	Fonds de Développment du Secteur de l'Electricité
FFEM	French Facility for Global Environment
FMO	Netherlands Development Finance Company
FUNAE	Fundo de Energia de Moçambique
FY	Fiscal Year
GBEP	Global Bioenergy Partnership
GDI	Gender Development Index
GDP	Gross Domestic Product
GEF	Global Environment Facility
GGGI	Global Green Growth Institute
GHCN	Global Historical Climatology Network
GHI	Global Horizontal Irradiation
GII	Gender Inequality Index
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoL	Government of Liberia
GRASS	Geographic Resources Analysis Support System
GTG	Growing the Grid
GW	Gigawatt
GWh	Gigawatt-hour
HC1	HelioClim-1
HDI	Human Development Index
HFO	Heavy Fuel Oil
HIPC	Heavily Indebted Poor Countries
HSD	High-Speed Diesel
HV	High Voltage
IAM	Incidence Angle Modifier
IBRD	International Bank for Reconstruction and Development
ICF	International Climate Fund
ICT	Information and Communication Technology
IDA	International Development Association
IEA	International Energy Agency
IFC	International Finance Corporation
IHDI	Inequality adjusted Human Development Index
IIB	International Investment Bank
IMF	International Monetary Fund
IMIC	International Mining & Infrastructure Corporation
INEP	Integrated National Electrification Program
IPP	Independent Power Producer
IRENA	The International Renewable Energy Agency
ITCZ	Inter-Tropical Conversion Zone
JICA	Japan International Cooperation Agency

KETRACO	Kenya Electricity Transmission Company Limited
KfW	Kreditanstalt fur Wiederaufbau
KP	Kyoto Protocol
kW	Kilowatt
kWh	Kilowatt-hour
LACEEP	Liberia Accelerated Electricity Expansion Project
LCOE	Levelized Cost of Electricity
LCPDP	Least Cost Power Development Plan
LEAP	Local Enterprise Assistance Program
LEC	Liberian Energy Corporation
LERC	Liberia Electricity Regulatory Commission
LF	Lease Fee
LHS	Liberian Hydrological Services
LIBCO	The Liberian Rubber Corporation
LIRENAP	Liberia Renewable Energy Access Project
LISGIS	Liberia Institute of Statistics and Geo-Information Services
LPG	Liquefied Petroleum Gas
LPRC	Liberia Petroleum Refining Company
LT	Linke Turbidity
LUC	Levelized Unit Cost
LURD	Liberians United for Reconciliation and Democracy
LV	Low Voltage
MDG	Millennium Development Goals
MIGA	Multilateral Investment Guarantee Agency
MIS	Management Information System
MLME	Ministry of Lands, Mines and Energy
MoP	Ministry of Power
MPI	Multidimensional Poverty Index
MSME	Micro, Small and Medium Enterprise(s)
MSW	Municipal Solid Waste
MV	Medium Voltage
MW	Megawatt
MWh	Megawatt-hour
MWL	Mean Water Level
NASA	National Aeronautics and Space Administration
NCEI	National Centers for Environmental Information
NDF	Nordic Development Fund
NEDCo	Northern Electricity Distribution Company
NEO	NASA Earth Observations
NEP	National Energy Policy
NGDC	National Geophysical Data Center
NGO	Non-Governmental Organization
NGP	National Gender policy
NIC	National Investment Commission
NOAA	National Oceanic and Atmospheric Administration
NORAD	The Norwegian Agency for Development Cooperation
NPFL	National Patriotic Front of Liberia

NRECA	National Rural Electric Cooperative Association
NVE	Norwegian Water Resources and Energy Directorate
NZAID	New Zealand Aid Program
O&M	Operation & Maintenance
ODA	Official Development Aid
OECD	Organisation for Economic Co-operation and Development
OFID	OPEC Fund for International Development
OPEX	Operational Expenditure
OTP	Other than Power
PHED	Port Harcourt Electricity Distribution Company
PNBEPH	Programa Nacional de Barragens com Elevado Potencial Hidroeléctrico
PPC	Power and Petrol Contribution
PPP	Public-Private Partnerships
PR	Performance Ratio
PRG	Partial Risk Guarantee
PRS	Poverty Reduction Strategy
PV	Photovoltaic
REA	Rural Energy Agency / Rural Electrification Authority / Rural Electrification Agency
RED	Regional Electricity Distributors
REEEP	Renewable Energy and Energy Efficiency Partnership
REF	Rural Electrification Fund
REFUND	Rural Energy Fund
RESMP	Rural Energy Strategy and Master Plan
RMSD	Root-Mean-Square Deviation
ROT	Rehabilitate, Operate, Transfer
RPM	Rotations per Minute
RREA	Rural and Renewable Energy Agency
SAPP	Southern African Power Pool
SBCS	Solar Battery Charging Station
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goal
SE4All	Sustainable Energy for All
SHS	Solar Home System
SoDa	Solar Radiation Data
SP	Social Protection
SP-1B	St. Paul River 1B Hydropower Plant
SP-2	St. Paul River 2 Hydropower Plant
SREP	Scaling-Up Renewable Energy Program
SRTM	Shuttle Radar Topography Mission
SSA	Sub-Saharan Africa
STC	Standard Test Conditions
TB5	TerrainBase 5
TJ	Terajoule
UK	United Kingdom
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNFCCC	United Nations Framework Convention on Climate Change

UNIDO	United Nations Industrial Development Organization
US	United States
USAID	United States Agency for International Development
USD	United States Dollars
USTDA	US Trade and Development Agency
WACC	Weighted Average Cost of Capital
WAPP	West African Power Pool
WB	World Bank
WGI	Worldwide Governance Indicators
WHO	World Health Organization
WHS	Wind Home Systems
WMO	World Meteorological Organization
WRDC	World Radiation Data Centre
WTP	Willingness to Pay
WWI	World War I
WWII	World War II
YEDC	Yola Electricity Distribution Company

EXECUTIVE SUMMARY

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Introduction

"Small light today, big light tomorrow". This document presents Liberia's Rural Energy Strategy and Master Plan (RESMP) for the period until 2030 and aims to set clear targets, to identify least-cost projects and technologies, to propose concrete investments for funding and implementation, with appropriate institutional framework and capacity to increase energy access and renewable energies to the country's rural areas and population – meaning all areas and population outside of greater Monrovia. This document responds to Liberia's President call for "Small Light Today, Big Light Tomorrow", and also responds to two global development goals - the Sustainable Energy for All (SE4ALL) and Sustainable Development Goals (SDGs).

Country context and background

Energy access is a key component of Liberia's Agenda for Transformation (AfT) and post-Ebola recovery strategy. Liberia was finally on the path of growth and development after fourteen years of devastating civil war and ten years of uninterrupted peace when it was hit by the Ebola outbreak in 2014. The Ebola outbreak had a devastating impact on the nation's economy and on the lives of millions of Liberians. A recovery plan was approved in 2015 with Energy Access and Renewable Energies being a key component as energy infrastructure is critical to enable economic activity, output and growth, but also a key lever to strengthen resilience, reduce vulnerability and promote gender equality through improved health, education and security services.

Liberia's energy access is still today one of the lowest in the world. Despite some progress on the electrification of Monrovia - the country capital - Liberia has still one of the lowest grid electrification rates in the world with less than 3% of the population connected to grid power – meaning less than 10% in Monrovia and less than 0.5% in the rest of the country. This leaves the vast majority of people reliant upon various informal and unreliable systems and leads also to an intensive use of diesel based generators in the less rural areas of the country.

Despite high renewable energy potential, electrical energy cost is one of the highest in the world relying mostly on fossil fuels. Liberia has more than 2.3 GW of hydro potential identified and a widespread solar irradiation and biomass vegetation. Many locations across the country offer the potential for lower cost renewable electricity. However, populations with electricity in Liberia face one of the highest costs of electricity in the world with the Liberian Energy Corporation (LEC) tariffs of USD 0.50 per kWh and power mostly generated from fossil fuels.

The Master Plan is based on the principles and policies of Efficiency, Equity, Sustainability, Transparency, Private Sector participation and Regional cooperation. The National Energy Policy principles remain effective, namely the principle of least cost development taking account of the

economic, financial, social and environmental factors and the special needs of the poor; the principle of promoting equity across regions, social classes and genders while balancing efficiency on the allocation of the available resources; the principle of optimizing the use of our indigenous and renewable resources in a sustainable way; the policy of facilitating private sector investment; the policy of a transparent and independent regulatory process to ensure safe, secure, reliable and sustainable power at a cost-reflective but affordable price; and the policy of promoting regional cooperation.

Vision and objectives for rural energy until 2030

Building a long term vision. Least cost studies show in the long term (potentially 2050) the most efficient way to bring “Big Light” to Liberia is to have the National Grid reach 89% of Liberia’s population and 96% of potential consumption with the remaining 11% scattered among 7 000 off-grid small settlements. However, the Government of Liberia opted not to delay access to energy for those far away from the existing National Grid and to benefit from the country’s immense renewable potential. The priority and scenario for rural energy is to start building the least cost long term vision based on Medium Voltage (MV) investments, Decentralized Grids and Renewable Energies that can maximize number of connections in an equitable way across the country until 2030 – from Monrovia to cities and towns, from cities and towns to more rural areas.

Ambitious objectives until 2030 for a decentralized and equitable transition to the “large grid” long term vision:

- Electrification rate for the population outside of Monrovia of 10% in 2020, 20% in 2025 and 35% in 2030, electrifying the largest cities and towns of the country first.
- All county capitals, health facility and secondary schools electrified already before 2025.
- 10 largest settlements in each County to be electrified by 2030 with minimum electrification of 15% per County.
- More than 75% of all electricity generated from renewables by 2030 with 19% coming from other than large hydro: Mini-hydro, Solar and Biomass.
- Universal access to affordable solar lamps, efficient appliances and cook stoves.
- Cooking gas available in all county capitals and efficiently produced charcoal widespread across the country.

Rural Energy Action Plan

Five Programs for rural electrification of Liberia. The Master Plan identifies 92 projects and investments to electrify 265 000 homes and 1.3M people outside Monrovia until 2030. The action plan and rural energy projects are structured under 5 main programs:

- **GTG: Growing the Grid Program**:
  Expanding Medium Voltage grid from the three planned corridors outside of Monrovia (Kakata, Kle and RIA), from new proposed corridors starting from Gbarnga and from the Côte d'Ivoire, Liberia, Sierra Leone and Guinea interconnection (CLSG) sub-stations and Shield Wire, representing a total investment of USD 308M and the electrification of 164 300 homes. Additionally, GTG includes additional USD 242M investment in on-grid renewable generation to be installed outside Monrovia.
- **DG: Decentralized Grids Program**:
  Building large decentralized grids supported by renewable generation, cross border inter-connections and Medium Voltage grids (Voinjama, Pleebo/Fishtown, Zwedru and Greenville); guaranteeing the electrification of the 10 largest settlements in each County, if not under GTG program, than through the development of transitional solar/diesel low voltage mini-grids. Represents a total investment of USD 292M and the electrification of 96 800 homes.
- **BTG: Beyond the Grid Program**:
  Electrifying community services, households and public buildings where the grid is not expected before 2025 through 100% solar based off-grid solutions, prioritizing health, education (secondary schools) and security (police stations, checkpoints, courthouses and public lighting); electrifying 75 future off-grid settlements in an equitable way across counties mainly through Solar Home Systems (SHS) while promoting the sale and rental of solar portable lamps or smaller Solar Home Systems across the country. Represents a total investment of USD 16M and the electrification of 4 000 homes.
- **OTP: Other than Power Program**:
  Promoting efficiency in buildings, appliances and cooking; developing Liquefied Petroleum Gas (LPG) storage and filling infra-structure while promoting availability of cooking gas in all county capitals; promoting efficient charcoal production and efficient cook stoves requires a total investment of USD 24M.
- **BC: Building capacity**:
  Creating the capacity, the institutional framework, the organization, the information and management systems and the infra-structure to implement the Master Plan requires a total investment of USD 52M.

Investment requirements and funding strategy

USD 746M still to be funded mostly for the period between 2020 and 2030. From the required USD 935M, around USD 140.8M are already committed and an additional USD 45M secured, representing a total of USD 185M – mostly from African Development Bank, World Bank and European Union. Most of the secured funding will be deployed in the first phase (2016-2020) representing a significant part of the estimated investment of USD 262M during that period. A gap of USD 749M

remains to implement the Rural Energy Master Plan with additional USD 102M being required in the next years, USD 303M between 2020 and 2025 and the remaining until 2030.

A compelling case for funding. The RESMP benefits from a strong initial focus on the electrification of the main cities and towns outside Monrovia (65% of all rural clients in 2030) where there is business activity and some capacity to pay for energy services. The support studies show that if initial investments in distribution and renewable based generation have a strong component of grants and if consumers are charged for what they consume based on pre-paid meters and reasonable tariffs, it is possible to create a financially sustainable system that can maintain the assets, pay for running costs and fund a part of the growth investments, potentially leveraging on a robust Rural Energy Fund (REFUND) to mitigate risks and reduce interests. In the National Grid where generation cost is lower due to regional imports and large scale hydro investments, investments in renewable generation and distribution can also be funded using Development Finance Institutions (DFIs) and the private sector.

Institutional framework and private sector participation

RESMP institutional framework is based on a Public Private Partnership model. The implementation challenge requires strong private sector involvement – in line with the recently approved electricity legislation. However, the need to combine a strong grant component to achieve affordable tariffs, also requires strong donor involvement with competent public sector interface and an acceptable asset ownership model.

The Regional Distribution Companies. At least 5 Regional Distribution Companies will be created to manage all Distribution activities in specific regions – one from LEC and others based on existing cross border grids, CLSG sub-stations and future large decentralized grids. Distribution companies will manage all distribution activities in their allocated region, either on or off national grid, except long term off-grid locations which may be managed by small local companies or cooperatives. Liberia Electricity Regulatory Commission (LERC) will regulate Distribution Companies revenues and tariffs guaranteeing an adequate cost recovery and return on investment while reducing differences in tariffs through use of REFUND as a balancing mechanism.

LEC National Grid Company or Unit. LEC Transmission and System Operation activities should be set up in an autonomous "LEC National Grid Company or Unit" that will treat all Distribution and Generation Companies without discrimination. This unit will also procure energy from on-grid Renewable Independent Power Producers (IPP) and other grid connected generation units in order to guarantee a secure and competitive sourcing for all Distribution Companies connected to the National Grid. Regional Distribution Companies will be allowed to procure part of the energy they consume directly, under limits to be approved by LERC.

Other private operators will be involved in rental or retail/supply of solar portable lamps, and non-electrical energy efficient cook stoves or cooking gas and related equipment. Rural Services Unit(s) (RSU) will give support in procurement and wholesale of Solar Portable Lamps, in monitoring progress

and to Distribution Companies on pre-paid meters. Petrol retailers will be required to distribute and make available cooking gas in different sizes down to at least 6 kg per bottle. The Liberian Petroleum Refining Company (LPRC) will also support LPG imports and storage.

Coordination, monitoring and communication

Coordination and monitoring. RREA will coordinate, supervise, and report progress yearly on the implementation of the Master Plan, while the Ministry of Lands, Mines and Energy (MLME) will provide policy oversight and monitoring of the Master Plan, along with the National Energy Committee. The latter will include all relevant ministries, agencies, Civil Society, the private sector, and county official and shall meet at least once every year to review progress made on the implementation of the Master Plan.

Communication. A web-site will be developed by RREA to communicate the implementation and results of the Master Plan and the Rural Electrification database and statistics. Other means such as brochure, newsletter, etc. will be prepared to provide information to the general public on the implementation of the Master Plan.

PART A. INTRODUCTION

1 INTRODUCTION

1.1 FOREWORD

The Rural and Renewable Energy Agency (RREA) is mandated by its Legislation to develop in collaboration with the Ministry of Lands, Mines & Energy and other stakeholders a Rural Energy Strategy and Master Plan for Liberia. The Master Plan shall be formulated on the basis of well-defined project selection and prioritization criteria designed to ensure enhanced energy access with equity, sustainable development and optimal use of indigenous and renewable resources, and ensure that these are integrated into the national energy Master Plan. This document has been prepared in fulfillment of this very important mandate.

Recently we suffered one of the most tragic civil wars in modern African history, and then, just when we had substantially recovered and begun to grow our economy the Ebola crisis came. It is once again time to rebuild our nation, to recover productivity and growth, to strengthen our resilience and reduce vulnerability with sustainable public finances and real results. Energy is one of the key elements and priorities for our recovery and for our development. Together with roads and communication, energy is critical for economic activity, for health, for education and for security.

Liberia has one of the lowest electrification rates in the world and, at the same time, one of the highest electricity tariffs globally. It is a major impediment to growth and development in health, education and security of the people, a huge restraint economic activity and job creation.

Some progress has been made in Monrovia. With donors' contributions the Government is electrifying the city of Monrovia and its environs, and with the rehabilitation of Mount Coffee we expect that electricity will become more affordable and that many diesel generators and consumers currently outside of the grid will be connected to the main grid sooner than later.

On the other hand, we cannot ignore and leave the rest of the country without electricity. It is therefore imperative to invest in rural electrification because we still have to electrify the cities and towns in the rest of the country taking advantage of the vast renewable energy resource potential, where affordable electricity is supplied to support social and economic activities thus leading to productive uses, and job creation. This Rural Energy Master Plan serves as a strategic roadmap for providing access to improved energy services as well as integrating energy into rural development programs and activities in Liberia. Identifying viable projects that can be maintained by the private sector is the purpose of this Master Plan. Financing the implementation of this Master Plan will require a combination of grants, concessional finance, and private sector investment in order to achieve the 35% rural electrification target in 2030.

We need a consolidated effort of all stakeholders – the Government, development partners, civil society and the private sector – for the implementation of this Rural Energy Master Plan to increase energy access and ensure social and economic development in rural Liberia.

1.2 OVERVIEW

The current document was developed by Gesto Energia, S.A., ("Consultant") under a contract celebrated with the Rural and Renewable Energy Agency of Liberia ("Client") for the *Development of the Rural Energy Master Plan for Liberia* ("Project"), under funding from the European Development Fund (10th EDF), and constitutes the Final Report of the Project.

The Consultant is an international firm specialized in energy planning and in the evaluation of renewable energy resources. It has know-how and experience in the development of renewable energy policy as well as master plans and supports all phases of renewable energy project development.

The Project's global objective is to develop and demonstrate a Rural Energy Strategy and Master Plan for Liberia up to 2030. More specifically, the Project aims to answer the question: "how to achieve 35% or more of rural electrification by 2030?" and to:

1. Serve as a strategic roadmap for providing access to improved energy services as well as integrating energy into rural development programs and activities, taking into consideration other cross-cutting issues such as gender, energy efficiency, and environmental protection;
2. Promote energy enterprise development;
3. Research and develop renewable energy technologies locally;
4. Establish standards for equipment and services;
5. Establish a central repository for all information on rural and renewable energy activities in Liberia.

This document consists of six parts:

A. **Introduction** – the current part, where the overview and objectives of the Project and methodology applied is presented;
B. **Background and Policy** – where the country and sector background is presented, the country's agenda and policies are evaluated and barriers, expectations and priorities for rural energy are addressed.
C. **Long Term Vision** – assesses the demand and supply options (including the existing endogenous resources), and analyses the long term network expansion.
D. **Rural Energy Vision and Targets to 2030** – sets the rural electrification scenarios to 2030, addresses the funding potential and strategy and establishes the vision and targets for rural energy.
E. **Rural Energy Investment and Action Plan** – forms the rural energy action plan, including implementation and investment plan, and evaluates country and local impact.
F. **Implementation Framework** – addresses several implementation issues such as the institutional and regulatory framework, the private sector participation, the funding strategy and coordination, communication and monitoring topics, as well as other cross-cutting issues.

1.3 METHODOLOGY

The methodological approach for the Project has been subject to debate between the Client and the Consultant in the inception phase of the Project, although there weren't substantive changes to the preliminary methodology proposed during the tender phase, other than some refinement of tasks and shifts in the work plan.

The final methodology is depicted in **Figure 1.1**, and a brief description of the tasks is presented in the following section.

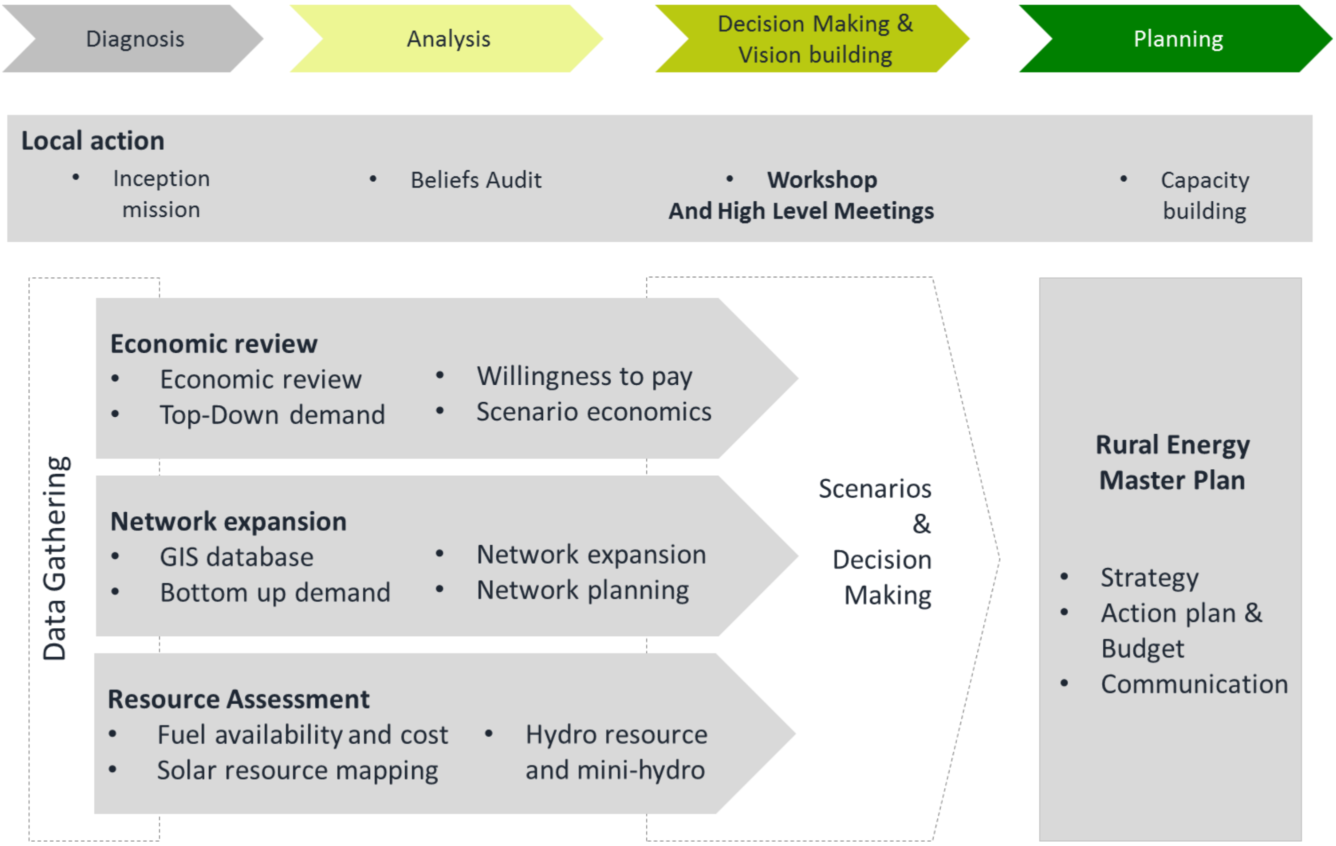

Figure 1.1 – Project methodology

Figure 1.1 shows a series of interconnected sub-activities and tasks that will go from diagnosis, analysis, decision making and vision building up to planning, into 4 different vectors (Local action, Economic Review, Network Expansion and Resource Assessment) that integrate the specific required work. The planning phase is built upon the deep technical and economic analysis and the political decision making and it delivers the strategy, action plan and capacity building.

This approach takes into account the target groups geographical areas to be covered and focus on the expected off-grid areas.

The planning phase, the report mapping and presentation was planned at the end of the Project, but the outcomes and interim results of the tasks were presented to the Client on a regular basis.

The **Local Action** vector comprised the tasks performed at a local level, together with the Client and other relevant stakeholders. As such, the inception mission, beliefs audit, funding and financing interviews, were carried out, ending up with the workshop and high level meetings[1] where the scenarios were presented for decision making and vision building.

The **Economic Analysis** vector comprised all the tasks related to the economic review, the top-down demand assessment, the willingness to pay and prioritization criteria and the scenario development based on the combined inputs from the later task with the funding and financing interviews and the network planning and budgeting.

The **Network Expansion** vector comprised the tasks related to the building and verification of the Geographic Information System (GIS) database, the updated bottom-up demand assessment, the network expansion model update and finally the network planning and budgeting.

The **Resource Assessment** vector was a differentiated approach proposed by the Consultant, in where it wasn't an actual requirement of the Terms of Reference apart from some specific activities that could fit in this broad category.

In reality, in order to assess the best option for rural electrification, the base rural electrification technologies should be properly assessed. From the Consultant's experience, given the geography, climate and country size, it was expected that in Liberia rural electrification might be achieved from fossil fuels, photovoltaic (PV), biomass or hydropower based solutions in competition with grid extension. The additional effort put into this task allowed a further comprehensive planning of the rural electrification options. The business models for each solution were developed, taking resource availability into account.

For the **Capacity Building** activity, the Consultant took into account its relevant experience in providing training and capacity building on renewable energies mapping and development not only in African countries but also worldwide. In fact, notwithstanding the permanent interaction with the client's local staff while developing the projects, that allowed for an overall awareness of the processes deployed and an ongoing exchange of knowledge, the Consultant is keen on providing this capacity building in more specific formats, usually in the form of workshops and seminars.

For the **Strategy**, taking into account all data collected and GIS mapping of Liberia, as well as the analysis that was done, a rural electrification strategy for Liberia was developed. Key recommendations include not only technical and economic aspects, but also a brief legal review.

The **Action Plan and Budgeting** task required all the inputs from the network expansion and resource assessment studies and resulted, together with the Strategy, in the drafting of the Rural Energy Master Plan.

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[1] Stakeholder's Consultation and Validation Workshop at the Passion Hotel, Gboveh Hill, Gbarnga City, Bong County, February 4, 2016

Finally, in the **Communication** activity, the Consultant designed materials for a communication strategy for public awareness towards rural energy development, renewable energy technologies and community requirement.

PART B. BACKGROUND AND POLICY

2 COUNTRY AND SECTOR BACKGROUND

2.1 ECONOMIC AND SOCIAL SITUATION OF LIBERIA

Liberia's geography. Liberia is situated in West Africa, neighboring Sierra Leone on the northwest with a 299 km border, Guinea to the north with a total length of land border of 590 km, and Côte d'Ivoire in the east, with a land border of 778 km. On the southwest it is bordered by the North Atlantic Ocean, having 579 km of coastline. Liberia's total area comprises 111 369 km^2, of which 96 320 km^2 is land and the remaining 15 049 km^2 is water [1].

Figure 2.1 – Map of Liberia.

Administrative divisions of Liberia. Liberia is divided into fifteen counties (see **Figure 2.1**), which, in turn, are subdivided into a total of 90 districts and further subdivided into clans. The biggest counties are Nimba and Grand Gedeh, with over 10 360 km^2, followed by Lofa, Gbarpolu, Sinoe, and Bong. These five counties account for 54% of Liberia's total area (96 917 km^2). On the other hand, the smallest county is Montserrado with only 1 880 km^2, followed by Bomi, Maryland, and Margibi, with 1 932, 2 294, and 2 690 km^2, respectively (see **Figure 2.2**).

Population distribution. Monrovia, Liberian capital, is the most populous city, with a total of 28% of the total population of Liberia, located in Montserrado County. More than 50% of total population of Liberia lives in Montserrado, Nimba and Bong Counties (see **Figure 2.3**).

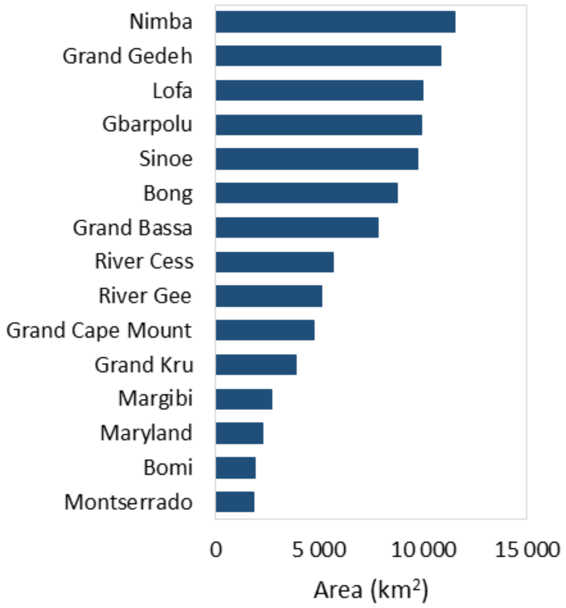

Figure 2.2 – County area.

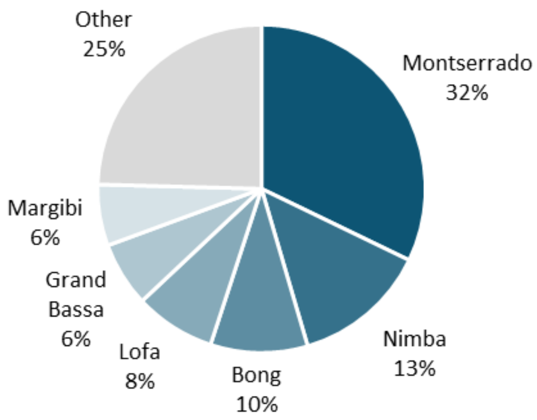

Figure 2.3 – Liberia's total population distribution per county [2].

Historical Background. Liberia was created through a settlement of freed slaves from the United States (US) in 1822 and by 1847 the American-Liberians were able to establish a republic, thus being Africa's oldest republic. Prior to the World War I Liberia was largely impoverished and unstable, as well as dependent on Germany for around 75% of its foreign trade. This economic cooperation with Germany was over in 1918 once Liberia joined the World War I (WWI) alongside with the USA, having a severe impact on the Liberian economy. In the World War II (WWII) Liberia supplied rubber for the Allies as they had the world's largest rubber plantation. During this war the USA constructed military bases, airports, the Freeport of Monrovia, roads to the interior, etc. After WWII, William Tubman, president from 1944-71, did much to promote foreign investment and to bridge the economic, social, and political gaps between the descendants of the original settlers and the inhabitants of the interior. President William R. Tolbert, Jr. pursued a policy of suppressing opposition and on April 12, 1980, Samuel Kanyon Doe led a bloody coup d'état against president Tolbert. This put an end to 133 years of American-Liberian political domination over Liberia.

Liberia's First Civil War. The First Liberian Civil War was an internal conflict in Liberia from 1989 until 1997. In December 1989, the National Patriotic Front of Liberia (NPFL), led by Charles Taylor, began an uprising against the Doe's regime. In 1990 Doe was executed by a splinter group of the NPFL. This conflict only came to an end in 1997, once Taylor won a presidential election which international observers declared as free and fair. Taylor won the elections with 75.33% of the votes, while the runner-up, Unity Party leader Ellen Johnson Sirleaf, received a mere 9.58% of the votes. This civil war conflict killed over 200 000 people and the involvement of the Economic Community of West African States (ECOWAS) and the United Nations was necessary. Between 1997 and 1999, although the bloodshed in Liberia slowed considerably, it did not end. Violence kept flaring up and during Taylor's entire reign he had to fight insurgencies against his government.

Liberia's Second Civil War. The peace did not last long, and in 1999 the Second Liberian Civil War broke out. Indeed, in 1999 Ghana and Nigeria accused Liberia of supporting Revolutionary United Front rebels in Sierra Leone, and Britain and the US threatened to suspend aid to Liberia. Meanwhile, the United

Nations Security Council in March 2001 concluded that Liberia and Charles Taylor played a role in the civil war in Sierra Leone, and therefore banned all arms sales to, and diamonds sales from Liberia; and banned high Liberian Government members to travel to UN-states. In 2002, rebels — Liberians United for Reconciliation and Democracy (LURD) — intensified their attacks on Taylor's government, supported by Sierra Leone and Guinea, as Taylor was supporting opposition factions in both countries. Finally, on August 11, 2003, Taylor stepped down and went into exile in Nigeria. During the period of 2003-2005, a peace agreement was achieved and a transitional government appointed.

Socio-Economic impact of Liberia's Civil Wars. By the end of the 14 year conflict, most of Liberia's infrastructures had been destroyed, food insecurity was widespread, poverty rates were high, and many people had been displaced. Indeed, this conflict had grave social, economic and environmental impacts and by the end of 2003, about a third of these people were still living as refugees in neighboring countries. Since 1989, about half a million people were killed in war-related circumstances, and of these, 50% were civilians. The economic impacts of these civil wars were clear: in 2003 Liberia was the second country with lowest Gross Domestic Product (GDP) based on Purchasing Power Parity per capita in the world. The major challenges facing Liberia's post-conflict development concerned infrastructure, human capital and institutional capacity.

Ellen Johnson Sirleaf elected president. After two years of rule by a transitional government, the 2005 Liberian general election were held. In these elections, President Ellen Johnson Sirleaf, former World Bank employee and Liberian finance minister, won the presidential elections and became the first democratically-elected female African head of state in January 2006. In 2011 she subsequently won reelection in another free, fair and transparent democratic elections. Moreover, President Ellen Johnson Sirleaf was jointly awarded the 2011 Nobel Peace with Leymah Gbowee of Liberia and Tawakkol Karman of Yemen, in recognition for "their non-violent struggle for the safety of women and for women's rights to full participation in peace-building work" [3]. President Ellen Johnson Sirleaf had the challenge to rebuild Liberia's economy, and to reconcile a nation still recovering from 14 years of fighting.

Rapid economic growth due to peace and stability. With the restoration of peace, Liberia faced a period of rapid economic growth, experiencing a GDP rate of 7.6% on average in the period of 2004-13, and its nominal GDP more than tripling during this period (**Figure 2.4**). The restart of iron ore production encouraged construction and service sector activities. There was also a boost in foreign direct investment inflows which provided a significant boost for the Liberian economy. This rapid growth driven by natural resources resulted in a significant improvement in the United Nations Development Programme's (UNDP) Human Development Indicators (from a very low base), from 0.35 in 2005 to 0.42 in 2013. Nevertheless, the level of this index remains well below the average for sub-Saharan Africa (0.51).

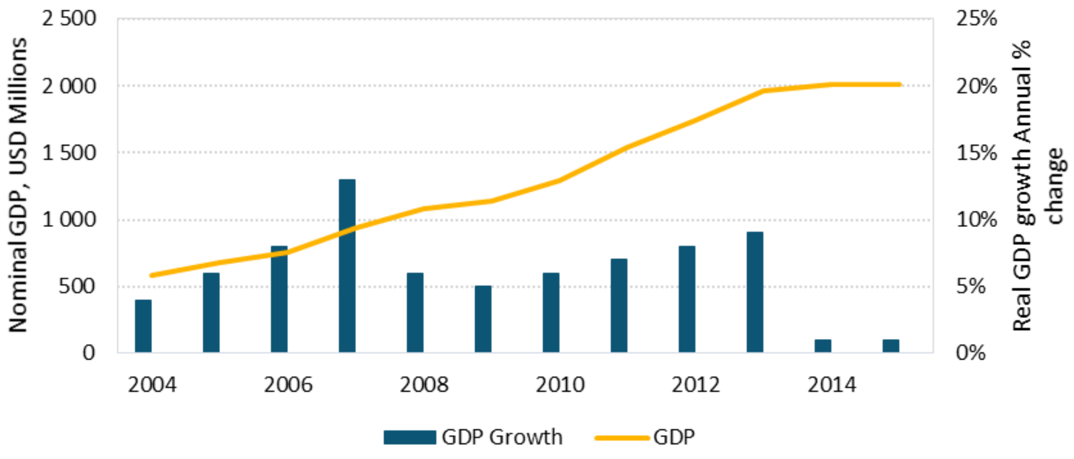

Figure 2.4 – Nominal GDP and Real GDP growth annual percent change [4].

Ebola outbreak. Liberia experienced an epidemic of Ebola Virus Disease in 2014 and 2015, along with the neighboring countries of Guinea and Sierra Leone. The first cases of virus were reported by late March 2014, and in the beginning of August Liberia declared 'State of Emergency' in order to contain the Ebola Virus Disease to spread. World Health Organization (WHO) only declared the country free of transmission a final time on January 14, 2016. It is estimated that Liberia suffered 10 675 Ebola cases, 4 809 of which were fatal [5]. The most affected county was Montserrado, where Monrovia (the capital) is located. This virus was extremely hard to contain given the country's weak health system resulting from long civil wars.

Economic impacts of the Ebola outbreak in Liberia. Ebola had a severe impact in the Liberian economy across all sectors of employment. Indeed, many of those in wage employment were either asked to stay at home or lost their positions entirely. Similarly, those involved in non-agricultural self-employment activities, such as small scale traders, saw their business fall as markets closed, potential customers become more reserved in their spending, and travel restrictions disrupted supply [6]. Moreover, Ebola drove up key food prices and led to food insecurity across the country [7]. This along with the decrease of incoming Foreign Direct Investment (FDI) as many businesses departing, taking capital and expertise with them, and a decline in exports of 38%, imposed a serious slowdown in Liberia's economy. Indeed, Liberia's GDP growth rate declined from 8.7% in 2013 to 0.7% in 2014. Also, the fiscal accounts in Liberia deteriorated significantly as a result of the epidemic.

Due to this troubled and difficult past, Liberia is today one of the least developed and poor countries in the world. In order to compare the level of development between countries the International Human Development Indicators were analyzed. These indicators are measured by the UNDP and used in the preparation of the 2015 Human Development Report, composed by five indices. The summary of Liberia's score in these five indices compared to the world and Sub-Saharan Africa (SSA) are indicated in **Figure 2.5**, as well as the percentile where Liberia falls regarding all the other countries analyzed (showed in **Figure 2.6**).

Human Development Index (HDI): This index emphasizes that people and their capabilities should be the ultimate criteria for assessing the development of a country, not economic growth alone. It is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living. Liberia has been

highly improving in the health dimension, assessed by life expectancy at birth, where Liberia went up from 56.1 years in 2006 to 60.9 in 2014 (above Sub-Saharan Africa's average of 58.5). The education dimension is measured by two indicators: mean of years of schooling for adults aged 25 years and more, where in Liberia is only 4.1 years compared to 5.2 in SSA; and expected years of schooling for children of school entering age, where again is lower in Liberia versus SSA (9.5 vs. 9.3). The standard of living dimension is measured by gross national income per capita and Liberia has the 5th lowest in the world. Taking these dimensions into account, Liberia has one of the lowest HDI scores in the world, ranking 177 out of 188 and thus being at the bottom 6% percentile. Moreover, Liberia's score (0.43) is well below the world's average (0.71), the Sub-Saharan Africa's score as a region (0.52). Nevertheless, Liberia's HDI score has been steadily increasing having gone up from 0.33 in 2005.

Inequality adjusted Human Development Index (IHDI): The IHDI takes into account not only the average achievements of a country on health, education and income, but also how those achievements are distributed among its population by "discounting" each dimension's average value according to its level of inequality. Thus, while the HDI can be viewed as an index of average achievements in human development dimensions, the IHDI measures the level of human development when the distribution of achievements across people in the society is accounted for. The IHDI will be equal to the HDI when there is no inequality, but falls below the HDI as inequality rises. Liberia's IHDI score is 0.28, thus having an overall loss of 34.8% in its HDI score. However, although Liberia's IHDI is lower than its HDI thus indicting that there is a loss in human development due to inequality, Liberia goes up 2 places regarding the HDI rank. Hence, although Liberia's human development decreased due to inequality, it decreased less than the overall of the other countries. Indeed, in this ranking Liberia is on the bottom 8% percentile, compared to 6% in the HDI score.

Gender Development Index (GDI). The GDI measures differences between male and female achievements in the three basic dimensions of human development. In Liberia, the life expectancy at birth for females is 61.8 years, which is higher than the male's (59.9). In the education dimension, there is a high discrepancy between genders, as the female expected years of schooling for children is only 8.9 compared to 12.4 years expected for males. Also regarding education, the male mean years of schooling for adults ages 25 and older is also higher than for females (5.8 years versus 2.6). Lastly, regarding the equitable command over economic resources, measured by the estimated gross national income per capita is USD 930 for males compared to USD 678 for females (measured in Purchasing Power Parity in 2011), evidencing even further the gender inequality in Liberia. Once again, Liberia has an overall GDI score bellow the SSA as a region.

Gender Inequality Index (GII): The GII is an inequality index and reflects how women are disadvantaged in two dimensions: empowerment and economic status. Since the GII includes different dimensions than the HDI, it cannot be interpreted as a loss in HDI itself. The GII ranges between 0 and 1 and higher GII values indicate higher levels of inequalities. Moreover, the component indicators highlight areas in need of critical policy intervention. This index takes into consideration the maternal mortality ratio, which is rather high in Liberia – 640 deaths per 100 000 live births – compared to SSA (506). Moreover, the adolescent (ages 15–19) birth rate in Liberia is 117 births per 1 000 women, versus 110 in SSA. Concerning the percentage of seats in

parliament held by women, in Liberia this share is only 10.7%, and the female population with 25 or more years with at least some secondary education is merely 15.4%. Regarding the labor force participation rate for females of 15 years and older, it is simply 58.2% compared to 64.8% for males. Moreover, Liberia is below the SSA as a region in all these dimensions, and thus it is only natural that its GII score is higher than SAA, hence indicating it has more gender inequality. Furthermore, Liberia is on the percentile 94%, and is the 9th country out of the 155 analyzed with the highest levels of gender inequalities.

Multidimensional Poverty Index (MPI). This index identifies overlapping deprivations at the household level across the same three dimensions as the Human Development Index (health, education and living standards) and shows the proportion of poor people and the average number of deprivations each poor person experiences at the same time. Liberia has a MPI value of 0.36 which indicated the percentage of the population that is multidimensional poor adjusted by the intensity of the deprivations. Moreover, its multidimensional poverty headcount is of 70.1%, which indicates the percentage of the population with a weighted deprivation score of at least 33%, (at least one deprivation in health, education of living standards), and 35.4% of the population have deprivation score of 50% or more (population in severe multidimensional poverty). Shockingly, the average number of deprivations poor people experience at the same time in Liberia is of 50.8%. Furthermore, living standards is the dimension with the highest contribution of deprivation to overall poverty, with a percentage of 51.4 of the MPI attributed to deprivations in this dimension, followed by health (25.6%), and lastly education (23%). The population living below the national income poverty line is of 63.8%, compared to 83.8% of the population living below a Purchasing Power Parity of USD 1.25/day. All these indicators point to the fact that Liberia is an extremely poor country, and indeed is the 10th country with the highest MPI score.

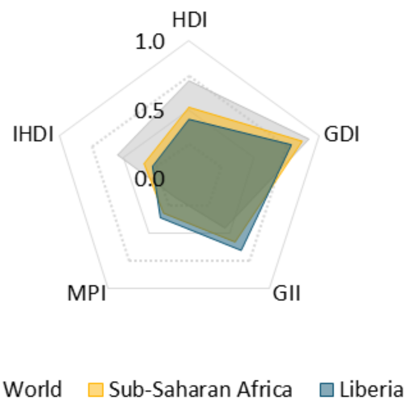

Figure 2.5 – International Human Development Indicators Scores [8].

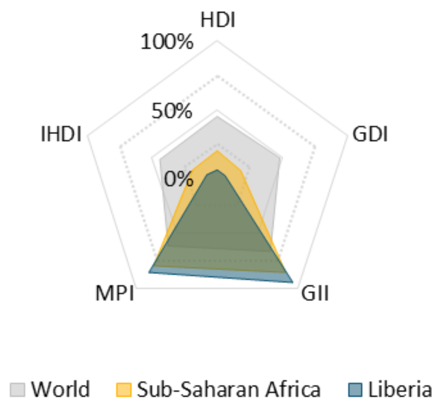

Figure 2.6 – International Human Development Indicators Percentile [8].

Although Liberia has a low score regarding gender equality, it has been greatly improving and several measures have been imposed in order to mitigate this issue. As demonstrated above, Liberia is one of the countries with most gender inequality. Nevertheless, this indicator has been improving with time. Indeed, its score has gone down from 0.675 in 2005 to 0.651 in 2014. More importantly, are the measure the Government of Liberia has been taking to tackle this issue. The National Gender Policy is an

example of the bold steps set in motion to promote gender equality and women empowerment. Moreover, the election of Ellen Johnson Sirleaf as President of Liberia is again a significant illustration of the empowerment of women. Indeed, her actions toward gender equality were recognized in 2011 when she won the Nobel peace prize and she took care of giving an important place to women in her government, women being at the head of the ministries of commerce, justice, finance, youth and sports and gender and development.

Liberia's demographic profile. In 2008, Liberia's total population was about 3.5M persons, as published in the house and population census. The sex ratio was 100.2 women to 100 men, indicating a balanced population in regards to gender. The distribution of population in Liberia in terms of age are identical to many developing countries, having an age pyramid that is very wide at the base, as seen by **Figure 2.7**, indicating high birth and death rates. Indeed, in Liberia, the 0-4 age group contains the largest number of people, thereafter declining steadily as the age increases. Due to this age distribution, Liberia has a large labor force, formed by people that age from 5 to 64 years. Hence, according to the Liberia Labor Force Survey 2010, if we consider all ages there are about 1.3 million people in the Liberian labor force, however the comparable figure for the adult population is about 1.1 million. There are approximately equal numbers of males and females in the labor force, and slightly more of them in rural areas than in urban. The great majority of the labor force is in the productive ages of 25 to 54, but there are a surprising number of younger people in the labor force, particularly in rural areas. Moreover, Liberia's unemployment rate is very low, at 3.7%.

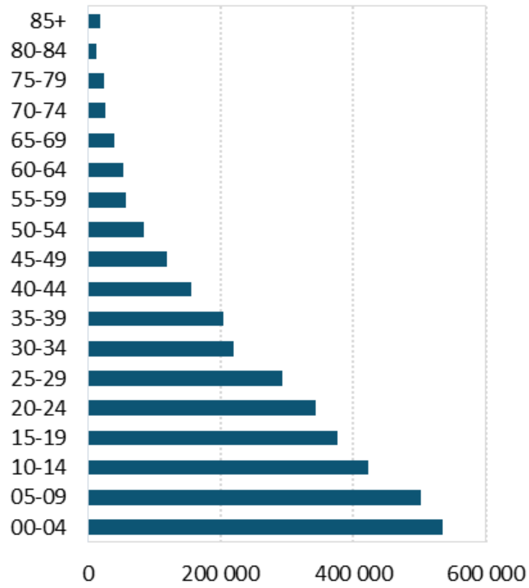

Figure 2.7 – Liberia's Distribution of Population by Age [2].

Population projections. In 2015, according to the World Bank, Liberia's population was up to 4.3 million, with a rural population growth rate per year of 1.4% and an urban population growth of 3.4%, observed in **Figure 2.8**.

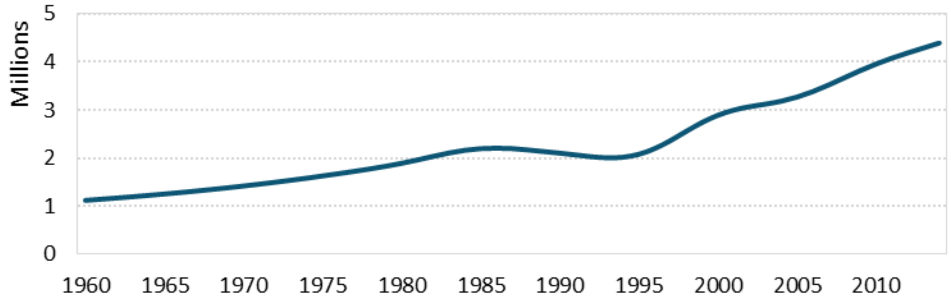

Figure 2.8 – Liberia's Total population [9].

Despite improvements, Liberia is still a fragile country. Regarding The Failed States Index, Liberia's score in 2015 was lower than in 2005 (97.3 vs. 99.5) and thus it was considered less fragile, as the highest the score the more fragile the country is. In fact, Liberia went from the 9th most fragile country in 2005 to the 21th in 2015. On the other hand, Liberia's score is still higher than the average of West Africa as a region (88.1) and it increased since 2014, when its score was 94.3. Thus, Liberia is still considered a fragile country and is on alert.

Liberia's Debt Relief. Liberia relies heavily on foreign assistance and was indeed the second country which received the highest Official Development Aid (ODA) grants as percentage of GDP in the period of 2003-2014 [10] (since the end of its civil war). Much of this ODA grants were as debt relief, given that in 2004 Liberia was the most indebted country in the world, with a government debt of 715.2% of GDP. Thus, in order to ensure that Liberia did not face a debt burden it could not manage, the International Monetary Fund (IMF) and the World Bank reduced tremendously Liberia's external debt stock under the Heavily Indebted Poor Countries (HIPC) Initiative (**Figure 2.9**). This granting of debt relief marked a significant milestone in Liberia's path toward recovery and according to Amara Konneh, Liberia's Minister of Planning and Economic Affairs, "The immediate challenge is to focus investment on roads, electric power, and ports to unblock bottlenecks that inhibit private sector investment". Moreover, the IMF mission chief for Liberia Chris Lane said IMF involvement with Liberia has been sustained and intensive, and will remain so for some time to come and that "After this debt relief milestone, the Fund program should catalyze further financial support from the donor community" [11].

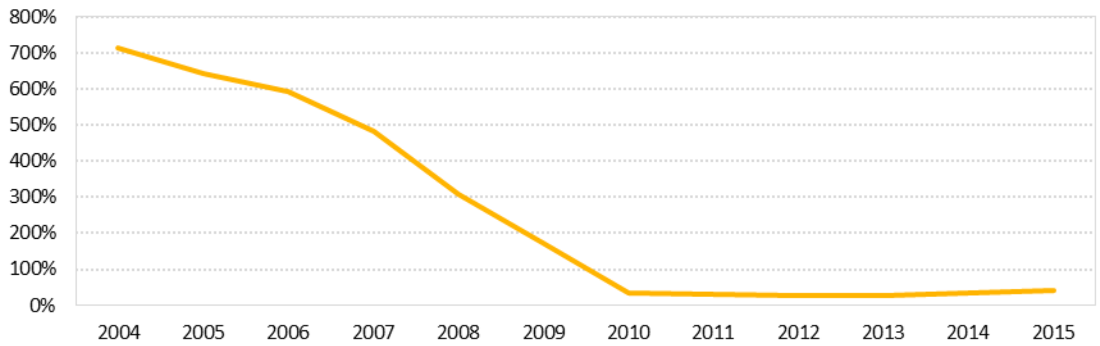

Figure 2.9 – Liberia's Government Debt as Percentage of GDP [4].

FDI in Liberia. As described in **Figure 2.10**, since 2008 Liberia has had a net Foreign Direct Investment inflow as percent of GDP extremely high, and in fact much higher than the average of the West African countries. Even more interestingly is that Liberia is the 5th country in Africa with highest Net Foreign

Direct Investment as percentage of GDP. In 2014 the net FDI as percentage of GDP had an accentuated decrease and was cut in half, declining form 22% in 2013 to 11% in 2014. This was mainly due to the Ebola outbreak as mentioned before. Although Liberia has high levels of net FDI as percentage of GDP, its position on the Doing Business Rank was 179/180, which is awfully low and this means that regulatory environment is not conducive to the starting and operation of a local firm.

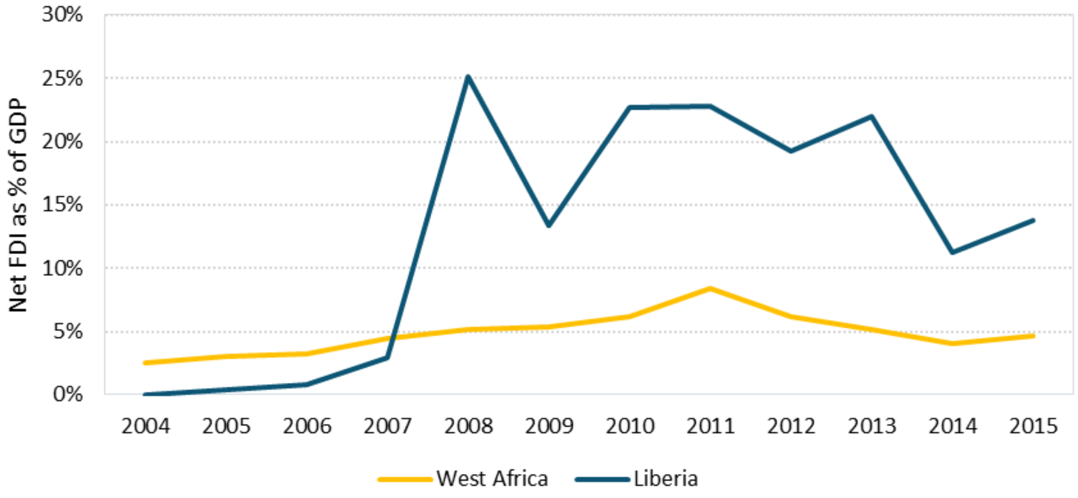

Figure 2.10 – Net Foreign Direct Investment, % of GDP [4].

GDP composition. In 2015, Liberia's nominal GDP was USD 2 015Bi, where 36% came from the agricultural sector, 16% from industry, and the remaining 48% from services. Liberia's agricultural products consist mainly in rubber, coffee, cocoa, rice, cassava (manioc, tapioca), palm oil, sugarcane, bananas, timber, sheep and goats, and its principal industries are mining (iron ore), rubber processing, palm oil processing, and timber. Moreover, comparing to Liberia's GDP composition by sector in 2002, where agriculture accounted for 76.9%, industry for 5.4% and services for 17.7%, it is evident that the country's service and industry sectors are developing, as depicted in **Figure 2.11**.

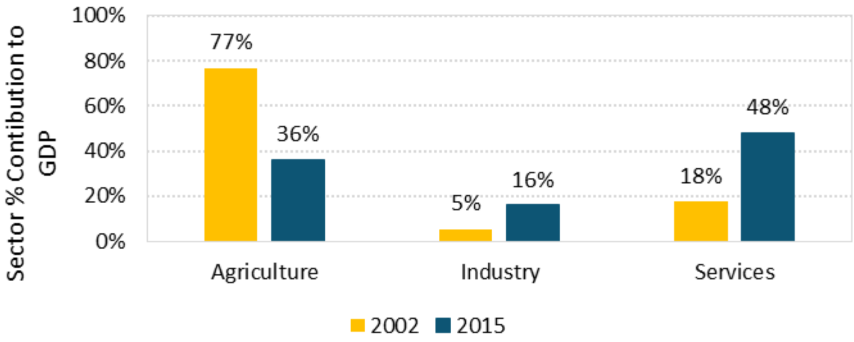

Figure 2.11 – Liberia's GDP composition by sector [1].

Labor Force Composition. As seen before, Liberia has an extremely large labor force and a very low unemployment rate. On the other hand, most people's status in employment is given as being own-account worker (63%) or contributing family member (16%), as described in **Figure 2.12**, thus Liberia has a vulnerable employment rate extremely high (79%). People in these two categories are employed under relatively precarious circumstances, as they are less likely to have formal work arrangements or

access to benefits or social protection programs, which puts them at risk when there is a downturn in the economic cycle. In developing countries, where very few people can afford to be totally without work and the unemployment rate is therefore very close to zero, this measure of vulnerable employment is likely to be more useful than the unemployment rate as an indicator of the state of the labor market. Moreover, regarding the labor force distribution by sector of economic activity, presented in **Figure 2.13**, almost half of the population worked in agriculture, forestry and fishing, and a quarter of the employed persons work in wholesale/retail trade. These are also the two sectors or activity with highest vulnerable employment.

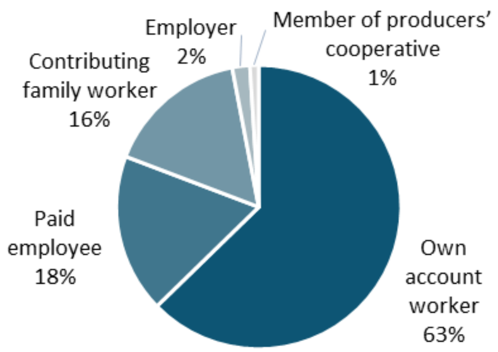

Figure 2.12 – Percentage distribution of the employed population by status in employment in their main economic activity [12].

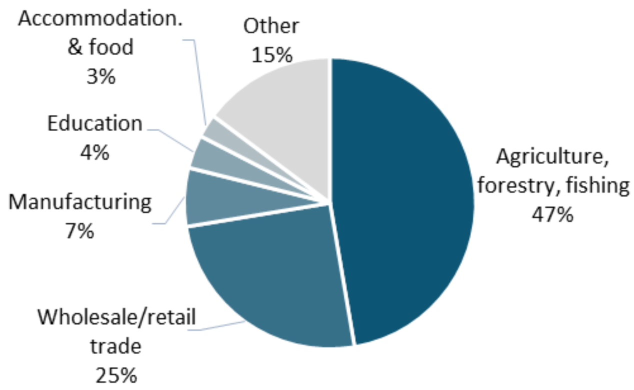

Figure 2.13 – Percentage distribution of the employed population by sector of economic activity in main job [12].

Economic projections. Liberia has had a difficult economic path. Nevertheless, its projections for the future are looking prosperous with IMF predicting an annual GDP growth rate of 6.9% on average from 2016 to 2020, as described on **Figure 2.14**.

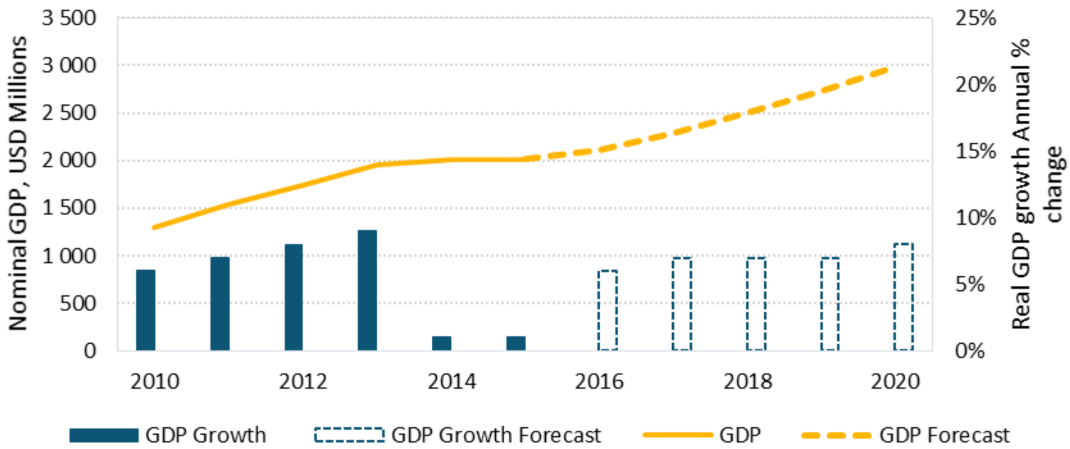

Figure 2.14 – Nominal GDP and Real GDP growth annual percent change forecast [4].

2.2 RURAL LIBERIA: A MORE DETAILED VIEW

Rural Population Definition. When talking about rural Liberia, there are two extremely different definitions used back and forth in different documents. Indeed, in the "Liberia and Energy Access: A Willingness to Pay Analysis" document [13], the rural households were considered all the households outside Monrovia, including both urban and rural areas. Contrasting with the population and housing census, where rural areas are referred to clans and urban areas to communities. The two definitions of rural areas differ greatly, as for example the first one considers county capitals as rural areas and the latter one does not. Indeed, when considering that rural areas are everything outside Monrovia, Liberia has a total percentage of rural population of 72%, compared to 53% considered in the population census conducted in 2008.

Rural Population Distribution per County. As mentioned before, about one third of the population lives in Montserrado. However, this county's population is mostly urban, with only 7% of its population living in rural areas. In fact, Montserrado is the only county which has a higher percentage of urban population than rural. All other counties have a higher percentage of rural population that urban population, with River Cess, Grand Kru, Grand Cape Mount and Gbarpolu having more than 90% of their population residing in rural areas. From **Figure 2.15** we can see that the counties with highest rural population percentage are situated in the southern coast line and in the frontier with Sierra Leone. On the other hand, when analyzing the percentage population distribution of Liberia's rural population per county, shown on **Figure 2.16**, we have that more than 50% of the rural population in Liberia is located in the counties of Nimba, Bong, Lofa and Grand Bassa. Indeed, while only 77% of the population of Nimba County resides in rural areas, this county accounts for 19% of Liberia's total rural population.

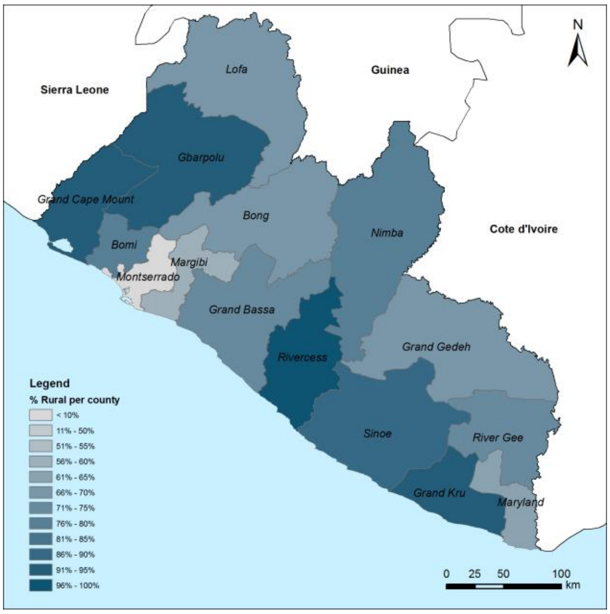

Figure 2.15 – Percentage of Rural Population per County.

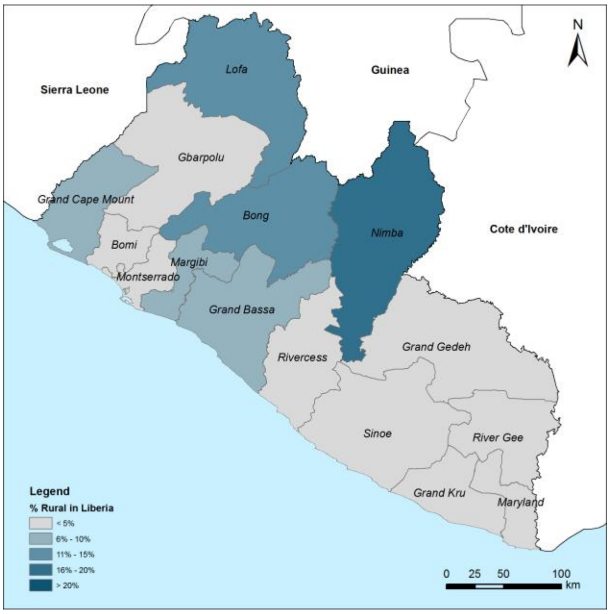

Figure 2.16 – Percentage Distribution of Liberia's Rural Population per County.

Rural Population Distribution per Region. Analyzing the rural population per county does not allow us to understand the regions of Liberia with most rural population. Thus, an analysis of this distribution per region is useful. Regions were defined as stated in the terms of agreement (see **Figure 2.17**). As it can be seen in **Figure 2.18** and **Figure 2.19**, by agglomerating the counties in regions, all regions except region 3

have a higher percentage or rural population than urban. Indeed, only 27% of the population of region 3 is rural. Interestingly, region 2 is the second region with the lowest percentage of rural population, however it aggregates almost half of Liberia's rural population. Contrastingly, region 4 is the region with most percentage of rural population, with 89% of its total population living in rural areas, however it is the region in which less rural people live. Obviously this depends on several exogenous factors, such as the dimension of the region and population density.

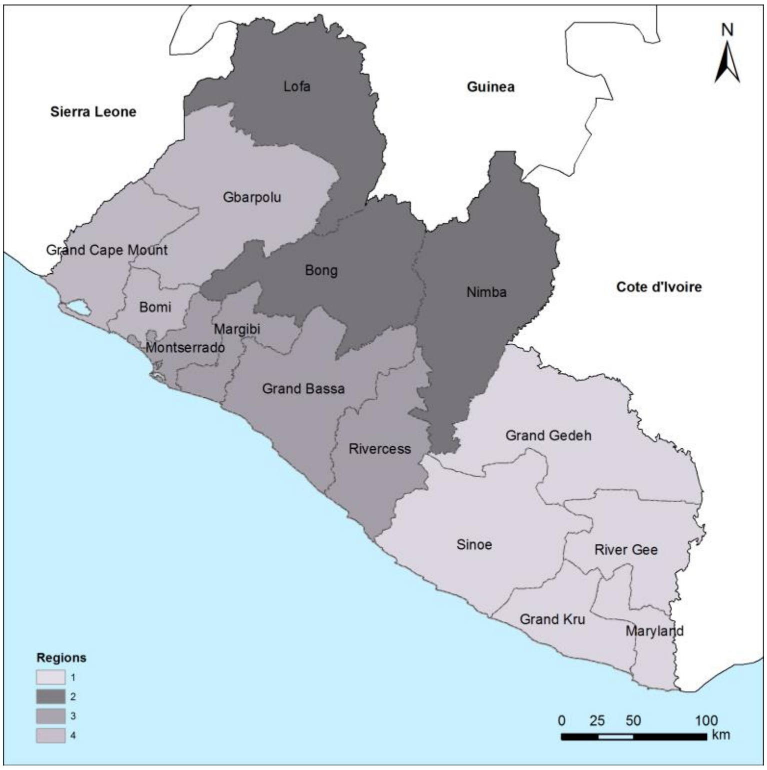

Figure 2.17 – Liberia division by regions.

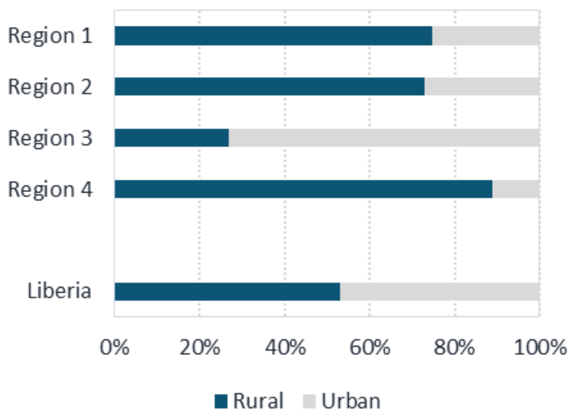

Figure 2.18 – Percentage distribution of Liberia's rural population per region.

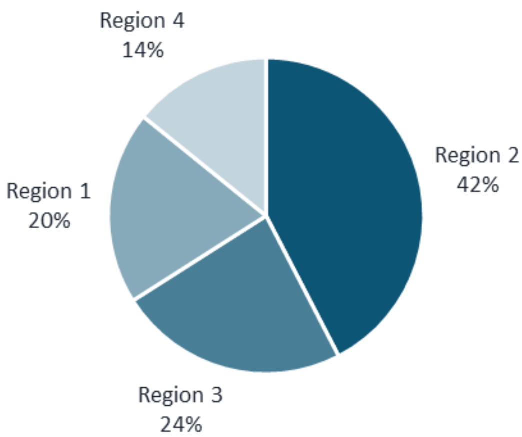

Figure 2.19 – Percentage of rural population per region.

Population Density. Rural population is highly correlated with population density. Indeed, urban areas are characterized by high population density. Thus, it only makes sense that Montserrado is by far the

county with higher population density, with more than 590 people per km^2. The county with lowest population density is Gbarpolu, with only 8 people per km^2, which is also one of the counties with highest percentage of rural population, 91%. Moreover, evidencing that much of Liberia's population is rural, we have that its overall population density is incredibly low, at 36 people per km^2 (see **Figure 2.20**).

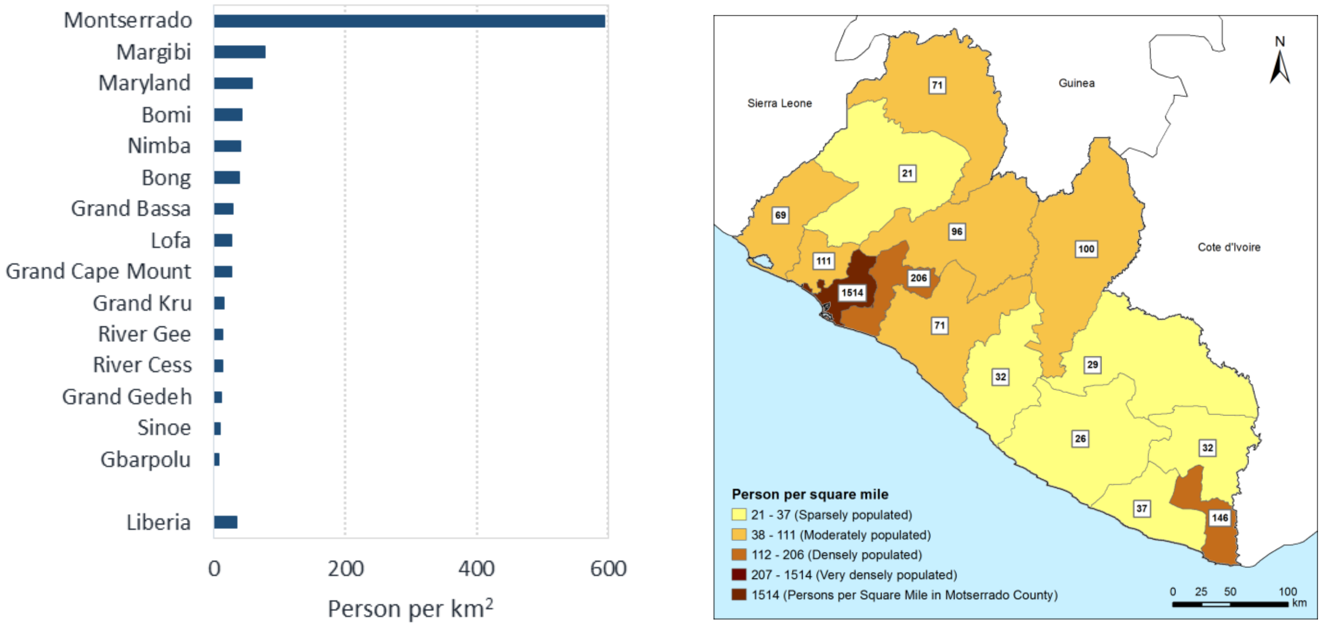

Figure 2.20 – Population density per county.

Household Dimension. As shown in **Figure 2.21**, the counties with highest household dimension are situated in southern Liberia and in the frontier with Sierra Leone, which are also the ones with highest rural percentage, as mentioned above, with the exception of Maryland. Moreover, Liberia's average household size is 5.1 persons, however this average is relatively different when it concerns rural areas rather than urban centers. In rural areas this averages goes up to 5.3 persons, compared to 4.9 in urban centers. This difference in average household size by area of residents is verified in almost every county, with rural households having on average more people than urban households. The counties in region 3, located in the center of Liberia, have fewer people per household, which may be due to the high concentration of urban centers in this area.

Figure 2.21 – Average household size.

The overall literacy rate is lower in rural versus urban areas. Information on literacy, while not a perfect measure of educational results, is probably the most easily available and valid for international comparisons. Low levels of literacy, and education in general, can impede the economic development of a country in the current rapidly changing, technology-driven world. Thus, evaluating the percentage of population who can read and write is important in order to understand the most developed counties within Liberia. As presented in **Figure 2.22**, the counties with lowest overall literacy rate are more rural counties, and the ones with highest literacy rate have a higher percentage of urban population. Indeed, the overall literacy rate in rural areas is 50%, compared to 69% in urban areas. Moreover, the literacy rate in women is much lower than the literacy rate among men (47% vs. 72%). This difference in literacy rates is extremely evident in Grand Kru, where the men literacy rate is 71% and the women is only 28%.

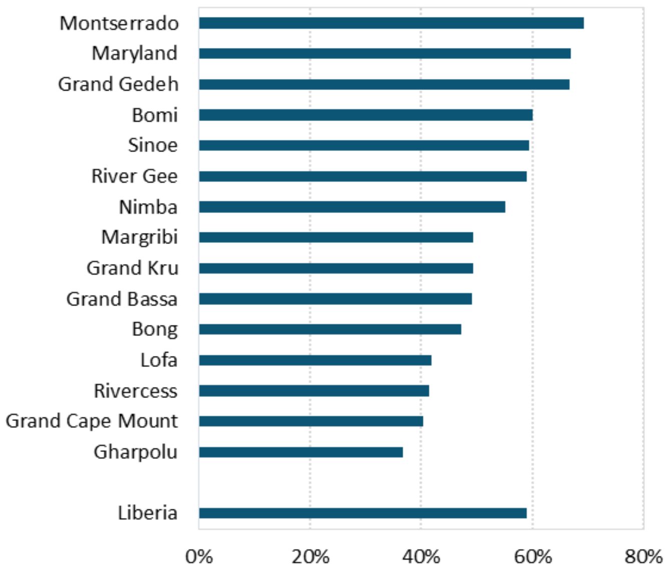

Figure 2.22 – Overall Literacy Rate [12].

The majority of rural population is employed in the agricultural sector. Agriculture, forestry and fishing are the most important activities in Liberia, particularly in rural areas. Indeed, as mentioned before, 47% of Liberia's employed population main job is in this sector of economic activity, and in rural areas this goes up to 73%, as presented in **Figure 2.23**. Moreover, according to the 2008 house and population census, Rivercess, River Gee, Grand Kru, Gbarpolu and Lofa are the counties with more population employed by this activity, with more than 75% being employed in the sector. The only counties with less than 50% of the population employed in the agricultural sector are Maryland, Margibi, Grand Bassa and Montserrado. Due to the large percentage of rural households involved in this activity, as well as wholesale/retail trade, urban areas has a vulnerable employment indicator very high (87%), thus putting them at risk when there is a downturn in the economic cycle. Also, the inactivity rate of people aged between 15 and 64 years in rural areas is lower than urban areas (27.5% vs. 44.6%).

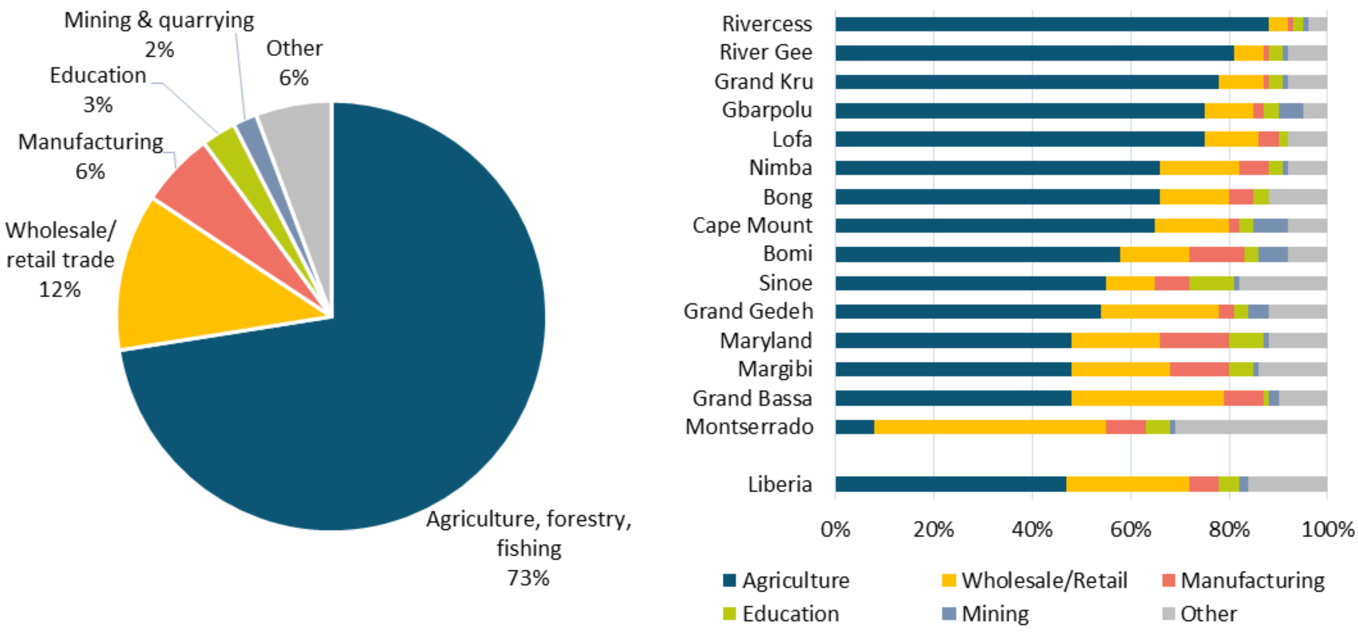

Figure 2.23 – Percentage distribution of the employed population by county and by sector of economic activity [12].

Rivercess, Bong and Sinoe are the counties with highest percentage distribution of poor households. Finally, in order to better understand the present purchase power of each county, the percentage distribution of households by perceived poverty status was analyzed. Only three counties had a percentage distribution of poor and fairly poor households below 50% - Lofa, Grand Gedeh and Margibi. All other counties had the majority of the households with a perceived poverty status of poor or fairy poor. Rivercess is by far the county with the highest percentage distribution of poor households, with more than a third having this perceived poverty status. Moreover, urban areas have a lower percentage of poor and fairly poor households than rural areas (40.8% vs. 49.9%). Nevertheless, more than half of the households in Liberia are perceived as having a middle income. On the other hand, when taking into consideration the percentage distribution of households by perception of wellbeing based on income, only 23% of the households are living well or reasonably well, while 40% are living carefully and 37% are living with difficulty. Once again, the percentage of households living carefully and with difficulty is

higher in rural rather than urban areas. The counties with lowest perception of wellbeing based on income are again Rivercess, Bong, Sinoe and River Gee, and the ones with highest perception of wellbeing are Grand Cape Mount, Grand Gedeh and Gbarpolu (see **Figure 2.24**).

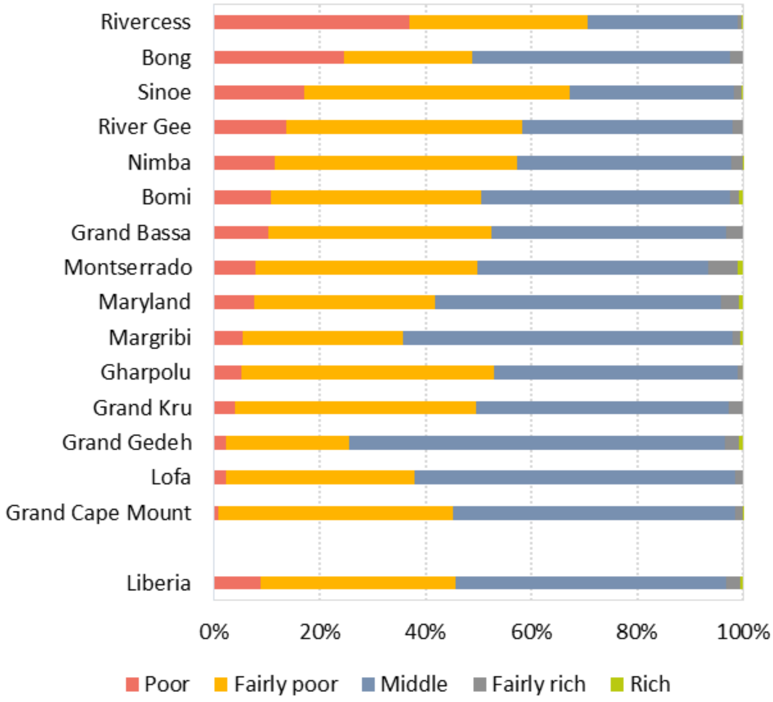

Figure 2.24 – Percentage Distribution of Households by Perceived Poverty Status [12].

2.3 LIBERIA'S ENERGY SECTOR

Liberia has one of the most underdeveloped energy sectors worldwide. While having one of the lowest rates of access to public electricity, it has one of the highest per-unit costs of electricity (around 0.50 USD/kWh). The long-lasting civil war (1989-2003) seriously damaged the power sector, and by 2005 most of what still remained had been destroyed by looting. Additionally, Liberia is highly dependent on fuel imports – almost 77 million US gallons of petroleum products (especially gasoline and diesel, but also jet fuel and kerosene) were imported in 2012, mostly for transportation, electricity generation and domestic lighting [14]. These two factors are considerable obstacles for the development of the Liberian energy sector and for the development of Liberia itself, since basic services such as health care, water and sanitation, education and telecommunications require access to electricity.

Liberia's civil war had severe consequences on the country's power sector. Before the civil war, more than 7% of the population had access to public electricity – around 35 000 costumers – with a total installed capacity of 191 MW, of which approximately 98% were in and around Monrovia [14]. Liberian Energy Corporation, the national electricity utility, was responsible for the generation, transmission and distribution of electricity in Liberia, although the system's low reliability, aggravated due the diminished hydropower generation during the dry season, forced the private sector to invest in self-generation.

With the destruction of most of the generation facilities during the war, including the Mount Coffee hydropower plant (63 MW and 5 MW during the wet and dry seasons, respectively), as well as of the transmission and distribution lines, LEC had to cease operations temporarily.

LEC's operations were resumed with the assistance of an emergency program. Its recovery started with an emergency program, which supported the construction of a small grid with high-speed diesel (HSD) generators totaling 9.6 MW of installed capacity, split in four locations: 5 MW in Kru Town, 2 MW in Congo Town and Bushrod Island each and 0.64 MW in Paynesville. The grid consisted of four substations and 400 V, 11 kV and 22 kV distribution lines covering 80 km. This emergency program was financed by several external institutions – the European Union, United States Agency for International Development (USAID), the Norwegian Agency for Development Cooperation (NORAD) and The World Bank Group.

External funding was and is helping the development Liberian energy sector, including LEC's development. The utility had inefficient and poorly engineered distribution, causing high technical losses, inadequate billing and collection systems and was also plagued with power theft. The poor quality of the generation and distribution was translated in frequent and lengthy outages. These factors, along with the high-cost diesel as the only source of power, the lack of financing for new connections and the consequently high tariffs constrained LEC's ability to increase its customers and fully utilize all generation capacity. The main bottlenecks to an efficient and sustainable development of a national electricity system are: (i) the lack of infrastructure for transmission and distribution; and (ii) an electricity utility in a precarious financial and technical situation, with an area of service limited to Monrovia. Taking the previously stated into account, external funding is helping the development of the Liberian power sector: to the 9.6 MW already installed were added two diesel generators, composed by 1 MW units – a 3 MW generator financed by NORAD and a 10 MW generator financed by USAID – totaling the 22.6 MW of installed capacity in 2013. Improvements for the transmission and distribution lines were also planned, as well as for the IT and data management systems. The increase in the quality of generation and distribution is fundamental for the decrease of the current high energy tariff. There are a number of different projects planned or under consideration, including the rehabilitation of the Mt. Coffee hydropower plant. According to an International Renewable Energy Agency (IRENA) report in 2013 [15], there are 551 MW distributed in centralized projects and 80 MW in decentralized ones. **Table 2.1** provides a summary of the already considered, committed or planned hydro and thermal generation projects.

Table 2.1 - Considered, committed or planned generation projects [15].

Project	Power Source	Capacity (MW)	Status	Start Year
Bushrod 2	Heavy Fuel Oil	40.0	Committed	2013
Kakata (Buchanan)	Biomass	35.0	Planned	2013
Mount Coffee	Hydro	66.0	Committed	2015
Saint Paul 1B	Hydro	78.0	Considered	2017

Project	Power Source	Capacity (MW)	Status	Start Year
Saint Paul 2	Hydro	120.0	Considered	2017
Unnamed name	Hydro	702.5	Considered	2019

There are several major players in the Liberian energy sector. Apart from the Government of Liberia (GoL) and LEC, already mentioned, there are other stakeholders concerning Liberia's energy sector, including Liberian organizations and external donors. The Ministry of Lands, Mines and Energy key roles are, among others, to provide energy to the domestic, commercial and industrial users, as well as to research and promote the usage of local energy sources. RREA is an independent agency of the GoL established in 2010 to promote the development and supply of modern energy products and services to Liberian rural areas. There are also many external donors and lending institutions, which assist in the development of Liberia's energy sector, such as the World Bank Group (WB), United States Agency for International Development, the European Union (EU), Kreditanstalt fur Wiederaufbau (KfW), Norwegian Water Resources & Energy Directorate (NVE), Japan International Cooperation Agency (JICA), African Development Bank (AfDB), West African Power Pool (WAPP) and United Nations Industrial Development Organization (UNIDO).

Liberia's rural population heavily relies on self-generation. In the last few years, much effort has been made to restore the electrification access rates to pre-war levels. In July 2010, LEC had around 2 500 customers, a number that increased more than five-fold up to July 2013, with approximately 13 875 customers connected to the network in Monrovia [14]. Despite this effort, according to the World Bank [9], Liberian urban and rural access in 2012 was 18.9% and 1.2%, respectively, averaging 9.8% nationwide. Although the access rate is still low, World Bank data states that the national electricity access rate was 4.1% in 2010, meaning that it has more than doubled in two years. Regardless of this, the World Bank data most likely considers self-generation, meaning that the access rates to public electricity are considerably lower. According to the same source, in 2012 the electricity access rates for the neighboring countries, Cote d'Ivoire, Guinea and Sierra Leone were 55.8%, 26.2% and 14.2%, respectively, more than in Liberia.

Traditional biomass is the most used source for cooking and lighting. The current lack of access to poor-quality and relatively expensive modern types of energy services in many areas induces a strong consumption of traditional biomass. Concerning cooking, as it can be observed in **Figure 2.25**, there are two main sources of fuel used by the Liberian population, wood and charcoal. According to the 2008 Census [2], more than half of the households use wood as a cooking fuel (57.2%) and a 37.0% uses charcoal. The remaining 5.8% are distributed between kerosene, gas, electricity/own generator, electricity supply/power supply, and other types of fuel. This is not evenly distributed between urban and rural households. Although the majority of the Liberian households uses wood as a source of cooking fuel, in urban areas 70% of the households use charcoal, and only 21% of the households use wood. On the other hand, almost every household in the rural areas use wood as a cooking supply, and only 5% use charcoal.

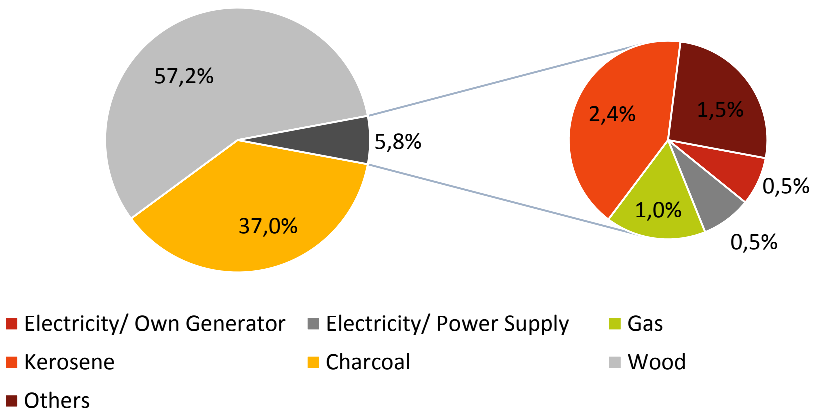

Figure 2.25 - Sources of cooking fuel.

Palm oil plays a major role as a lighting fuel. In 2008, almost one third of the households of Liberia used palm oil lamps as source of lighting (32%), followed by kerosene (30%), and candles (26%). The remaining 12% are distributed by the outstanding sources – wood, electricity/own generator and electricity/power supply – as depicted graphically in **Figure 2.26**. There was a major difference in the fuel used by urban versus rural households. A vast number of urban households in 2008 used candles as lighting fuel (44%), followed by kerosene (34%), and only a small amount used palm oil (9%). On the other hand, in rural households more than half of the households used palm oil as lighting fuel (54%), followed by 27% of the rural households that used kerosene, and only 9% used candles. Some percentage of households use electricity/own generator as lighting fuel, however this is only true in urban areas, as the percentage of rural households that use this source of lighting fuel is almost zero.

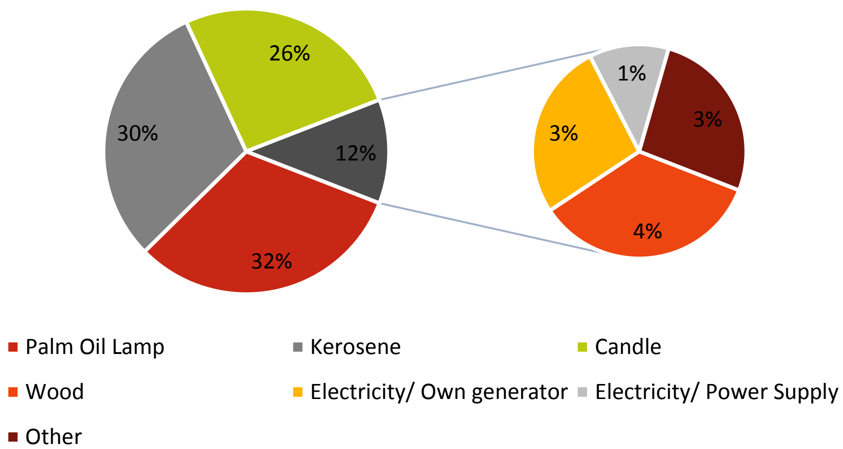

Figure 2.26 - Sources of lighting fuel.

2.4 WEST AFRICA POWER SECTOR AND CROSS-BORDER PROJECTS

There are significant disparities on the power sectors of the West African countries closest to Liberia (Cote d'Ivoire, Ghana, Guinea, Guinea-Bissau, Mali, Senegal and Sierra Leone). According to an IRENA report [15] from 2013 the installed capacities ranged from 5.6 MW in Guinea-Bissau to 4056.4 MW in

Cote d'Ivoire, although the available capacity values were lower, ranging from 3.7 MW in Guinea-Bissau to 1909 MW in Ghana. The average available power is 212.2 MW. Liberia has the second lowest installed capacity, of 12.6 MW – note that the 10 MW USAID-financed diesel generators are not yet in this data, although the third lowest installed capacity is 106.9 MW, in Sierra Leone, much higher than the 22.6 MW in Liberia. All the data regarding the installed and available capacities is presented in **Figure 2.27**.

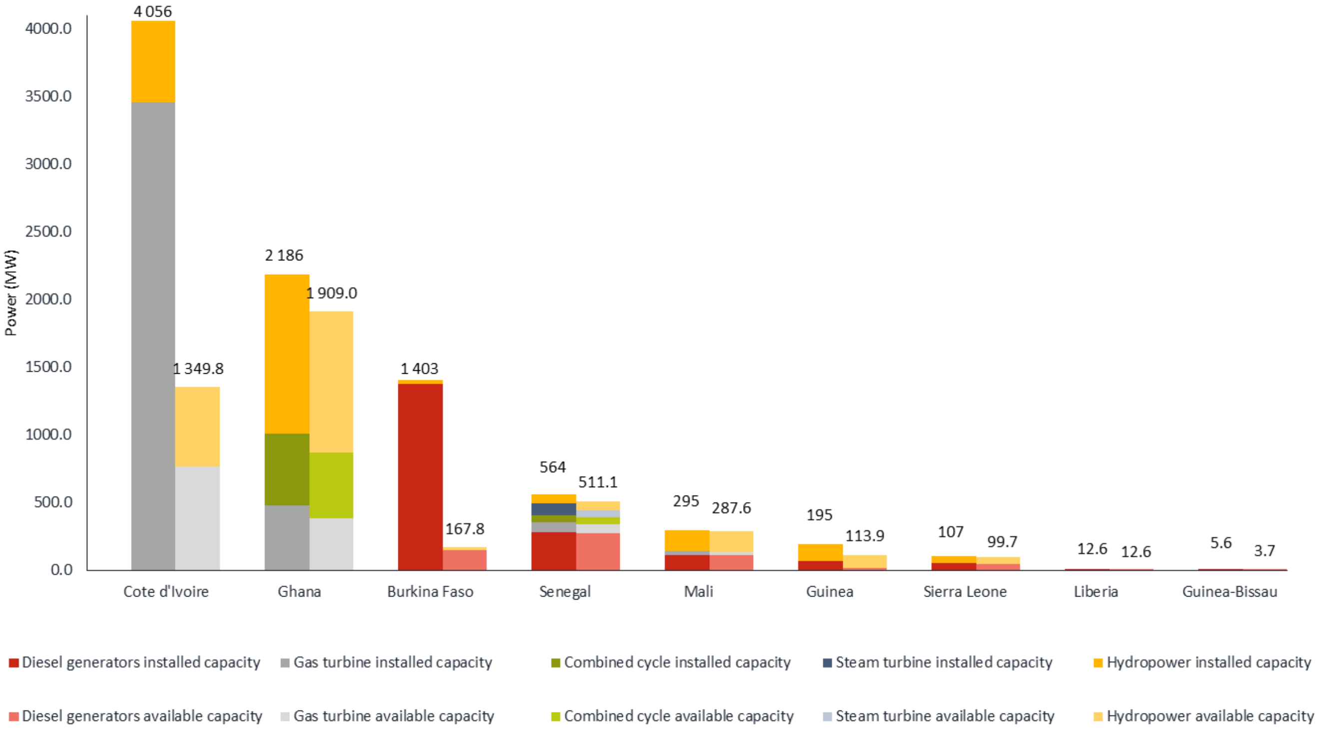

Figure 2.27 - Installed and available capacities in countries near Liberia.

Liberia ranks as the second lowest country in the region regarding the normalized available capacity. Since the countries don't have the same population, in order to compare the installed and available capacities a normalized value was calculated based on the population, providing the values of capacity per capita, in W (Watt) per person (which is equivalent to MW per million people). The results, displayed graphically in **Figure 2.28**, show that the lowest value of available capacity is 2.1 W per capita in Guinea-Bissau, close to Liberia's 2.9 W per capita, the second lowest value (or 5.3 W per capita if considering already 22.6 MW for the capacity). The highest value is 73 W per capita in Ghana and the average value for the normalized available capacity is 25.5 W per capita. Regarding the installed capacities, Côte d'Ivoire's 4 GW translates into 188 W per capita. As a reference, it is estimated that the European Union had more than 1 700 W per capita in 2013 of installed capacity.

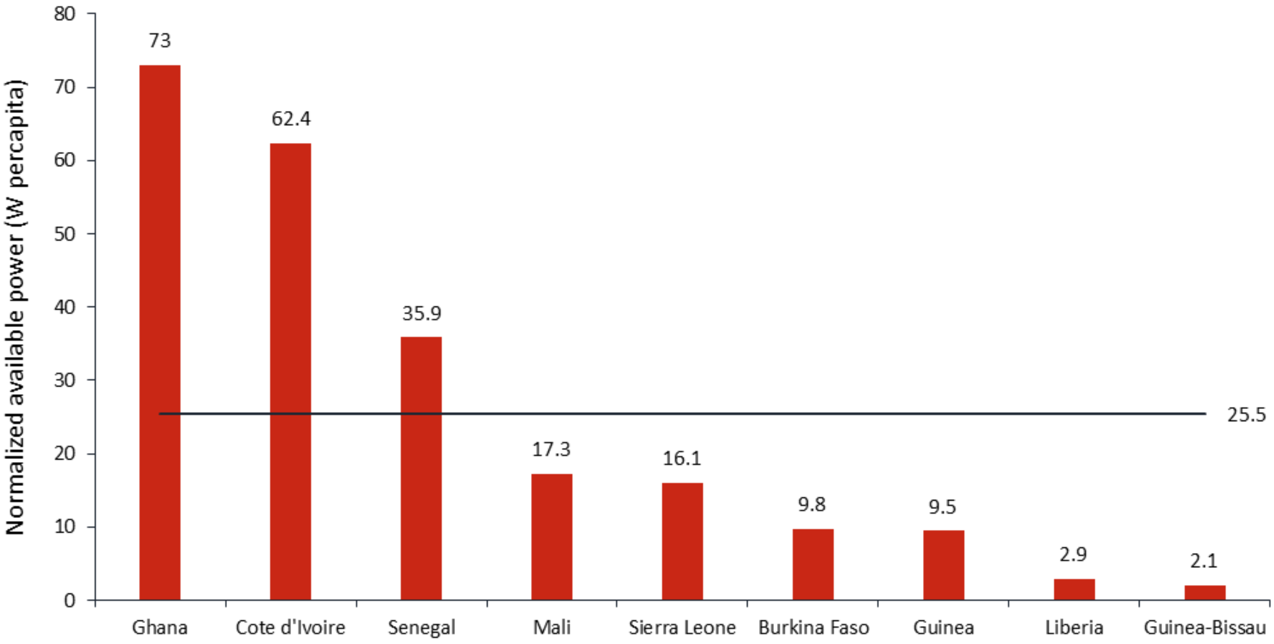

Figure 2.28 - Normalized available power in countries near Liberia.

The countries closest to Liberia can be divided in three subclasses, according to their normalized capacity values. Ghana and Cote d'Ivoire make up the most developed group, with available capacities above 60 W per capita. The middle group consists of Mali, Senegal and Sierra Leone, with values ranging from 15 to 36 W per capita. Finally, the least developed group according to this indicator, is composed of Liberia, Burkina Faso, Guinea and Guinea-Bissau, where the values for the normalized available capacity don't go over 10 W per capita. Even considering already the most recent 22.6 MW in Liberia, the installed capacity has to triple for Liberia to be part of the middle group, and it has to increase almost 14-fold in order to become the highest normalized available capacity in the region.

Two cross-border projects involving Liberia are already funded. According to a USAID report [16], the two regional interconnection projects being implemented are:

- The Cross Border Rural Electrification project, which was scheduled to be finished in mid-2013. This projects aims to connect the Cote d'Ivoire network to three Liberian counties, via a 66 kV transmission line, providing electricity to about 130 000 dwellings. The funding for this project is already secured, divided in half between WAPP and EU.
- The CLSG interconnection project (Cote d'Ivoire, Liberia, Sierra Leone and Guinea), implemented by WAPP and funded by several donors. Its objective is to provide access to least-cost (hydro) power options for the sub region and to enable the pooling of power resources across these four countries. The 225 kV transmission lines are to pass by the soon-to-be rehabilitated Mt. Coffee hydropower plant, and their planned path can be seen in **Figure 2.29**. The project is split in two phases, in order to avoid an oversized solution; phase 1, consisting of a single-circuit line with a power capacity of 150 MW, predicted to be finished by late-2015, and phase 2, providing an additional circuit, increasing the total line power capacity to 300 MW.

Figure 2.29 - Proposed transmission lines for the CLSG project [17]

3 COUNTRY'S AGENDA AND POLICY

3.1 AGENDA FOR TRANSFORMATION – STEPS TOWARDS LIBERIA RISING 2030

Liberia's reconstruction. After the civil war, and since 2004, Liberia embarked on national reconstruction, making efforts to improve economics, political and social governance in Liberia. The efforts to rebuild take into account what was learnt in the past, and consider the close relationship of conflict, peace and sustainable use of resources. National development strategies, such as the Interim Poverty Reduction Strategy (2006-2008), the Poverty Reduction Strategy (2008-2011) and a medium-term Poverty Reduction Strategy (PRS) (2012-2018) guide the country to this goal.

Liberia aspires to become a middle-income country by the year 2030. The Agenda for Transformation (AfT) is the Government of Liberia's five-year development strategy. It appears as a successor of the PRS (2008-2011), but its goal is not to deliver transformation by the end of the fifth year. AfT is the first step toward the Liberian long-term national vision of socio-economic transformation, a strategy named Liberia Rising 2030. Becoming a middle-income country until 2030 is the main goal of this strategy, which reflects Liberia's dedication to come closer toward economic transformation, prosperity and inclusive growth. Ensuring that the resources are correctly directed, used in priority areas and interventions, is of the utmost importance for the success of the program, as well as is the funding from development partners.

The focus is not only on accelerating growth, but also on ensuring that that growth is can be sustained and lead to a more inclusive society. Beyond income growth, AfT also supports initiatives that contribute to a greater proportion of the population sharing the growth and experiencing better quality of life. This implies more than just economic growth – with the AfT, GoL's strategy embraces inclusion, equity, justice, peace, reconciliation, human development and good governance. Therefore, after wealth creation, a second key objective is to increase inclusiveness for a more equal and just society. The progress towards these objectives will be measured through three indicators:

1. Per capita income and consumption measures
2. Millennium Development Goal (MDG) indicators
3. Census indicators of unmet basic needs

AfT is supported by four main pillars and an additional core pillar. These pillars, which are mutually reinforcing, are:

1. Peace, Security and Rule of Law, which includes the continuation of professionalization of security institutions, the investment in institutions that manage to resolve conflicts in a peaceful manner and the expansion of the justice system, with the strengthening of its transparency.
2. Infrastructure and Economic Transformation, as one of the key objectives is to improve infrastructure – energy, roads and bridges, post and telecommunications, public buildings and affordable housing. This also involves the development of the power sector, the results

of smallholder sectors (agricultural, fishing and forestry), and increasing exports, among others.

3. Governance and Public Institutions, in which the government is to develop a closer relationship with the people, strengthen good governance and peace-building and maximize resources available for the public good.
4. Human Development, where areas such as free basic education for children, opportunities to develop skills among youth to make them employable and productive, and the increase of access to health facilities, safe water supplies and waste management are considered.
5. Cross-Cutting Issues, the fifth cross-cutting pillar, which summarizes critical issues that need to be taken into consideration in all other pillars. These include a segment of four group-specific issues – Gender Equality, Child Protection, Disability and Youth Empowerment, and other four for all society – Environment, HIV and AIDS, Human Rights, and Labor and Employment.

3.2 THE ECONOMIC STABILIZATION AND RECOVERY PLAN

Rationale for the development of the Economic Stabilization and Recovery Plan (ESRP). As discussed before, Liberia was in the right path to recovery and was facing a period of peace and stability when the Ebola Virus Disease (EVD) epidemic hit the country. This Ebola outburst caused significant economic and social damages in Liberia. It negatively impacted household livelihood and welfare across the country, closed schools and hospitals for a significant period of time, led to major delays and cost overruns on key projects, and created many 'Ebola orphans'. Moreover, according to President Ellen Johnson Sirleaf, this outbreak "highlighted the vulnerabilities inherent within our systems but has paradoxically provided us an opportunity to rebuild the fabric of our economic and service delivery systems". Thus addressing this issues emphasized by the EVD was mandatory.

Overall Objectives of the ESRP. The primary aim of the ESRP (the Plan) is to "set out the actions that are needed to respond to the EVD epidemic, to stabilize the economy, and get Liberia on a path to inclusive growth" [18]. The Plan, therefore, is intended to highlight investments that have the greatest potential of bringing economic stabilization and recovery in the shortest time possible, creating jobs, and improving the lives of the citizens. In order to get the economy back on track toward the primary goals of the country's medium and long-term development plans, the plan focuses on three core objectives that are fully aligned to and consistent with the objectives of the Agenda for Transformation and Liberia Rising 2030. These objectives focus not only on the immediate direct and indirect socio-economic impact of the Ebola epidemic but also are intended to address enduring institutional and infrastructure weaknesses. These three core objectives are to:

- **i.** Revitalize growth to pre-crisis levels whilst ensuring that it is inclusive and that it creates more and better jobs;
- **ii.** Provide support for the poor and other at-risk group to strengthen resilience and reduce vulnerability;

iii. Rebuild and strengthen the capacity to deliver core social services including education and health with better coverage particularly in the rural areas.

Main Strategic Interventions of the Plan. The ESRP is to be implemented in two different timeframes, one for immediate stabilization in the Fiscal Year of 2014/15 (FY2014/15), and another through FY2015/2016 and FY2016/2017 for recovery and resilience. This will be done through intensive coordination within Government and in alignment with Development Partners' current and pipeline activities that reflect Government-driven priorities. Liberia's ESRP is categorized under three broad strategic interventions:

Strategy 1: Recovering Output and Growth. This strategy seeks to revitalize growth to pre-crisis levels, such as restoring GDP growth to at least the pre-crisis rates of 5.9% by 2017, whilst ensuring that it is more inclusive by creating more and better jobs. Under this Strategic Intervention, the Government hopes to increase employment in key sectors through efforts to increase competitiveness, enhance exploitation of the value chain by stimulating private sector growth in value chains sectors which are labor intensive and have most potential for export (e.g. rubber, oil palm, cocoa, fish, and cassava) given Liberia's comparative advantage and potential for diversifying exports, and facilitate better access to domestic and external markets. Additionally, addressing the infrastructure deficit and associated cost increases caused by the crisis remains a critical priority of this plan, thus activities under this Strategic Intervention will be conducted in private sector development (including SMEs); agriculture, fisheries and forestry; services; manufacturing; mining and panning; and critical support infrastructure (energy, roads and transport; sanitation and water); and Information and Communication Technology (ICT)

Strategy 2: Strengthening Resilience and Reducing Vulnerability. The Government of Liberia will implement activities in four key sectors, (i) Health and Social Welfare activities to increase access to, and utilization of, quality health and social welfare services and offer a comprehensive package of interventions of proven effectiveness; (ii) Education activities to ensure equitable access to free basic education for all children; (iii) Social Protection (SP) activities, which will adopt a clear and comprehensive policy and fiscally sustainable system for SP to support the poorest and most vulnerable, in the recovery from the Ebola crisis and to improve resilience through future shocks; and (iv) Security and Rule of Law activities to maintain the current security situation, ensure their sustainability and to increase the accountability and legitimacy of national security institutions and the public's confidence in them.

Strategy 3: Reinforcing Public Finances and Ensuring Service Delivery. GoL plans to secure public finances and ensure service delivery through the improvement revenue administration to increase tax compliance; enhancing economic governance; and prioritizing public expenditure to ensure efficiency in the use of the limited resources.

Energy Sector Strategic Objectives. As mentioned before, activities under the first Strategic Intervention will be conducted in critical support infrastructure, and in particular to the energy sector. It is important to note that this sector is extremely underdeveloped: Liberia currently has an electrification

rate extremely low and one of the highest electricity tariffs in the world. Thus expanding access to reliable and affordable electricity supply is among the main priorities of the GoL. Indeed, the strategic objectives defined for this sector are "To supply affordable power from the national grid to public services in health and education, as well as Micro, Small and Medium Enterprises (MSMEs), industries and households in urban areas, while supporting alternative modes of generation that can extend electricity to consumers in other areas using small-scale thermal, solar and hydro technologies". Moreover, Liberia's Ministry of Lands, Mines and Energy's strategy for the power sector aims to accelerate the expansion of affordable services and bring electricity to 35% of the Liberian population and 70% of people in Monrovia by 2030, including vital public services. The proposed interventions under the plan include:

> **Recovery and Resilience (FY2015/16 and FY2016/17).** Secure funding for additional costs incurred due to delays in the implementation of priority Energy projects, specifically the Mt. Coffee (USD 100M); and adopt an integrated approach to address both short-term and long-term electricity supply needs.

Agenda for Transformation objectives and outstanding funding. In regard to taking forward the AfT objectives in the Energy sector, there remains a delivery challenge to ensure disbursement of funding already committed to Energy (USD 355.6M outstanding). However, further critical priority Energy projects remain in need of funding, including:

> **Additional Transmission & Distribution lines**. Transmission and Distribution lines from Monrovia to Tubmanburg and Monrovia to Firestone – about <u>UDS 50M</u>;
>
> **Via Reservoir/St Paul river major hydro project**. Detailed study and documents being prepared by the European Investment Bank (EIB), that will require at least <u>USD 300M</u> investment.

3.3 THE NATIONAL GENDER POLICY

Rationale for the National Gender Policy (NGP). As analyzed before, Liberia has a high level of gender inequality, being the 9th country with the highest Gender Inequality Index. The National Gender Policy is therefore an instrument for change illustrating the Government's bold step to breaking with the past and moving on with sustainable development for both women and men in Liberia. The Policy demonstrates high political will and commitment by the Government to eliminate all forms of gender based discrimination in order to achieve gender equality, as equal opportunity for all people is essential to the construction of a just and democratic society. Thus, the vision of this NGP is to guide the country towards achieving gender equity and equality, building and utilizing the potential of women and men, boys and girls in pursuing and benefiting from national development goals.

Objective of the NGP. The National Gender Policy seeks to address gender inequalities and the marginalization of women in Liberia. In addition, it is intended to break away from the cultural and traditional mind set of individuals. The Policy mandates mainstreaming gender in all national development processes, as well as to enhance women's and girls' empowerment for sustainable and equitable development; promote gender-equitable socioeconomic development processes and

mechanisms in which women participate equally and that ensure that women and men can equally access, control, and benefit from the country's resources and benefit from development programs on an equal basis. The time frame for the policy's implementation spans ten years, from 2010 to 2020.

Policy priority areas and strategies. The Policy identifies 19 priority areas for intervention each with their own objective. The priority areas in which rural electrification can have a positive impact and help achieve the goals established in the National Gender Policy are presented below:

Gender and the Economy: There are several priority areas regarding gender equality in the economy, namely, women economic empowerment; employment; trade, commerce and industry. The key challenges identified for action include complex and expensive requirements for business registration and public tendering; limited capacity of technocrats to mainstream gender perspectives into macro-economic; low literacy of women in issues of economics; unequal benefits to women in trade; low representation of women in formal employment; discrimination against women in labor markets etc. Indeed, women are responsible for most household cooking, gathering firewood or making charcoal, and fetching water which takes time away from other productive activities. Due to these traditional gender roles, financial subordination, lack of education, and social constraints limit women's ability to improve their economic and political status. Typical divisions of labor keep women at home with responsibilities for everyday household maintenance tasks and child rearing, restricted in their ability to earn their own money and engage in civic activities. Thus, better access to energy services frees women from extreme household drudgery, increases their educational and employment possibilities, and allows them to participate more fully in community and political affairs. Moreover, they can become gainfully employed in industries such as tailoring, which makes use of electric sewing machines, and other cottage industries such as small bakeries, canteens, and laundry services, which require very little electricity yet can transform lives.

Gender and Education: The main goals in this priority area are to mainstream gender in all sectors and at all levels of education and to close gender gaps in the education sector. It is true that the women's literacy rate in Liberia stands below the men's (47% vs. 72%) [12]. The main reason for this is, as mentioned before, that women lose out on education and employment opportunities due to their household burdens. Moreover, girls are more likely than boys to be kept home from school because they are needed to help their mothers with the burdens of gathering fuel and water and performing domestic and agricultural chores, or because there is not enough money to send them. With electricity, women who have no opportunity to go to school during the daytime can take advantage of night literacy classes, which require electricity to function. Indeed, electricity enables study groups which can meet at night, parents are able to help their children in the evenings to do their homework for school without straining their eyes to work by candlelight, and schools are able to installed equipment such as tape recorders, projectors, and other devices to facilitate learning.

Gender and Health: Women suffer health problems from hauling heavy loads, working over smoky fires, and giving birth without adequate health care facilities. Access to modern fuels eases

the domestic burden on women, reducing the strain on their health and allowing them to pursue educational, economic, and other opportunities. Moreover, given that without electricity women use biomass to cook, providing cleaner cooking fuels and improved stoves would help reducing respiratory illnesses that affect women and children. Also, modern energy services allow health clinics to refrigerate vaccines, treat patients at night, and have more medical instruments, fans and sterilizers, and access to electricity also leads to significant reductions in maternal mortality. Furthermore, pumped water from clean sources, and/or energy for purifying water, reduces the spread of water-borne diseases associated with child mortality. It is important to remember that improvements in health raise human productivity, which in turn raises incomes.

Gender and Security & Equality Awareness: Other than providing safer sources of cooking and lighting fuel, electricity can also provide street lighting which is a valuable service to improve women's security. Moreover, with access to electricity people have also access to more sources of information such as TVs and radios, where gender equality and campaigns against gender based violence can be advertised through the media promoting gender sensitivity. Hence, with electricity information is spread across the country more easily, being thus able to create awareness to important issues to women safety and well-being such as HIV/AIDS protection (which affects more women than men), contraceptive and family planning, women's rights, and other important issues to women.

3.4 SUSTAINABLE ENERGY FOR ALL REGIONAL TARGETS AND POLICY

Sustainable Energy for All (SE4All) is an initiative which aims to transform the world's energy systems in order to build a more prosperous, healthier, cleaner and safer world. The initiative was launched in 2011, by the UN Secretary-General Ban Ki-Moon, who shared his vision for making sustainable energy for all a reality by 2030. Governments from 106 countries and the European Union, as well as the private sector and multilateral institutions, have already partnered with this global initiative in order to mobilize action from all sectors of society in support of three interlinked objectives:

1. Energy access – to provide universal access to modern energy services
2. Energy efficiency – to double the global rate of improvement in energy efficiency
3. Renewable energy – to double the share of renewable energy in the global energy mix

There are regional hubs for the initiative, as the SE4All Africa Hub, to better coordinate and facilitate the SE4All implementation in Africa.

Liberia is working toward the SE4All goals. As stated previously, Liberia's energy sector was severely damaged by the armed conflict, and is now trying to recover. Therefore, as far as the first goal is concerned, access to electricity in Liberia remains one of the lowest in the world – the largest part of the population is not electrified and some depend on self-generation. To assess the second goal, energy efficiency, the energy intensity was estimated with the 2008 Census data, since the energy intensity is a measure of the energy efficiency of a nation's economy. The value obtained was approximately 0.3 toe/kUSD. This low value can be linked to Liberia's dominant use of biomass and to its dependency

on thermal generated electricity. Renewable energy in Liberia, the third objective, is currently improving, with the planned and on-going renewable projects. Despite this fact, to this day LEC's generation is 100% diesel dependent. Off-grid renewable generation exact values are unknown, although Liberia's large use of traditional biomass should be considered as a renewable if extracted from sustainable forest resources. Different programs and initiatives support Liberia's efforts to achieve the SE4All targets.

3.5 NATIONAL ENERGY POLICY

The National Energy Policy (NEP) [19] **contains Liberia's national vision in the energy sector.** This is Liberia's first energy policy. It was started in 2006 and after an extensive process of consultations a White Paper [20] was released in 2007 by the Ministry of Lands, Mines and Energy. NEP [19] was finally endorsed in 2009, resulting of the transformation of that White Paper after a process of scrutiny and validation, with the technical and financial assistance from several partners. Through the NEP [19] Liberia aims to ensure universal access to modern energy services in an affordable, sustainable and environmentally-friendly manner in order to foster the economic, political, and social development of Liberia. This is crucial to the achievement of the Millennium Development Goals and Liberia Poverty Reduction Strategy, and reaffirms the Government's conviction that economic development is only possible with access to reliable, accessible and affordable energy.

The National Energy Policy [19] **is founded on three essential features and four key policy issues.** The three essential features for the implementation of proposed energy sector reforms are: (1) demonstrating the Government's resolve for good governance and ensuring financial transparency in all sector transactions, as transparency improves efficiency, also assuring potential investors that all participants in the energy sector are treated equitably; (2) overcoming the significant obstacles to private sector investment in energy supply, since the perceptions of political risk or a lack of buying power discourage investors from considering Liberia; and (3) creating the requisite institutional and legal framework and an independent regulatory regime, by restructuring to create conditions to introduce competition, transparency and investment, promoting private sector participation, having a cost-reflective pricing and ensuring that the regulatory process is able to balance investor and consumer interests.

There are four main strategic issues in which the NEP [19] **is based on:**

1. Access – regarding availability of energy products and services, the goal is to achieve growth with equity, making sure that every urban and rural household, economic enterprise and social and administrative center has access to modern energy services, with the expansion of energy supply and delivery systems;
2. Quality – the issue is acceptability, by emulating international best practice in terms of product and service standards, as well as management and regulatory practices;
3. Cost – the minimization of economic, financial, social and environmental costs is required in order to address the affordability of energy products and services, ensuring a balance between the interests of investors, consumers and the general public;

4. Institutional framework – the issue of adequacy or capacity for energy delivery is addressed by creating a partnership between the public and private sectors, resulting in the involvement of the private sector to the greatest extent possible.

Goals were set by the GoL, in line with the Millennium Development Goals. According to the National Energy Policy document [19], these are:

1. 40% of Liberian citizens living in rural and peri-urban areas and using traditional biomass for cooking shall have access to improved stoves and kerosene or efficient-gas cookers in order to cut indoor pollution;
2. 30% of the urban and peri-urban population shall have access to reliable modern energy services enabling them to meet their basic needs (lighting, cooking, communication, and small production-related activities);
3. 15% of the rural population shall have access to reliable modern energy services toward meeting the same basic needs;
4. 25% of the schools, clinics, and community centers in rural areas shall have access to modern energy services for lighting, refrigeration, information and communication, etc., and shall be equipped with productive energy capacity.

Additional targets were set by the Government of Liberia, considering the sustainable expansion of the energy access. Both these goals and the ones stated before are in line with the national vision, Liberia Rising 2030, and the initiative Sustainable Energy for All. The additional targets set take into consideration environmental costs and benefits, as well as the maximization of efficiency to minimize costs and environmental impacts. The targets defined are:

1. Reducing greenhouse gas emissions by 10% by 2015;
2. Improving energy efficiency by 20% by 2015;
3. Raising the share of renewable energy to 30% of electricity production and 10% of overall energy consumption by 2015;
4. Increasing the level of biofuels in transport fuel to 5% by 2015;
5. Implementing a long-term strategy to make Liberia a carbon neutral country in energy production and transportation by 2050.

3.6 NEW ELECTRICITY LAW

On September 24, 2015, the House of Representatives passed the 2015 Electricity Law of Liberia, which opens the Liberian electricity market to private investors. This new electricity law was predicted in the National Energy Policy, and its objective is to regulate and promote the development of the electricity sector and to review the mandate of LEC in line with the National Energy Policy. The then act, according to the committee, contains essential ingredients on the liberalization of the electricity sector and is largely consistent with international best practices, since it is a way to liberalize the electricity sector as a means of driving competition which could improve access, improve quality and lower costs. The proposed act establishes the legal and regulatory framework for the generation, transmission, distribution and retail sale of electricity and for import and export. This will create an enabling

environment for private sector investment in the energy sector of Liberia. Independently of this legal framework, there are a lot of companies and institutions operating their own power plants. Especially the mining companies include their rights to power production in the concession agreements.

Although this new Electricity Law represents a significant improvement, some argue that there are still constraints. This is supported by the fact that the authority in charge of the Regulatory Commission is LEC, which is at the same time a referee and a player. Even though the law will ensure the establishment of an independent Liberia Electricity Regulatory commission, which will consist of a chairperson and two other members to be appointed by the President with the consent of the Senate, many believe involving the government will make the commission no different from the LEC. From the effective date of the proposed law, LEC will be considered to be licensed provisionally to engage in the power generation business, power generation transmission, distribution and sale of electricity.

3.7 RURAL ENERGY POLICY AND PRIORITIES

Country agenda and policy. Liberia aspires to become a middle income country by 2030 and has approved its Agenda for Transformation - Liberia Rising 2030 - with the focus not only on accelerating growth, but also on ensuring that growth can be sustained and lead to a more inclusive society. Equity is a key principle of Liberia's policy which is reflected not only on the Agenda for Transformation but also on the National Gender Policy which aims to guide the country towards achieving gender equity and equality, building and utilizing the potential of women and men, boys and girls in pursuing and benefiting from national development goals.

National Energy Policy principles. The National Energy Policy [19] that details the Agenda for Transformation of the Energy Sector was approved in 2009 with a focus on 4 key strategic issues and objectives: **Access** with **Quality** and reasonable **Cost** with an adequate **Institutional Framework.** President Ellen Johnson Sirleaf defined the following guiding principles for Liberia's Energy Policy in the keynote address to the National Energy Stakeholders Forum in 2006 which still remain valid:

- Leveraging enhanced energy access for improvements in education, health and economic development;
- Providing access to modern energy (fuels and electricity) for previously neglected rural consumers;
- Enhancing transparency and accountability at every stage of energy operations;
- Ensuring the long-term financial viability of electric utilities and other energy companies;
- Ensuring the affordability of all energy forms for poor consumers;
- Balancing the environmental costs and benefits of all energy programs, taking into account the collective global effort to control harmful greenhouse gases responsible for climate change;
- Maximizing energy efficiency and demand-side management to minimize the financial and environmental costs of energy development;

- Ensuring the involvement of the private sector to the "greatest degree possible" throughout the energy sector; and
- Ensuring that Liberia takes all requisite actions on a timely basis to integrate its domestic energy policies into ECOWAS Protocol and other regional and international projects, commitments, standards and obligations.

Rural and Renewable Energy. The National Energy Policy [19] in order to promote rural and renewable energy established RREA, the REFUND and the need to develop the Rural Energy Master Plan as a key tool and development program to achieve universal energy access.

The following key Policies and Principles shall apply to the Rural Energy Strategy and Master Plan:

1. **Least Cost development taking account of the economic, financial, social and environmental factors and the special needs of the poor through the use of targeted and transparent capital subsidies**. The Rural Energy Master Plan shall be developed on the basis of a "Least Cost Universal Access" long term vision. All locations, people, businesses and services shall be electrified using the technology that minimizes the cost of service to that particular location, person or business. Only in such a way will Liberia be able to achieve universal access at the lowest cost possible. Subsidies for the poor will be transparently applied to the least cost solution.
2. **Equity across regions, social classes and genders while balancing efficiency on the allocation of available resources**. All Liberians, independently if they are at Montserrado, Maryland or other parts of the country, independently if they are rich or poor or independently if they are men or women, have equal right to access energy services. However, resources are limited and therefore the Master Plan has to decide who to electrify first and with which level of service or support – considering also the fact that some precedent investments may be required to electrify a given area or location. The Master Plan is formulated on the basis of well-defined project selection and prioritization criteria which considers first Equity but also Efficiency.
3. **Priority to electrification of community services and health facilities**. Key decision makers across Liberia share the perspective that electrification should start with Health Facilities, than Schools and Public Lighting (Education and Security), and only after households and businesses. The common services shall have priority relative to the individual solutions.
4. **Use of indigenous and renewable resources in a sustainable way while avoiding dependence on solutions with very high running costs**. If it is possible to use indigenous and renewable resources instead of importing oil or other fuels in a competitive and reliable way, the Master Plan shall opt for the use of such indigenous and renewable resources. Sustainability means, among other things, that the utilization of biomass or other sources of renewable energy do not contribute to deforestation or to food insecurity. Diesel only based electrification is considered as very expensive to maintain, environmentally unfriendly and unsustainable.
5. **Facilitating private sector investment through the unbundling of power sector activities, the implementation of clear and transparent award and remuneration mechanisms and the targeted use of subsidies and grants**. It is the Government intention to involve the private

sector to the "greatest degree possible". Unbundling of Power Sector activities and the award of some of those activities to Independent Private Operators through clear and transparent mechanisms will facilitate private sector participation. The Government shall ensure the long term financial viability of power sector players allowing full cost-recovery at affordable tariffs by reducing capital expenditure and remuneration through the targeted use of "grants" and capital subsidies.

6. **Transparent and independent regulatory process to ensure safe, secure, reliable and sustainable power at a cost-reflective but affordable price**. Regulation is the most effective mechanism of control for natural monopolies such as Power Transmission or Distribution. Regulation offers transparency and also risk mitigation which can provide confidence both for private investors, donors and lenders. Cost-reflectiveness and affordability trade-offs in rural areas can be also mitigated through the use of regulatory mechanisms. Where feasible the regulator shall promote free and fair competition – namely in Generation and in Procurement of goods and services – to enable consumers to get the best prices.
7. **Promoting regional cooperation**. Liberia is a member of the Economic Community of West African States. Rural Energy Strategy shall promote the participation of the key actors in the regional market to enhance international trade of electricity and to maximize opportunities for cost reduction, for investment and for cross-border electrification.

Sustainable Development Goals and Sustainable Energy for All. The National Energy Policy established targets in line with the Millennium Development Goals having 2015 into perspective. The Millennium Development Goals have been updated with the Sustainable Development Goals which incorporate the Sustainable Energy 4 All initiative and goals of universal energy access, doubling of renewable energy and energy efficiency. Liberia is fully committed to the Sustainable Energy 4 All initiative and therefore the Rural Energy Strategy and Master Plan updates the rural energy targets with the 2030 horizon and new more ambitious goals into perspective.

ECOWAS Renewable Energy Policy. The ECOWAS Renewable Energy Policy was adopted by the 43rd Ordinary Session of the ECOWAS Authority of Heads of State and Government, which held in Abuja, Nigeria, from 17 to 18 July 2013. This policy on renewable energy aims at ensuring increased use of renewable energy sources such as solar, wind, small-scale hydro and bioenergy for grid electricity supply and for the provision of access to energy services in rural areas. The ECOWAS region set a clear target to increase the share of renewable energy in the region's overall electricity mix to 10% in 2020 and 19% in 2030. Including large hydro, the share would reach 35% in 2020 and 48% in 2030. Around 25% of the rural ECOWAS population will be served by mini-grids and stand-alone systems by 2030.

4 BARRIERS, EXPECTATIONS AND PRIORITIES FOR RURAL ENERGY (BELIEFS AUDIT RESULTS)

4.1 BELIEFS AUDIT: METHODOLOGY AND QUESTIONNAIRE

Beliefs Audit Questionnaire purpose. The Beliefs Audit questionnaire was conducted to key representatives of the power sector during the development of the RESMP across all Liberian counties aiming to support a series of individual interviews with key decision makers and stakeholders to assess beliefs, reasonable goals and expectations regarding rural electrification in order to elaborate the Rural Electrification Master Plan. This Beliefs Audit questionnaire provided the Consultant a better understanding of the countries features and its people's opinion, as well as other key information. Site visits and interviews were done not only in Monrovia, but also in the 15 counties where beliefs audits interviews were undertaken, data from the local authorities and relevant stakeholders was collected, and discussions with local and central authorities were conducted in order to revisit or establish priorities and objectives for the development of a voluntary vision for increasing energy access to rural Liberia.

Beliefs Audit methodology. Interviews and questionnaires were structured in a way to obtain comparable and statistically relevant information. A total of 60 belief audit questionnaires were conducted across all 15 Liberian counties and at least three interviews were done in each county. Nevertheless, the county in which more beliefs audit questionnaires were conducted was Montserrado, where 14 interviews were conducted, mainly to central authorities located in the capital Monrovia. Also, within these 60 interviews, 14 were made to central authorities, including five RREA representatives, six central representatives of the Ministry of Lands, Mines and Energy, one central representative of the Ministry of Internal Affairs, one LEC representative, and one energy specialist of the Energy and Security Group. Furthermore, 29 interviews were conducted to local authorities, including 9 superintendents and 7 acting superintendents, three city mayors, and two regional coordinator mining agents. The remaining interviews were made to other power sector players such as petrol and energy equipment sellers.

Beliefs Audit structure. The beliefs audit questionnaire had a total of 27 questions, divided in six groups: A. General Targets; B. Specific targets; C. Priorities; D. Funding; E. Institutional/policy; and F. Other questions, made only for county questionnaires. The beliefs audit questionnaire, as well as the list of respondents, is presented in **ANNEX I**.

4.2 MAIN BARRIERS FOR DEVELOPMENT OF RURAL ENERGY

Slow development of rural electrification. In the nearly ten year period between the end of the war and the beginning of the Ebola crisis not much electrification happened. Moreover, as mentioned before Liberia only has a rural electrification rate of 2%, and is far behind the other West African countries. Thus it is of a major importance to understand the reasons for this slow rural electrification and its barriers.

Main barriers for development of rural energy appointed in the beliefs audit. The two main reasons were appointed to this lack of development in the power sector in the beliefs audit: absence of funding and the exclusion of government's priorities (see **Figure 4.1**). However, the barriers to rural electrification vary a lot depending on the type of authority or player in the power sector. Indeed, while central authorities do not have a unanimous vision as to what is the main barrier to electrification, the local authorities' visions converge to the absence of funding (53%), and the other players agreed it is due to the exclusion of government's priorities (76%). Limited private sector investment is also appointed to be a cause for the slow development of rural electrification followed by lack of human capital.

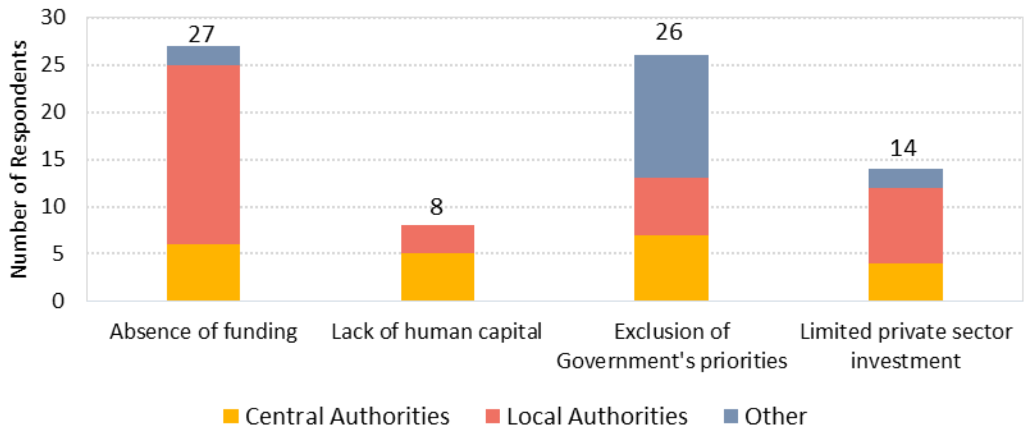

Figure 4.1 – Main barriers to electrification.

Bottlenecks to the development of a national electricity system according to the ESRP. Other than these barriers appointed in the beliefs audit, according to the Economic Stabilization and Recovery Plan developed in April 2015, the main bottlenecks to an efficient and sustainable development of a national electricity system are:

- Lack of infrastructure for transmission and distribution;
- Electricity utility in a precarious financial and technical situation, with an area of service limited to Monrovia.

Moreover, in the Gbarnga workshop for validation, participants also appointed several barriers to electrification. In the Stakeholder's Consultation and Validation Workshop which took place in Gbarnga City, Bong County, on February 4, 2016, there was extensive discussion to assess the main barriers to electrification in Liberia. Several barriers mentioned were in accordance with the ones appointed in the beliefs audit, such as the lack of funding and political support, and the lack of human capital and technical capacity. Nevertheless, other barriers were also brought up in this workshop that should be evaluated. These new barriers to electrification disclosed in the workshop were the lack of transparency and accountability, the need to raise awareness and provide affordable solution that also address gender sensibility and thus are adoptable by the population, and the electricity theft which undermines the power sector sustainability.

Given all these sources, several barriers to electrification were detected. The main barriers to the underdevelopment of the power sector in Liberia are as follows:

Barrier 1: Absence of Funding. Liberia's power sector is seriously underdeveloped and thus a great deal of funding is needed in order to build the necessary infrastructures for transmission and distribution. As any other type of infrastructures, the capital expenses are extremely high and thus there is a need to raise capital in order to invest in this sector. An analysis of the funding potential will be conducted latter in this study.

Barrier 2: Lack of Political Support. As mentioned above, in order to develop the energy sector a great deal of funding is necessary. A major part of the funding available to a country passes through the government on various form, from tax and grant revenues to concessional loans. Thus it is the government's responsibility to allocate the funding available to the several sectors. Many respondents appointed that a barrier to electrification was the exclusion of government's priorities, thus indicating that this sector has a lack of political support which challenges its expansion.

Barrier 3: Lack of Transparency and Accountability. Several studies show how information asymmetries, lack of transparency and accountability affect the quality of public services and have a negative impact on development. Indeed, the monopolistic nature of grid-based electricity, the main means of delivery, presents opportunities for rent seeking and can lead to inefficient services, underinvestment and poor maintenance of infrastructure. Hence, addressing the lack of transparency and accountability can ensure the power sector's sustainability and benefit the customers.

Barrier 4: Lack of Human Capital and Technical Capacity. Human capital and technical capacity are two factors that are mandatory in order to develop a sector. Without the human capital and thus the know-how to develop the power sector it will be impossible to do it. However, human capital alone will be no good if there is a lack of technical capacity, indeed without technical capacity the know-how would not be able to be used. Concluding, having the funds and resources to pay for large-scale projects like electrification is essential, but without the skilled labor and technical capacity it is impossible.

Barrier 5: Limited private sector investment. More than funding, power sector investment also provides human capital and assumes substantial financial, technical and operational risk in the projects. Indeed, the amount of funding needed to invest in the power sector cannot be financed by the public purse alone, and thus encouraging private investment in infrastructure is an option that governments cannot afford to ignore. Moreover, private sector participation can bring benefits other than additional capital. The examples include the end-user benefits of a more competitive environment, as well as the mobilization of the private sector's technological expertise and managerial competences in the public interest. Moreover, private participation in infrastructure can help boost both the coverage and efficiency of infrastructure services.

Barrier 6: Need to raise awareness and provide affordable options for electrification thus granting the adoption of the population. When introducing something new to the population, in this case electricity, there is a need to ensure that the options provided for the population fits their needs and that it can be adaptable to their life. Hence, it is extremely important to raise awareness to the benefits of electrification to the population while adapting these options to their customs and life. For example, people in rural areas usually have larger families and prepare their meals in larger pans, thus when promoting efficient cook stoves there is a need to ensure that they are adaptable for the population and that they can continue using their utensils. Furthermore, this utility also needs to be affordable for the population. Addressing issues such as gender sensibility is also necessary in order to ensure that these new options are welcome by everyone and that enable an equitable growth.

Barrier 7: Electricity theft which undermines the power sector's sustainability. In order to ensure the sustainability of the sector of for it the keep developing, there is a need to mitigate factors such as electricity theft. This is a bigger problem where monitoring and oversight is weak and when accountability mechanisms between politicians and citizens (electricity consumers) and between politicians and electricity service providers are not strong.

The analysis of these barriers is presented in **ANNEX II**.

4.3 EXPECTATIONS ON OVERALL ACCESS GOALS

Introduction. Part of the beliefs audit questionnaire aimed to understand the general targets of rural electrification in Liberia from the achievable goals across several periods of time to the distribution of electrified people between large cities (including county capitals) versus rural areas. The knowledge regarding these topics is crucial for the elaboration of the Rural Energy Master Plan for Liberia, as the Consultant and the Liberian authorities and players of the power sector need to have their general beliefs aligned. Thus understanding the expectation on overall access goals in Liberia regarding rural electrification is mandatory.

Target regarding rural electrification rate in Liberia. In order to understand the rural electrification rate target across several timeframes, it was asked what the respondents believed could be genuinely achievable as an electrification target for the population outside of Monrovia in the next 5, 10 and 15 years. The answers to this question are presented on **Figure 4.2**. It is clear that there is a convergence of visions regarding the electrification rate in the short term (next 5 years, until 2020), and in the long run (next 15 years, until 2030). Indeed, 56% of the respondents agreed that the achievable electrification target for the population outside Monrovia until 2020 would be less than 25%. Moreover, in the long term (until 2030), the majority of the respondents (68%) thought a rural electrification rate of more than 50% could be achievable. Regarding the views for the rural electrification rate in the medium term scenario, in the next 10 years (until 2025), there was no convergence of visions, as 41% thought that the rural electrification rate achievable would be below 35%, 15% said between 35 and 50%, and the remain 41% agreed it could be more than 50%.

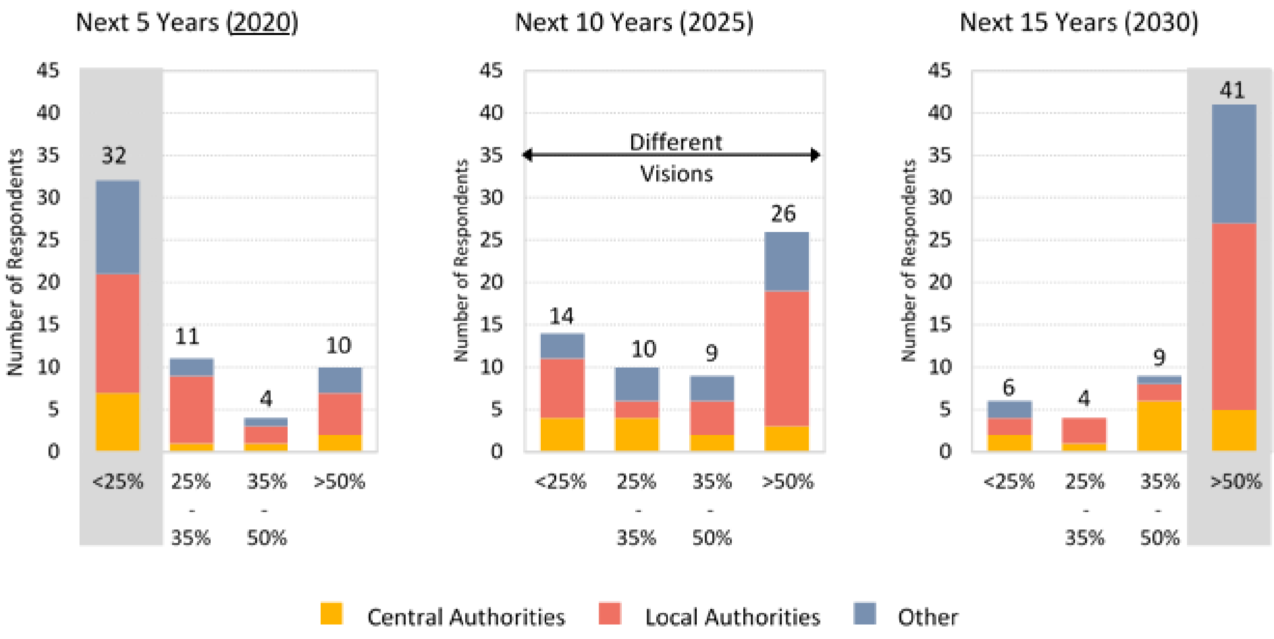

Figure 4.2 – Electrification target genuinely achievable for the population outside of Monrovia.

Central authorities have more conservative rural electrification targets. When comparing the beliefs of the different players of the power sector, it is noticeable that central authorities have more conservative rural electrification targets, especially when it comes to the long run. Indeed, the rural electrification target set by central authorities for the next 5 years was, on average, 21%, compared to 25% of local authorities and other power sector players. Concerning the medium term rural electrification target, the average of the central authorities is 35%, versus 46% of local authorities and 45% of other agents. Lastly, it is in the long term (up to 2030) where the discrepancy between central authorities and other players is more evident, as the rural electrification target for central authorities in the next 15 years is on average 51%, and the local authorities and other agents is 71% and 74%, respectively (see **Figure 4.3**).

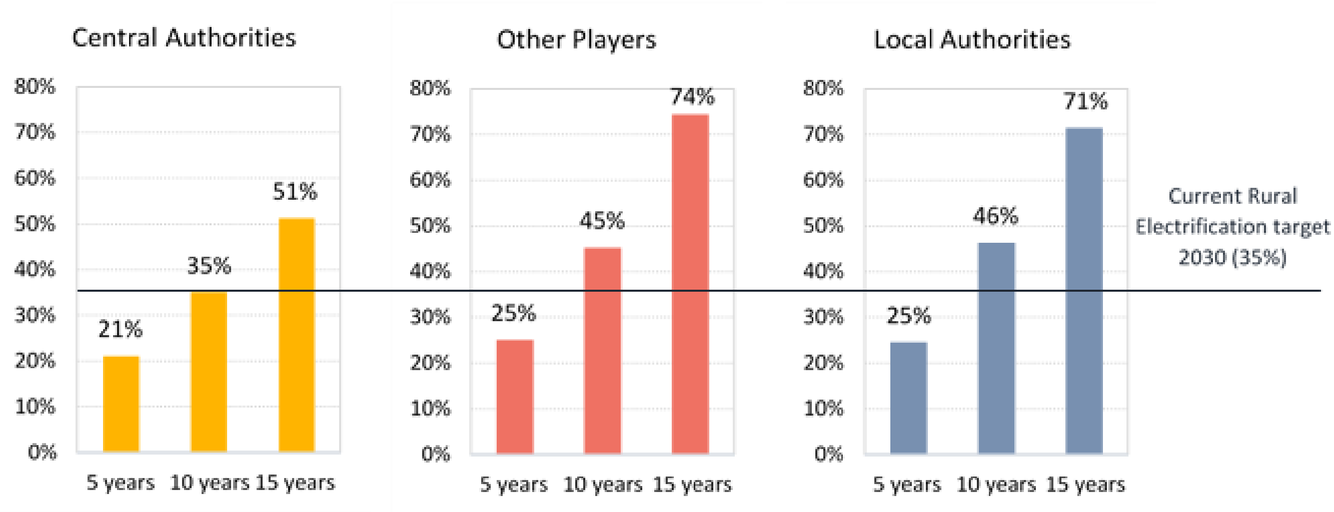

Figure 4.3 – Rural electrification targets by type of authority.

High rural electrification targets, especially in the long run. One thing to retain from the answers of this question is that the targets set for rural electrification are extremely ambitious – the Rural Energy Master Plan, as agreed with the Client in preparatory meetings, has a target of electrifying 35% of all non-Monrovia population until 2030 (i.e. without benefitting from the 70% of Monrovia). In fact, from the 68% who though a rural electrification rate of more than 50% could be achievable until 2030, 44% answered that there could be 100% electrification. Hence the expectation for the rural electrification targets are extremely high and thus a more ambitious scenario is going to be developed (**Chapter 8**).

More balance between large cities and rural areas in the future. When asked what should be the distribution of electrified people between large cities (including county capitals) versus rural areas in the next 5 years, 66% of the respondents answered that it should be 75% to large cities versus 25% to rural areas, thus allocation more resources to large cities. Interestingly, in the longer run (next 10 to 15 years), this percentage shift to 50% allocation to large cities and 50% allocation to rural areas (see **Figure 4.4**). Thus, the general belief if that first large cities and county capitals should be consolidated first, and then a more balance focus should go to rural areas. Hence, the Rural Electrification Master Plan must target both cities and more rural areas – with larger cities being electrified first.

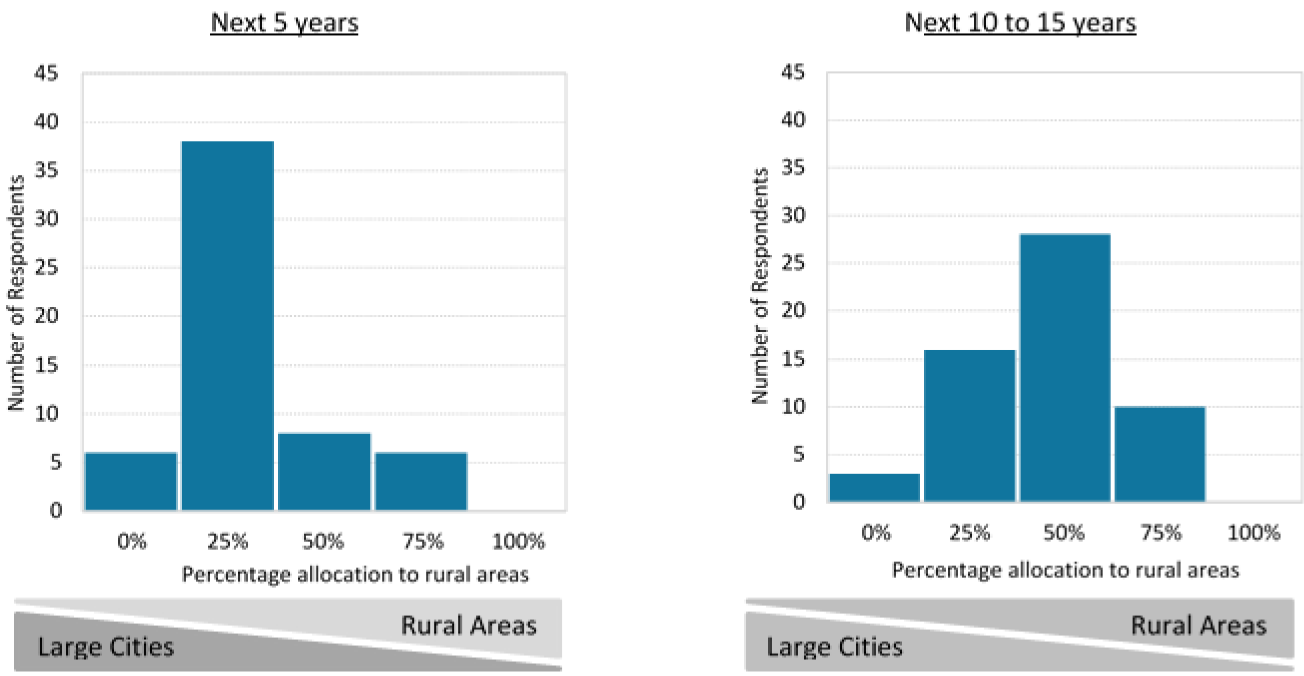

Figure 4.4 – Distribution of electrified people between large cities versus rural areas.

4.4 EXPECTATIONS ON SPECIFIC TARGETS

Expectation on specific targets. After analyzing the general targets, there is a need to perform a deeper analysis in order to better understand the specific targets. The beliefs audit questionnaire was subdivided between the specific targets regarding electrification, cooking, and diesel for generators. Concerning electrifications, the questions were developed in order to better understand the realistic targets for electrification of certain locations and buildings such as county and district capitals, health facilities and schools. Moreover, the beliefs regarding promoting Solar Portable Lamps be for the

population not electrified were also analyzed, and if so how should they be promoted. Regarding cooking, the questions were made in order to weigh several different energy sources and options and understand how these should be promoted. The final subdivision was made in order to evaluate if diesel/gasoline is easily available in all the counties.

County capitals and health facilities are given extremely ambitious electrification targets. It was asked to the respondents what they considered to be a realistic target for electrification of locations and buildings in the next 10 to 15 years. As presented in **Figure 4.5**, high electrification targets were set to county capitals and health facilities, as the majority of respondents advocated a target above 80%. Indeed, 100% of the respondents answered that county capitals should all be electrified by the year 2030, and 52% agreed that a realistic target for electrification of health clinics in the next 10 to 15 years should be between 80% and 100%, where 37% answered it should be 100%. These two types of buildings are thus very high priority to electrify. Administrative buildings, schools and district capital have high priority to electrify as the majority advocates a target above 60%, and settlements with more than 1 000 inhabitants are the ones with least priority as the majority only advocates a target above 40%. These targets are extremely ambitious and are not going to be easy to obtain, nevertheless an effort will be put in the master plan in order to consider these beliefs.

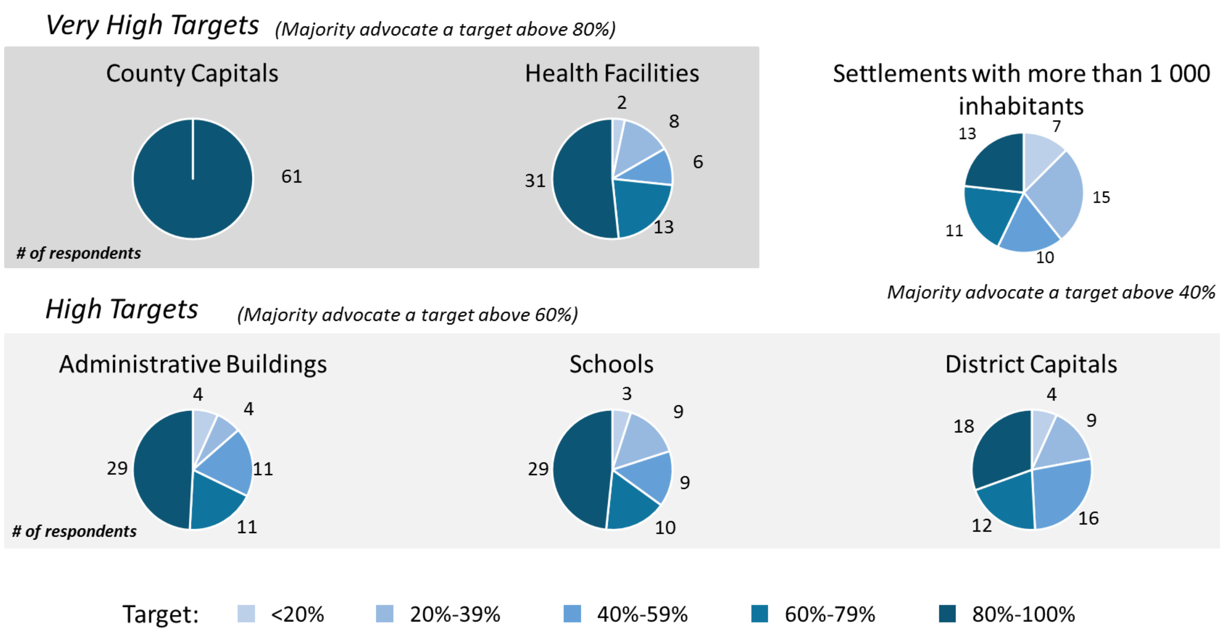

Figure 4.5 – Realistic target for electrification of locations and buildings.

Solar portable lamps, LPG and cook stoves should be promoted by making them available at reasonable prices. Regarding Solar Portable Lamps for the population not electrified, 97% of the respondents answered they should be promoted by making them available at reasonable prices. This situation is extremely similar with the source of energy that should be promoted for cooking. Indeed, when asked if LPG should be promoted for the large cities and urban areas, cook stoves for charcoal for the large cities and urban areas and efficient cook stoves for wood for rural areas, 93%, 90% and 95%

answered yes, respectively, and agreed they should be promoted by making them available at reasonable prices as well (**Figure 4.6**).

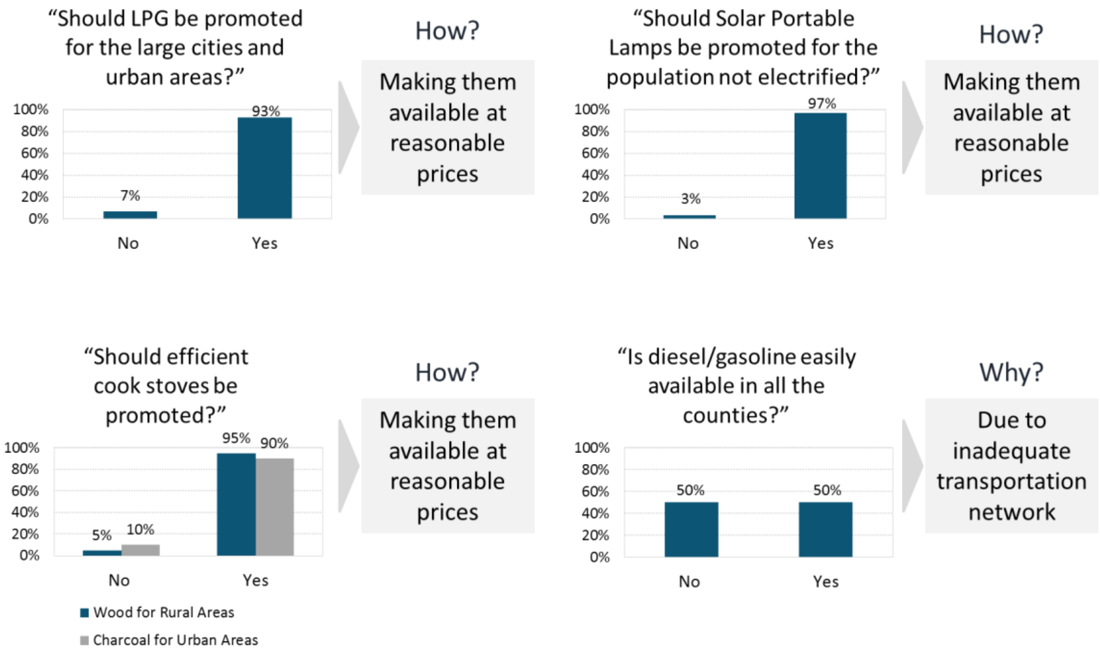

Figure 4.6 – Beliefs regarding different energy sources.

Diesel/gasoline is not available in all counties. In the beliefs audit questionnaire it was asked whether diesel/gasoline is easily available in all the Liberian counties. The respondents were split 50/50 when answering this question, as exactly 50% answered yes and 50% answered no. This however, may differ on the county, as the reason given to why diesel/gasoline was not available in all counties was due to inadequate transportation network. Indeed, as described in the **Figure 4.7**, while in Bong and Gbarpolu counties 100% of the respondents agreed that diesel/gasoline was available, in Maryland, River Gee and Sinoe this percentage is down to 0.

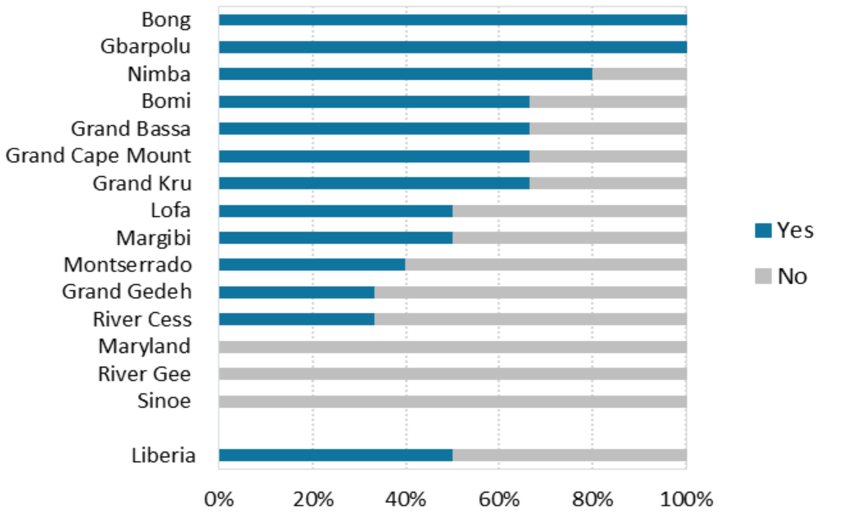

Figure 4.7 – Availability of diesel/gasoline across all counties.

4.5 RURAL ELECTRIFICATION PRIORITIES

Introduction. Having the electrification targets set, the next step is to define priorities. Indeed, as mentioned before the electrification target set were extremely ambitious and so establishing priorities will enable the Consultant to create a master plan more fitted to the country's needs and beliefs. Thus, priorities to electrification were evaluated in this stage, as well as the comparison of two situations regarding source of generation, dispersion, and service level.

Health facilities are given priority to be electrified first, followed by schools and street lighting. In order to understand the rural electrification priorities the respondents were asked to rank what should be electrified first. The results are presented in **Figure 4.8**. All power sector players agreed that health facilities are the ones who should be given more priority to electrify, which is in accordance with previous results. Following health facilities, there was a general belief that schools and street lighting should be given priority next electrify. Households, businesses and administrative building were the facilities given least priority, however their order varies with the type of authority. Indeed, central authorities agreed that households should be electrified first and administrative building last, while local authorities have the contrary belief. Interestingly enough is the fact that when asked what were the most important impacts and benefits of electrification for the population, central authorities ranked first Productivity & Business, and now, in the priorities to electrify, they ranked businesses second to last.

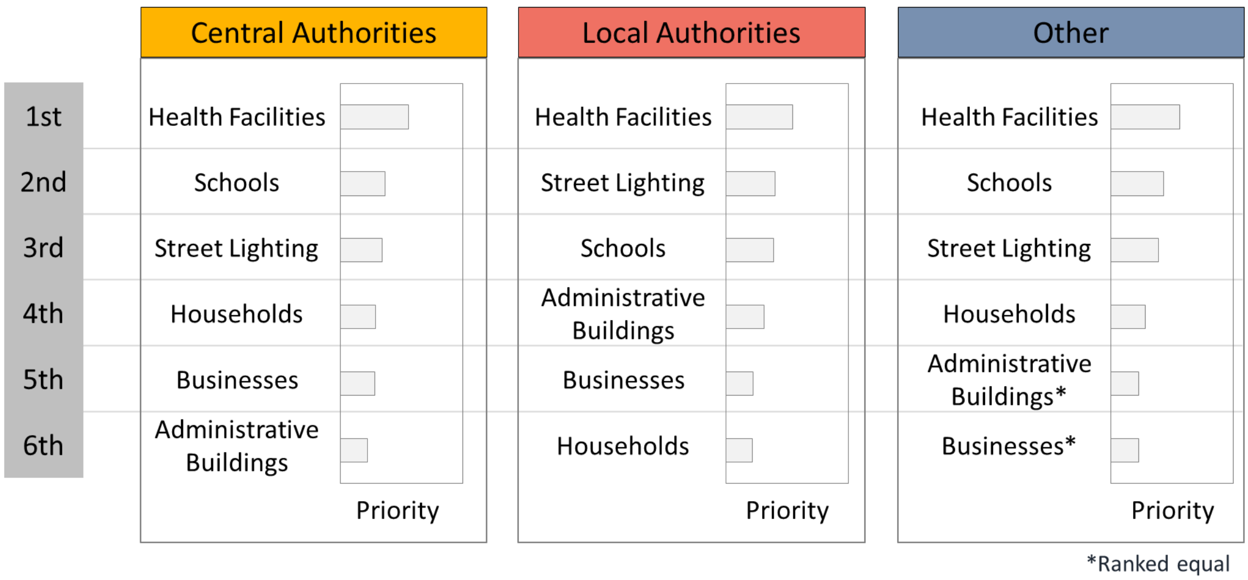

Figure 4.8 – Priority to electrify.

Majority valued lower generation costs over electrifying five times more households. In order to better understand the priorities regarding source of generation, the respondents were asked to allocate a certain budget that could only be used for one and one only electrification purpose. Thus respondents had to choose between electrifying 500 households with efficient diesel generators, but the households would still have to pay for the diesel consumption, versus spending the same money and electrifying only 100 households with solar panels and batteries, however these households would have to pay very

few for energy. 68% believed the best option was the second one, thus electrifying less households – one fifth – with lower running costs, as it can be seen in **Figure 4.9**. Thus, diesel generation does not seem to be the preferred way to electrify given high running cost, and so diesel only electrification will not be considered as an option.

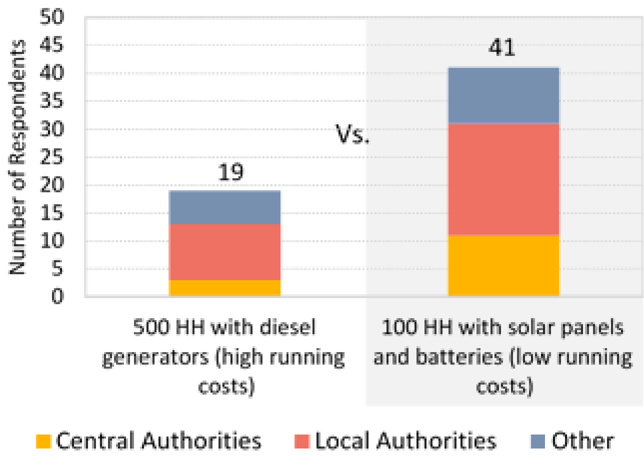

Figure 4.9 – Priority regarding source of generation.

Majority preferred equity across the country over electrifying twice the households. The second question of this type was for respondents to set their priority towards the dispersion of electrified households. Hence they had to choose between electrifying 150 households distributed throughout the nation, at the rate of 10 per each county, or spending the same money electrifying 300 households, all concentrated in only one county. 68% of the respondents answered they would rather electrify half the households in order to have equity across the country (**Figure 4.10**).

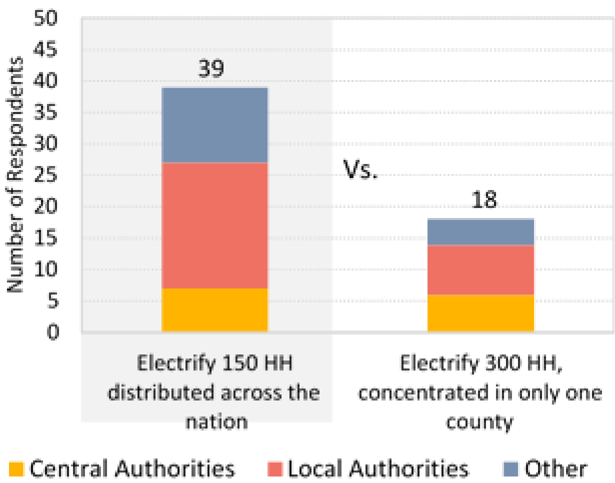

Figure 4.10 – Priority regarding dispersion across the country

Majority would prefer lower service level to reach more households. In regards to the service level available to the households, interviewees had to weight between electrifying 100 households with full day (24 h) current, versus spending the same money electrifying 200 households with half day (12 h)

current, from 6 PM to 6 AM. To this question, the vast majority (85%) would prefer providing a lower service level to reach twice the households (**Figure 4.11**).

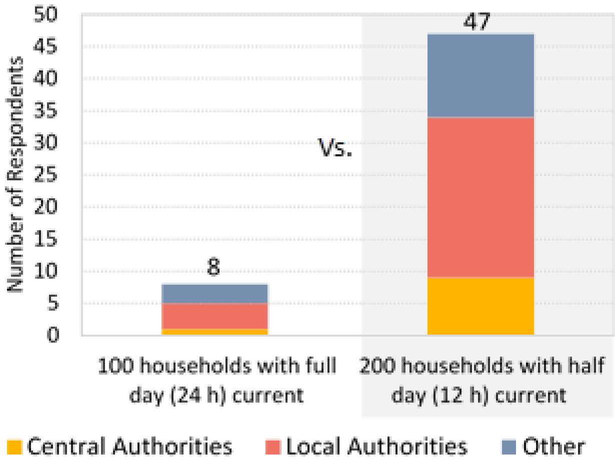

Figure 4.11 – Priority regarding service level

PART C. LONG TERM VISION

5 DEMAND ASSESSMENT

5.1 INITIAL CONSIDERATIONS

In this Chapter, the methodology and results of the demand analysis are presented.

Rural demand analysis. This analysis was focused on two major demand sectors which are intended to portray all the rural demand: 1) the residential sector and 2) the institutional & commercial services sector. The large industries sector (namely the mining infrastructure and agricultural plantations) was not quantified as electrical consumption since they were not considered part of rural assessment. However, these infrastructures were indirectly considered in the rural demand studies, as they can influence the consumption patterns of nearby communities. Also, this analysis considers that all settlements, with the exception of the capital Monrovia, are in the scope of the study, even though some may have urban characteristics (e.g. County Capitals and large cities). Therefore, due to its size and development, Monrovia is the only settlement that will not be considered in this work overall, and namely in the demand analysis.

Chapter organization. In **Chapter 5.2** the analysis of the population of Liberia is presented, with special focus on rural population. It was assumed that the consumption level varies from settlement to settlement due to several factors. So, in order to obtain this differentiation, a classification of all the cities and villages of Liberia was performed and the results presented also in **Chapter 5.2**. In **Chapter 5.3** the residential demand assumptions are presented. It is shown the current potential residential consumption estimates as well as the assumptions used to determine the demand growth of the domestic clients. **Chapter 5.4** describes the Services and Commercial demand assumptions. Additionally to the current and future consumption estimates of the rural Institutional & Commercial Services, this **Chapter** also illustrates the data gathering used in this analysis, namely the geo-located infrastructures. In **Chapter 5.5**, three demand projection scenarios for rural demand are shown. **Chapters 5.6** and **5.7** aim to obtain an overall idea of the total electricity demand of the Country. So, firstly a quick review of the demand projections of the *2013 Least Cost Development Plan* (LCPDP) [21] is performed and afterwards a nationwide electricity consumption and demand projection is presented. Moreover, a list of the potential beneficiaries is presented in **ANNEX III**.

5.2 POPULATION AND SETTLEMENTS CLASSIFICATION

5.2.1 POPULATION DATABASE AND UPDATE

Rural settlements and rural population. The development, safety and well-being of rural populations is the main driver for rural electrification. Therefore, the first step was to determine the distribution of the Country's *rural* settlements and consequently of the *rural* population. The data used for this task was a GIS database gathered from RREA, which was accomplished by LIS-GIS for the *2008 National population and housing census* [2]. **Figure 5.1** displays the referred database, highlighting Monrovia and the County Capitals.

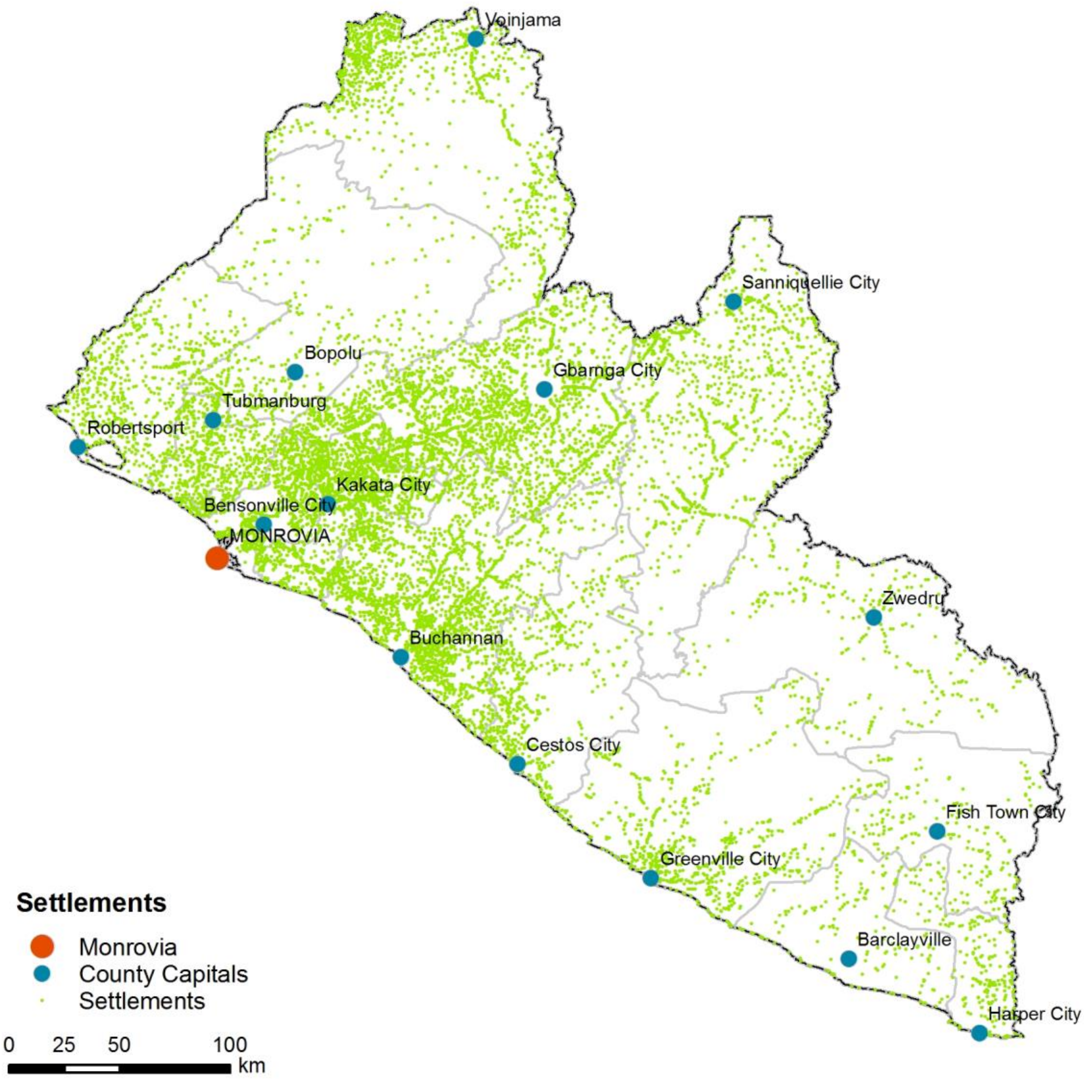

Figure 5.1 –Gathered GIS database of Liberia's Settlements - 2008.

Settlements distribution. The previous map shows that, besides the Capital of the Country, there are fifteen County Capitals. There is a large concentration of settlements in the center strip of the Country – between Monrovia, Buchannan and Gbarnga. However, a large concentration of settlement doesn't necessarily mean that there is a large density of inhabitants. In fact, the population in the mention region is based in several dispersed small villages with low population density.

Distribution of population. The number of total population in the collected database was around 3.5 million people, of which almost 1 million is located in Monrovia. In 2008, 43.4% of the total population of Liberia was in urban settlements and 56.6% was in rural communities. In order to get these percentages, a threshold of 5 000 inhabitants was used to differentiate urban settlements from rural villages. So, if a settlement has more than 5 000 inhabitants, it is considered a city. On the other hand, if a settlement has less than 5 000 inhabitants, then it is considered a rural village. The distribution of population in each County (considering Monrovia) is shown in **Table 5.1**.

Table 5.1 – Population per County - 2008

County	Population 2008	%
Bomi	84 119	2.41%
Bong	333 481	9.56%
Gbarpolu	83 388	2.39%
Grand Bassa	236 912	6.79%
Grand Cape Mount	126 976	3.64%
Grand Gedeh	125 937	3.61%
Grand Kru	57 903	1.66%
Lofa	276 385	7.92%
Margibi	208 174	5.97%
Maryland	135 738	3.89%
Montserrado	1 118 341	32.05%
Nimba	461 745	13.23%
River Gee	66 789	1.91%
Rivercess	71 509	2.05%
Sinoe	102 391	2.93%
Total	**3 489 788**	**100.00%**

Population per County. As expected, and also presented in **Chapter 2.2,** the most populated County is Montserrado because of Monrovia, representing almost third of all population of Liberia. Nimba also stands out from the other counties with more than a 13% share of population. The less populated counties are Grand Kru and River Gee with less than 2% of the population. Rivercess, Gbarpolu and Bomi also stand out since all of them have less than 2.5% share.

Population database update. Since the database was prepared in 2008, the population numbers shown previously are out of date. Therefore there was the need to update these values up to 2015, in order to have an estimate of the current situation. To do so, the United Nations population growth rates for urban and rural settlements in Liberia were used. The mentioned reports stated that the population growth rate in urban Liberia is to be 3.21% per year and in rural Liberia 1.42%. So, taking into account the population distribution in 2008, the estimate population in 2015 is above 4 million people, which represents a 2.2% annual growth.

The distribution of population in each County for 2015, considering Monrovia, is shown in **Table 5.2**. Comparing **Table 5.1** with **Table 5.2** it can be seen that the more "urban" counties have risen their share of population due to the higher growth rate of urban population. This is a typical result since, besides the normal birth rate, there is a tendency for a migration of the dispersed populations to the large conurbations.

Table 5.2 – Population per County - 2015

County	Population 2008	%
Bomi	94 941	2.3%
Bong	377 583	9.3%
Gbarpolu	92 038	2.3%

County	Population 2008	%
Grand Bassa	271 827	6.7%
Grand Cape Mount	140 148	3.4%
Grand Gedeh	143 977	3.5%
Grand Kru	63 910	1.6%
Lofa	314 117	7.7%
Margibi	241 840	5.9%
Maryland	156 647	3.8%
Montserrado	1 379 929	33.9%
Nimba	524 117	12.9%
River Gee	74 642	1.8%
Rivercess	78 927	1.9%
Sinoe	114 935	2.8%
Total	**4 069 579**	**100.0%**

5.2.2 SETTLEMENTS CLASSIFICATION

5.2.2.1 CONTEXT

Settlements development and electrical demands. In this kind of studies, it is common to associate the social and economic development of a certain region to its electrical consumption levels. Basically, they rely on the assumption that more developed settlements will have, for example, more services and commercial facilities than those on small villages, which consequently results on bigger electrical demands. Also, due to higher development levels, residential clients have superior incomes and a greater purchasing capability, which also reflects on higher per capita consumptions when compared to the inhabitants in small and dispersed villages. So the first step to classify all the settlements is to understand and distinguish the different social and economic development areas of the Country, which are different from region to region. For example, there are areas with a higher development growth potential because of the presence industry facilities, other areas are more favorable because of commercial development, some cities may have higher progression because they are the administrative center of the region, etc. Thus, the level of development of each region and location is uneven and is something that cannot be taken as univocal for the whole territory.

Settlements categorization. In order to differentiate the development and ultimately the electric consumption between different regions of the Country, two factors were taken into account to categorize all settlements: 1) the Economic Potential of the area in which a given settlement is in, and 2) the population and business Attraction Capacity a settlement may have. Therefore, it is assumed that each village is influenced differently depending on a development category (or demand category) assigned to it, which later was reflected in the electricity consumption per household.

On the next subsections these factors are described.

5.2.2.2 ECONOMIC POTENTIAL

The Economic Potential factor relates with:

- The expected Development Areas of the country (e.g. proximity to the Capital, to the Sea, the Growth Corridors, etc.) and,
- The proximity to projects or areas with economic potential. For example, mining industries, agricultural plantations and large administrative centers are considered to have a positive impact on nearby settlements.

Economic growth area. A relevant development area is the one classified as the "Economic Growth Corridors" by the 2011 Ministry of Planning and Economic Affair's report "*Developing Liberia's Economic Corridors Volume I and II*" [22], and also referred in the LCPDP [21] elaborated in 2014. This area which has been described as "*a triangle, the northern end of which anchored in the mining concession community of Yekepa, the south-western end which reaches the Margibi County boundary with Montserrado County, and the southeastern end which fronts on the sea at Buchanan*" in the report *Liberia Infrastructure and Inclusive Growth* elaborated by the African Development Bank Group, accommodates more than 30% of the Liberia's *rural* population[2] and is expected to be, alongside Monrovia and its nearby areas, the backbone of Liberia's economic development. The Economic Growth Corridor is illustrated in **Figure 5.2**.

[2] All Liberia's population except Monrovia.

Figure 5.2 – Economic Growth Corridors.

Five different areas were defined to reflect and distinguish the different economic potential areas:

- *Areas near Monrovia and Seaside Growth Corridor:* this area accommodates the districts that are within and neighboring Greater Monrovia and also the ones inside the Growth Corridors, adjacent to the seaside. This area was created because it is expected that the populations near the capital and the sea will experience a greater economic development due to the proximity to the main economic center of the country – Monrovia, and because of the economic benefits that sea trades can bring.
- *Countryside Growth Corridor:* this area accommodates the remaining districts of the Growth Corridors, namely, the inland districts. It is expected that these regions, although not benefiting as much as the seaside growth corridors districts, may have a high development due to being located in the Growth Corridor.

- *Non Growth Corridor with Economic Potential:* these are the areas outside of the previously defined regions which may have some economic potential due to several factors. This area was defined taking into account the following aspects:
  1. *Proximity to mining facilities, plantations and county capitals.* Usually, settlements near the mining industries, agricultural plantations and the region's administrative centers are positively affected, since these locations and infrastructures employ many of the nearby inhabitants and promotes the development of the region. Thus, every 10 km buffer for each mining facility, plantations and county capital were considered as areas with a moderate economic potential. In total, as already mentioned, there are fifteen County Capitals in Liberia. Seven mining related facilities were considered: Arcelor Mittal, Bong Mines, Putu Mine and Putu Shipping and Western Clusters I, II and III. Lastly, sixteen plantations were used, in which nine were palm tree plantations and seven were rubber tree plantations.
  2. *Proximity to international cross borders.* The main international cross roads were also considered to have a moderate impact on the nearby settlements local economy. A 5 km buffer of fifteen cross border roads was considered.
  3. *Dense populated districts.* Higher population density may represent a greater exchange of goods. So, the denser districts were also considered to have a moderate economic impact.
  - *Other Areas near Main Roads*

  The areas near the main transportation routes tend to have some degree of development. So, taking into consideration the *Road Infrastructure Development Maps*, of the Ministry of Public Works, the planned main roads of Liberia were sketched, and a 5 km buffer area was defined.

- *Peripheral:* the remaining areas of the country are expected to have little economic development, due to isolation and low population density. These are classified as peripheral areas.

All of the previously defined areas are illustrated in **Figure 5.3**.

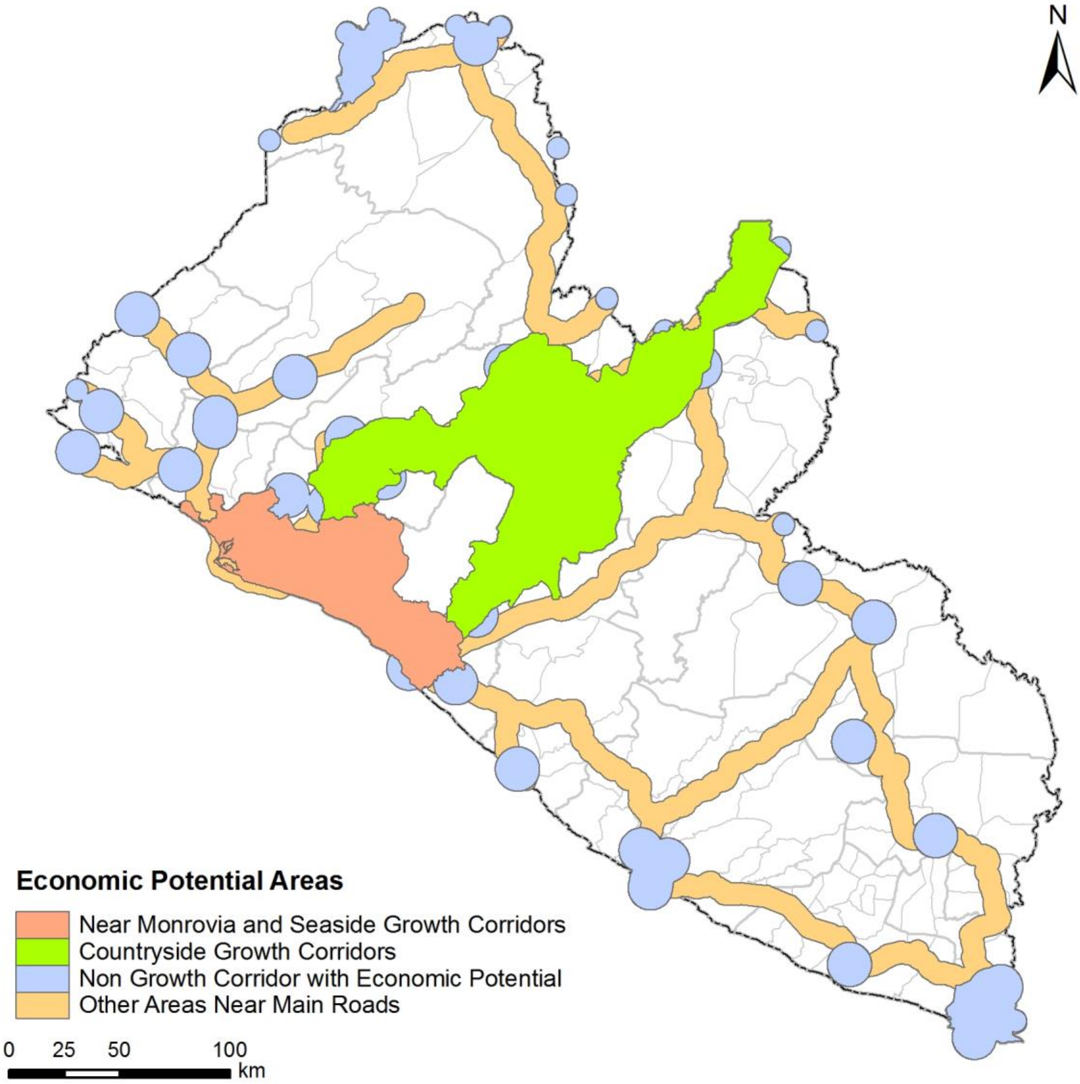

Figure 5.3 – Different Economic Potential Areas.

5.2.2.3 ATTRACTION CAPACITY

The Attraction Capacity is a specific feature of each settlement and has the objective to evaluate the quality of life in certain city or village, due to several aspects. It relates with:

- The administrative category of the settlement;
- The size of the settlement;
- The provided social and institutional services, which have the capacity to offer better life conditions to the community's inhabitants.

The characteristics considered to define the Attraction Capacity were the following:

- Capital of the Country, Monrovia: the Capital is and will continue to be the highest attraction pole of the Country;

- County Capitals and Major Cities: the region's administrative center, as well as the larger cities, tend to offer better life conditions to new residents and businesses due to higher employment opportunities and social & institutional services availability (health, education and security). In this study, a city with more than 5 000 inhabitants was considered a major city;
- District Capitals, Medium settlements, Small settlements with services: it was considered that the district *capitals*[3], settlements above 1 000 habitants and settlements above 500 habitants with services, offered some level of attraction;
- Small Settlements: small settlements aren't expected to attract many new businesses, and so, stand in last in the Attraction Capacity factor.

The higher the relevance of the settlement's administrative category and size, the higher is the expected growth and development of the locality, and consequently the average electrical consumption of its inhabitants and services.

In **Figure 5.4** is illustrated in a map the classification of all Liberia's Settlements according to it attraction capacity. In total, there are thirty-nine settlements classified as County Capital/Major City and 512 settlements are accommodated in the District Capitals, medium sized settlements, and small settlements with services classification. The remaining settlements, with the exception of Monrovia, are classified as small villages.

[3] In the gathered database, the district capitals identification was unavailable. Thus, to overcome this lack of information, it was considered that the largest city or village in a district is its capital.

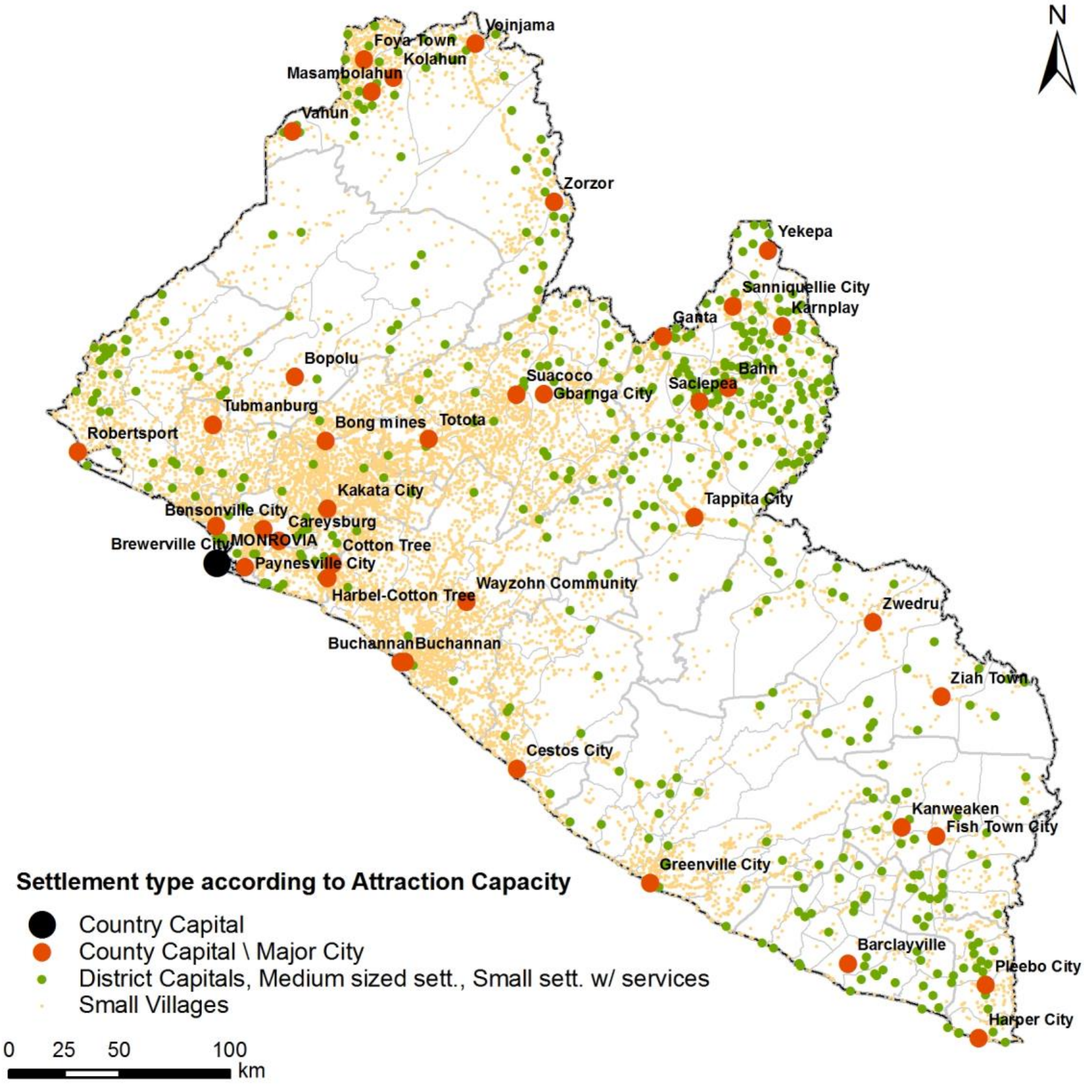

Figure 5.4 – Settlement's classification according to its Attraction capacity.

5.2.2.4 SETTLEMENTS CLASSIFICATION - DEMAND CLASS MATRIX

Categorization of the country's population communities. The combination of all the factors defined in the previous subsections allowed the creation a class matrix to categorize each one of the country's population communities. Thus, six different categories were generated to allocate to every inhabited location in Liberia. This matrix is presented in **Table 5.3**.

Table 5.3 – Settlement's demand class matrix.

Economic Potential	Attraction Capacity: **Monrovia** *(Capital of the Country)*	**County Capital & Major Cities** *(Above 5000 hab.)*	***Dist. Capital* or with Services** *(District Capitals; Above 1000 hab., above 500 hab. With services)*	**Small Settlement** *(Below 1000 hab.)*
Near Monrovia and Seaside Growth Corridor *(Area between Monrovia and Buchanan near sea)*	1	2	3	5
Countryside Growth Corridor *(All country side areas within Growth Corridor)*		3	4	5
Non Growth Corridor with Economic Potential *(Areas within: 10km of mines, plantations and County Capitals, 5km of International Cross Boarders and Dense Populated Districts*		3	4	5
Other Areas near Main Roads *(Areas in the proximity of the Country's main roads (5km proximity)*		4	5	5
Peripheral *(Peripheral areas, outside of any of the above mentioned)*		4	5	6

Using this matrix, it was possible to classify each one of the geo-located settlements with one of the six demand categories, according to its location, administrative class and size. As Monrovia is the capital of Liberia, it is expected to continue to have a higher level demand, and for that reason is apart from the other settlements of the Country. The regions close to Monrovia and within the Growth Corridors near the sea are expected to have higher electrical consumptions. Index 2 was assigned to all County Capitals and major cities that fit the referred area. Paynesville, Careysburg, Bensonville, Harbel-Cotton Tree and Buchannan are a few of the locations classified with the index 2. The remaining County Capitals are all categorized as 3, since they are considered to always have some degree of economic potential as well as having a positive effect on the well-being of its inhabitants because of their administrative status. The major cities that are outside of areas with high economic potential were classified with the index 4. The District Capitals, medium settlements and small villages with access to some services located in the area between Monrovia and Buchanan were given the index 3, since they are expected to benefit from the close-by development. However, if the communities with this classification are located in more remote areas, their demand category is 5. All Small villages were

classified below the index 5. Small settlements in peripheral areas are the lowest graded (index 6) since their development should be extremely reduced.

Objective of the definition of demand categories. In conclusion, the definition of these demand categories allows the differentiation of the electrical average consumptions that each inhabited point may have in future. Overall, settlements with higher indexes (Categories 1, 2 and 3) should have higher per household consumptions due to higher economic activity, inhabitants' purchasing power and social development. More dispersed settlements, located further away from larger population poles and economic centers, were assign with lower demand indexes (Categories 4, 5 and 6). Due to lower development and economic potential, the average consumptions will be lower. These can be defined as the more rural communities.

A Country map with the classification of all settlements can be observed in the map of **Figure 5.5**. In **Figure 5.6**, a graph with the distribution of population per each category demand is presented.

As it can be observed, Category 5 as the largest portion of population, and together with categories 4 and 6, represent a total 55% of all population. Regarding the most urban population, with exception of Monrovia, Category 3 has the largest share of population with 11%.

In the next sections, this classification will be used to estimate the average consumptions for the Residential and Institutional & Commercial sectors.

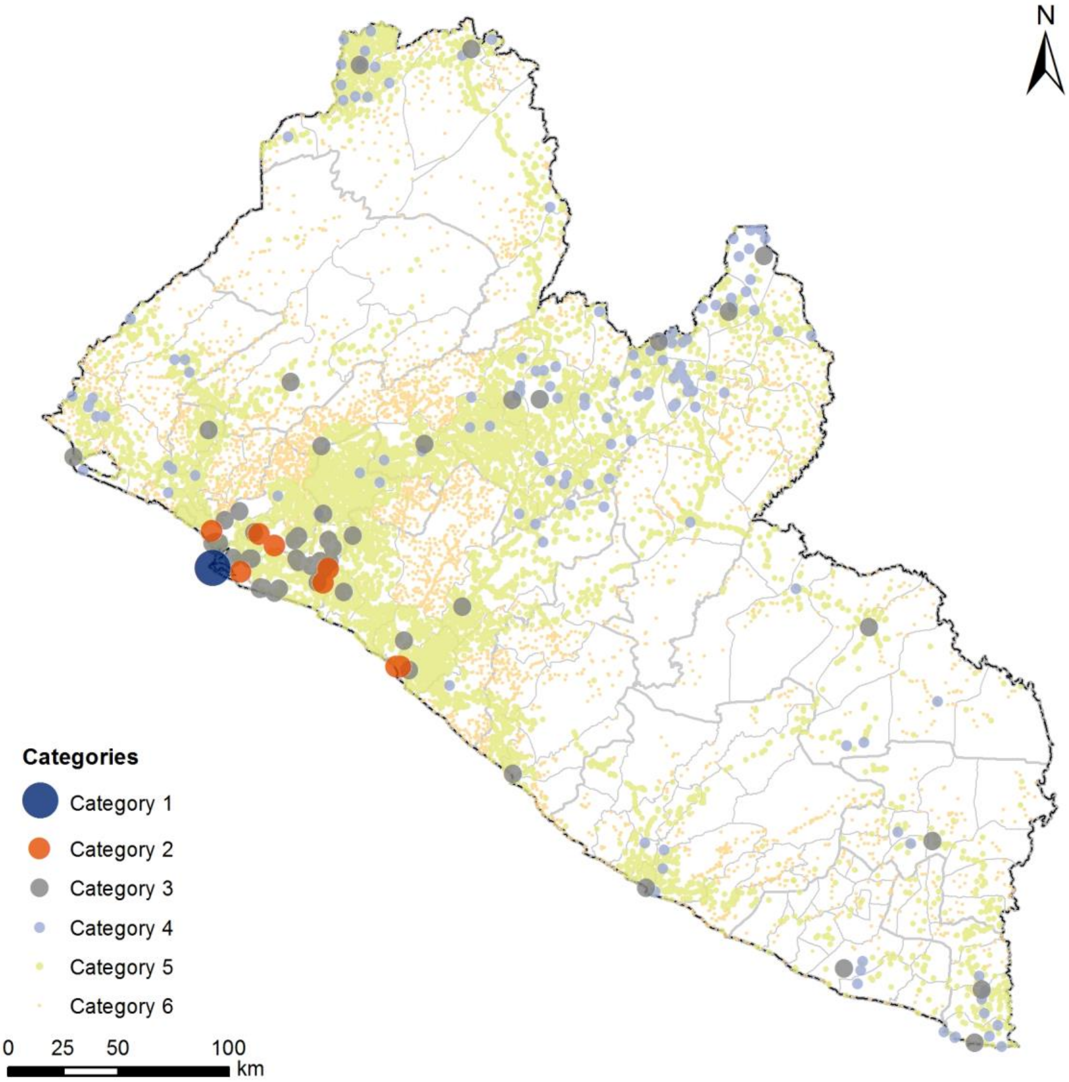

Figure 5.5 – Settlement's classification according the estimated social and economic development.

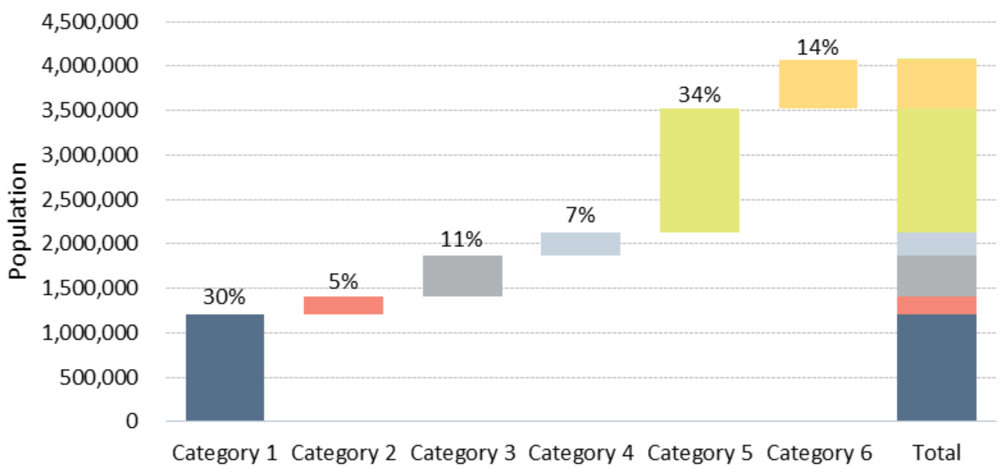

Figure 5.6 – Population distribution in each demand category (2015).

5.3 RESIDENTIAL DEMAND: GROWTH AND WILLINGNESS TO PAY

5.3.1 POPULATION GROWTH

In order to establish the Country's population growth, the United Nations growth rates [23] for Liberia were once again used, now up to 2030, the target year of this study. These annual growth rates were applied to the previously 2015 estimated population and the results are the ones presented in **Figure 5.7**.

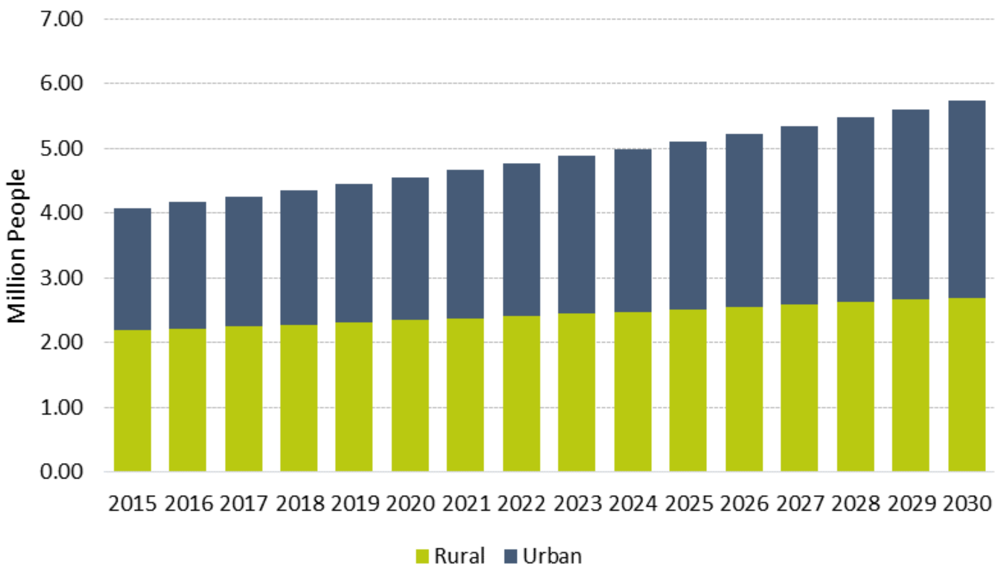

Figure 5.7 – Liberia's estimated population growth for the period 2015-2030.

The population of Liberia is expected to reach 5.7 million people in 2030, and the urban and rural partition is projected to be 53% and 47%, respectively. Therefore, due to higher urban growth rates a turnover in these percentages will occur and the urban population will be higher than the rural.

The population distribution per each demand category, for the year 2030, is presented in **Figure 5.8**. Although the results present little differences to the ones shown **in Figure 5.6**, it is clear that there has been a migration of the population from the more rural settlements (categories 4 to 6) to the more urban (categories 1, 2 and 3).

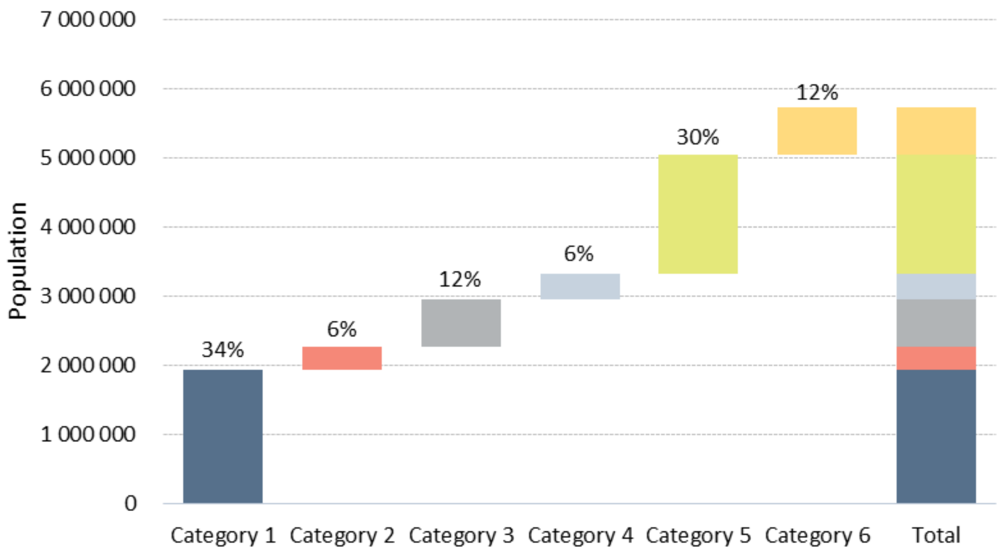

Figure 5.8 – Population distribution in each demand category (2030).

5.3.2 HOUSEHOLD DEMAND ESTIMATES PER CATEGORY

5.3.2.1 CURRENT HOUSEHOLD DEMAND ESTIMATES – WILINGNESS TO PAY

Introduction. In order to estimate the household demand for each one of the previously defined categories, the 2012 *Liberia and Energy Access: A Willingness to Pay Analysis* report [13], developed by the World Bank was used. In the work made for the Willingness to Pay (WTP) [13] report, several surveys were made throughout the Country to enquiry about various topics like housing conditions, total household expenditures and incomes, overall energy consumption, expenditures on energy, etc. The finding on this report were firstly presented in respect to rural and urban households outside Monrovia (classified as *Rural Survey*), and then for Monrovia households (divided in LEC clients and Non-LEC households). This structure, namely the Rural Surveys, is compliant with the present work, since the Rural Energy Master Plan for Liberia is focused on all non-Monrovia population. Also in the Willingness to Pay Analysis [13], households were divided into four income/expenditure quartiles, with quartile 1 (Q1) being the lowest income and quartile 4 (Q4) being the highest. Additionally, average results for urban and rural households are presented too.

Households Energy Expenditures. For demand studies, the most interesting findings of the Willingness to Pay Analysis are the households Energy Expenditures, presented in **Table 5.4**. These values show that in the lowest quartile, households spend on average 5.71 USD/month and that in Quartile 4 the average spending on electrical energy equivalent goods is 23.36 USD/month. Urban and Rural averages are 18.06 USD/month and 8.94 USD/month, respectively.

Table 5.4 – Energy Consumption, Expenditure and WTP: Rural Survey - By Quartile [13].

	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Urban	Rural
	Spent per Month	Spent per Month	Spent per Month	Spent per Month	Spent per Month	Spent per Month
Electric Bulbs	0.07	0.01	0.07	1.46	0.87	0.2
DC Battery Lamps	3.32	4.82	6.05	6.58	6.17	4.76
Kerosene Lamp	0.41	0.52	0.52	0.52	0.55	0.47
Palm Oil Lamp	0.26	0.15	0.12	0.04	0.03	0.19
Candles	0.49	1	0.75	1.1	0.99	0.77
Other Electric	0.1	0.18	0.4	11.33	7.34	1.07
Other Battery	1.08	1.2	2.1	2.33	2.11	1.49
TOTALS	**5.71**	**7.88**	**10.02**	**23.36**	**18.06**	**8.94**

Allocation a quartile to each category. Analyzing and comparing the WTP [13] quartiles with the consumption and development categories previously defined, it was possible to combine and allocate for each category a quartile and consequently an average energy expenditure per household. The chosen allocation can be seen in **Table 5.5**.

Table 5.5 – Monthly household energy expenditures per demand category.

Consumption Category	WTP Quartile or Average Result	Monthly Energy Expenditures (USD/Month)
Category 1	*Monrovia (LCPDP)**	-
Category 2	Quartile 4	23.36
Category 3	Urban Average	18.06
Category 4	Quartile 3	10.02
Category 5	Quartile 2	7.88
Category 6	Quartile 1	5.71

*Since this study is focused only on rural Liberia, Monrovia (Category 1) was not considered.

Correspondence between quartile and each category. Category 2 settlements should have urban-like patterns, and, due to its proximity to high developed economic clusters, higher incomes are expected. Therefore, this category was assigned Quartile 4, the highest of the WTP Analysis [13]. Category 3 settlements are mainly urban, and therefore the urban average expenditures were assigned to this category. Category 4 settlements are a mix of urban and rural populations that can be in areas with some economic activity. Thus, for this category Quartile 3 was assigned. Categories 5 and 6 settlements were given with the Quartiles 2 and 1 respectively, since they should present the lower incomes, and consequently the lower expenditures.

Electrical tariff applied. In order to convert the monthly energy expenditures in equivalent electrical consumptions, an electrical tariff estimate was needed. The current tariff of Liberia is very high and it

wasn't used for this calculation because 1) it is expected to drop when new, less expensive and more efficient generation options come into operation (e.g. Mount Coffee Hydro) and 2) it would excessively repress electrical consumptions. The LCPDP [21] report assumes that, due to the connection of Mount Coffee Hydro to the electrical grid, as well as other less expensive generation options, *a price drop of about 50%* is expected in the future. At the time, tariffs were around 50 USD cent/kWh, thus the estimated future tariff was around 25 USD cent/kWh. Additionally, the current cross border project clients also pay about 25 USD cent/kWh. Therefore, to estimate the residential consumptions per client, the 25 USD cent/kWh tariff was applied to the expenditures on energy for each category. The results are presented in **Table 5.6**.

Table 5.6 – Household electricity consumption per demand category (*Network Expansion Work Session, September 2015)*.

Consumption Category	Monthly electricity consumption (kWh/month)	Used yearly electricity consumption (kWh/year)
Category 1	-	-
Category 2	93.4	1 100
Category 3	72.2	865
Category 4	40.1	480
Category 5	31.5	380
Category 6	22.8	275

In order to determine the peak load of the residential demand, the load factor for residential clients in Liberia was set at 0.3, which represents an equivalent yearly peak utilization of 2 628 hours. This value, based on LCPDP [21] assumptions, is considered typical value for residential clients.

To validate these values, they were all presented, analyzed and discussed with RREA, LEC and MLME representatives on a *Network Expansion Work Session* at RREA in Monrovia in September 2015.

5.3.2.2 HOUSEHOLD DEMAND GROWTH

Having established the estimates of household demand for each one of the six demand categories defined in **Chapter 5.2.2**, it is now important to estimate the demand growth for the future.

Household consumption growth. The household consumption growth was based on the *National Electrification Master Plan* report [24], developed by the Columbia University Sustainable Lab – Earth Institute in 2013. In this study, residential demand was estimated to grow at a rate of 2.34% per year. This is a common value used in this kind of studies since it represents the duplication of the consumption in 30 years' time. Note that this consumption growth only considers the actual growth of household consumption (e.g. due to the purchase of more electrical equipment). The actual growth of residential demand is expected to be higher because of both population growth and higher electrification rates.

The present household demand, based on the WTP report [13], as well as the projected household demand for 2030, per demand category, is presented in **Table 5.7**.

Table 5.7 – Current and projected household demand per demand category.

Consumption Category	Current consumption 2015 (kWh/year)	Projected consumption, 2030 (kWh/year)
Category 1	-	-
Category 2	1 100	1 556
Category 3	865	1 224
Category 4	480	679
Category 5	380	538
Category 6	275	389

5.4 SERVICES AND COMMERCIAL DEMAND

5.4.1 TYPES OF CLIENTS

The demand of the institutional and commercial services sector was divided in two types of clients:

- Specific regional commercial and institutional services (geo-located);
- Other local services, which intend to estimate additional clients, proportional to the size of the settlement.

5.4.2 SPECIFIC REGIONAL COMMERCIAL AND INSTITUTIONAL CLIENTS

One of the main collected databases was the commercial and institutional services geo-located clients, gathered from RREA, LIS-GIS and the National Rural Electric Cooperative Association (NRECA). These include Health, Security and Education services (hospitals, health clinics, police stations, primary and secondary schools, etc.) as well as some commercial and productive facilities (markets, radio stations, cell phone towers, etc.). A map of the total collected information is presented in **Figure 5.9**.

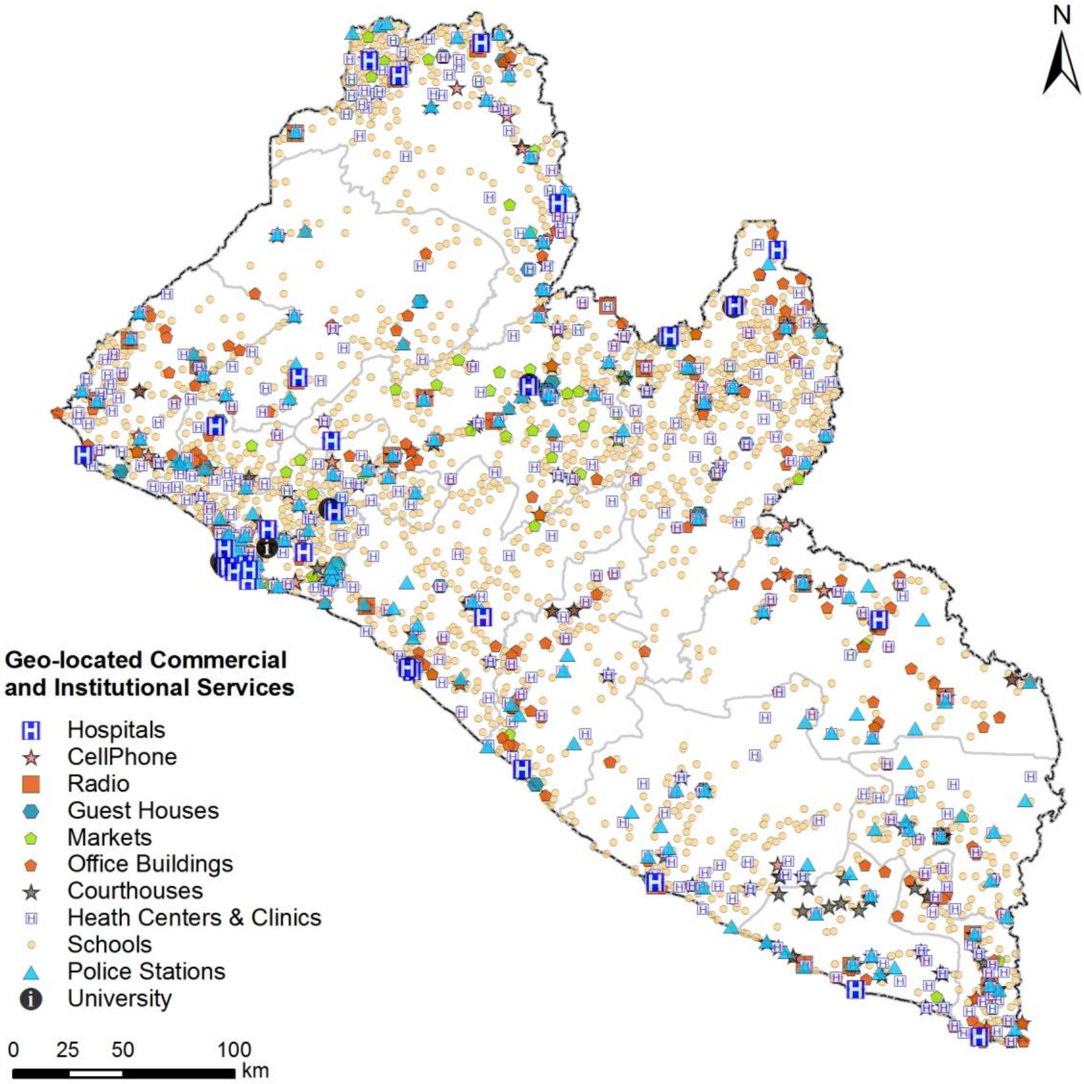

Figure 5.9 – Settlement's classification according the estimated social and economic development.

By comparing **Figure 5.9** with **Figure 5.5** it is possible to observe that there is a big concentration of services, around the settlements classified with index 3 and above. In particular, it is possible to observe that almost all of these settlements have a Hospital in the vicinity or nearby.

The specific electric demands for each one of these services are presented in **Table 5.8**.

In particular, the health and education facilities demand were based on the *National Electrification Master Plan* report [24] findings. The remaining consumptions are average values, based on market evaluations on similar facilities. All of the expressed values were discussed and validated on the *Network Expansion Work Session, September 2015*.

Table 5.8 – Geo-located regional commercial and institutional services demands (*Network Expansion Work Session, September 2015*).

Facility	Demand (kWh/year)
Clinic	2 000
Health Centers	2 000
County Hospital	60 000
Regional Hospital	100 000
Secondary School	600
University	50 000
Both Primary & Secondary School	1 000
Office Buildings	5 000
Markets	2 000
Police Stations	3 000
Cellphone/Radio Towers	25 000
Guest Houses	5 000
Courts	10 000

In order to determine the peak load of the service sector demand, the load factor for commercial and institutional clients in Liberia was set at 0.72, which represents an equivalent yearly peak utilization of 6 307 hours. This value was once again based on LCPDP [21] findings. In the *Network Expansion Work Session, September 2015* it was also agreed that the Commercial and Public services average consumption growth should be 3% per year.

5.4.3 OTHER LOCAL SERVICES

Despite being a rather complete set of data, the Consultant found that the geo-located database did not meet all the commercial, productive and business services provided in each community. Also, as this is a study to project demands for the future, it is reasonable to assume that the number of institutional, commercial and small businesses clients will grow over time. So, in order to estimate these additional clients, another class of services demand was created, based on the LCPDP [21] methodology.

The number of the other local services, in a certain settlement, was modeled taking into account the number of households in a community. The premise was that, in urban-like settlements, for each 100 households, there are 0.66 additional commercial or institutional customers. On the other hand, in rural villages, this number decreases and for each 100 households, there are 0.4 additional commercial or institutional customers.

The demand per clients is also different in urban and rural communities. In urban settlements the peak demand for these additional clients is 12 kW and in rural villages the peak demand is 5 kW. The load factor is the same as before, 0.72. As in the specific regional commercial and institutional clients, the average consumption growth was set at the rate of 3% per annum.

5.5 RURAL ENERGY DEMAND FORECAST

The previous sections presented the main assumption to determine the projections for the residential and services demand. These assumptions can be used to determine preliminary rural demands, taking into consideration the future electrification targets, i.e. the number of electrified people. The real number of electrified habitants, and mainly its distribution throughout the country will only be accomplished in **Chapter 10**, when the 2030 Rural Energy Vision is presented. However, in this section, three different scenarios are presented, regarding three distinct ambitions regarding electrification rates in the target year – a Conservative Electrification Scenario that complies with the LCPDP [21] target of 35% nationwide electrification[4], a Base Electrification Scenario that represents the latest political ambition of a 35% rural electrification and an Aggressive Electrification Scenario that assumes a 50% rural electrification rate.

In order to model the client distribution throughout the country, the categories defined in **Chapter 5.2.2.4**, were used. Basically, a target rate was given for each one of the demand categories, in order to reach the global electrification rate of the three scenarios. These are presented in **Table 5.9**.

Table 5.9 – Estimated electrification rates in 2030 for each category.

Category	Conservative Electrification	Base Electrification	Aggressive Electrification
Category 1[*]	*70%*	*70%*	*70%*
Category 2	50%	70%	70%
Category 3	30%	70%	70%
Category 4	15%	45%	70%
Category 5	10%	25%	45%
Category 6	5%	5%	20%

[*] LCPDP target for Monrovia

As stated, in the Conservative Electrification Scenario, a nationwide electrification of 35% was selected. In terms of rural electrification this implies a 17% target of all non-Monrovia population in 2030, which represents slightly more than 125 000 residential clients or 630 000 electrified people.

The 35% rural electrification target objective of the Base Electrification Scenario implies more than 260 000 electrified households in 2030, benefiting more than 1 300 000 people.

Finally, the Aggressive Electrification Scenario has a 50% target for rural population, meaning almost 370 000 residential clients and 1 900 000 electrified people in 2030.

The estimated projections results for each one of the electrification scenarios is presented in the next figures (**Figure 5.10** and **Figure 5.11**).

[4] Note that in LCPDP [21], there is a 70% electrification target for Monrovia. Hence, the remaining electrified people are located in *rural* settlements, outside Monrovia.

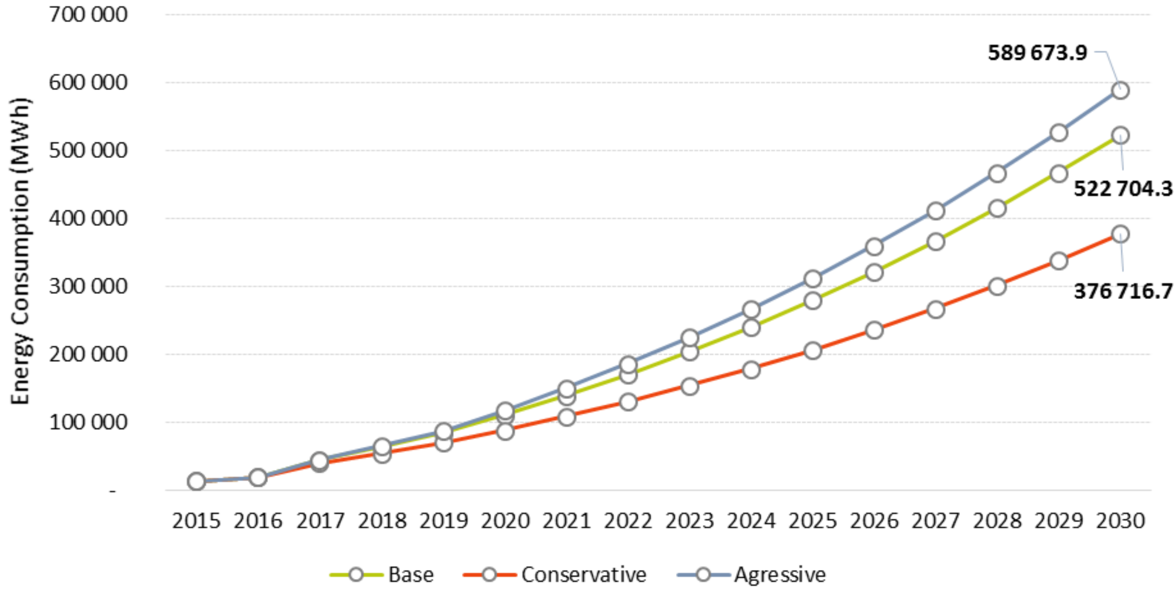

Figure 5.10 – Energy consumption projections for rural Liberia.

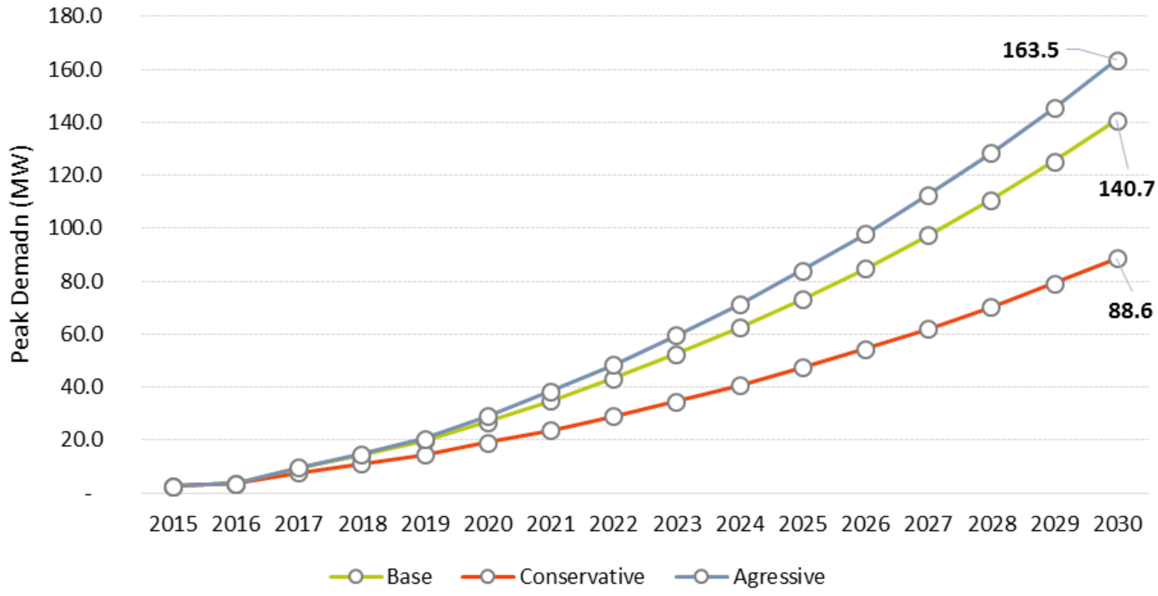

Figure 5.11 – Peak demand projections for rural Liberia.

From the previous figures it can be observed that in 2030 the expected energy consumption for rural communities is between 380 GWh and 590 GWh and that the rural peak demand is in the range of 89 MW to 164 MW, implying high mean annual growth rates:

- Conservative Scenario: 25% per year
- Base Scenario: 27.7% per year
- Aggressive: 28.8% per year

It can be seen that even the conservative scenario has an extremely high consumption growth with a 25% rate. However, it should be noticed that these values are due to the extremely low electric grid

coverage currently observed in Liberia. The annual electrification growth rate and consequently the consumption growth are expected to slow down as more people are connected over the years.

Particularizing for the base case scenario, since it represents the political ambitions for rural electrification, **Figure 5.12** and **Figure 5.13** present the energy and peak demands for 2030, divided by residential and services sectors, for each one of the five rural demand categories.

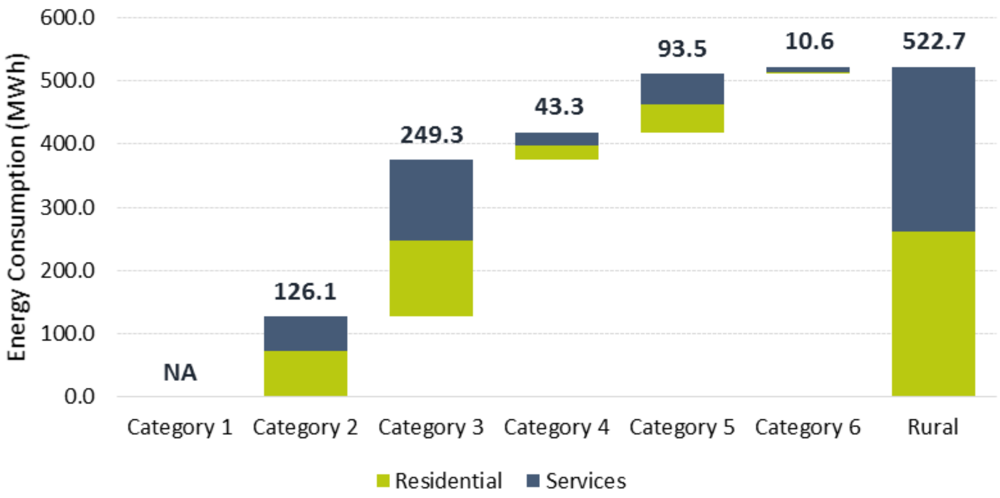

Figure 5.12 – 2030's Residential and Services sectors energy consumption per demand category.

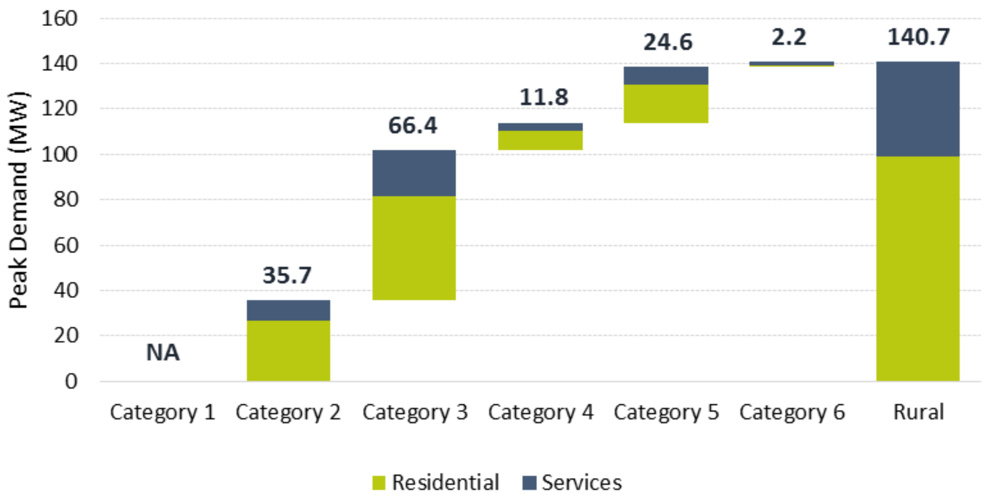

Figure 5.13 – 2030's Residential and Services sectors peak demand per demand category.

By observing the previous graphs it can be noticed that in Category 3 expected consumption is the highest, although having smaller per capita consumptions that in the ones observed in Category 2. This is due to the higher number of clients enclosed in category. The more rural categories have lower electrification rates, thus it is natural to see lower total consumptions in these classes.

We remind that these results are only preliminary since the actual distribution of electrified population throughout the country and consequently in each category is only be accomplished in the findings of **Chapter 10** where the 2030 Rural Energy Vision and targets is presented. However, this estimates offer

a good starting point to evaluate the potential demand as well as potential clients the future system may have to benefit.

5.6 REVIEW OF LEAST COST DEVELOPMENT PLAN DEMAND PROJECTIONS

5.6.1 INITIAL CONSIDERATIONS

The LCPDP [21] main objective was to develop a least cost generation plan for Liberia. To do so, it accomplished a nationwide demand projection up to 2033, which took several other demand forecast studies for Liberia into consideration. Since it is a fairly recent study and considering that it was based on other consolidated demand studies of Liberia, the LCPDP [21] was used as one of the sources of the present work.

In this section, a quick review of the LCPDP [21] assumptions and results is performed. Note that some of these assumptions were already mentioned in the previous sections.

The LCPDP [21] considers three scenarios (base, low and high demand), forecasting the peak and energy demands, among others, by demand sector and by region.

The consumer sectors considered in the study were:

- Residential sector – corresponding to household demand;
- Commercial and public entities – which includes public facilities such as hospitals and police stations;
- Industrial sector (Monrovia) – such as the manufacturing or food processing industry;
- Other demand – mainly street lighting, but also post offices, churches, cell towers, among others.

Regional demand was separated as follows:

- Greater Monrovia – Monrovia and its surroundings, the only area where there are existing connections;
- Other on-grid – areas where grid expansion plans include the connection to the main grid, including corridor projects and the CLSG transmission interconnection;
- Off-grid demand – urban and rural off-grid electrification, also considering cross-border connection projects with no intended connection to the main grid.

Apart from the categories above, an additional region was considered to take into account the industrial demand outside Monrovia. Basically, this region does not have demand from the consumer sectors above, but only considers the forecasted demand from the industrial sector outside Monrovia, that includes mining, agriculture and forestry demand. The LCPCP [21] proposed two scenarios from the forecasted demand, to take into account different growths in the mining demand – secured mining demand and ramp-up mining demand.

5.6.2 DEMAND REGIONS AND SCENARIOS ASSUMED IN LCPDP

Greater Monrovia

In Greater Monrovia, the average household annual electricity consumption was set at 1 300 kWh and is expected to increase 1.5% per year until 2016 and after 2020. Between 2016 and 2020, electricity consumption is expected to grow even more, due to the expected connection of the Mt. Coffee hydropower plant and consequent one-time reduction of the electricity tariff. An average electricity consumption of 800 kWh was applied to new connections, with a growth rate of 3% during 5 years and 1.5% from then on. Regarding the commercial and public sector, it considers the existence of 0.66 commercial and public customers per 100 households, with the connection rate growing 10% per year until it reaches 75%, and for whom the electricity consumption is modelled similarly to households. There is also demand from other sources, such as street lighting, modelled in line with the World Bank study [13].

Other on-grid

The methodology for other on-grid demand is similar to the one applied for Greater Monrovia. Geographical distinctions were made according to the areas affected by the WAPP and the corridor project extending the Monrovian grid. Furthermore, specific urban electricity consumption has also been set at 800 kWh for urban areas, due to similar characteristics exhibited as in the case of newly connected Monrovian users, and 216 kWh for all rural areas, indistinctive of their location. In terms of other on-grid demand, the increase in electricity consumption rate is set at 3% for reasons similar to newly connected Monrovian consumers, until it reaches saturation. Commercial and public demand behaves in the same way as in Greater Monrovia, but with only 0.4 entities for 100 households in rural settlements. There is also demand from other sources, such as street lighting, modelled in line with the World Bank study [25].

Off-grid

The model used to forecast urban and rural off-grid demand is basically the same as the one used to model other on-grid demand for rural areas. The only difference is the assumption that commercial peak demand and average household consumption are lower than in on-grid cases. Average household consumption is estimated at 216 kWh with a 3% growth rate until saturation, because electricity consumption in off-grid areas is generally lower due to lower income and, therefore, a reduced ability to buy electric appliances. Commercial and public consumers are expected to have a peak demand of only 10 kW in the base year, considering 0.66 commercial and public entities for every 100 households in urban areas and 0.4 in rural areas. Other demand is estimated as previously. Furthermore, areas affected by the cross-border electrification projects have been treated separately. The areas affected were identified through the 2011 World Bank load forecast and the population numbers were calculated based on the 2008 census.

Low-growth and high-growth scenarios

The assumptions above are the ones used in LCPDP [21] for the base scenario. As previously stated, the study also analyzed a low demand and a high demand scenario, corresponding to a slow and high growth, respectively. The slow growth scenario considers the average energy consumption to be 20% less than expected in the base scenario, and the connection rates 15% less. The high growth scenario considers a 10% increase both in the average energy consumption and in the connection rates.

Mining demand scenarios

Other types of demand include the non-Monrovian industrial sector, particularly the mining sector, agriculture and forestry. The demand forecast of the mining sector is highly dependent on the materialization of current plans, and so two scenarios were considered to categorize the potential impact of the mining demand.

- Secured mining demand, which is highly probable and assumes a mining demand which has been clearly defined by the various mining corporations and can be seen as a high certainty scenario that does not assume that ramp-up will take place;
- Potential long-term demand, resulting from a significant mining ramp-up.

5.6.3 RESULTS

Given the assumptions above, LCPDP's [21] results for the three scenarios for both Liberian electricity consumption and peak load demand in 2030 were as displayed in **Figure 5.14** and **Figure 5.15**:

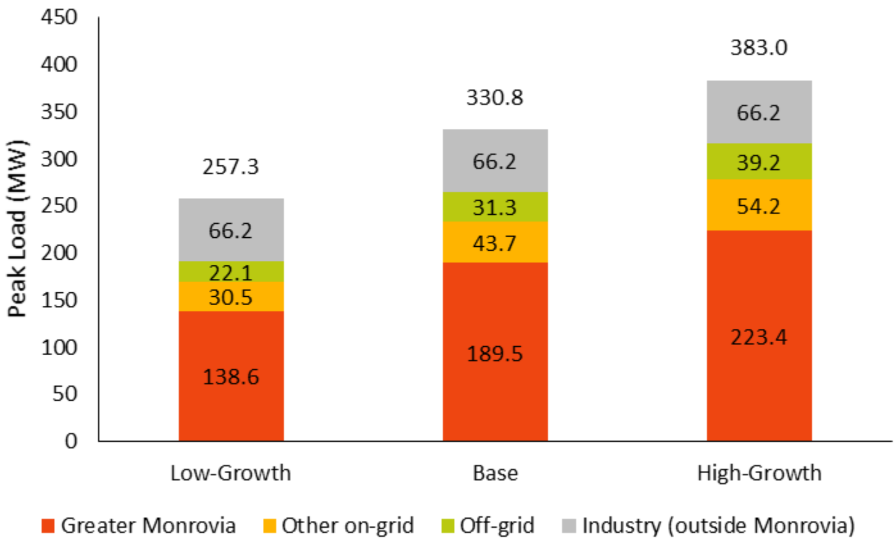

Figure 5.14 - Electricity demand in 2030 (GWh)

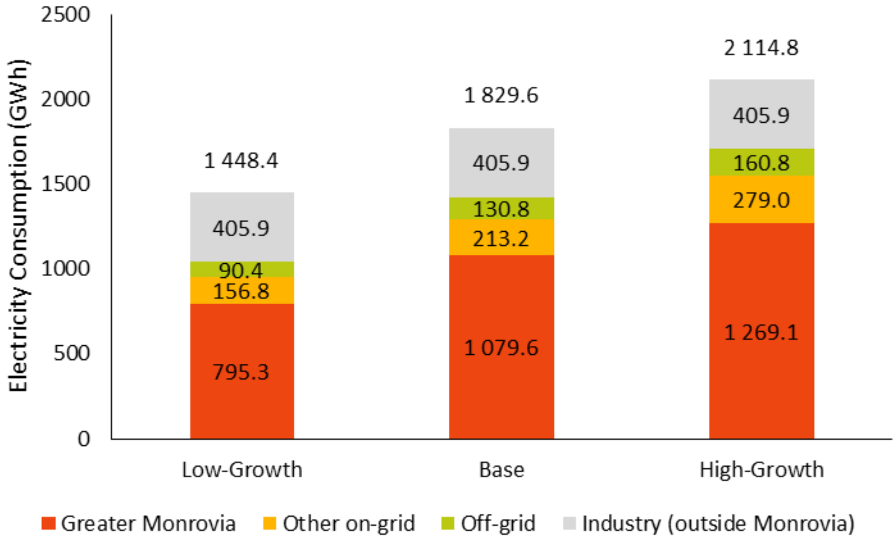

Figure 5.15 – Peak load demand in 2030 (MW)

All the results above consider the secured mining scenario, as it is highly probable. As expected, demand in the area of Greater Monrovia is what influences total demand the most.

In conclusion, the LCPDP [21] study accomplished the demand studies with the main purpose to obtain projection of the global electrical needs as a whole. However, in terms of rural demand, the Consultant feels that these projections do not have the required detail and differentiation needed to correctly quantify and distribute the rural needs throughout the country, thus taking it to a further level. Nevertheless, the LCPDP [21] study presented itself as a good basis for the present studies, with sound and validated hypothesis, which in some cases were replicated in the current Rural Energy Master Plan demand studies.

In the next section, in order to deliver a nationwide vision of Liberia future demand, the estimated rural demands presented in the previous section and the Monrovia and Industrial demands discussed in this section are aggregated and shown.

5.7 INTEGRATED LIBERIA POWER DEMAND FORECAST UNTIL 2030

In this Section, a nationwide projection of the electric power demand is presented. To do so, the rural energy demand forecasts presented in **Chapter 5.5** are integrated with the Monrovia and Industry sector demand projections of the LCPDP study [21]. To be more specific the each scenario defined in **Chapter 5.5** will be aggregated with one Scenario of the LCPDP [21]. The correspondence is in **Table 5.10**:

Table 5.10 – Correspondence between Rural energy master plan scenarios and LCPDP scenarios.

Rural Energy Master Plan for Liberia Scenario (only Rural demand)		Least Cost Development Plan Scenario (only Monrovia and Industrial Sector demand)
Conservative Electrification Scenario	↔	Slow Sensitivity Scenario
Base Electrification Scenario	↔	Base Sensitivity Scenario

Aggressive Scenario	⟷	High Sensitivity Scenario

The aggregated results are depicted in the following figures (**Figure 5.16** and **Figure 5.17)** for the Conservative, Base and Aggressive electrification scenarios.

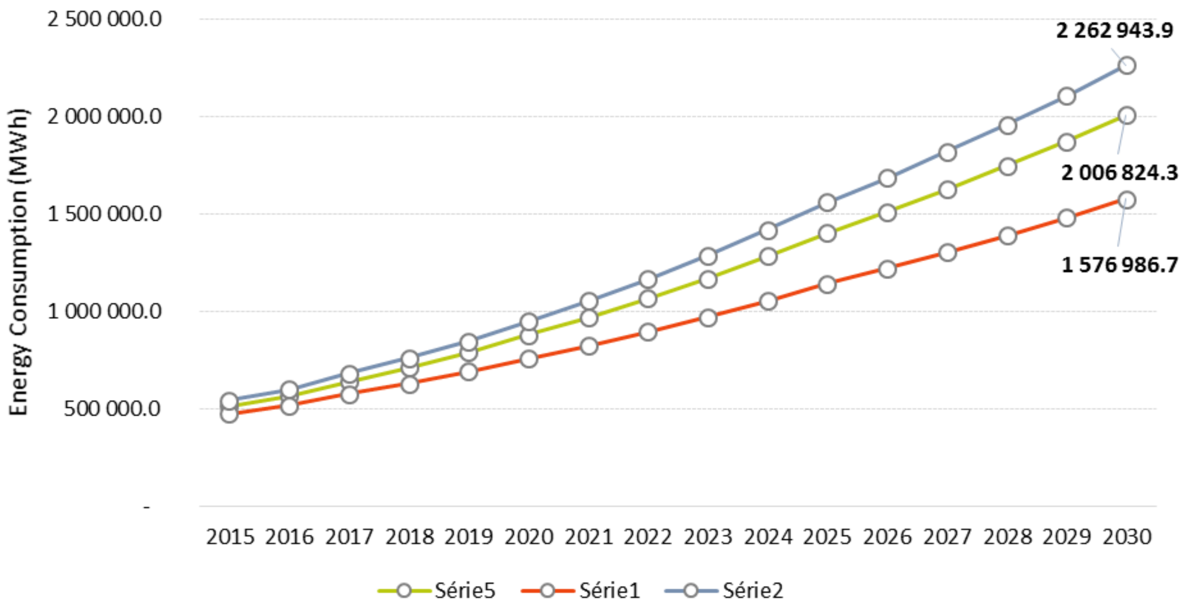

Figure 5.16 – Integrated Liberia energy consumption projection.

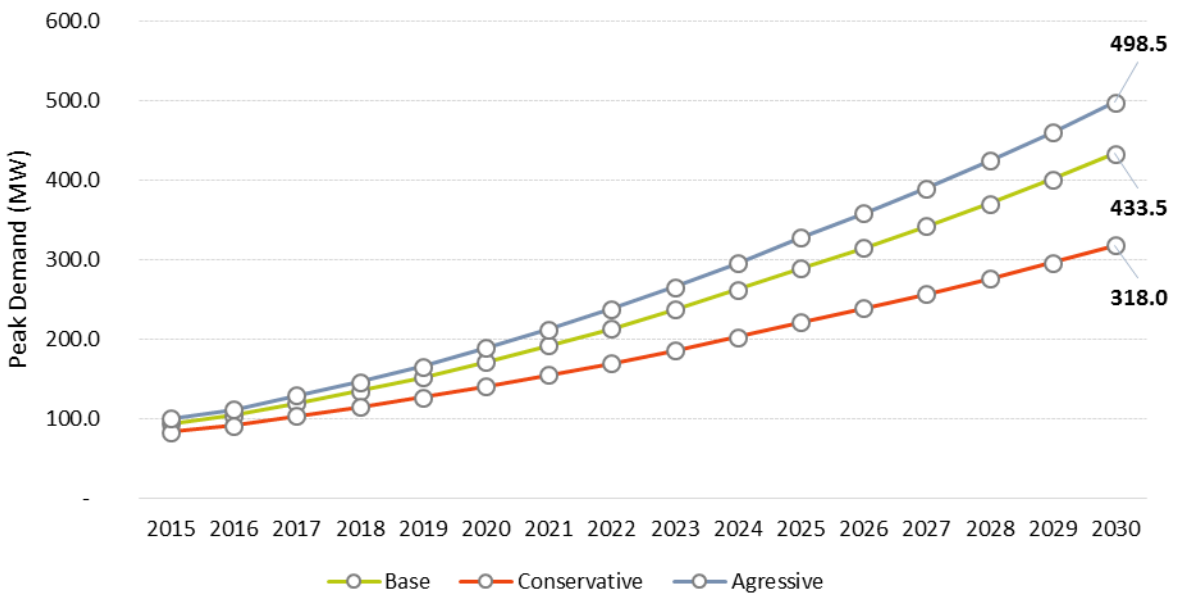

Figure 5.17 – Integrated Liberia peak demand projection.

Figure 5.18 illustrates the results for 2030 for each scenario, but now differentiating the rural demand from the consumptions of Monrovia and the Industrial sector.

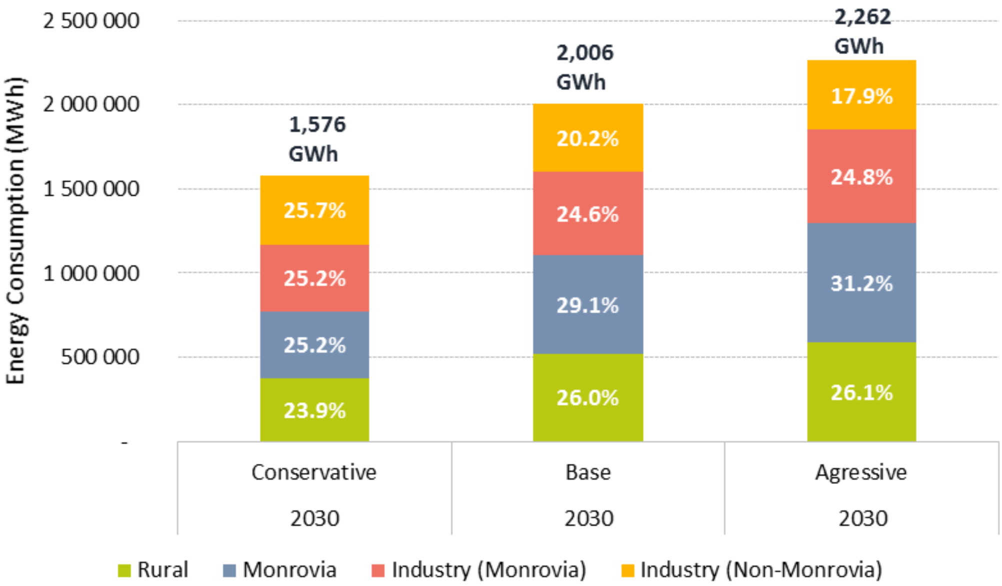

Figure 5.18 – 2030 Integrated Liberia energy demand projection differentiated between sectors.

These projections show that the rural demand is expected to be about a ¼ of total consumption in all scenarios. However it can be seen that as the scenarios become more aggressive, the percentage of rural consumption gets even higher. This denotes that in these scenarios the rural consumption grows a bit more than the other sectors, since more people and services are consuming electricity.

Figure 5.19 shows the results considering the peak demand.

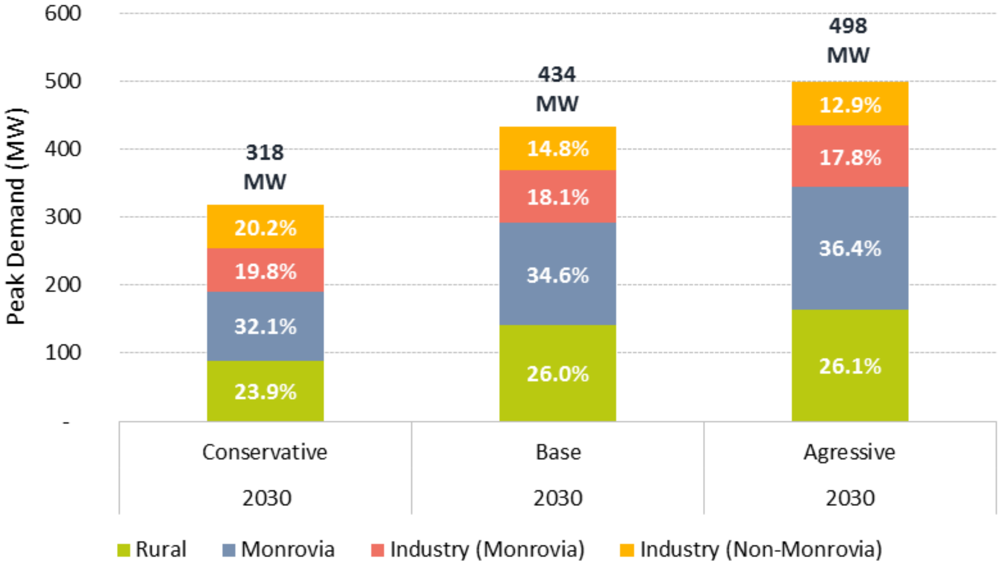

Figure 5.19 – 2030 integrated Liberia peak demand projection differentiated between sectors.

6 SUPPLY OPTIONS AND RESOURCES

6.1 GRID: REVIEW OF LEAST COST DEVELOPMENT PLAN SUPPLY PERSPECTIVES

Building on the topics addressed in **Chapter 5.6**, this section is a review of the least cost development plan supply perspectives, based on the same document, LCPDP [21]

Cross-border and corridor projects are of LEC's interest concerning its grid expansion. The 225 kV CLSG line, which crosses the most populated areas in Liberia, is also near most of the main big hydropower sites (Manu River, Mt. Coffee, and St. John River) and some big mining areas. Therefore, the CLSG line can be used as a backbone of the national grid, including the option to import or export electricity from or to neighboring countries. Alongside the CLSG project, there are three corridor projects which are important transmission/sub-transmission projects for expansion of the system and for the electrification of households across the country (Kle-corridor, Kakata corridor and RIA corridor).

Investment reduction and power centralization are some of the advantages in using cross-border and corridor projects. The use of the CLSG line as a backbone also reduces additional investment in a country-wide high-voltage grid, which is necessary in the long term for a low-cost, reliable power supply system. Also, the current routing of the CLSG line, which also touches the cities of Monrovia and Buchanan, both of which have basic harbor facilities, allows centralized power generation systems at these locations based on imported fuels. The main advantage of this is that the number of power plant locations can be minimized. A second advantage of concentrated power generation is that fuel transport can be minimized in Liberia, since, at present, the infrastructure is not in a good condition in all areas of the country. Finally, operation and maintenance of the grid can also be more easily managed and organized than in the case of power generation and fuel supply all over the country.

The main objective of the grid development plant is to meet the forecasted peak on-grid demand plus 10% reserve each year. Supply options will be chosen based on their levelized unit cost (LUC), so that the lowest cost options are selected first, which is determined by the long-run marginal costs (LRMC). LCPDP's [21] grid development plan considers that the CLSG line will be used as a backbone for the transmission of power from the supply centers, which will be located at coastal areas and at major hydropower plant sites. It also takes into consideration that connections near the CLSG line, as well as the ones in the regions of the three ongoing corridor projects (Kle-corridor, Kakata corridor and RIA corridor), will be on-grid connections. Other assumptions for the grid development plan were an 8% discount rate, a 3.5% yearly fuel price increase, that no single power-generating unit should exceed 10-15% of the total grid capacity and that the capacity considered is the firm capacity (instead of the installed capacity). Finally, the demand considered excludes the demand from mines.

The Levelized Unit Costs of the grid expansion candidates range from 5 USD cent/kWh, in Mt. Coffee, to 35.5 USD cent/kWh, in a reciprocating high-speed diesel engine of 1 MW. The calculation of the Levelized Unit Costs allows the comparison between different power generation options, according to cost/benefit criteria. **Figure 6.1** below represents the estimated LUC in the LCPDP [21] document.

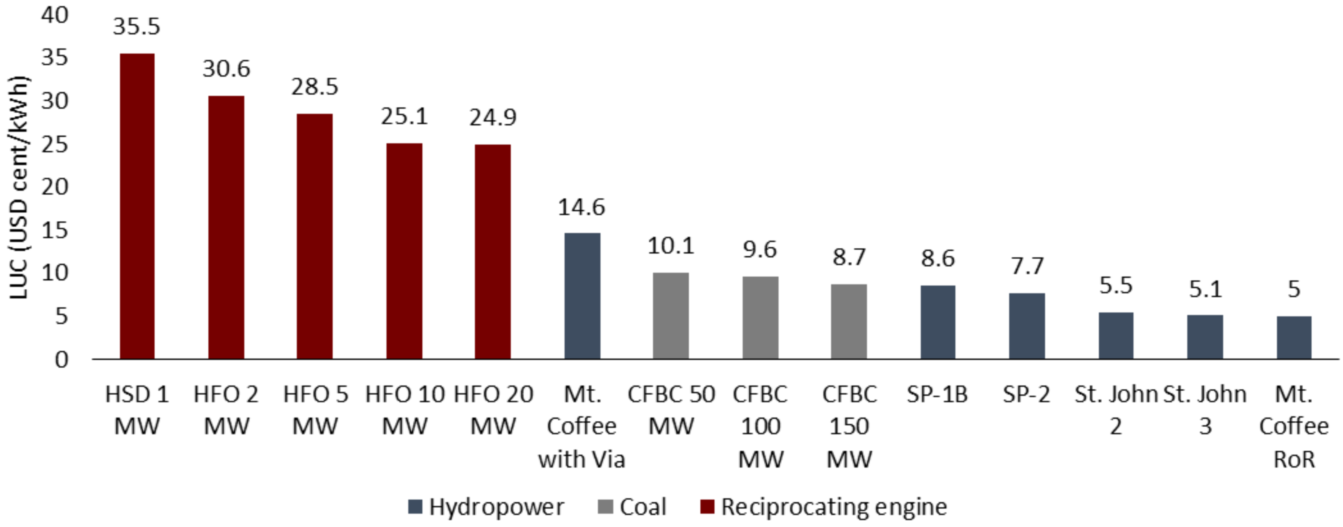

Figure 6.1 – Levelized Unit Costs

As can be seen from the figure above, thermal options are, in general, less competitive in terms of cost efficiency than hydropower options. However, coal-fired power plants may become relevant in the later stages of the planning period.

Base case results include reciprocating Heavy-Fuel Oil (HFO) power plants and hydropower plants, and a USD 1 567M investment. In the short term, HFO-fueled plants appear to be one of the most suitable options for Liberia's power extension. Not only is HFO energy production relatively cheap (compared with current high-speed diesel plants), but this type of energy production has also been handled before by LEC. Hydropower, on the other hand, might remain confined to the role of a fuel saver at an early stage, since Mt. Coffee can provide only a very limited amount of firm capacity. However, if reservoir addition appears feasible, hydropower turns into a firm energy option. In addition to cheap energy production, hydropower has the advantage of long plant lifespans, and as such it is suggested in the LCPDP [21] to have hydropower solutions as soon as possible (in this case, this happens after 2022). **Figure 6.2** and **Table 6.1** below represent LCPDP's [21] lowest cost solution.

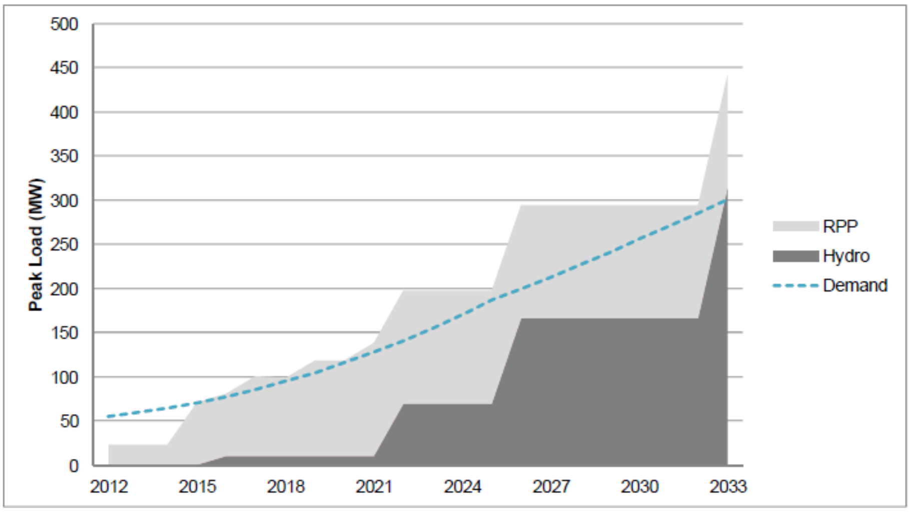

Figure 6.2 – Least cost supply options

Table 6.1 - Detailed least cost supply options

Expansion Plan (Base Case) in firm capacity (MW)										Installed Capacity (MW)
	2015	2016	2017	2018	2019	2021	2022	2026	2033	
HFO at Bushrod Island	48									**48**
Mt. Coffee		10								**66**
HFO plant			20							**20**
HFO plant				20						**20**
Decommissioning of existing HSD				-23						**-23**
HFO plant					20					**20**
HFO plant						20				**20**
Mt. Coffee + Via Reservoir							59			**88**
SP-1B								97		**120**
SP-2									147	**214**
Total	**48**	**58**	**78**	**98**	**118**	**138**	**197**	**294**	**441**	**593**

Generation through hydropower plants reduces the system costs. Hydropower plants have the lowest marginal costs, and are therefore the first in merit order for the dispatch of electricity. If the demand can be entirely satisfied with hydropower, then there is no need of operating thermal power plants, decreasing the system costs. Until 2022, and especially during the dry season, more thermal power plants are needed in order to compensate for Mt. Coffee's lower output, increasing system costs. The LCPDP [21] document states that after St. Paul River 1B Hydropower Plant (SP-1B) becomes operational in 2026, system costs will round 7.7 USD cent/kWh, when all demand can be satisfied by hydro generation only.

Hydropower plants have the potential to mitigate Liberia's fuel price dependency. As was outlined before, the fuel costs of the thermal power options to be installed in the base scenario will weigh heavily on Liberia's finances. For instance, considering the demand in 2023 (790 GWh) and adding 15% losses and subtracting the annual power generation of Mount Coffee, this results in 566 GWh per year that has to be covered by HFO thermal plants. The HFO thermal plants, in turn, would consume some 13 835 tons of fuel. The annual fuel costs will then be approximately USD 87M, which has the potential to easily double if fuel price volatilities are extreme. Hydropower generation, as well as biomass power plants, will help the reduction of Liberia's vulnerability concerning fuel prices and availability.

A sensitivity analysis was also performed, concerning the potential variability of the demand, fuel prices, discount rate, investment costs, as well as the robustness of hydropower investment costs and the possibility of importing energy. LCPDP's results [21] were as follows:

- If the demand is lower than expected, the main alteration is that St. Paul River 2 Hydropower Plant (SP-2), as well as 20 MW in HFO, will not be needed. Consequently, investment costs decrease by more than 40%. Also, SP-1B is only added to the system in 2030;

- On the other hand, for the high demand scenario, SP-1B and SP-2 are added earlier and an additional 20 MW in HFO generation is needed. System costs increase and the investment is 1.1% more comparing to the base scenario;
- Considering that fuel prices only increase according to the inflation rate, system costs decrease by approximately 5%, but there are no changes in the generation portfolio;
- If fuel prices have a real price increase of 5%, although there are no changes in the generation portfolio, though system costs increase by 9%;
- The variation of the discount rate influences system costs. The higher the discount rate is, the higher are the hydropower costs and thus so are the system costs;
- The generation portfolio remains unchanged if the investment costs increase by 10%. However, system costs in this scenario increase;
- Concerning the robustness of hydropower investment costs, the LCDPD document states that even if the costs of hydropower were to triple, it would still be cheaper than the cheapest HFO-fired power plant;
- When considering the possibility of importing energy through the CLSG line, the imported energy essentially replaces 50 MW in HFO generation after its completion. Thus, system costs fall to the lowest of all scenarios and investment costs decrease approximately 4%.

As described previously in Chapter 5.6, mining demand has significant impact on future demand, and thus impacts on the grid expansion plan. As such, the supply alternatives for the same two scenarios which include demand from the mining sector were included, as well as a third scenario:

- For the first scenario, secured mining demand, mining supply only becomes feasible after cheap hydropower is available. Before that, the installation of HFO plants would be too expensive to support. Furthermore, the expansion plan includes the addition of the St. John's hydropower plant. This scenario appears to be feasible in some respect, as excess power from hydropower plants can be distributed to the mines, although the total investment would increase to USD 1 767M;
- Regarding the second scenario, ramp-up mining demand, similar conclusions apply, as mines supply is only sustainable after the development of cheap hydropower. Additionally, three 100 MW coal-fired power plants would be needed, with their development between 2026 and 2029. Despite the fact that the total investment would greatly increase, amounting to USD 2 682M, coal-fired power plants are relatively cheap, especially when compared to HFO power plants;
- The third scenario takes into account that the mines will probably develop their own generation portfolio. The LCPDP [21] document states this does not have a positive financial impact in the grid expansion plan, since the mining companies will most likely use HFO-fired power plants, which are the most expensive options for LEC.

The investment costs for the different scenarios range from USD 875M to USD 2 682M. Figure 6.3 below summarizes the investment costs and installed capacities for each scenario. It is important to

state that the investment requirements are only approximate, due to the uncertainty of several factors, especially with regard to hydropower. On the other hand, investment requirements for HFO power plants are somewhat predictable. However, additional factors such as transportation and storage infrastructure might influence the final investment cost.

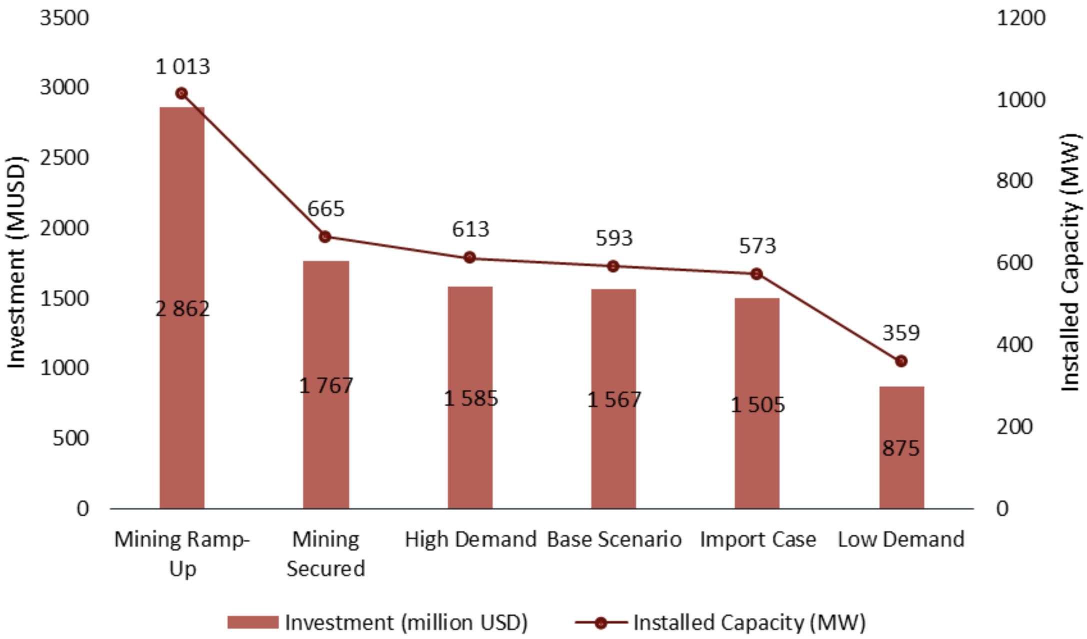

Figure 6.3 - Investment and Installed Capacity for the different scenarios

To sum up, LCPDP [21] **recommends that the grid generation should come primarily from HFO-fired power plants, until hydropower plants are available.** Until the addition of Mt. Coffee's Via Reservoir in 2022, Mt. Coffee will only serve as a fuel-saver, with its limited firm capacity. The LCPDP [21] document states that apart from hydropower, other renewables will not play a significant role on the expansion of the grid due to their high investment costs, although this situation might change in the future. Also, biomass is not considered a suitable alternative for a grid-connected power supply, as the resource is spread out across the country, and grid-connected power plants would be competition for its use in cooking or as a source of fuel for other appliances. Regarding mining demand, it is possible to say that to take it into consideration implies hydropower should be rapidly developed and potentially coal fired power plants. However, even in the base case, excess hydropower can be distributed to generate additional income streams, contributing to an overall reduction of power generation costs. Apart from this, the LCPDP [21] reinforces the importance of capacity-building, as the increasing complexity of the power system, with different types of power plants, will require an increase of the skills and capabilities of LEC's staff.

6.2 EXISTING AND PLANNED OFF-GRID ELECTRIFICATION PROJECTS

Increasing access to electricity all over Liberia, especially in rural areas, has been one of the main objectives of Liberian government, since it accelerates the country's reconstruction and its economic revitalization. To help achieving this objective, RREA has been studying and developing different rural

generation alternatives for Liberia, including solar, hydro, biomass projects, as it can be seen in **Figure 6.4**, where existing and on-going rural electrification projects are presented.

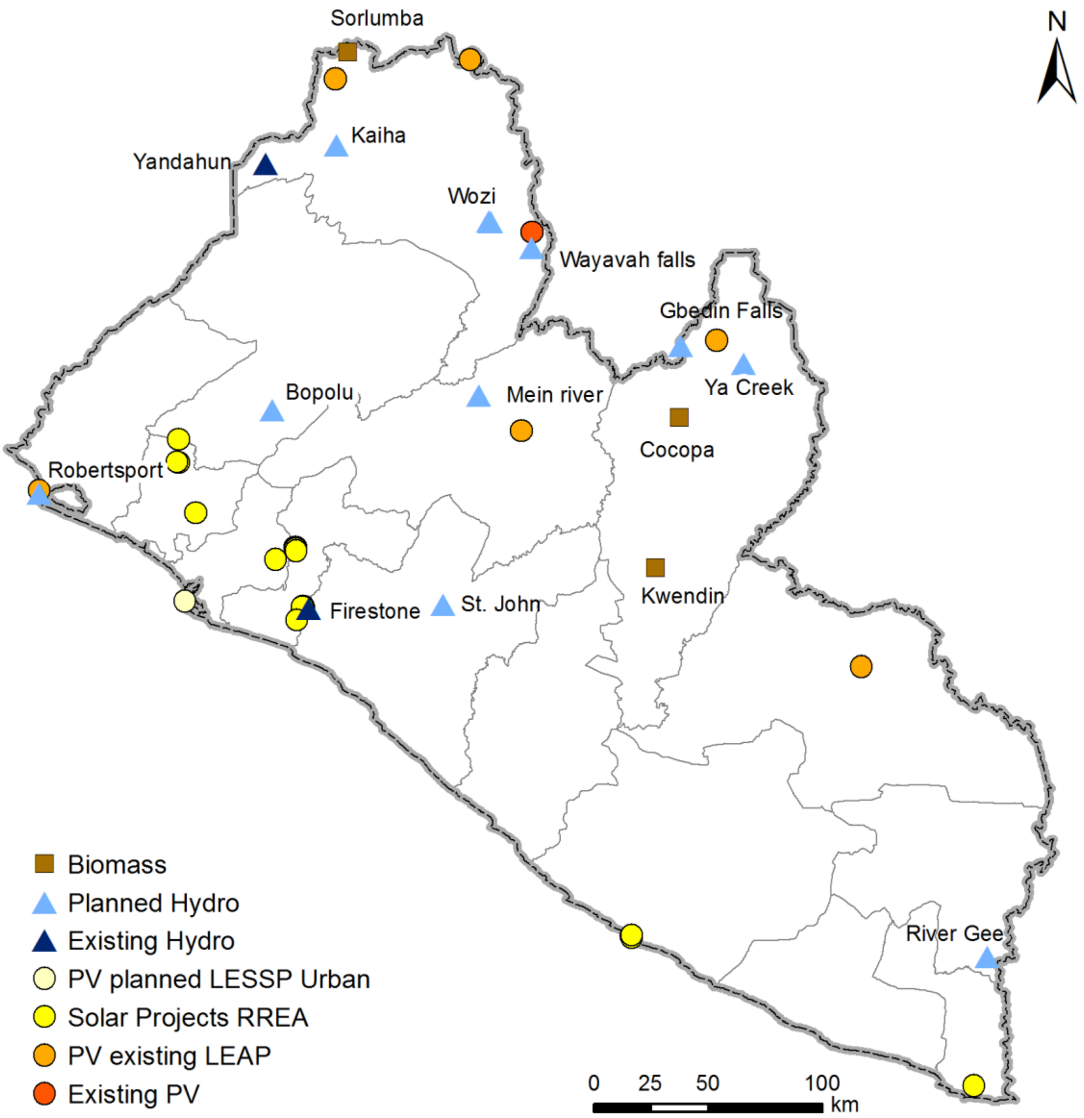

Figure 6.4 – Existing and on-going rural electrification projects.

Before the war, only two small hydro-sites had been developed: Firestone Plantation with 4 MW of installed capacity is still in operation, providing electricity to Firestone rubber plantation and several other villages near Harbel, and a 60 kW micro-hydro in Yandahun in Bong County, which was destroyed during the war. The Yandahun micro-hydro, implemented by RREA and financed by the World Bank, involved the rehabilitation of 60 kW to serve 240 households and was commissioned in May 2013. It is the country's first community-owned power system.

Nowadays, several micro and mini hydro projects are being studied to ensure its feasibility and select the ones which can be assumed as an alternative to rural electrification. A brief description of these projects is presented next.

Micro-hydro projects:

- Robertsport, located near St John's mission at Robertsport in Grand Cape Mount County on a small creek, with 70 kW of expected capacity [26];
- Bopolu. Located in near village Bopolu in Gbopolu County on Marvo creek (Mahe River basin), with 90kW of expected capacity [26];
- Wayavah falls located in the Salayea District, Lofa County. The hydropower plant will have 15 kW of installed capacity (but can be enlarged for 120 kW). This project is developed by USAID and is currently on hold for financing reasons [26].

Mini-hydro projects:

- Kaiha, located in Lofa County, with an expected capacity between 1 to 3 MW.
- Wozi is located at Wozi village in Zorzor city in Lofa County and across “Via River” which is a tributary of St. Paul River. The project has an expected capacity of 1.7 MW [26];
- Ya Creek, located near village Boaplay in Nimba County, on Ya creek with 450 KW of expected capacity [26];
- Mein River, located in Suakoko District, Bong County, with an expected capacity of 1 MW, will electrify 500 households and 250 commercial consumers. The project will be financed by USAID and will cost around USD 5.8M. At present, however, development is on hold due to uncertainties of financing [16];
- St John, with 10 MW of capacity, located in John River, Gampa water falls, Nimba County. The project is financed by UNIDO and has an expected cost of USD 26M. The project will electrify Ganta city, Sanniquellie town, Zuluyee town, Gbedein village, Kapawleh-Snoh village. At present, project is on hold due to lack of capacity in country to implement the project [27];
- River Gee, located in River Gee County, 55 km from Fish Town.
- Gbedin falls, with an expected capacity between 5 to 10 MW, is located in St John river, in Nimba County. This project is located in an international part of St John river and its construction will require accordance between Liberia and Guinea [28].

PV based rural electrification projects are also being studied and/or implemented. According to the Scaling-up Renewables Energy Program (SREP) [3], the five PV projects with more relevance are:

- Liberia Energy Assistance Program (LEAP): PV installation in 19 schools, clinics and public buildings, financed by USAID. Installation is already completed.
- Renewable energy for health care facilities: PV installation in 205 public health facilities with support from RREA and implemented by Merlin Non-Governmental Organization (NGO). Project financed by EU (75%) and Ministry of Health (25%). Project will be implemented countrywide and has an expected cost of USD 2M.
- PV installation in public buildings, in Lofa County, financed by EU.

- LESSP Urban: PV installation to be implemented under LESSP project, financed by USAID and with an expected cost of USD 2.7M. The project will be implemented in Bushrod and has 1 MW of installed capacity.
- Lighting Lives in Liberia: Market development for cost-effective distribution of solar lanterns through private retailers, financed by WB and with an expected cost of USD 1.45M. 120 000 solar lanterns will be distributed nationwide.

Regarding to biomass projects, LESSP completed three feasibility studies [16]:

• 35 kW Sorlumba Biomass Project: located in Lofa County, this biomass plant involves combustion of Crude Palm Oil (CPO) in an internal combustion engine to generate power. Technical issues still need to be resolved, as CPO has the potential of gumming up a traditional diesel-fired engine. LESSP is looking at two options: (1) pretreatment of CPO; and (2) use of a Lister-type engine. The bidding process has been delayed due to this issue.

• 240 kW Cocopa Biomass Project: located in Nimba County. The Liberia Rubber Corporation (LIBCO) was recruited as a private sector partner for the Cocopa biomass plant, however, the organization has formally withdrawn support, most likely, due to an inability to raise the USD 1M in private sector capital required. The project is financially infeasible without LIBCO support.

• 60 kW Kwendin Biomass Project: located in Nimba County is the substitute for the Cocopa project and can be completed with current funds.

6.3 MINI-GRID THERMAL SUPPLY ALTERNATIVES (DIESEL AND BIOMASS)

6.3.1 DIESEL GENERATION LOGISTICS AND ECONOMICS

Diesel genset. One of the alternatives for mini-grid supply is diesel generation. A diesel generator is the combination of a reciprocating diesel engine with an electric generator – the diesel engine provides mechanical energy, which is converted into electricity by the generator. Similarly to the already existing units in Liberia, the most common type of fuel for small-scale power generation is HSD. For even smaller-scale generation, including home systems, gasoline is commonly used, although this will not be analyzed, as the minimum installed capacity considered here is 6 kW.

Advantages. One of the biggest advantages of this type of generation is its easy installation and Operation & Maintenance (O&M), especially when compared to steam-based power plants. Additionally, diesel generation is predictable and rapidly dispatchable, useful for balancing the intermittent production of renewable energy sources, and as there are modules of nearly any size available, it is possible to have a power plant consisting of several units, depending on the load demand. Finally, its low Capital Expenditures (CAPEX) makes diesel generation an attractive short-term option. Concerning Liberia, it may be added that there is already some experience with this type of technology, as it was and is operated by LEC and by several other private entities.

Disadvantages. Despite these advantages, diesel engines require fuel to operate. Considering the high costs of diesel itself and the costs of transport and storage, it is possible to say that diesel generation has high running costs, aggravated by the fact that continuous use of diesel engines severely shortens its lifespan to 3-4 years (assuming 25 000 hours). Moreover, the availability of fuel is a major concern, especially in rural areas of developing countries. These two factors have been a problem in the past for Liberia, and it is only advisable to install this type of system where a reliable fuel supply can be guaranteed and where customers have the necessary financial means to supports its operation costs. Apart from this, diesel generation systems are noisy and polluting, having a direct impact on users, especially when the generators are located next to the house.

Considerations. Some possible solutions have been analyzed, and the specific cost of each solution strongly depends on its rated power: lower rated powers have higher specific costs. However, it is important to state that a correct sizing of the power generation unit is of the utmost importance, since specific consumption, and therefore specific costs, increase when the engine is not operating at full load (considering the alternatives in **Table 6.2**, the increase can reach almost 20%). Also, operating a diesel engine in non-rated conditions may shorten its lifespan, especially when overloading the engine. Considering this, a demand assessment is needed before sizing the generation system, in order to optimize its composition. **Table 6.2** provides some examples of possible alternatives, considering 0.94 USD/L as the diesel price [9]. The analyzed alternatives have specific operation costs ranging from 0.283 USD/kWh to 0.382 USD/kWh, working at full load. It is important to notice that these costs only consider fuel consumption, therefore the global specific cost is higher, due to factors such as the investment in equipment and maintenance, personnel, grid O&M and other costs. Moreover, fuel prices will vary depending on the location, thus the fuel price needs to be assessed when a specific location is being studied.

Table 6.2 - Diesel generation alternatives [29].

Technical Data		C1.1 [DE9.5E3]	C1.5 [DE13.5E3]	C2.2 [DE18E3]	C2.2 [DE22E3]	C3.3 [DE33E0]	C3.3 [DE50E0]	C4.4 [DE55E0]	C4.4 [DE65E0]
Rated power (kW)		6.8	10	13.2	16	24	36	40	48
Frequency (Hz)		50							
Voltage (V)		400/230							
Fuel		Diesel							
Fuel tank (L)		62	62	66	66	161	219	219	219
Fuel Consumption (L/h)	110% Load*	2.9	4.0	4.8	5.9	7.7	11.7	12.7	14.9
	100% Load	**2.6**	**3.7**	**4.4**	**5.3**	**7.0**	**10.5**	**11.5**	**13.6**
	75% Load	2.0	2.8	3.4	3.9	5.2	7.8	8.7	10.2
	50 Load	1.5	2.0	2.6	2.9	3.8	5.5	6.2	7.1
Specific consumption (L/kWh)	110% Load*	0.388	0.364	0.331	0.335	0.292	0.295	0.289	0.282
	100% Load	**0.382**	**0.370**	**0.333**	**0.331**	**0.292**	**0.292**	**0.288**	**0.283**
	75% Load	0.392	0.373	0.343	0.325	0.289	0.289	0.290	0.283
	50% Load	0.441	0.400	0.394	0.363	0.317	0.306	0.310	0.296
Specific Cost of Operation (USD/kWh) @100% Load		0.359	0.348	0.313	0.311	0.274	0.274	0.271	0.266
No. of Cylinders/Alignment		3 / In Line	3 / In Line	4 / In Line	4 / In Line	3 / In Line	3 / In Line	3 / In Line	3 / In Line
Cycle		4 Stroke							

*use a max of 1 hour in 12 and cannot exceed 25 hours per year

Fuel Distribution

Limitations. Nowadays, Liberia has serious issues and limitations regarding fuel distribution outside of Greater Monrovia. The major barriers in diesel distribution lie on the lack of accessibility – namely the deficiency of the communication routes that allow the passage of oil trucks to the rest of the country.

TOTAL, one of the major fuel retailers in Liberia, revealed that they had 30 stations scattered in nine counties. However, despite covering 60% of the country, during the rainy season distribution to the countryside is often interrupted due to road flooding.

Diesel cost varies with the distance. During the Beliefs Audit performed in all counties and presented in **Chapter 4**, in the month of September of 2015, a diesel cost assessment was performed and the findings confirmed that the prices of diesel were higher the further away from Monrovia and from the main national roads, **Figure 6.5**.

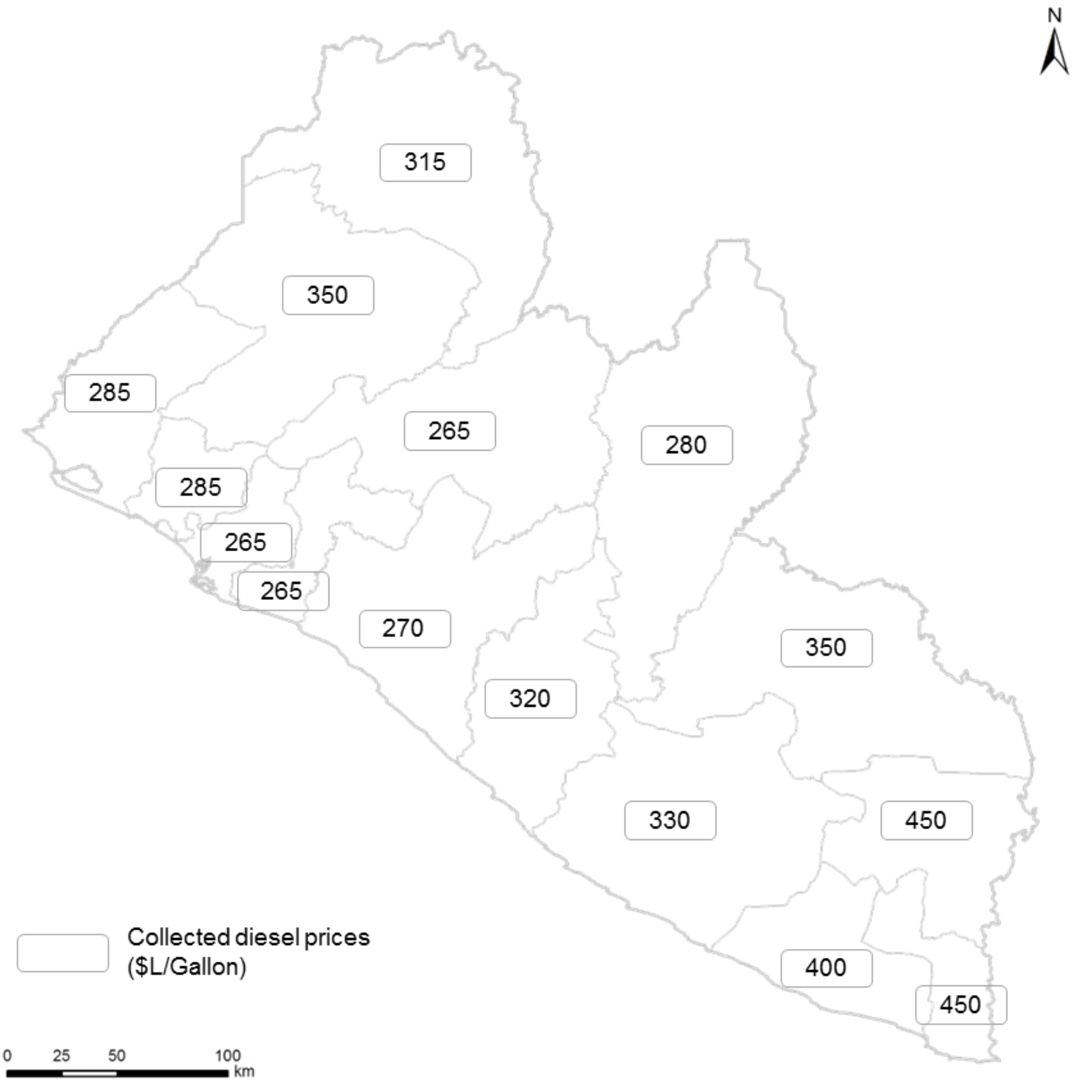

Figure 6.5 – Observed diesel prices during the Beliefs Audit (October/November 2015).

The base price in Monrovia was, at the time of the questionnaires, 265 LD/gallon (or 0.76 USD/L), being the lowest diesel cost in the country. However, in Maryland and Grand Kru counties the prices were almost the double reaching 450 LD/gallon (or 1.29 USD/L).

A 5% increase per 100 km was considered. Since 1) there are currently several plans to rehabilitate and improve the national transportation network and 2) it is expected that the base diesel price (cost of diesel in Monrovia) rises in the future, the retrieved information in the Beliefs Audit questionnaire should not be used to assess the future diesel cost distribution throughout the country. To consider the distribution costs of diesel, a cost/distance proxy was used. Basically, to determine the price of diesel fuel in the future, a 5% cost increase for each 100 km distance from Monrovia (fuel import point) was used. In **Figure 6.6**, the results of this assumption are presented.

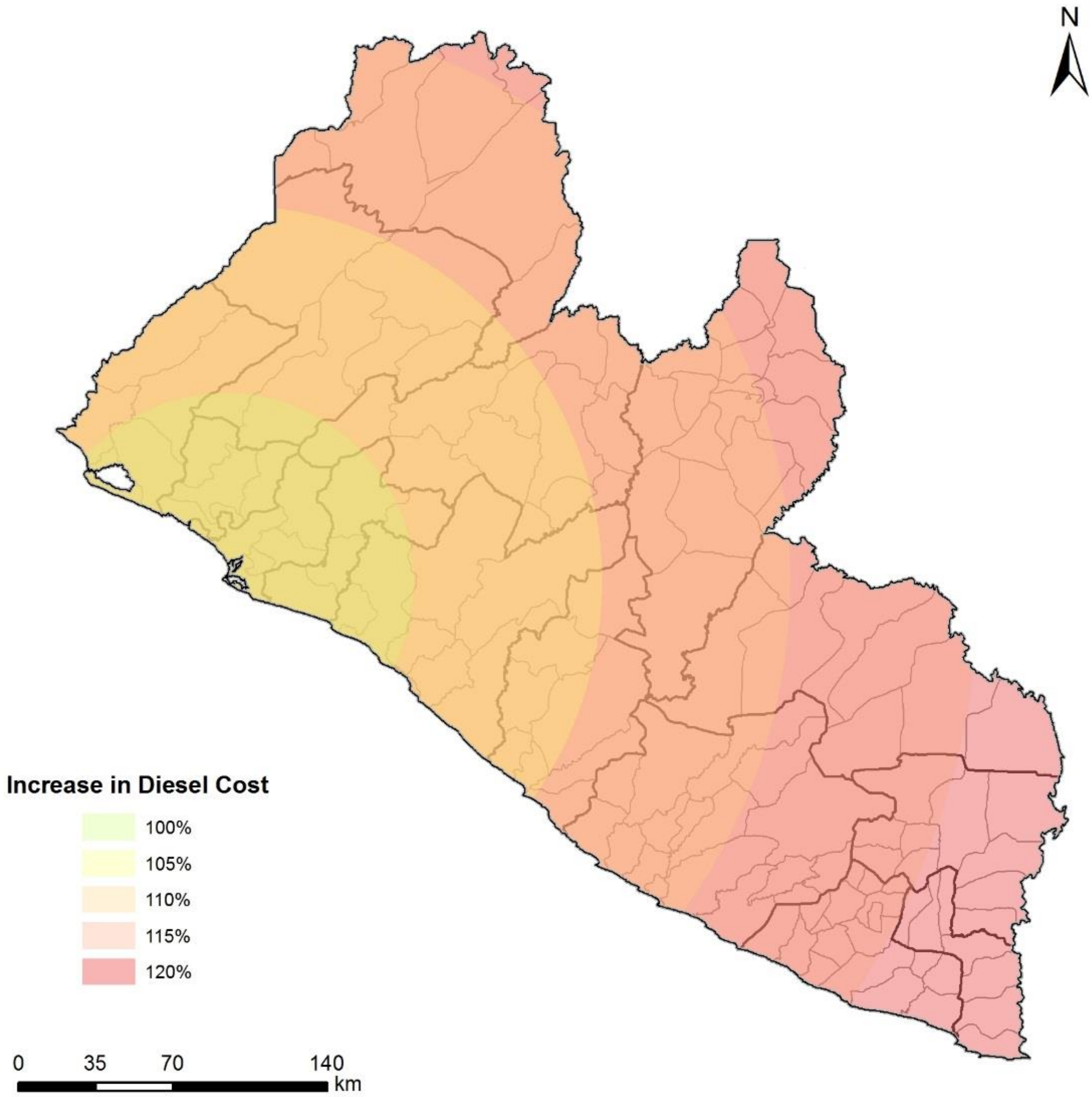

Figure 6.6 – Diesel fuel costs considered for the future.

The considered future diesel base cost was 350 LD/Gallon (or 1 USD/L). So, each 100 km stripe, presented in the previous figure, has a different diesel cost. For example, diesel price in Monrovia is 1 USD/L, and in the most northern and eastern regions of the country the cost should be 20% higher (1.2 USD/L).

Diesel cost. Considering the differentiated diesel costs and several diesel generation technical and economic assumptions[5], the Diesel Levelized Cost of Energy for each one of the county capitals was determined as an example, and the obtained results are presented in **Table 6.3**. Note that these results are only intended to verify the influence of fuel cost in the costs of energy of diesel gensets. Therefore, demand is considered to be the same for each location.

[5] CAPEX: 250 USD/kW +25% Inst. Cost, Generator lifetime: 5 years, Fuel Consumption (50% Load) 0.35 l/kWh, Estimated future Diesel Cost in Monrovia: 350 $L/Gallon (or 1 USD/l), WACC = 5%

Table 6.3 – Diesel Levelized Costs of Energy considering the diesel fuel cost in each County Capital and Monrovia.

City	Levelized Cost of Energy
Monrovia, Bensonville, Kakata, Tubmanburg and Robertsport	~380 USD/MWh
Buchanan, Gbarnga, Bopolu and Cestos City	~395 USD/MWh
Sanniquellie and Greenville	~415 USD/MWh
Voinjama, Zwedru, Fish Town and Barclayville	~430 USD/MWh
Harper	~450 USD/MWh

As expected, the costs of energy rise the further apart a city is from the country's fuel import point.

6.3.2 BIOMASS POTENTIAL ASSESSMENT

Advantages and disadvantages of biomass. Biomass sources include forestry products and residues, agricultural crops and residues, manure and waste residues. On the one hand, biomass is a renewable, widely available, low carbon and low-cost fuel, which may help in dealing with waste or other residues and that can be produced domestically or in small scale, thus a potential source of energy for mini-grid or stand-alone systems. The fact that biomass generates energy through fuel implies storage is much cheaper and easier than energy sources that need batteries. On the other hand, it is energy intensive to produce, is usually expensive to transport (as it has low energy density), may require extensive use of land and can be seen as competition for the food production industry. Biomass is already extensively used in Liberia as a source of cooking fuel, and also to provide heat and light.

Forest resources. Liberia's forests are of special importance to the economy because they provide employment in the rural areas, fuel sources (charcoal and firewood), and export products (logs and timber). With forest resources covering about 5.7 million hectares, Liberia has 11 National Forests (under very limited protection) and two legally protected areas. Forest resources have been mismanaged in the past, resulting in United Nations Security Council sanctions on timber exports, between 2003 and 2006, when it was lifted after the new Liberian National Forestry Reform Law. Wood, especially charcoal and firewood, has already a high demand, since it is used in low-efficiency traditional ovens and cook stoves. Consequently, it is important to properly manage these resources, so as to avoid environmental impacts such as deforestation and loss of biodiversity from excessive logging. Although only few contracts are still effective, forest residues from logging or wood-processing activities can be used to generate heat, electricity and liquid or solid fuels. This generation potential will increase after logging concessions resume operations, and a study has estimated that 15 248 GWh per year of electricity could be available [30]. It should be noted that, also in other countries, byproducts from wood harvesting and timber processes are used only in close connection with the source of these products, because transport is expensive and the energy-specific transport costs are very high, especially for Liberia in the present situation, since the transport infrastructure and the quality of the transport infrastructure is very poor. For forestry byproducts during the harvesting process, it must also be examined whether it is necessary to leave them in the forest to fertilize the forest.

Agricultural resources. Agriculture is the backbone of Liberia's economy, providing informal employment for more than 70% of the workforce (mostly in rural areas) and contributing an estimated 53% to the gross domestic product in 2006. Liberia has climate and terrain conditions very favorable for agricultural development, with an estimated 3.7 million hectares of arable land. Agricultural resources may be divided in three categories:

- Food crop residues – residues and byproducts that remain after these crops are harvested and processed, such as stalks, straw, husks and shells, from rice, cassava, sweet potato, maize and other types of food crops, have an estimated energy content equivalent to 188 GWh of electricity per year [30]. Despite this, much of Liberia's production is run by small households for self-consumption or local markets. The lack of large-scale food crops production, and their dispersion, increases collection and transportation costs, which would restrain the use of these residues for centralized electricity generation. However, even if food-crop production were to increase, it would most likely be used to secure food supply and not as a biomass resource. Moreover, many crop residues and byproducts are seasonal and become available all at once at the same time of the year. Therefore, treatment and storage facilities will be required if they are to be made available as a bio-power feedstock throughout the year.
- Cash crop residues – mainly rubber, but also oil palm, cacao and coffee plantations. Liberia is the third biggest African producer of natural latex, having large-scale rubber plantations, making this its most important cash crop. This type of plantation generates considerable amounts of wood residues from pruning and replanting activities, as tree trunks and branches become available. Tree trunks are usually used as timber and the small branches are left in the field. If only 10% of the current rubber tree stock (about 5 800 ha) is replanted, it would result in roughly 254 000 dry tons of wood branches. The corresponding energy content is about 4 600 TJ, equivalent to 381 GWh of electricity [30]. This analysis doesn't evaluate the residues generated from rubber trees grown on household farms as it is assumed that these residues are already in use as firewood or on farm applications.

    Oil palm grows throughout Liberia but is particularly abundant in the coastal areas. It can yield cooking oil, animal food, and raw material for the manufacture of cosmetics, detergents, and pharmaceuticals. Palm oil can be used to produce biodiesel or used directly to run low-rpm (rotations per minute) diesel generators. In addition, the oil palm residues can be a feedstock for heat and power generation. The average yield per hectare is about 80 dry tons of biomass, which means that if only 10% of the area planted with oil palm trees in Liberia (about 3 000 ha) were replanted, it would yield 240 000 tons of biomass, equivalent to 4 320 TJ (360 GWh) [30].

    Cacao trees need shade and are not very suitable for large-scale monoculture plantations, making intercropping with other cash or food crops a common practice in the small household farms. They need regular pruning, which would yield about 8 GWh of electricity per year in Liberia, and replanting would yield more 15 GWh [30]. Some of this

resource is already in use as cacao trees are being cut and burned as charcoal in some areas of Liberia.

Coffee cash crops in Liberia are pruned yearly, but there is no information on the amount of residues generated. Despite this, coffee processing generates husk, among other by-products, which is usually used as a fertilizer but could also be compressed into pellets. It is estimated that about 500 dry tons of husk are generated per year, with a corresponding energy content of 8 TJ and electricity generation potential of less than one GWh [30].

Other cash crops in Liberia include coconuts, bananas, plantains, sugarcane and pineapple. Even though the energy content of the biomass generated is high, these resources are sparsely distributed and/or have many other competing uses, being difficult to estimate the amount available for power generation.

- Animal Manure – Although the livestock sector has never been a major feature in Liberia, it is an important activity to traditional farmers. About 8% of farming families own ducks, and 5% own pigs and goats. Sheep and cattle are hardly present. Before the war, there were seven large cattle farms in Maryland, Grand Kru, and Sinoe counties. Today they are slowly being rehabilitated, mainly in Maryland. Livestock manure is used as an organic fertilizer, building material, and energy source. It can be used as fuel in two ways: either burned directly or anaerobically digested to produce biogas, which is then burned, more efficiently than raw manure. It was estimated that Liberia's potential biogas production could yield approximately 219 GWh of electricity per year [30], and it is considered that digestion processes based on cattle manure may be a solution in the future.

Urban resources. The concentration of population and activities in urban areas is responsible for the generation of waste. This waste, referred to as municipal solid waste (MSW), is generated by households and the commercial and industrial sectors. The waste takes many forms, including plastics, paper, textiles, glass, metal, wood, food, and other organic wastes. MSW, particularly the biogenic fraction, is a resource that can be converted to electricity, heat, gaseous and liquid fuels. The use of waste to provide energy has one major benefit derived from the production of electricity, which is the safe waste management and disposal, reducing waste volume by 90%, and consequently in a decrease in the amount of land needed for waste disposal. The power generation can be achieved through several processes, including incineration, gasification and digestion. Despite the fact that there are no landfill sites in Liberia, a study [30] estimates the generation potential of waste-to-power in 18 major populated places in Liberia with more than 5 000 people, which have a total potential of 52 GWh per year.

Processes and technologies. Biomass resources may be used in different manners, existing several processes and technologies which allow electricity generation from biomass. Regarding this report, biomass to electricity or fuel processes can be separated in two main processes – thermo-chemical (incineration, gasification and pyrolysis) processes and bio-chemical-processes (anaerobic digestion). A

brief description of processes and technologies to produce electricity from biomass is presented in **Table 6.4**.

Table 6.4 –Processes and technologies to electricity generation by biomass.

Thermo-chemical processes	
Incineration	Consists on burning the biomass to generate steam, which is used to generate power through a turbine and a generator. To be economically feasible, biomass based steam process power plants should have a demand superior to 5 MW, with a continuous supply of biomass throughout the year, in order to ensure a constant price level for the project. The fuel has to be pretreated. Considering the above, using biomass for steam generation could be a suitable option for rural Liberia, in areas where the demand is high enough and with secured access to biomass supply.
Gasification	Using a gasifier, this is a process described by the partial combustion of biomass (wood chips, charcoal, among others) with a controlled amount of oxygen, from which results a gas that can be used in reciprocating engines, fuel cells and gas turbines. This process is more efficient than incineration and needs pretreated biomass as well. Using the process gas in reciprocating engines, it is possible to have smaller-size generation units than in incineration, with electric outputs as low as 1 kW. This is a fairly new technology in Africa, with most projects still at planning or demonstration stages. It is important to state that past studies indicate charcoal gasifiers present less operation problems than, for example, gasifiers fueled with wood or agricultural residues. Small and micro-scale gasification systems could be a suitable alternative for villages, as they are portable, small, cheap and simple. Gasifiers are already being tested in Liberia: in Booker Washington Institute, Kakata, three 15 kW PP20 gasifiers are being used to provide electricity to the campus (**Figure 6.7**). As Kakata is in the center of extensive rubber farms, there is a considerable amount of biomass supply. Despite this, the models being tested haven't proven to be as long-lasting as desirable, having had technical problems which made some of them unavailable for power generation. Although biomass gasification is promising, the process is still under development, not being a suitable option for power generation at the present time.
Pyrolysis	Similar to gasification, with extremely low amounts of air (theoretically in the absence of air), but the combustion stops at lower temperatures, converting the biomass in a bio-oil, a liquid fuel. Taking into consideration that this process is still being developed, it is not regarded as a suitable alternative.
Bio-chemical processes	
Anaerobic digestion	Consists in a natural decomposition process, favored by low-oxygen, hot and dry conditions, typically based on manure from livestock farming, residues from palm oil processing or municipal solid waste. This process uses a digester and gives biogas as product, which can be used in reciprocating engines, gas turbines or fuel cells. It allows small-scale generation units, with capacities ranging from a few kW to a few MW.

Figure 6.7 – BWI Biomass gasifiers pilot project.

Liberia's biomass potential assessment. Taking into consideration Liberia's resources and the present goal, which is the analysis of suitable processes for mini-grid operation, it is possible to draw some conclusions.

Concerning the resources, the analysis above indicates that a careful planning is of the utmost importance. Most of the biomass which could be used to produce electricity can also be used elsewhere, especially when considering the much more important charcoal market. For example, using arable land in order to produce fuel, and not food, may have negative impacts; as could the use of crop residues for energy generation, instead of cattle feeding. A sustainable use of the available resources is also necessary, so as to prevent deforestation and other related issues. It is recommended to use resources that do not compete with other uses, in a sustainable manner, but it is important to ensure that the resources will be available at a reasonable cost.

Considering that biomass has low energy density, the distance between the resource and the power generating unit must be minimized. In general, biomass transport is limited to 30-50 km, especially with poorly developed infrastructure. Moreover, processing the feedstock to enable its use may be an energy intensive process which will increase the cost of biomass power generation, such as the pretreatment of wood and wood residues in a chipper.

To sum up, the many competing alternatives and the lack of concentrated resources discourage the use of most of the possible biomass sources for medium-scale generation. However, viable alternatives may exist, such as power production in combination with the palm oil mill process, although it is not clear if that would be cost effective. Additionally, small-scale generation, as gasifiers and anaerobic digesters, is not considered to be suitable at the present time, as gasifiers are not yet a mature technology and experience has proven their lifespan is not long enough, and digesters probably wouldn't have enough resources, as there are no large farms (for concentrated quantities of animal manure, such as cattle) nor centralized waste collection systems.

In the future, if the demand is high enough, biomass-fired power plants may become feasible. For smaller-scale generation, both gasifiers and anaerobic digesters may be suitable, given that their respective limitations are overcame – reliable technology for gasifiers and concentrated resource supply for digesters. The main constraints to surpass for generating power through biomass are the availability of resources and the need of capacity building, as the technologies used are considerably complex. That way, biomass could start replacing diesel generation.

6.4 SOLAR POTENTIAL ASSESSMENT

6.4.1 SOLAR POTENTIAL MAP

Global scale factors effect on solar radiation. On a global scale, solar irradiation essentially depends on the atmosphere, geometry and movement of the planet in relation to the sun, however on a local scale the changes in solar irradiation are mainly due to the topography, that is, variation in elevation, slope, aspect and shading.

Solar irradiation model. The mapping of the solar resource is accomplished with r.sun model using satellite data. The mentioned model is implemented under an open source environment, estimating global radiation under clear-sky conditions from the sum of its beam, diffuse, and reflected components for a given day, latitude, surface, and atmospheric conditions.

Clear and Real-sky parameterization. Real-sky solar radiation is calculated from the clear-sky values by applying a factor that parameterizes attenuation caused by cloudiness. The effect of cloudiness is considered in the application as a transmission factor (a model parameter that reflects the relation between clear-sky and real-sky radiation). A good estimate of this parameter depends on the availability of radiation measurements as well as the estimation of the proportion of diffuse radiation.

Local meteorological data. For the study of the solar potential for Liberia were collected and analyzed global radiation data from 7 weather stations in Ghana and Nigeria, provided by World Radiation Data Center (WRDC) since for Liberia, meteorological data from ground stations are very sparse and has few years of records.

Global meteorological data. Historical data and collected measurements of global radiation were used to calibrate the HelioClim-1 (HC1) satellite data for the whole territory and calculate the global irradiation on horizontal plane. HC1 database is available to meet the need for long-term radiation data series, which contains 20 years of data (1985-2005). The data used for this study as well as the methodology and assumptions of modeling the solar resource for Liberia are presented in more detail in **ANNEX IV**.

Liberia Potential Atlas. As presented in **Figure 6.8**, Liberia is characterized by high levels of solar radiation, especially in central and northern territory. The mapping of Global Horizontal Irradiation (GHI) for Liberia was performed with a resource grid of 1 km x 1 km.

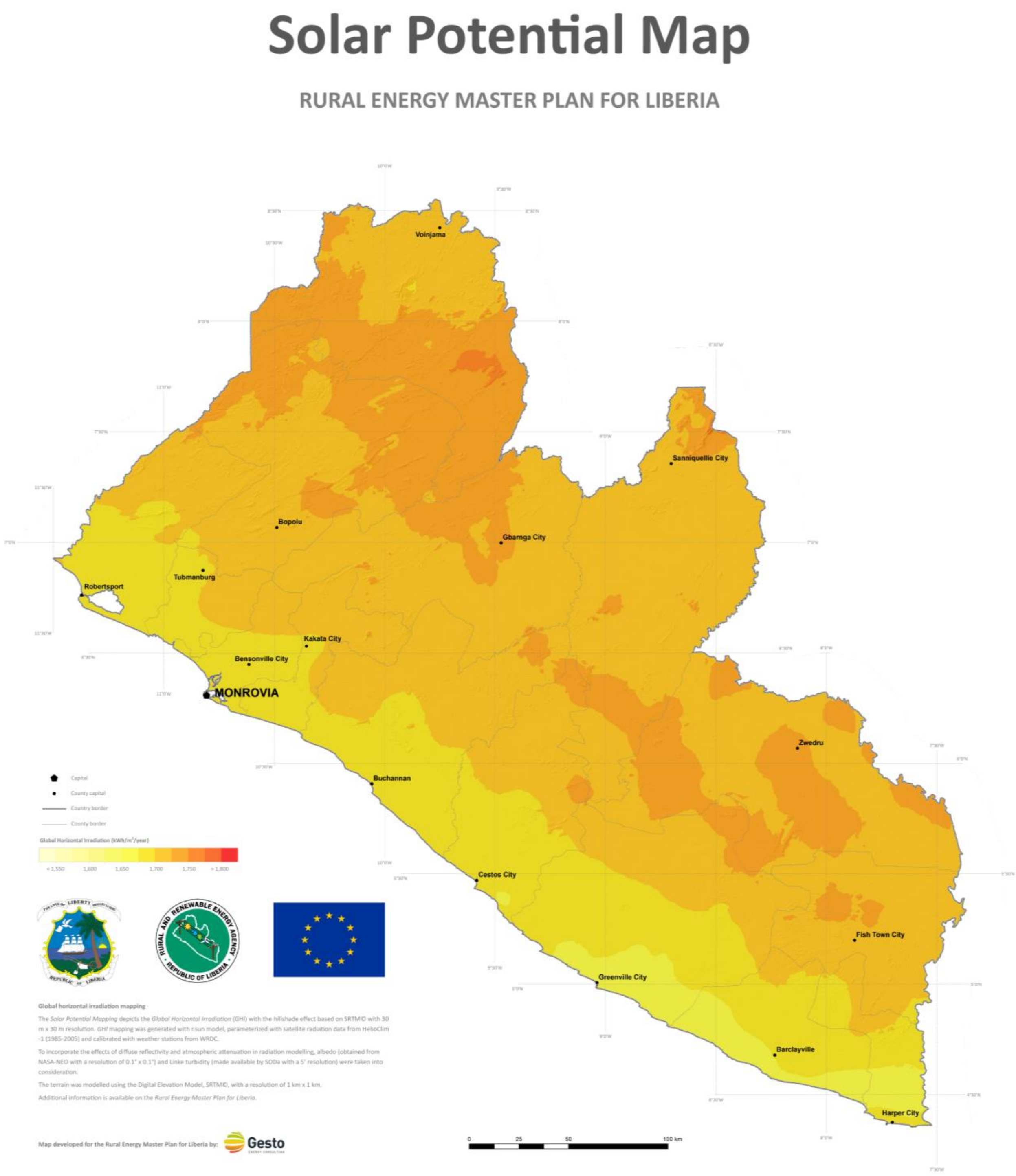

Figure 6.8 – Solar Potential Atlas for Liberia.

Liberia vs. worldwide solar radiation. Liberia is characterized by high levels of solar radiation when compared with good locations in Europe and Asia (**Figure 6.9**). On average, the solar potential of Liberia ranges between 1 665 and 1 771 $kWh/m^2/year$, being Greenville City the county capital with the minimum value of GHI, 1 673 $kWh/m^2/year$, and Zwedru the county capital with the average highest value of 1 728 $kWh/m^2/year$.

Solar Atlas allows project identification. The Solar Atlas of Liberia will allow the identification of any site nationwide with generation capacity between any power ranges, being an auxiliary tool to promote rural electrification based on solar energy.

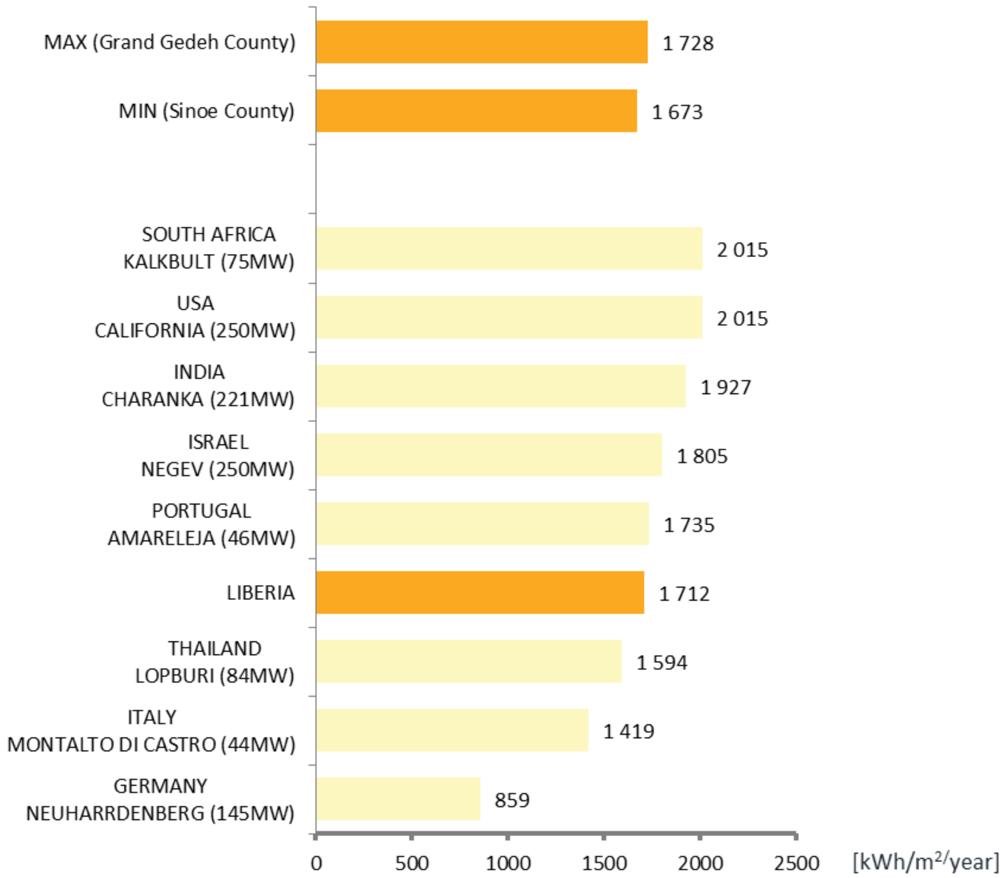

Figure 6.9 – Solar benchmark for the world.

PV potential. Specific production of a PV system is assessed by PVSyst application. The methodology and assumptions are detailed in **ANNEX IV**. There were performed 45 simulations, for a total of 45 points covering Liberia territory, with a typical technical solution of a PV project with 10 kWp of solar panels[6] limited in the inverter[7] of 10 kW. To the results was applied a linear regression in order to include the most significant variables and therefore estimate the PV production for all the territory (**Figure 6.10**).

[6] For simulation purpose, were adopted Yingli Solar panels, YL250P-29b.

[7] For simulation purpose, was adopted the Siemens inverter, Sinvert PVM10.

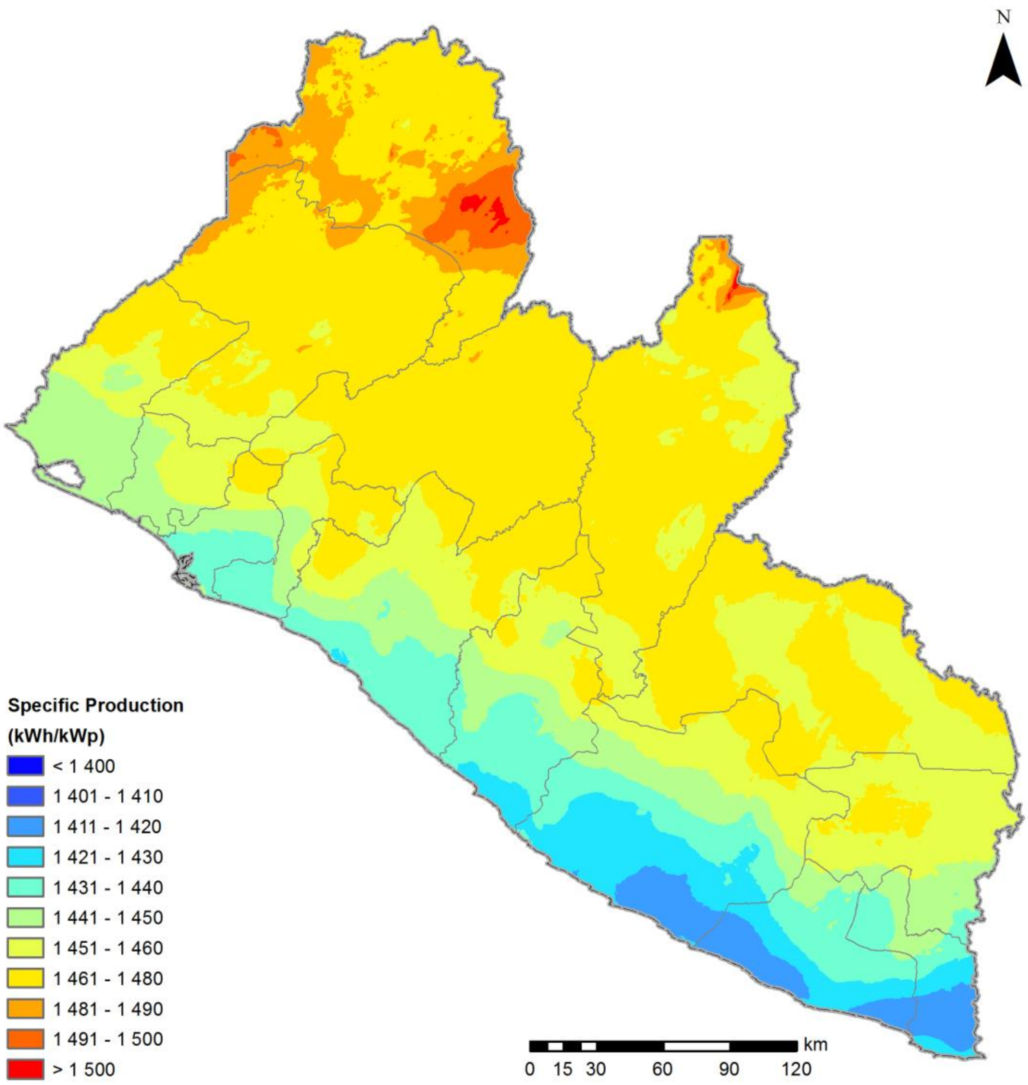

Figure 6.10 – Specific production mapping for Liberia.

6.4.2 PV BASED SUPPLY ALTERNATIVES

6.4.2.1 ALTERNATIVES COMPARISON

PV based solutions. There are several different PV based solutions to be taken into account in the rural electrification options, with different levels of service from solar shops to mini-grids, including Solar Home Systems (SHS).

PV and Diesel Hybrid system. Three distinct PV based alternatives were considered. One consists of 100% PV solution, considering individual home systems. The two other alternatives take into account distinct approaches of hybrid PV/Diesel systems with different PV penetration ratios. Note that the main objective of implementing solar into an existing diesel mini-grid is to achieve diesel fuel savings, thus reducing on-going operational costs and diesel fuel price exposure.

- <u>Diesel & PV Inverter Hybrid System (no batteries)</u>

This alternative includes a solution based in a 100% diesel system along with a solar system (without batteries). In this approach, solar penetration could reach up to 20% of the diesel genset nominal power.

- Diesel & PV Battery Inverter Hybrid System

  Solution based in a 100% diesel system along with a solar system (with batteries). In this approach, due to batteries usage, solar penetration could reach up to 60% of the diesel genset nominal power.

  However if a Grid Manager system is considered, the PV penetration could ascend up to 100% to reach economic optimum, including support for diesel off-mode. An intelligent management ensures that the amount of solar energy fed into the system matches exactly the demand at that time.

- Standalone solar system (Solar Home Systems – SHS)

  This alternative consists in individual 100% solar powered systems with batteries.

It is presented in **Figure 6.11** the summary of the PV based off-grid and mini-grid technology alternatives discussed above, which are better detailed in **ANNEX V**.

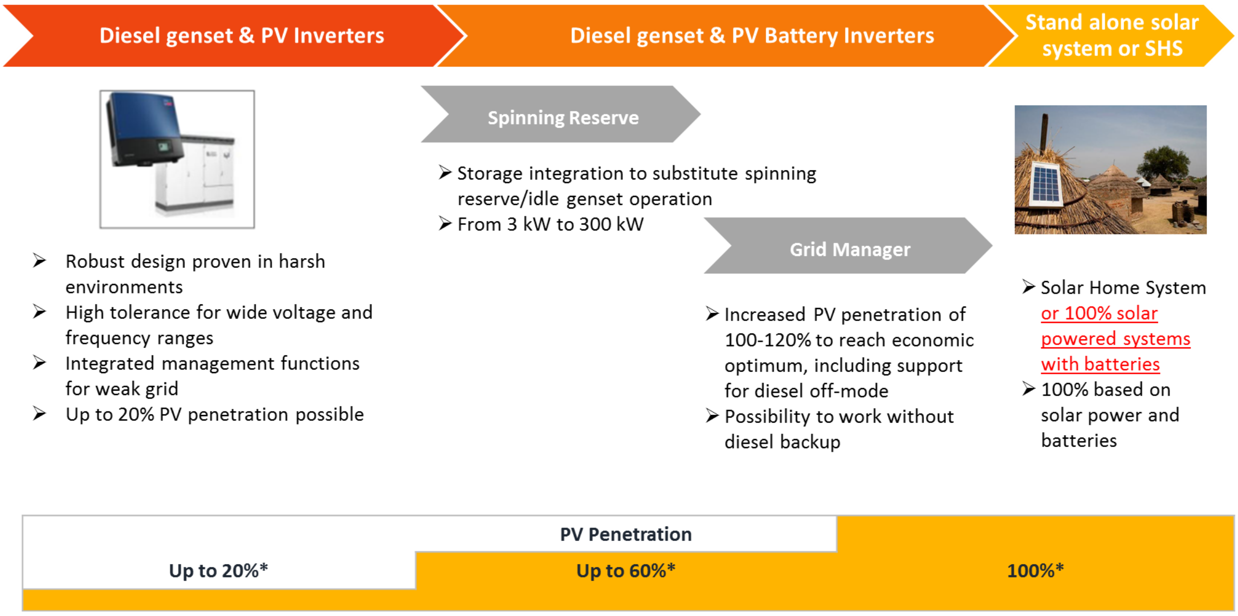

Figure 6.11 – Off-Grid and Mini-Grid Technology Alternatives.

Market assessment. In order to accomplish the financial pre-feasibility analysis, a market assessment of the PV solutions in Liberia was carried out. This market assessment allowed the evaluation of CAPEX and Operational Expenditures (OPEX) costs to be taken into consideration in the business models and the suitability of the solutions to the regions, types of settlement, social and environmental background. The assumptions taken into consideration for the economic analysis of the PV based alternatives are presented in **ANNEX VII**.

LCOE simulations. Four different simulations for the Levelized Cost of Electricity (LCOE) were performed in order to better understand the cost differences between the previously presented alternatives. The simulations took into account the technology alternatives of the PV based solutions presented

previously. It was also carried out a simulation considering an alternative with a system operating 100% diesel.

LCOE example for Monrovia. As an example, it is presented a specific case for the capital Monrovia, thus considering its local fuel costs and solar radiation. In **Table 6.5** is presented the operation assumptions that were used. The results for the alternatives simulations of LCOE are presented in **Figure 6.12**.

Table 6.5 – Example of operation assumptions for each PV based alternative and Diesel standalone solution.

	Diesel Capacity (kW)	PV Capacity (kW)	Battery Capacity (kWh)
100% Diesel Standalone	100% Peak load	-	-
Hybrid PV/Diesel (no batteries)	100% Peak load	20% Peak load	-
Hybrid PV/Diesel (with batteries)	100% Peak load	160% Peak load (*)	432 kWh (*)
100% PV Standalone	-	280% Peak load	1942 kWh

(*) Designed for 50/50% ratio of solar/diesel energy supply.

Comparative costs between the alternatives simulations. For the mini-grid operation options (standalone diesel and hybrid systems) distribution cost must also be considered. It is possible to observe that in these alternatives, for the used assumptions, the costs of energy are very similar, just below 450 USD/MWh. Diesel standalone system is the most expensive of the mini-grid solutions due to its high operational costs (i.e. fuel consumption). As the solar energy is introduced in the system it is possible to observe that there is a slight decrease in the LCOE, because of fuel savings. When a 100% PV solution is considered (SHS), no distribution network is required and therefore there are no distribution costs. However, due to the high investment costs of batteries, the LCOE becomes the highest of the four alternatives, reaching 475 USD/kWh.

LCOE for SHS can decrease considerably in case of Grants or Concessional Finance. Since, no fuel is required in PV systems, their operational costs are practically inexistent, and consequently, the price of energy for this type of systems is mainly affected by the initial investment, CAPEX. This represents an opportunity cost for solar systems since in case of Grants or Concessional Finance, the resulting costs of energy can decrease substantially.

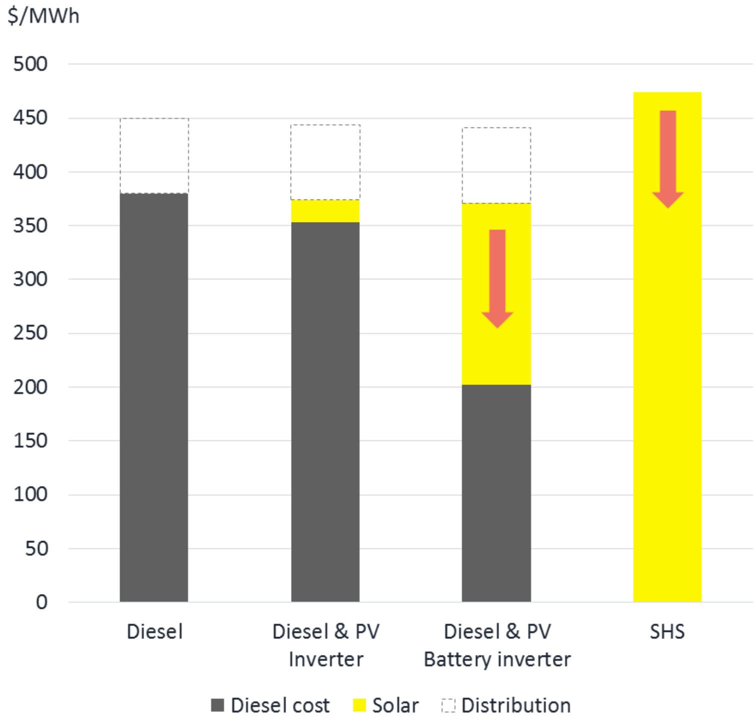

Figure 6.12 – Levelized Cost of Electricity, Monrovia example (5% WACC).

6.4.2.2 GRID ANTICIPATION – SOLAR/DIESEL TRANSITIONAL GRIDS

Hybrid solutions offer the possibility to anticipate electrification. Solar/Diesel hybrid systems are a very interesting solution to anticipate electrification in more remote settlements, where the national grid may take several years to come.

Solar/Diesel Transitional grids for short-term scenario. In the present work, a simple solution to enable grid anticipation was considered in a way that the implemented equipment of the mini-grid can continue in operation when the system is integrated in the national grid, thus optimizing the initial investment. The Solar/Diesel Transitional grids consist on several distributed low voltage (LV) mini-grids connected to different hybrid solar/diesel systems which would provide in the short-term, a first stage of electrification in an off-grid location. Transitional grids are better described in **ANNEX IV**. These hybrid systems are to be scattered within the community, as if they were Medium Voltage (MV)/LV transformation stations, forming several small clusters of isolated micro-grids. To avoid high PV and storage capacities, which would translate in high CAPEX costs, lower household service levels could be provided. As a hypothesis, a 12 hours supply service and 1 Amp per client limitation were considered.

Hybrid Systems design. The hybrid systems may have a wide range of design solutions, depending on several aspects, as PV radiation or consumption profiles. In order to ensure service continuity, thermal generation should always be designed for 100% peak load. To maximize its efficiency of operation, diesel generators would operate only in peak hours (~4 hours/day), and the remaining hours would be supplied by the renewable source. As discussed above, PV penetration depends on the combination of PV installed power and storage capacity, and several near-optimum solutions are possible.

Long-term scenario. In the long-term, when grid coverage is available, the hybrid systems would be replaced by transformation stations that would be connected to the existing LV grid and PV systems, which would remain in operation. For national network integration, the transformation stations would be connected with the required medium voltage distribution lines.

Case study for Salala. In order to evaluate the feasibility and economics of the Solar/Diesel Transitional Grids, a case study was performed for the community of Salala. Firstly, a demand assessment of the potential clients was performed, and then the hybrid systems were designed and distributed in the community as MV/LV transformation stations would, taking into consideration household scattering. In this case study, the considered solution consisted on a PV capacity equal to 100% peak load, and enough storage capacity for the nocturnal off-peak hours. Hence, during daytime, all consumption could be satisfied by solar resource, and the excess energy could be used to charge the batteries. Peak hours would be supplied by diesel generation and batteries would be used in off-peak hours. In total, five PV/Diesel systems were design according to the aggregated demand, and to the specific solar radiation of Salala community. The low voltage grids, emerging from the hybrid systems were also designed, as seen in **Figure 6.13**.

Long-term scenario for Salala. When the grid reaches Salala, hybrid systems can be replaced by MV/LV transformation stations, as shown in **Figure 6.14**. At this stage, additional investment would be required to connect the substations to each other and to the national grid. However, the existing LV grid, and the PV systems would continue to be used since they would be connected to the new medium voltage grid.

Case study conclusions. The case study revealed that the diesel generation would be responsible for 65% of total consumption and that the remaining 35% would be based on the renewable resource.

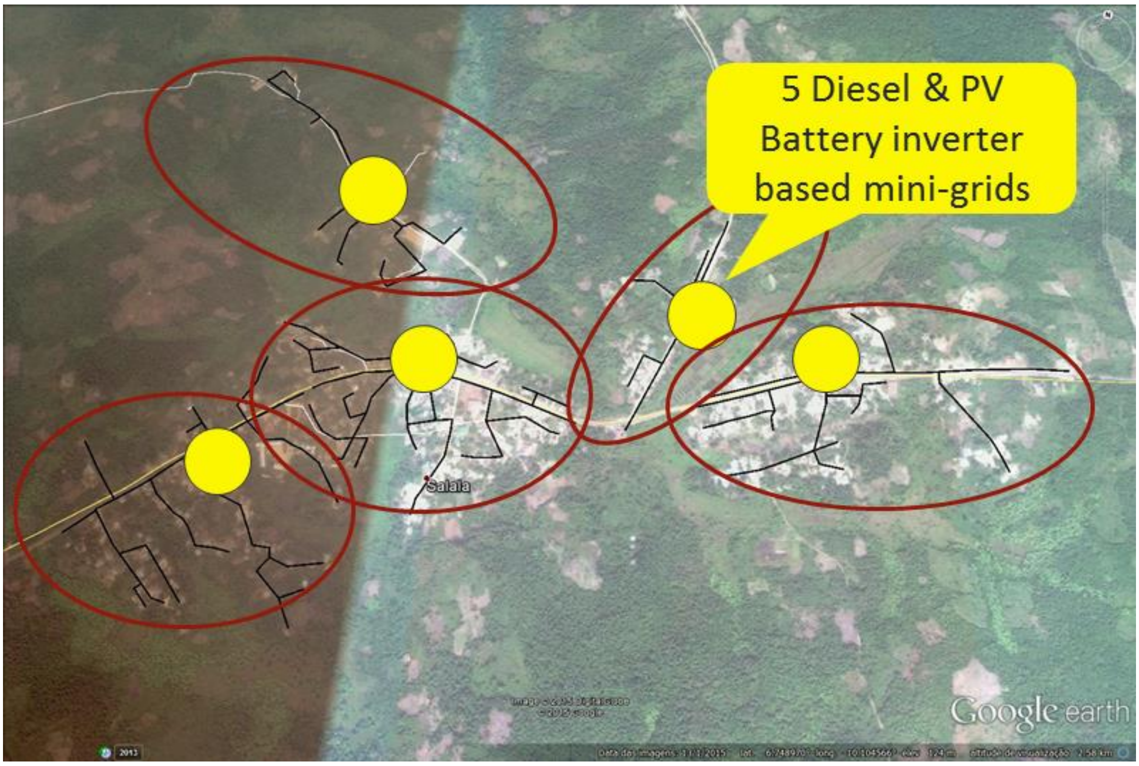

Figure 6.13 – Short-term mini-grids (low voltage).

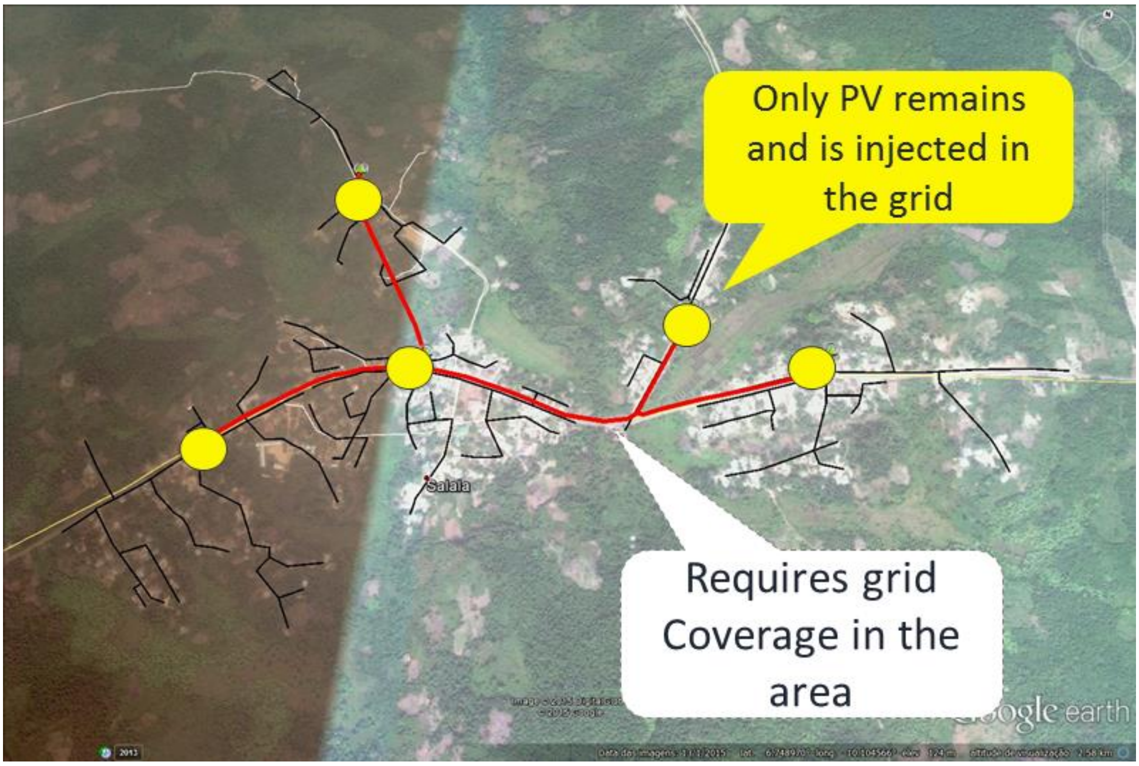

Figure 6.14 – Long-term medium voltage and Grid.

Budget of aggregated costs. All the equipment costs were budgeted and the main results of the designed system are presented in **Table 6.6** for both off-grid and on-grid operation. The aggregated costs of energy of the system are around 450 USD/MWh.

Table 6.6 – Short-term and Long-term scenarios for Salala.

	Solar / Diesel Transitional Grid (Short-Term)	Grid Connection (Long-Term)
Number of clients:	834 Residential + 18 Services	834 Residential + 18 Services
Limited service:	Residential clients: 12 hours / 1 amp per Household Services clients: normal services	Normal Service
Installed capacity:	340 kW (Solar: 170 kW + Diesel: 170 kW + 543 kWh batteries)	170 kW Solar (remaining from mini-grids) + 255 kW HFO (+50% load/24 hour service)
CAPEX generation:	USD 426k (510 USD/client)	Additional CAPEX generation (HFO*): USD 255k (+300USD/client)
CAPEX distribution:	(LV and client connection): USD 486k (585 USD/client)	Additional CAPEX Distribution (LV): None (MV): USD 106k + MV Grid extension (+125 USD/client)

Solution of Transitional Grids. Transitional Solar/Diesel Grids can be an interesting alternative to electrify remote communities until national grid access is available. This solution is a renewable energy based alternative with the objective to substitute diesel fuel consumption, thus reducing operational

costs and contributing for the reduction in greenhouse gas emissions. In addition due to small storage needs, investment costs are also reduced. Continuity in service is guaranteed due to diesel backup and a storage capacity. One of the main aspects of this solution is the optimization of the initial investments, since both the PV system and the low voltage grid can continue to be used, when the system is connected to the national grid. Additionally, as discussed above, the solar component allows a considerable decrease in energy costs, in case of Grants or Concessional Finance. In this case, the cost of energy could reduce to the predicted future tariff, keeping the sustainability of the system.

6.5 HYDRO POTENTIAL ASSESSMENT

6.5.1 INITIAL CONSIDERATIONS

Evaluation of hydropower potential. The evaluation of hydropower potential integrates hydrological results and terrain features as well as technical and economic criteria in order to obtain regions reflecting the higher or lower potential of the analyzed locations. For the development of these analyzes, the Consultant has spatial analysis tools as well as extensive experience in developing custom made models appropriated to each geography.

Hydropower potential map as an auxiliary tool to promote rural electrification. Hydropower potential map is intended as an auxiliary tool to promote rural electrification through hydropower, since it is a map with representation of the rivers and its hydropower potential as power capacity. This map allows identifying any site nationwide with generation capacity between any power ranges. Based on the hydropower potential maps, pico and micro hydro off grid were assessed based on an algorithm developed by the Consultant.

Small hydro feeding mini-grids. Concerning to small hydropower plants, a desktop study will be conducted in order to perform a preliminary design for the hydro potential sites identified in the past and calculate different LCOE's for different hydro size. The different hydro solutions will be compared with demand size of closest clusters of settlements (potential mini-grids) or future sub-stations (which could be electrified before based on such mini-hydro). In terms of rural electrification, this kind of mini-grids present several advantages, namely the possibility of constituting transitional grids for places where grid should meet in the long term, given the usual low generation LCOE's for this kind of project.

6.5.2 AVERAGE ANNUAL FLOW

The average annual flow was obtained by applying the Turc method. Turc method consists on a formulation that determines, for each watershed, the flow deficit considering only climatic variables: average temperature and mean annual precipitation. Its application is particularly suitable when the existing hydrometric data not allows describing properly the hydrological phenomenon, as is the case of Liberia.

Performing Turc method using GIS. In the present study, the implementation of Turc methodology was performed using a Geographic Information System. The procedure was computed in matrix format

(raster), with a resolution of 30 x 30 m and as result an average annual runoff value at each pixel was obtained. The flow value calculated for each pixel corresponds to the annual average runoff in the catchment area defined by that pixel. This methodology was applied in all river basins of Liberia discretized for each pixel, for which precipitation and temperature (annual average) of the watershed were calculated. Annual average precipitation and temperature in the catchment area defined by each pixel were obtained considering data available on WorldClim website.

The average annual runoff obtained by Turc Method is presented in Figure 6.15, as well as annual average precipitation and temperature.

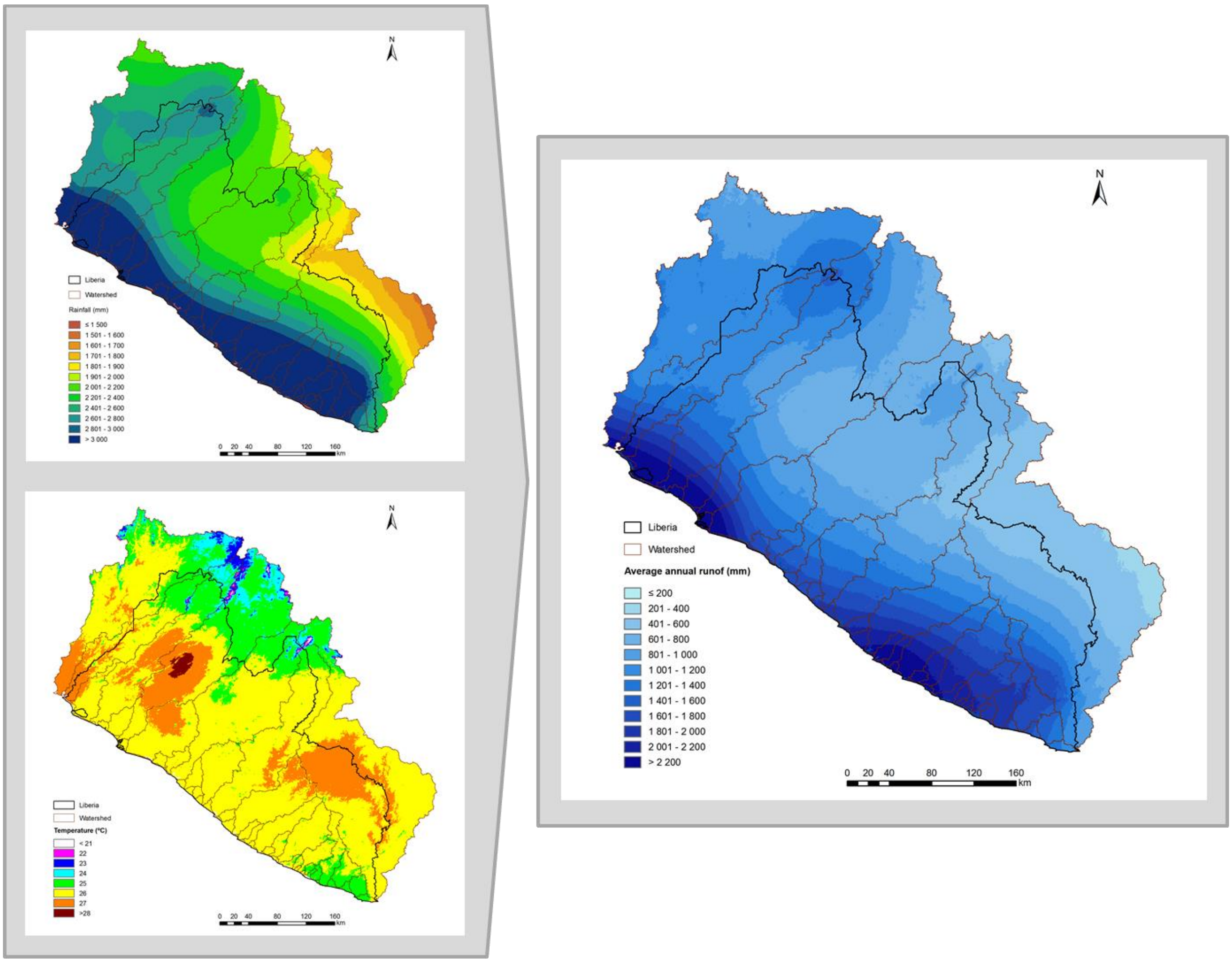

Figure 6.15 – Scheme of Turc formulation.

6.5.3 HYDROPOWER POTENTIAL MAP

Hydropower potential map. In theory, hydropower potential map is the mapping of possible capacities that can be installed on each point of the analysis, considering the estimated average daily flow rate and the usable head at each point. Based on the runoff map of Liberia obtained by Turc formulation, it was possible to determine the modular flow at each point of the territory. Gross head was calculated based on the difference of altitudes given by the digital terrain model of the Shuttle Radar Topography Mission (SRTM).

The hydropower potential is determinate by:

$$P = \eta \, \gamma \, Q \;\; H \qquad (6.1)$$

where:

P – capacity (W)

η – turbine-generator efficiency (86%)

γ – specific weight of water (kN/m^3)

Q – design flow (m^3/s)

H – net head (m)

Design flow and net head and global efficiency were determined differently according to main objective of the hydropower potential map, as is exposed in **Figure 6.16**.

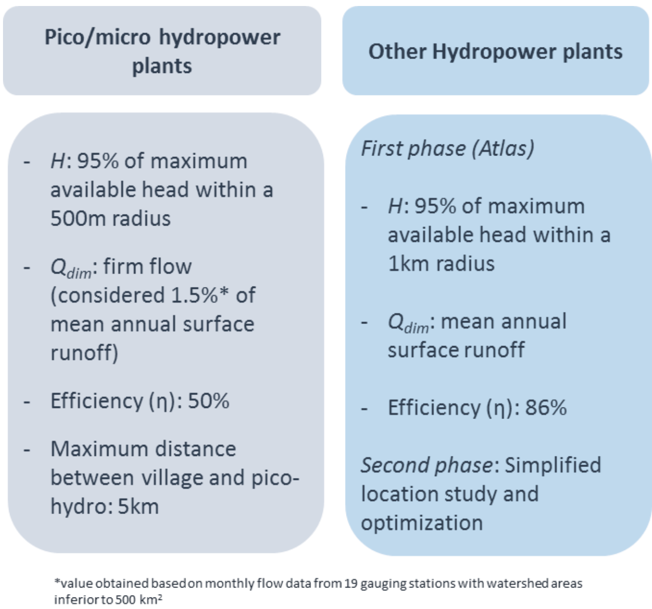

Figure 6.16 – Hydropower potential map inputs.

Average annual isoenergetic lines. To complement the map of hydropower potential, average annual isoenergetic lines were also calculated, that express the producible energy per unit area per year. The expression used was as follows:

$$W \; = \; 0.002 \, E \, h \qquad (6.2)$$

where:

W – average annual energy (kWh/m^2)

E – flow (m)

h – altitude above mean sea level (m)

Hydropower potential map obtained for small hydropower assessment is presented in **Figure 6.17**.

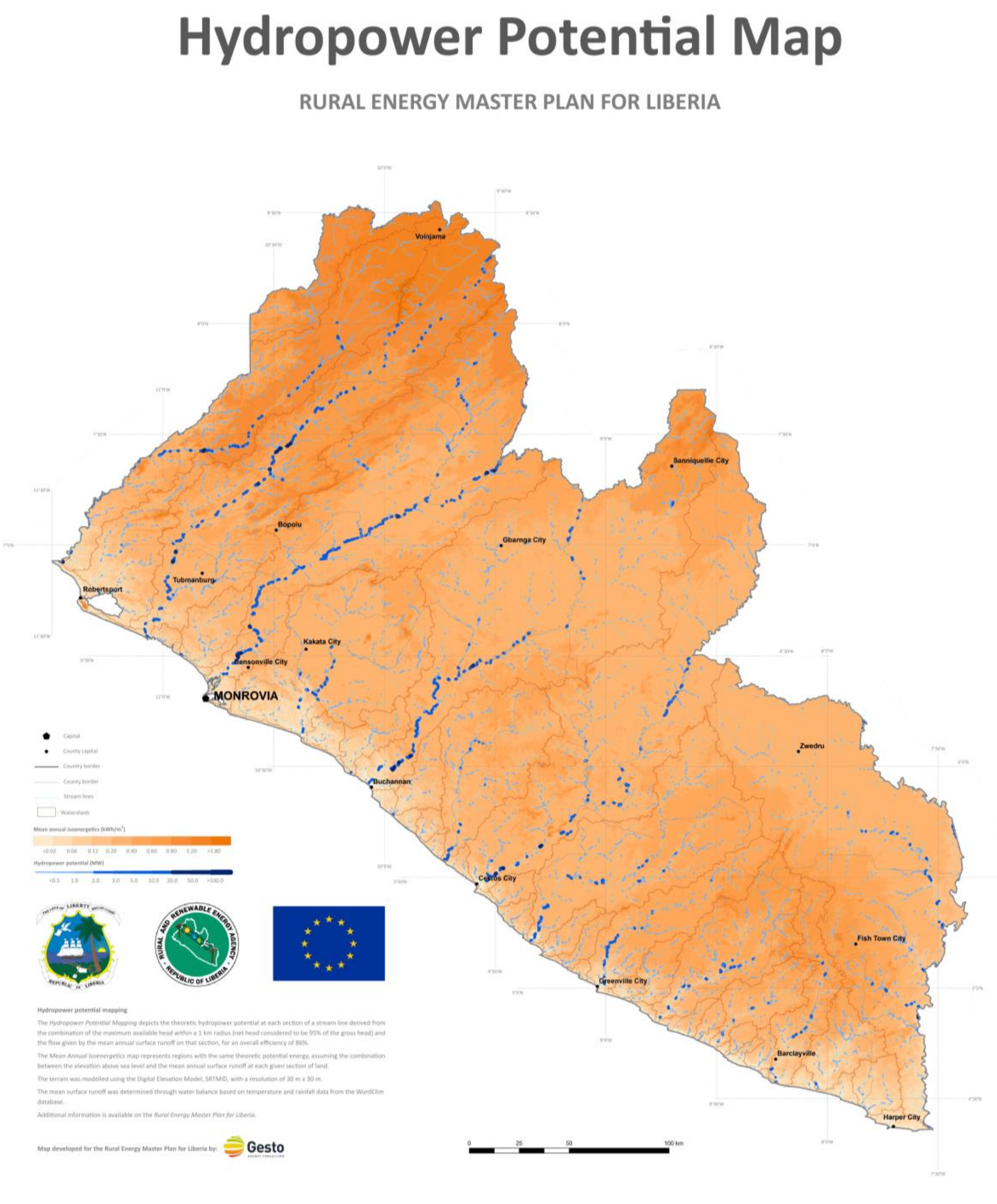

Figure 6.17 – Hydropower potential map.

In **ANNEX VI**, a more detailed methodology used in determining the potential map is presented.

6.5.4 PICO AND MICRO HYDRO ASSESSMENT

Pico and micro hydro definition. According to the Liberian White Paper, pico and micro hydro differs by power output ratings, so, hydropower systems with installed generation capacity from 100 W to 1 kW are denominated pico hydro and micro hydro are the ones with installed capacity from 1 to 100 kW.

Objective of pico/micro assessment. The main objective of pico and micro assessment is to find for each village, a hydro location with sufficient capacity to feed its power peak. To do so, an algorithm was developed by the Consultant in order to identify the hydro locations. As input in the algorithm, villages' locations and its respective long term power peak were required, as well as the hydropower potential map.

More than 8 000 villages were analyzed with the algorithm, and as a result, more than 700 pico and micro hydropower plants were identified as a possible solution to feed the villages, considering a maximum distance of 5 km between the village and the hydropower plant. In **Figure 6.18**, villages and pico /micro hydro locations are presented.

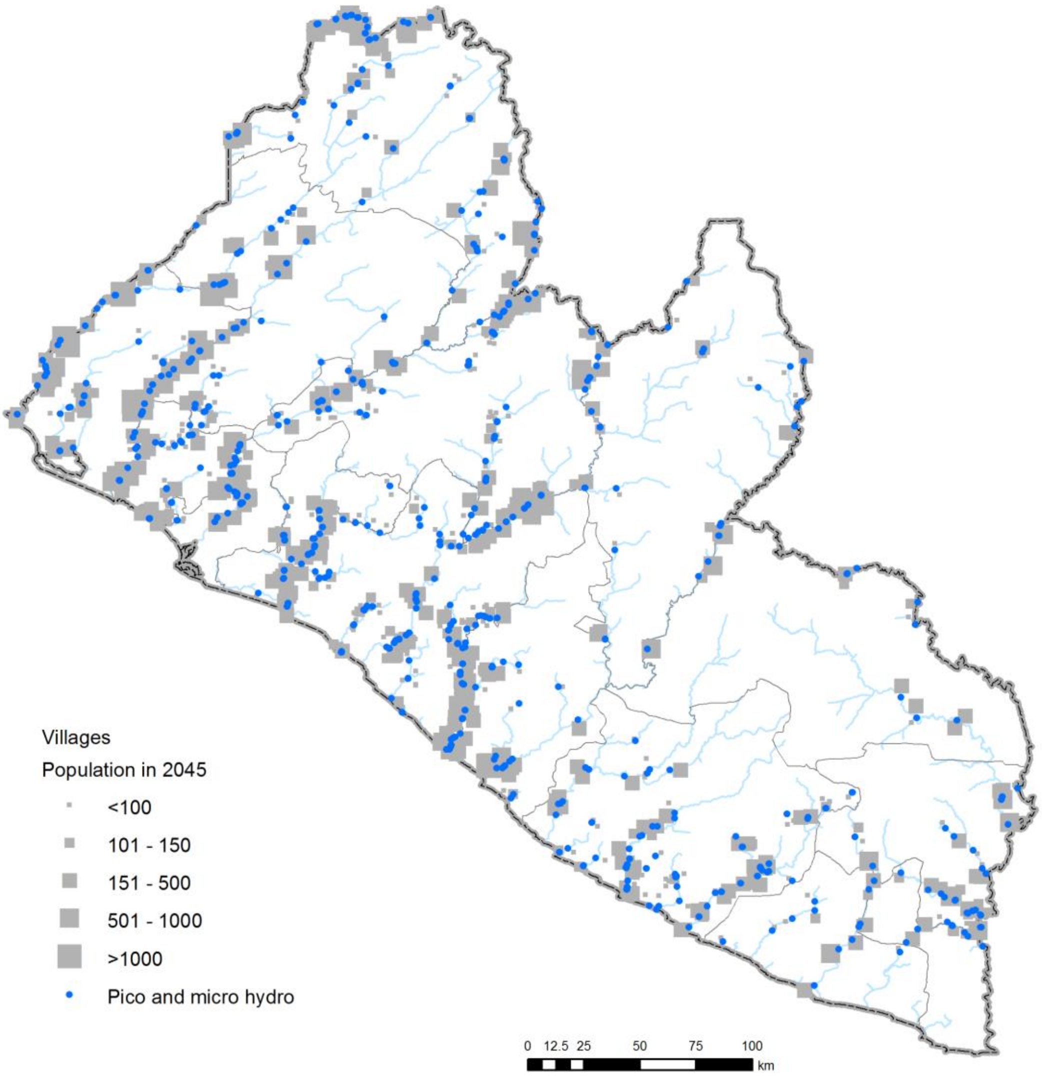

Figure 6.18 – Villages that can be feed by a pico and micro hydro solution, including each pico/micro hydro location.

Ranges of LCOE obtained. Costs of all the 769 pico and micro hydro were obtained by applying simplified cost curves. As a final result, levelized costs of energy were obtained for all micro end pico hydro analyzed. The range of LCOE's obtained is 243 to 6816 USD/MWh (**Figure 6.19**).

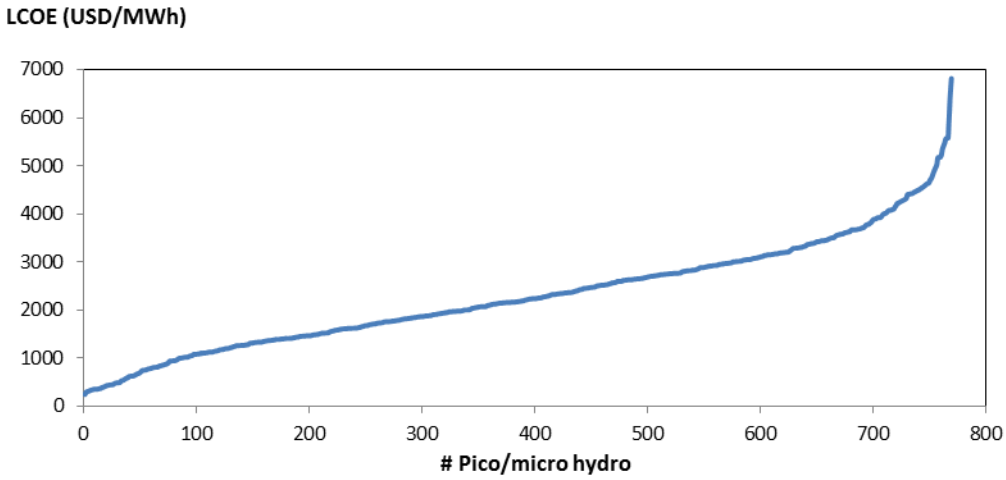

Figure 6.19 – LCOE's range for pico/micro Hydro.

The end of this analysis led to the selection of 9 locations (see **Figure 6.20**), which have lower cost than solar/diesel based mini-grids and will not be connected to grid up to 2030.

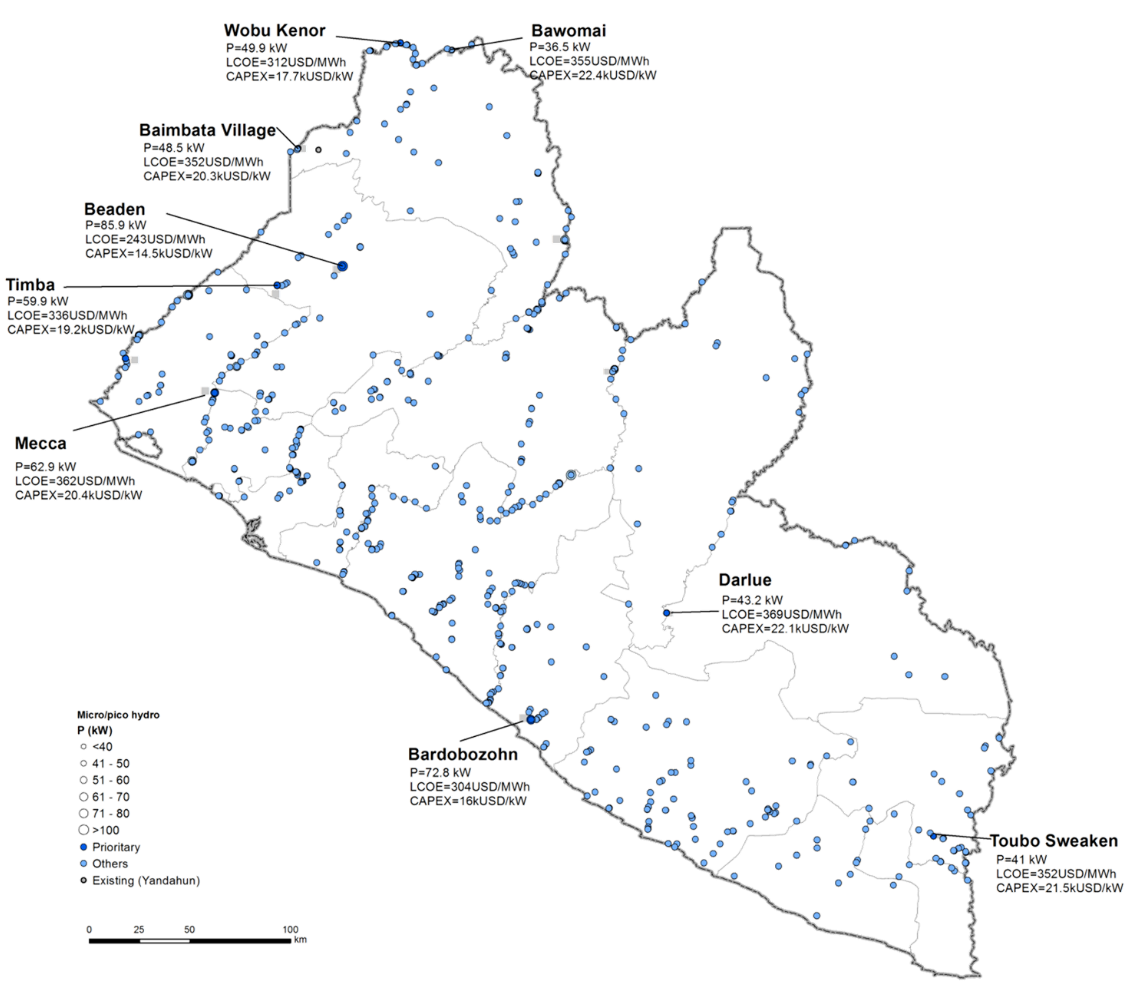

Figure 6.20 – Micro hydro selected.

Local studies are required in further stages of the projects. It has to be noted that the study performed evaluate micro hydro in an automatic way and offers only an indication of potential. Given small size of the hydropower projects, local studies are required to confirm location and respective geometric characteristics.

In **ANNEX VII** a description of the methodology used in pico and micro hydro assessment are presented, including restrictions of the algorithm developed by the Consultant, cost curves used and economic assumptions included in the analysis. Results obtained for 769 micro hydro identified are also included in the mentioned Annex.

6.5.5 SMALL HYDRO ASSESSMENT

Collection of old hydropower plants studies. Small hydro analysis began with the collection of old studies that includes hydropower plants identification and analysis. The hydropower plants identified in the past were georeferenced and evaluated with the goal of update the old analysis.

Georeference of hydropower studies identified in the past. Despite all the efforts to identify and georeference hydropower plants previously studied, each exact location was not always possible to

obtain, since they are included in country level studies or even a national plan with a scale that does not allow identifying the exact location of the dam and power house. Nevertheless, a total of 147 hydropower plants were georeferenced and included in a database with a total of 2.4 GW of cumulative installed capacity. Note that the cumulative capacity is taking into account many hydropower plants that do not have information about the capacity to install.

In **Figure 6.21**, hydropower plants georeferenced are presented.

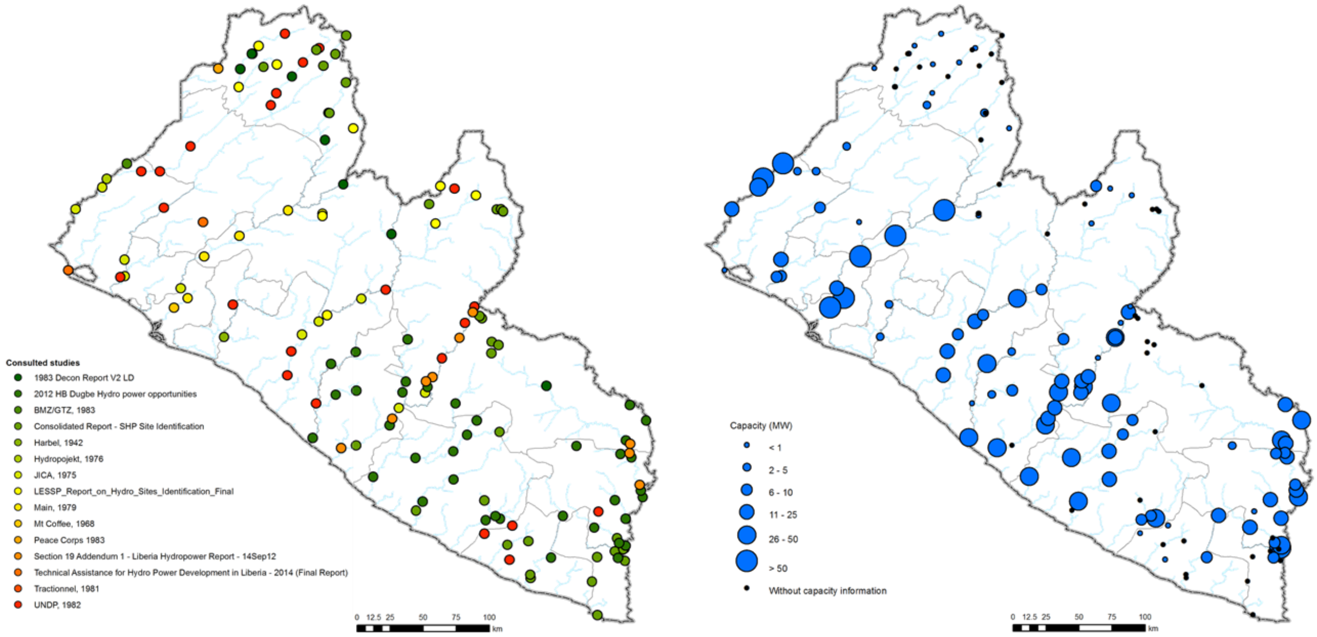

Figure 6.21 – Hydropower plants georeferenced. Left: Old studies consulted. Right: Expected capacity to install included in the old studies.

Methodology used to update the old studies. After georeferencing hydropower plants, a simplified pre-feasibility approach were done in order to update old studies. The methodology used is as follow (and is presented in **Figure 6.22**):

a. Find the best location (or locations) near the georeferenced place to implement hydro projects. In this analysis hydropower plants located in international rivers were excluded, since international agreement between both countries will be needed to its construction
b. Verify the geometric and hydrological characteristics (head, mean surface runoff, hydraulic circuit length, etc.). It has to be noted that during the execution of this work, it was impossible to obtain topographic maps of Liberia and the definition of the geometry of the hydropower plant was made taking into account contour lines generated from SRTM, with poor resolution.
c. Calculate investment costs using cost curves calibrated from existing feasibility studies. Since the objective of this characterization is the preliminary study of the hydroelectric power plants in order to ranks the projects and the update of old studies, it is not feasible to do market research to obtain the cost of each individual hydropower plant component. Thus, the costs were obtained using simplified cost curves calibrated with existing studies to reduce inaccuracy.

d. Obtain modular flow for each location, using Turc method calculated with World Clim global data, given very limited local hydrological data available. Obtain mean annual power production, using duration curves determine with three gauging station data available.
e. Investment cost and Levelized Cost of Electricity determination and optimization.
f. For the hydro with most potential for rural electrification (LCOE and location) study best alternatives for 1, 2, 5 and 10 MW capacity.

Algorithm developed by the Consultant to define the main characteristics of hydropower plants. To identify the best solution for each location in terms of geometric and hydrological characteristics an algorithm was developed by the Consultant. To make this task possible and obtain the desired results, various assumptions had to be made in the algorithm, namely, economic criteria, design assumptions, investments costs of the hydropower plant, and also simplified hydrological data to make this analysis the quickest as possible. These assumptions are presented in **ANNEX VII**.

Algorithm objectives. For each location, the algorithm tests different design solutions (different dam height, design flow, hydraulic circuit length etc.), and costs and energy production are determine. The solution with lower LCOE value is selected.

In **Figure 6.22** methodology applied on hydropower plants analysis are presented.

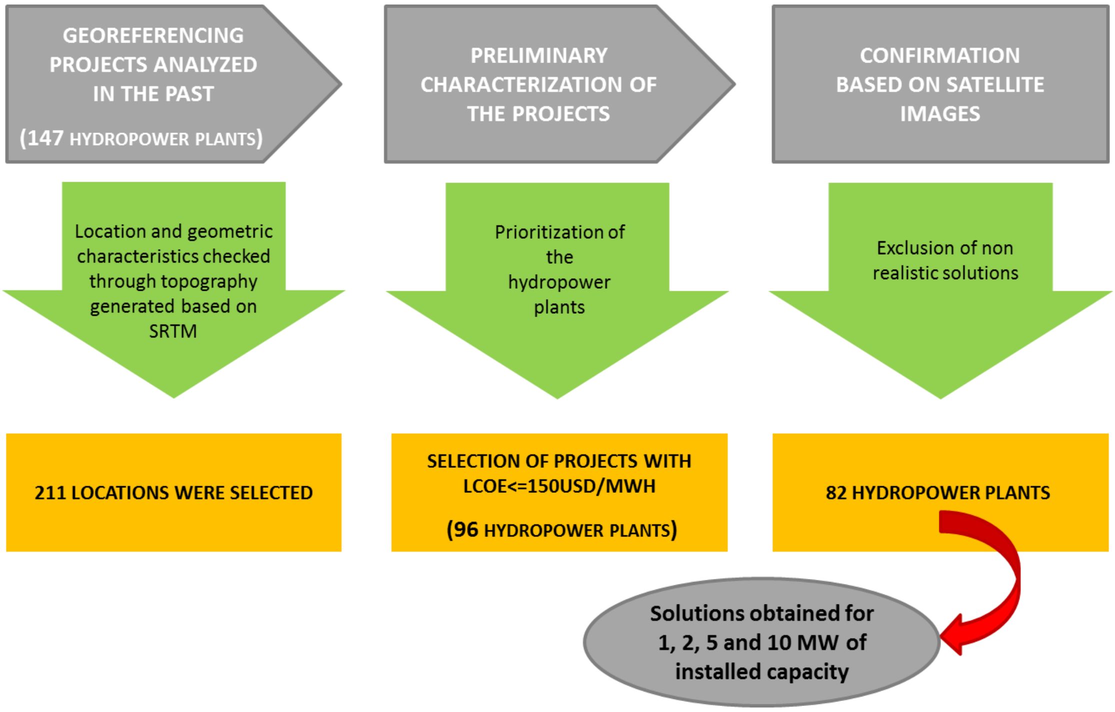

Figure 6.22 – Methodology applied on hydropower plants analysis.

Ranges of LCOE obtained .The range of LCOE's obtained to the 211 locations is 39.8 to more than 25000 USD/MWh. Hydropower plants with low LCOE are the ones presented in main rivers, with concentrated head nearby. Hydropower plants with high value of LCOE are the ones located in small rivers, with modular flow lower than 5 m^3/s. In **Figure 6.23**, hydropower plants are presented by capacity installed and LCOE value.

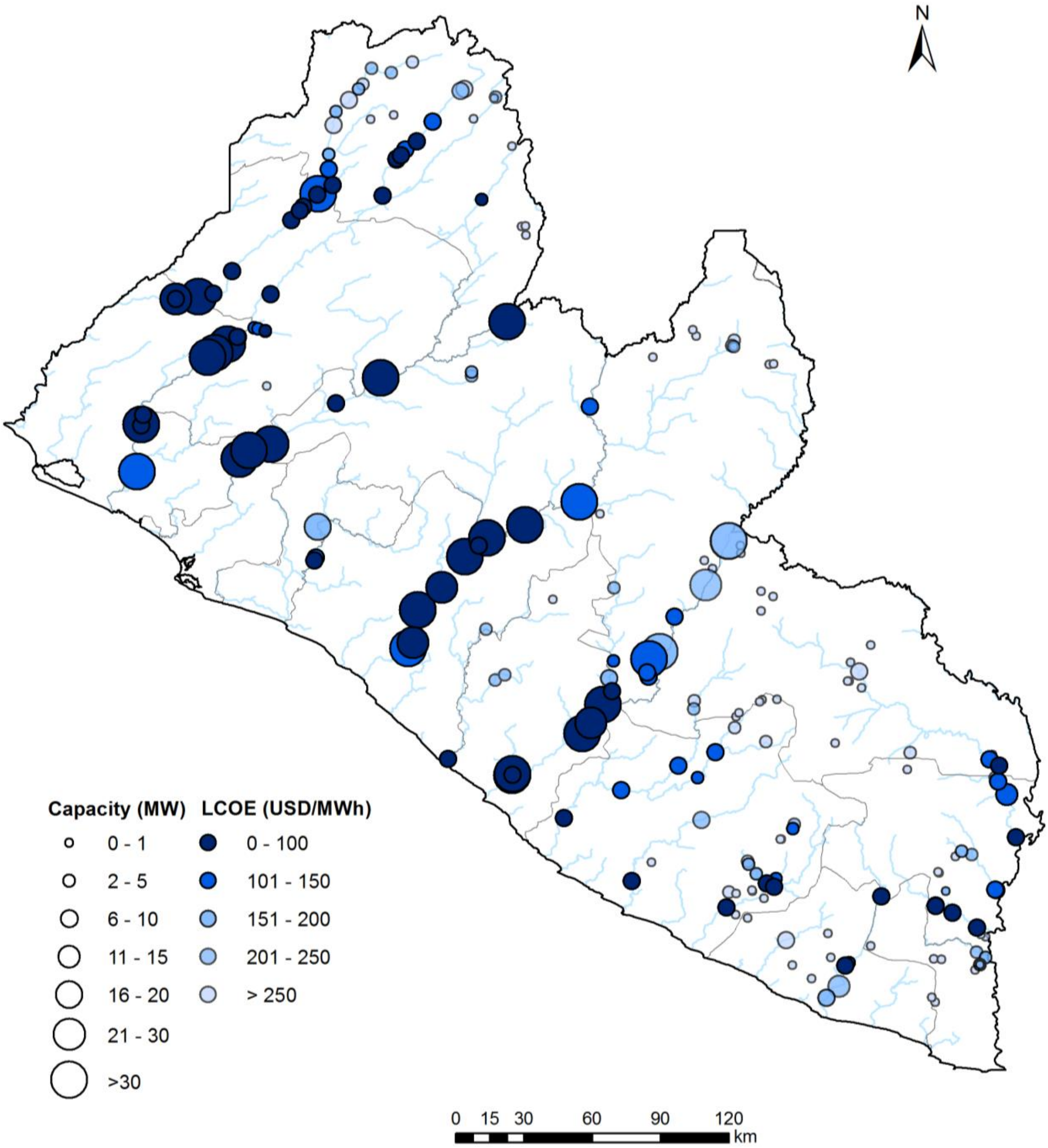

Figure 6.23 – Hydropower plants results (solution: lower LCOE).

Most competitive hydropower plants located in Liberian main rivers. As it can be seen in **Figure 6.23**, most competitive locations (hydropower plants with LCOE inferior to 150 USD/MWh) are large hydropower plants located in the main Liberian rivers, however there are some mini hydropower plants, with installed capacity between 5 to 10 MW that have also LCOE inferior to 100 USD/MWh.

In **Figure 6.24** a summary of LCOE results is presented and is reaffirmed that there are 309 MW with a low value of LCOE that requires more detailed studies.

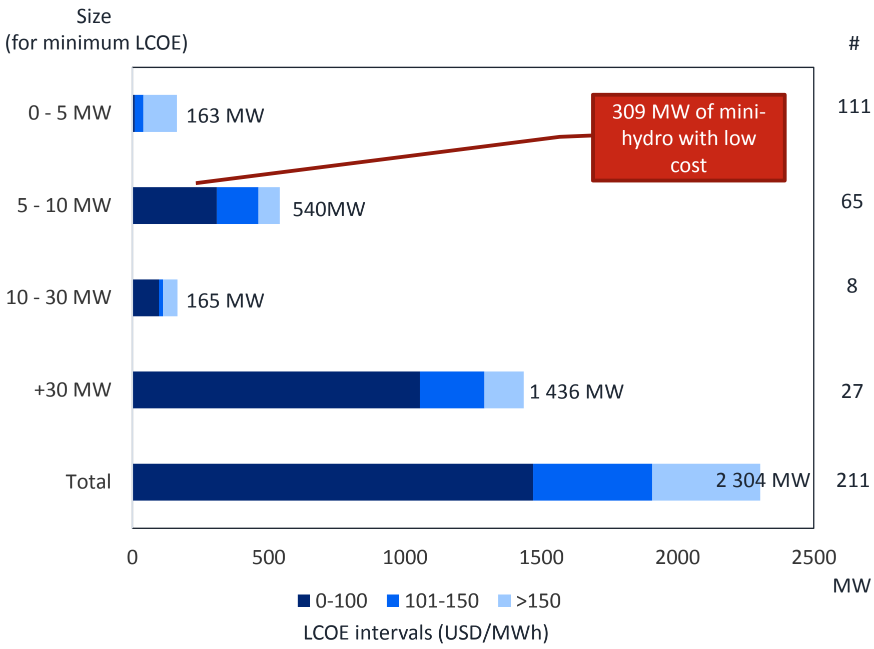

Figure 6.24 – Hydropower potential and cost summary.

Further studies have to be done in locations with high natural heads and flows above 50 m^3/s that seems to be optimal for 5 to 20 MW hydro schemes. As mentioned before, Liberia hydro potential is concentrated on large rivers (high mean annual flow) with low heads, concentrated most of the potential in St. Paul and St. John, Cestos and Lofa rivers. The hydropower schemes in these large rivers are dam based powerhouses power plants, where cross section narrowness and flow are key economic parameters. However, the hydro assessment study identified several locations with high natural heads and flows above 50 m^3/s that seems to be optimal for 5 to 20 MW hydro schemes (mini/medium hydro), with potential for lower costs given higher natural head, as it is showed in **Figure 6.25**.

It must be stressed that the number of sites studied are only a portion of Liberia's total potential. Thus a comprehensive hydro mapping study should be undertaken in the future.

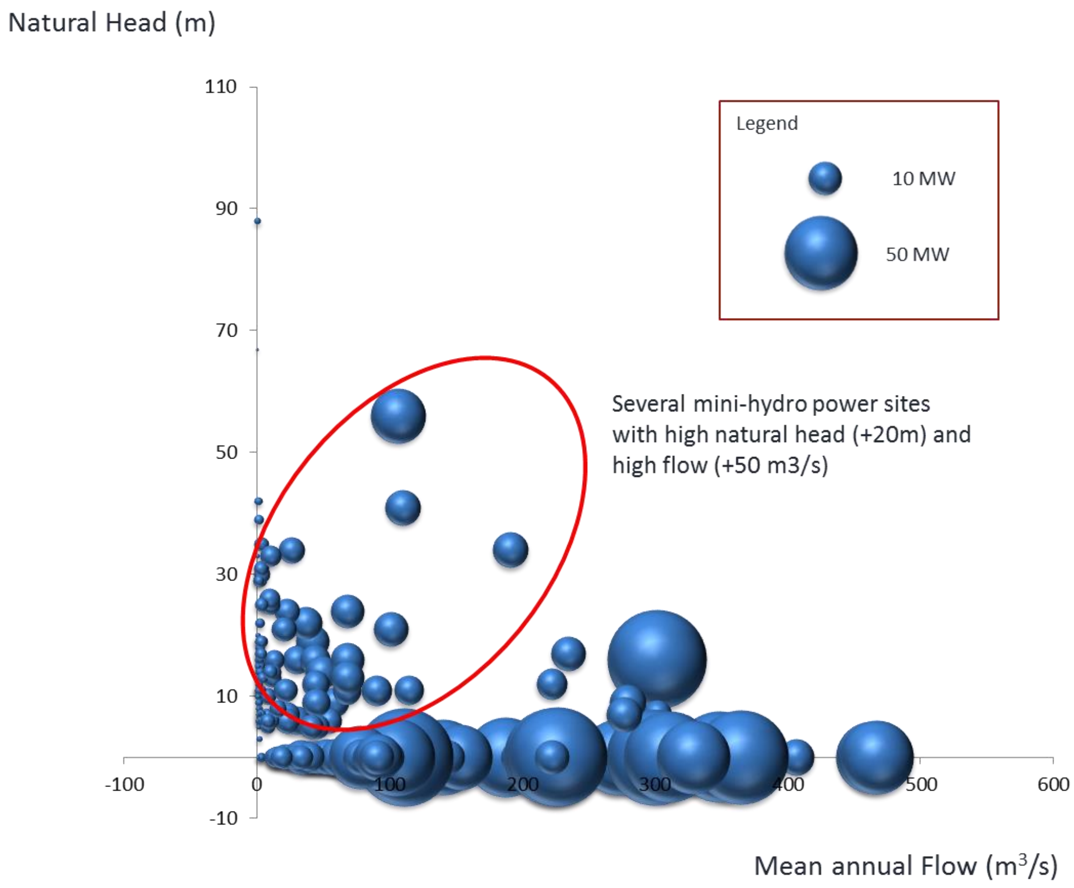

Figure 6.25 – Distribution of head and flow among 211 studied hydro sites.

82 locations with LCOE inferior to 150 USD/MWh. The most competitive locations (LCOE lower than 150 USD/MWh) were confirmed based on satellite images. With this analysis 14 hydro locations were excluded because its solutions obtained by the algorithm were not a realistic solution. At the end, 82 locations were validated and were studied for rural electrification according to Grid expected growth and area potential demand. Sizes of 1, 2, 5, 10 MW were considered. The main results of these hydro projects are presented in **ANNEX VII** and in **Figure 6.26**.

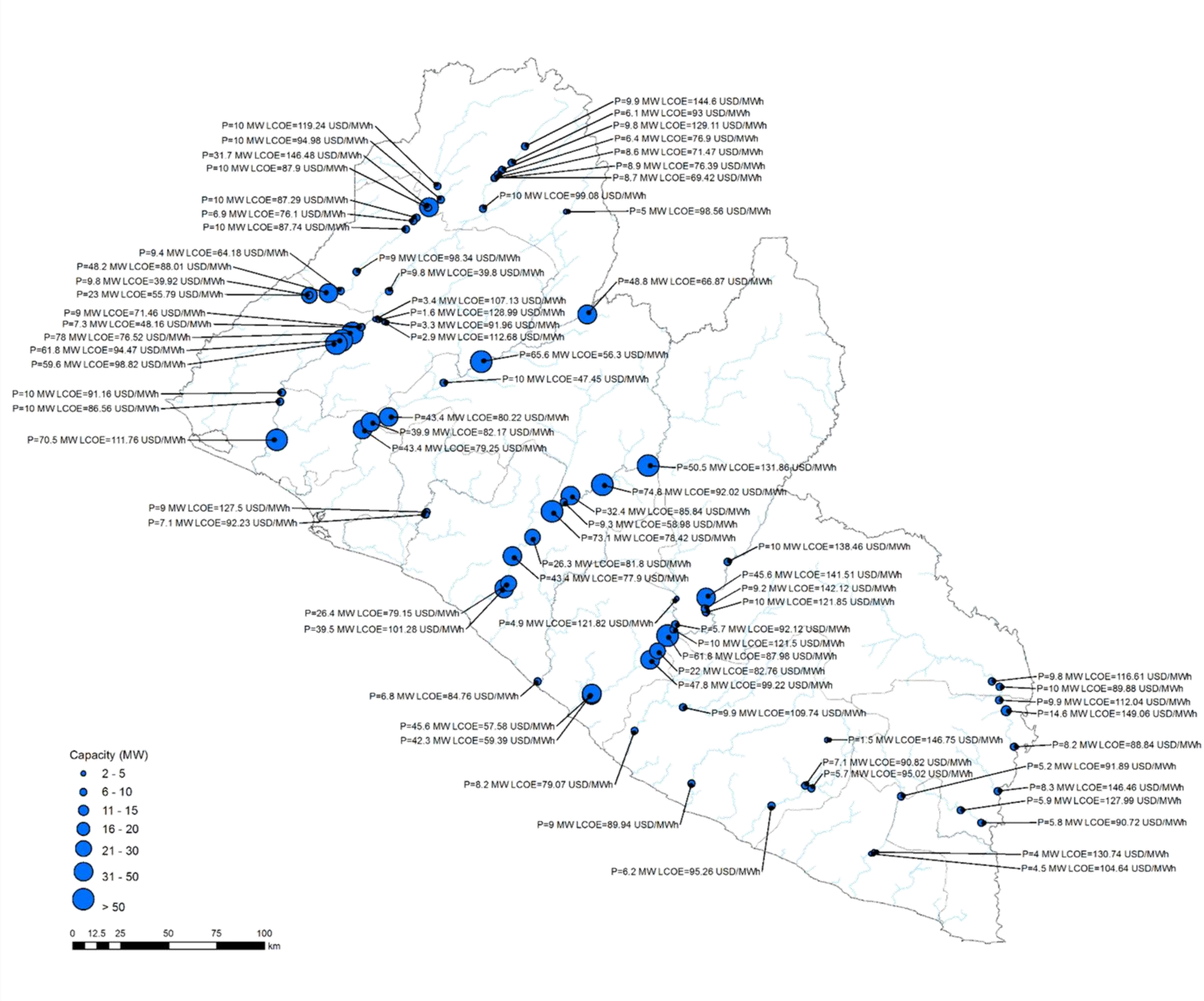

Figure 6.26 – Hydropower plants with LCOE ≤150USD/MWh.

Priority hydropower plants. After the analysis of the hydropower schemes with LCOE lower or equal to 150 USD/MWh, five mini-hydro were considered priority locations due to its locations near big villages. One Medium-hydro site (River Cess) was also selected given its potential impact on High Voltage (HV) grid extension decision from Buchanan to Pleebo. Two alternative sites were also identified. Priority sites are presented in **Figure 6.27**.

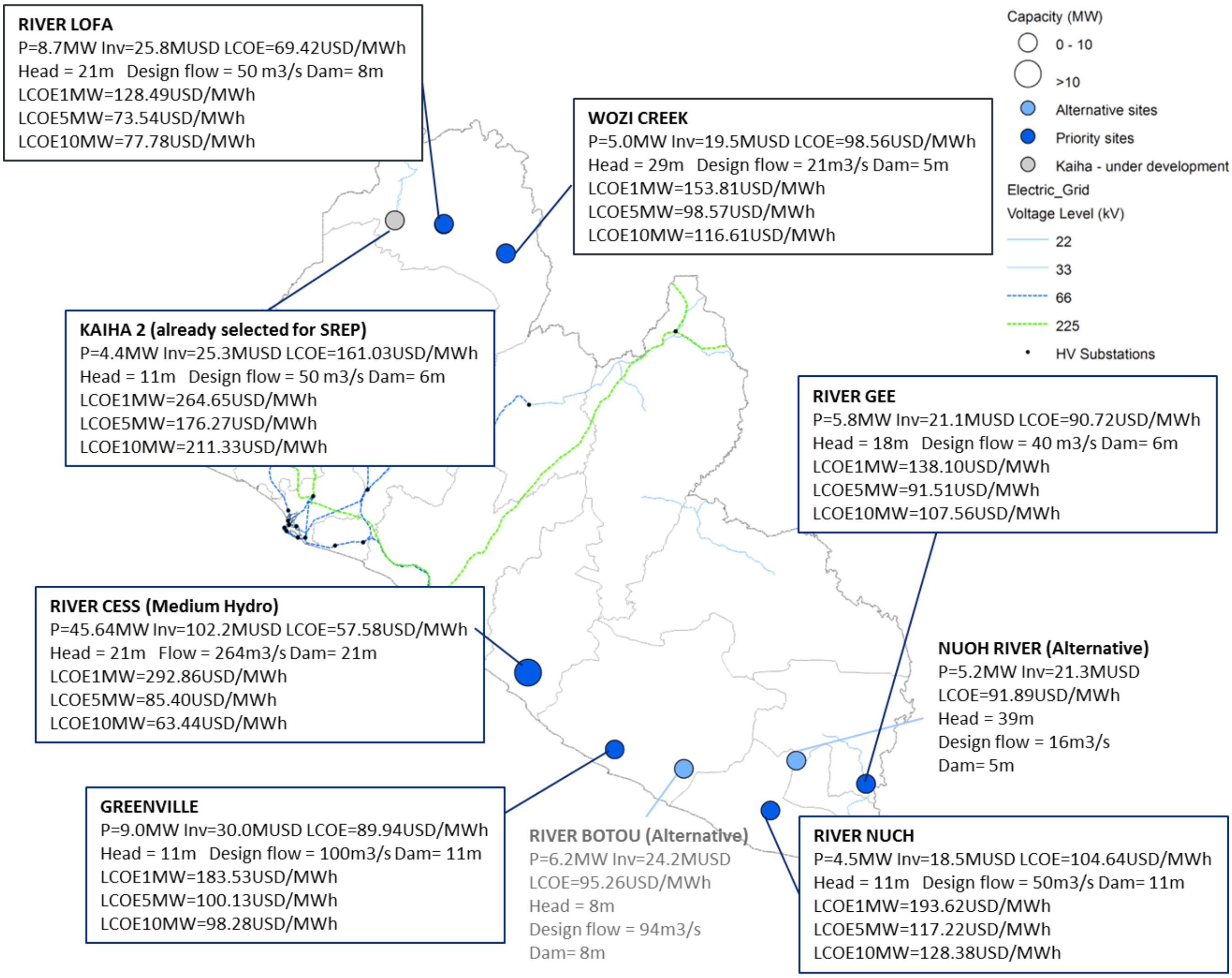

Figure 6.27 – Priority hydro sites for rural electrification.

6.6 SUMMARY OF MAIN SUPPLY ALTERNATIVES FOR RURAL ELECTRIFICATION

Introduction. Before implementing rural electrifications projects, an exhausted study must be prosecuted in order to compare technologies options and identify the best alternative for each location considering local renewable energy potential. Once it is established that connecting an unserved community via grid extension is not justified, decentralized technology or mix of technologies have to be analyzed to identify which solution is suitable.

Individual systems and micro/mini-grids definition. There are two types of rural electrification considering the characteristics of the settlements/ villages to electrify: Individual systems, appropriate to install in settlements where customers are few and dispersed and their main electricity use is lighting, and micro-grid or mini-grid, where most costumers are concentrated enough to be economically interconnected.

The general decision-making steps in off-grid project design and the typical technology choices are illustrated in **Figure 6.28**.

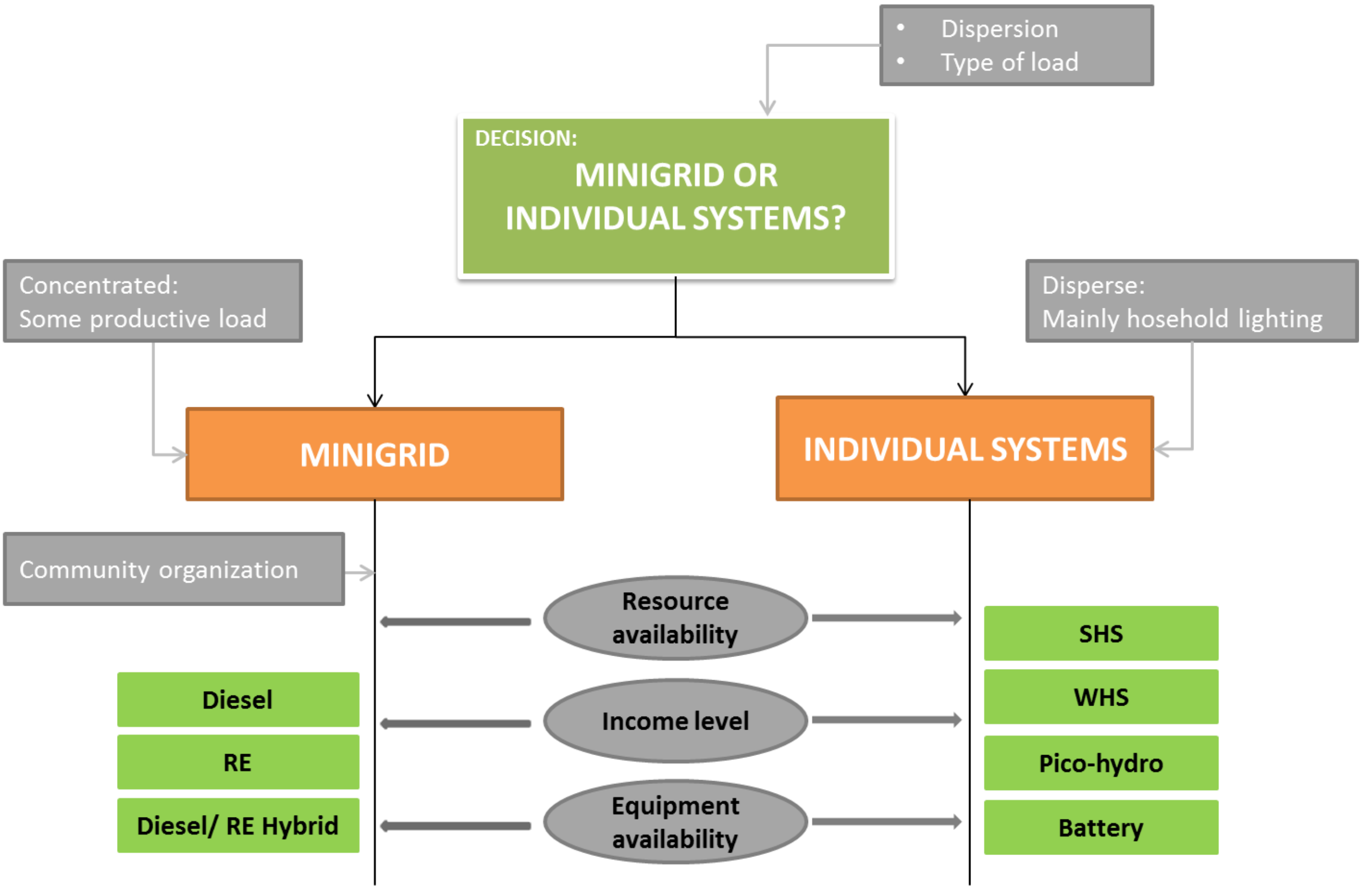

Figure 6.28 – Decision-making steps in off-grid project design.

As it can be seen in **Figure 6.28**, there are many alternatives for energy supply in rural electrification.

Rural electrification solutions to install in Individual systems. For individual systems, the most common are se solar home systems, but is possible to install also wind home systems (WHS) and pico-hydro, for example where small farms, or clustered households are located near the river. World Bank has also some pilot projects using centralized battery charging systems powered by solar PV, known as the solar battery charging station (SBCS).

Rural electrification solutions to install in micro/mini-grids. Micro or mini-grids are dimensioned to feed an entire village or settlement and it is possible to install diesel generators or/and RE projects. Diesel generators ranging from a few kW portable systems to MW-capacity power plants have been the traditional solution to decentralized electrification needs. They can provide larger amounts of power at much lower investment cost per kW than hydropower or wind-based alternatives. For off-grid applications, the two main disadvantages of diesel are 1) the high cost of fuel and its transport to the remote site and 2) the need for regular, skilled maintenance of equipment. The latter disadvantage also applies to certain RE systems, such as biomass gasifier engines. Recent skyrocketing oil prices have dramatically increased recurring fuel costs and greatly diminished the low capital-cost advantage of the

diesel option. Nevertheless, in many situations, diesel mini-grids may still offer the most practical solution.

RE solutions limitations. However, REs that use wind, hydropower, and biomass face strict limitations imposed by site specificity and seasonality of resources. For example, micro and mini-hydropower plants can only be built at sites where hydropower resources meet minimum requirements for head and flow rates on a year-round basis and wind-power systems require average wind speeds of at least 4 m/s [31] for small turbines. To gain confidence in the continued availability of the resource, site monitoring of wind speeds must be conducted for at least a year prior to building a turbine. Biomass-based systems must be assured a constant supply of the appropriate type of biomass fuel over the project life.

Hybrid solutions. Seasonal and daily resource variability adds significantly to the cost since the off-grid generating source must be designed to meet the energy demand when resource availability is lowest. For example, a micro-hydropower plant large enough to supply demand during the dry season would have to dump the energy generated in the other months unless optional loads could be added at that time. To circumvent the problem of intermittent resources, wind and even small hydro systems are sometimes hybridized with diesel generators. Such hybrid systems are used in cases where interruptions in electricity supply cannot be tolerated. PV systems have also been used in hybrid systems with diesel and wind but the significantly higher cost of PV may make such combinations uneconomic, except when the electricity is used to reduce expensive fuel consumption. Hybrids with diesel generators are possible only where diesel fuel can be reliably transported to the site and users can afford fuel costs that may escalate over time.

Individual systems: solutions adopted in Rural Energy Master Plan for Liberia. During the development of this work, only SHS were considered to implement in individual systems, because PV is the only technology that can function virtually anywhere despite geographic variations in the resource (i.e., solar radiation intensity or number of days without sunshine). In most areas of developing countries, the solar resource is more than sufficient throughout much of the year to enable PV systems to function usefully. There is usually no need to conduct a solar radiation measurement program during the pre-investment phase. PV systems are modular and rugged; they require little maintenance (mainly periodic cleaning of the glass panel), although arrangements must be made to obtain spare parts and repair services.

Micro/mini-grids: solutions adopted in Rural Energy Master Plan for Liberia. Concerning to micro and mini-grids, various technologies were evaluated to feed the villages and settlements and the economical option was selected for each grid. Depending on the expected consumption, some technologies shown to be more economical than others:

- When the expected consumption is very low, only solar, diesel and solar/diesel hybrid solutions were considered in this study, since pico and micro hydropower plants showed to be very expensive when compared with these technologies. Biomass is not a possible alternative due to the reasons presented on chapter 6.3.2.

- When consumption is higher, the technology that shows to be the most economical is mini-hydropower, when is possible to install this type of projects. However due to the high intra-annual variability of the resource and the impossibility of river's regularization, hybridization is needed. During this study, the annual complementarity between hydro and solar was analyzed in order to evaluate the negative correlation of these two renewable energies (see **Figure 6.29**).

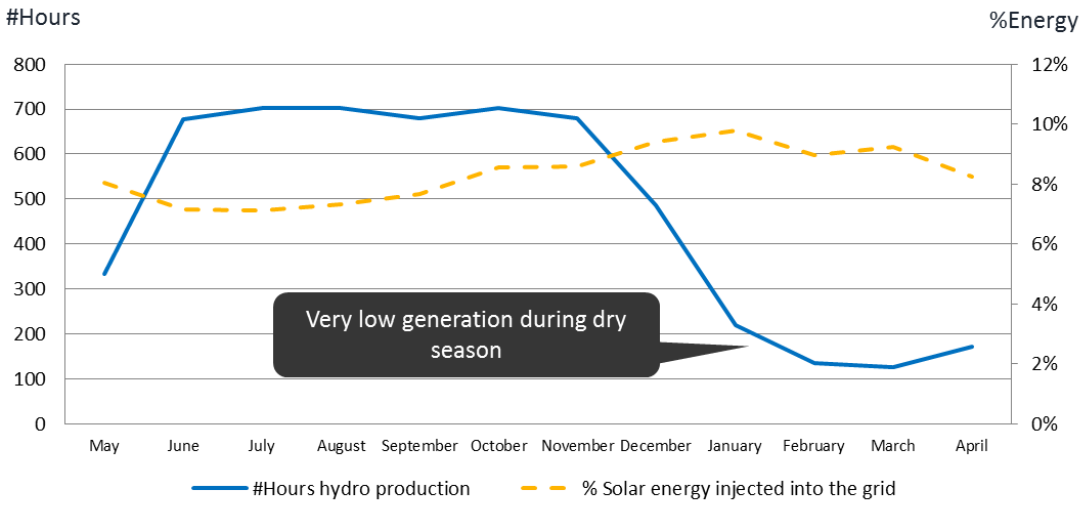

Figure 6.29 – Example of monthly generation profile of River Lofa hydro and a solar plant.

As it can be seen in **Figure 6.29**, despite solar radiation has negative correlation with hydro, still generates a lot of energy in wet season. However, solar could be integrated with hydro using intraday storage (peaking pond). During dry season, hybridization with thermal generation (diesel or biomass) will always be required. In these cases, when consumption is higher, biomass appears to be an alternative to diesel, depending on the scale of the project.

7 LONG TERM NETWORK EXPANSION RESULTS

7.1 INITIAL CONSIDERATIONS

Present situation. Liberia has one of the lowest electrification rates in the world, and the great majority of customers are located in the Monrovia, since it is the only area with fairly consolidated grid coverage. Nowadays, rural electrification is practically inexistent, with the exception of a few generation and electrification developments, namely the Yandahun micro-hydro, some solar villages and the Cross-Border initiative. Additionally, a first stage of the grid expansion is already underway with the Monrovia Corridors extension, destined to electrify important demand points close to the capital, and the construction of the 225 kV international system, which will connect Liberia to Cote d'Ivoire, Sierra Leone and Guinea.

Methodology. The methodology to reach the vision for 2030 was firstly to get a glimpse of what could be the electrical system in the long term[8], and then backtrack to 2030 having in consideration the chosen targets for that year. This Chapter has the objective to exhibit a possible long term network of Liberia. The assessment of this network consisted in two steps:

- The first task was to retrieve all the existing and planned grid, detailed in **ANNEX VIII**, and from there expand the medium voltage network in order to connect all the grid compatible demand points in the long run, i.e., the settlements that, due to its specific demand and distance to the network, should be connected to the national system. To perform the grid expansion, the Network Planner Tool, developed by Columbia University's Modi Research Group and the Earth Institute, was used. Thus, at the end of this task, two sets of data were accomplished: 1) the least cost medium voltage grid extension for the long term along with the respective connected demand points, and 2) the villages that, due to long distances to the national grid or low consumption levels, should have an off-grid decentralized operation. This task, besides the least cost MV grid, allowed a vision of the future rural loads as well as geo-locate them.
- The second task had the objective to develop a preliminary sketch of the high voltage transmission long term network to be used as backbone for the medium voltage extension previously determined.

Chapter's structure. Firstly, in **Chapter 7.2**, a succinct explanation of the Network Planner Tool is given. Then, **Chapter 7.3** does a review of the collected information regarding the existing and the planned network to be used in the expansion software. **Chapter 7.4** presents the results of the network expansion model in terms of the long term medium voltage grid, and also illustrating the demand points that will be connected to the grid and that should have a decentralized operation, specifying the technology that should be used. Finally, **Chapter 7.5** shows the complete preliminary long term network.

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[8] The simulation was performed for a 30 year time span, which was considered the long term run.

7.2 NETWORK PLANNER TOOL

Brief description. The Network Planner Tool, developed by the Columbia University's Modi Research Group and the Earth Institute, is a least cost energy planning software, which can predict both the geospatial extent of the medium voltage grid and the off-grid power systems for a defined time span simulation, using a least cost combination of grid extension and off-grid solutions.

This model allows to input locally customized financial and socio-economic data along with policy criteria to evaluate the feasibility and costs of electrification, and ultimately help define an action plan for nationwide electrification. Thus, this tool is meant to be used as a guide for national planners and policymakers as well as donor organizations and lenders for investments quantification and prioritization.

Application in Liberia. This software has been used in several nationwide planning works, namely in Kenya, Senegal and Indonesia and also in Liberia in the 2013 *National Electrification Master Plan*. Regarding this previous work in Liberia, despite offering a first view of the action plan for the global access to electricity in 2030, the findings only included the grid extension at medium voltage levels and didn't yet considered the present plans of high and medium voltage extensions. Therefore, the Consultant, in line with the Earth Institute, decided to update the past work, in order to implement the new reality and targets of Liberia and take it to the next level, designing a preliminary long term high voltage network to serve as backbone for the medium voltage ramifications.

Necessary inputs. To perform the least cost electrification the network planner relies upon two primary classes of inputs. The first is geospatial data, of two main types, a) demands points, which include inhabited settlements, services and productive facilities, and b) geographically accurate information for existing and planned medium voltage grid lines. HV/MV substation can also be considered for grid extension. The second class of input data are several model settings or parameters related to a range of topics including:

- Electricity demand and demographic parameters. This data was discussed in **Chapter 5**;
- Economic and technical aspects regarding grid extension, and local electricity distribution;
- Decentralized alternatives economics and technical aspects. This topic was already discussed in **Chapter 6**;
- Financial assumptions.

Establishment of inputs. In order to correctly replicate the local reality in the simulation, the model input parameters and key assumptions were presented and discussed with several local stakeholders in the Network Expansion Work Session, performed in September 2015 in RREA's headquarters. The attendants of the work session were the RREA, the Ministry of Lands, Mines and Energy and the Liberia Electricity Corporation. In addition to the discussed topics in the previous chapters, the resulting input parameters used in this chapter's model are shown in **ANNEX IX**.

Methodology. After the input parameters and geospatial data establishment, the simulation of the network expansion and least cost electrification is at hand. The model performs four main steps to achieve its results, namely:

1. Assessment of demand for all points in the system, including both population growth and electricity demand growth, over a defined time horizon of 30 years. The parameters and assumptions used for this step were the ones discussed in **Chapter 5**.
2. Assessment of the best off-grid solution for each one of the demand points (or settlements) as well as costs computation. Hence, in this step, the system designs the off-grid systems and calculates all local costs for electricity access and service delivery for every point in the system. In this context, "local" refers to all the equipment, replacement, operations and maintenance, and electricity tariffs within a specific location – omitting only the non-local costs, i.e. the costs of distribution line to connect separate locations with medium voltage grid lines. Local costs for grid connection of a community include the costs of all low-voltage distribution lines, transformers, and household connection costs, such as meters and service drops, as well as all electricity tariffs summed over the entire time horizon. By definition, all decentralized solutions in a community include only local equipment and costs, since these systems, in this model framework, are "standalone" and do not inter-connect separate communities.
3. Cost comparison between the least expensive off-grid solution and the costs of grid connection. Based on the cost difference between the two alternatives (Grid connection versus Decentralized operation) a demand point specific parameter is determined, L_{MAX}. This parameter defines the opportunity cost of connecting a certain point to its nearest neighbor. If a demand point is at a distance from its nearest neighbor below L_{MAX}, it should be connected. If the distance to its nearest neighbor is above L_{MAX} that specific point should have an off-grid operation, considering the best decentralized alternative.
4. The system uses the geographic distances between all points in the system, along with the comparison between grid connection and off-grid solution costs for each point, to determine which locations in a least-cost system should be connected with the electricity grid, and which should instead utilize the lowest-cost decentralized solution. It then algorithmically constructs the grid that connects these points in the most efficient manner.

Figure 7.1 shows a summary of the basic methodology of the used network expansion model.

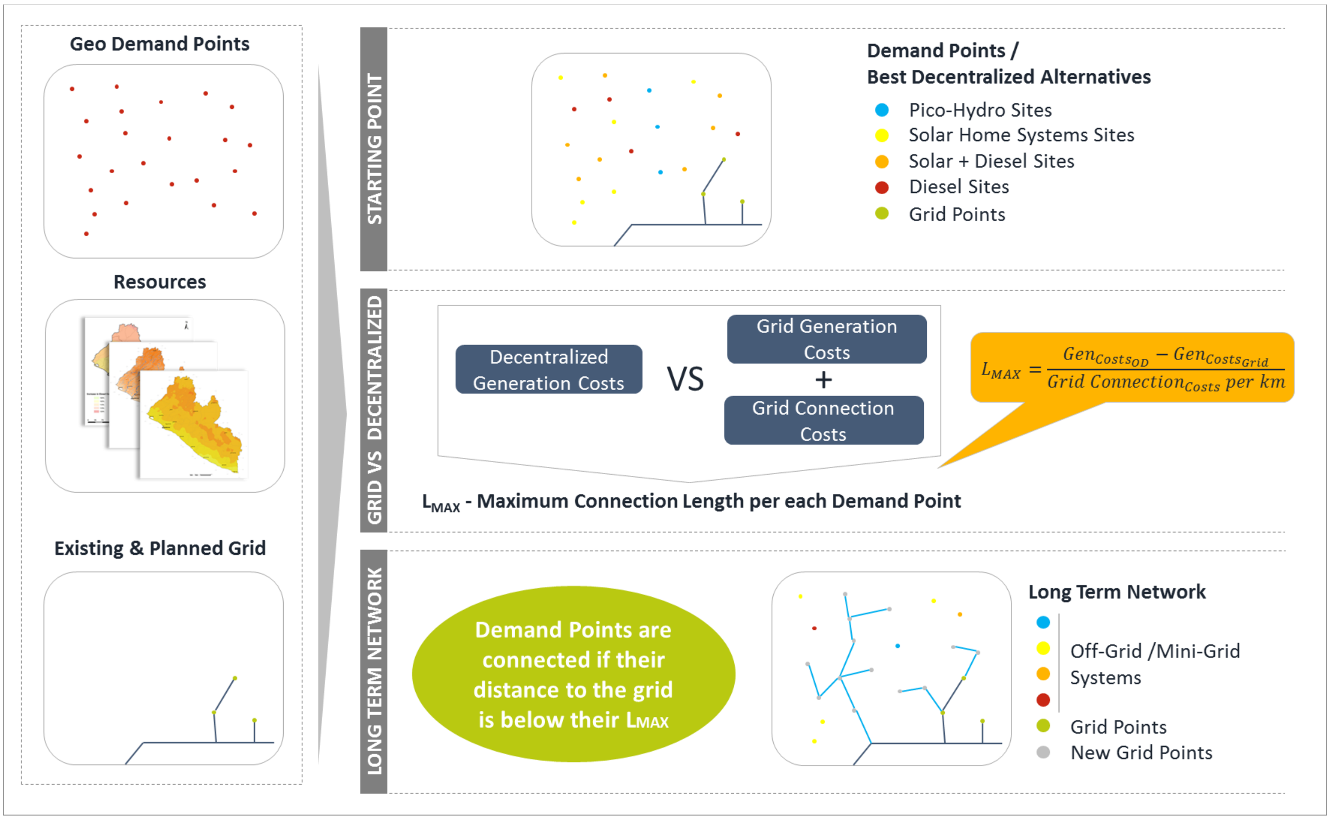

Figure 7.1 – Network Expansion Model basic methodology.

7.3 EXISTING AND PLANNED GRID INFRA-STRUCTURE

The analysis of the current, on-going and planned projects for the electrical network are amongst the relevant tasks for the development of the Rural Energy Master Plan. This data was important to understand the starting point of the country's electrification as well as the plans for the short and medium-term. Ultimately, the insight of the planned national grid coverage will enable the analysis of the most feasible method to electrify rural settlements: grid extension versus the establishment of off-grid or mini-grids systems.

Existing grid infrastructure. The existing electrical grid of Liberia is shown in **Figure 7.2**. Currently, Liberia's power network is composed by 1) the Monrovia 22 kV distribution network and 66 kV grid which connects the existing centralized power stations to some parts of Monrovia and 2) by the Cross Border projects, which consist on medium voltage power lines operating at 33 kV, currently connecting the Counties of Nimba, Grand Gedeh and Maryland to Cote d'Ivoire's national grid, at different connection points. As can be seen, the grid coverage is very limited since the only consolidated grid is in Monrovia. Although having some extent, the cross border projects are still in a premature stage, and client connection is still very incipient.

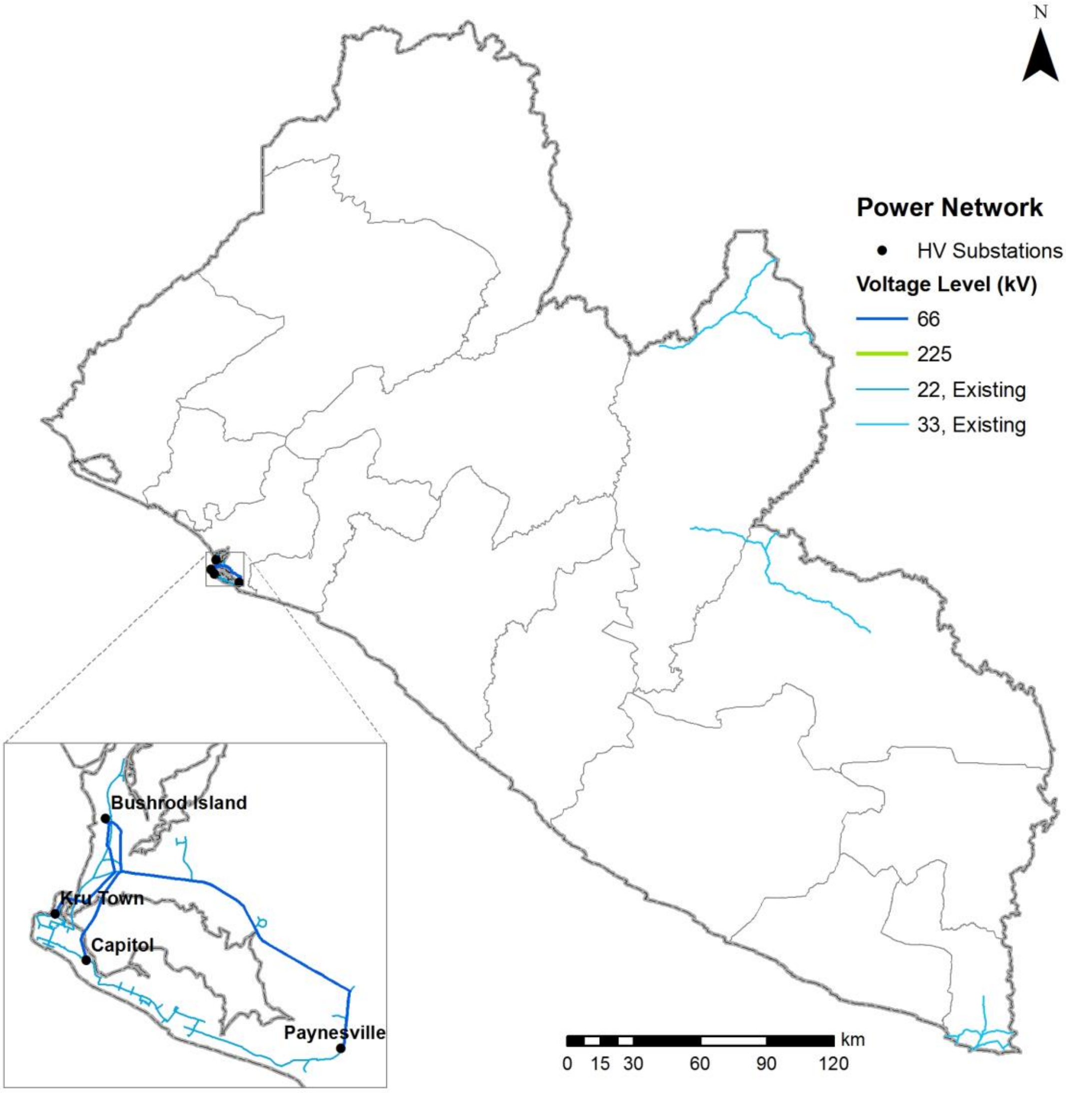

Figure 7.2 – Existing electrical power grid of Liberia (2015).

Planned grid infrastructure. The existing plans for the electrical grid of Liberia are shown in **Figure 7.3** together with the existing network.

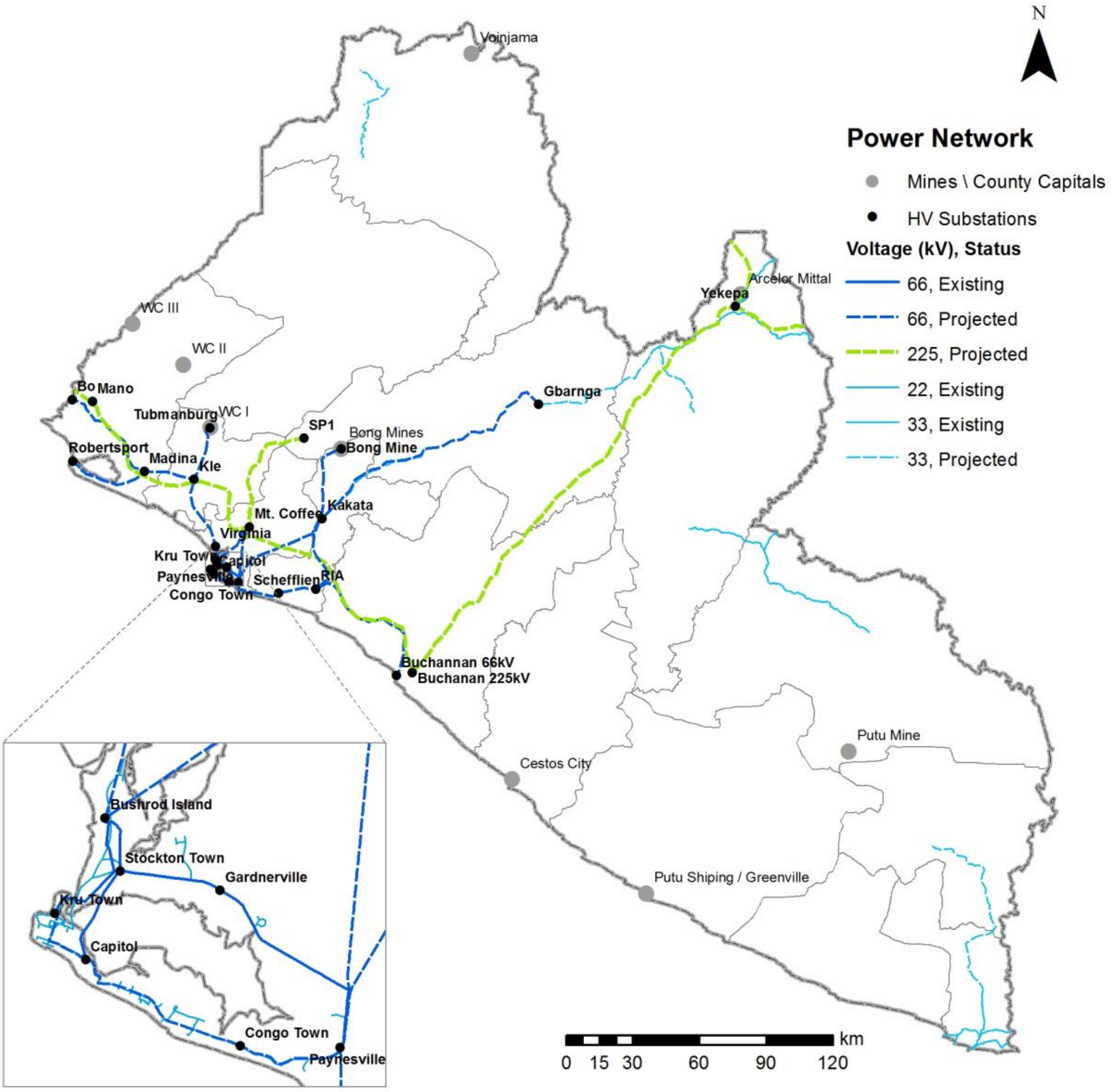

Figure 7.3 – Already planned electrical power grid of Liberia and future mining entities.

Planned expansion. There are already several plans to expand the high voltage network and also some medium voltage extensions from the cross border projects. The main additions are the following:

- *Mount Coffee Hydro Power Plant:* Network integration of Mt. Coffee hydro plant. The start of operation of this hydro plant will allow an important increase in generation capacity as well as a tariff relief in the future. The power plant will be connected to Monrovia using the 66 kV voltage level of the city and will later be connected to the 225 kV WAPP project.
- *The CLSG interconnection project promoted by the West African Power Pool:* This project consists on a 225 kV transmission system which will connect Côte d'Ivoire, Liberia, Sierra Leone and Guinea. The Liberian planned substations are located at Mano, Monrovia (Mt. Coffee), Buchanan and Yekepa. Also, the 225 kV power lines will be prepared for future electrification of nearby settlements, through the use of its shield wires. This solution is intended for more remote areas where this line will eventually go through.

- *Monrovia Corridor Extension:* This initiative consists on the extension of the 66 kV network to the West, North and Easter regions of Greater Monrovia. The West corridor will extend from Bushrod Island substation and will reach the towns of Tubmanburg, Robertsport and Bo Waterside. Substations in Virginia, Kle and Madina will also be implemented. The North Corridor will connect Kakata City to Paynesville. Additionally, the 66 kV grid will also reach Bong Mines and Gbarnga. Finally, the East corridor intends to lead the high voltage network to the Roberts International Airport area connecting also Cotton Tree and Harbel. This extension is also planned to go all the way to Buchannan.
- *Lofa County Mini-Grid:* Mini-grid implementation, operated at 33 kV, to connect the Kaiha 2 Small-Hydro to several settlements in Lofa County.
- *Cross Border Extensions:* Consists on several extensions of the existing 33 kV grid connected to Cote d'Ivoire. The projected extensions will reach Gbarnga and Saclepea (from Ganta) in Nimba County, and Fish Town (from Pleebo) in River Gee County.
- *SP1 Hydro Power Plant:* Network integration of SP1 hydro plant. This is considered a long term project.

Considerations. The network depicted in **Figure 7.3** was considered the starting point for the future MV grid extension, and therefore was one of the inputs of the Network Planner Tool. Hence, the future MV grid will grow (or extend) from the medium voltage lines shown, and from the HV/MV substations. Since there is the intention to use the shield wires of the CLSG's 225 kV power lines, this voltage level was also considered in the expansion model. However, only the area between Buchannan and Ganta was considered. The reason behind this choice lies behind the fact that the settlements in this area are the most distant to the medium voltage planned grid, hence the ones which can benefit more from the shield wire distribution.

Additionally, **Figure 7.3** shows the future mines' location and the most distant County Capitals to the planned grid (Voinjama, Greenville and Cestos City). These facilities and locations were also considered a starting point of the grid extension. Due to its distance, the considered County Capitals are expected to be connected to the high voltage grid in the long term, and so those substations were anticipated. This would allow the creation of transitional grids until the connection to the national network. Mining facilities can use their own power sources to supply nearby settlements, and also because it is expected that they will also be grid connected in the long term. However, since many of these mining facilities are not yet in operation, their hypothetical electrical supply can only be accomplished in later stages.

7.4 NETWORK EXPANSION MODEL RESULTS: ON-GRID AND OFF-GRID SETTLEMENTS

Long term grid results. The long term medium voltage grid that resulted from the Network Planner Tool is presented in **Figure 7.4**.

As can be seen, the resulting medium voltage grid covers a great part of the Country's populated areas. In the long term[8] this grid will connect more than 89% of all population, corresponding to 97% of total

energy demand. These results present a high density of settlement connections in the Monrovia Corridors areas and also in Nimba and Lofa Counties. In other regions, the grid is less dense but can reach long lengths to connect important communities along the way.

Population connected. Although the majority of the population is grid connected, only 40% of the inhabited settlements (>5000) are covered by the long term grid. For the remaining 60% (>7000), the least cost option was the off-grid solution based on solar home systems. The difference between the connected population and settlement percentages is due to the small size of many of the considered communities. As already discussed in **Chapter 5**, there are several small sized dispersed villages throughout the country with very little expected consumptions. These are the potential beneficiaries of the off-grid systems. As a note, the average size (referred to the long term) of the off-grid supplied communities is around 115 habitants, which confirms the small size of these settlements.

100% electrification scenario. The best electrification alternatives, grid connection or off-grid operation, for a 100% electrification scenario in the long term are illustrated in **Figure 7.5**, together with the main roads of the Country. It is observed that the on-grid communities are adjacent with the main communication routs. The more dispersed communities are mainly off-grid.

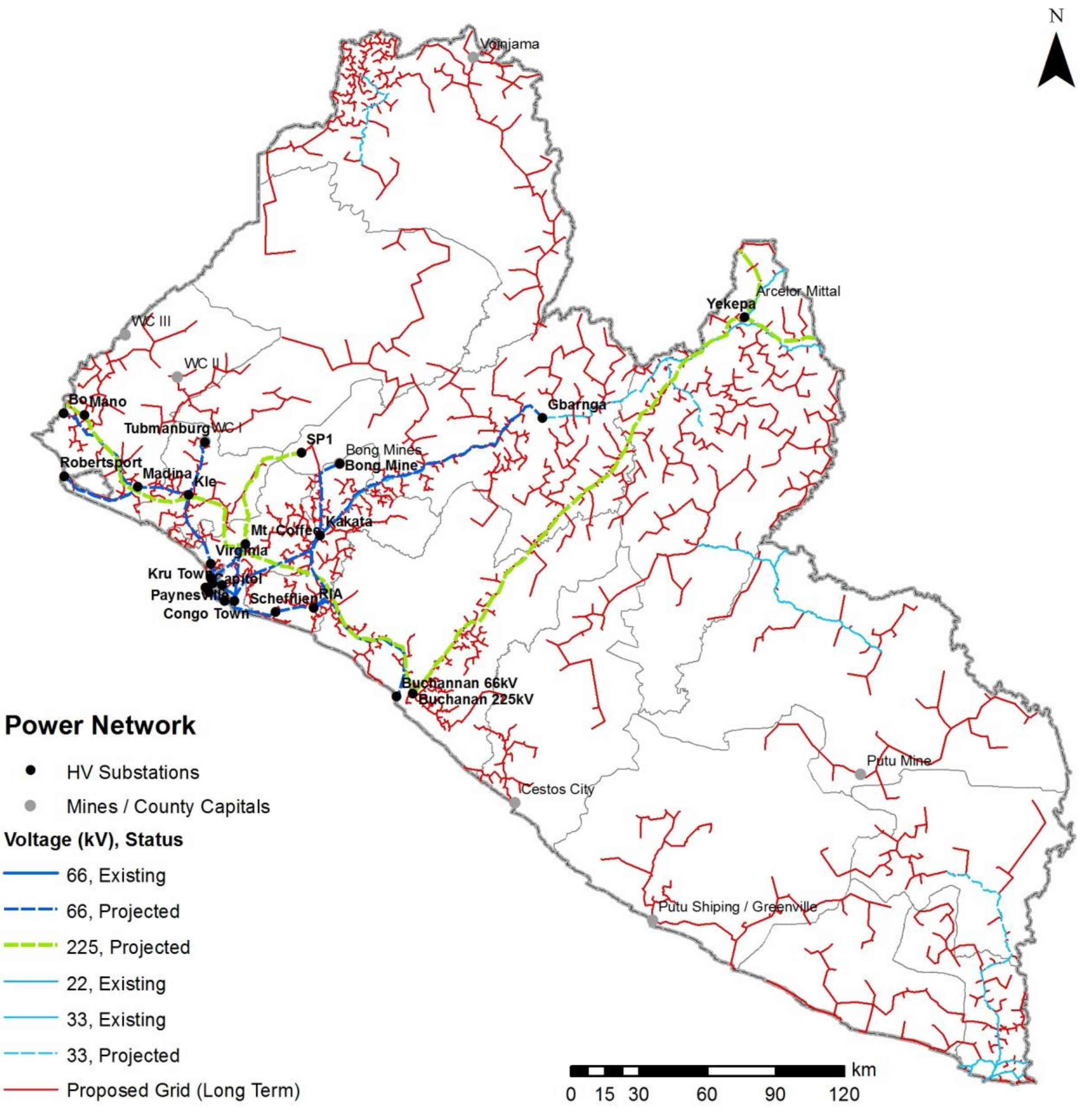

Figure 7.4 – Network expansion model medium voltage output.

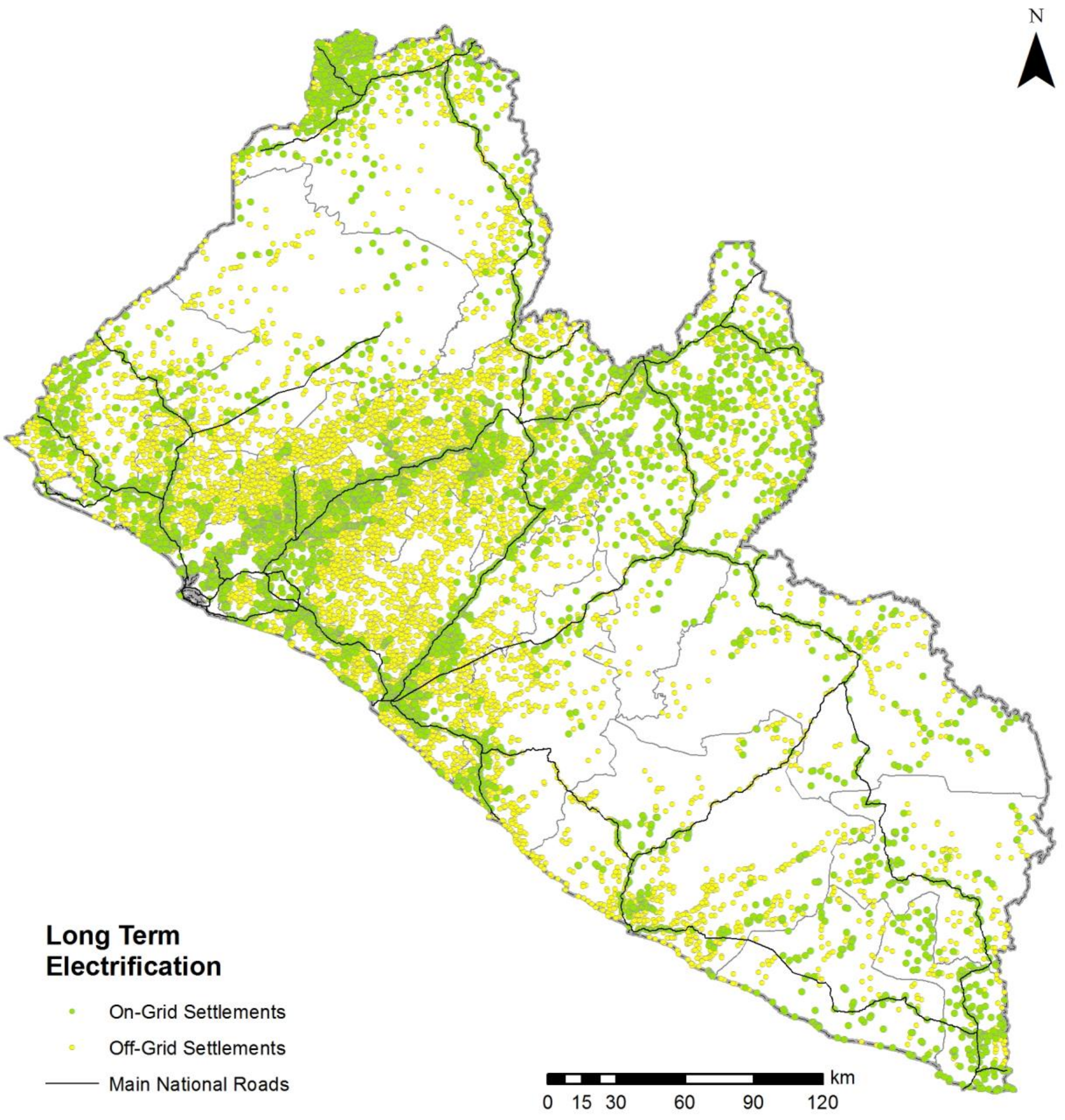

Figure 7.5 – Type of electrification per settlement in the long term (100% electrification).

Voltage drops limitation. Regarding technical aspects, the grid presented in **Figure 7.4** is a preliminary sketch of the long term grid and by itself is not a feasible solution since the extensions (in some cases with more than 200 km) are all explored at a medium voltage level, thus excessive voltage drops are to be expected.

7.5 HIGH VOLTAGE / MEDIUM VOLTAGE POSSIBLE LONG TERM NETWORK

Considerations. This section aims to present a possible long term high voltage backbone to support the medium voltage grid that resulted from the Network Planner Tool. To accomplish this grid, four main aspects were taken into consideration:

1. The future estimated long term loads and its distribution throughout the country (including mining facilities);
2. The minimization of medium voltage high lengths by introducing additional HV/MV substations. This was done taking into account a load/distance rationale, so that the MV branches with higher aggregated loads had smaller lengths and branches with lower loads could be longer;
3. The major future generation and energy sources points of origin (for example, the Saint Paul hydro power plants);
4. The stability and redundancy of the system.

Alternative for Liberia's long term national grid. The long term vision of the national grid of Liberia can be observed in **Figure 7.6**. Note that this system is only conceptual, and was not tested. Nevertheless, it is a good approximation of what can be the future electric power system of Liberia.

The additions in the 225 kV voltage level are mainly to connect large generation and demand centers, and were mainly defined in the LCPDP study [21]. The Saint Paul River's hydro projects are connected to the 225 kV substation in Mount Coffee and the Western Corridor mines are also supplied by this system, being connected to SP1 substation. In Bogota a new 225/66/33 kV substation is foreseen to improve the operation of the long (>220 km) 225 kV connection from Yekepa to Buchannan. Due to its location, Bogota substation will be crucial for rural grid extension in the center of the country, supporting the connection of Grand Gedeh and Lofa electric systems to the national transmission grid. In the 225 kV a new WAPP connection that is still under study is also predicted to arise, connecting Liberia's high voltage grid to San Pedro in Cote d'Ivoire. 225 kV substations in Pleebo and Greenville should be considered for power line control issues. Lofa County system is to be connected to the national grid, namely in Gbarnga substation, with 66 kV power lines. The substations to be implemented are located in Voinjama, Foya Town and Zorzor. Additionally to Kaiha 2 small-hydro, two other hydro plants will be constructed and connected to the system. One hydro plant is Wozi Creek, which has already been subjected to some studies and the other has been identified in the hydro assessment presented in **Section 6.5**, located closer to Voinjama and Foya Town. This power plant would be connected to those cities using 66 kV power lines. In the eastern counties (Grand Gedeh, River Gee, Grand Kru, Maryland and Sinoe), 66 kV level would be used to connect all the major cities and mining facilities to the national grid. In River Cess and Sinoe, there are some viable hydro projects that could influence the HV network growth. In the Long Term network is foreseen a promising hydro near Cestos City that could have an installed capacity around 50 MW. Due to the high installed capacity of this hydro, it should be seen as a national grid project, instead of regional, and could promote the interconnection of the south regions (Grand Bassa – River Cess – Sinoe – Grand Kru – Maryland).

This grid, although preliminary, presents itself as a vision for the future, and a milestone to achieve in the long term. Using this grid, it was possible to backtrack to the objective year of 2030, and to create different scenarios, where distinct electrification targets and/or electrification methodologies could be analyzed.

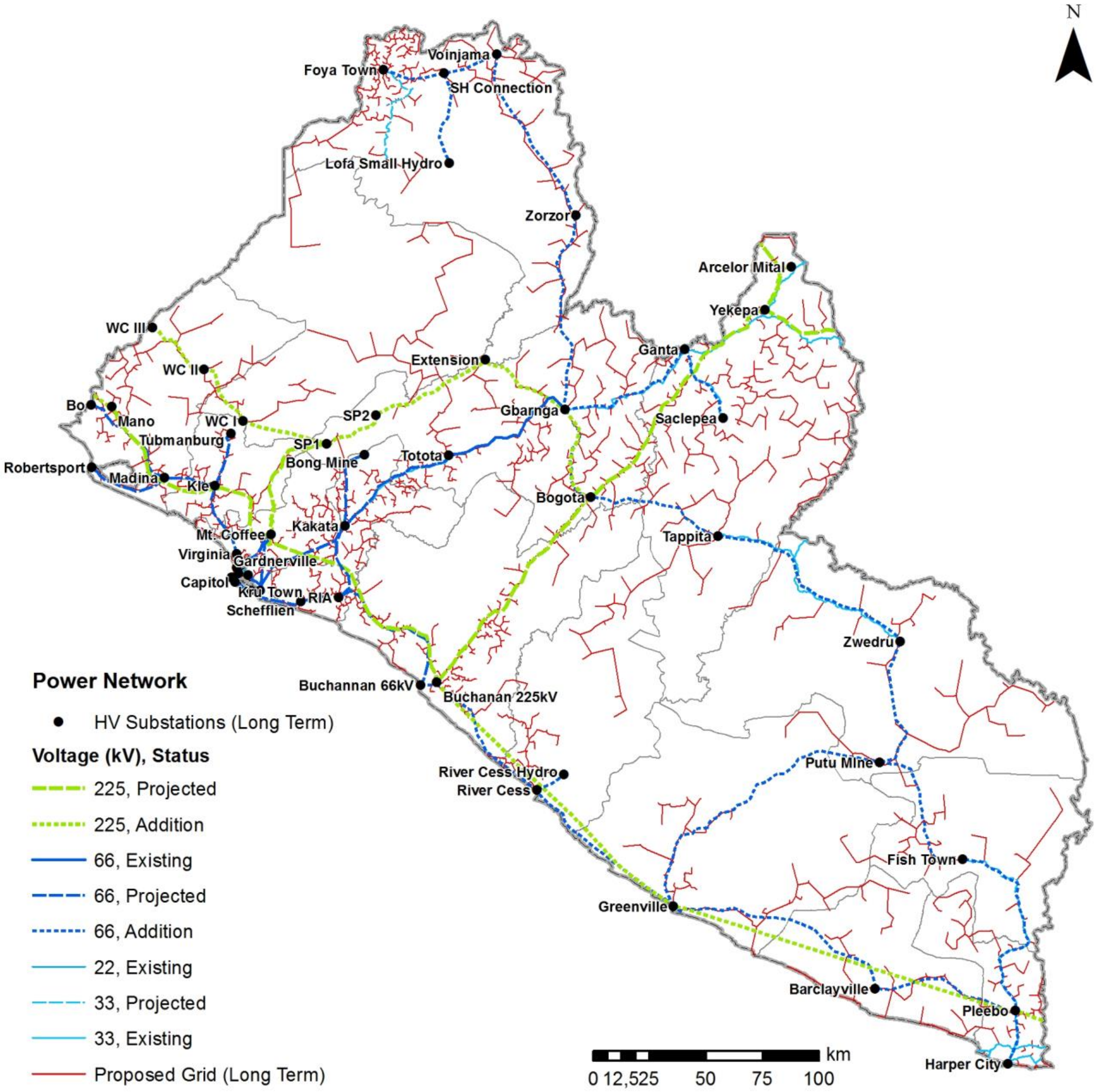

Figure 7.6 – Vision for the long term national grid of Liberia.

PART D. RURAL ENERGY VISION AND TARGETS TO 2030

8 RURAL ELECTRIFICATION SCENARIOS TO 2030

8.1 PROPOSED SCENARIOS: RATIONALE AND APPROACH

8.1.1 CONTEXT

Four scenarios were developed. The rural electrification scenarios to 2030 were built on different ideas for rural electrification based on the network planning and budgeting, the willingness to pay and prioritization criteria and the funding and financing interviews.

The main goal was to establish alternative rural electrification visions (with different models and ambitions) based on the beliefs audit criteria and the subsequent technical analysis. Each vision was budgeted and detailed in a way that main implications and trade-offs could be understood by key stakeholders.

In the end, four scenarios were developed based on the combination of two different vectors: the electrification targets (either more realistic or ambitious) and the electrification approach (either more economic or more equitable).

These scenarios were discussed in the Stakeholder's Consultation and Validation Workshop[9], and the selected alternative constitutes the basis for the Rural Energy Master Plan (**Chapter 10.1**).

8.1.2 ELECTRIFICATION TARGETS

Two different targets were considered. The electrification target vector for electrification outside Monrovia in 2030 focused on: (1) a more realistic target of 35% and (2) a more ambitious target of 50%.

Regarding (1), it aims for the current target of 35% electrification outside of Monrovia in the next 15 years, with intermediate targets of 10% and 20% electrification by 2020 and 2025, respectively. It considers:

- All County Capitals electrified by 2025;
- All health centers electrified by 2025;
- All secondary schools electrified by 2030.

With these assumptions, it was possible to determine a total of around 1.3 million people electrified in rural areas (260 000 clients).

As for (2), its goal is a more ambitious target of 50% electrification outside of Monrovia in the next 15 years, with intermediate targets of 15% and 30% electrification by 2020 and 2025, respectively. It considers:

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[9] Passion Hotel, Gboveh Hill, Gbarnga City, Bong County, February 4, 2016

- All County Capitals electrified by 2020;
- All health centers electrified by 2020;
- All secondary schools electrified by 2030.

With these assumptions, it was possible to determine a total of around 1.9 million people electrified in rural areas (370 000 clients).

8.1.3 ELECTRIFICATION APPROACH

Two electrification approaches were analyzed. The electrification approach vector focused on: (A) traditional grid extension and (B) accelerated electrification.

Regarding (A), it concentrates on grid extension and on the growth of a high voltage network (66 kV), with electrification concentrated on areas near existing or planned networks and on high demand clusters. It considers decentralized hydropower and biomass plants focused on giving support to long high voltage connections or far away cross-border reinforcements, whilst avoiding upgrade to 66, 110 or 225 kV in the medium term.

As for (B), it concentrates on low and medium voltage accelerated electrification of the most populated settlements in an equitable way across the country, focusing on the largest ten settlements in each county (if not already electrified) and using a mix of solar and diesel. The national grid extension is mostly focused on growth corridors. Large isolated grids based on hydropower and biomass plants in Lofa County, East Counties and Greenville are considered.

Both options assume grant based off-grid programs, flexible to donors' priorities, which target health clinics, schools, administrative buildings and future off-grid settlements.

8.1.4 SCENARIOS

Four scenarios were studied. Based on the above combination of the two vectors, four scenarios were established and are detailed in the next sections (**Figure 8.1**):

- Scenario 1A: Current Policy;
- Scenario 1B: Accelerated Electrification through Decentralized Grids alongside Grid Extension;
- Scenario 2A: Aggressive Grid Extension;
- Scenario 2B: Aggressive Mini-Grid and Grid Extension Electrification.

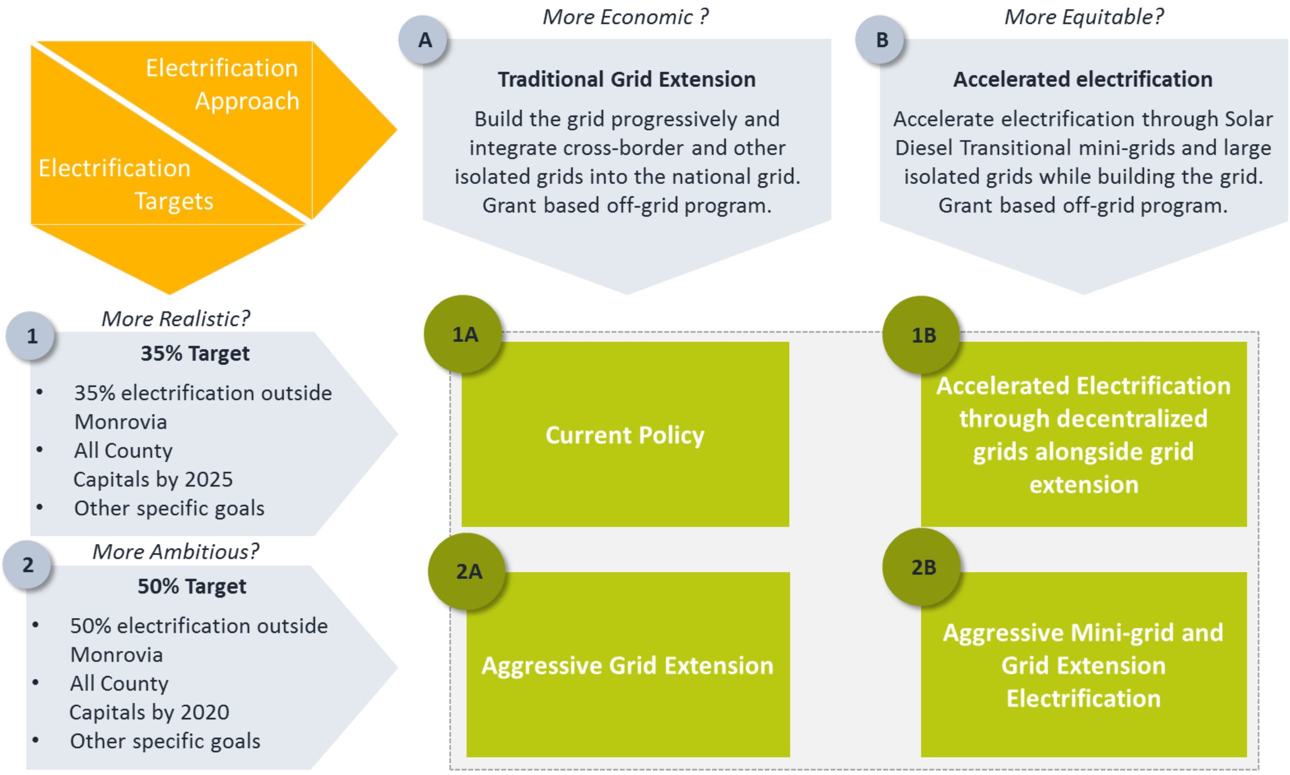


Figure 8.1 – Rural electrification scenarios.

Given their respective assumptions, a comprehensive technical and economic analysis was conducted to assess its impact.

The scenario comparison and selection is presented in **Chapter 10.1**.

8.2 CURRENT POLICY SCENARIO (1A)

Scenario 1A consists on the development of the current policy. In terms of electrification target it aims for the existing target of 35% electrification outside of Monrovia in the next 15 years, with intermediate targets of 10% and 20% electrification by 2020 and 2025, respectively and considers all County Capitals and health centers electrified by 2025 and all secondary schools electrified by 2030. Regarding the electrification approach, it concentrates on grid extension and on the growth of a high voltage network (66 kV), with electrification concentrated on areas near existing or planned networks and on high demand clusters. It considers decentralized hydropower and biomass plants focused on giving support to long high voltage connections or far away cross-border reinforcements, whilst avoiding upgrade to 66, 110 or 225 kV in the medium term.

This scenario represents an estimated total CAPEX of around **USD 0.9Bi** (USD 283M for rural grid extension (MV/HV), USD 395M for generation[10] and USD 224M for distribution), for a peak demand of 140 MW in 2030. The spatial representation of this scenario is presented in **Figure 8.2**.

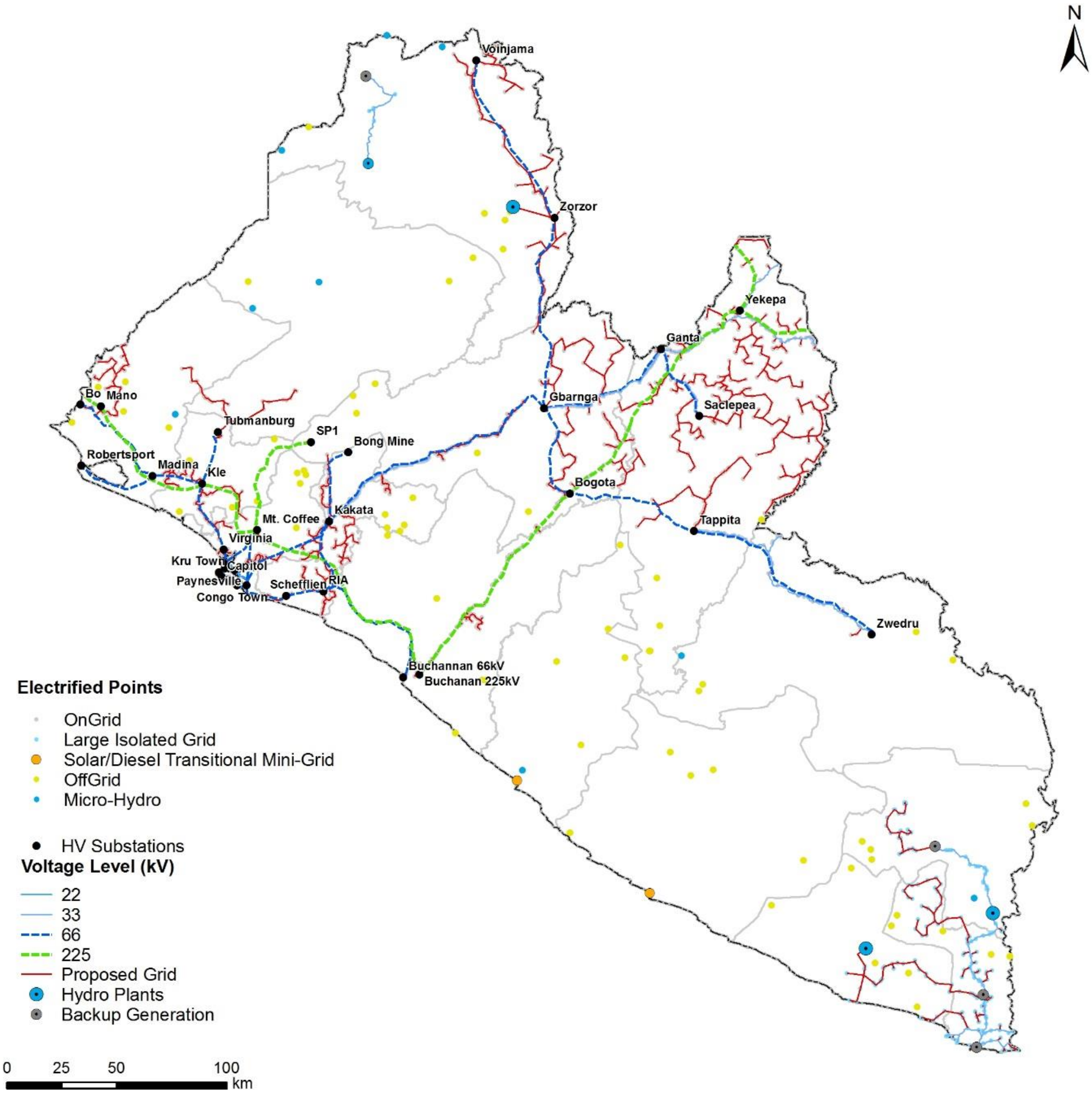


Figure 8.2 – Spatial representation of Scenario 1A.

The distribution of the electrified population per type for this scenario is represented in **Figure 8.3**.

[10] Depending on level of imports. Estimated CAPEX considers all generation in Liberia except for already committed cross-border imports

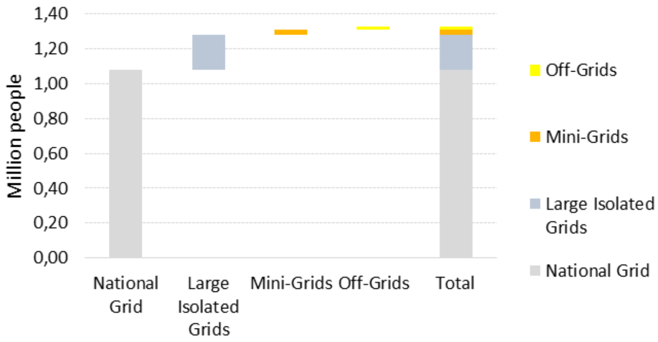


Figure 8.3 – Electrified Population Distribution for Scenario 1A.

The resulting rural electrification rate per county (and region) in 2030 is presented in **Figure 8.4**.

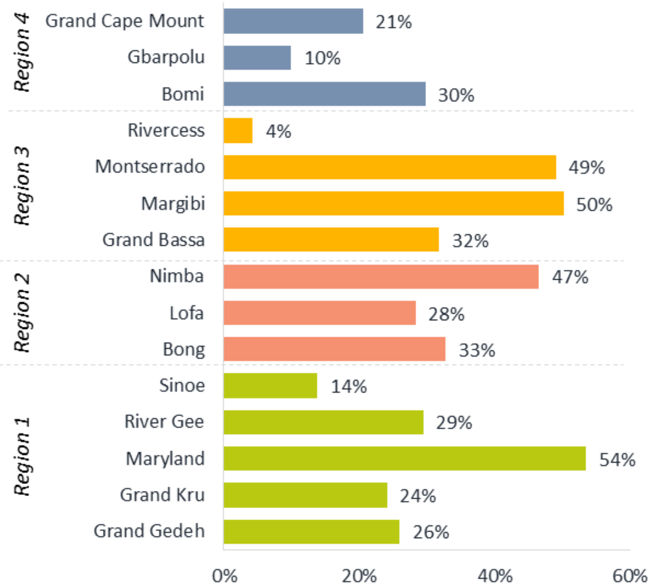


Figure 8.4 – Rural electrification rate per county in 2030 for Scenario 1A.

8.3 ACCELERATED ELECTRIFICATION THROUGH DECENTRALIZED GRIDS ALONGSIDE GRID EXTENSION SCENARIO (1B)

Scenario 1B consists on accelerated electrification through decentralized grids alongside grid extension. In terms of electrification target it aims for the existing target of 35% electrification outside of Monrovia in the next 15 years, with intermediate targets of 10% and 20% electrification by 2020 and 2025, respectively, and considers all County Capitals and health centers electrified by 2025 and all secondary schools electrified by 2030. Regarding the electrification approach, it concentrates on low and medium voltage accelerated electrification of the most populated settlements in an equitable way across the country, focusing on the largest ten settlements in each county and using a mix of solar and diesel. The national grid extension is mostly focused on growth corridors. Large isolated grids based on hydropower and biomass plants in Lofa County, East Counties and Greenville are considered.

This scenario represents an estimated total CAPEX of around **USD 0.8Bi** (USD 222M for rural grid extension (MV/HV), USD 402M for generation[11] and USD 223M for distribution), for a peak demand of 140 MW in 2030. The spatial representation of this scenario is presented in **Figure 8.5**.

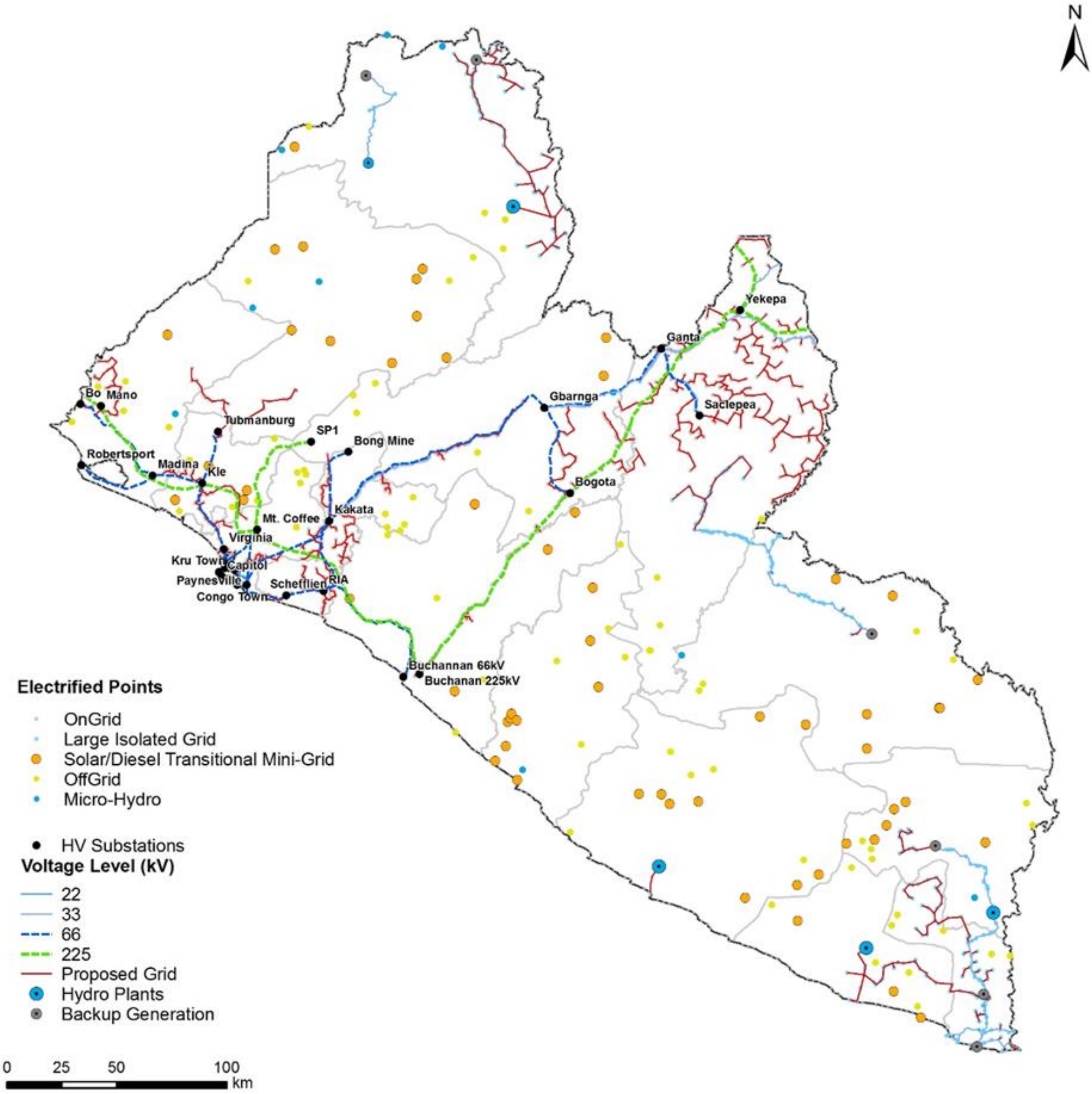


Figure 8.5 – Spatial representation of Scenario 1B.

The distribution of the electrified population per type of electrification for this scenario is represented in **Figure 8.6**.

[11] Depending on level of imports. Estimated CAPEX considers all generation in Liberia except for already committed cross-border imports

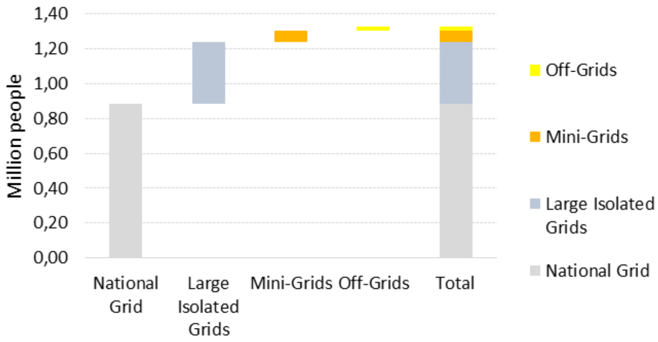


Figure 8.6 – Electrified Population Distribution for Scenario 1B.

The resulting rural electrification rate per county (and region) in 2030 is presented in **Figure 8.7**.

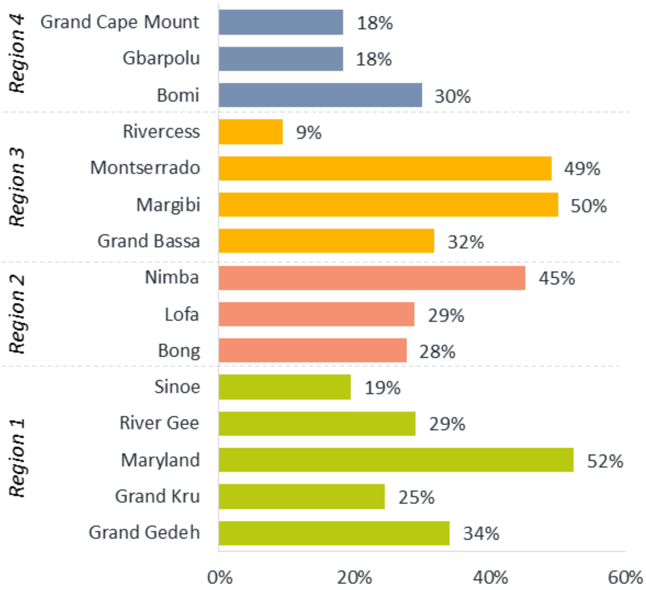


Figure 8.7 – Rural electrification rate per county in 2030 for Scenario 1B.

8.4 AGGRESSIVE GRID EXTENSION SCENARIO (2A)

Scenario 2A consists on aggressive grid extension. In terms of electrification target its goal is a target of 50% electrification outside of Monrovia in the next 15 years, with intermediate targets of 15% and 30% electrification by 2020 and 2025, respectively, and considers all County Capitals and health centers electrified by 2020 and all secondary schools electrified by 2030. Regarding the electrification approach, it concentrates on grid extension and on the growth of a high voltage network (66 kV), with electrification concentrated on areas near existing or planned networks and on high demand clusters. It considers decentralized hydropower and biomass plants focused on giving support to long high voltage connections or far away cross-border reinforcements, whilst avoiding upgrades in the medium term.

This scenario represents an estimated total CAPEX of around **USD 1.2Bi** (USD 401M for rural grid extension (MV/HV), USD 454M for generation[12] and USD 332M for distribution), for a peak demand of 166 MW in 2030. The spatial representation of this scenario is presented in **Figure 8.8**.

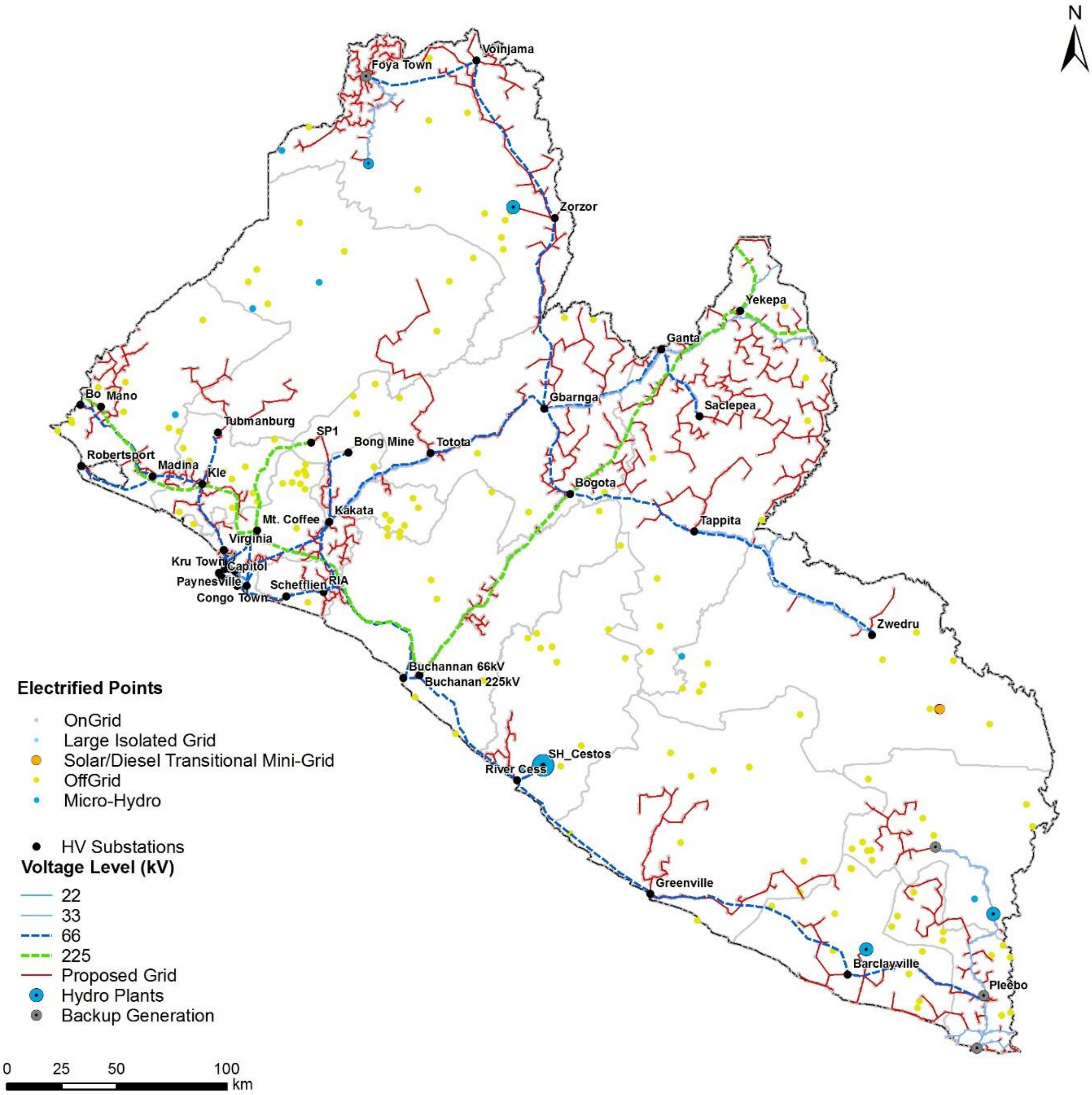


Figure 8.8 – Spatial representation of Scenario 2A.

The distribution of the electrified population per type for this scenario is represented in **Figure 8.9**. By its own definition, virtually no large isolated grids will be developed.

[12] Depending on level of imports. Estimated CAPEX considers all generation in Liberia except for already committed cross-border imports

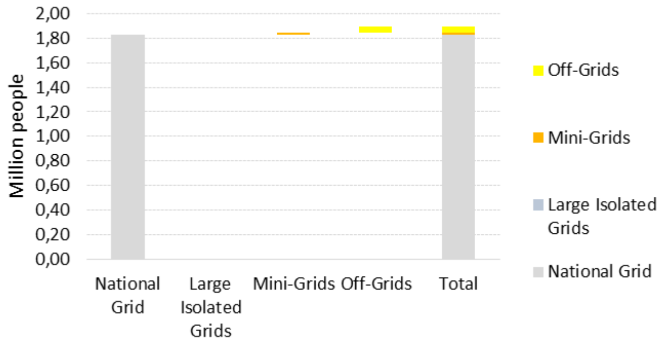


Figure 8.9 – Electrified Population Distribution for Scenario 2A.

The resulting rural electrification rate per county (and region) in 2030 is presented in **Figure 8.10**.

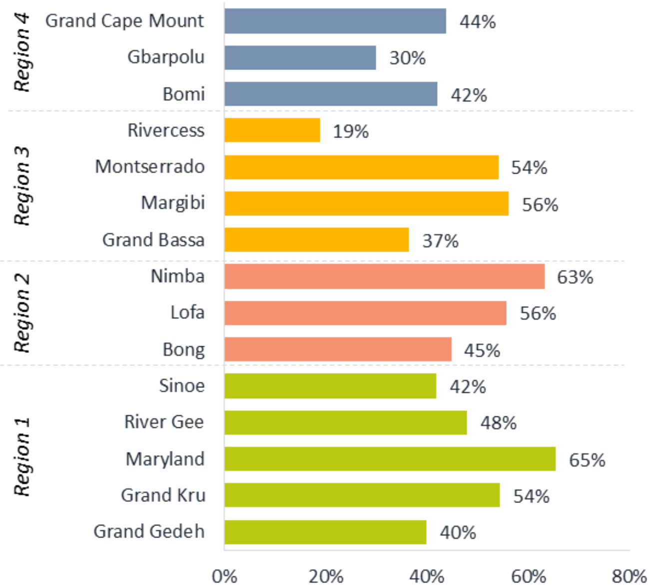


Figure 8.10 – Rural electrification rate per county in 2030 for Scenario 2A.

8.5 AGGRESSIVE MINI-GRID AND GRID EXTENSION ELECTRIFICATION SCENARIO (2B)

Scenario 2B consists on aggressive mini-grid and grid extension electrification. In terms of electrification target its goal is a target of 50% electrification outside of Monrovia in the next 15 years, with intermediate targets of 15% and 30% electrification by 2020 and 2025, respectively, and considers all County Capitals and health centers electrified by 2020 and all secondary schools electrified by 2030. Regarding the electrification approach, it concentrates on low and medium voltage accelerated electrification of the most populated settlements in an equitable way across the country, focusing on the largest ten settlements in each county and using a mix of solar and diesel. The national grid extension is mostly focused on growth corridors. Large isolated grids based on hydropower and biomass plants in Lofa County, East Counties and Greenville are considered.

This scenario represents an estimated total CAPEX of around **USD 1.1Bi** (USD 314M for rural grid extension (MV/HV), USD 475M for generation[13] and USD 330M for distribution), for a peak demand of 166 MW in 2030. The spatial representation of this scenario is presented in **Figure 8.11**.

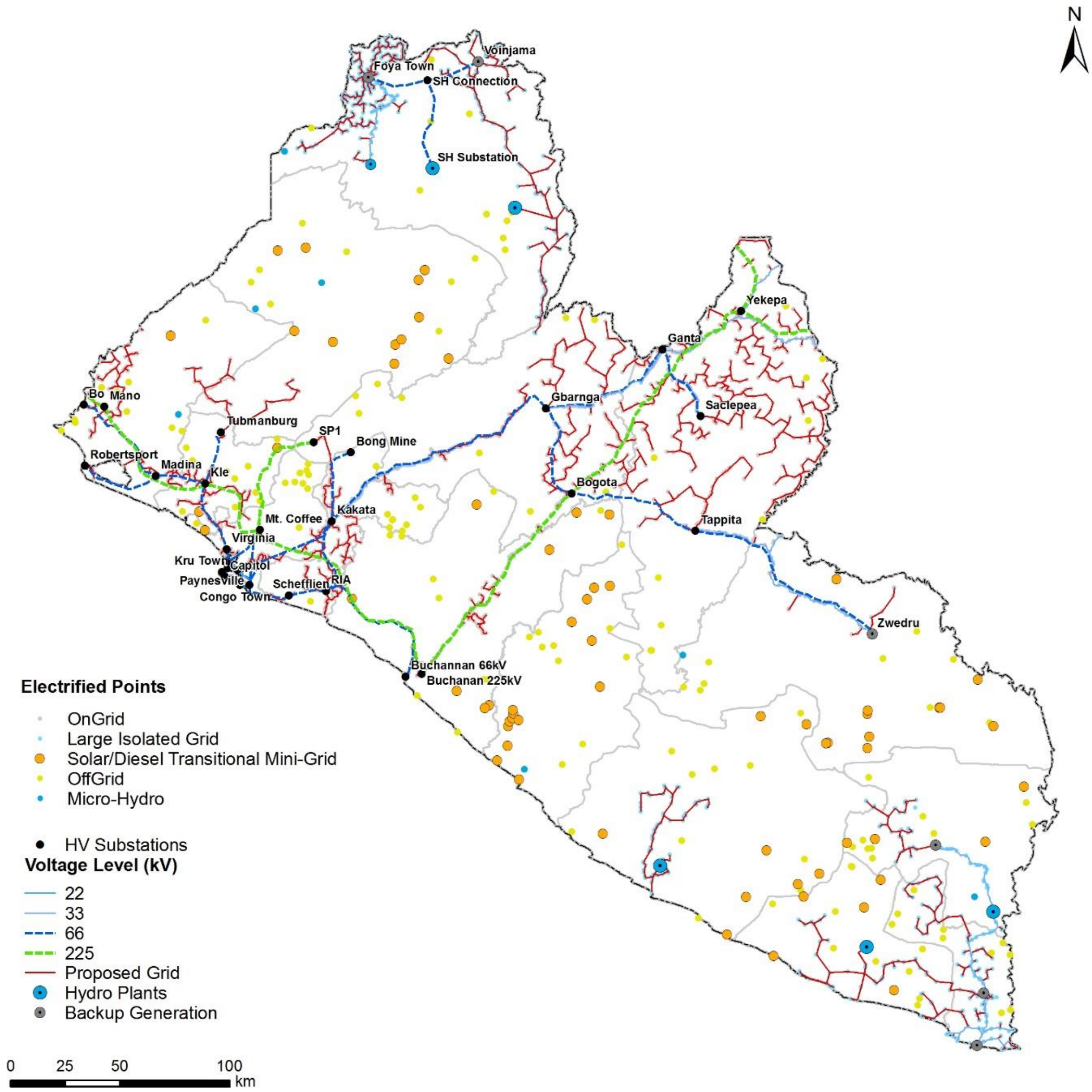


Figure 8.11 – Spatial representation of Scenario 2B.

The distribution of the electrified population per type for this scenario is represented in **Figure 8.12**.

[13] Depending on level of imports. Estimated CAPEX considers all generation in Liberia except for already committed cross-border imports

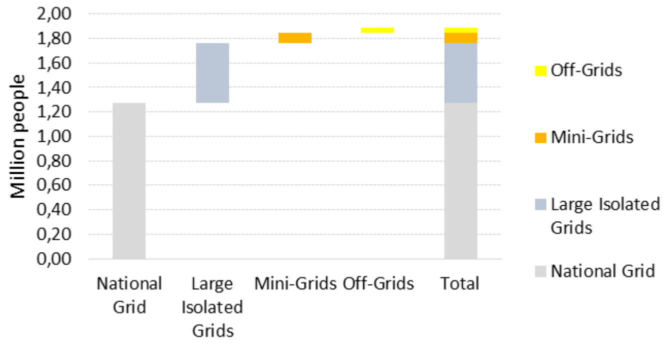


Figure 8.12 – Electrified Population Distribution for Scenario 2B.

The resulting rural electrification rate per county (and region) in 2030 is presented in **Figure 8.13**.

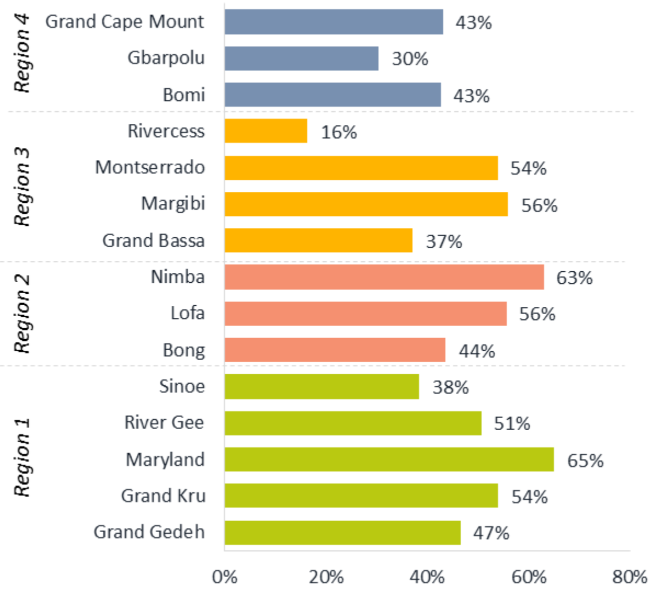


Figure 8.13 – Rural electrification rate per county in 2030 for Scenario 2B.

9 FUNDING POTENTIAL AND STRATEGY

9.1 COUNTRY RELATED FUNDING: GRANTS

Only a part of country related funding will be allocated to rural electrification. Country funding is the overall funding available for a country, passing through the government, and thus part has to be allocated to rural electrification. Hence, in order to calculate the funding available to this sector we had to: first, determine the total amount of funding available, then create an energy allocation scenario, and lastly create a rural allocation scenario. The two instruments governments have to gather funding are grants and concessional loans (see **Figure 9.1**).

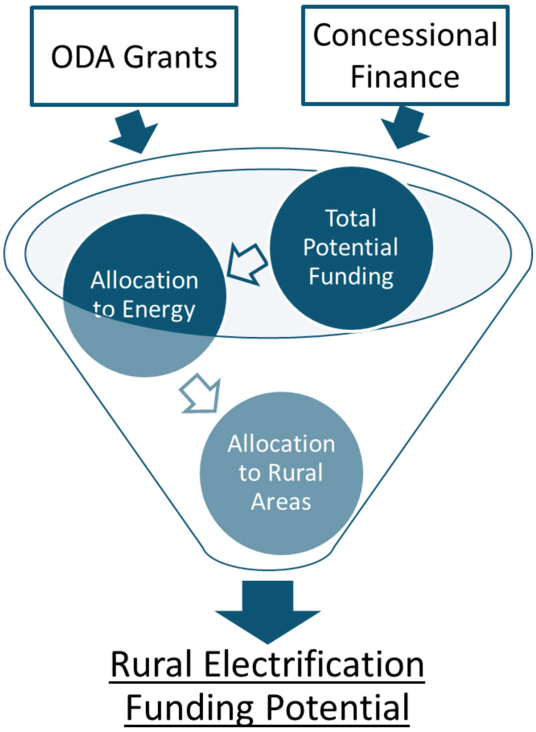


Figure 9.1 – Allocation process of country funding.

Grants. Grants are transfers for which no repayment is required, made to developing countries which are undertaken by the official sector and with promotion of economic development and welfare as the main objective. As no repayment is required, this type of funding is free, however it depends on donor's availability. The main players in this type of funding are AfDB, EU Institutions, the International Development Association (IDA), and USAID. A list of the existing financial players and potential financial stakeholders with focus on energy sector can be found in **ANNEX X**.

Liberia has been a leading recipient of ODA grants. In order to calculate the funding potential coming from grants we analyzed Liberia's historical grants revenue in order to estimate its future revenue. Considering an average from 2006 to 2014, Liberia was the 2nd highest global ODA grant receiver as percentage of nominal GDP, with an average of 62.0% per year. This value is much higher than the average West African countries (12.9%). Nevertheless, Liberia's GDP is limited due to historical reasons,

and consequently when taking into consideration the total amount of ODA grants Liberia is only the 22nd largest recipient in Africa in the same period. Moreover, ODA grants are subject to high variability given donors context. Indeed, it varied from 25% (in 2013) to 133% of GDP (in 2010) and between USD 261M (in 2006) and USD 1 721M (in 2010), as it can be seen in **Figure 9.2**.

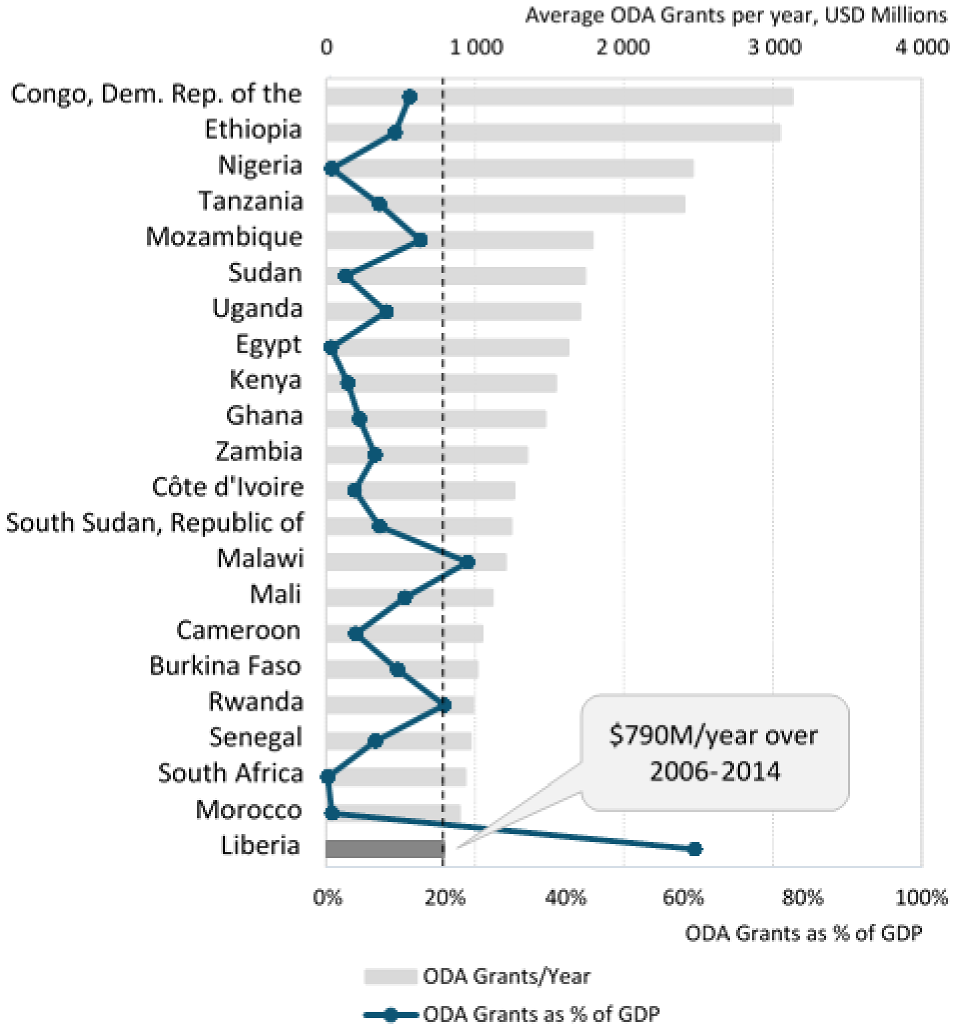


Figure 9.2 - Top African ODA grant receivers 2006-2014.

The USA and IDA accounted for almost a third of all the ODA grants donated to Liberia. In the period of 2006-2014, the biggest ODA grant donor to Sub-Saharan Africa was the United States, donating on average more than USD 7 700M per year. Moreover, the USA is also the biggest ODA donor to Liberia, donating USD 176M on average every year. The second top ODA donor to SSA is the International Development Association – the World Bank's fund for the poorest – which provides more than USD 5 500M per year to SSA. IDA is also the grant donor which donates the highest amount to the energy sector, donating on average USD 618M per year. Although these are the top two ODA grant donors to Liberia, the United States allocation to Liberia of its total amount donned was merely 1%, and only 2.3% of the ODA grants donated to SSA went to Liberia. IDA allocated 1.2% and 1.5% accordingly. Nevertheless, although this may be a small percentage, when taken into consideration the GDP and

population and size of Liberia it is an extremely high amount. Indeed, the USA and IDA contributed to 22% and 10% of the ODA grants donated to Liberia in the period of 2006-2014, respectively. Hence, about a third of the total ODA grants allocated to Liberia came from the USA and IDA.

The IMF, Germany, Sweden and Norway are the donors who allocated a higher percentage of their ODA grants budget to Liberia. As demonstrated in **Figure 9.3** below, several donors allocate a high amount of ODA grants to Liberia compared to other countries in Sub-Saharan Africa. Liberia's support from donors such as Germany, Sweden and Norway is extremely high. Indeed these three European countries allocate about 3.5% of the ODA grants provided for SAA to Liberia. More interestingly is IMF's contribution to Liberia, who donated 15% of their global budget over the period of 2006-2014 to Liberia, which corresponds to 18% of their budget to SSA. However, most of these ODA grants were as debt forgiveness, as was mentioned above.

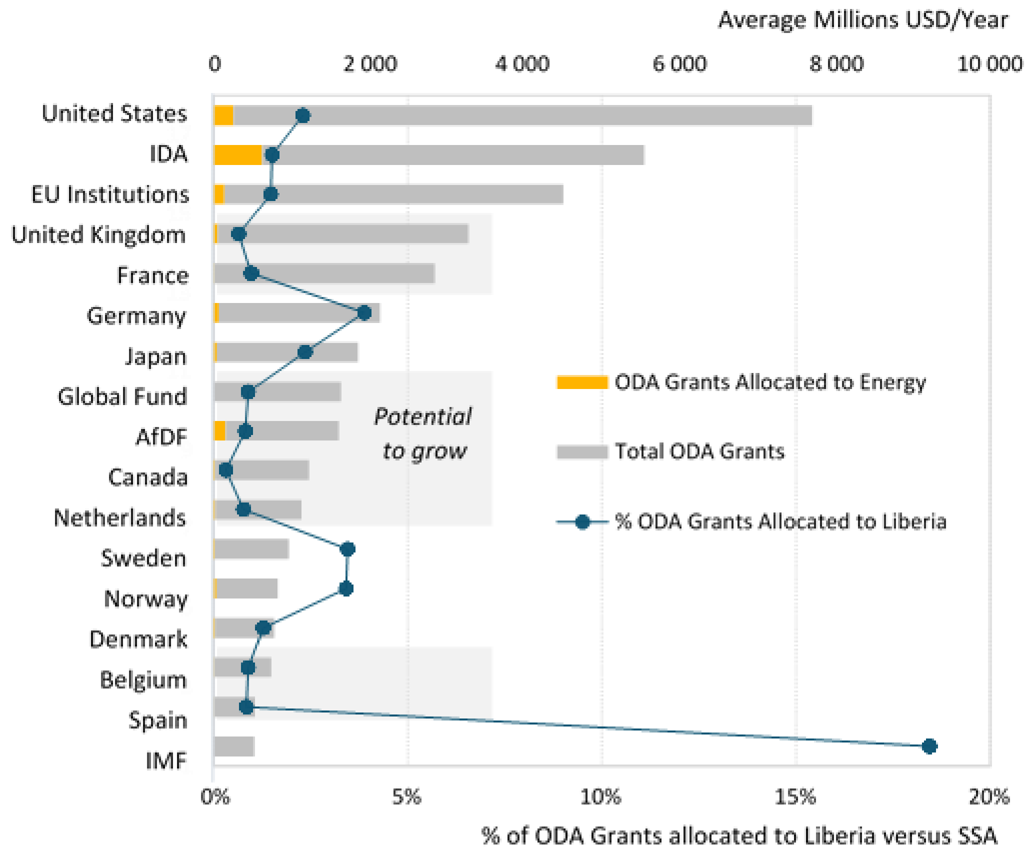


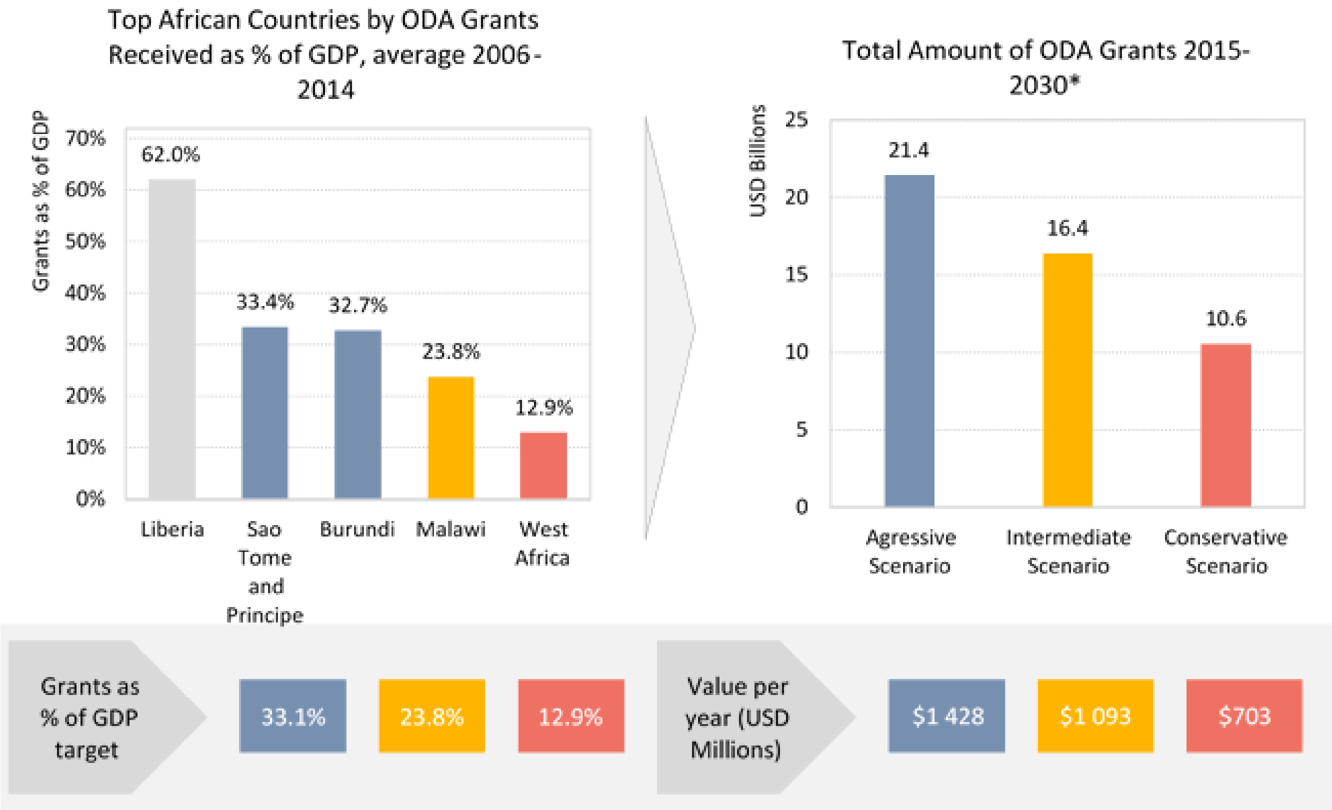
Figure 9.3 – Top ODA grant donors to SSA for the period 2006-2014.

Liberia still has potential to grow with several donors. Although Liberia has had an extremely high average of ODA grants as percentage of GDP, it still has potential to grow with several donors. In fact, Canada, the United Kingdom, the Netherlands, the African Development Fund (AfDF), Spain, the Global

Fund, Belgium and France all allocated less than 1% to the ODA grants donated to SSA to Liberia. Thus Liberia can still grow with these donors in order to increase the funding coming from ODA grants.

Total amount of ODA grants scenarios. Although Liberia has had an extremely high average of grants as percentage of GDP, it is fairly likely that as GDP increases as is expected[14] this average will decrease. Thus three scenarios were generated in order to estimate the total amount of grants Liberia can potentially receive until 2030[15] (see **Figure 9.4**):

> **Aggressive scenario.** In this scenario Liberia's grants as percentage of GDP will decrease to the average of the following top two West African countries with higher ratio (São Tomé & Principe and Burundi) to 33.1%;
>
> **Intermediate scenario.** Liberia's grants as percentage of GDP will fall between the following top two West African countries with higher ratio (aggressive scenario) and the West African average (conservative scenario). Hence the level of ODA grants as percentage of GDP in this scenario would be 23.8%, which is currently the same as Malawi's average;
>
> **Conservative scenario.** Liberia's grants as percentage of GDP are considered to have the same ratio as the West African average of 12.9%.



[14] Assumed GDP annual rate growth of 8.2%.

[15] As Liberia's average currently is higher than any of the scenarios, a linear reduction of grants as percentage of GDP towards these target until 2020 was considered, as in the following 5 years Liberia is still expected to have high grants revenues.

Figure 9.4 – Scenarios of total ODA grants allocation to Liberia.

10.6 to 21.4 billion USD of potential ODA grants in 2015–2030. Considering these three scenarios and an annual GDP growth rate until 2030 of 8.2% based on IMF's predictions, Liberia's potential ODA grants are estimated to range from 10.6 to 21.4 billion USD between 2015 and 2030. This range is particularly large as it depends highly on donors' preferences and their ability to provide funding, and thus it is extremely hard to predict the amount they are planning to grant to Liberia. Under the intermediate scenario – considered the most plausible one – Liberia could receive a total of USD 16.4Bi of ODA grants until 2030, which is equivalent to USD 1 093M per year. This is only USD 303M more than what Liberia has been receiving per year on average in the period of 2006-2014.

Allocation of ODA grants to the energy sector depends on government's priorities. Having the total ODA grants available it is then necessary to allocate part to electrification and subsequently to rural electrification. Previously, in order to estimate the total amount of ODA grants available to Liberia, the only dependent factors (donors' preferences and ability to provide funding) were not under the control of Liberia. However, the amount of ODA allocated to electrification is highly dependent on the country's priorities, as well as donor's priorities, as several donors have preferences on the sector they concede grants to.

In recent years the energy sector has been Liberia's top priority. According to the World Bank, in 2012 Liberia was the 6th country with lowest national electrification rate in the world, with a national electrification rate as low as 9.8% and with a rural electrification rate of only 1.2%. This may be partly explained by the lack of allocation to the energy sector in previous years as demonstrated on **Figure 9.5**. Indeed, Liberia only started to allocate ODA to the energy sector in 2006. Nevertheless, the average of ODA grants allocated to energy in 2006-2013 in Liberia was 7.2% above the West Africa average (10.5% vs. 3.3%). This is due to the high allocation of ODA grants to energy in recent years. Indeed, in 2013, "Clean and Affordable Energy" was the Sustainable Development Goal (SDG) in which Liberia allocated most ODA grants (27.7%), while the average of the West African Countries allocated only 4.6%.

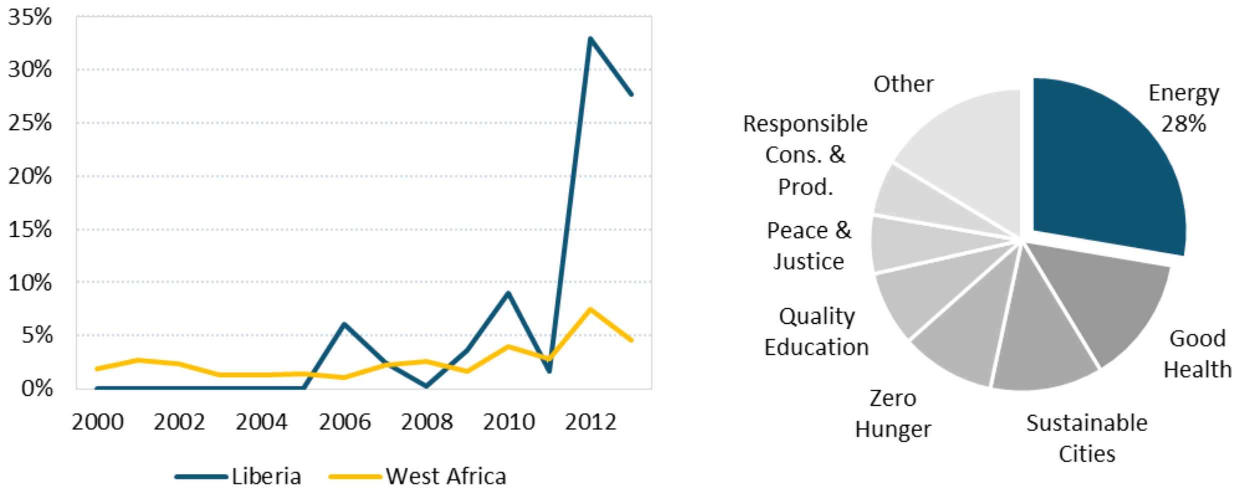


Figure 9.5 – Percentage allocation of ODA to the energy sector compared to the other SDG [9].

ODA grants allocation to the energy sector scenarios. Again, three scenarios were considered for ODA grants allocation to energy:

> **Aggressive scenario.** Liberia would keep allocating ODA grants to the energy sector at the same percentage of the average of the past seven years (2006-2013) – 10.5%. This is an aggressive scenarios as all except one West African country allocate less to the energy sector;
>
> **Intermediate scenario.** Allocation to the energy sector would be in between Liberia's average and West Africa (thus between the aggressive and conservative scenario) allocating 6.9% of the total ODA grants to energy;
>
> **Conservative scenario.** This energy allocation scenario considered was again the average of the West African countries (3.3%).

Depending on government priorities, the total funding for electrification can range from 1 714 to 539 million USD. Taking into consideration the scenarios for ODA grants allocation to Liberia and then allocated to the energy sector, we have a range of ODA allocated to energy from 2 240 to 347 million USD, equivalent to 149.3 to 23.1 million USD per year. Once again, this extremely large range is due to its dependence on donors' preferences and ability to provide funding, and on top of that on government priorities. Under the intermediate scenario of ODA grant allocation to Liberia, the total funding for electrification ranges from 1 714 to 539 million USD. Thus government priorities play an extremely important role on the amount of ODA grants available for electrification funding.

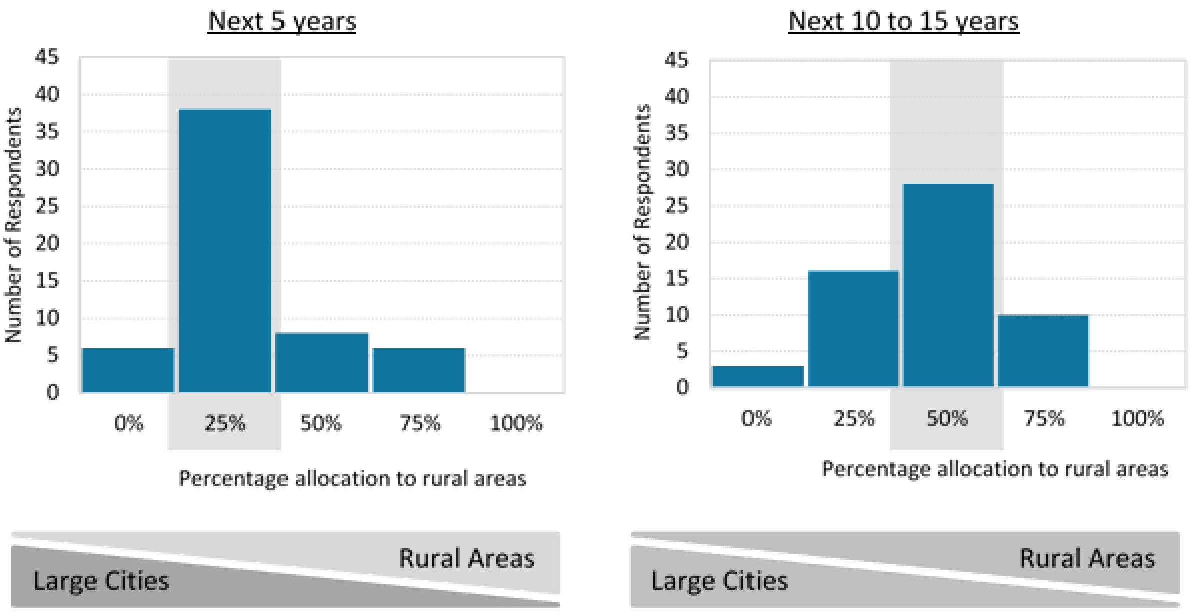


Figure 9.6 – Distribution of electrified people between large cities versus rural areas.

ODA grants allocation to rural electrification. The last step in order to determine the potential funding available for rural electrification is to allocate part of the grants available to energy for rural areas. In order to do this allocation, the results of the beliefs audit were used (see **Figure 9.6** above). As mentioned before, the beliefs audit were conducted to key representatives of the power sector across all the Liberian counties and thus provide goals set for the Rural Electrification Master Plan. When asked

"What should be the distribution of electrified people between large cities (including county capitals) versus rural areas?", there was a very clear vision that in the next 5 years (from 2015 to 2020) the allocation should be 25% to rural areas and the remaining 75% to urban areas. For the remaining 10 years (from 2020 to 2030) the vision wasn't as clear, however there was a convergence on 50% to rural areas and 50% to urban areas. This means that once Monrovia's electrification is consolidated there is a higher focus on rural electrification.

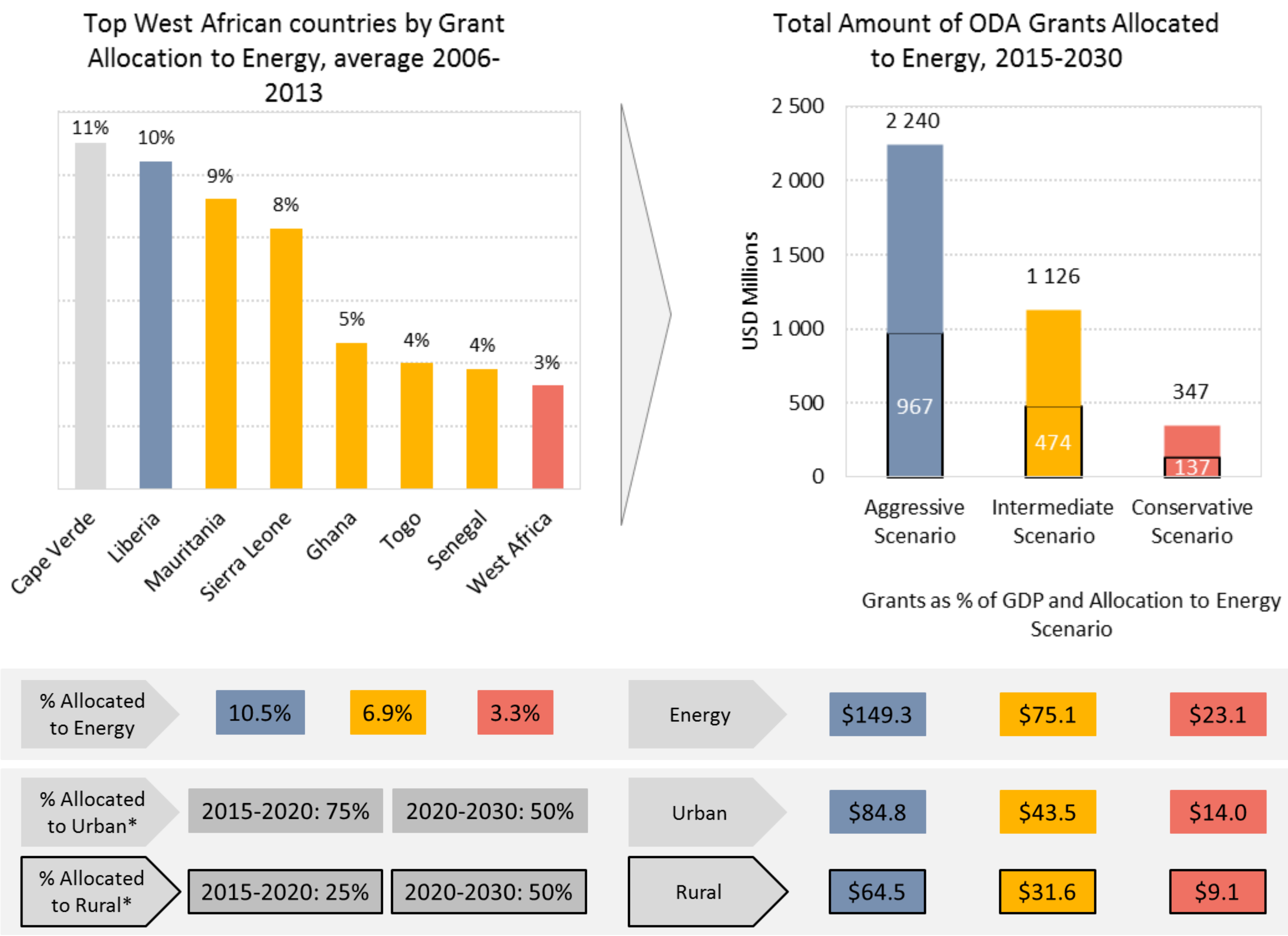


Figure 9.7 – Grants allocation to energy scenarios.

If energy and rural electrification remain a government priority, ODA funding allocated to rural electrification could go above USD 474M. Going through all the allocation steps, we finally have the funding potential for rural electrification, as shown in **Figure 9.7** above. Considering the aggressive allocation scenario on both ODA grants to Liberia and to energy we had a total of USD 2 240M allocated the energy sector. From this, USD 721M would be allocated to rural electrification. Taking into consideration the most conservative scenarios, this funding potential would go down to 539 to energy and 347M to rural electrification. As mentioned before, the intermediate allocation scenario is the most plausible one, and under this scenario a total of USD 1 126M would be allocated to the energy sector, from which USD 652M would go to urban electrification and USD 474M would be allocated to rural

electrification. This scenario could be possible if rural electrification remains a government priority and it would yield USD 31.6M per year for rural electrification (see **Figure 9.8**).

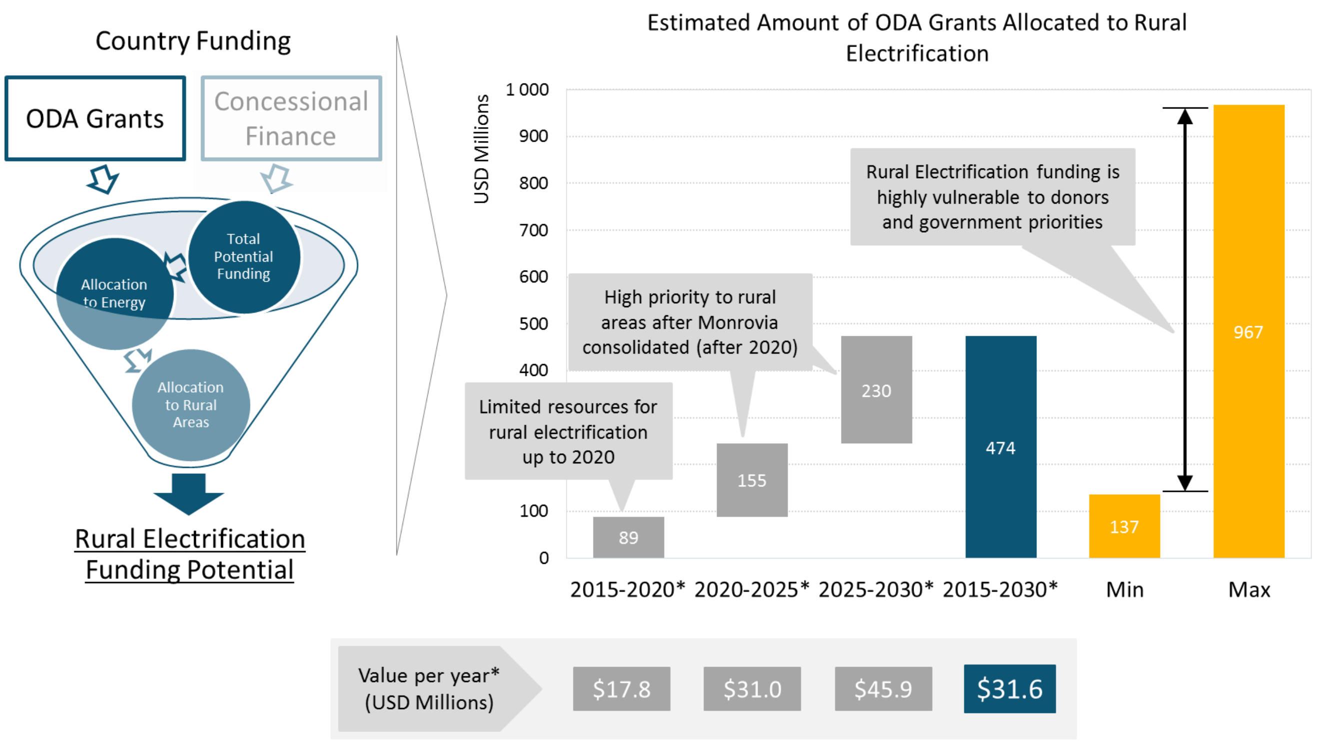


Figure 9.8 – Potential ODA Grants until 2030, under intermediate scenarios.

Limited resources for rural electrification up to 2020. Given the higher prioritization to urban areas versus rural areas for electrification until 2020, the funding potential for rural electrification is limited in the near future. Indeed, under intermediate scenarios, the funding potential in the first 5 years (2015-2020) will be only USD 89M, equivalent to USD 17.8M per year, compared to the last period (2025-2030) where the estimated funding is USD 230M, equivalent to USD 45.9M per year. Thus there are limited resources for rural electrification up to 2020 and then, given a more balanced prioritization to rural electrification, the funding available will be higher.

High vulnerability to donors and government priorities. It is important to note once again that as ODA grants are highly vulnerable to several factors such as donor's availability and preferences and country's priorities, the potential ODA grants funding have an extremely high range – from 967 to 137 million USD.

9.2 GOVERNMENT GUARANTEED FUNDING: CONCESSIONAL FUNDING AND DEVELOPMENT FINANCE

9.2.1 CONCESSIONAL LOANS

Concessional loans are the cheapest way to incur in debt. Concessional loans are loans to government that are extended on terms substantially more generous than market loans, with interest rates below available on the market (between 0.5 and 3%), and have long grace periods which can extend up to 50

years. Thus, this is the cheapest way for a country to incur in debt. However, the total potential funding from concessional loans depends on the country's debt re-payment capacity, the level and cost of public secured debt, IMF limitations/policy, and country priorities. The main agents which provide concessional loans are AfDB, IDA, IMF and Organization for Economic Co-operation and Development (OECD) countries.

Liberia's debt relief under the HIPC initiative in 2009/10. As discussed before, Liberia was granted a high amount of debt relief in 2009/10. Indeed, Liberia was the most indebted country after the war and almost all its debt was forgiven. Given this debt relief, Liberia is currently under the IMF control and its amount of debt is restrained as it need to stay on a level where it can be managed, along with other Highly Indebted Poor Countries.

Government Debt as percentage of GDP scenarios. In order to develop scenarios for Liberia's debt until 2030 we combined IMF's prediction of Liberia's government debt as percentage of GDP until 2020 and Given this, three debt scenarios was developed in order to estimate the potential funding from concessional loans, as depicted in **Figure 9.9**:

Aggressive scenario: Liberia's government debt as percentage of GDP will go up to 60% in 2030;

Intermediate scenario: Liberia's debt will go up to 50% in 2030;

Conservative scenario: Liberia's government debt as percentage of GDP will stay at 41.2%.

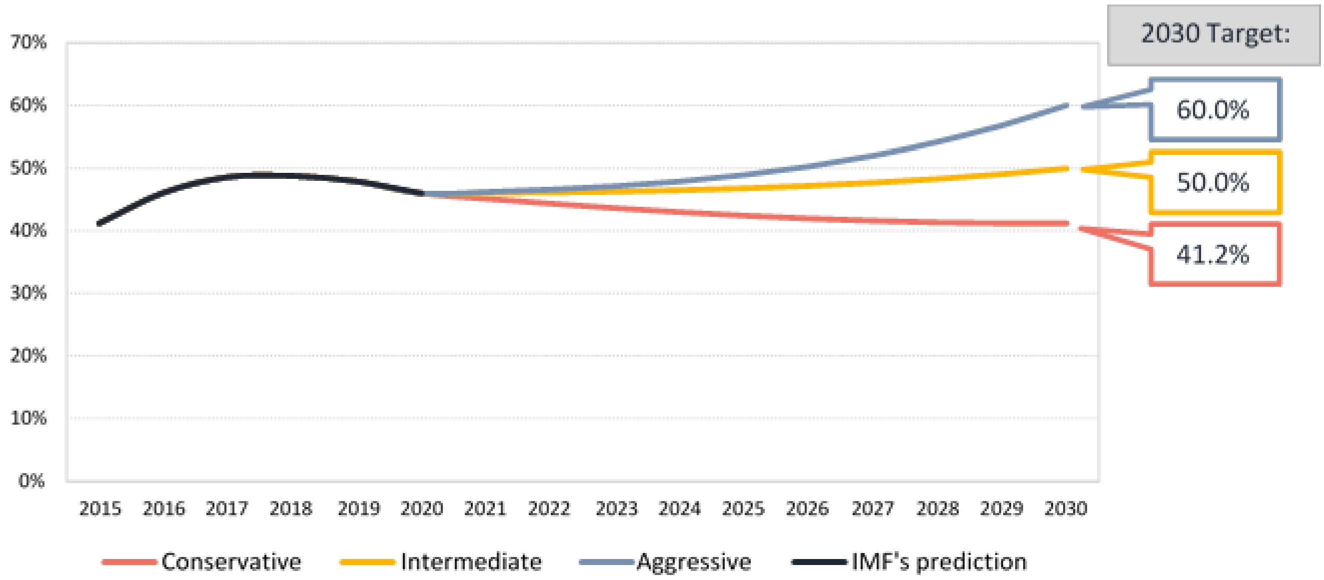


Figure 9.9 – Liberia's Government Debt as Percentage of GDP Scenarios.

Total amount of concessional loans available to Liberia. The concessional loans available to Liberia each year equals the incremental amount of debt it undertakes each year, taking into consideration its GDP growth and debt percentage of GDP. Thus, for the period of 2015 to 2030, the amount of concessional loans available to Liberia equals the sum of the incremental amount of debt it undertakes each year, as demonstrated in **Figure 9.10** with the example of the intermediate debt scenario.

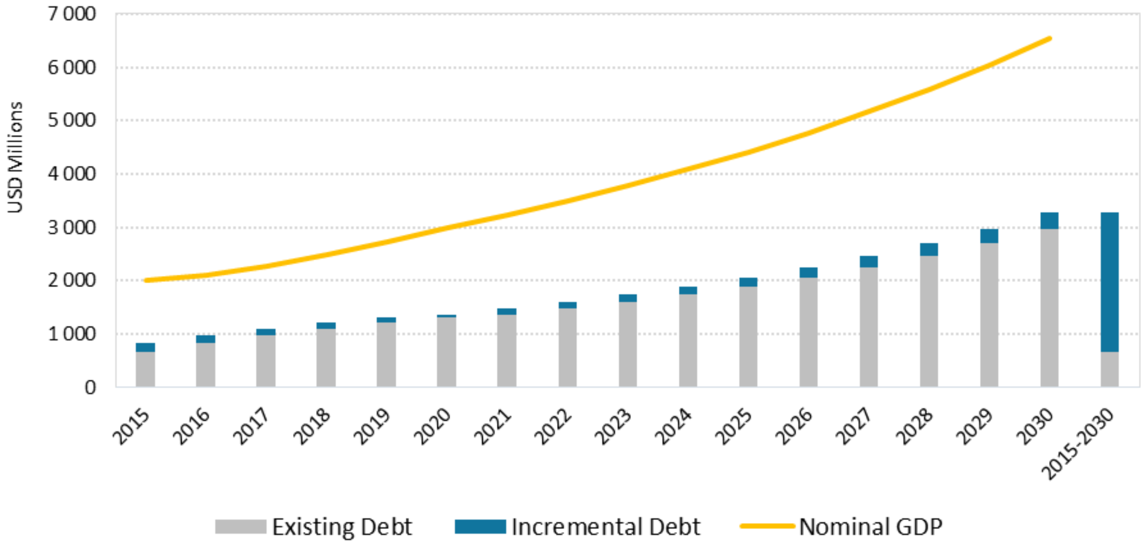


Figure 9.10 – GDP and yearly incremental amount of debt available under the Intermediate Debt Scenario.

Total amount of concessional loans allocated to rural electrification can range from USD 26 to USD 148 million. This type of funding is also a country related funding, thus it has to go through the same allocation process for energy and rural as grants. Given this, we have the available rural electrification funding potential from concessional loans. The funding potential of concessional loans ranges for energy ranges from USD 324M under the most aggressive scenario, where USD 148M would be allocated to rural electrification; to USD 61M in the most conservative scenario, where only USD 26M would be allocated to rural electrification (see **Figure 9.11**). These two scenarios would yield an average value per year of 9.84 to 1.75 million USD to be allocated in rural electrification.

Limited concessional loans potential. The amount of concessional loans is limited and its potential funding is much lower than the potential funding coming from grants as analyzed before. This is partly due to Liberia's past with the IFM and the amount of debt relief received, and thus it needs to stay within a level where it can be managed.

If rural electrification remains government's priorities, concessional loans allocated funding can go above USD 75M. This type of funding is also highly dependent on the country priorities. Indeed, under the intermediate debt allocation scenario – where Liberia's general government gross debt as percentage of GDP reaches 50% in 2030 –, the rural electrification funding can range from 113 to 36 million USD depending on the priorities of the government regarding energy allocation – whether it continues Liberia's priority or it goes down to the west Africa's average.

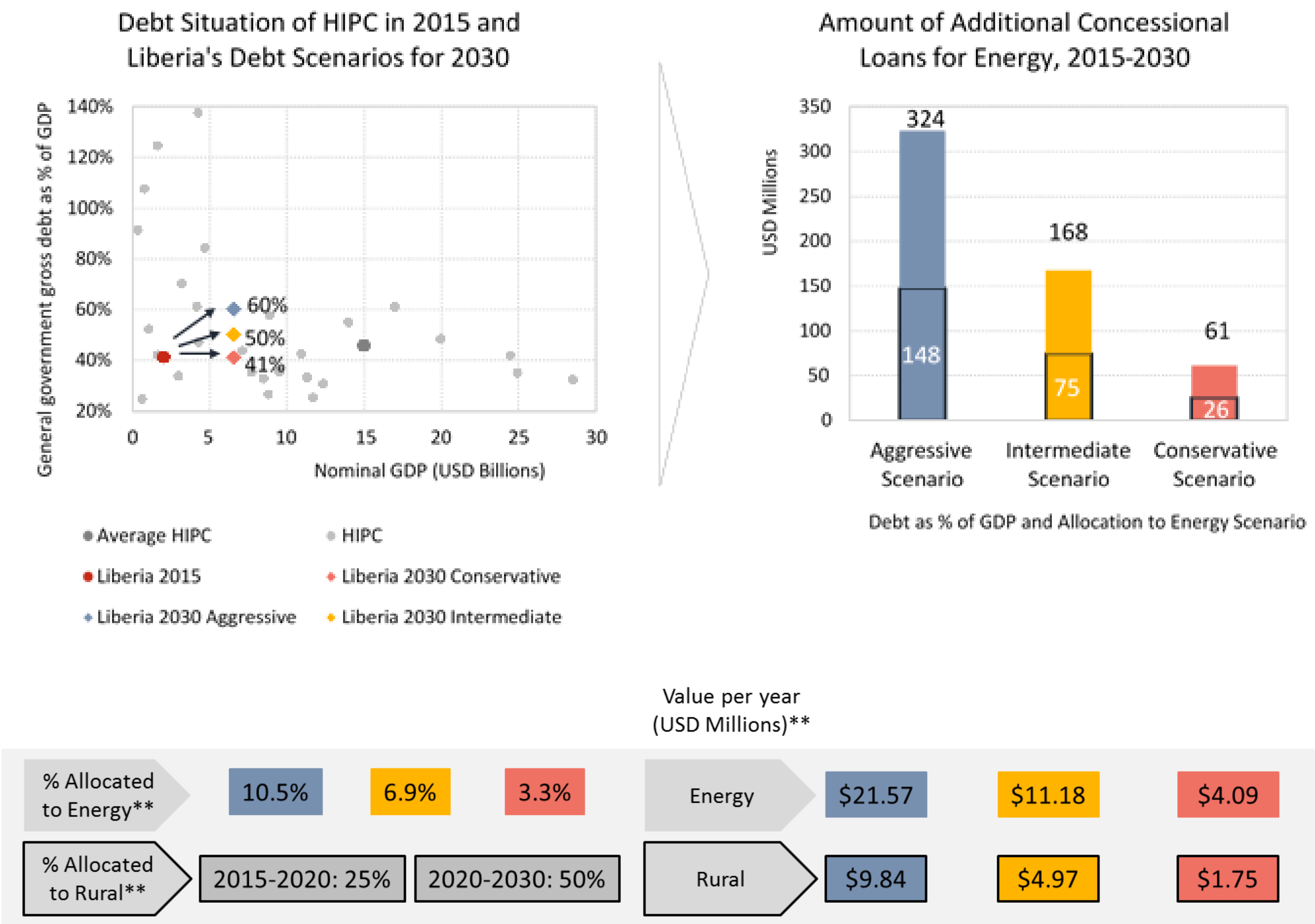


Figure 9.11 – Concessional loans allocation to rural electrification scenarios.

9.2.2 DEVELOPMENT FINANCE

National and international development finance institutions (DFIs) are specialized development banks or subsidiaries set up to support private sector development in developing countries. They are usually majority-owned by national governments and source their capital from national or international development funds or benefit from government guarantees. This ensures their creditworthiness, which enables them to raise large amounts of money on international capital markets and provide financing on very competitive terms.

Bilateral DFIs are either independent institutions, such as the Netherlands Development Finance Company (FMO), or part of larger bilateral development banks, such as the German Investment and Development Company (DEG), which is part of the German development bank KfW. They are both among the largest DFIs worldwide.

Multilateral DFIs are the private sector arms of international financial institutions (IFIs) that have been established by more than one country, and hence are subject to international law. Their shareholders are generally national governments, but could also occasionally include other international or private institutions. These institutions finance projects in support of the private sector through mainly equity investments, long-term loans and guarantees. They usually have a

greater financing capacity than bilateral development banks and also act as a forum for close co-operation among governments. The main multilateral Development Finance Institutions to Africa are the African Development Bank Group, the International Finance Corporation (IFC), and the World Bank's Multilateral Investment Guarantee Agency (MIGA).

Concessional and development finance offer low cost funding, but IMF restrictions and DFI requirements may limit access. Development Finance are loans provided by these DFIs to the private sector or public companies in developing countries with limited access to private sector funding. This type of finance is between public aid and private investment, and thus has low interest rates, around 5 to 7%, and tenors up to 20 years. However, in energy sector, DFIs normally require Government Guarantee given financial situation of off-takers (power utilities). Indeed, the LEC does not have a robust financial situation, hence there will be a need to secure the private debt by the Government, and thus private debt becomes "public secured debt", reducing country's access to concessional loans. Nevertheless, this can be mitigated with different mechanisms that may be accepted by DFI's, such as partial risk guarantees or a well-functioning regulator in place or other less binding types of government involvement and support.

Given this trade-off, Liberia should maximize concessional loans and structure investments in a way to have access to Development Finance without requirements for Sovereign Guarantees that could limit the maximization of concessional loans.

9.3 RURAL ENERGY BUSINESS MODEL AND FREE CASH FLOW POTENTIAL ANALYSIS

9.3.1 PROJECT RELATED FUNDING

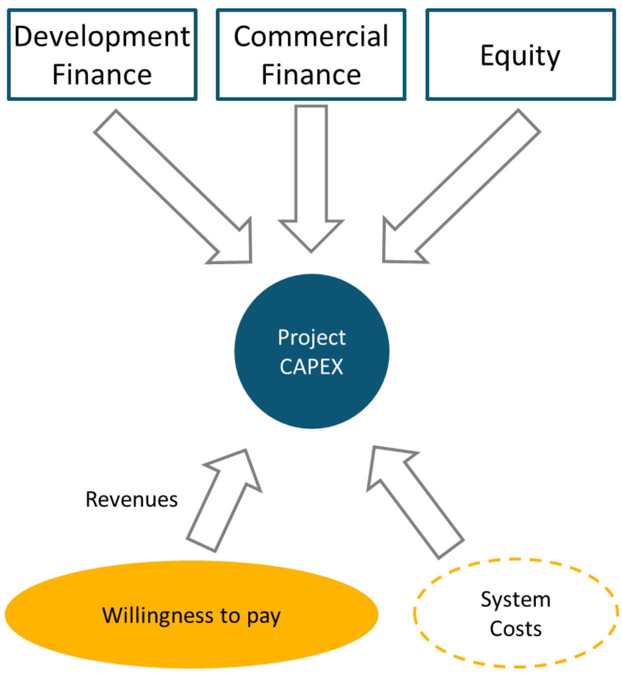


Figure 9.12 – Project Related Funding Scheme.

Project Related Funding. Project related funding comes from the free cash flows generated by the power sector, which can be used to repay debt and interest of such funding. Project related funding does not have to go through the allocation trade-offs country related funding has, as the incoming cash flows generated from the rural electricity system will be used to self-finance it. The total funding that can be generated will depend on the level of free cash flow and therefore in the rural energy sector fundamental of revenue and cost, and with the risk of uncertainty associated with the cash flows. A scheme can be seen in **Figure 9.12**.

OPEX and CAPEX. The revenues generated by the rural electricity system will therefore be used to pay its OPEX, and the CAPEX investment and its interest. This distinction between OPEX and CAPEX is necessary because what is intended to quantify in project related funding is the potential profits of the system, thus we should only take into consideration the revenues that the system enables minus its operational expenses. Indeed, these two activities are extremely different:

> **OPEX** refers to expenses incurred in the course of ordinary business. As these costs are related to the day-to-day costs of operation they are variable depending on the energy produced and sold. They can be, for example, expenses on wages, sales, general and administrative expenses, utilities, and rent;
>
> **CAPEX** are funds used to purchase major physical goods in order to enable the company to generate profits. These expenditures tend to cover fixed non-consumable physical assets. Moreover, these assets cannot be fully deducted in the period when they were incurred. The CAPEX in the power sector are for example the infrastructures needed to produce, transport and distribute electricity, hence it is the initial investment in the sector.

Thus, in order to finance the CAPEX the system will need to borrow money and use its revenues to repay it at the agreed terms. The costs of generation, transmission and distribution of electricity were calculated taking into account this differentiation between CAPEX and OPEX. Each of these costs have both CAPEX (the infrastructures and machinery needed), and OPEX (the wages, administrative expenses).

It is also important to note that this exercise is a rough estimate to calculate project related funding, and hence it is a simplified approach and not precise nor a final model.

9.3.2 REVENUES

9.3.3 WILLINGNESS TO PAY

Willingness to Pay. In order to evaluate how much consumers are willing to pay for electricity, two different methods were used: deduction of the implicit willingness to pay taking into consideration the sources of electrification most available (community current and diesel generators), and the willingness to pay study.

Community Current. Currently, community current is the most used modern energy supply alternative in large cities in Liberia, although only around 20% of the population in such large cities uses it. This source of energy is made available by small entrepreneurs who create mini-grids, and has a cost from 36 to 54 USD per month, for 1 amp with limited service of around 12 hours. This price is equivalent to 0.74 to 1.12 USD/kWh.

Diesel Generators. Some people own small diesel generators. Smaller individual generators are less efficient with a cost of 1.3 USD/kWh. Bigger and more efficient diesel generators can have significantly lower costs of around 0.38 USD/kWh, but require significant individual demand and investment.

Willingness to Pay Study. Regarding the willingness to pay survey, the rural households were divided into four expenditure quartiles, with quartile 1 (Q1) being the lowest and quartile 4 (Q4) being the highest. In this study the expenditures were used to indicate ability and willingness to pay and the results on the willingness to pay by kWh are presented in **Table 9.1**. According to this willingness to pay, the quartile with lowest affordability is 1.98 USD/kWh, which is way higher than the rents in both community current and diesel generators. However, despite the higher cost per kWh, the levels of consumption are very low resulting in limited revenue per month.

Table 9.1 – Willingness to pay by quartile [13].

Quartile	WTP - USD/kWh
1	2.46
2	2.40
3	2.32
4	1.89

These three sources demonstrate that people are willing to pay extremely high tariffs to satisfy basic needs. However, such high willingness to pay may not apply for higher levels of consumption, hence monthly expenditure is a better indicator of capacity to pay.

LEC's tariff. The current electricity tariff that LEC asks in Monrovia (the only place where it operates) is 0.55 USD/kWh [13]. This tariff is much higher than many other African countries, as it can be seen in **Figure 9.13**. Moreover, LEC operates in cross-border with a tariff of 0.25 USD/kWh, which is more in line with the international benchmarks. Current situation in Monrovia, where tariffs are higher than self-generation, results in high levels of privately owned generators. Hence a tariff above 0.38 USD/kWh would result in low demand as many clients may opt to have their own generator.

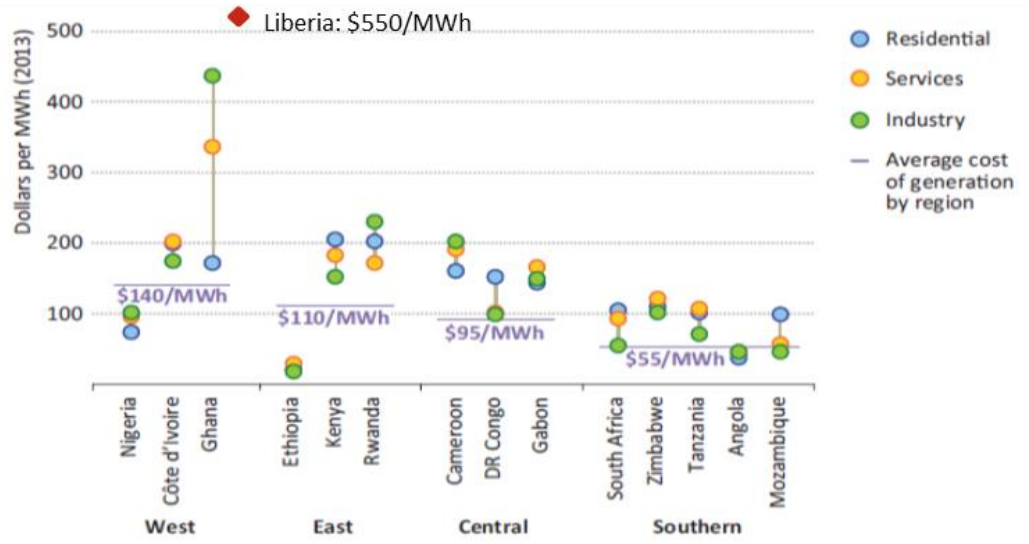


Figure 9.13 – Grid electricity prices by end-use sector [32].

9.3.4 REVENUE ESTIMATION

Electricity price is a key variable. In order to estimate rural energy revenues and energy consumed we have considered not the unitary willingness to pay, but the monthly expenditure for each consumer category. If consumers have maximum budget, then as long as price is competitive against alternatives they will consume as much kWh as they can afford. Therefore electricity price is a key variable. As we have seen, it should not be higher than 0.38 USD/kWh, otherwise people would have their own generators, and it should ideally match the long term estimate for the national grid (0.25 USD/kWh), which is in line with neighboring countries and is already used in cross-border. Two scenarios were evaluated in order to set the electricity tariff and a price simulation for community current for 1 Amp rent with 12 hours service and 40% utilization was made:

- The long-term electricity tariff target of 0.25 USD/kWh, which would yield a cost of rent of 7.4 USD/month, equivalent to 24 LRD/day
- A higher electricity tariff of 0.35 USD/kWh, which would yield a cost of rent of 10.4 USD/month, equivalent to 34 LRD/day.

Setting the tariff. The tariff of 0.35 USD/kWh was the one considered, as this electricity tariff is viable for villages up to category 5 which represent the majority of clients electrify and would benefit the population compared to their current alternatives. Moreover, it is wiser to enforce a higher tariff in the first periods in order to ensure the financial stability of the power sector.

Consumption per month. Having the tariff defined, we are left with determining how much clients will spend on electricity per month in order to determine the revenues each type of client will generate. The WTP report [13] also has information regarding the amount of kWh used per month on each quartile, thus by multiplying the monthly consumption in kWh by the tariff we have the monthly USD spent by quartile. Moreover, the consumption quartiles were converted into categories by type of client, and its spending per month is presented in **Table 9.2** below.

Table 9.2 – Amount of USD spent per month on electricity per client category [13].

Category	Source (WTP)	Spent per Month (USD/Month)	Obs.
1	X	X	(Monrovia)
2	Quartile 4	23.36	
3	Urban (Average)	18.06	
4	Quartile 3	10.02	
5	Quartile 2	7.88	
6	Quartile 1	5.71	

In order to calculate the monthly expenditure in future years, a consumption growth rate of 2.34% per year was assumed. As the number of expected electrifies households will depend on the scenario of electrification, the final profits generated by the system will be calculated later on the free cash flow part. It is important to note that the demand is always uncertain, and thus it can impact seriously the revenues.

9.3.5 PROPOSED BILLING SYSTEM

The proposed billing system for rural electrification is similar to the already used in community current and could be based on pre-paid meters for all mini-grid and national grid rural clients.

Fixed charge. The existing community current system is based on a fixed charge per month, and thus the similarities with the proposed billing systems is that customers would pay a minimum charge of USD 10 monthly (~30 kWh) or USD 2.5weekly (~7 kWh) for 1 Amp service. However, previous experiences in other countries such as Senegal with fixed charges without metering have not been successful. Indeed, a billing system with only a fixed charge has several problems:

- Operators minimize fuel and reduce service
- Not fair for poorer settlements
- No energy efficiency incentive
- Commercial costs require monthly collection (which many cannot afford)
- Higher change of mismatch when collecting payments

Prepaid metering system. In order to address the issues of a fixed charge billing system, a prepaid meter should be installed and if clients want to consume more than 1 Amp per month they have to pay extra for additional kWh (35c) or Amp (additional fixed charge and energy credit). Indeed, examples such as Mozambique show that pre-paid metering can be very successful in rural settings, as it has the following benefits:

- Allows consumers to adjust their bill
- Reduces commercial costs

Proposed billing system. The proposed billing system takes into consideration the two previous examples, as presented in **Figure 9.14**. Clients have a minimum fixed charge 1 Amp of electricity and then if they want to consume more electricity they have to pay additional pre-paid credit at

0.35 USD/kWh. The option of starting with a 2 Amp monthly charge should also be available for those who consume more electricity.

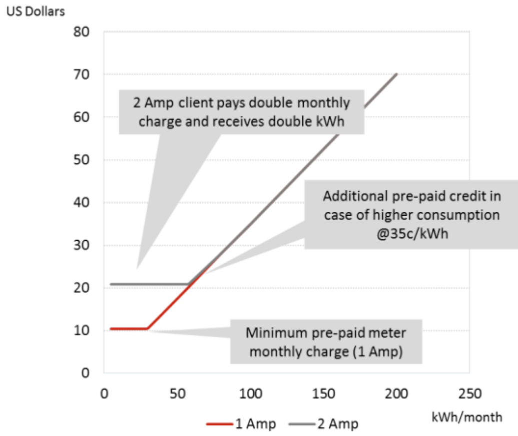


Figure 9.14 – Monthly electricity bill proposed structure.

9.3.5.1 DISTRIBUTION COSTS

Method of computing the distribution costs. As mentioned before, the transmission and distribution of electricity were calculated taking into account this differentiation between CAPEX and OPEX. Each of these activities have both CAPEX (the infrastructures and machinery needed), and OPEX (the wages, administrative expenses). The distribution and transmission costs were estimated by two approaches – benchmarks from other African countries, and scenario budgeting with the Consultant's experience.

The distribution costs were estimated to be 70 USD/MWh. This value was calculated based on several international benchmarks of distribution companies and on the Salala case study, where the hypothetical distribution network for the referred community was dimensioned and budgeted. The benchmark for the distribution OPEX is presented in **Figure 9.15**, where the power distribution companies from Nigeria, Ghana and South Africa OPEX were analyzed. The average OPEX of these distribution companies yielded 25.33 USD/MWh. The CAPEX of distribution on investment was calculated using the Salala case study, which yielded 45 USD/MWh - considering 5% WACC (Weighted Average Cost of Capital). Thus, the total distribution costs are 70 USD/MWh. These distribution costs are applicable to all grid types where there is a need to have distribution lines, hence all except off-grid

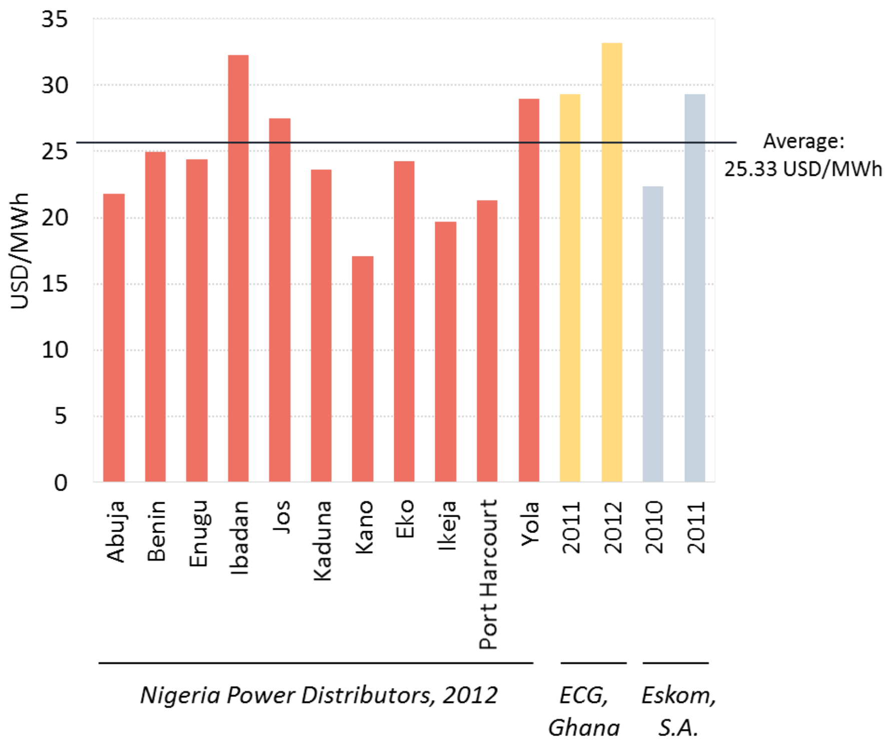


Figure 9.15 – Distribution OPEX Benchmark.

9.3.5.2 TRANSMISSION COSTS

The transmission costs were calculated based on scenario budgeting, benchmark and the Consultant's experience. The total transmission cost yielded by this scenario budgeting was 30 USD/MWh, where the OPEX was 12 USD/MWh and the CAPEX the remaining 18 USD/MWh (considering 5% WACC). These transmission costs are only applicable to the national grid and decentralized grids as they are the only ones needing transmission lines.

9.3.5.3 ENERGY LOSSES

Moreover, the power system also suffers from energy losses costs, which are about 13% energy of the total energy sold. Given this, energy losses requires excess generation and transmission in order to fulfill demand levels, thus incurring in an extra cost.

9.3.5.4 GENERATION COSTS

The generation costs were calculated using the Levelized Generation Cost based on WACC of 5%. These costs were calculated for each of the generation alternatives and are shown in **Figure 9.16** and **Table 9.3**:

Off-grids. The off-grids are going to be generated by 100% solar energy. This type of generation used for off-grids has a high component of CAPEX (580.8 USD/MWh) as the majority of the costs incurred are in the investment of the solar panel and then the running costs are extremely low. Hence, although the

total levelized generation cost of 100% solar (646 USD/MWh) is higher than the sale tariff, when taking into consideration only the OPEX (65.2 USD/MWh) it is below 350 USD/kWh.

Mini-grids. For the mini-grids three levelized generation costs were calculated – two short-run scenarios where the mini-grid would run with 50% solar and the remaining diesel. In the first scenario the diesel cost taken into consideration was the price currently charged in Monrovia as it's the cheapest price in Liberia (363 USD/MWh). The second scenario is still a short-term scenario and what differs from the first scenario is that the cost of diesel used is the one charged in Harper, which is the highest price in Liberia, and thus the levelized generation cost is higher than the first transitional diesel and solar scenario (399 USD/MWh). The third scenario is a long-term scenario, as it is expected that the mini-grid will have a more intense utilization in the future. Hence, as no more solar can be used the mini-grid will shift from 50% solar to 30% solar, thus using 20% more diesel. This last scenario yields the highest levelized generation cost (402 USD/MWh). The OPEX is obviously higher in the scenarios where more diesel is used. Moreover, once again the levelized generation costs are above the sale tariff, however the OPEX is below.

Decentralized grids. These grid type have generation costs coming from hydro power, imports and diesel. The levelized cost (237 USD/MWh) is already below the sale tariff.

National grid. The national grid will have power generated from hydro and HFO and is the type of grid with the lowest levelized generation cost (150 USD/MWh), and significantly lower than the sale tariff.

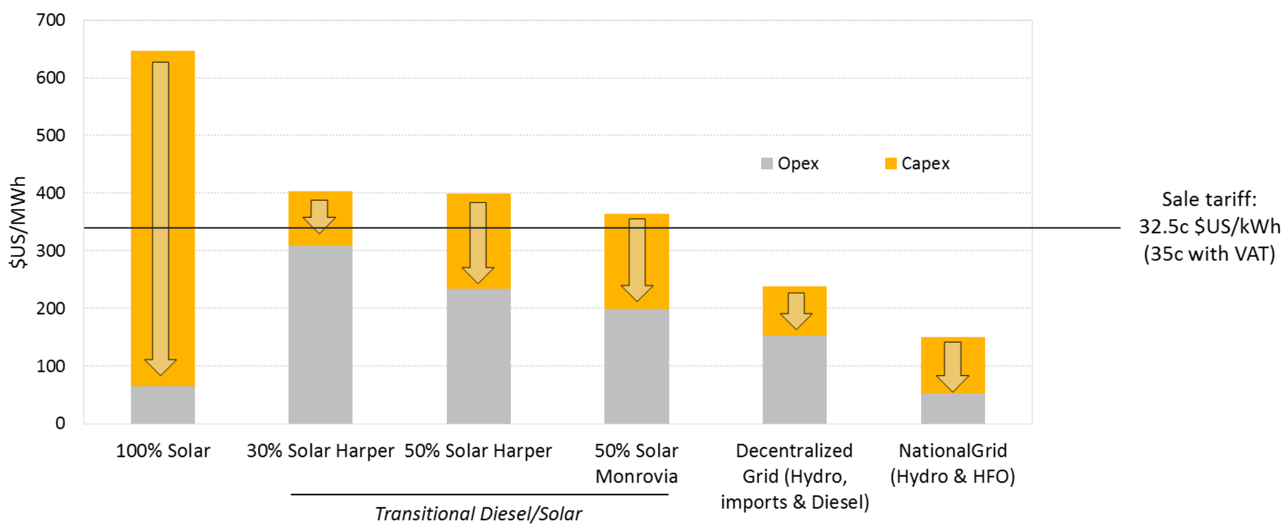


Figure 9.16 – Levelized Generation Cost.

Table 9.3 - Distribution of clients and generation cost for each scenario.

Scenario	% Distribution of Clients by Type of Grid				Generation Cost	
	Off-Grids	Mini-Grids	Decentralized Grid	National Grid	Average (USD/MWh)	% of rural Renewable Energy
1A	1%	2%	16%	81%	172.59	11%
1B	1%	5%	27%	67%	185.77	16%
2A	2%	1%	0%	97%	156.18	5%
2B	2%	4%	26%	68%	183.99	16%

Though low-OPEX solutions have high CAPEX, it can be reduced through funding. Although the levelized generation costs for 100% solar (used in off-grids) and the transitional grids is higher than the sale tariff of 32.5c USD/kWh without VAT, what matters in the end is that the OPEX is below the tariff. Indeed, the CAPEX related costs can be significantly reduced by using the grants revenues to fund it, hence allowing for system sustainability.

Generation costs will depend on the type of electrification scenario, as they differ in the amount of clients they reach. Indeed, scenarios 1A and 2A are more based on grid expansion and thus have higher percentage of clients will be connected to the national grid, and scenarios 1B and 2B have a higher percentage distribution of clients in mini-grids and decentralized grids, and thus a higher percentage of renewable energy. Moreover, given that the national grid is the type of grid with the lowest generation cost, scenarios 1A and 2A will have a lower generation costs versus the others with have a lower percentage of clients connected to this type of grid.

9.3.6 FREE CASH FLOWS

Revenues and costs depend on the scenario. Having in consideration all the revenues and costs, we can then calculate the free cash flows for each scenario. As mentioned above, each scenario will have a different number of expected electrified households and the percentage distribution of clients by type of grid will differ from scenario to scenario. Thus the revenues and costs will be different for each type of scenario, and consequently the free cash flows.

Calculations. The free cash flows were calculated by subtracting from the revenues the OPEX costs. In turn, the revenues were, as mentioned above, calculated by multiplying the number of expected electrified households by category for each scenario by the amount of USD spent on electricity, plus the consumptions of the services. The costs presented above are only the OPEX, as we are calculating the free cash flows for CAPEX.

This rural energy revenues breakdown and profits were analyzed for the year 2025 for the reason that these free cash flows will be used to pay for the loans and equity borrowed in order to afford the CAPEX. Hence, the funding potential of the electricity system was calculated for the intermediate years as a simplification.

Results. Figure 9.17 shows that scenarios 1A and 1B are the ones which have the lowest free cash flows. This is due to the lower electrification rate and hence revenues, as they will only electrify 35% of the rural households by 2030, compared to 50% in scenarios 2A and 2B.

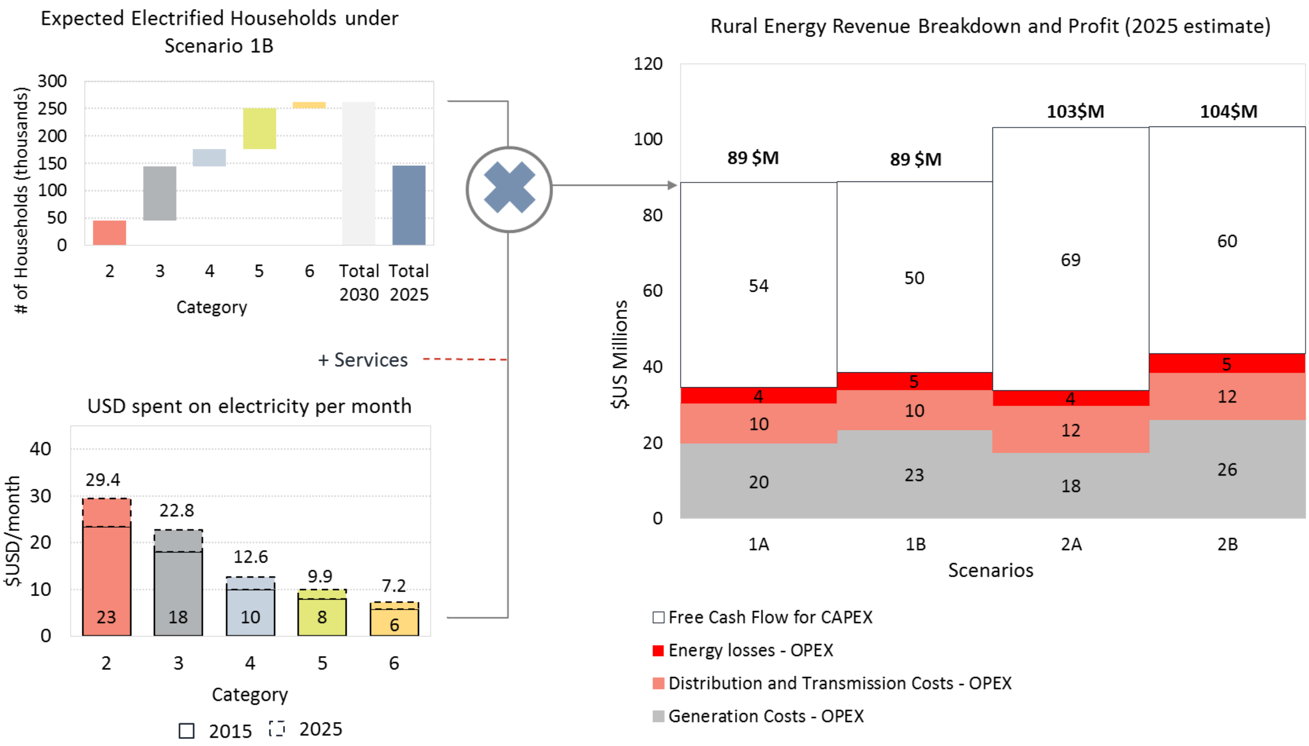


Figure 9.17 – Rural Energy Breakdown and Profit Estimation for the year 2025.

Regarding the percentage contribution to Free Cash Flow by type of grid, we have that 84% in scenario 1B to 99% in scenario 2A of Free Cash Flow is generated by rural clients connected to the National Grid. Indeed, other than being the type of grid with the highest percentage of connections, it is also the type of grid with the lowest costs. It can also be seen by **Figure 9.18** that the contribution of mini-grids and off-grids to the free cash flow is extremely low, bellow 1.25%.

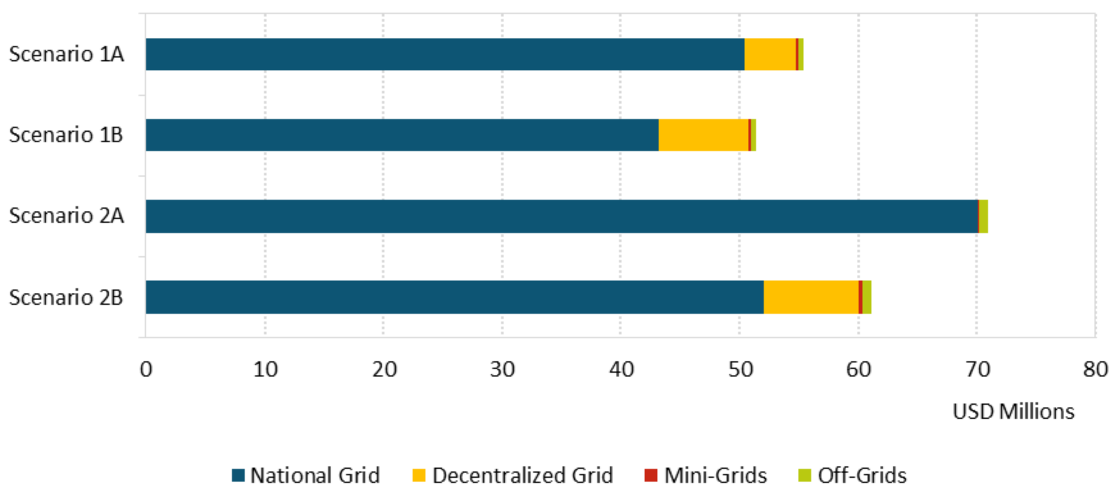


Figure 9.18 –Contribution to Free Cash Flow by Type of Grid and Client.

9.4 PROJECT FINANCING IN THE ENERGY SECTOR AND SCENARIO FUNDING ANALYSIS

Loans will be paid back using free cash flows generated. As mentioned before, project related funding comes from the free cash flows generated by the power sector and can in turn be used to self-finance it. Given that the CAPEX for the infrastructures is extremely high there is a need to borrow money to finance it. However, the amount of money borrowed will have to be paid back by using the free cash flows released by the power system.

Different types of funding have different conditions. The types of funding which can be used are the grants, concessional loans and DFI loans which were already mentioned, and commercial finance and equity (private sector). Each of these types of funding have different requirements and terms of payment. The free cash flows generated by the power system will have to be used to repay these types of funding (except grants as no repayment is necessary), at their own terms.

Types of loans. Hence, having the free cash flows determined, the next step it to understand how much loans can be borrowed using them. Thus the cost of financing needs to be determined by computing the yearly payment of each loan taking into consideration their terms:

- Concessional loans – in order to borrow USD 1M of CAPEX with an interest rate of 2% and a maturity of 40 years, the yearly repayment would be USD 37k;
- DFI loans – the interest rate for DFI loan are 6% with a maturity of 15 years, which would yield a cost of financing of USD 103k per year per USD 1M of CAPEX;
- Commercial finance/Equity – this type of financing has a 20% interest rate with a maturity of 5 years. Thus the yearly rent would be USD 334k yearly rent per USD 1M of CAPEX.

The concessional loans and grants were already estimated in the previous chapter, as it not project funding but country related funding. It was determined that the amount of grants and concessional loans the government should be able to allocate to rural electrification was USD 474M of grants and USD 75M of concessional loans (taking into consideration the intermediate scenario).

DFI loans and commercial finance. Each scenario has a certain CAPEX requirement, which cannot be funded with grants and concessional finance alone as it would yield a funding gap (USD 355M in scenario 1B), thus development finance and commercial finance will have to fund this gap. These DFI loans and commercial finance/equity depend on the free cash flows from the system and thus will be different for each scenarios. In this simulation for project related funding it was assumed that after repaying the yearly cost of concessional finance the free cash flows will be used to pay DFI loans and commercial finance, with an equal weight of 50%. Hence, after the repayment of the concessional loans, which would have a total yearly cost of USD 2.725M, the remaining free cash flows for that year will be used to repay DFI loans and commercial finance/equity. Other than the remaining free cash flow, the amount of loans available from DFI's and commercial finance will depend on the terms of payments calculated above, and are presented in **Figure 9.19**.

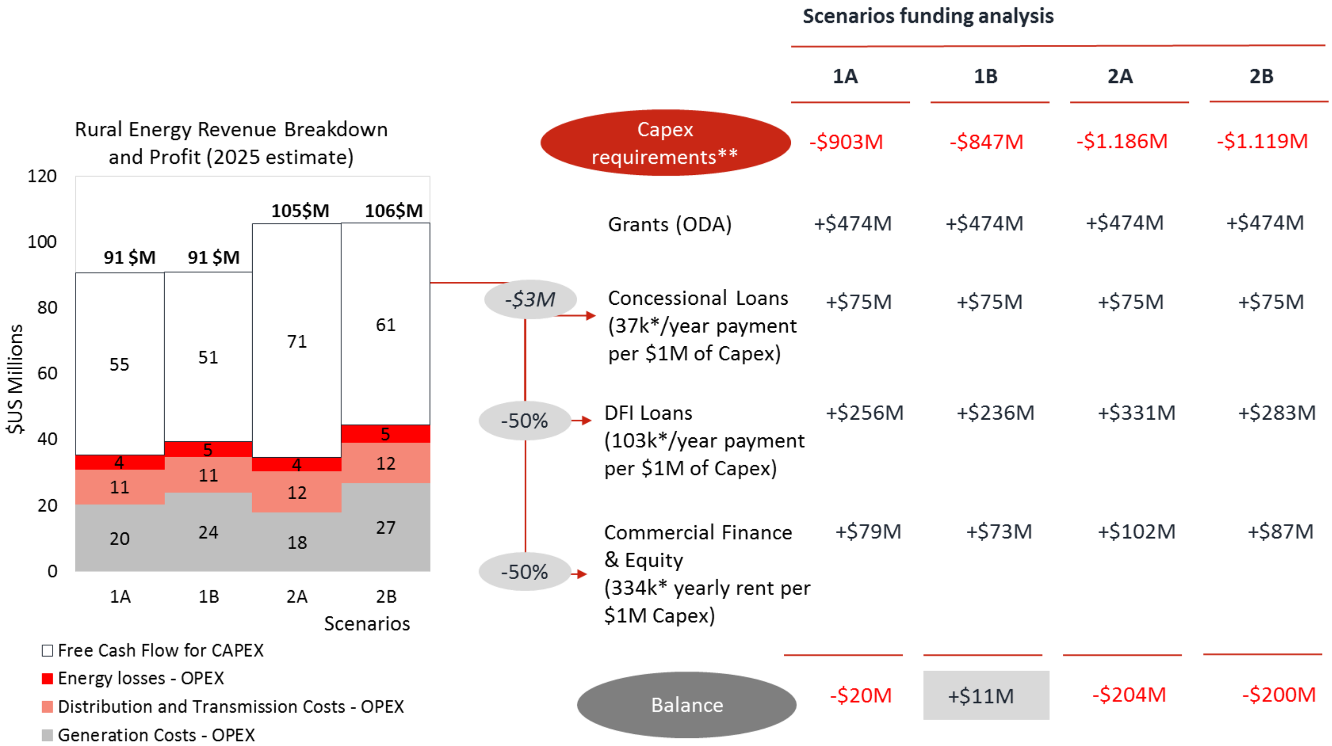


Figure 9.19 – Scenarios funding analysis.

Scenario 1B is the only without a funding gap. All these sources of funding will be used to pay the CAPEX, however as demonstrated in the figure above, scenario 1B is the only one with a positive balance and thus be funded. Indeed, although this scenario is the only with the lowest amount of free cash flow, it is the only with the lowest CAPEX requirement as well. This is partly explain because country related funding is a main source of funding and it is the same amount for every scenario. On the other hand, scenarios 2A and 2B has an extremely large CAPEX requirement (given that they are more ambitious scenarios) and also have a large amount of free cash flows, nevertheless due to the cost related to DFI loans and commercial finance being so much higher than country related funding, it has a funding gap. Thus, scenario 1B can be more easily funded, however a target of 50% of rural electrification is ambitious for 2030 and could imply a significant funding gap.

9.5 RISK MITIGATION AND AVAILABLE FINANCING SUPPORT INSTRUMENTS

DFI access must be ensured. As demonstrated below in **Figure 9.20**, development finance will be an important instrument in order to cover the CAPEX requirements. Indeed, without development finance scenario 1B would not be able to be funded. Even if all the project free cash flow was allocated to concessional loans and commercial finance/equity, the amount of commercial finance that could be raised with available cash flows would be only USD 146M, hence there would be a funding gap of USD 153M, taking into consideration scenario 1B. Thus, a complex structure may need to be implemented in order to manage risk and have access to development finance, without compromising the amount of concessional loans.

Scenario 1B:	Base Case (50% DFI)	Without DFI funding
Capex requirements	-$847M	-$847M
Grants (ODA)	+$474M	+$474M
Concessional Loans (37k*/year payment per $1M of Capex)	+$75M	+$75M
DFI Loans (103k*/year payment per $1M of Capex)	+$256M	+$0M
Commercial Finance & Equity (334k* yearly rent per $1M Capex)	+$79M	+$153M
Balance	+$11M	-$155M

Figure 9.20 – Funding analysis sensitivity of DFI loans for scenario 1B.

PRGs may grant access to DFI loans. One way to have access to DFI loans without sovereign guarantee is through a partial risk guarantee scheme, which with the correct design could allow funding and thus not limiting concessional loans. Partial Risk Guarantees (PRGs), also known as political risk guarantees, cover private lenders and investors against the risk of the government (or a government owned agency) failing to its obligations with respect to a private undertaking. PRGs ensure payment in the case of default resulting from the nonperformance of contractual obligations undertaken by governments or their agencies in private sector projects. PRGs typically cover outstanding principal and accrued interest of a debt tranche in full. Payment is made only if the debt service default is caused by risks specified under the guarantee.

Partial Risk Guarantees instruments are designed to:

- Crowd in private financing;
- Accelerate foreign direct investment;
- Promote infrastructure development;
- Encourage private sector participation in public-private partnerships.

PRGs' advantages. Moreover, PRGs can cover a range of risks relating to government performance, including changes in law, failure to meet contractual payment obligations, obstruction of an arbitration process, expropriation and nationalization, foreign currency availability and convertibility, nonpayment of a termination amount or an arbitration award following a covered default, and failure to issue licenses, approvals, and consents in a timely manner.

PRGs sources. These partial risk guarantees can provided by the World Bank or the African Development Bank, where 1 USD of grants could be exchanged by 4 USD of Partial Risk Guarantees (PRG). An example of a potential scheme is demonstrated below on **Figure 9.21**.

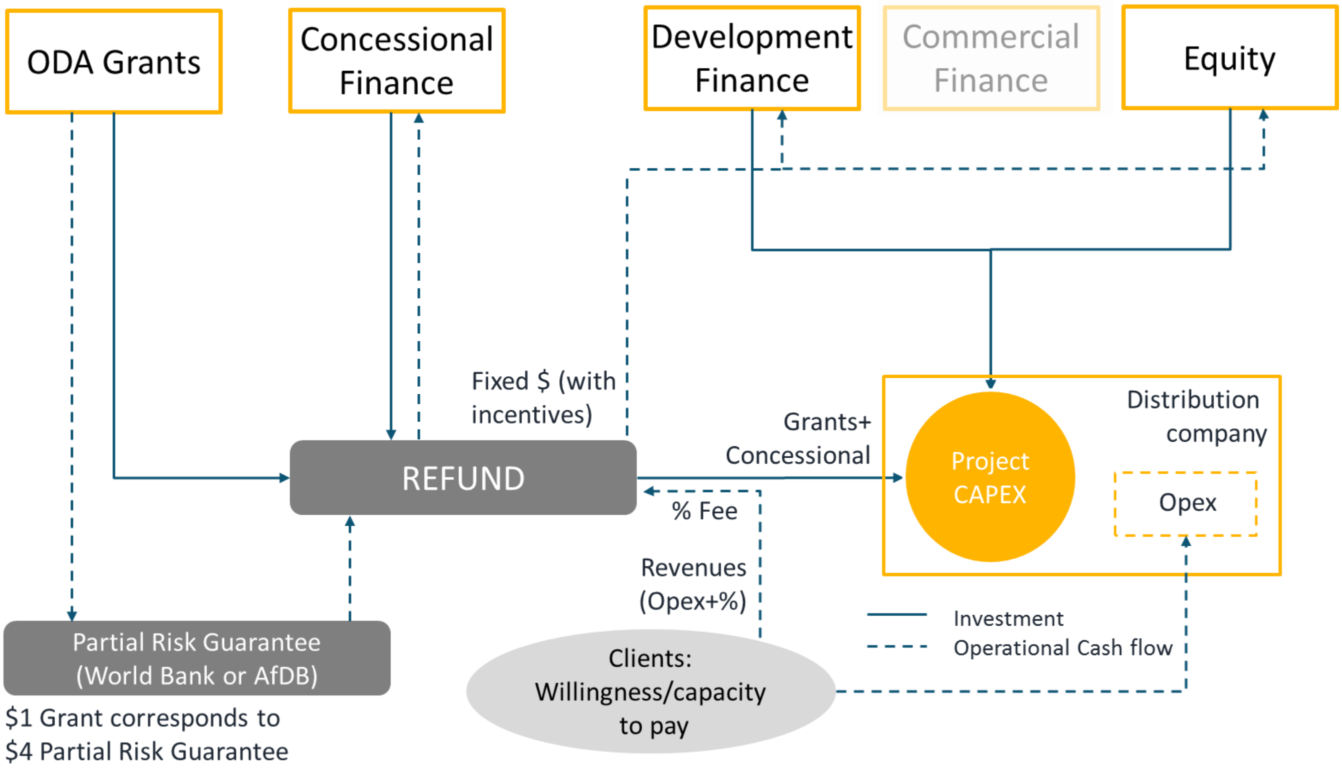


Figure 9.21 – Example of a potential scheme to obtain development finance without limiting concessional loans.

In this scheme, the REFUND would be used to allocate the revenues coming from country related funding, then allocating it to the project CAPEX, as well as to serve as to honor DFI re-payment assuming rural demand risk. Indeed, grant incorporation would allow for REFUND financial sustainability. Moreover, the partial risk guarantee scheme with a correct design could allow funding without sovereign guarantee and thus not limiting concessional loans.

9.6 OTHER POTENTIAL FUNDING SOURCES

Alternatives to DFIs. Given that development finance is critical for the ability to pay the project CAPEX and in order to obtain it a complex structure is necessary, other alternatives should be taken into consideration and explored.

In the beliefs audit interviews the additional preferred sources of funding were identified, namely tariffs from other clients and State Budget:

Tariffs from clients – Several countries impose a small levy on other consumers to finance rural electrification (Example: 5% levy in Ghana). A 5% levy on the Liberian clients could correspond to USD 15M/year (1 250 GWh in 2030 at USD 0.25/kWh) for rural electrification. Moreover, this levy could allow the repayment of up to USD 146M/USD 45M additional funding based on DFI/Commercial finance terms.

State budget/taxes – additionally to grant allocation and Partial Risk Guarantees, an allowance from State Budget could be considered. The total Government of Liberia tax budget predicted

for of 2016/17 is USD 437M. A 1% tax revenue would correspond to USD 4.4M/year, and if allocated to rural electrification could allow the repayment of up to USD 42M/USD 13M additional funding based on DFI/Commercial finance terms.

10 2030 RURAL ENERGY VISION AND TARGETS

10.1 LONG TERM VISION

Least Cost Long term vision. The starting point for the Rural Energy Master Plan was the development of a long term vision for the universal electrification of all Liberians – most likely only achievable on the 2050 horizon – using the most advanced geo-spatial network and off-grid planning tools developed by the Earth Institute of Columbia University. The resulting Medium Voltage optimal network was than processed by the Consultant to develop a conceptual High Voltage infra-structure with adequate levels of tension for estimated loads and location of HV/MV sub-stations and generation centers that can minimize investments in HV infra-structure while offering adequate n-1 redundancy. The vision is presented in **Figure 10.1**.

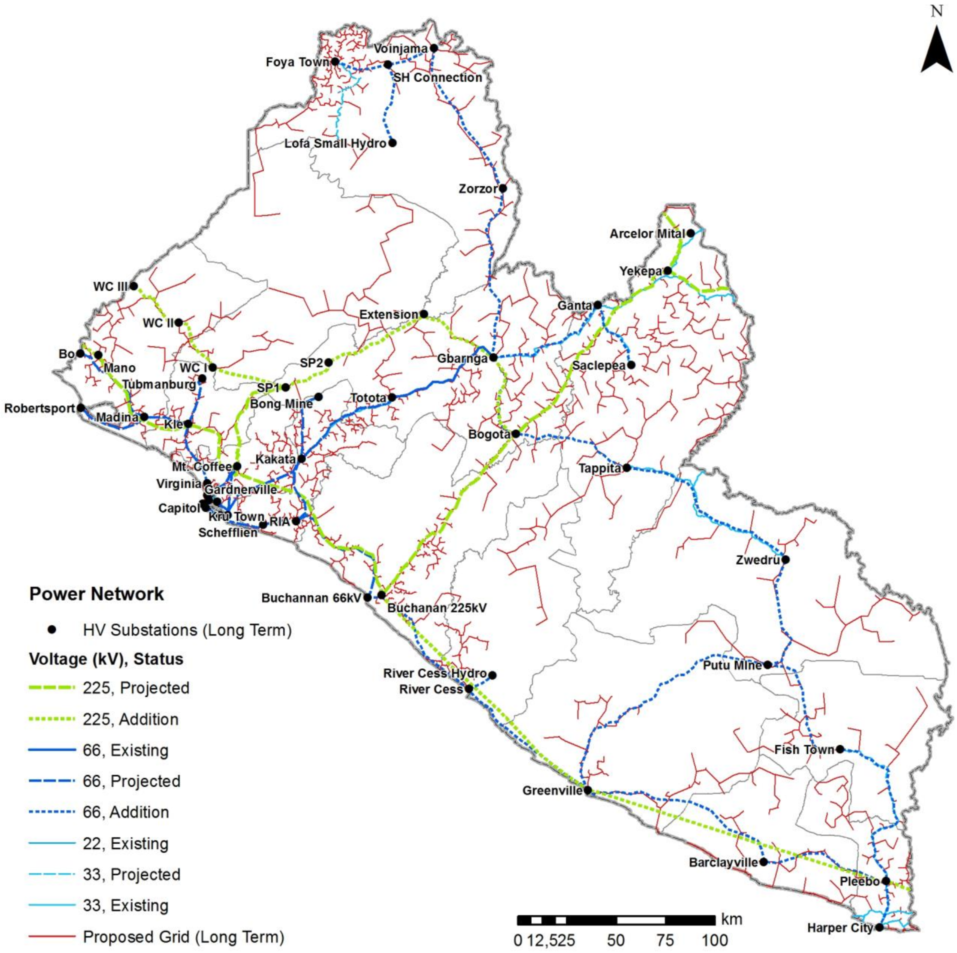


Figure 10.1 – Vision for the long term national grid of Liberia.

Long term grid results. As can be seen from **Figure 10.1**, the resulting National Grid covers a great part of the Country's populated areas and connects all County Capitals. In the long term the national grid will connect more than 89% of all population, corresponding to 97% of total energy demand. Although the majority of the population is grid connected, only 40% of the inhabited settlements (more than 5 000)

are covered by the long term grid. For the remaining 60% (>7000), the least cost option was the off-grid solution based on solar home systems. These off-grid locations are mainly small size settlements with an average size of 115 habitants scattered across the country far away from the main roads. Detailed tables of the energy supply and demand considered are presented in **ANNEX XI**.

10.2 SCENARIO COMPARISON AND SELECTION

Backwards to 2030. The Rural Energy Master Plan studied four alternative scenarios for the electricity sector in 2030 to reflect the vision and expectations of the different stakeholders interviewed (**Chapter 8**). All the scenarios were based and moved towards the long term vision (possibly 2050), but varied the electrification approach and the level of ambition (**Figure 10.2**), namely:

- Scenario 1A focused on traditional grid extension with a target of 35% rural electrification by 2030;
- Scenario 1B proposed an accelerated and more decentralized electrification approach to reach 35%;
- Scenario 2A defended an aggressive national grid extension to reach 50% rural electrification by 2030;
- Scenario 2B defended an aggressive investment program both on national grid, large decentralized grids and mini-grids to reach 50%.

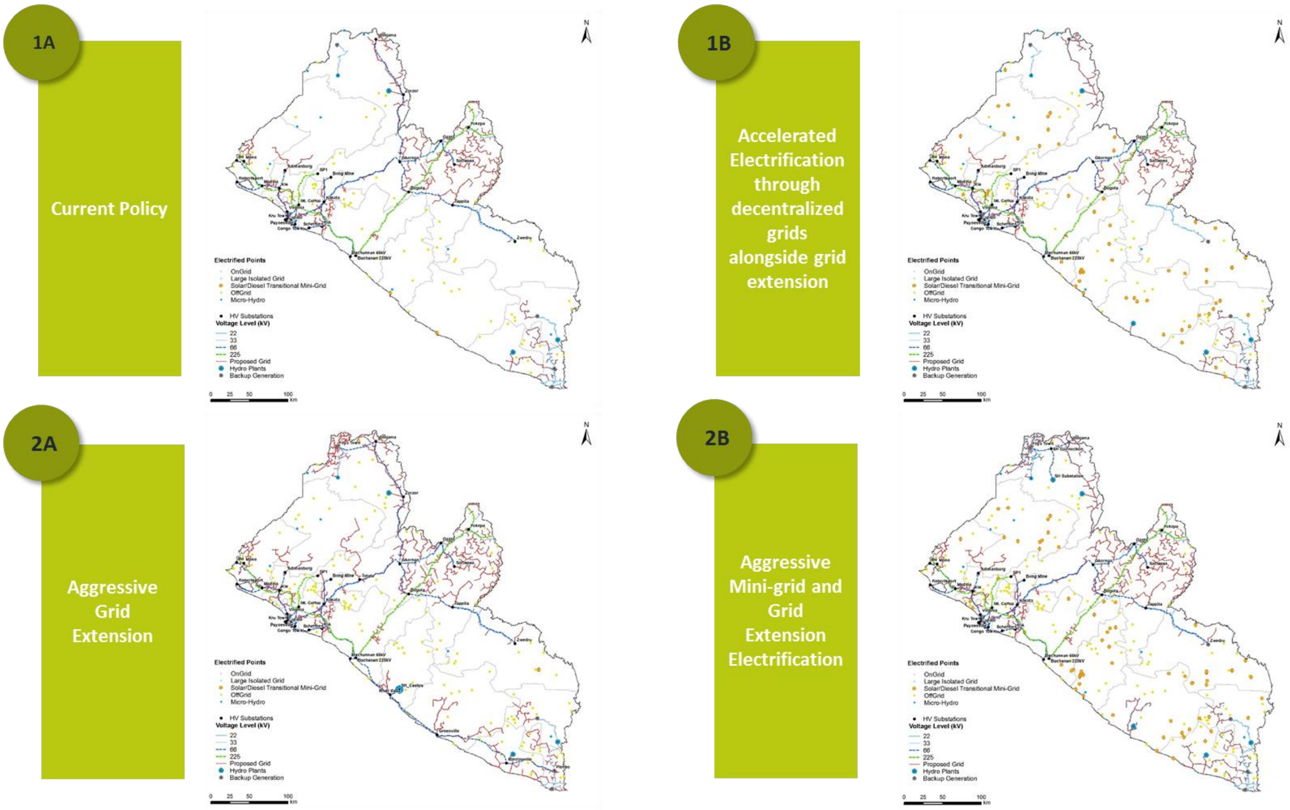


Figure 10.2 – Four scenarios studied for the 2030 horizon

The present section aims to make the comparison and selection between the scenarios.

Electrification strongly depends on grant allocation. From the funding analysis presented in **Chapter 9**, it is clear that a target of 35% rural electrification (Scenarios 1A and 1B) already requires significant commitment and urgency from the Government of Liberia, demanding a grant allocation to energy above the regional historical average. Moreover, funding a 50% rural electrification target (Scenarios 2A and 2B) would require a very strong commitment and grant allocation to rural energy by the Government of Liberia and is considered challenging to implement.

Mini-grids and decentralized grids versus traditional grid extension. Transitional mini-grids and decentralized grids (Scenarios 1B and 2B) represent lower investment compared to the corresponding scenarios with traditional grid extension (Scenarios 1A and 2A) and are easier to fund. Additionally, they represent more equitable electrification across the country, especially in more remote regions, when compared with national grid extension. For example, the county with the lowest electrification (River Cess) more than doubles the electrification rate between the traditional grid extension proposed in Scenario 1A (4%) and the decentralized grids proposed in Scenario 1B (9%), as can be seen from **Figure 10.3**. A similar trend occurs in other remote regions like Gbarpolu, Sinoe and Grand Gedeh counties.

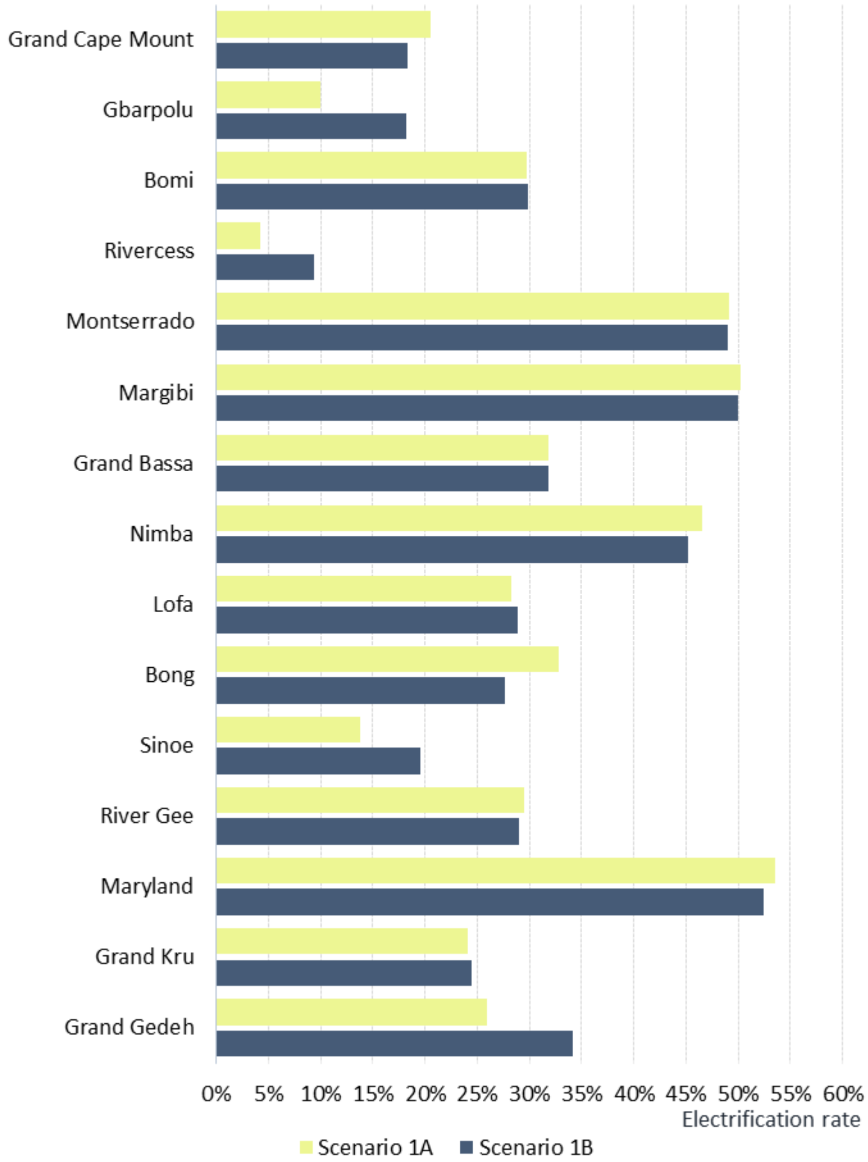


Figure 10.3 – County by county electrification rate comparison between Scenarios 1A and 1B.

Grid extension takes longer to reach remote areas. Furthermore, decentralized grids allow for faster electrification of many large consumption centers outside the national grid, benefiting from cross border energy imports or from hybrid generation centers (solar and diesel plants) investments. Usually, this represents more clients in decentralized grids, which can anticipate electrification in more remote areas, whereas grid extension is dependent on the grid growth schedule and, therefore, takes longer to reach said remote areas (**Figure 10.4**).

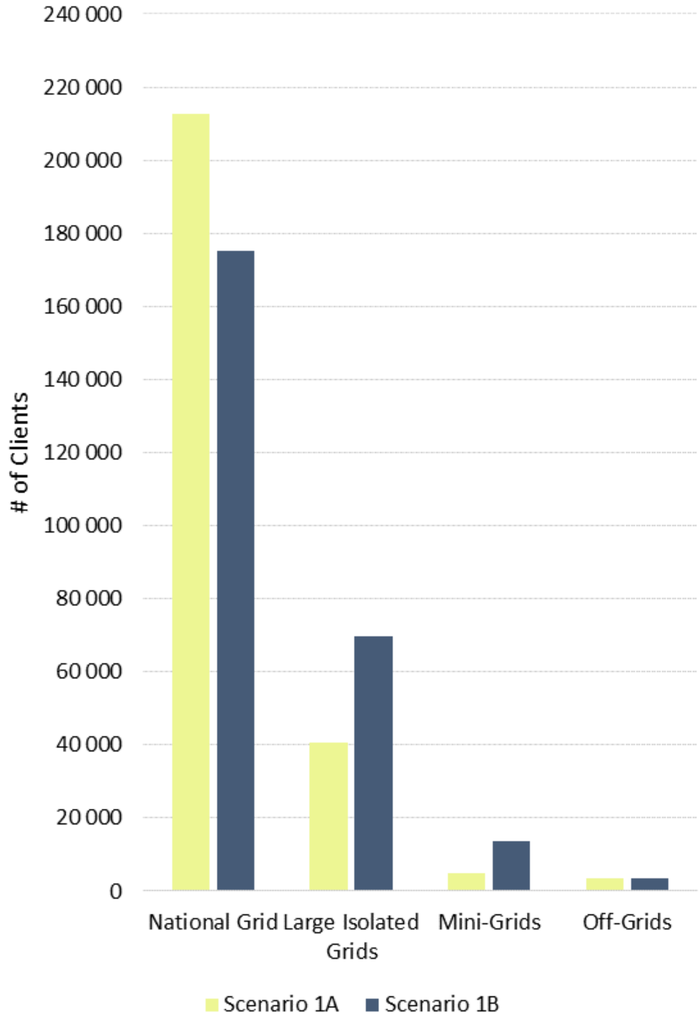


Figure 10.4 – Comparison between number of clients achieved in different types of electrification for Scenarios 1A and 1B.

Scenario 1B is the only scenario without a funding gap. It is also worth mentioning that the scenario proposing the accelerated electrification through decentralized grids alongside grid extension (Scenario 1B) has the lowest CAPEX and is the only scenario capable of raising sufficient funding for the planned investments, being the only scenario without a funding gap (**Chapter 9.4**).

Therefore, the Consultant proposes that the Rural Energy Master Plan is built from the accelerated electrification through decentralized grids alongside grid extension (Scenario 1B). This conclusion was also validated in the Stakeholder's Consultation and Validation Workshop[16], whose key notes are addressed in **ANNEX XII**. In fact, the accelerated electrification through decentralized grids alongside grid extension option (Scenario 1B), offers a faster and more equitable electrification process. This scenario represents an estimated total CAPEX of around **USD 0.8Bi**, for a peak demand of 140 MW in 2030.

[16] Passion Hotel, Gboveh Hill, Gbarnga City, Bong County, February 4, 2016

The representation of the proposed electrification map in 2030 (Scenario 1B) is presented in **Figure 10.5**.

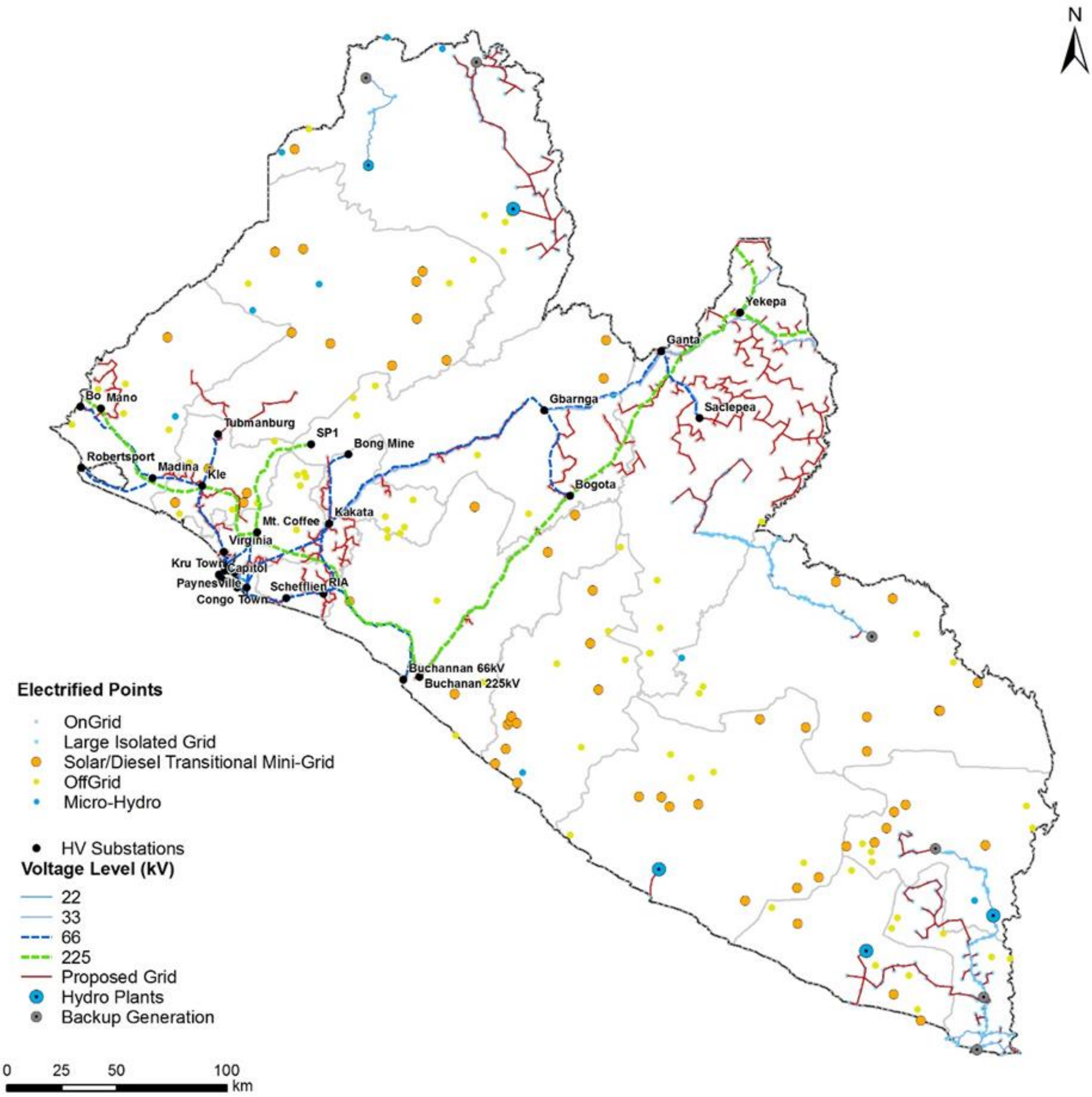


Figure 10.5 – Spatial representation of the proposed electrification map in 2030 (Scenario 1B).

10.3 RURAL ELECTRIFICATION VISION/MAP AND ACCESS TARGETS TO 2030

In line with the Sustainable Energy 4 All initiative and the Sustainable Development Goals, Liberia aims to achieve the following in terms of rural electricity access:

- Electrification rate for the population outside of Monrovia of 10% in 2020, 20% in 2025 and 35% in 2030. We intend to electrify outside of Monrovia more than 65 000 customers already by 2020, 140 000 by 2025 and 265 000 by 2035.
- Electrify at least 2 000 settlements with grid infra-structure (national, decentralized or mini grids) connecting at least 50% of those settlement's population by 2030.

- All County capitals will be already electrified before 2025. Electrification of County Capitals either through the National Grid, Decentralized Grids or Transitional Mini-Grids will be a priority of the Government.
- All Health facilities and Secondary schools electrified already before 2025. We intend to bring electricity to all health facilities and all secondary schools in Liberia either through grid-based electrification or through 100% solar based individual solutions.
- 10 largest settlements in every County will be electrified and no County will have less than 15% electrification rate by 2030. We intend to take electricity to the largest settlements across the country guaranteeing equity between Counties.
- Establish a credit/subsidy mechanism for connection of poor and woman-led households through REFUND and promote active participation of women in the jobs that will be created for electrifying the country. Energy access has to be inclusive offering opportunities for women and poorer settlements.

Rural Electrification map. The following map in **Figure 10.6** shows the future map of the power sector infra-structures if the targets are met and all projects of the Master Plan are implemented by 2030. The National Grid will be complemented by Large Decentralized Grids in Lofa, the Southeast Counties and Grand Gedeh that will extend from the on-going SREP and Cross Border initiatives. Multiple Solar/Diesel Low Voltage Transitional mini-grids will enable the electrification of the 10 largest settlements in each County in anticipation of the National Grid.

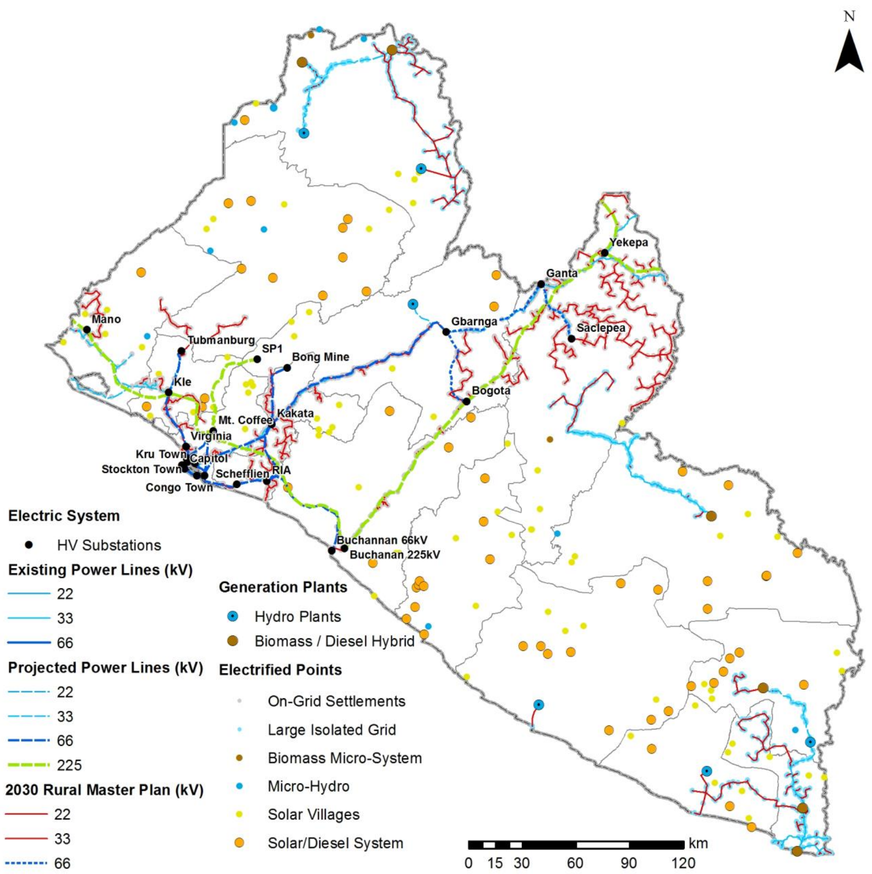


Figure 10.6 – Map of the Liberia's Power System in 2030.

Combining grid extension with decentralized grids to electrify 1.3 million people. The National Grid will develop mostly in the Growth Corridor area where the majority of the population are concentrated thus electrifying 66% of all rural consumers. The large decentralized grids will represent 27% of the consumers with 5% for mini-grids. Individual off-grid solutions will only bring electricity to 18 900 people (around 1%). 33% will be served by decentralized grids in excess of the 25% target established under Renewable Energy Policy of ECOWAS (see **Figure 10.7**).

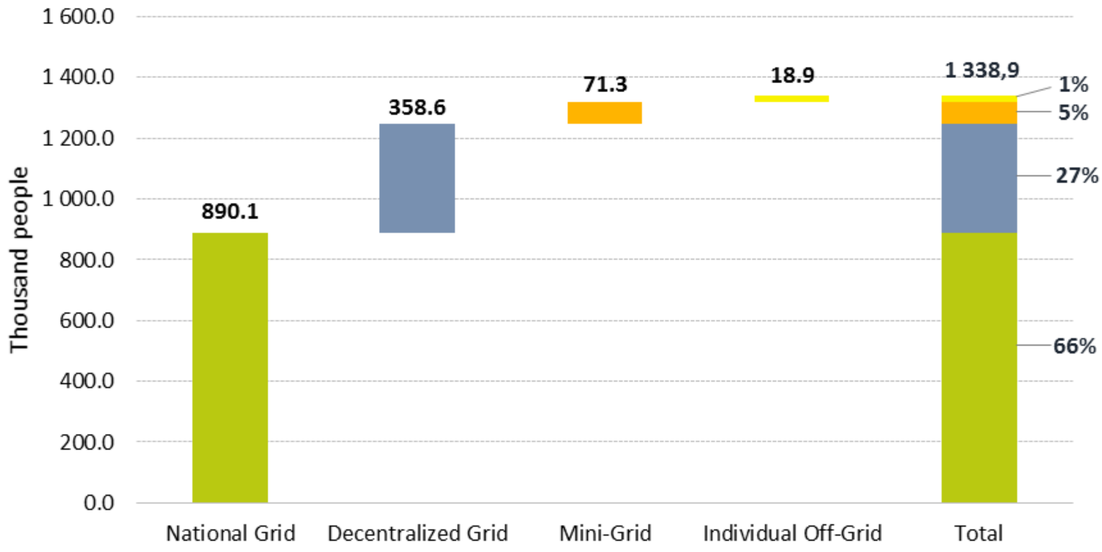


Figure 10.7 – Number of people per type technology in 2030 – nationwide values.

Minimum rural electrification rate per County of 15%. Rural electrification rate will vary per County according to the level of concentration of population and the proximity to the existing grid infra-structure. Nevertheless, decentralized grids allow for a more equitable electrification with no County having less than 15% of its population electrified by 2030, as seen in **Figure 10.8**.

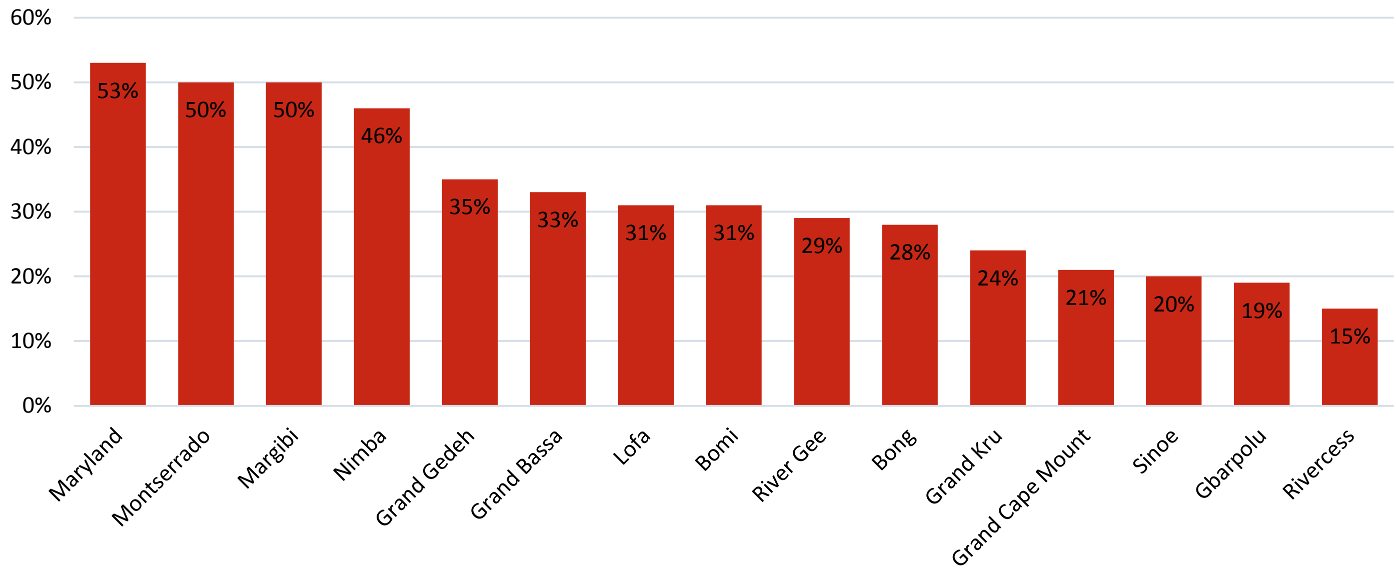


Figure 10.8 – Rural electrification rate per County in 2030.

10.4 RURAL ENERGY MIX AND RENEWABLE TARGETS TO 2030

In line with the ECOWAS Regional Renewable Energy Policy, the Sustainable Energy 4 All initiative and the Sustainable Development Goals, Liberia aims to achieve the following in terms of renewable electricity to be installed outside Monrovia:

- Total share of renewable electricity in the electricity mix from renewable energies excluding large hydro (mini-hydro, solar and biomass) of 10% in 2020 and 19% in 2030. In line with the target of 10% in 2020 and 19% in 2030 established under ECOWAS Regional Renewable Energy Policy.
- Total share of renewable electricity (including large hydro) in the electricity mix in excess of 45% by 2020 and 75% by 2030. Considering the new target of 10 and 19% for renewables without large hydro plus the planned 200 MW large hydro developments of Mount Coffee, St. Paul and VIA reservoir. In excess of the 48% regional target.
- Develop a Renewable Atlas and Strategy for Liberia, including a more detailed and comprehensive hydro potential assessment. In order to select the most adequate locations and renewable energy mix for the goal of 10% and 19% incorporation.
- Installation of at least 150 MW of renewable generation - excluding large hydro - by 2030 and 45 MW already by 2020. Target capacity estimated according to tentative renewable mix and the goal of 10% and 19% incorporation.
    a. On the National Grid: More than 25 MW until 2020 and 100 MW until 2030;
    b. Outside the National Grid: More than 20 MW until 2020 and 50 MW until 2030.
- On Solar Energy: At least 20 MW on the National Grid by 2020 and 60 MW by 2030. At least 15% of total estimated peak load can be implemented without significant impact on the system and no requirement for storage – being already competitive with HFO.
- On Biomass: At least one 5 MW biomass power plant on the National Grid already by 2020. In large decentralized grids to install as much diesel capacity as biomass gasifiers in order to minimize diesel generation. Biomass energy should be developed in areas and in a way without significant competition with biomass for charcoal.
- Universal access to affordable solar renewable lamps (to all non-electrified population) with the target of 250 000 solar renewable lamps sold in Liberia by 2030.

Renewable share. The following graph in **Figure 10.9** shows the estimated evolution of electricity consumption in all of Liberia (both Monrovia and rural) that results from combining the LCPDP [21] with the Rural Energy Master Plan. The large hydro generation results from the proposed development plan of the LCPDP [21] which considers the implementation before 2030 of Mount Coffee, VIA reservoir and St. Paul hydro schemes in a total of 200 MW and 1 369 GWh generation per year. The other renewables (Solar, Biomass and Mini-hydro) result from the Rural Energy Master Plan and the targets set above. Estimated generation by HFO/Diesel and imports will depend on available regional opportunities.

Between 2020 and 2025 a significant growth in non-renewable generation will be required as the St. Paul hydro scheme with 120 MW is only expected to commence delivery after 2025.

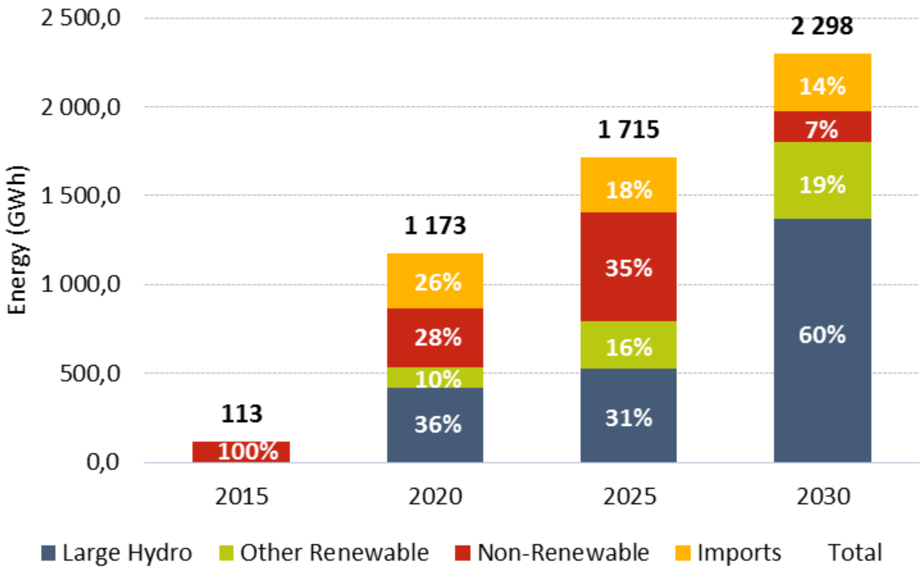


Figure 10.9 – Electricity supply mix for Liberia (Monrovia and Rural) until 2030

Flexibility for project location in the National Grid. Rural Energy Master Plan targets the installation of a total of 150 MW of renewable based generation until 2030, as seen in **Figure 10.10**. On Decentralized Grids the locations for project installation have already been selected, subject to more detailed feasibility studies. On the National Grid the possibilities are innumerous for the location of solar, biomass or mini-hydro power plants and even different combinations to achieve the 10% and 19% targets are possible. The Rural Energy Master Plan proposes a tentative distribution without identifying concrete projects or locations. A comprehensive renewable atlas and strategy taking into consideration the levelized cost of electricity of the different options, the technical feasibility and the capacity of the grid to absorb such projects should be completed and a tendering Legislative, Regulatory and Administrative framework defined.

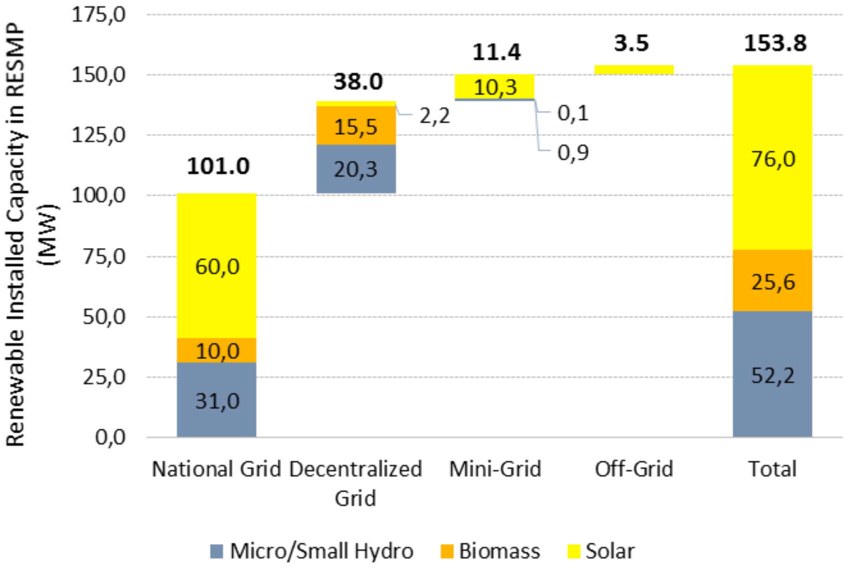


Figure 10.10 – Capacity to be installed until 2030 by type of renewable (excluding large hydro)

10.5 ENERGY EFFICIENCY TARGET / COOKING FUELS

Other than power. Rural Energy is not only about consumption of electricity. It is also about the electricity one does not consume because it makes better options on usage and appliances and also about the thermal energy used for cooking or water heating.

In line with the Sustainable Energy 4 All initiative, the Sustainable Development Goals and ECOWAS Regional Renewable Energy Policy which establishes clear targets also for cooking fuels, Liberia aims to achieve the following in terms of energy efficiency and cooking fuels:

- Universal use of pre-paid meters from 2020 onwards and availability of 1 Amp social tariff to make electricity affordable to the Poor and less wealthy. Universal access means also affordability which depends not only on the price of electricity but also on the ability to pay and control your consumption. Fixed tariffs without a variable charge do not promote energy efficiency and good use of resources.
- Total energy losses on rural electricity below 12% by 2030. Current levels of losses reported by LEC are significant with relevant impact on the economics of the power sector and on investment. Reducing power sector losses also outside of Monrovia will be a key priority.
- Universal access to efficient lights, TVs, refrigerators and freezers at affordable prices. Electricity affordability is not only about electricity price. If appliances are inefficient the running cost can be significantly higher and the overall demand will be unnecessarily high. People tend to make decisions on initial price and available budget – not considering many times the total cost.

- Solar Water Heating suppliers and installers available in every County Capital. Availability of services and equipment for Solar Water Heating is a key first step for its adoption as high prices of electricity make such technology already least cost.
- Cooking gas available in all County Capitals and gas stations at affordable prices with at least one reception and storage facility in Liberia. Incentivizing cooking gas is the most effective way to reduce charcoal consumption and reduce the pressure on deforestation.
- Universal access to affordable and efficient locally manufactured cook stoves with the target of 250.000 efficient cook stoves sold until 2030. Efficient cook stoves are already being manufactured in Liberia. Such initiatives
- Increase the share of efficient charcoal production to 60% by 2020 and 100% by 2030. In line with ECOWAS Renewable Energy Policy goals.

PART E. RURAL ENERGY INVESTMENT AND ACTION PLAN

11 RURAL ENERGY ACTION PLAN

11.1 RURAL ENERGY PROGRAM STRUCTURE

11.1.1 INTRODUCTION

Five programs for rural electrification of Liberia. The Master Plan is organized under five main programs, sub-divided into 21 initiatives which are then composed of 92 concrete projects and investments, as represented in **Figure 11.1**. A detailed list is provided in **ANNEX XIII**.

I. GTG Growing the National Grid	II. DG Decentralized Grids	III. BTG Beyond the Grid	IV. OTP Other than Power	V. BC Building Capacity
National Grid extension	Solar/Diesel transitional mini-grids, decentralized grids and renewable energy.	Small scale off-grid initiatives in non-grid and rural areas.	LPG and efficient cook stoves. Energy Efficiency	Building capacity and systems for implementation and operation
4 initiatives • 15 Projects	4 initiatives • 24 Projects	3 initiatives • 9 Projects	4 initiatives • 12 Projects	6 initiatives • 32 Projects

Figure 11.1 – Outline of the five Rural Energy Master Plan Programs

GTG: Growing the National Grid Program. The Program includes all rural energy investments related with the National Grid, either Distribution, High Voltage transmission (>60 kV) or Renewable generation. It is composed of 4 initiatives and 15 projects.

DG: Decentralized Grids Program. The Program includes all "grid based" rural electrification investments in areas to be connected to the national grid only after 2030, such as Large Decentralized Grids, Solar/Diesel transitional mini-grids and generation to supply those grids. It is composed of 4 initiatives and 24 projects.

BTG: Beyond the Grid Program. The Program is dedicated to electrification based on stand-alone individual solutions – mostly outside of the future national grid. It includes the electrification of community services and public buildings where the grid is not expected before 2025, the electrification of future off-grid villages based on Solar Home Systems and the supply and incentive to individual solar lamps. It is composed of 3 initiatives and 9 projects.

OTP: Other than Power Program. The Program is dedicated to energy efficiency and access to other sources of energy for cooking or heating. It is composed of 4 initiatives and 12 projects.

BC: Building Capacity Program. The Program is dedicated to creating the capacity, the institutional framework, the organization, the information systems and the infra-structure to implement the Master Plan. It is composed of 6 initiatives and 32 projects.

11.1.2 PROGRAM CALENDAR

A three phase approach. The Program is structured in three main phases:

- Phase 1 – From now until 2020 with a strong emphasis on the setup of the rural energy master plan and the implementation of ongoing/planned projects.
- Phase 2 – From 2020 to 2025, with acceleration and roll out of the main initiatives.
- Phase 3 – From 2025 to 2030, the consolidation phase when most people will be electrified.

Figure 11.2 shows the rural energy sector infra-structures already deployed at the end of each phase.

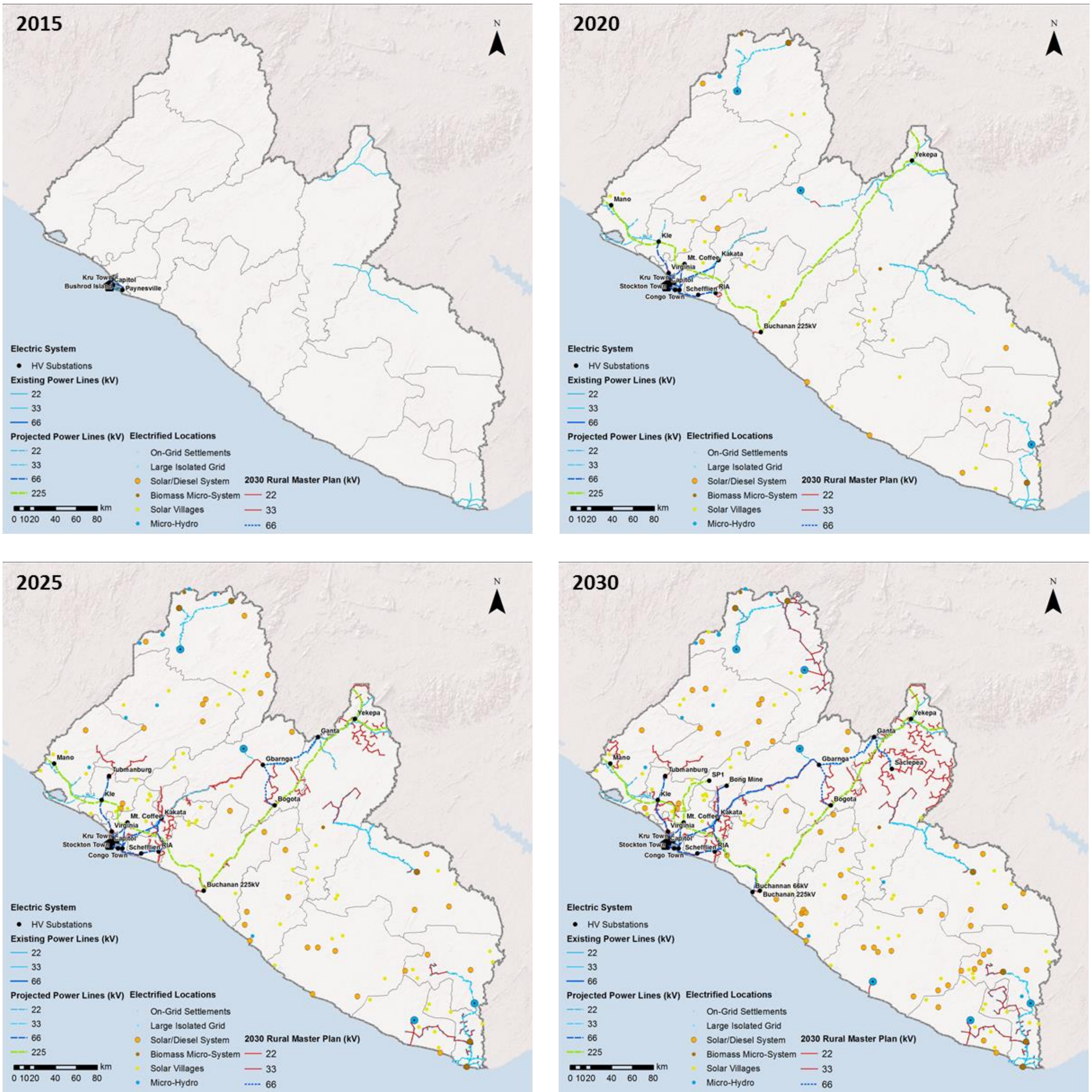


Figure 11.2 – Evolution of Liberia's Power System – Phases 1, 2 and 3.

11.2 GTG: GROWING THE GRID PROGRAM

11.2.1 INTRODUCTION

GTG has three main initiatives. The **Growing the Grid Program** relates with the extension of the national high and medium voltage electric networks. This program is divided in three main Initiatives that will cover the area located within Monrovia (currently the only part of the country with a high voltage network), Buchannan, Yekepa and Mano/Robertsport (locations of future CLSG Substations). Thus, this program covers the Growth Corridors triangle and will also reach the West region of the country. The main recommended interventions are shown in **Figure 11.3**. On the next subsections, a description of the several initiatives included in this program is given.

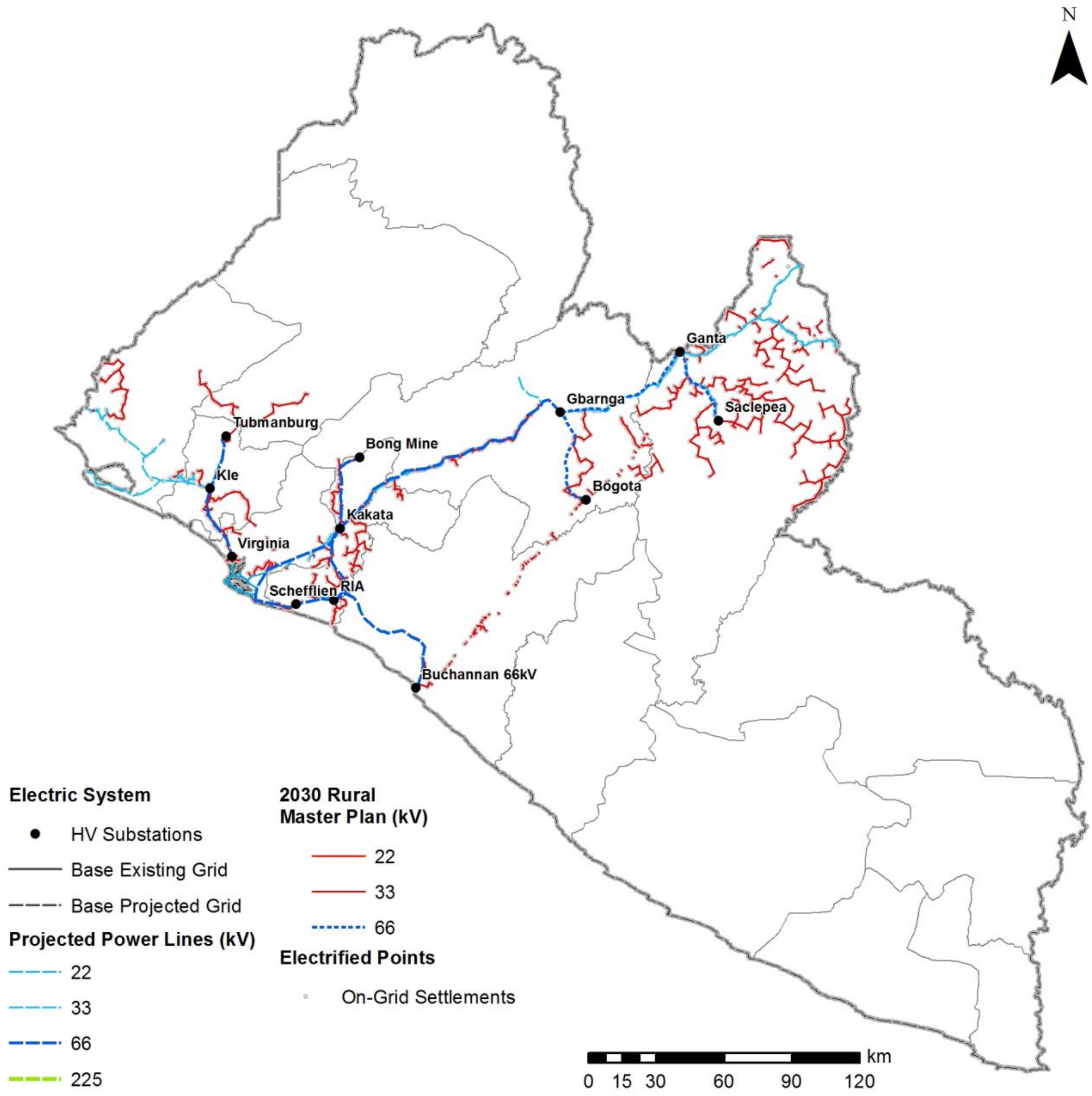


Figure 11.3 – Growing the Grid Program Infrastructure.

11.2.2 GTG.1 – MONROVIA CORRIDORS ELECTRIFICATION INITIATIVE

Grid extension around Monrovia. The objective of this Initiative is to promote the extension of Monrovia's existing network to the West, North and East of the Capital. Six main projects are to be implemented regarding the transmission network and major cities electrification, as well as rural distribution, in the three mentioned regions. These projects are depicted in **Figure 11.4** and defined next:

- **GTG.1.1. Monrovia Corridors West Extension (Phase 1 and Phase 2)**
    - Implementation of 66/33 kV substations in Virginia, Kle and Tubmanburg and construction of the required 66 kV power lines to connect these substations to the Monrovia 66 kV power network.
    - Implementation of 33 kV power lines from Kle to Madina, Robertsport and Bo Waterside, connecting in route settlements.
    - Electrification of major cities in the region, including Brewerville, Tubmanburg, Robertsport and Bopolu);
- **GTG.1.2. Monrovia West Corridor rural grid extension (Phase 1 and Phase 2)**
    - National network extension from the new substations and MV grids to electrify rural communities;
- **GTG.1.3. Monrovia Corridors North Extension – (Phase 1 and Phase 2)**
    - Implementation of 66/33 kV substations in Kakata, Bong Mines and construction of the required 66 kV power lines to connect these substations to the Monrovia 66 kV power network;
    - Implementation of 33 kV power lines from Kakata to Totota and Salala;
    - Electrification of major cities in the region, namely Kakata;
- **GTG.1.4. Monrovia North Corridor rural grid extension (Phase 1 and Phase 2)**
    - National network extension from the new substations and MV grids to electrify rural communities;
- **GTG.1.5. Monrovia Corridors East Extension (Phase 1 and Phase 2)**
    - Implementation of 66/33 kV substations in Schefflien, RIA and Buchannan and construction of the required 66 kV power lines to connect these substations to the Monrovia 66 kV power network;
    - Electrification of major cities in the region, including Harbel and Cotton Tree;
- **GTG.1.6. Monrovia East Corridor rural grid extension (Phase 1 and Phase 2)**
    - National network extension from the new substations and MV grids to electrify rural communities;

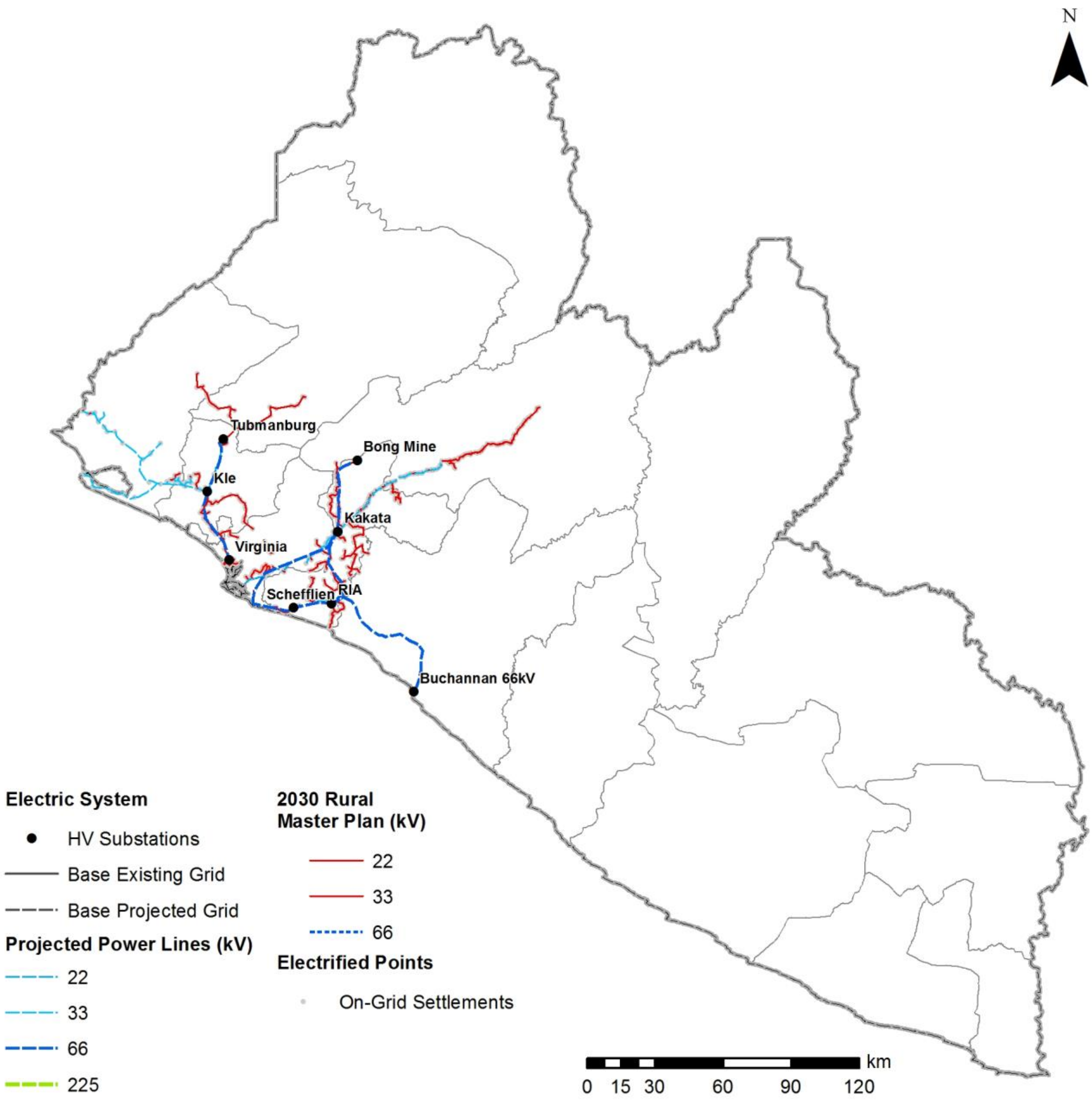


Figure 11.4 – Monrovia Corridors Electrification Initiative.

11.2.3 GTG.2 – GBARNGA CORRIDORS ELECTRIFICATION INITIATIVE

Electrification in Gbarnga corridors. The objective of this Initiative is to promote the extension of the national network from the future substation of Gbarnga, which due to its location presents a strategic point for the future grid expansion. It is located near a future switching station of the CLSG and can allow the extension of the grid to connect the Lofa decentralized grid. Two main projects are to be implemented regarding transmission network and major cities electrification, as well as rural distribution in Bong and Nimba counties. These projects are depicted in **Figure 11.5** and defined next:

- **GTG.2.1. Gbarnga Corridors Extension**
  - Implementation of 66/33 kV substation in Gbarnga and construction of the required 66 kV power lines to connect it to Kakata;
  - Implementation of 66/33 kV substation in Ganta and Saclepea, and construction of the required 66 kV power lines to connect these substations to Gbarnga;
  - Electrification of major cities in the region, including Gbarnga and Ganta);
- **GTG.2.2. Gbarnga Corridors rural grid extension (Phase 1 and Phase 2)**
  - National network extension from the new substations and MV grids to electrify rural communities, namely in Bong and Nimba Counties;

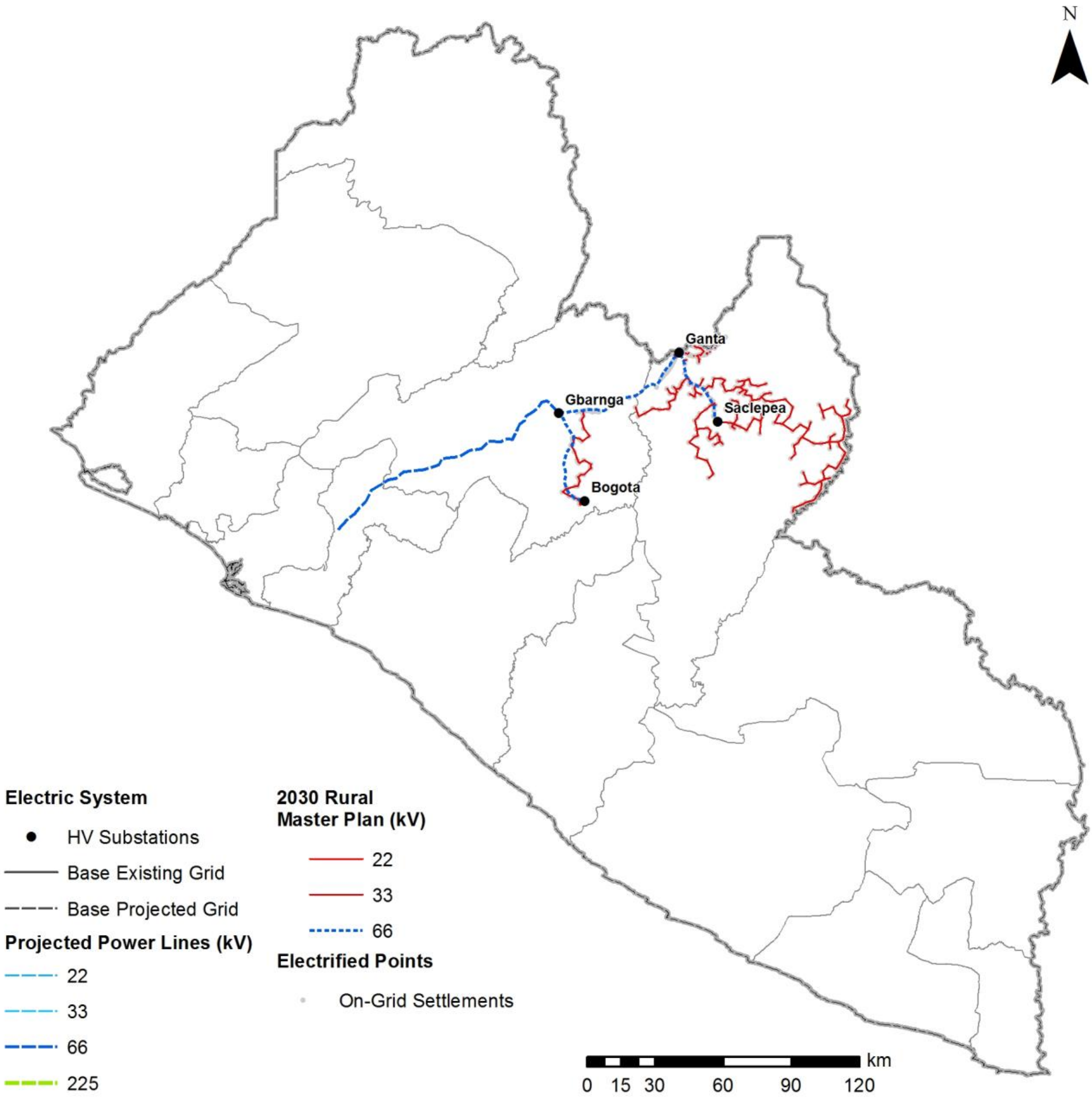


Figure 11.5 – Gbarnga Corridors Extension Initiative.

11.2.4 GTG.3 – CLSG ELECTRIFICATION INITIATIVE

CSLG. The objective of this Initiative is to promote the extension of the national network from the future substations of the CLSG system, and from the power line itself, since it is planned for it to be prepared for distribution through its shield wires. Four main projects are to be implemented, mainly regarding client connection and rural grid extension in the counties of Nimba, Bong, Grand Bassa and Grand Cape Mount. These projects are illustrated in **Figure 11.6**.

- **GTG.3.1. Yekepa (CLSG) major cities electrification and rural grid extension (Phase 1, Phase 2 and Phase 3)**
    - Connection of the Cross Border grid to the CLSG substation located in Yekepa, and electrification of Sanniquellie and Yekepa cities;
    - Grid extension from the Yekepa substation and MV grids to electrify rural communities in Nimba County;
- **GTG.3.2. Buchannan (CLSG) city electrification and rural grid extension (Phase 1, Phase 2 and Phase 3)**
    - Electrification of Buchannan from the CLSG substation located in Buchannan;
    - Grid extension from the Buchannan substation to electrify rural communities in Grand Bassa County;
- **GTG.3.3. CLSG Shield Wire rural electrification**
    - Rural electrification from the shield wires of the CLSG 225 kV power line. The main benefited areas are located in Nimba, Bong and Grand Bassa counties;
- **GTG.3.4. Mano rural grid Extension**
    - Grid extension from the Yekepa substation to electrify rural communities in Grand Cape Mount;

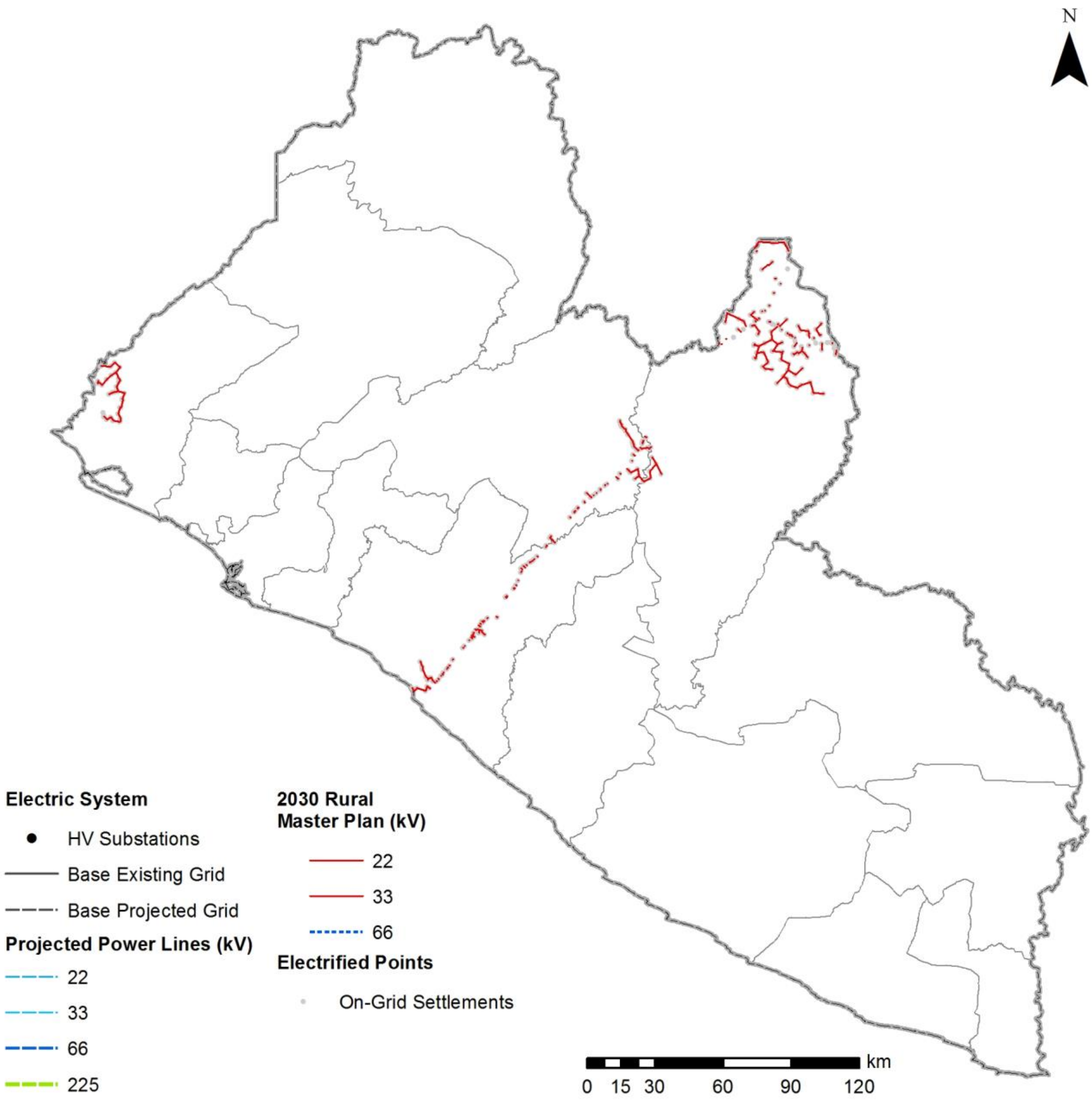


Figure 11.6 – CLSG Electrification Initiative.

11.2.5 GTG PROGRAM: BENEFITS AND ESTIMATED INVESTMENTS

GTG implies an estimated investment of USD 548.9M. The Growing the Grid Program aims for the medium and high voltage networks extension of the existing and planned national grid. Thus, the beneficiaries of this Program are the communities that are somewhat near the planned grid, namely the area near Monrovia and the future CLSG system substations.

The estimates of inhabitants and clients that are planned to benefit from this program as well as the projected investments are shown in **Table 11.1** below.

Table 11.1 – Estimated electrified people, clients and projected global investments in GTG Program.

	Number of People (Thousands)	Installed Capacity (MW)	Estimated Investments (MUSD)
I. GTG - GROWING THE GRID PROGRAM	**830.8**	**100.0**	**550.9**
GTG.1 Monrovia Corridors Electrification	391.0	0.0	157.1
GTG.2 Gbarnga Corridors Electrification	212.3	0.0	99.5
GTG.3 CLSG Electrification	227.5	0.0	52.3
GTG.4 Renewable On-Grid Generation	0.0	100.0	242.0

11.3 DG: DECENTRALIZED GRIDS PROGRAM

11.3.1 INTRODUCTION

DG is composed of four initiatives. The **Decentralized Grid Program** relates with the implementation of several isolated systems, in order to promote a higher electrification coverage and equity throughout the Country. This program is divided in four main Initiatives which will include large decentralized grids execution, Cross Border extension, and the implementation of several town mini-grids using different generation technologies. The recommended interventions are shown in **Figure 11.7**.

On the next subsections, a description of the several initiatives included in this program is given.

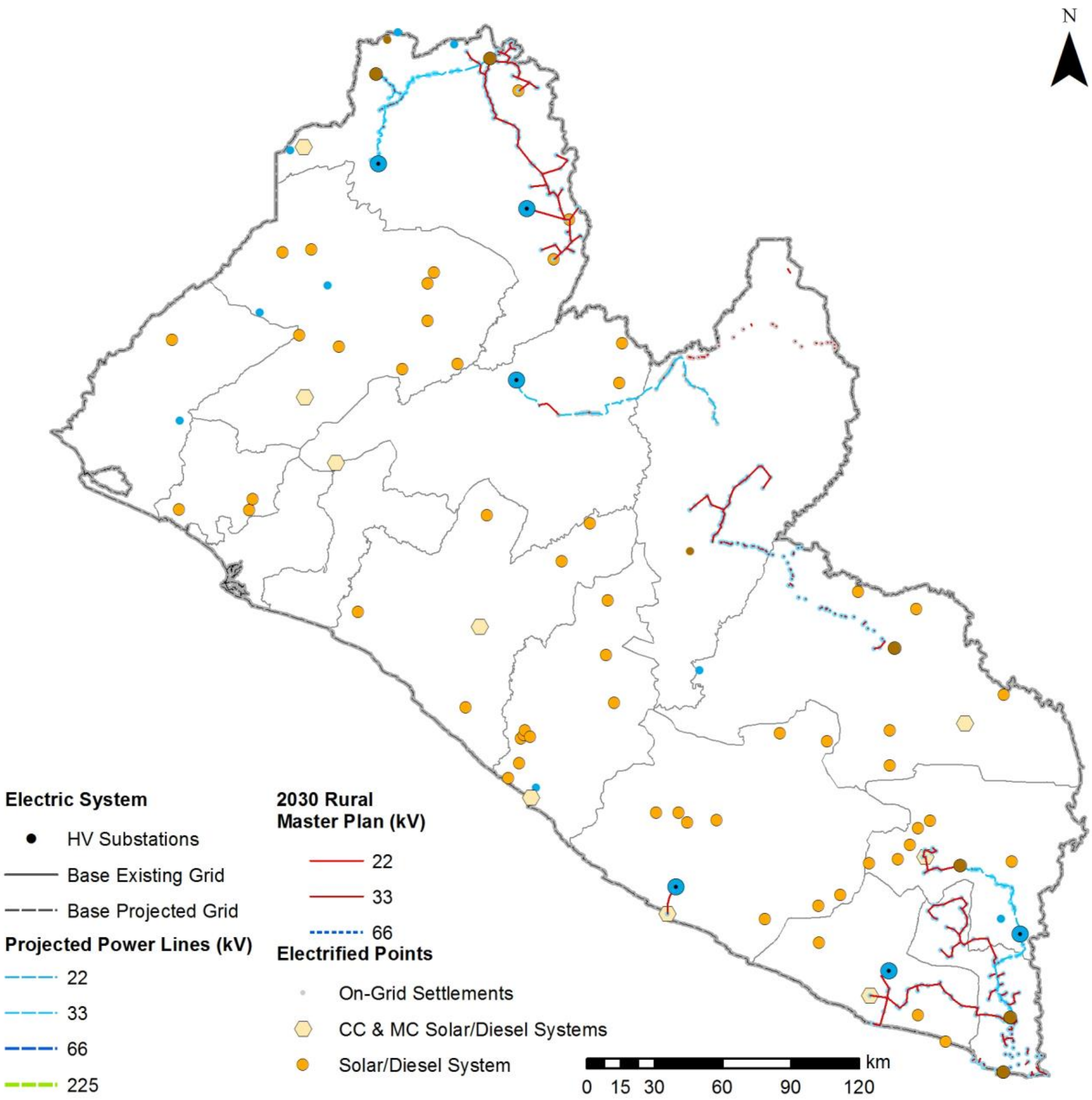


Figure 11.7 – Decentralized Grids Program Infrastructure.

11.3.2 DG.1 - DIESEL/SOLAR TRANSITIONAL MINI-GRIDS INITIATIVE

Hybrid mini-grids. The objective of this Initiative is to promote the anticipation of electrification in several large and medium sized settlements, located in areas where the grid coverage is not expected in the short and medium term. In total four main projects are to be executed in all regions of the country. These projects will consist in the implementation of solar/diesel hybrid systems and the electrification of the town's residential and services clients. The distribution grids are to remain in operation when grid coverage is available, as discussed in Chapter 5. The projects comprised in this initiative are illustrated in **Figure 11.8**.

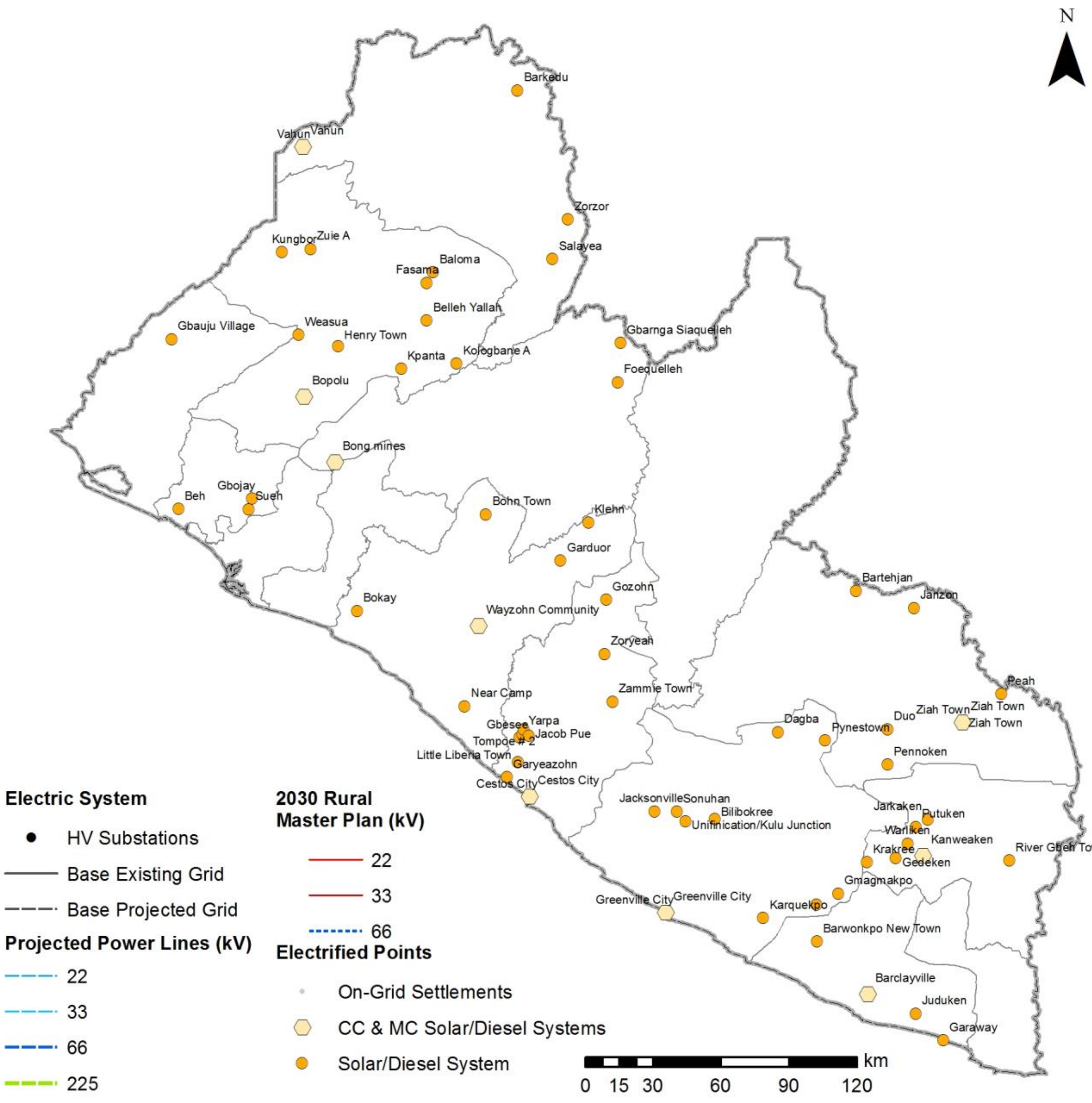


Figure 11.8 – Diesel/Solar Transitional Mini-Grids Initiative.

- **DG.1.1 County Capitals and Large Cities Transitional Grids**
  - Implementation of solar/diesel transitional grids in important cities that, in the short term, should not be connected to the national grid nor to any decentralized grid. The benefited towns are Greenville City, Bopolu, Bong mines, Ziah Town, Cestos City, Barclayville, Wayzohn Community, Kanweaken and Vahun;
- **DG.1.2 East Liberia (Region 1) Diesel/Solar Transitional Mini-Grids – Phase 1 and Phase 2**
  - Implementation of solar/diesel transitional grids in the largest cities of Region 1, that will not be connected to the national or decentralized grids in 2030;

- **DG.1.3 North and South Liberia (Regions 2 & 3) Diesel/Solar Transitional Mini-Grids – Phase 1 and Phase 2**
    - Implementation of solar/diesel transitional grids in the largest cities of Regions 2 and 3, that will not be connected to the national or decentralized grids in 2030. Additionally, in the towns of Zorzor, Barkedu and Salayea, which will be connected in to Lofa Decentralized grid in 2030, transitional grids are also planned in Phase 2 (2020-2025) to stimulate electrification in other districts of Lofa County, besides the ones already covered by the Lofa Decentralized grid;
- **DG.1.4 West Liberia (Region 4) Diesel/Solar Transitional Mini-Grids – Phase 1 and Phase 2**
    - Implementation of solar/diesel transitional grids in the largest cities of Region 4, that will not be connected to the national or decentralized grids in 2030;

11.3.3 DG.2 - DECENTRALIZED GRIDS AND CROSS BORDER CONSOLIDATION INITIATIVE

Decentralized and cross border grids. The objective of this Initiative is to promote the consolidation and extension of the Cross Border grids connected to Cote d'Ivoire, and the creation of Large Decentralized Grids that will have some extent, although not being connected to the national system. In total, eight projected are to be implemented in Regions 1, 2 and 4. The projects comprised in this initiative are presented in **Figure 11.9**.

- **DG.2.1 *Nimba Cross Border Grid* consolidation and extension to Gbarnga and Saclepea**
    - Consolidation of the Nimba Cross Border grid, by electrifying the settlements nearby the existing power lines;
    - First stage extension of the Cross Border grid, creating power lines to connect Ganta to Gbarnga and Ganta to Saclepea. In route communities will also be connected.
- **DG.2.2 *Grand Gedeh Cross Border Grid* consolidation**
    - Consolidation of the Grand Gedeh Cross Border grid, by electrifying the settlements nearby the existing power lines;
- **DG.2.3 *Maryland Cross Border Grid* consolidation and extension to Fish Town**
    - Consolidation of the Maryland Cross Border grid, by electrifying the settlements nearby the existing power lines;
    - First stage extension of the Cross Border grid, creating power lines to connect Pleebo City to Fish Town in River Gee County. In route communities will also be connected;
- **DG.2.4 Voinjama / Foya Town / Kolahun decentralized grid creation**
    - First stage of the Decentralized Grid of Lofa County. A 33 kV system will be implemented to connect the Kaiha 2 small hydro plant to Voinjama, Foya City, Kolahun, and other communities in route;

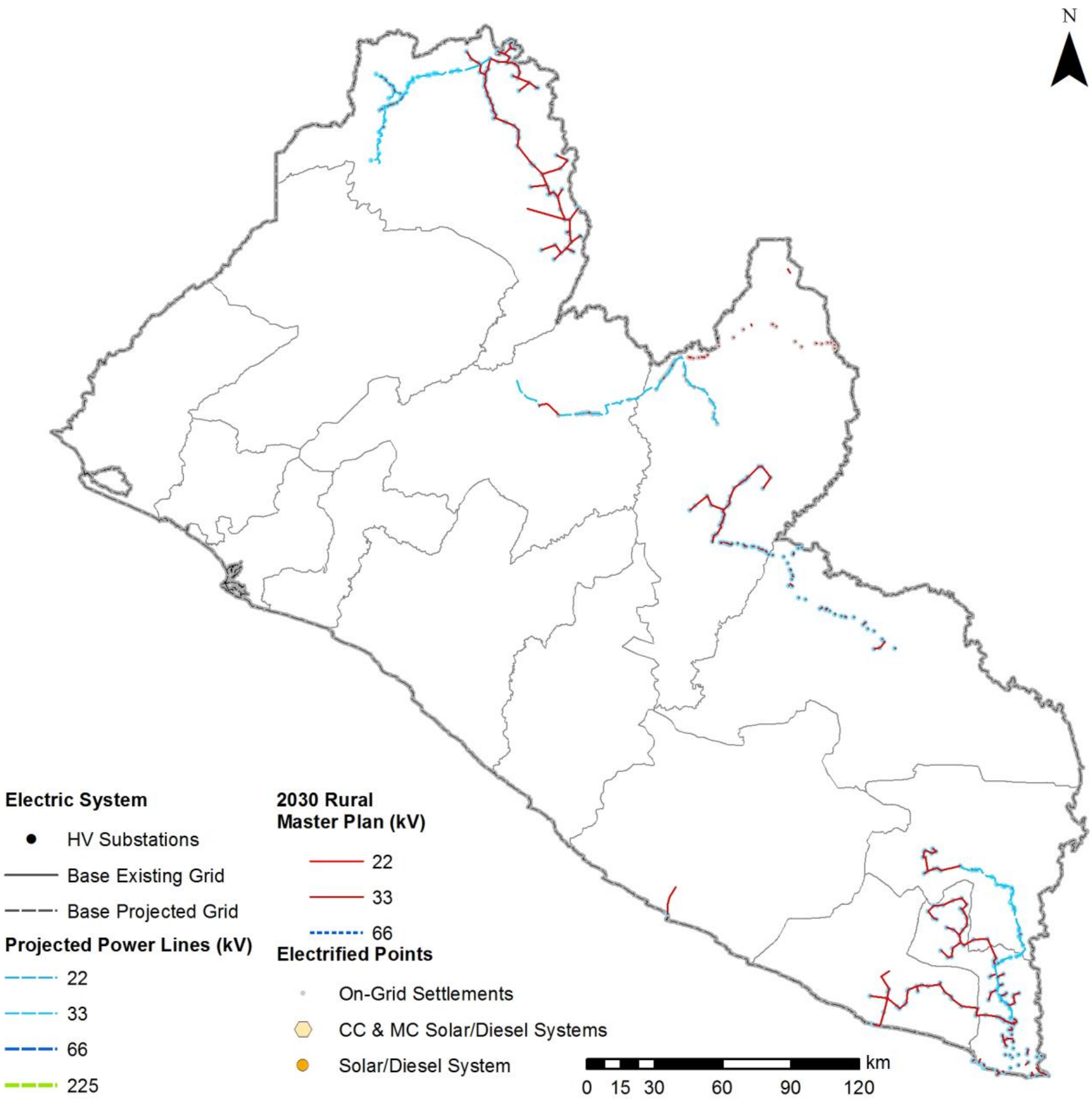


Figure 11.9 – Decentralized Grids and Cross Border Consolidation Initiative.

- **DG.2.5 Maryland / River Gee / Grand Kru decentralized grid extension**
    - Rural grid expansion from the Cross Border grid of Maryland. Extension will reach Grand Kru County, namely Barclayville and other several communities in Maryland and River Gee counties. Grid will also connect to new generation options, namely the River Gee and Barclayville small hydro plants;
- **DG.2.6 *Grand Gedeh / Nimba decentralized grid extension***
    - Rural grid expansion from the Cross Border grid of Grand Gedeh;
- **DG.2.7 Greenville decentralized grid creation**
    - Connection of Greenville City to the future small hydro near Greenville with a 33 kV power line;

- **DG.2.8 Voinjama / Foya Town / Kolahun / Zorzor decentralized grid creation**
  - Second stage of the Lofa Decentralized Grid. This project relates with the implementation of grid to connect Wozi Creek small-hydro to Zorzor and lately the Kaiha 2 grid;
  - Implementation of the Rural grid extension in Lofa;

11.3.4 DG.3 - GENERATION IPP FOR DECENTRALIZED GRIDS INITIATIVE

Generation. This Initiative relates with the construction of generation projects for energy supply to the previously mentioned Decentralized Grids. In total, this initiative is composed by seven main generation projects to be implemented in different parts of the country. The projects comprised in this initiative are presented in **Figure 11.10**.

- **DG.3.1 Kaiha 2 hydro power plant**
  - Construction of the Kaiha 2 small hydro power plant in Lofa County, with an installed capacity of 3 MW. This power plant will supply the first stage Decentralized Grid of Lofa;
- **DG.3.2 River Gee hydro power plant**
  - Construction of the River Gee small hydro power plant in River Gee County, with an installed capacity of 5.79 MW. This power plant is to be connected to the Maryland / River Gee Decentralized Grid;
- **DG.3.3 Mein River hydro power plant**
  - Construction of the Mein River small hydro power plant in Bong County, with an installed capacity of 1 MW. In a first stage, this power plant is intended supply the Phebe Hospital and Cuttington University. However, later it is planned to be connected to the national grid;
- **DG.3.4 Biomass / Diesel Hybrid power plants**
  - Construction of several Biomass / Diesel power plants to be used as backup up in the different Decentralized Grids. The generation plants will be implemented in Voinjama (3 + 3 MW), Foya Town (4 + 4 MW), Zwedru (4 + 4 MW), Harper City (2 + 2 MW), Pleebo City (2 + 2 MW) and Fish Town (1 + 1 MW);
- **DG.3.5 Barclayville hydro power plant**
  - Construction of the River Gee small hydro power plant in Grand Kru County, with an installed capacity of 4.5 MW. This power plant is to be connected to the Maryland / River Gee / Grand Kru Decentralized Grid;
- **DG.3.6 Wozi Creek hydro power plant**
  - Construction of the Kaiha 2 small hydro power plant in Lofa County, with an installed capacity of 5 MW. This power plant will supply the second stage Decentralized Grid of Lofa;

- **DG.3.7 Greenville hydro power plant**
    - Construction of the Greenville small hydro power plant in Sinoe County, with an installed capacity of 2 MW. This power plant is to be connected to the city of Greenville;

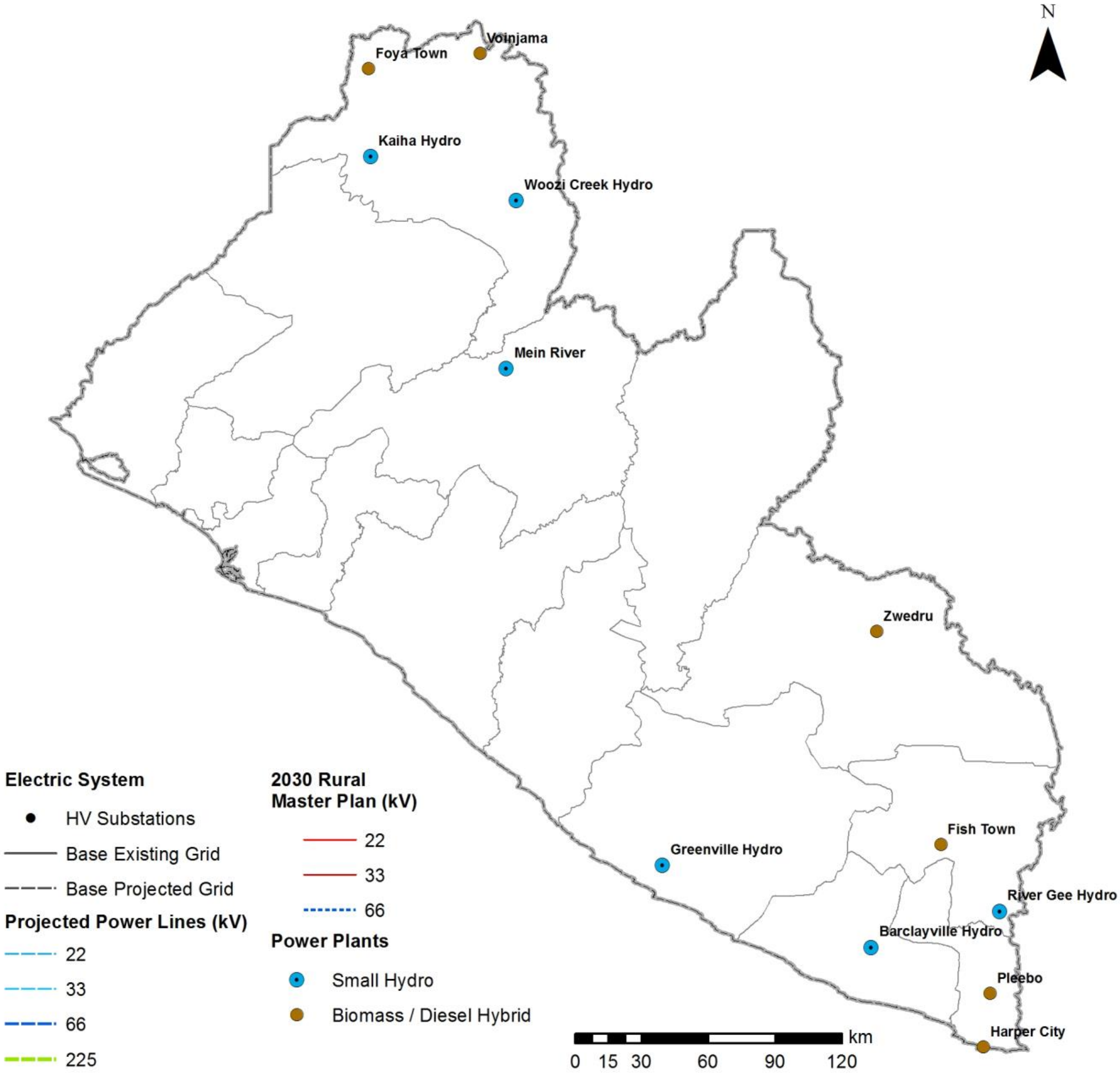


Figure 11.10 – Generation IPP for Decentralized Grids Initiative.

11.3.5 DG.4 - MICRO-SYSTEMS

Biomass and micro-hydro generation. This Initiative relates with the implementation of micro-generation systems in several communities using hydro and biomass resources, as well as the electrification of those communities. This initiative is composed by five projects to be implemented in

Gbarpolu, Grand Cape Mount, Lofa, Nimba, River Cess and River Gee counties. The projects comprised in this initiative are presented in **Figure 11.11**.

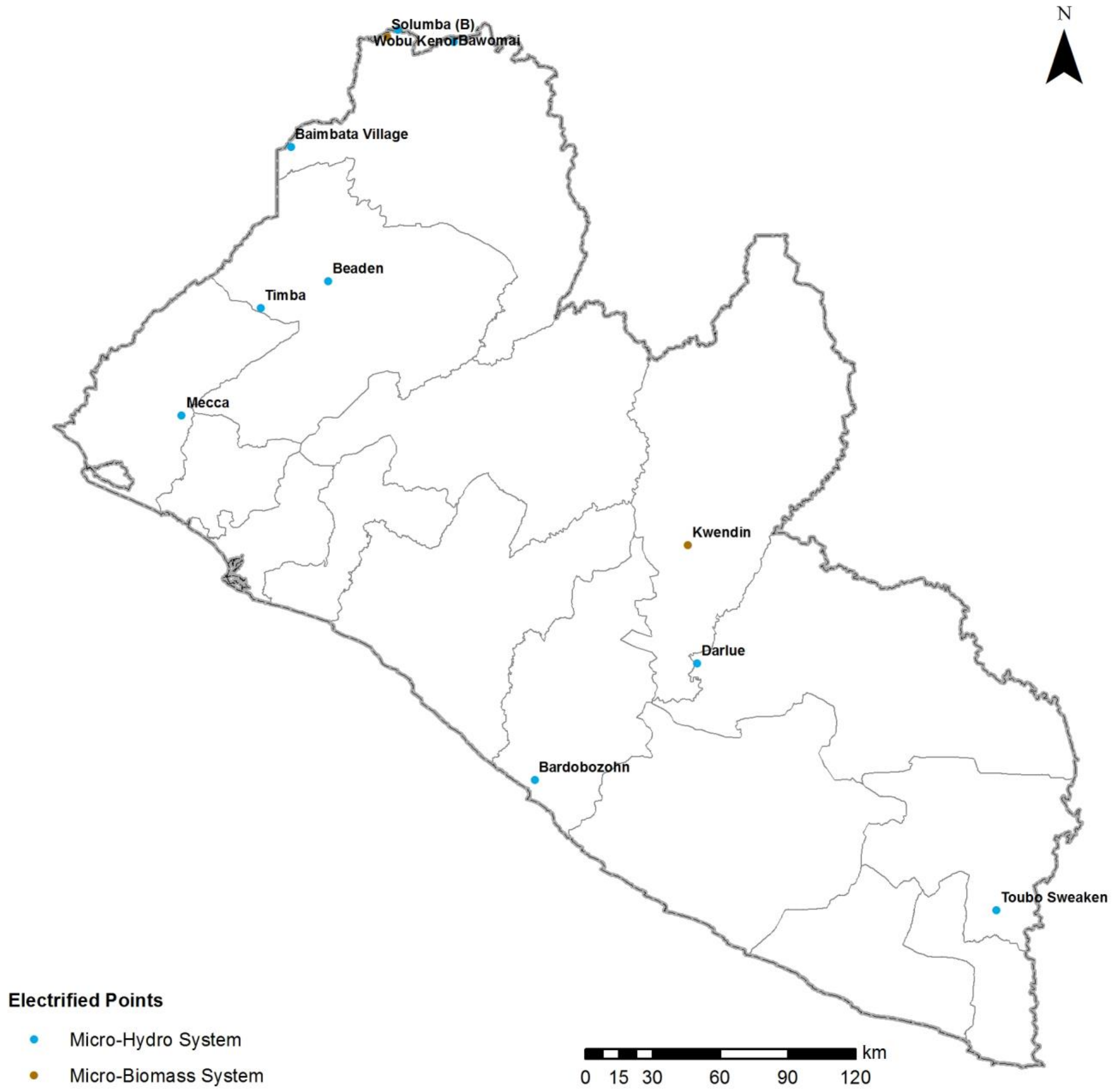


Figure 11.11 – Micro-hydro Villages Initiative.

- **DG.4.1 Solumba Micro-Biomass Village**
    - Implementation of a 35 kW Biomass pilot power plant to supply the village of Solumba, in Lofa County;
- **DG.4.2 Kwendin Micro-Biomass Village**
    - Implementation of a 60 kW Biomass pilot power plant to supply the village of Kwendin in Nimba County;

- **DG.4.3 North and South Liberia (Regions 2 & 3) Micro-Hydro Villages**
  - Implementation of micro-hydro power plants to supply several villages in Regions 2 and 3. In total, four micro-hydro villages are to be executed.
- **DG.4.3 West Liberia (Region 4) Micro-Hydro Villages**
  - Implementation of micro-hydro power plants to supply several villages in Region 4. In total, three micro-hydro villages are to be executed.
- **DG.4.4 East Liberia (Region 1) Micro-Hydro Villages**
  - Implementation of micro-hydro power plants to supply several villages in Region 1. In total, two micro-hydro villages are to be executed.

11.3.6 DG PROGRAM: BENEFITS AND ESTIMATED INVESTMENTS

DG implies an estimated investment of USD 291.8M. The Decentralized Grids program has the objective to promote the equity of the electrical service in the Country, by creating several decentralized grids with different forms. Large isolated grids will be implemented, or by extending the existing Cross Border grids, or by creating new systems supplied by small hydro plants and also, several town level hybrid systems will be implemented with the purpose to anticipate the grid coverage in that settlement.

The estimates of inhabitants and clients that are planned to benefit from this program, as well as the projected investments are shown in **Table 11.2**.

Table 11.2 – Estimated electrified people, clients and projected global investments in DG Program.

	Number of People (Thousands)	Installed Capacity (MW)	Estimated Investments (MUSD)
II. DG DECENTRALIZED GRIDS	**489.1**	**62.5**	**291.8**
DG.1 Diesel/Solar Transitional Mini-Grids	101.8	25.1	47.8
DG.2 Decentralized grids and Cross Border consolidation	382.1	0.0	104.6
DG.3 Generation IPP for decentralized grids	0.0	36.8	128.9
DG.4 Micro-Systems	5.2	0.6	10.5

11.4 BTG: BEYOND THE GRID PROGRAM

11.4.1 INTRODUCTION

BTG considers regions where the grid is not expected to reach in the long term. The **Beyond the Grid Program** relates with the implementation of several solar solutions to provide electrification in small or remote settlements, where the grid is not expected to reach in the long term, as seen in **Figure 11.12**. It also includes the implementation of several Solar Community Services and the distribution of Solar Lamps program. Thus, BTG program is divided in three main initiatives. The recommended interventions are shown in **Figure 11.7**. On the next subsections, a description of the several initiatives included in this program is given.

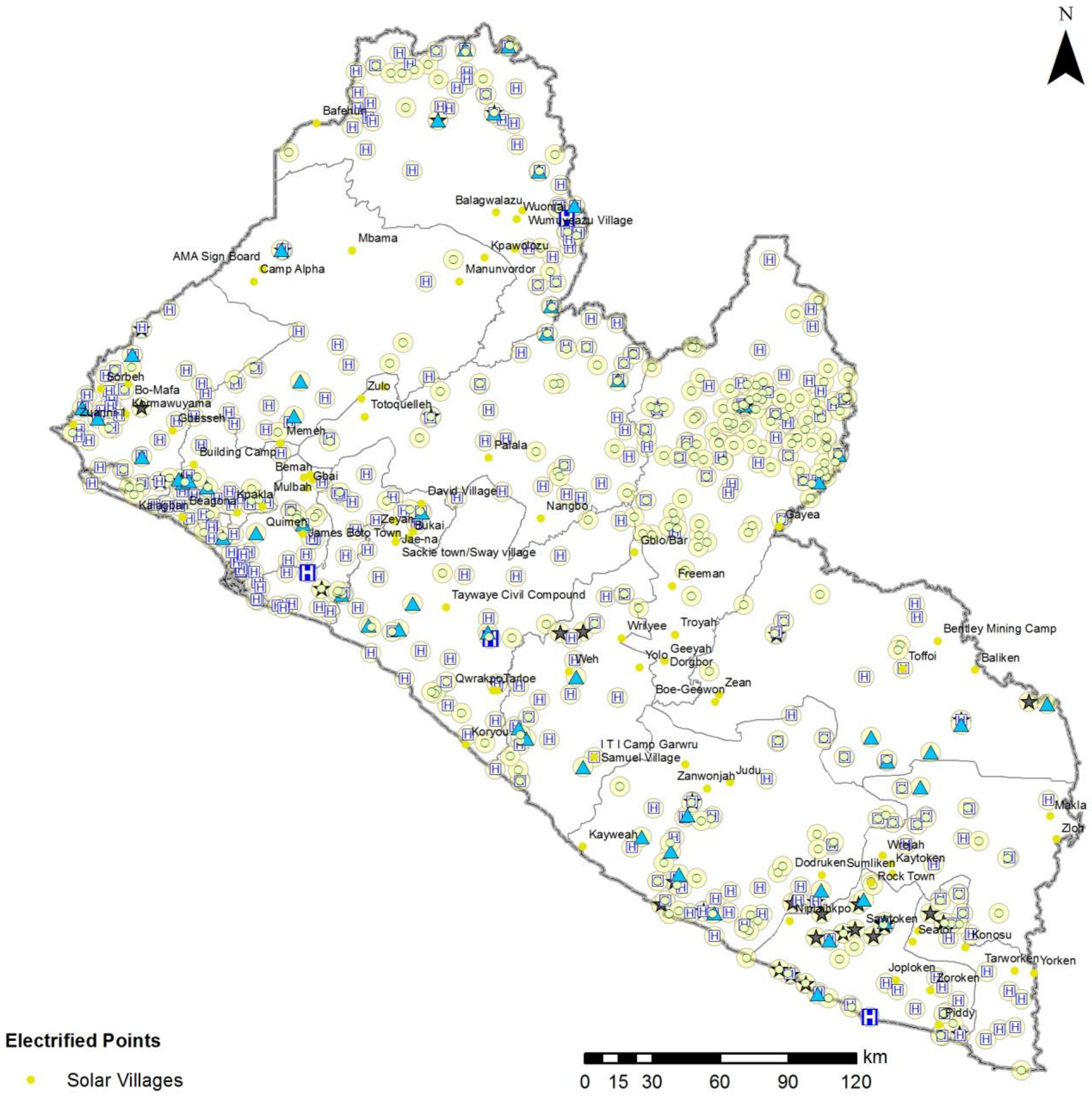


Figure 11.12 – Beyond the Grid Program Infrastructure.

11.4.2 BTG.1 - SOLAR VILLAGES & HOME SYSTEMS INITIATIVE

Solar systems. This initiative is associated with the creation of solar villages throughout the Country. These systems are intended for communities that, due to its small size (and consequently reduced consumption levels) and high distance to electric grids, are not viable for grid connection in the long term. Until 2030, five communities in each County will be connected with these system, totaling 75 solar systems nationwide. This initiative is composed by three main projects, and the planned infrastructures are located in **Figure 11.13**.

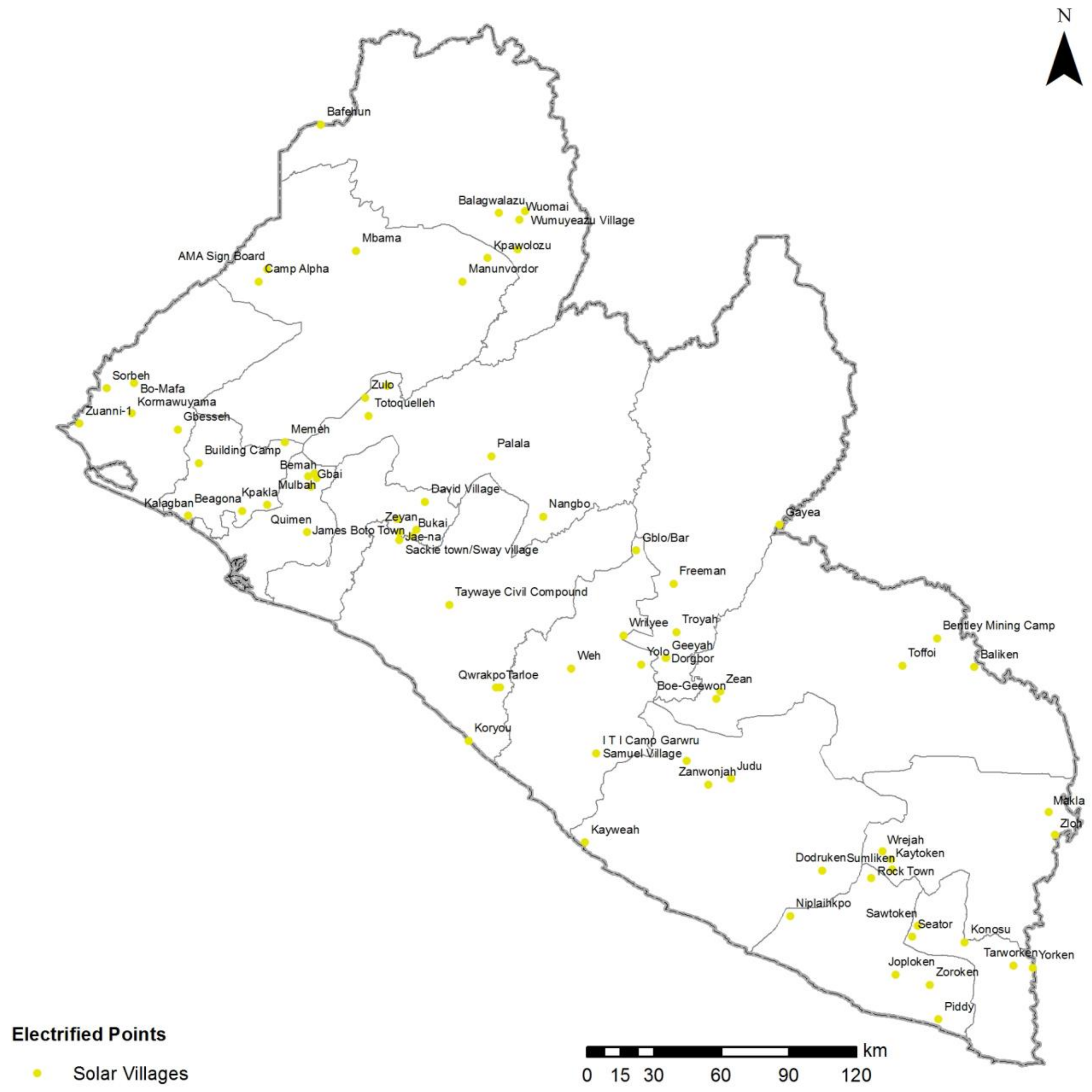


Figure 11.13 – Solar Villages & Home Systems Initiative.

- **BTG.1.1 East Liberia (Region 1) Solar Villages – Phase 1 and Phase 2**
    - Implementation of 25 solar systems in villages of Region 1.

- **BTG.1.2 North and South Liberia (Regions 2 & 3) Solar Villages – Phase 1 and Phase 2**
  - Implementation of 15 solar systems in villages of Region 2;
  - Implementation of 20 solar systems in villages of Region 3.
- **BTG.1.3 West Liberia (Region 4) Solar Villages – Phase 1 and Phase 2**
  - Implementation of 15 solar systems in villages of Region 4.

11.4.3 BTG.2 - SOLAR COMMUNITY SERVICES INITIATIVE

Community services electrification. This initiative consist in implementing solar systems in non-electrified important community services, related with Health, Security and Education – Hospitals, health centers and clinics, police stations and courthouses and secondary schools. This initiative is composed by three projects, phased through the years. In the first phase, all health facilities will benefit, and the anticipation of all services that will be electrified in 2030 by the national grid will also be implemented with a solar system. In the second phase and third phase solar community services will gradually be implemented in facilities that are not expected to be electrified by the national grid before 2030. The total facilities that are planned to benefit from this initiative are presented in **Figure 11.14**.

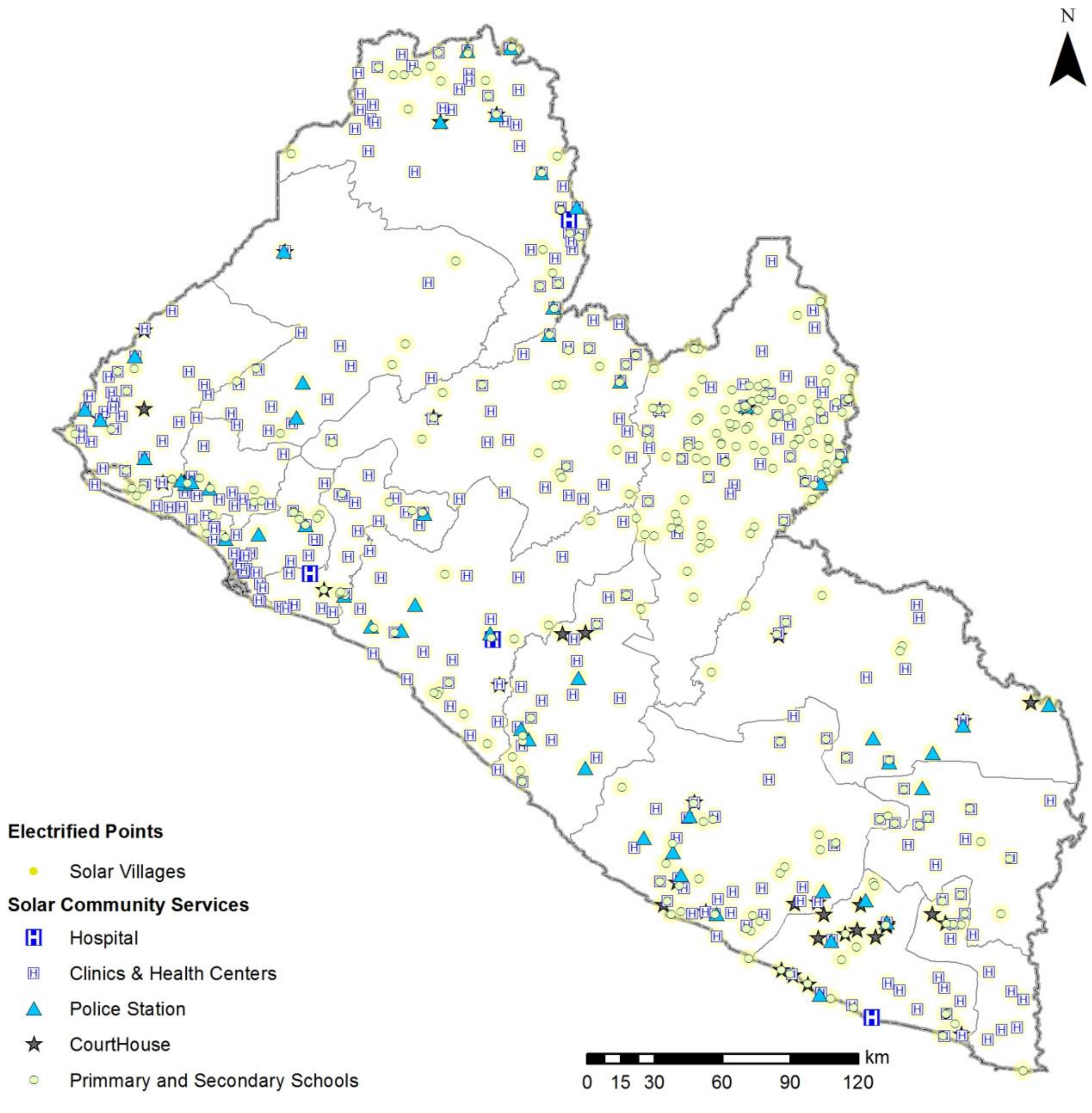


Figure 11.14 – Solar Community Services Initiative.

11.4.4 BTG 3 - SOLAR PORTABLE LAMPS INITIATIVE

Solar Portable Lamps Initiative. This initiative consists on the continuation and reinforcement of the existing Solar Portable Lamp initiative through the creation of a “Delegated importer/wholesaler” who will manage the imports while RREA will maintain responsibility for procurement and for communication/ information campaign. Additionally, a tender to attract the best rental model operators to Liberia will also be launched. This initiative is composed of 2 projects.

11.4.5 BTG PROGRAM: BENEFITS AND ESTIMATED INVESTMENTS

BTG implies an estimated investment of USD 10.5M. The Beyond the Grid program consists on the installation of several solar system solutions to provide some level of electricity to small and remote communities. In total, 75 villages will benefit from these system and more than 700 systems will be installed in community services.

The estimates of inhabitants and clients that are planned to benefit from this program, as well as the projected investments are shown in **Table 11.3**.

Table 11.3 – Estimated electrified people, clients and projected global investments in BTG Program.

	Impact		Investments per phase (USD M)				Estimated funding committed (USD M)			
	Number of People (Thousands)	MW	Phase 1	Phase 2	Phase 3	Total	Phase 1 Committed	Phase 2 Committed	Phase 3 Committed	Committed funding (estimate)
III. BTG BEYOND THE GRID PROGRAM	**18.9**	**3.5**	**8.1**	**4.7**	**3.2**	**16.0**	**0.0**	**0.0**	**0.0**	**0.0**
BTG.1 Solar Villages & Home Systems	18.9	2.2	3.4	2.1	0.9	6.5	0.0	0.0	0.0	0.0
BTG.2 Solar Community Services	0.0	1.3	2.8	0.7	0.5	4.0	0.0	0.0	0.0	0.0
BTG.3 Solar Portable Lamps	0.0	0.0	1.8	1.8	1.8	5.5	0.0	0.0	0.0	0.0

Figure 11.15 represents the overall BTG impacted locations.

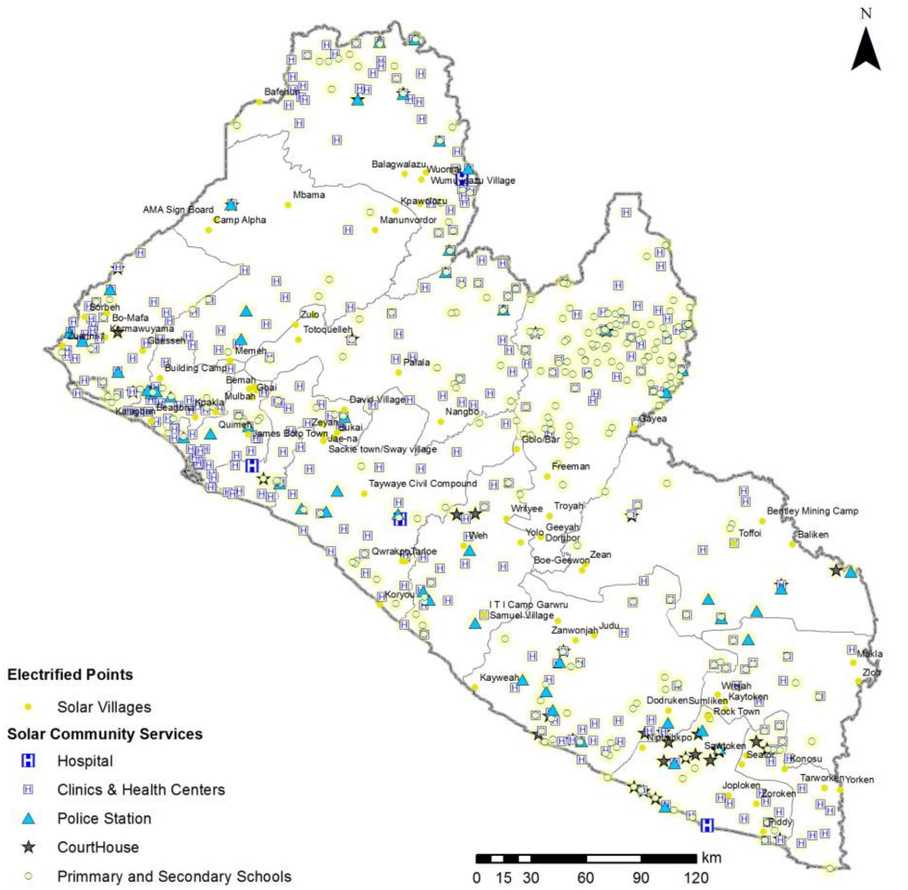


Figure 11.15 – Beyond the Grid Program impacted locations.

11.5 OTP: OTHER THAN POWER

11.5.1 INTRODUCTION

Other than Power Program. The OTP Program represents a total investment of USD 24M and will enable the installation of pre-paid meters in all rural electricity clients and promote the use of energy efficient appliances, of cooking gas and efficient cook stoves across Liberia. The OTP Program has significant setup investments in the first phase, but on prepaid meters grows with the number of electrified clients being also significant in Phase 3. The Program has no funding committed at the present stage.

Other than Power Program is composed of 4 main initiatives, described in the next sections.

11.5.2 OTP.1 - EFFICIENT LIGHT & APPLIANCES INITIATIVE

Efficient Light & Appliances initiative. This initiative intends to reduce the acquisition of inefficient appliances and lamps in Liberia, thus making power consumption more affordable to people living in rural areas. It includes the creation of a rating system and brand for energy efficient appliances and lamps which will be required to obtain import tax exemptions, thus making the more efficient appliances and lamps more competitive. The tax will be adjusted to avoid reduction in tax income. The initiative includes also the creation of service centers across the country to support installation of Solar Water Heating systems.

11.5.3 OTP.2 - PREPAID METERS AND POWER LOSS REDUCTION INITIATIVE

Prepaid meters and power loss reduction initiative. This initiative intends to enable the universal use of prepaid meters in Liberia with a similar tariff structure across the country and to deploy the metering infra-structure that allows for a clear identification of where power losses are generated. Given the potential for multiple companies acting in the distribution area, this initiative will allow for a centralized management of the prepaid metering system and support the creation of an adequate georeferenced information system.

11.5.4 OTP.3 - CITY COOKING GAS INITIATIVE

City cooking gas initiative. This initiative intends to make cooking gas bottles available in the main cities of the country and increase competition in retail through an obligation to petrol sellers to sell cooking gas in their stations. Additionally, to increase competition and access to LPG import, storage and filling infrastructure, a new facility will be built initially by LPRC but with the intention to be privatized and owned also by petrol sellers and other private entities.

11.5.5 OTP.4 - EFFICIENT BIOMASS FOR COOKING INITIATIVE

Efficient biomass for cooking initiative. This initiative intends to increase efficiency in the utilization of biomass for cooking in order to reduce deforestation and energy costs for consumers. It includes support to improvements on existing efficient cook stove manufacturing and marketing activity, including the organization of multiple trial sessions where potential consumers in a community are given training and borrowed a cook stove for trial and possible future acquisition. Additionally, it includes also a project dedicated to branding and certification of efficient charcoal production.

11.5.6 OTP PROGRAM: BENEFITS AND ESTIMATED INVESTMENTS

OTP implies an estimated investment of USD 24.3M. The estimates of inhabitants and clients that are planned to benefit from this program, as well as the projected investments are shown in **Table 11.4**.

Table 11.4 – Estimated electrified people, clients and projected global investments in OTP Program.

	Impact		Investments per phase (USD M)				Estimated Investments (USD M)			
	Number of People (Thousands)	MW	Phase 1	Phase 2	Phase 3	Total	Phase 1 Committed	Phase 2 Committed	Phase 3 Committed	Committed funding (estimate)
IV. OTP OTHER THAN POWER	**0.0**	**0.0**	**10.3**	**5.8**	**8.2**	**24.3**	**0.0**	**0.0**	**0.0**	**0.0**
OTP.1. Efficient Light & Appliances	0.0	0.0	0.8	0.2	0.2	1.2	0.0	0.0	0.0	0.0
OTP.2. Prepaid meters & loss reduction	0.0	0.0	5.5	3.8	6.2	15.4	0.0	0.0	0.0	0.0
OTP.3. City cooking gas	0.0	0.0	3.0	1.0	1.0	5.0	0.0	0.0	0.0	0.0
OTP.4. Efficient cooking biomass	0.0	0.0	1.1	0.9	0.9	2.8	0.0	0.0	0.0	0.0

11.6 BC: BUILDING CAPACITY

11.6.1 INTRODUCTION

Building capacity. The BC Program is transversal to all the other four and supports the implementation and impact of all the other programs. The total estimated investment of the BC Program is of USD 52M.

The Building Capacity Program is composed of 6 main initiatives, described in the next sections.

11.6.2 BC.1 - PUBLIC SECTOR SCALE UP INITIATIVE

Public sector scale up initiative. This initiative intends to strengthen the internal capacity of key public sector entities dedicated to rural energy. RREA will have a key role and its organizational structure and competencies need to be adjusted to the challenges of the Master Plan and a training and capacity building plan needs to be designed. The initiative includes funding for the creation of several new units inside RREA, MLME and LERC for the management of the Rural Energy Master Plan Programs and initiatives. Additionally, the initiative includes also the creation of a Rural Energy Management Information System which will support monitoring and reporting of the progress of the Master Plan.

11.6.3 BC.2 - OWNERS ENGINEERING AND PROCUREMENT INITIATIVE

Owners engineering and procurement initiative. This initiative intends to bring external qualified support to the deployment of the key projects and investments led by the public sector with grant or concessional loan funding. “Owners engineering” contracts are to be celebrated for most of the investments to be deployed including design of technical specifications, management of procurement process and supervision of construction. This initiative also includes the support to setup and manage the renewable IPP procurement program and the *affermage* contracts to be celebrated in phase 1 for external management of distribution activities in Decentralized Grids.

11.6.4 BC.3 - SECTOR REORGANIZATION INITIATIVE

Sector reorganization initiative. This initiative intends to support the creation of the new institutional framework. It includes creation of laws and regulations, the support and operational budget for the Rural Services Unit(s), all activities regarding the setup of the Regional Distribution Companies and the restructuring of LEC to separate the Distribution activities from the Transmission and Power sourcing.

11.6.5 BC.4 - RURAL ENERGY TRAINING AND ACCREDITATION CENTERS INITIATIVE

Rural Energy Training and accreditation Centers initiative. This initiative intends to create four Rural Energy Training and Accreditation Centers for Rural Energy, one in each of the country’s regions, who will train and/or accredit electricians, mechanics and other technicians required for the operation of the future rural energy infra-structure. The Centers will be created in existing educational entities and will correspond to a New Department of such entities. A scholarship program to incentivize the enrollment of women will be created.

11.6.6 BC.5 - REFUND INITIATIVE

REFUND initiative. This initiative intends to start the operationalization of the Rural Energy Fund with concrete projects and measures. It includes the creation of stable sources of revenue - the Power and Petrol Contribution (PPC) and the Lease Fee (LF) – and the creation of several credit lines to be made available by local banks to retailers: for acquisition of efficient appliances; to Distribution Companies: for grid connection and house electrification (to be recuperated from clients on a monthly basis) and/or for other growth investments; to new companies and business models such as Solar Portable Lamp rental or efficient cook stove manufacturing. Additionally, the use of REFUND to support renewable off-taking together with Partial Risk Guarantee schemes or to help mitigate tariff differences across regions will be studied.

11.6.7 BC.6 - COMMUNICATION INITIATIVE

Communication initiative. This initiative includes the communication on the implementation of the Rural Energy Master Plan to key stakeholders, the communication to the general public on areas that

require more awareness such as Solar Portable Lamps, efficient cooking or appliances, and finally the communication to potential donors for fund raising.

11.6.8 BC PROGRAM: BENEFITS AND ESTIMATED INVESTMENTS

BC implies an estimated investment of USD 51.9M. The estimates of inhabitants and clients that are planned to benefit from this program, as well as the projected investments are shown in **Table 11.5**.

Table 11.5 – Estimated electrified people, clients and projected global investments in BC Program.

	Impact		Investments per phase (USD M)				Estimated Investments (USD M)			
	Number of People (Thousands)	MW	Phase 1	Phase 2	Phase 3	Total	Phase 1 Committed	Phase 2 Committed	Phase 3 Committed	Committed funding (estimate)
V. BC BUILDING CAPACITY	**0.0**	**0.0**	**24.2**	**14.2**	**13.6**	**51.9**	**0.0**	**0.0**	**0.0**	**0.0**
BC.1. Public sector scale up	0.0	0.0	1.4	0.9	0.9	3.2	0.0	0.0	0.0	0.0
BC.2. Owners engineering & procurement	0.0	0.0	14.9	8.4	7.8	31.1	0.0	0.0	0.0	0.0
BC.3. Sector reorganization	0.0	0.0	3.5	1.0	1.0	5.5	0.0	0.0	0.0	0.0
BC.4. Rural Energy Training and Accreditation Centers	0.0	0.0	1.2	1.2	1.2	3.5	0.0	0.0	0.0	0.0
BC.5. REFUND	0.0	0.0	2.7	2.3	2.3	7.2	0.0	0.0	0.0	0.0
BC.6. Communication	0.0	0.0	0.7	0.5	0.5	1.6	0.0	0.0	0.0	0.0

12 IMPLEMENTATION AND INVESTMENT CALENDAR

12.1 ALREADY FUNDED AND ON-GOING PROJECTS

Several programs and projects that may impact of this Rural Energy Master Plan are already funded or even on-going. Although these projects were taken into account during the development of the Rural Energy Master Plan, it is important to state that they were not taken as granted, as it is unclear when they are going to be finished. A detailed list of such projects is on **Table 12.1**, consisting of 14 different projects, funded by three donors (World Bank, USAID and AfDB), totaling an estimated investment almost USD 152M, of which approximately USD 141M are estimated to be secured.

Table 12.1 - Funded and on-going projects.

Program/Project	Description	Estimated Investment (USD)	Estimated Funding Secured (USD)	Donor
LACEEP	Substations (Virginia, Kle, Kakata)	8 400 000	8 400 000	World Bank
	HV Power Lines (Bushrod - Virginia, Virginia - Kle, Paynesville - Kakata)	11 600 000	11 600 000	World Bank
	MV Power Lines and Distribution (Paynesville – Kakata - Weala)	10 250 000	10 250 000	World Bank
West Monrovia	MV Power Lines and Distribution (Kle - Tubmanburg, Kle - Madina, Madina - Bo Waterside, Madina - Robertsport)	14 500 000	14 500 000	World Bank
LIRENAP	Lofa Mini-grid Generation (Kaiha 2 and Diesel + Biomass backup)	20 750 000	21 000 000	World Bank
	Lofa Minigrid MV Power Lines and Distribution	11 300 000		World Bank
Mein River Project	Mein River Hydropower Plant (1 MW)	6 700 000	6 700 000	USAID
Biomass Pilot Projects	Biomass Generation Pilot Projects and Distribution (36 kW in Solumba and 60 kW in Kwenin)	530 000	530 000	USAID
LEAP	Substations (Schefflien, RIA)	5 600 000	5 600 000	AfDB
	HV Power Lines (Paynesville-Schefflien, Schefflien-RIA)	5 000 000	5 000 000	AfDB
	Distribution	7 200 000	7 200 000	AfDB
Cross Border Extension Project	MV Power Lines and Distribution (Plebo - Fishtown)	8 000 000	8 000 000	AfDB
CLSG Shield Wire Distribution Project	MV Power Lines and Distribution	18 000 000	18 000 000	AfDB
SREP	MV Power Lines and Distribution (River Gee and East transitional grids)	24 000 000	24 000 000	AfDB
Total		**151 830 000**	**140 780 000**	

12.2 PHASE 1: 2015-2020

Phase 1 comprises the period 2015-2020, and its main objectives are initial the electrification of the large population centers outside Monrovia, the consolidation of the Cross Border grids and a first stage of the rural grid extension. At the end of this phase, a 10% rural electrification rate is projected. To achieve these goals, the high voltage Monrovia Corridor Extension will begin its execution and, together with the CLSG system, the electrification from the new installed substations will be possible. Also, several off-grid projects will be implemented in this phase, whether to anticipate grid electrification, or to create new decentralized grids or even to promote some level of comfort in remote areas of the country. **Figure 12.1** below shows all the infrastructures that are predicted to be in operation in the end of 2020, and the main changes to be implemented in this phase are summarized next.

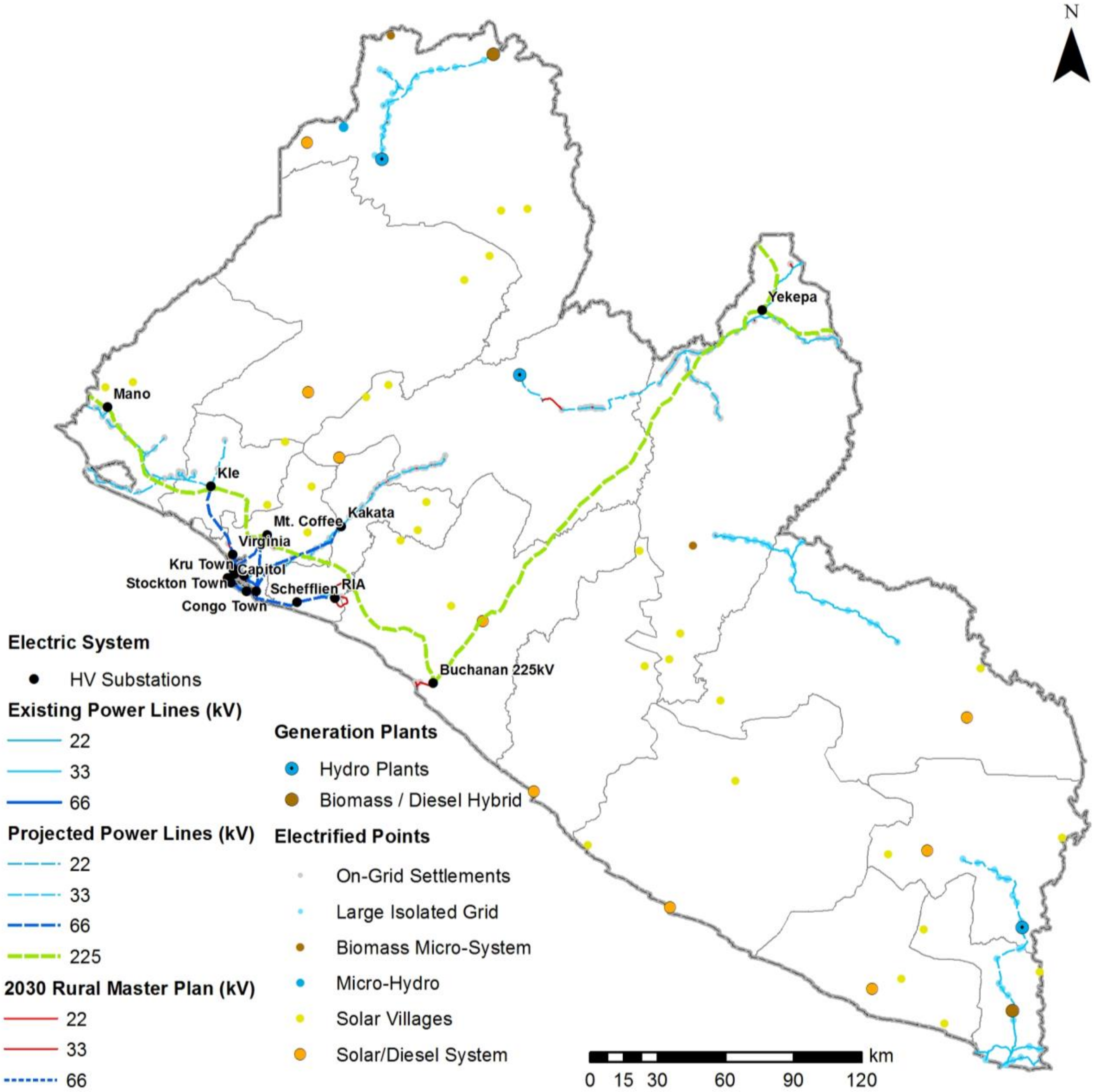


Figure 12.1 – Map of the Liberia's Power System in Phase 1 – 2015-2020.

GTG: Growing the Grid Program

- First stage implementation of HV/MV substations in Virginia, Kle, Kakata, Schefflien and RIA, included in the Monrovia Corridor extension;
- First stage implementation of 66 kV power lines to connect the previous substations to the Monrovia 66 kV network. Virginia will be connected to Bushrod Island and Kle will be connected to Virginia. Kakata and Schefflien substations will be connected to Paynesville and RIA will be connected to Schefflien;
- Included in the Monrovia West Corridor Project, from Kle substation, several 33 kV power lines will be executed to connect Tubmanburg, Robertsport and Bo Waterside. Tubmanburg will be directly linked to Kle, as Robertsport and Bo Waterside will be connected to the switching station located in Madina, which will be coupled to Kle substation. Additionally, several other rural communities will be electrified along the 33 kV power lines;
- Execution of the projected 33 kV power line to link Kakata to Salala and Totota, and electrification of the communities along the way of passage;
- First stage electrification of Buchannan, Yekepa and Sanniquellie, from the CLSG substations located in Buchannan and in Nimba County;

DG: Decentralized Grids Program

- Implementation of several Solar/Diesel transitional grid to provide electricity to large cities that will not have any grid coverage at this phase, thus anticipating grid connection. In total nine cities, all in different counties, will benefit from this project: Barclayville, Bong Mines, Bopolu, Cestos City, Greenville City, Kanweaken, Vahun, Wayzohn Community and Ziah Town;
- Consolidation of all Cross Border grids by electrifying several communities that are near the existing international grids;
- Extension of Nimba's Cross Border from Ganta to Gbarnga and to Saclepea, electrifying these cities and other rural communities along the lines' route;
- Extension of Maryland's Cross Border from Pleebo to Fish Town, with a 33 kV power line with a length of approximately 100 km.
- Connection of Mein River small hydro to Phebe's Hospital and Cuttington University and later to Gbarnga;
- First stage implementation of the decentralized grid in Lofa, with the goal to connect Kaiha 2 small hydro to Voinjama, Foya Town and Kolahun, as well as some other rural communities near the projected medium voltage lines.
- Implementation of several generation plants to partially supply the decentralized grids operation, namely:
    - Kaiha 2 small hydro, 3 MW;
    - River Gee small hydro, 5.79 MW;
    - Mein River small hydro, 1 MW (this hydro will be connected to the national grid);

    - Biomass/Diesel power plants to support decentralized grids operation. At this stage, the projected facilities are located in Voinjama (3+3 MW) and in Pleebo (2+2 MW);
- Two micro biomass pilots will be implemented in the communities of Solumba (35 kW) and Kwendin (60 MW);

BTG: Beyond the Grid Program

- Implementation of two solar villages per county. Thus, in total, 30 solar systems will be installed in this phase, shown in **Table 12.2**, with the following distribution per region:
    - Region 1 (Grand Gedeh, Grand Kru, Maryland, River Gee and Sinoe): 10 systems
    - Region 2 (Bong, Lofa, Nimba): 6 systems
    - Region 3 (Grand Bassa, Margibi, Montserrado and Rivercess): 8 systems
    - Region 4 (Bomi, Grand Cape Mount and Gbarpolu): 6 systems
- In this phase is projected that health related facilities, not connected to any kind of electrical grid will benefit from a solar system. Thus, in 2020 all health facilities are expected to have some degree of electrification. At this stage, the electrification of all services that should only be electrified in the last phase of the Master Plan, is also anticipated through the use of these systems.

Table 12.2 – Summary of benefited regions, communities and habitants benefited in Phase 1.

Project	Regions Affected	Settlements	People
GTG.1.1.1	∣ Region 3 ∣ Region 4 ∣	35	26 566
GTG.1.3.1	∣ Region 3 ∣	1	17 698
GTG.1.4.1	∣ Region 2 ∣ Region 3 ∣	54	14 264
GTG.1.5.1	∣ Region 3 ∣	3	25 243
GTG.3.1.1	∣ Region 2 ∣	2	10 378
GTG.3.2.1	∣ Region 3 ∣	2	33 545
GTG.4.1	∣ Undefined ∣	NA	NA
GTG.4.2	∣ Undefined ∣	NA	NA
GTG.4.3	∣ Undefined ∣	NA	NA
DG.1.1	∣ Region 1 ∣ Region 2 ∣ Region 3 ∣ Region 4 ∣	9	49 712
DG.2.1	∣ Region 2 ∣	101	49 650
DG.2.2	∣ Region 1 ∣ Region 2 ∣	21	15 280
DG.2.3	∣ Region 1 ∣	27	26 932
DG.2.4	∣ Region 2 ∣	22	43 411
DG.3.1	∣ Region 2 ∣	NA	NA
DG.3.2	∣ Region 1 ∣	NA	NA
DG.3.3	∣ Region 2 ∣	NA	NA
DG.3.4.1	∣ Region 1 ∣ Region 2 ∣	NA	NA
DG.4.1	∣ Region 2 ∣	1	397
DG.4.2	∣ Region 2 ∣	1	1 608
BTG.1.1.1	∣ Region 1 ∣	10	2 977
BTG.1.2.1	∣ Region 2 ∣ Region 3 ∣	14	4 101
BTG.1.3.1	∣ Region 4 ∣	6	1 807
BTG.2.1	∣ Nationwide ∣	389	NA

12.3 PHASE 2: 2020-2025

Phase 2 comprises the period 2020-2025. In this Phase, the electrification of the previous covered areas will be increased, the high voltage networks will be expanded to other regions of the Country and new off-grid systems will be implemented in remote areas. A new small hydro plant will be installed in Grand Kru Country and also new biomass backup systems will be installed. Rural MV grids in both the national and decentralized grids will be extended to reach new communities. At the end of this stage a 10% increase in rural electrification is projected, totaling a 20% rural electrification rate nationwide. **Figure 12.2** shows the infrastructures that are predicted to be in operation in the end of 2025, and the main changes to be implemented in this phase are summarized next.

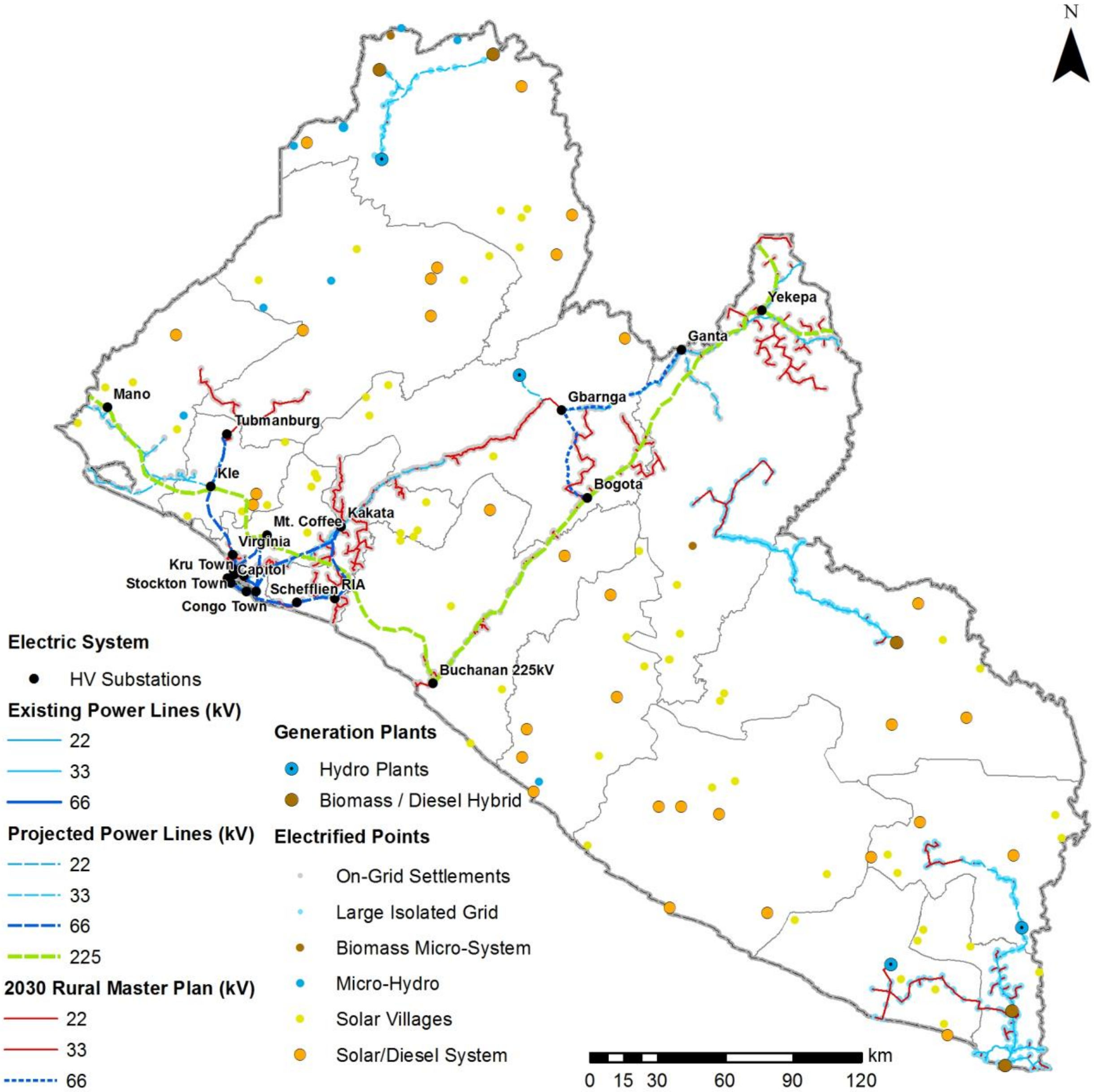


Figure 12.2 – Map of the Liberia's Power System in Phase 2 – 2020-2025.

GTG: Growing the Grid Program

- Consolidation of Phase 1 electrified communities and new medium voltage extensions from the installed substations to cover additional rural communities; In particular, Bong Mines and Bopolu towns will be connected to the main grid and a medium voltage connection between Kakata and Gbarnga will be achieved, electrifying all communities along the way;
- Reinforcements of the Monrovia Corridors substations implemented in Phase 1 namely, Virginia, Kle, Kakata, Schefflien and RIA, as well as the upgrade of respective 66 kV power lines;
- Installation of a new substation in Tubmanburg and the 66 kV connection line to Kle substation;
- Implementation of a new 66 kV power line to link Kakata and RIA substations;
- Creation of the Gbarnga Corridor high voltage grid. Gbarnga and Ganta substations will be constructed, and connected to each other. Gbarnga substation will connect to the main grid in the CLSG switching station located in Bogota. In Bogota, 225/66 kV transformation will be implemented;
- Consolidation of existing clients and MV grid extension from the CLSG substations in Nimba and Grand Bassa, connecting several new rural communities;
- First stage of rural electrification with the use of the shield wires of the CLSG, benefiting Nimba, Bong and Grand Bassa counties.

DG: Decentralized Grids Program

- First stage implementation of Solar/Diesel grid systems throughout the country. In total 27 diesel/solar based mini-grids are implemented in this phase, with the following county distribution:
    - Bomi County: 2 transitional grids
    - Bong County: 1 transitional grid
    - Gbarpolu County: 4 transitional grids
    - Grand Bassa County: 2 transitional grids
    - Grand Cape Mount County: 1 transitional grid
    - Grand Gedeh County: 2 transitional grids
    - Grand Kru County: 1 transitional grid
    - Lofa County: 3 transitional grid
    - River Gee County: 3 transitional grids
    - Rivercess County: 4 transitional grids
    - Sinoe County: 4 transitional grids
- Construction of the Barclayville small hydro power plant, with an installed capacity of 4.5 MW;
- Extension of the Maryland / River Gee Decentralized grid to Grand Kru County, connecting Barclayville small hydro;
- Implementation of Biomass/Diesel power plants to support decentralized grids operation. In this phase, the projected facilities are located in Foya Town (4+4 MW) and in Zwedru (4+4 MW);

- Implementation of seven micro-hydro villages systems distributed in regions 2, 3 and 4. The benefited villages are:
    - Wobu Kenor, Bawomai and Baimbata Village in Lofa;
    - Bardobozohn in Rivercess;
    - Mecca in Grand Cape Mount;
    - Timba and Beaden in Gbarpolu.

BTG: Beyond the Grid Program

- Second stage of the implementation of solar villages, consisting on the installation of two solar systems per county. Thus, in total, 30 solar systems will be installed in this phase, shown in **Table 12.3**, with the following distribution per region:
    - Region 1 (Grand Gedeh, Grand Kru, Maryland, River Gee and Sinoe): 10 systems
    - Region 2 (Bong, Lofa, Nimba): 6 systems
    - Region 3 (Grand Bassa, Margibi, Montserrado and Rivercess): 8 systems
    - Region 4 (Bomi, Grand Cape Mount and Gbarpolu): 6 systems
- Second stage of the implementation of solar community services. In this phase solar systems will be distributed through security and education facilities in some of the largest remote and off-grid communities.

Table 12.3 – Summary of benefited regions, communities and habitants benefited in Phase 2.

Project	Regions Affected	Settlements	People
GTG.1.1.2	| Region 3 | Region 4 |	36	24 319
GTG.1.2.1	| Region 3 | Region 4 |	74	18 794
GTG.1.3.2	| Region 3 |	1	14 872
GTG.1.4.2	| Region 2 | Region 3 |	495	49 133
GTG.1.5.2	| Region 3 |	3	21 221
GTG.1.6.1	| Region 3 |	80	13 761
GTG.2.1.1	| Region 2 |	2	36 867
GTG.2.2.1	| Region 2 |	157	11 662
GTG.3.1.2	| Region 2 |	96	29 008
GTG.3.2.2	| Region 3 |	5	28 572
GTG.3.3.1	| Region 2 | Region 3 |	170	21 446
GTG.4.1	| Undefined |	NA	NA
GTG.4.2	| Undefined |	NA	NA
GTG.4.3	| Undefined |	NA	NA
DG.1.2.1	| Region 1 |	10	12 435
DG.1.3.1	| Region 2 | Region 3 |	10	10 562
DG.1.4.1	| Region 4 |	7	7 647
DG.2.5.1	| Region 1 |	158	45 611
DG.2.6.1	| Region 1 | Region 2 |	114	25 764
DG.3.4.2	| Region 1 | Region 2 |	NA	NA
DG.3.5	| Region 1 |	NA	NA
DG.4.3	| Region 2 | Region 3 |	4	1 212
DG.4.4	| Region 4 |	3	1 424
BTG.1.1.2	| Region 1 |	10	2 347
BTG.1.2.2	| Region 2 | Region 3 |	14	2 903
BTG.1.3.2	| Region 4 |	6	1 593

Project	Regions Affected	Settlements	People
BTG.2.2	| Nationwide |	106	NA

12.4 PHASE 3: 2025-2030

Phase 3 comprises the period 2025-2030, and represents the final implementation stage of the Rural Energy Master Plan. A 35% rural electrification rate will be achieved, which corresponds to a 15% increase in the 5 year duration of this phase. The main focus in this period is to maximize rural grids extension from the national grid and from the decentralized grids, although some investments in the high voltage network are also planned. In parallel with the grid extension, several off-grid systems will be implemented allowing electricity supply in remote areas where the grid coverage is not existent. **Figure 12.3** shows the infrastructures that are predicted to be in operation in the end of 2030, and the main changes to be implemented in this phase are summarized next.

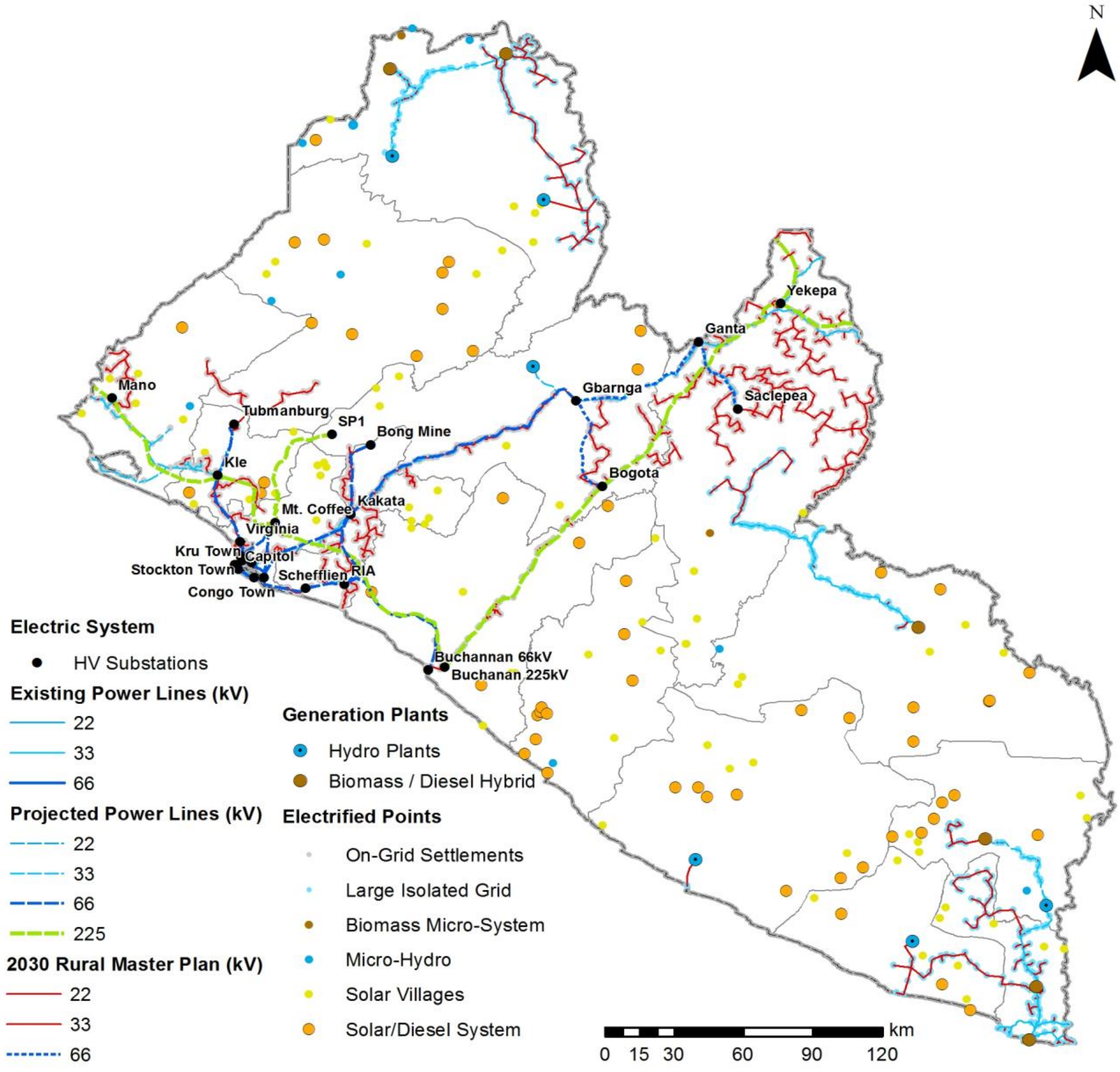


Figure 12.3 – Map of the Liberia's Power System in Phase 3 – 2025-2030.

GTG: Growing the Grid Program

- Consolidation of the electrified communities connected in the previous phases and new medium voltage extensions from the installed substations to cover additional rural communities; the rural grid extension will be mainly focused in Nimba, Bomi and Grand Cape Mount;
- Installation of a new 66/33 kV substations in Bong Mines, Buchannan and Saclepea.
- Installation of new 66 kV power lines to connect:
  - Bong Mines to Kakata substation;
  - Buchannan to RIA substation;
  - Saclepea to Ganta Substation;
- Additionally, a 66 kV power line to connect Kakata to Gbarnga will also be installed;

DG: Decentralized Grids Program

- Second phase implementation of Solar/Diesel grid systems throughout the country. In total 29 diesel/solar based mini-grids are implemented in this phase, with the following county distribution:
  - Bomi County: 1 transitional grid
  - Bong County: 1 transitional grid
  - Gbarpolu County: 5 transitional grids
  - Grand Bassa County: 3 transitional grids
  - Grand Gedeh County: 4 transitional grids
  - Grand Kru County: 2 transitional grid
  - River Gee County: 3 transitional grids
  - Rivercess County: 5 transitional grids
  - Sinoe County: 5 transitional grids
- Construction of Wozi Creek and Greenville small hydro power plants, with installed capacity of 5 MW and 2 MW, respectively;
- Connection of Greenville small hydro to Greenville city;
- Expansion of Lofa's Decentralized Grid to the east of the county and connection to Wozi Creek small hydro;
- Implementation of one Biomass/Diesel power plant to support the Maryland/Grand Kru/River Gee decentralized grid operation, in Fish Town (0.5+0.5 MW).
- Implementation of two micro-hydro villages systems in regions 1. The benefited villages are:
  - Darlue in Grand Gedeh;
  - Toubo Sweaken in River Gee;

BTG: Beyond the Grid Program

- Third stage of the implementation of solar villages, consisting on the installation of one solar system per county. Thus, in total, 15 solar systems will be installed in this phase, presented in **Table 12.4**, with the following distribution per region:
  - Region 1 (Grand Gedeh, Grand Kru, Maryland, River Gee and Sinoe): 5 systems

- Region 2 (Bong, Lofa, Nimba): 3 systems
- Region 3 (Grand Bassa, Margibi, Montserrado and Rivercess): 4 systems
- Region 4 (Bomi, Grand Cape Mount and Gbarpolu): 3 systems

- Third stage of the implementation of solar community services. Once again, the systems will be distributed through security and education facilities in some of the largest remote and off-grid communities. At the end of this phase is projected that all Health, Security and Education Community services are electrified.

Table 12.4 – Summary of benefited regions, communities and habitants benefited in Phase 3.

Project	Regions Affected	Settlements	People
GTG.1.1.3	| Region 3 | Region 4 |	36	30 971
GTG.1.2.2	| Region 3 | Region 4 |	174	34 063
GTG.1.3.3	| Region 3 |	1	15 977
GTG.1.4.3	| Region 2 | Region 3 |	495	51 955
GTG.1.5.3	| Region 3 |	3	22 812
GTG.1.6.2	| Region 3 |	80	9 349
GTG.2.1.2	| Region 2 |	2	39 605
GTG.2.2.2	| Region 2 |	354	124 159
GTG.3.1.3	| Region 2 |	96	35 909
GTG.3.2.3	| Region 3 |	5	30 436
GTG.3.3.2	| Region 2 | Region 3 |	170	23 224
GTG.3.4	| Region 4 |	38	15 027
GTG.4.1	| Undefined |	NA	NA
GTG.4.2	| Undefined |	NA	NA
GTG.4.3	| Undefined |	NA	NA
DG.1.2.2	| Region 1 |	14	11 431
DG.1.3.2	| Region 2 | Region 3 |	9	5 469
DG.1.4.2	| Region 4 |	6	4 556
DG.2.5.2	| Region 1 |	184	72 672
DG.2.6.2	| Region 1 | Region 2 |	114	32 835
DG.2.7	| Region 1 |	1	NA
DG.2.8	| Region 2 |	155	69 988
DG.3.4.3	| Region 1 |	NA	NA
DG.3.6	| Region 2 |	NA	NA
DG.3.7	| Region 1 |	NA	NA
DG.4.5	| Region 1 |	2	538
BTG.1.1.3	| Region 1 |	5	1 076
BTG.1.2.3	| Region 2 | Region 3 |	7	1 354
BTG.1.3.3	| Region 4 |	3	765
BTG.2.3	| Nationwide |	118	NA

12.5 INVESTMENT NEEDS AND QUANTITIES SUMMARY

In this section a summary of the quantities and its estimated investments is presented. The following tables (**Table 12.5**, **Table 12.6**, **Table 12.7** and **Table 12.8**) show the main quantities and investments for generation, high voltage substation and power lines additions, medium voltage extensions and for distribution. In **ANNEX XIV** more detailed lists are given.

Table 12.5 – Investment needs and quantities summary - Generation.

Infrastructure	Installed Capacity (MW)	Estimated Investment (USD)
GENERATION	**181.5**	**420 311 250**
Small Hydro	51.3	214 005 000
Hybrid Biomass/Diesel	31.0	34 875 000
Biomass	10.1	30 166 250
Micro Hydro	0.5	9 365 000
Hybrid Solar/Diesel	25.1	31 425 000
Solar	63.5	100 475 000

Table 12.6 – Investment needs and quantities summary – High Voltage Grid.

Infrastructure	Number of Substations	Line Length (km)	Estimated Investment (USD)
HIGH VOLTAGE GRID	**12**	**572.3**	**102 550 000**
Substations	12	-	31 000 000
HV Power Lines	-	572.3	71 550 000

Table 12.7 – Investment needs and quantities summary – Rural medium voltage extension grid.

Infrastructure	Length (km)	Estimated Investment (USD)
MEDIUM VOLTAGE EXTENSION GRID	**3 228.4**	**102 350 000**
MV Power Lines	3 228.4	102 350 000

Table 12.8 – Investment needs and quantities summary – Distribution.

Infrastructure	Benefited People	Number of Connections	Estimated Investment (USD)
DISTRIBUTION	**1 338 893.0**	**264 713.0**	**226 400 288**
MV Power Lines	1 338 893	264 713	226 400 288

Regarding generation, more than 180 MW are projected to be installed, representing a global estimated investment of USD 420M in the 15 year period. Half of this investment will be allocated to Small hydro power plants with a total share of USD 214M. Solar energy will also play an important role in the planned investments. In total USD 100M will used to install 63.5 MW of PV power plants, of which 60 MW are allocated to the Renewable IPPs to be connected to the national grid. The total share for the on-grid solar generation is estimated at USD 90M. Hybrid systems and Biomass power plants will also represent a significant cut of total investment, with an individual share of more than USD 30M each.

The total investment in high voltage grid is around USD 100M, of which USD 70M will be used to build almost 600 km of 66 kV power lines.

During the three phases of the action plan, more than 3 200 km of medium voltage lines will be built to reach rural communities all over the country. This will represent a total investment of USD 100M.

In 2030, around 265 000 new customers will be connected to the national grid or decentralized grids (large and small). The estimated investments in distribution to connected all of these clients is more than USD 225M.

13 COUNTRY AND LOCAL IMPACT

13.1 OVERALL IMPACT: ADDRESSING THE BARRIERS AND PROMOTING DEVELOPMENT

Impact. In 2030 more than 2 000 rural towns and communities will have electric supply access, either from the national grid or from other decentralized systems. This will correspond to more than 1.3 million electrified people and an aggregated rural electrification rate of 35%. A list of all the electrified towns and communities in 2030 is presented in **ANNEX XV**.

Regions near the existing or planned grid can easily be electrified through grid extension, but in order to promote electrification equity, four large decentralized medium voltage grids will be created or consolidated to electrify the more remote regions. Additionally, more than a hundred town-scaled supply systems will be implemented to give access to remote large cities and also to small communities that, due to its small dimension would not be viable for grid connection.

Figure 13.1 shows the overall evolution of the situation of Liberia's power system for the period 2015-2030, as discussed in the last chapter.

Phase 1. In Phase 1 the main focus will be the initial electrification of all county capitals and main cities of the country. The existing grid will be the main base to achieve this goal, and therefore the investments will be concentrated in the regions near the national and cross border grids. In this phase almost 65 000 households will be connected which will correspond to more than 320 000 electrified people. Thus, in 2020 a 10% rural electrification rate is expected.

Phase 2. In Phase 2 rural grid extension will begin in a more intensive way and an additional of 75 000 clients will be connected to the power system, corresponding to a total of 705 000 people connected to the electric system. A 20% rural electrification rate is projected in 2025.

Phase 3. Finally, in Phase 3, a total of 35% of all Liberian's located outside Monrovia will be electrified, corresponding to 265 000 connected households.

The evolution of the electrification rates for each region for the mentioned phases is presented in **Figure 13.2.**

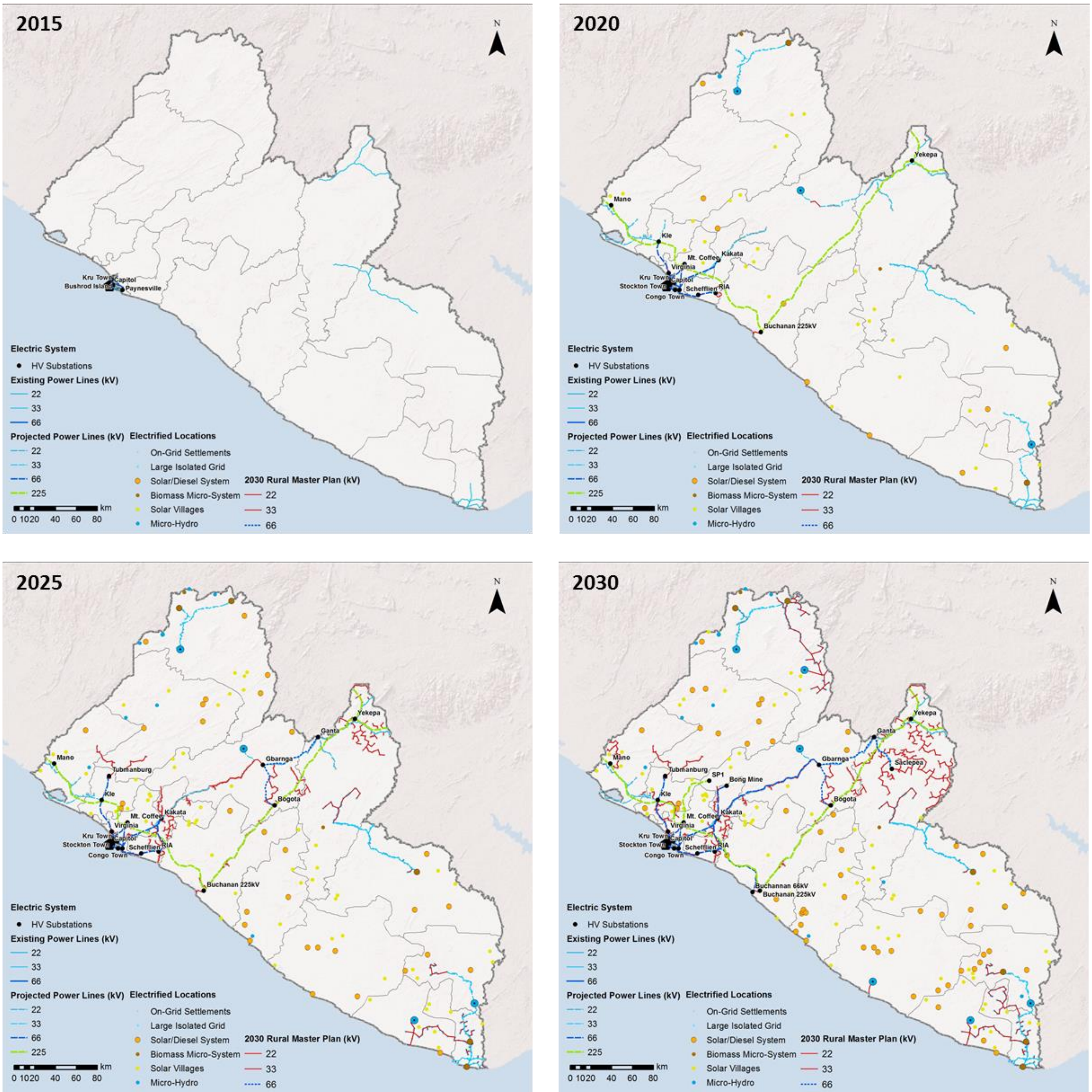


Figure 13.1 – Evolution of Liberia's Power System – Phases 1, 2 and 3.

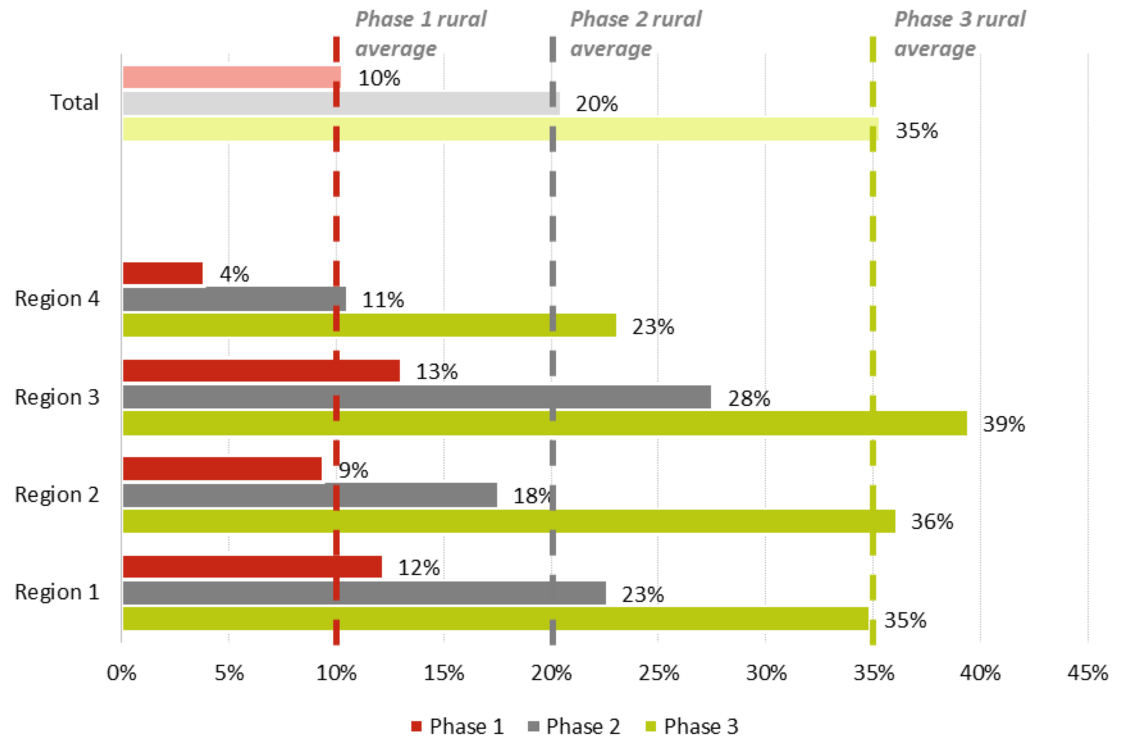


Figure 13.2 –Rural electrification rate evolution per Region.

Regional electrification. Region 3 has highest electrification percentages. In every phase, this region presents rates above national average, mainly because it comprises areas that are near the existing and planned grids, namely the Monrovia existing and planned Corridors and the CLSG in Buchannan and Mount Coffee, and therefore, electrification is more cost effective. On the other hand, Region 4 has the lowest electrification rates of the four regions. In 2030 this is the only region with less than a 30% electrification, although the supply to all main cities and villages of the region is secured. These reduced rates are a combination of several factors, specifically: 1) the high distance of this area to the national grid, mainly Gbarpolu County; 2) the lack of viable medium-large scale renewable supply alternatives; 3) the lack of international connections that could offer access to more inland communities and 3) the small number large cities to attract large grid implementation in the short term. All these factors combined result on low cost effectiveness in this region. However, to overcome the lack of grid extension, mainly in Gbarpolu and Grand Cape Mount, and to promote some level of electrification in these uncovered areas, several mini-grid (13 in total) and off-grid (10 in total) systems will be implemented until 2030.

Region 2 will experience the biggest grid extension mainly due to 1) the existence of many large villages in Nimba County and its proximity to the national grid and 2) the creation and consolidation of the already committed Lofa decentralized grid that will connect a major part of the county.

Population electrified. The number of electrified people nationwide, taking into account the type of supply technology, is presented in **Figure 13.3. Figure 13.4** shows the percentage of people supplied by each one of the 4 technology alternatives, differentiated by geographic regions.

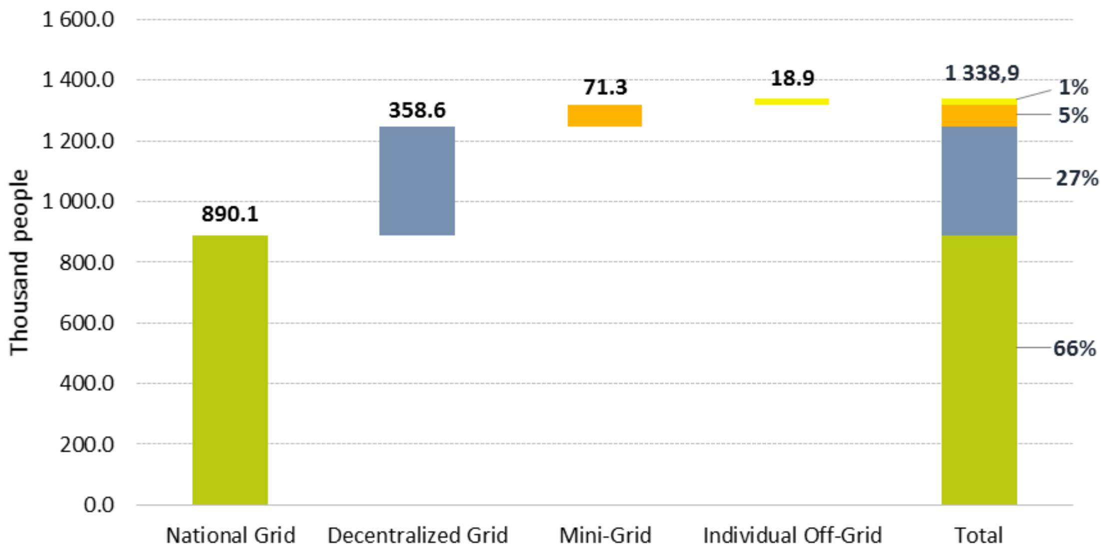


Figure 13.3 – Number of people per type technology in 2030 – nationwide values.

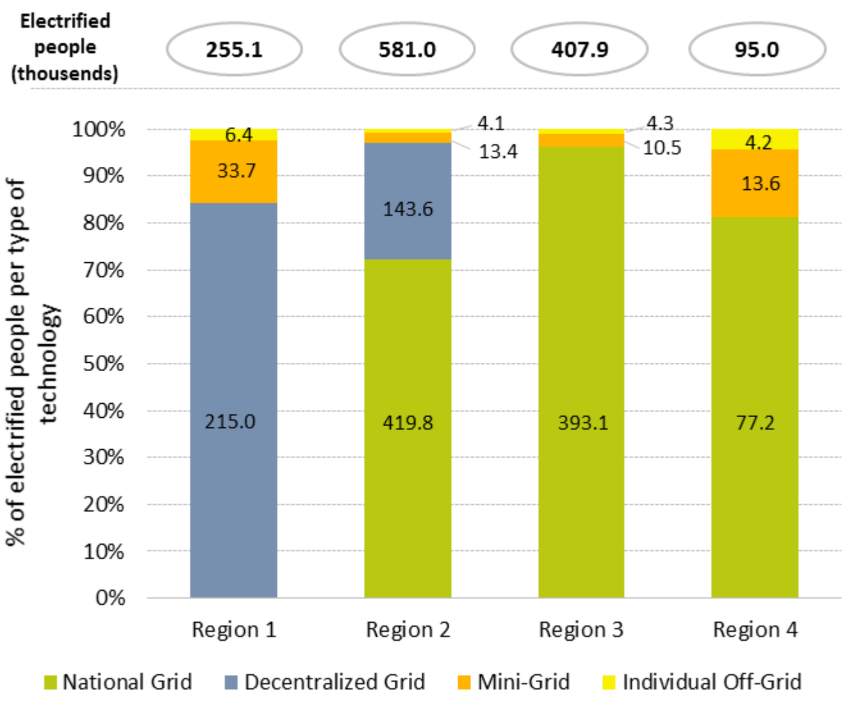


Figure 13.4 – Distribution of electrified people regarding technology type for each Region in 2030.

Observing **Figure 13.3**, it can be seen that two thirds of all rural electrified population will be connected to the national grid. The other third of the population will have a decentralized operation, where 27% will be connected to a large decentralized grid, 5% will be connected to PV/Diesel hybrid systems and biomass and hydro micro systems. The implementation of the 75 solar villages will translate in only 1% of the population connected to this kind of systems.

Geographic desegregation. Regarding the geographic desegregation, the difference in the way to electrify the population in each region is patent. In Region 1, the most distant to the existing and

planned national grid, all electrification is done by off-grid alternatives. More than 84% of the electrified population is connected to the Maryland/River Gee/Grand Kru decentralized grid, the PV/Diesel hybrid systems are responsible for 13% of the population electrified. 2.5% of the region electrified will be electrified through 100% solar systems. Regions 2, 3 and 4 are covered by the national grid, thus the great majority of electrified people are connected to this alternative. However of these three regions, Region 2, comprised by the northern counties has about a quarter of the electrified population connected to decentralized grids, namely Lofa's. Nimba and Bong counties are mainly connected to the national grid, due to its proximity. Region 4 has the highest relative percentage of people connected to transitional grids, with almost 14 000 people. This was already mentioned previously, and is due to the nonexistence of grid coverage in the northern areas, either national or decentralized (international connections), obliging the use of isolated systems. Note that Region 4 has the lowest rate of electrified people in the country.

Regional investment. A summary of the investment needs in each region is presented in **Figure 13.5**. In **Table 13.1**, the same results are presented but considering the distribution of the investment per each supply alternative.

In **ANNEX XVI**, more detailed set of information of the investment breakdown for each technology per County can be consulted, based on the energy supply and demand forecast provided in **ANNEX XVII**.

Figure 13.5 – Investment needs per region for each phase.

Table 13.1 – Distribution of Investments needs in each region per type of technology

Region	Technology	Phase 1 (MUSD)	Phase 2 (MUSD)	Phase 3 (MUSD)	Technology Total (MUSD)	Region Total (MUSD)
Region 1	Grid					150.23
	Transitional Grid	14.91	4.12	3.90	22.93	
	Decentralized Grid	35.15	51.33	35.19	121.67	
	Micro-Biomass System					
	Micro-Hydro System			1.94	1.94	
	Off-Grid SHS	1.75	1.41	0.52	3.69	
Region 2	Grid	24.07	56.54	80.50	161.11	270.56
	Transitional Grid	8.27	3.44	0.53	12.24	
	Decentralized Grid	32.09	14.01	45.06	91.17	
	Micro-Biomass System	0.53			0.53	
	Micro-Hydro System		2.83		2.83	
	Off-Grid SHS	2.00	0.42	0.26	2.68	
Region 3	Grid	38.70	44.82	44.13	127.65	138.55
	Transitional Grid	4.58	1.34	1.50	7.41	
	Decentralized Grid					
	Micro-Biomass System					
	Micro-Hydro System		1.24		1.24	
	Off-Grid SHS	1.53	0.38	0.34	2.26	
Region 4	Grid	12.63	13.13	15.09	40.86	51.92
	Transitional Grid	1.15	2.51	1.58	5.24	
	Decentralized Grid					
	Micro-Biomass System					
	Micro-Hydro System		3.94		3.94	
	Off-Grid SHS	0.97	0.63	0.28	1.88	

The regions that will have the highest investment needs are Regions 1 and 2, which correspond to the regions that cover the most area. In Region 2, the estimated investment is USD 270M, of which are mainly divided between national grid (USD 161.1M) and large decentralized grids (USD 91.2M). Note that the grid investments include the implementation of substations and HV voltage power lines. In Region 1, the investment needs are estimated at USD 150M. More than 80% of this investment will be applied in the Maryland/River Gee/Grand Kru decentralized grid, i.e. the implementation of small hydro plants, medium voltage extensions and distribution grids. More than 90% of the investment needs of Region 3 will be used in the national grid extension. This makes sense since this is the region with the highest grid coverage due to the Monrovia Corridors extension. Finally, Region 4 has the lowest investment of the three regions. Almost 80% of total investment will be applied in national grid extension to electrify mainly Bomi County and to reach Robertsport. Although, in the implementation period of this Master Plan the national grid reaches Gbarpolu, in this county the grid coverage will be reduced because of its distance. Therefore in Gbarpolu electrification will be mainly executed by isolated transitional grid.

In the following sections each specific region and aggregated counties will be analyzed in more detail, in order to observe the regional impact within each region. Detailed maps per county are presented in **ANNEX XVIII**.

13.2 REGION 1: GRAND GEDEH, GRAND KRU, MARYLAND, RIVER GEE AND SINOE COUNTIES

The impact in Region 1 for each implementation phase is illustrated in **Figure 13.6, Figure 13.7** and **Figure 13.8.**

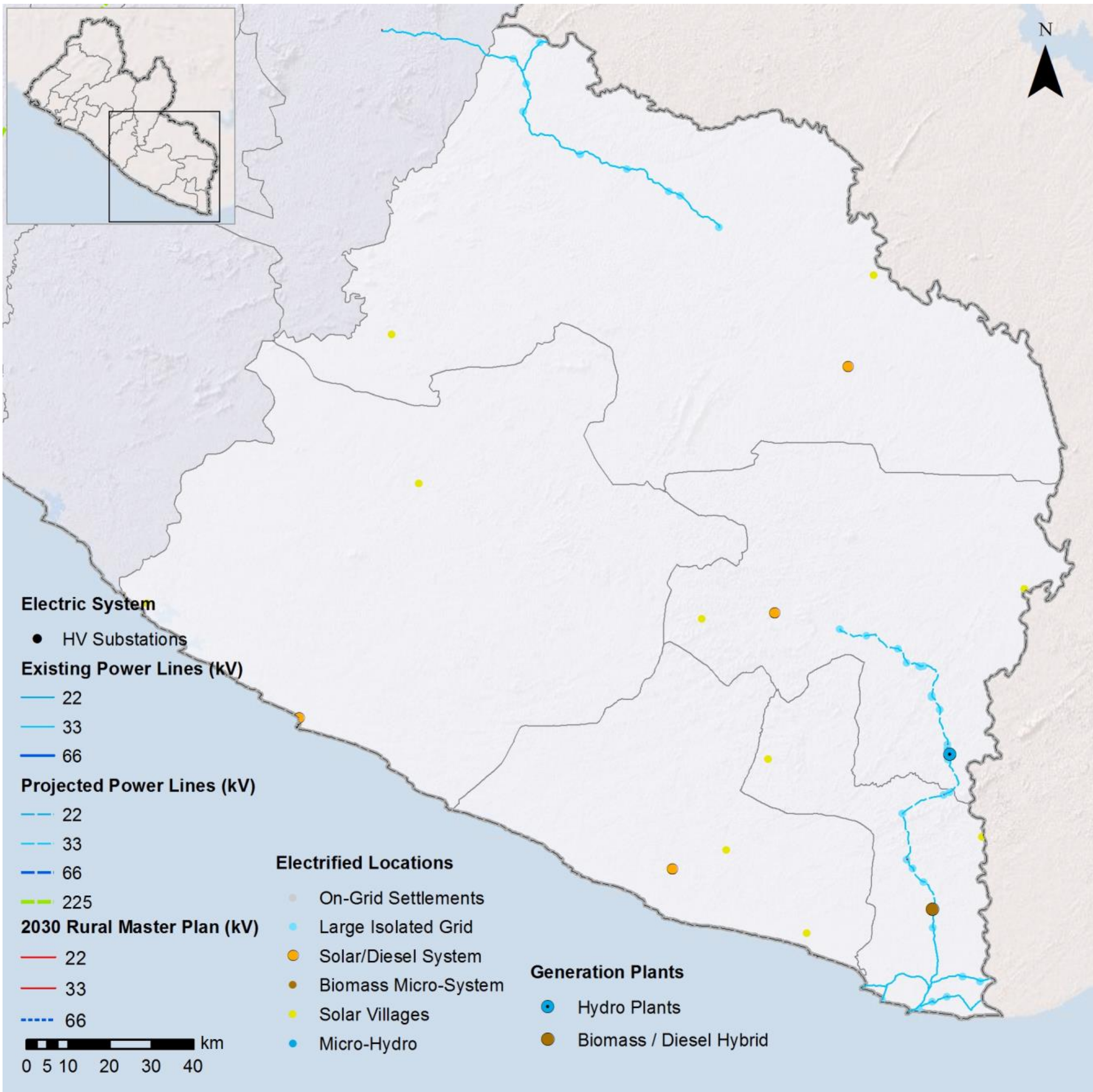


Figure 13.6 – Infrastructure map for Region 1 – Phase 1.

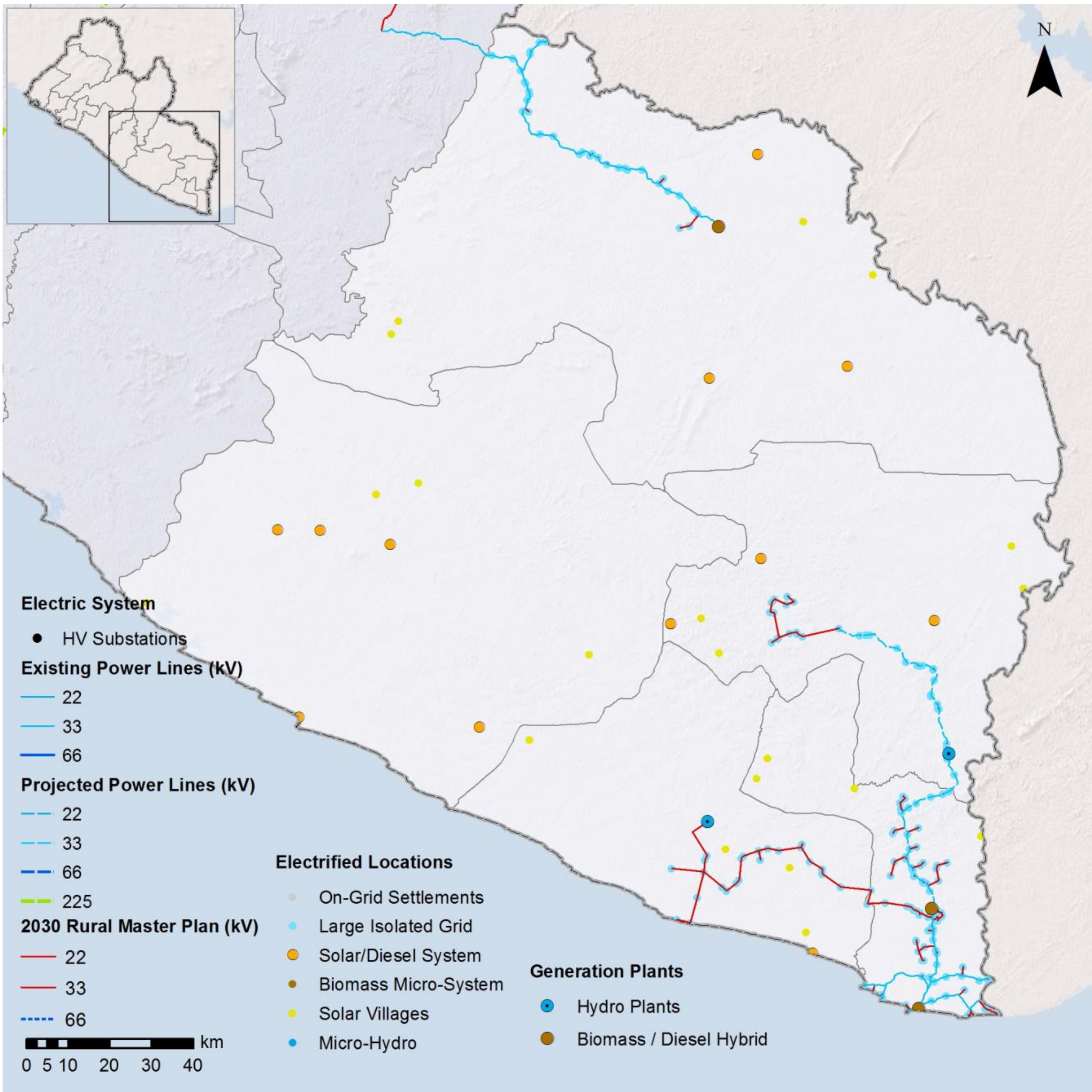


Figure 13.7 – Infrastructure map for Region 1 – Phase 2.

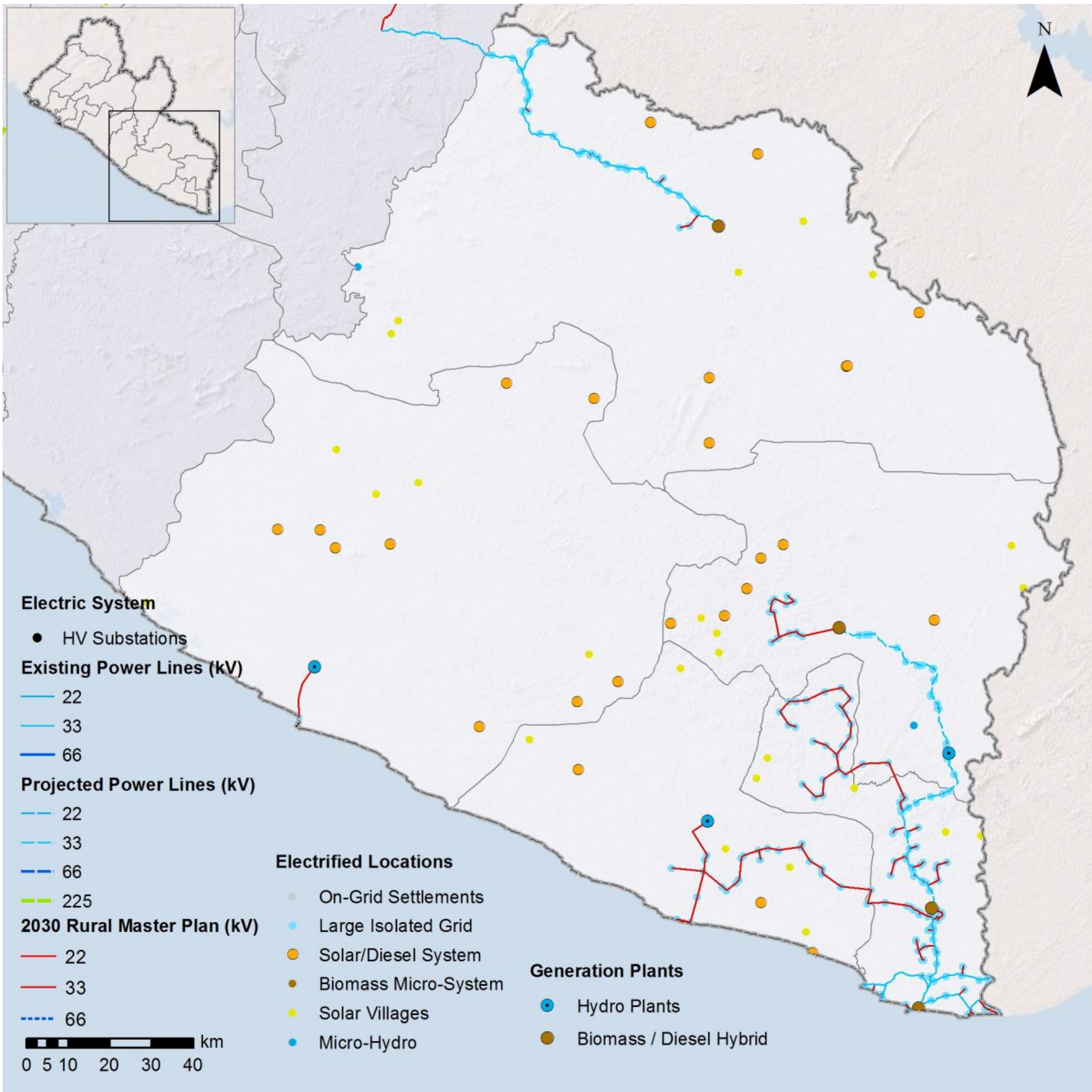


Figure 13.8 – Infrastructure map for Region 1 – Phase 3.

Aggregated electrification rates. The aggregated electrification rates of Region 1 are projected to be 12% in 2020, 23% in 2025 and 35% in 2030. After all implementation phases a total of 50 000 households will be connected in this region corresponding to 255 000 people electrified, of which 66 400 in Grand Gedeh, 19 400 in Grand Kru, 112 900 in Maryland, 27 000 in River Gee and 28 900 in Sinoe.

Electrification rates per county. The evolution of the electrification rates per county in Region 1 is presented in **Figure 13.9**.

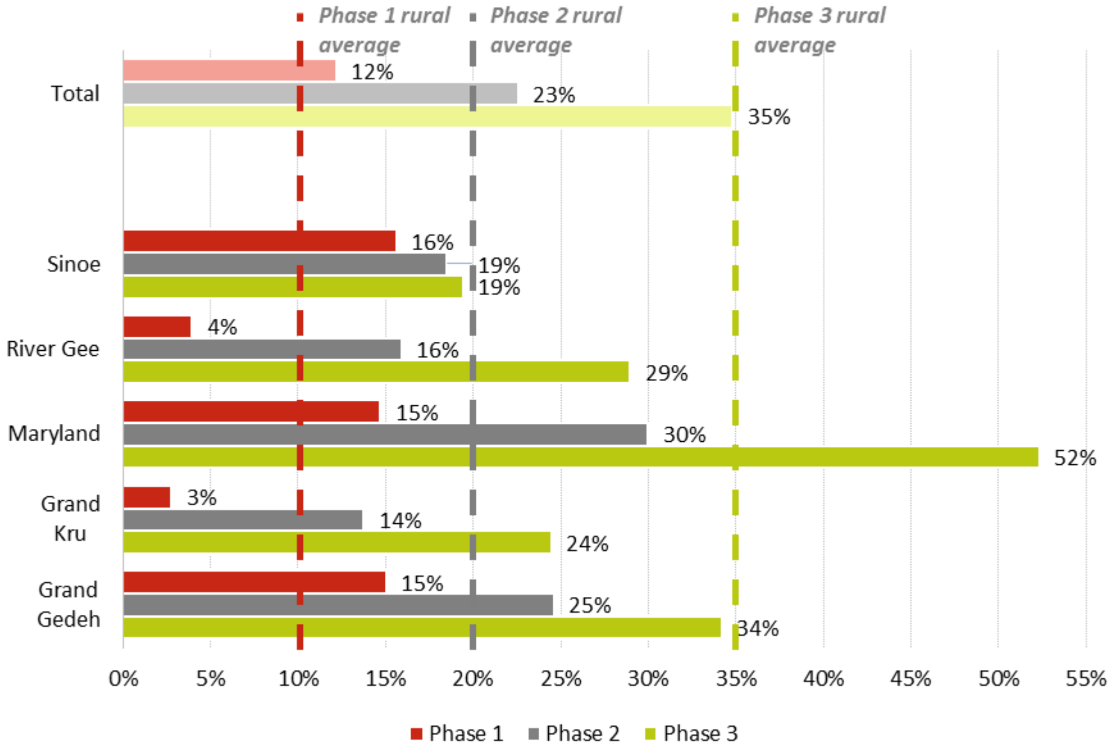


Figure 13.9 – Evolution of rural electrification rates in Region 1 per county.

Overall, in each phase, Region 1 presents rates above or equal to national rural average. For this, Maryland clearly stands out above the other counties with a 52% electrification rate in 2030. The high number of electrified people in this county is due to the existing Cross Border of Maryland and the consequent decentralized grid of the east. The least electrified county is Sinoe with almost 20% of its population electrified in 2030. It can also be observed that Grand Kru and River Gee counties have an extremely small electrification rate in 2020. However, due to the expansion of the Maryland/River Gee /Grand Kru decentralized grid (or southeast decentralized grid), their electrified population rises above national average.

The main supply and distribution alternatives used in this Region are the decentralized grids of the southeast, Grand Gedeh, both based on existing Cross Borders to Cote d'Ivoire, and Greenville.

Evolution per phase. In Phase 1 the investments will be used to consolidate and expand the Cross Border to Fish Town and to construct the River Gee Hydro. Also in Phase 1 four transitional grids will be implemented, in Greenville, Barclayville, Kanweaken and Ziah Town, as well as 10 solar villages. In Phase 2, the southeast decentralized grid will expand to Grand Kru and, Barclayville small hydro will also be connected. In total, 12 PV/Diesel systems and 20 solar villages systems will be in operation. In Phase 3, Greenville hydro will be constructed and the city of Greenville will be connected to the homonymous decentralized grid. Note that Greenville's PV generation as well as its distribution network, implemented in the past transitional grid will be availed at this phase.

The total number of people electrified per type of supply alternative in Region 1 is presented in **Figure 13.10**. As already mentioned, in Region 1 there is no national grid coverage, and all electrification is based on isolated systems where the large decentralized grids are the main source.

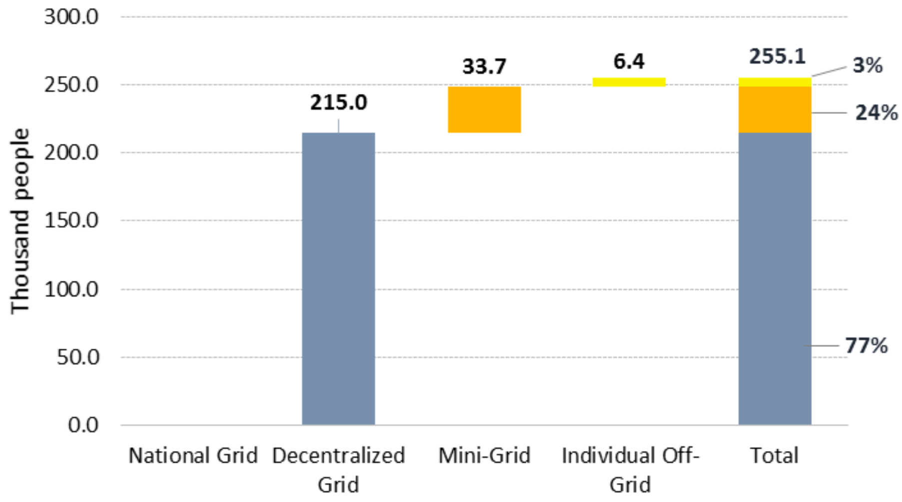


Figure 13.10 – Number of people per type of technology in 2030 – Region 1.

Figure 13.11 shows the percentage of people supplied by each one of the four technology alternatives, differentiated by county.

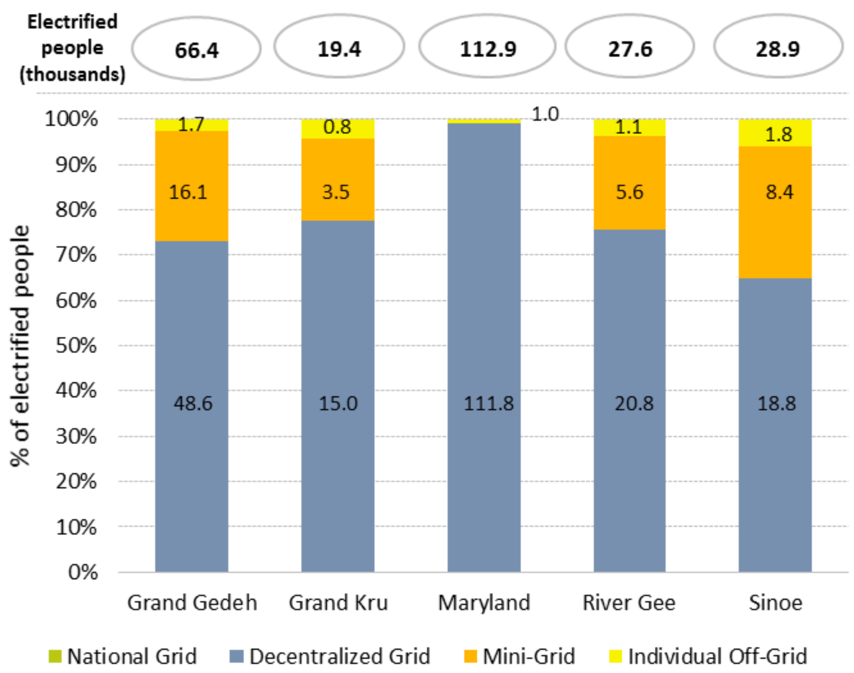


Figure 13.11 – Number of people per type of technology in 2030 – Region 1 values.

Maryland is the County with most electrified population (113 000 people) followed by Grand Gedeh with 66 400 people. On the other hand, Grand Kru, which is characterized by a significant population dispersion, is the county of Region 1 with less connected population.

Maryland is the only County that doesn't have any PV/Diesel hybrid transitional grid, and almost 100% of the supply source is based on the southeast decentralized grid. Grand Gedeh decentralized grid is also responsible for the connection of almost 50 000 people and the hydro in Greenville will allow to electrify 19 000 people in 2030. The highest number of electrified population based on transitional systems is located in Grand Gedeh, where 16 000 people will benefit from these systems.

Investment. The total investments needs per county in each phase is presented in **Table 13.2**. More detailed information regarding the investment needs per type of technology and per county is given in **ANNEX XVI**.

Table 13.2 – Distribution of Investments needs in each county of Region 2

County	Phase 1 (MUSD)	Phase 2 (MUSD)	Phase 3 (MUSD)	Total (MUSD)
Maryland	9.75	13.22	12.12	35.09
River Gee	25.10	3.94	5.41	34.45
Grand Gedeh	5.89	13.34	5.47	24.69
Sinoe	9.32	2.11	16.52	27.94
Grand Kru	1.77	24.24	2.04	28.05
Total	**51.82**	**56.86**	**41.55**	**150.23**

As can be seen, the investments in each county is very similar. River Gee and Maryland have the highest needs, with approximately USD 35M. Grand Gedeh will have the lower cut with USD 25M. Phase 1 and 2 are the periods where the most investment will be needed.

13.3 REGION 2: BONG LOFA AND NIMBA COUNTIES

The impact in Region 2 for each implementation phase is illustrated in **Figure 13.12, Figure 13.13** and **Figure 13.14**.

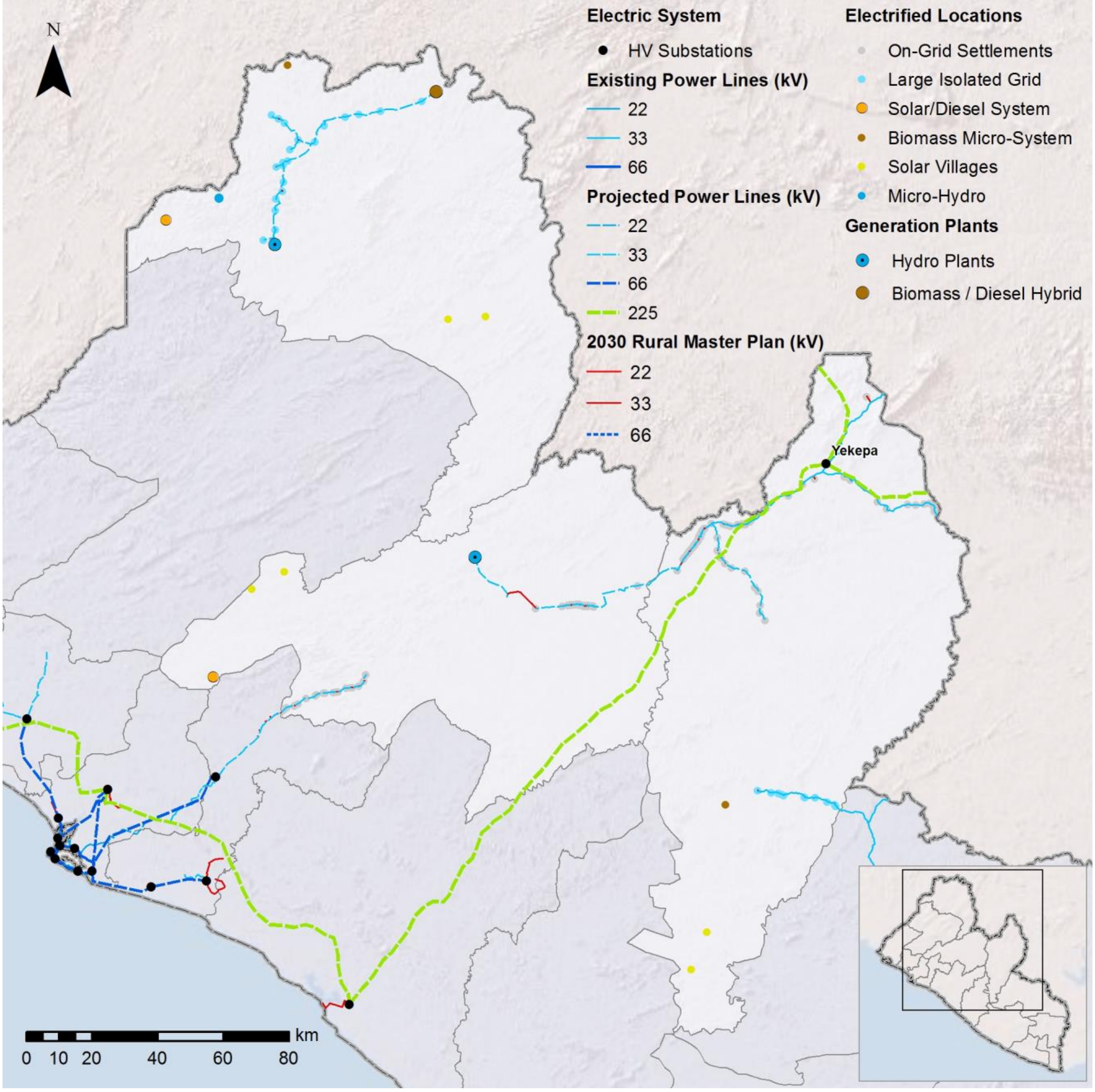


Figure 13.12 – Infrastructure map for Region 2 – Phase 1.

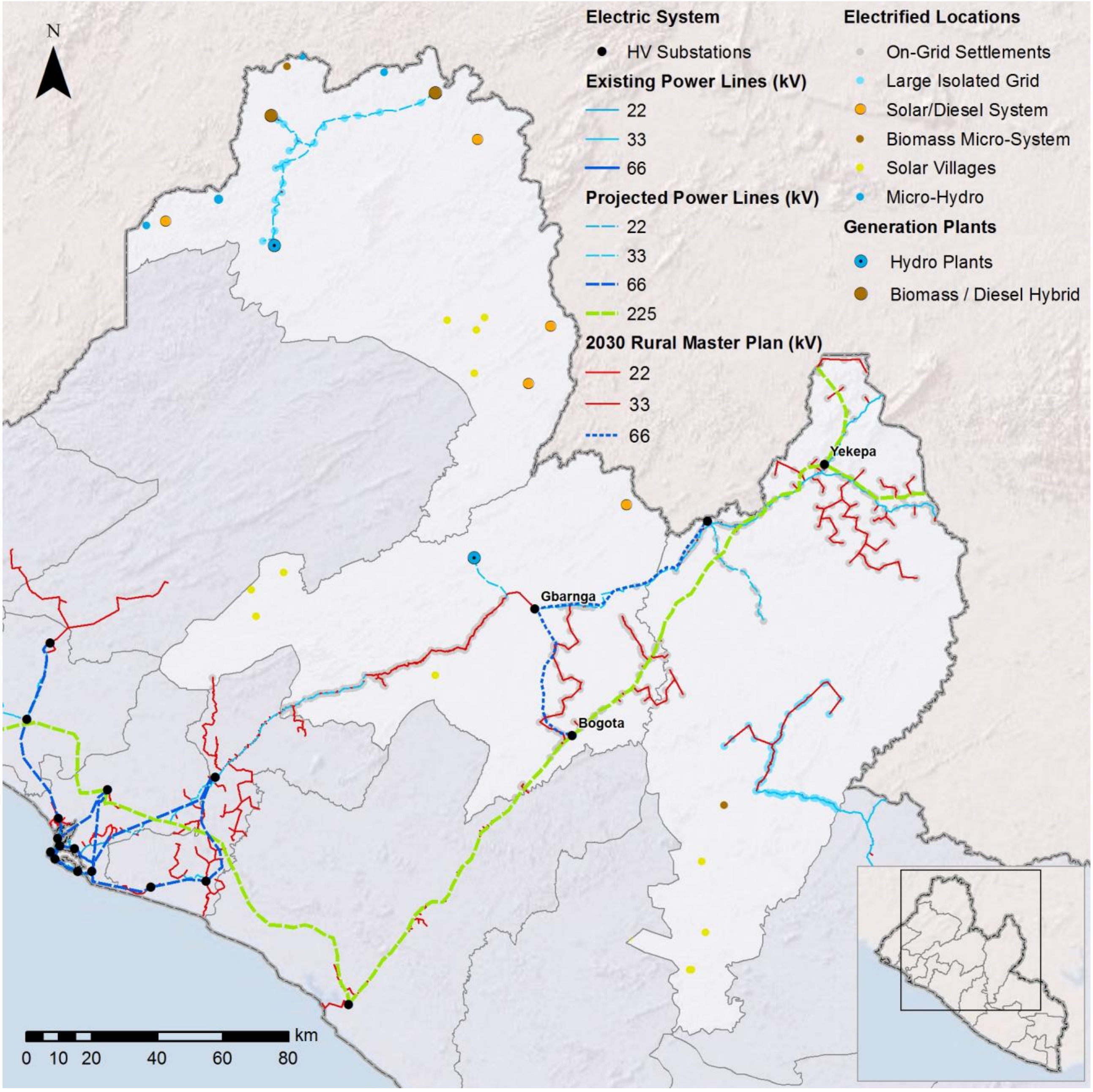


Figure 13.13 – Infrastructure map for Region 2 – Phase 2.

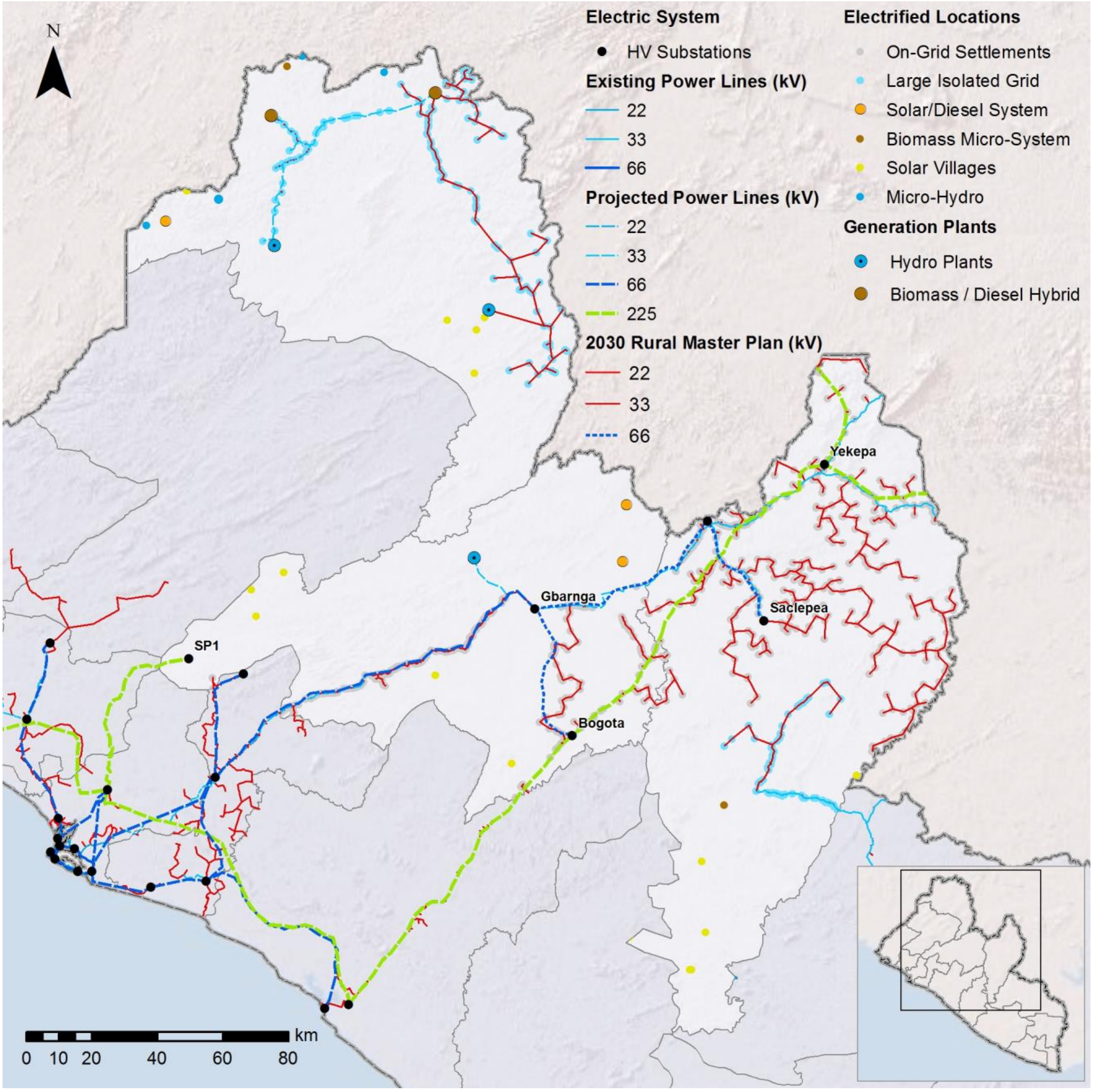


Figure 13.14 – Infrastructure map for Region 2 – Phase 3.

Aggregated electrification rates. The aggregated electrification rates of Region 2 are projected to be 9% in 2020, 18% in 2025 and 36% in 2030. After all implementation phases, a total of 115 000 households will be connected in this region corresponding to 581 000 electrified people, of which 137 400 in Bong, 128 000 in Lofa and 315 400 in Nimba.

Electrification rates per county. The evolution of the electrification rates per county in Region 2 is presented in **Figure 13.15**.

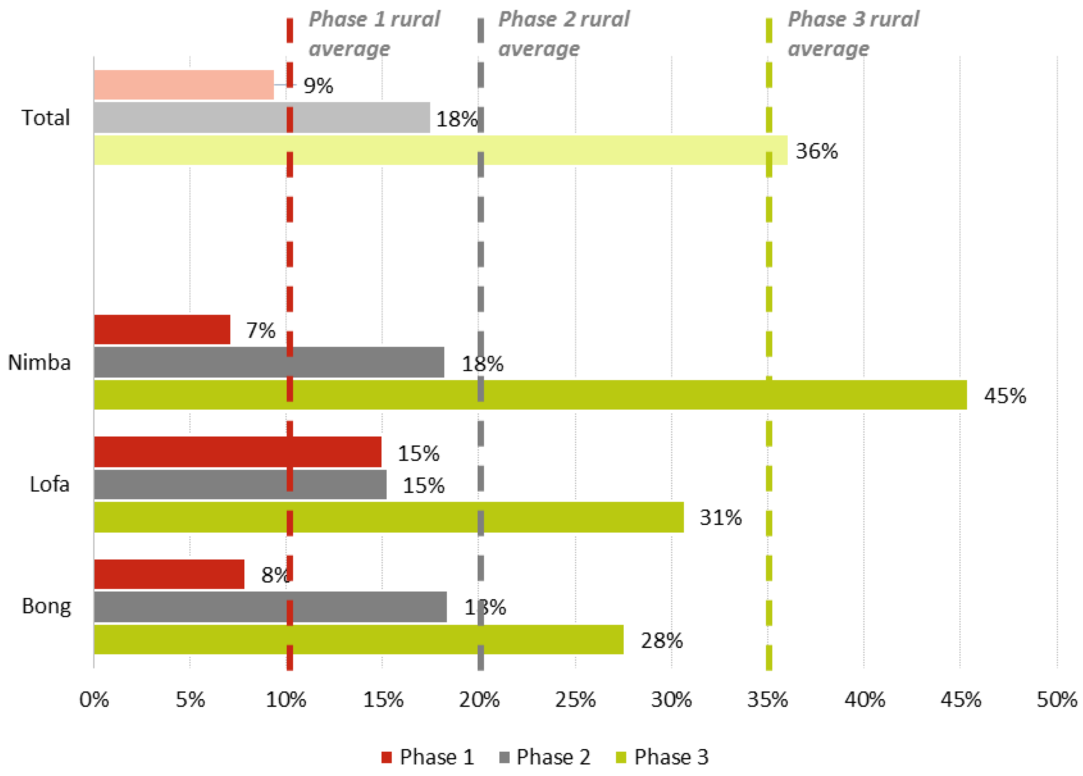


Figure 13.15 – Evolution of rural electrification rates in Region 2 per county.

Overall, in each phase, the electrification rates of Region 2 are close to national averages. In 2030 Nimba has the highest electrification percentage with 45% of its population electrified. In this year, all other counties are below average but close, nonetheless. Lofa presents similar rates in Phases 1 and 2, but in Phase 3 doubles its percentage, due to the second stage expansion of Lofa's decentralized grid. The least electrified county in 2030 will be Bong with a 28% rate. In this county, the benefited communities are the ones along the main road. In earlier phases this county benefits from the Monrovia North corridor extension and presents the highest percentage of electrified people of all counties.

In this Region the main supply and distribution alternative is the national grid that covers Nimba and Bong counties. However, in Lofa the main source is the homonymous large decentralized grid, created to connect, firstly Kaiha 2 small hydro, and then Wozi Creek small hydro, to several towns and communities near the mains roads.

Phase 1. In Phase 1, Nimba's Cross Border grid will be consolidated and extended to Gbarnga and Saclepea. In this period this grid will also be connected to the national grid, namely to Nimba's CLSG substation. Mein river small hydro will also be implemented to firstly supply Phebe Hospital and Cuttington University and later to be connected to the national system. Southeast Nimba (Around Tappita City) will also benefit from Grand Gedeh's Cross Border. In Lofa County, Kaiha 2 small hydro will be implemented and the first stage of Lofa's Decentralized Grid will begin operation. To support the small hydro a biomass/diesel system in Voinjama, with (3+3) MW is installed. Also in Phase 1 two transitional grids will be implemented, one in Bong Mines and the other in Vahun, as well as 6 solar villages. The two micro-biomass pilots in Kwendin and in Solumba will also be implemented.

Phase 2. In Phase 2, begins the rural grid extension. Near Sanniquellie several communities will be connected to the existing MV existing branches and to Yekepa substation. Gbarnga will firstly be connected to Totota with a 33 kV power line and all villages near the main road will also be electrified. In Gbarnga a 66/33 kV substation will be erected and connected to the CLSG switching station in Bogota. Ganta will also benefit from this new HV system – Gbarnga Corridor – with a new 66/33 kV substation which connects to Gbarnga. In Lofa, the main investment will be in Foya, with the installation of the biomass/diesel system with (4+4 MW) to serve as backup in the decentralized system. Several communities in Nimba and Bong will also benefit from the CLSG shield wire distribution grid. Regarding Mini-grid and Off-grid operation, three additional PV/Diesel systems will be installed in Zorzor, Barkedu and Salayea, and twelve solar villages systems will be in operation. Micro-hydro systems will be implemented in three villages, all located in Lofa County.

Phase 3. In Phase 3, rural grid will expand further. Nimba will suffer the most additions with the rural grid expansion from a newly installed 66/33 kV substation in Saclepea that will cover most of the Center and East of Nimba. In Bong, Gbarnga substation will be directly connected to Kakata, and also several communities will also be connected to the main grid from Gbarnga. In Nimba, Wozi Creek small hydro will be constructed and the villages near the main road that connects Voinjama to Gbarnga, will be electrified. Due to high grid coverage, in 2030 Region 2 will only have 3 PV/Diesel systems in isolated operation. Regarding, solar villages, in the end of Phase 3, 15 PV systems will be in operation, 5 per each county.

Overall impact. The total number of people electrified per type of supply alternative in Region 2 is presented in **Figure 13.16**. As already mentioned, the national grid is responsible for the majority of the electrification with more than 70% share of all connected people. Nonetheless, the decentralized grid of Lofa will electrify more than 140 000 people. Mini-Grid and Off-grid will be responsible for 3% of total electrified population share.

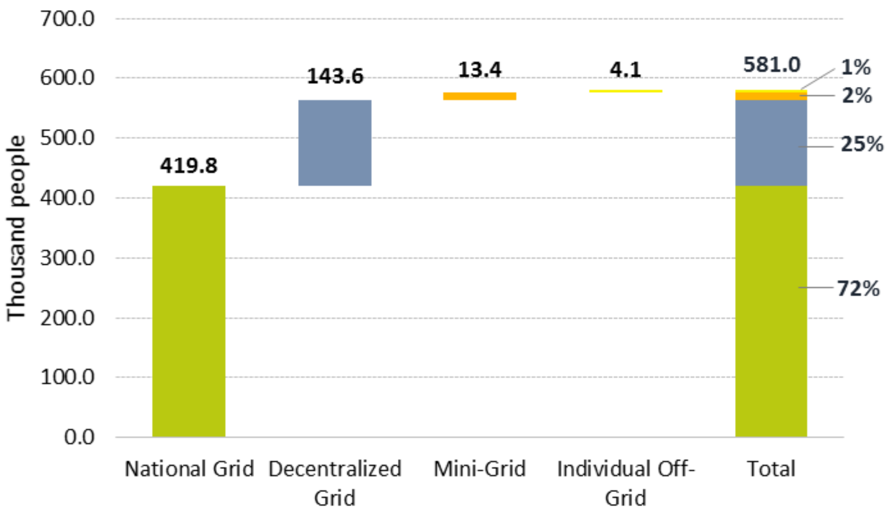


Figure 13.16 – Number of people per type of technology in 2030 – Region 2.

Figure 13.17 shows the percentage of people supplied by each one of the four technology alternatives, differentiated by county.

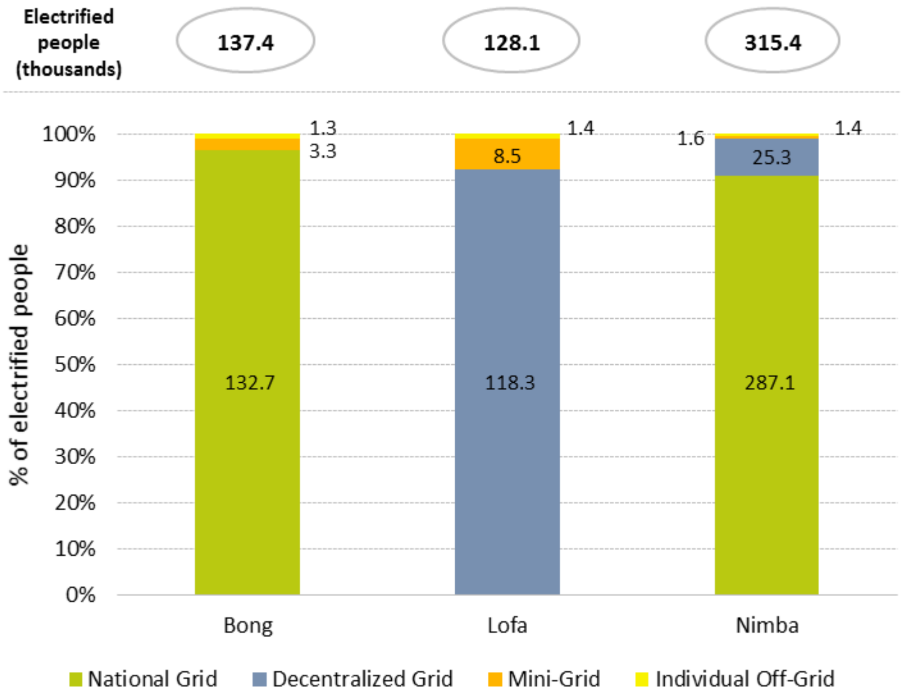


Figure 13.17 – Number of people per type technology in 2030 – Region 2.

Nimba will be by far the most electrified county of Region 2, greatly due to the proximity to Nimba's CLSG substation which allows for a stable operation right from the beginning of implementation, and to the fact that Nimba possesses a large concentration of medium and large towns that, because of the least cost methodology applied in this study, are electrified first. Lofa is the less electrified county, just behind Bong. In Lofa results is possible to see the prominence of the decentralized grid since it connects more than 90% of the county population.

Investment. Total investments needs per county in each phase is presented in **Table 13.3**. Detailed information regarding the investment needs per type of technology and per county is given in **ANNEX XVI**.

Table 13.3 – Distribution of Investments needs in each county of Region 2

County	Phase 1 (MUSD)	Phase 2 (MUSD)	Phase 3 (MUSD)	Total (MUSD)
Bong	20.74	31.12	23.96	75.83
Lofa	35.36	14.83	42.38	92.57
Nimba	10.86	31.29	60.01	102.16
Total	**66.97**	**77.25**	**126.35**	**270.56**

As it can be seen, the investments in Nimba are somewhat higher than those of Bong and Lofa. However, considering the number of electrified people, the per capita investment is much lower than in other counties[17], since in general, the communities of Nimba are more dense and because MV grid extension is cheaper. For example, in Lofa the construction of the two small hydro inflates the per capita investments, and in Bong the installation of HV power lines and substation also rises the investment needs. The highest cut of the investments will be used in Phase 3.

13.4 REGION 3: GRAND BASSA, MARGIBI, MONTSERRADO AND RIVERCESS COUNTIES

The impact in Region 3 for each implementation phase is illustrated in **Figure 13.18, Figure 13.19** and **Figure 13.20.**

[17] 323 USD/person in Nimba, 552 USD/ person in Bong and 723 USD/person in Lofa

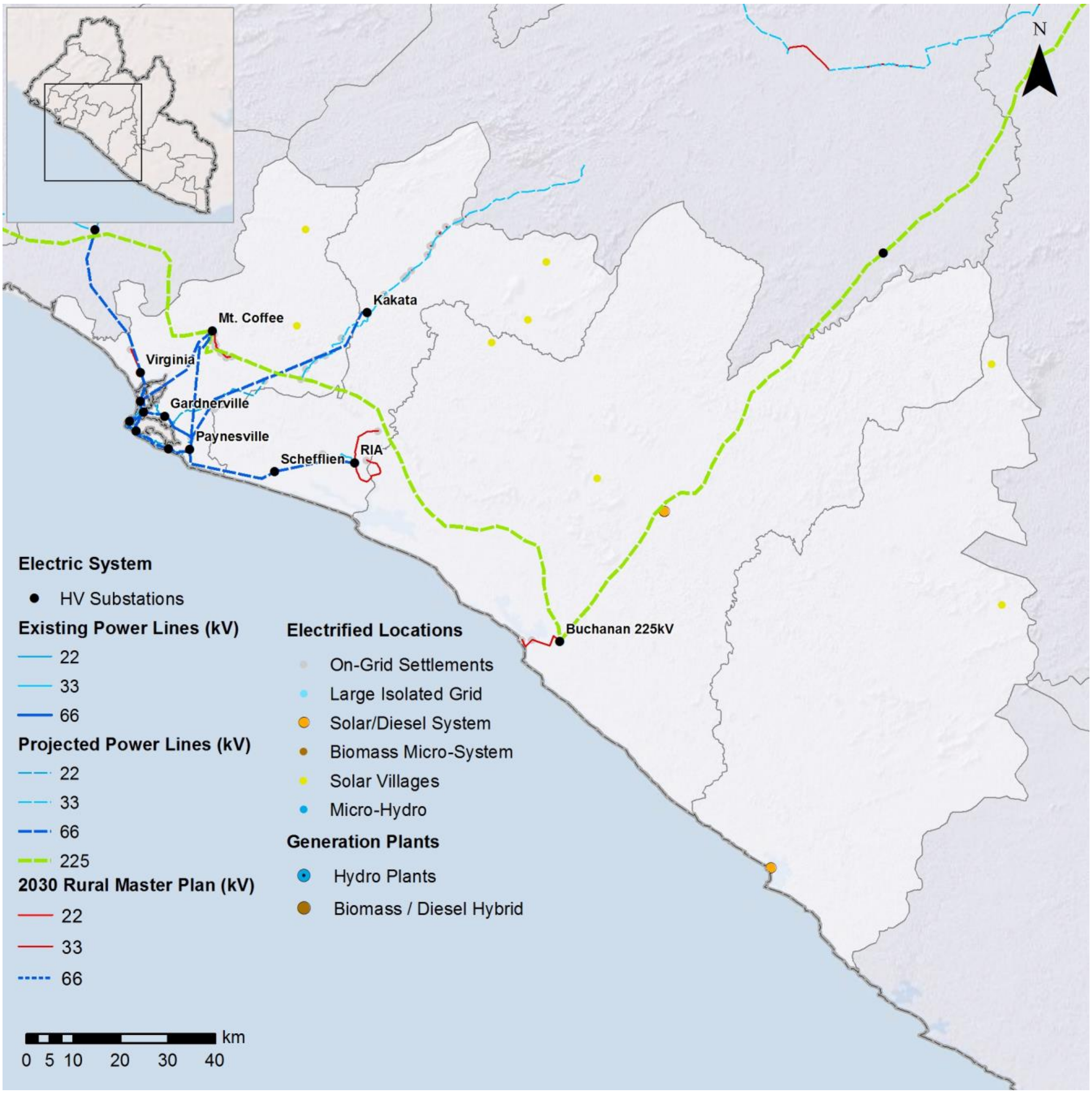


Figure 13.18 – Infrastructure map for Region 3 – Phase 1.

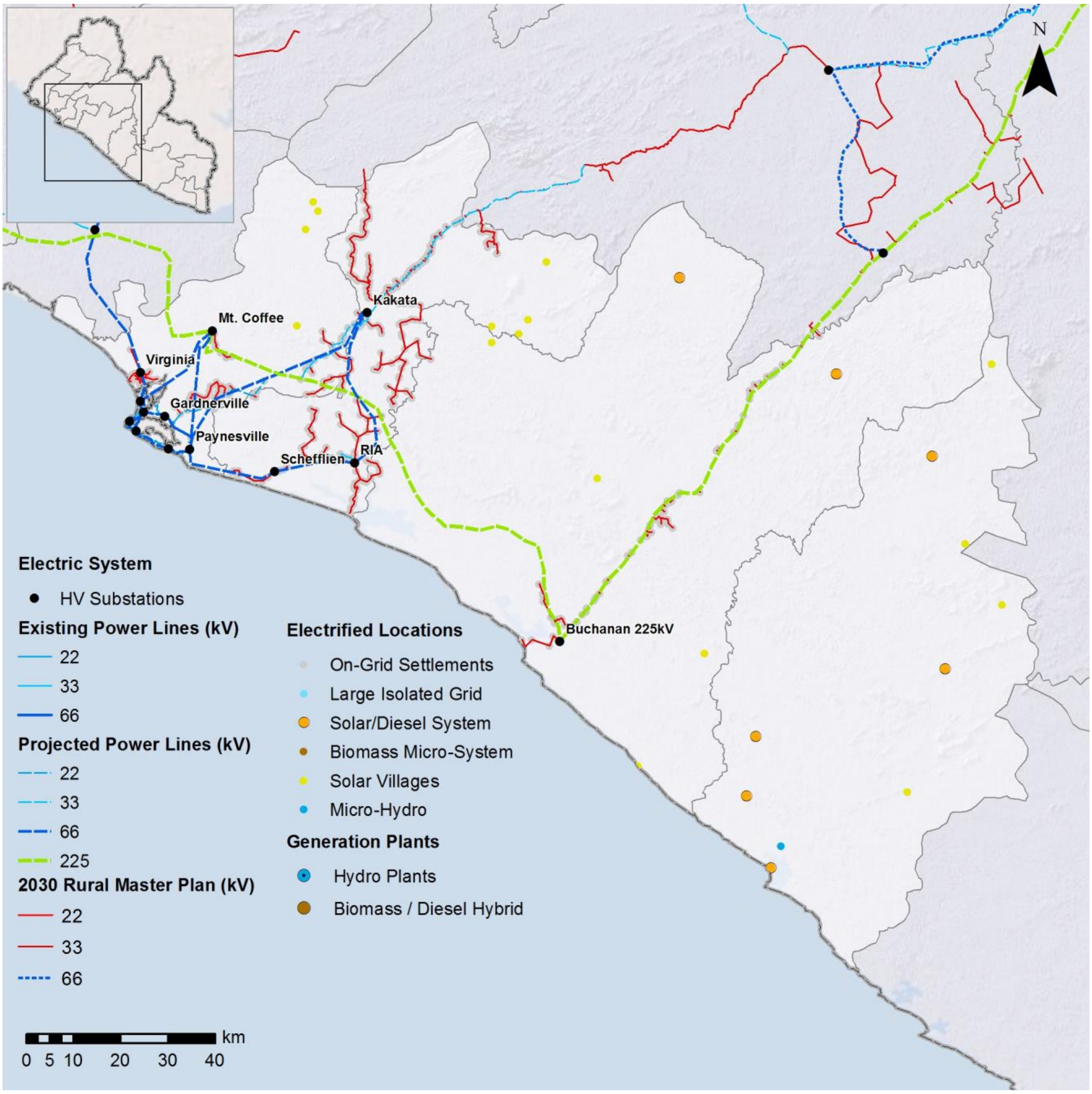


Figure 13.19 – Infrastructure map for Region 3 – Phase 2.

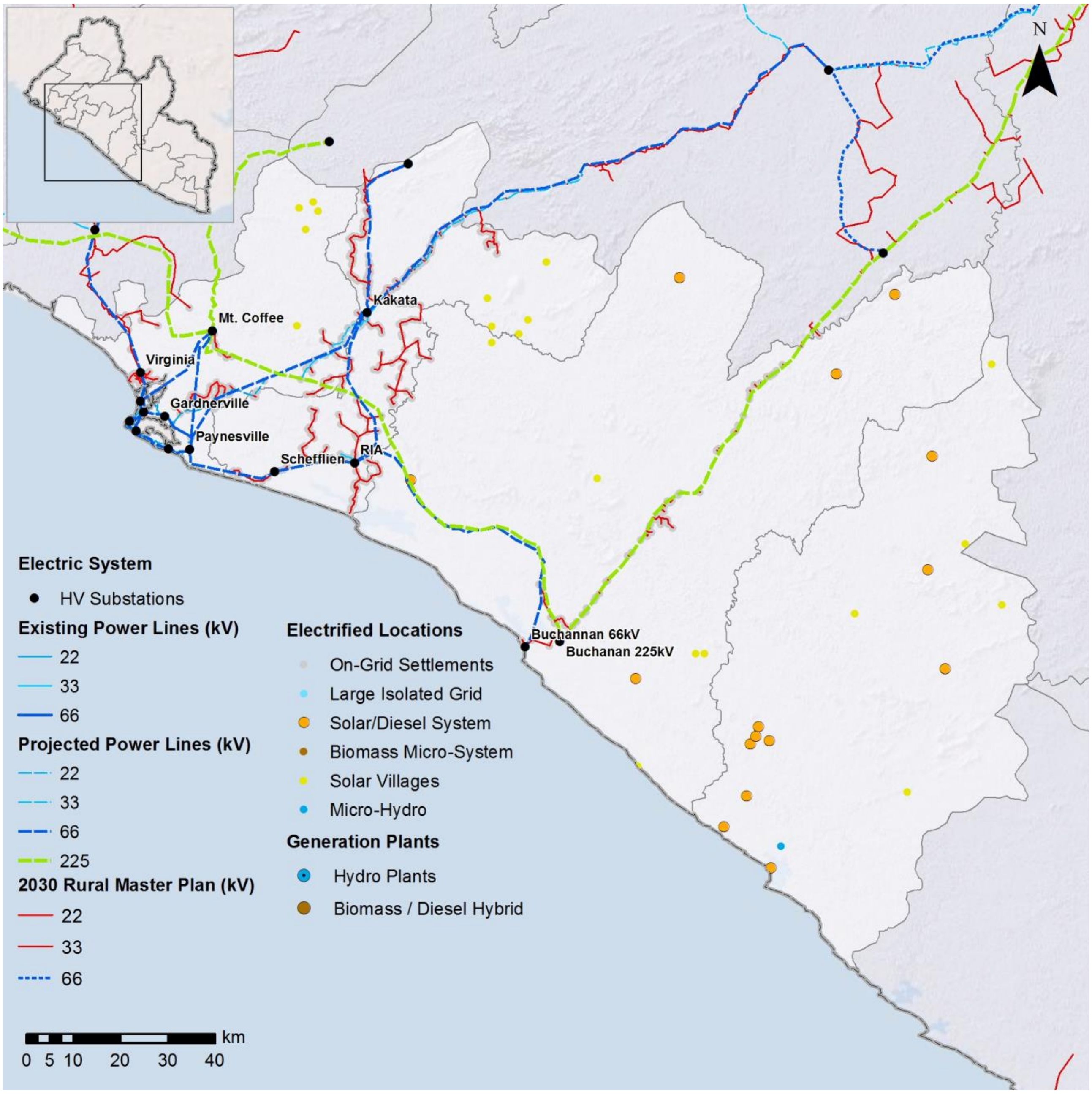
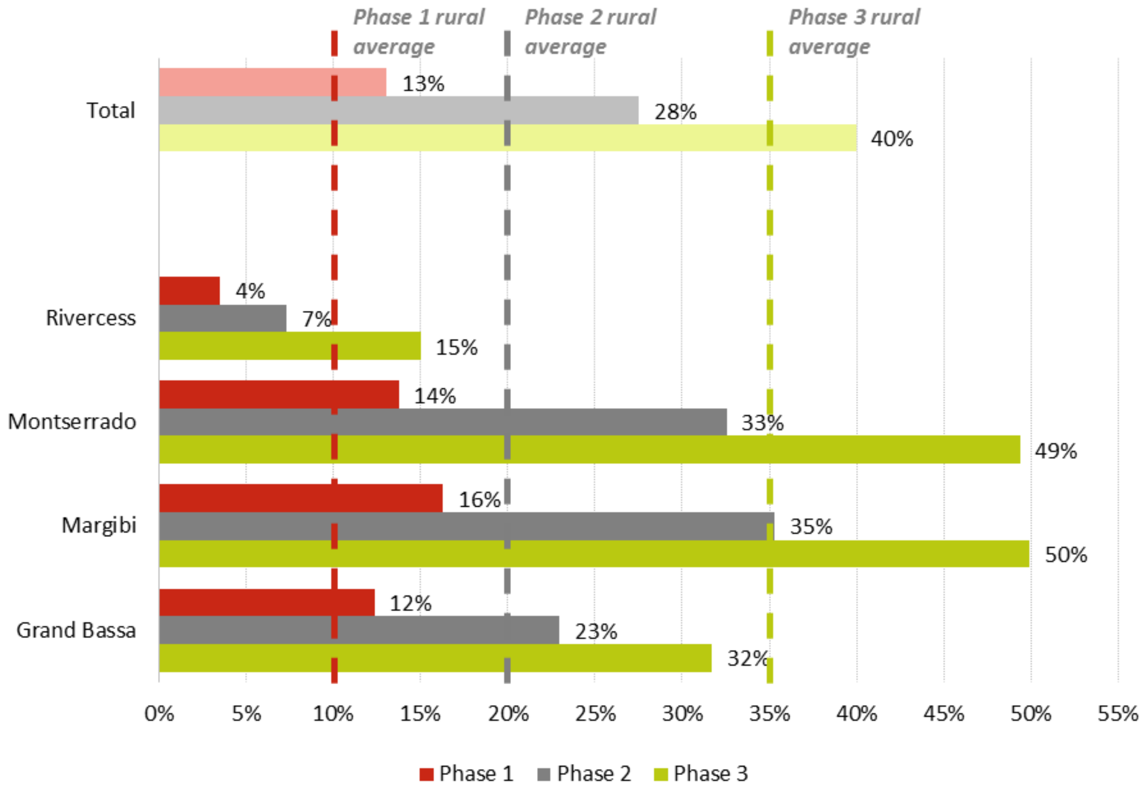


Figure 13.20 – Infrastructure map for Region 3 – Phase 3.

Aggregated electrification rates. The aggregated electrification rates of Region 3 are projected to be 13% in 2020, 28% in 2025 and 39% in 2030. After all implementation phases, a total of 81 500 households will be connected in this region corresponding to 408 000 electrified people, of which 117 300 in Grand Bassa, 168 800 in Margibi, 112 600 in Montserrado (excluding Monrovia) and 9 200 in Rivercess.

Electrification rates per county. The evolution of the electrification rates per county in Region 3 is



presented in

Figure 13.21.

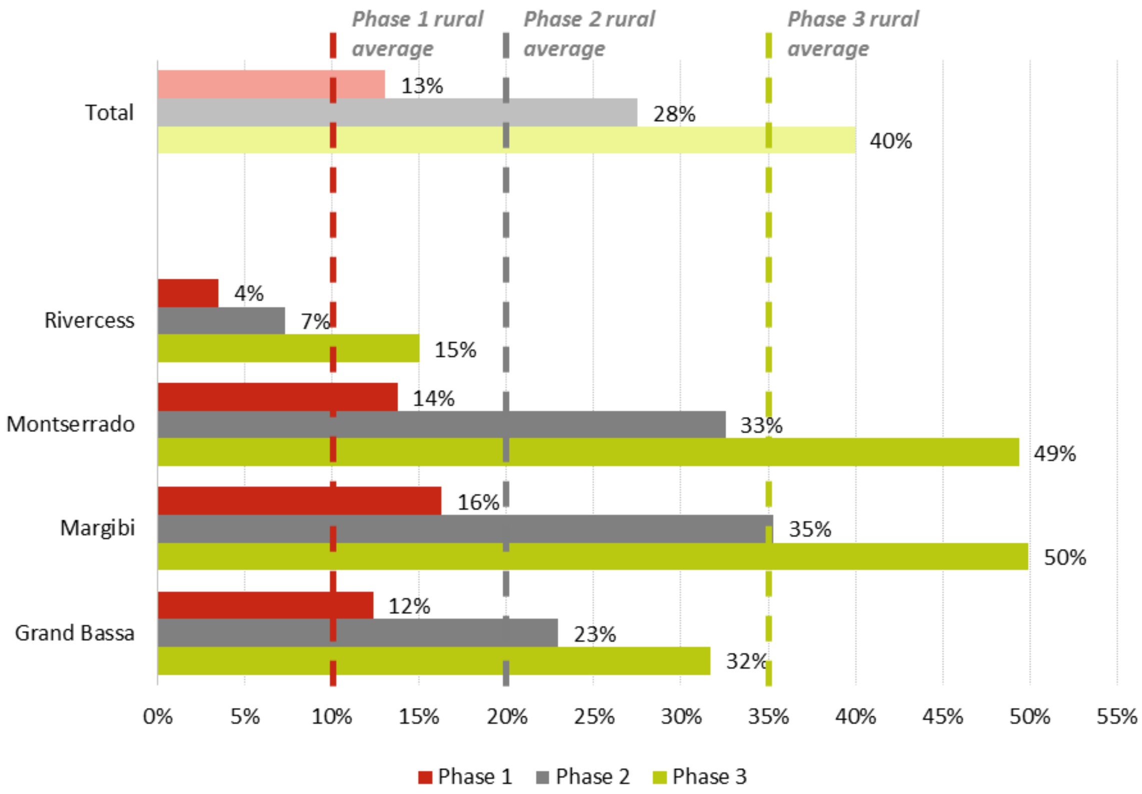


Figure 13.21 – Evolution of rural electrification rates in Region 3 per county.

Overall, in each phase, the electrification rates of Region 2 are well above national averages. To this, much contributes the electrified households in Montserrado and Margibi that, in 2030, have a rate 15% above the national average. Regarding Grand Bassa, in earlier stages, when Buchannan and the major towns are connected to the CLSG, this county as an electrification rate higher than 10% (in phase 1) and 20% (in phase 2). However in Phase 3, the percentage falls just below the 35% national target because the non-electrified larger towns of the county are located far from the grid. Notice that Grand Bassa is characterized by having a large number of very small communities. Rivercess has the lowest electrification rate of Region 3, with less than 15% of its population electrified in 2030. Rivercess is extremely far from any kind of grid (national or decentralized), and due to the low aggregated consumption of its communities, didn't managed to attract any viable small hydro plant so that a decentralized grid could be created. Thus, all electrification in this county will be based on mini-grid and off-grid operation. Although a reduced electrification rate, the ten largest towns, including Cestos City, will be electrified using PV/Diesel systems.

Phase 1. With the exception of Rivercess, the major part of the electrified population is connected to the national grid. In Phase 1, the first stage of the Monrovia Corridor extension will be executed benefiting Montserrado and Margibi counties. The main cities and towns of these counties will be connected and additionally a 33 kV power line from Kakata to Salala will be installed, connecting settlements in its way. In Grand Bassa the establishment of the 225 kV CLSG system will benefit mainly the city of Buchannan. In this phase two PV/Diesel systems will be installed, one in the Capital of Rivercess, Cestos City and another in Wayzohn Community, in Grand Bassa. Eight solar villages will be implemented during this period.

Phase 2. In Phase 2, the implemented substation and HV power lines in Phase 1 are reinforced and rural grid extension begins, mainly from Kakata and RIA substations. Grand Bassa will also benefit from the CLSG distribution based on the Shield Wire program. Six additional PV/Diesel systems will be installed, four in Rivercess and two in Grand Bassa, and in total 16 solar villages will be in operation. A micro-hydro villages will also be implemented in Rivercess.

Phase 3. In Phase 3, rural extension will expand further, however less than before. Eight more PV/Diesel systems will be installed during this period in order to electrify two towns in Bassa and six more towns in Rivercess. So, in 2030 there will be 14 solar transitional grids in Region 3, 4 in Bassa and 10 in Rivercess. At the end of this phase a total of 20 solar villages will be in operation, 5 per each county.

Overall impact. The total number of people electrified per type of supply alternative in Region 3 is presented in **Figure 13.22**. As already mentioned, the national grid is responsible for the great majority of the electrification connecting almost 400 000 people. In this region there are no large decentralized grid operation, and 4% of the population will be connected to mini-grid and off-grid systems.

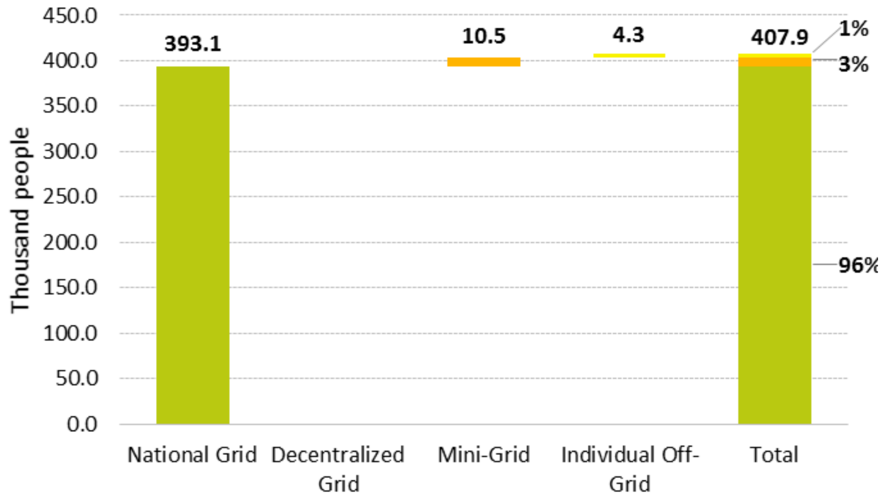


Figure 13.22 – Number of people per type technology in 2030 – Region 3.

Figure 13.23 shows the percentage of people supplied by each one of the four technology alternatives, differentiated by county.

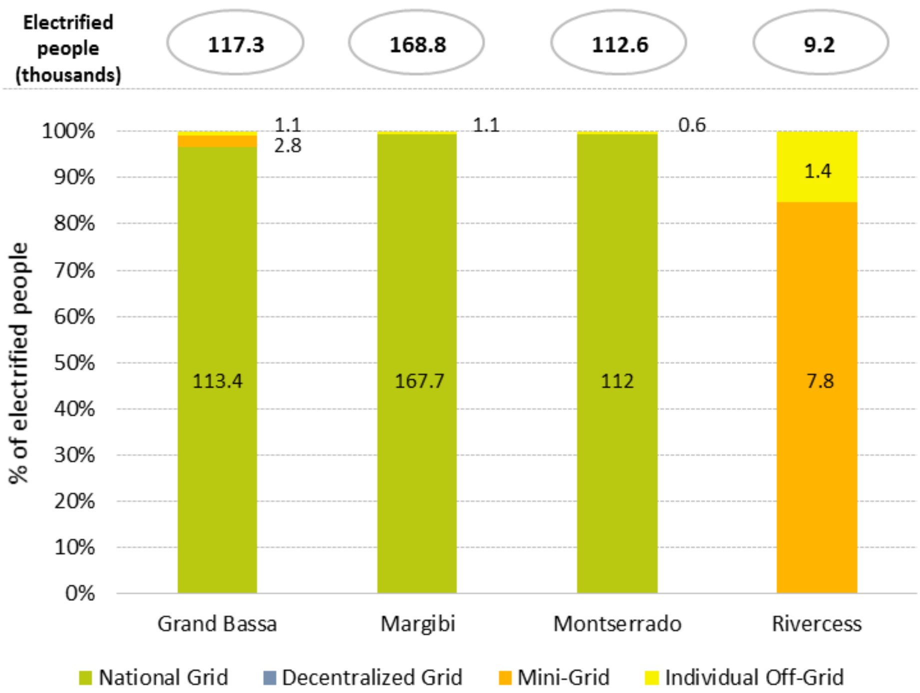


Figure 13.23 – Number of people per type technology in 2030 – Region 3.

Margibi will have the highest number of electrified people and as already seen, Rivercess will have the least with almost 10 000 people connected. Grand Bassa and Montserrado stand in the middle with around 115 000 people with electricity.

Investment. The total investments needs per county in each phase is presented in **Table 13.4**. More detailed information regarding the investment needs per type of technology and per county is given in **ANNEX XVI**.

Table 13.4 – Distribution of Investments needs in each county of Region 3

County	Phase 1 (MUSD)	Phase 2 (MUSD)	Phase 3 (MUSD)	Total (MUSD)
Montserrado	14.36	12.51	7.83	34.70
Grand Bassa	9.22	7.97	17.74	34.93
Rivercess	1.58	2.33	0.90	4.81
Margibi	19.64	24.98	19.50	64.12
Total	**44.80**	**47.78**	**45.97**	**138.55**

As can be seen, the investments in Margibi are almost the double than those in the other counties in result of the higher grid extension and HV system implementation. Rivercess investment need are very small when compared with the other counties, because electrification will not be as intensive. It is also possible to observe that the same throughout the three phases.

13.5 REGION 4: BOMI, CAPE MOUNT AND GBARPOLU COUNTIES

The impact in Region 3 for each implementation phase is illustrated **Figure 13.24, Figure 13.25** and **Figure 13.26**.

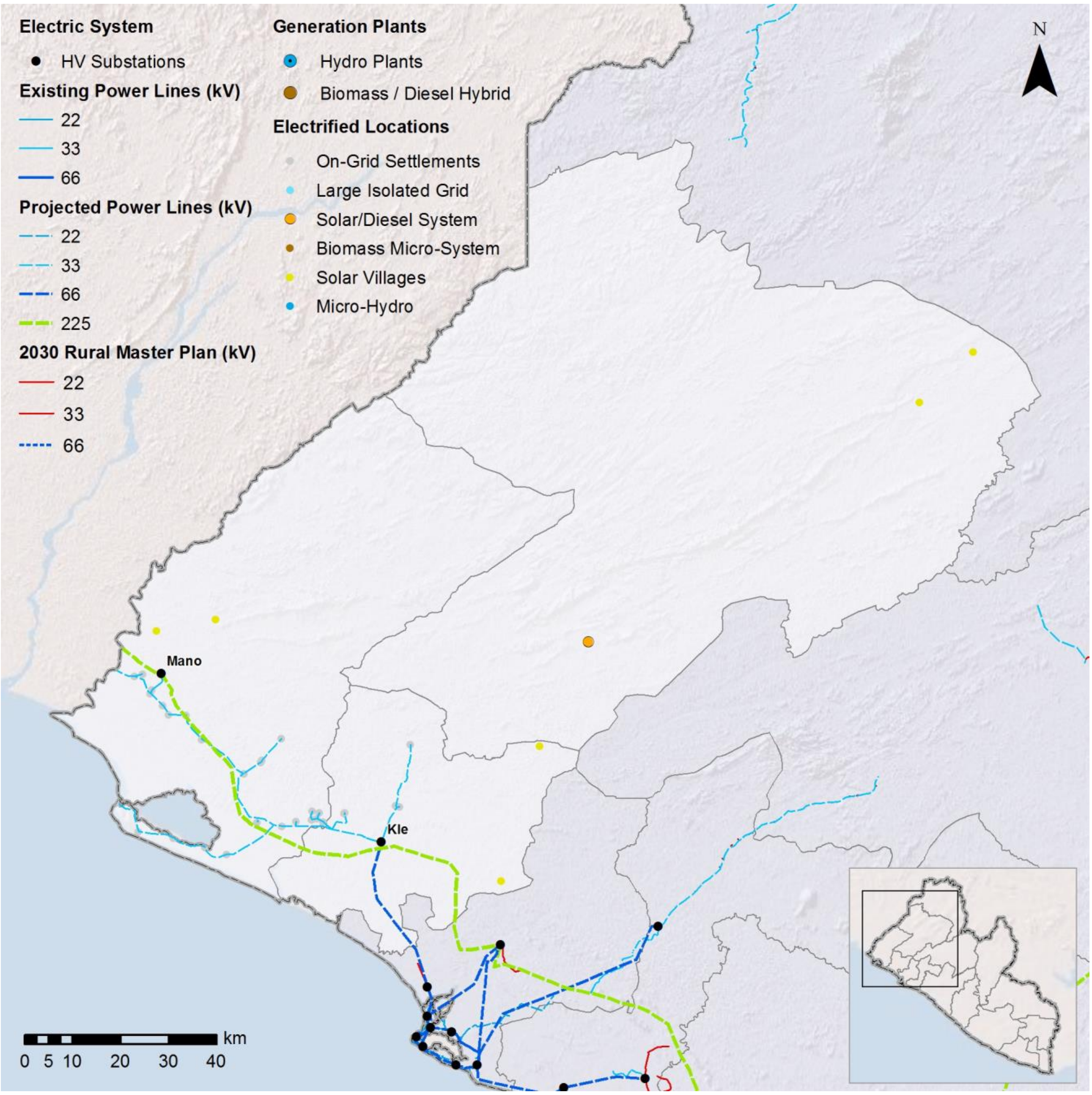


Figure 13.24 – Infrastructure map for Region 4 – Phase 1.

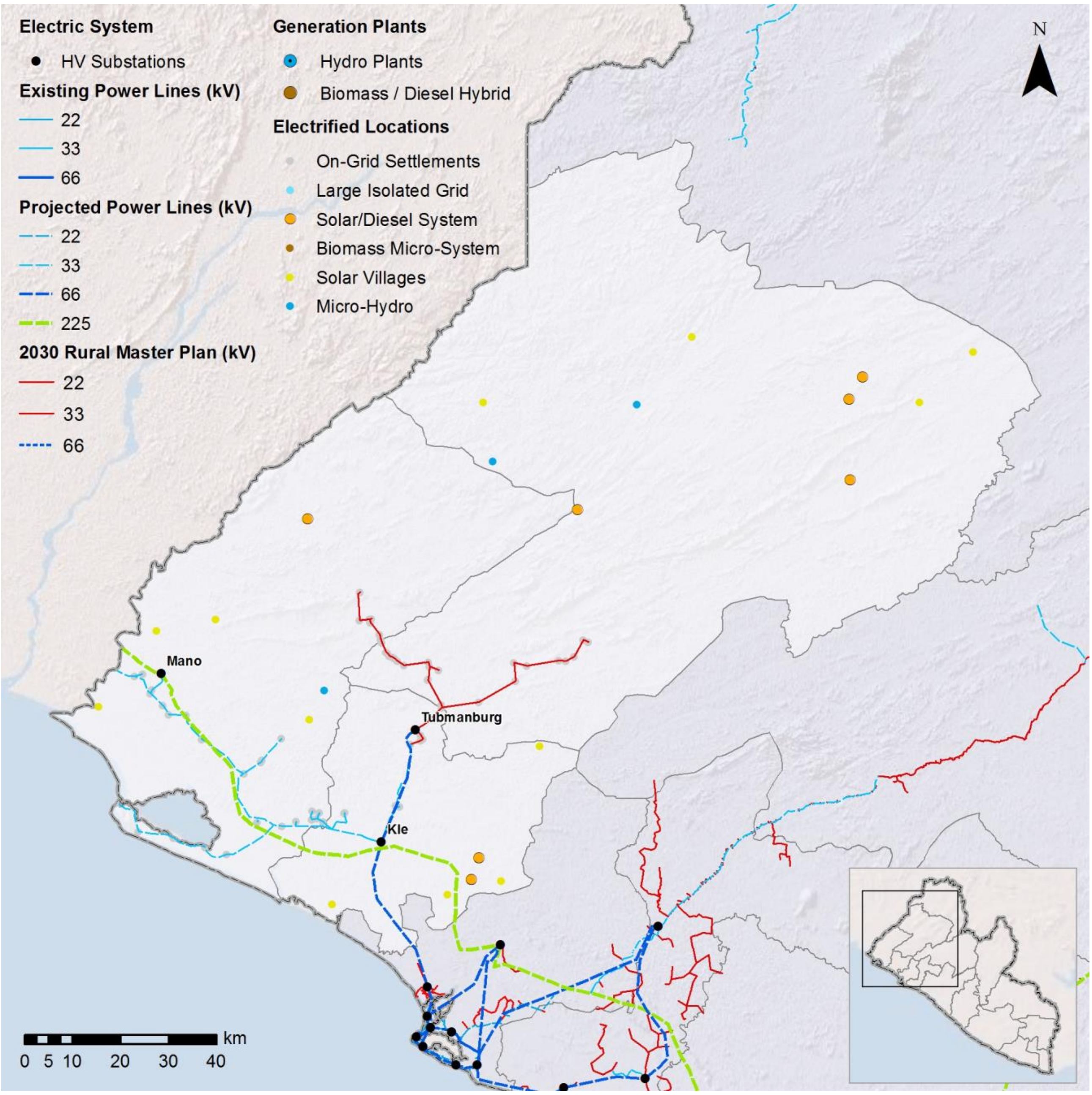


Figure 13.25 – Infrastructure map for Region 4 – Phase 2.

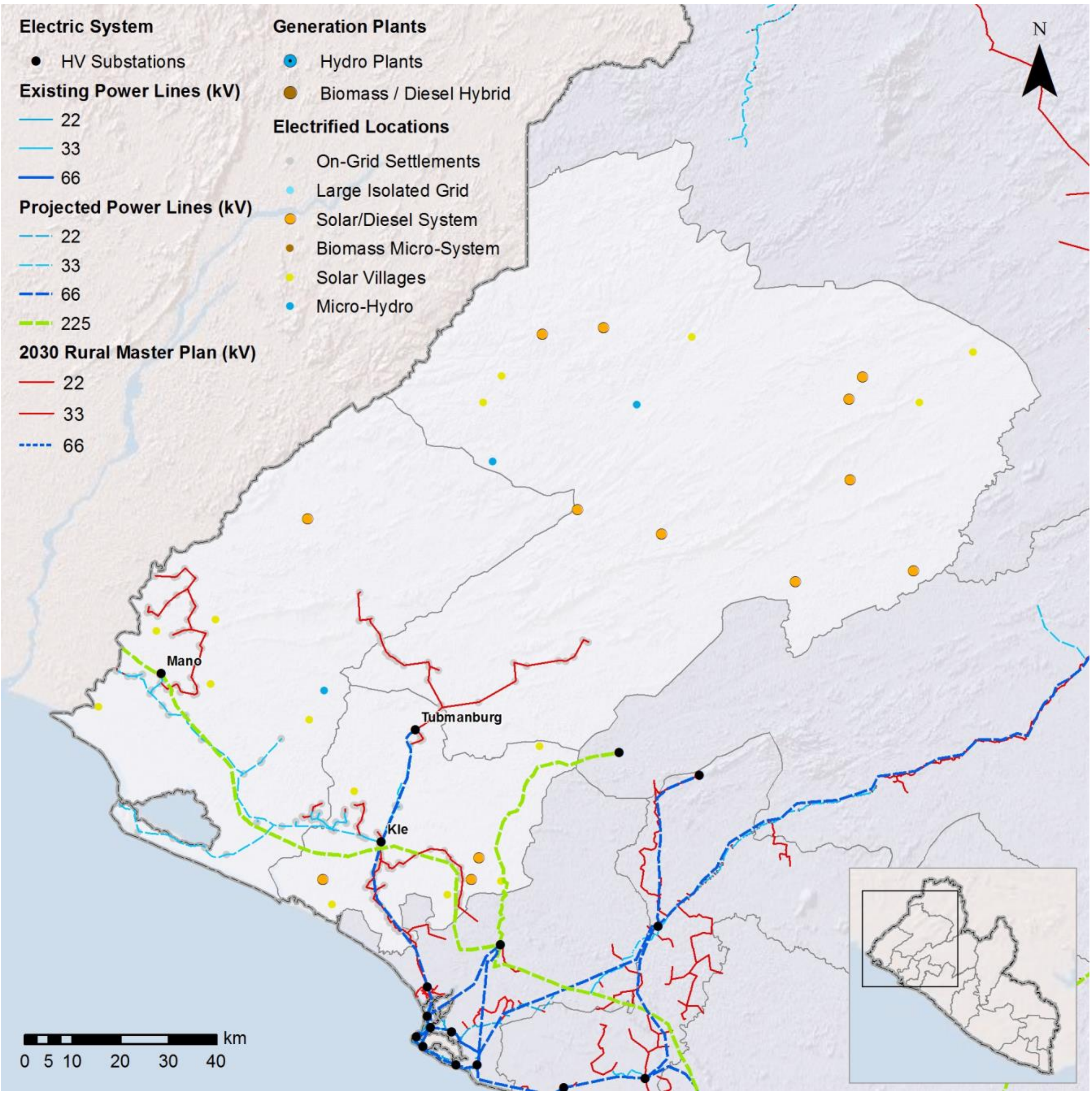


Figure 13.26 – Infrastructure map for Region 4 – Phase 3.

Aggregated electrification rate. The aggregated electrification rates of Region 4 are projected to be 4% in 2020, 11% in 2025 and 23% in 2030. After all implementation phases, a total of 18 300 households will be connected in this region corresponding to 95 000 electrified people, of which 37 400 in Bomi, 36 000 in Grand Cape Mount and 21 500 in Gbarpolu.

Electrification rates per county. The evolution of the electrification rates per county in Region 3 is presented in **Figure 13.27**.

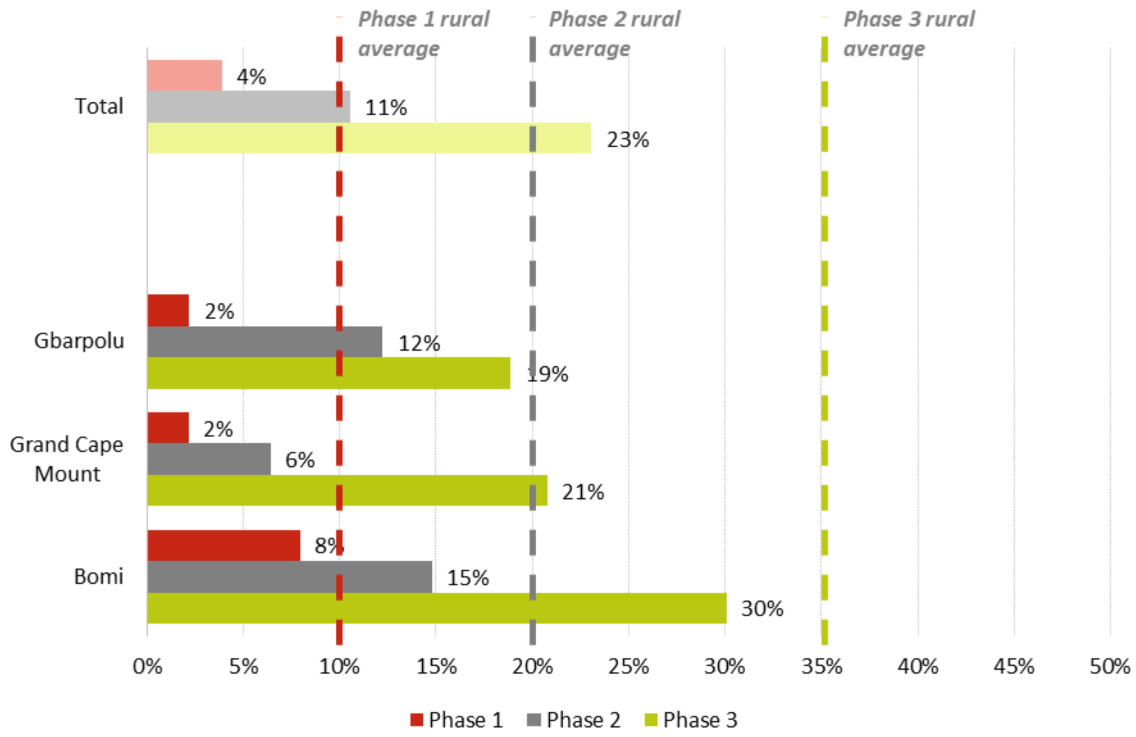


Figure 13.27 – Evolution of rural electrification rates in Region 4 per county.

As can be observed the global electrification rates in Region 4 are, in all implementation phases, below national average, which also happens in all of the comprising counties. Bomi presents itself with the higher electrification rates, with 30% of its population with electricity in 2030. On the other hand, as already discussed in **Chapter 13.1**, Gbarpolu has the lower connection rate because of the remoteness of most of its settlements from any type of electrical grid, national or decentralized. In earlier stages Grand Cape Mount has very small rate, however in Phase 3, electrification boosts reaching 21% of the population.

Most of the electrification in this region will be performed by connections to the national grid, much due to the Monrovia West Corridor extension. Several off-grid systems will also be implemented, most of them located in Gbarpolu.

Phase 1. In Phase 1, Kle substation will be constructed, and from there several MV branches will emerge: a MV connection to Tubmanburg and two MV lines, one to Robertsport and another to Bo Waterside, which will both connect to a switching station in Madina and afterwards to Kle. One solar transitional system will be installed in Gbarpolu to bring electricity to the capital of the county, Bopolu. 6 solar villages will be implemented in this phase, 2 per each county.

Phase 2. In Phase 2, a 66/33 kV substation will be installed in Tubmanburg, which will be connected to Kle. From this substation the MV grid extension to Bopolu and Gbarpolu will be possible. Regarding Mini-Grid systems, 7 PV/Diesel based grids will be installed, 1 in Grand Cape Mount, 2 in Bomi and 4 in Gbarpolu. Also in Gbarpolu, 2 micro-hydro villages will be implemented. In total 12 solar villages will be in operation in the end of Phase 2.

Phase 3. In Phase 3, MV rural grids will extend further, manly in Bomi and Grand Cape Mount. Six more PV/Diesel systems will be installed during this period in order to electrify one town in Bomi and five more towns in Gbarpolu. So, in 2030 there will be 13 PV/Diesel grids in Region 4, 1 in Cape Mount, 3 in Bomi and 9 in Gbarpolu. At the end of this phase a total of 15 solar villages will be in operation, 5 per each county.

Overall impact. The total number of people electrified per type of supply alternative in Region 4 is presented in **Figure 13.28**. The national grid is responsible for the great part of the electrification, connecting more than 80% of the electrified people. In this region there are no large decentralized grid operation, and around 18% of the population will be connected to mini-grid and off-grid systems.

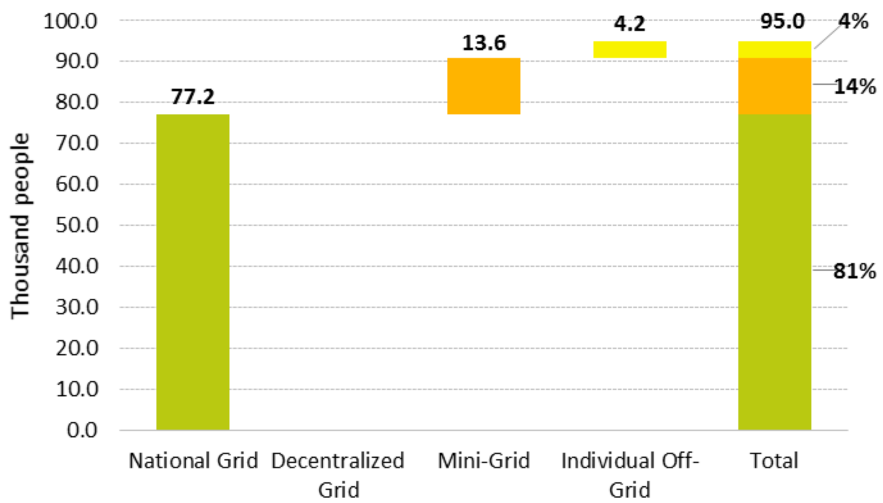


Figure 13.28 – Number of people per type technology in 2030 – Region 4.

Figure 13.29 shows the percentage of people supplied by each one of the four technology alternatives.

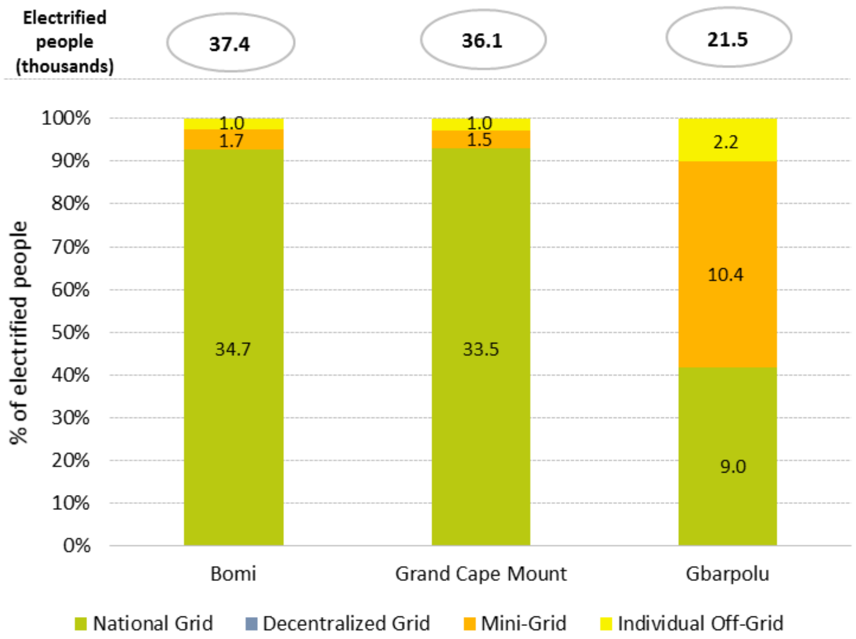


Figure 13.29 – Number of people per type technology in 2030 – Region 4.

Bomi and Grand Cape Mount have almost the same number of connected population. Gbarpolu will have 21 500 habitants with electricity, of which 10 400 will be connected to mini-grid of PV/Diesel or hydro source. In this county 9 000 people will be connected to the main grid.

Investment. The total investments needs per county in each phase is presented in **Table 13.5**. More detailed information regarding the investment needs per type of technology and per county is given in **ANNEX XVI**.

Table 13.5 – Distribution of Investments needs in each county of Region 4

County	Phase 1 (MUSD)	Phase 2 (MUSD)	Phase 3 (MUSD)	Total (MUSD)
Bomi	7.57	9.07	6.96	23.60
Grand Cape Mount	5.55	3.32	7.68	16.56
Gbarpolu	1.63	7.82	2.31	11.76
Total	**14.75**	**20.22**	**16.95**	**51.92**

As can be seen, the investments in Bomi are the highest in result of higher electrification but also due to the HV system implementation. In Gbarpolu, the investment need are the lowest. Phase 2 is predicted to be the one with the highest needs.

PART F. IMPLEMENTATION FRAMEWORK

14 INSTITUTIONAL AND REGULATORY FRAMEWORK

14.1 INTRODUCTION

Need for an adequate institutional framework. An effective and successful implementation of the Rural Energy Master Plan requires not only adequate funding, but also competent and well aligned institutions with clear roles for implementation, both on the public and private sectors.

The next sections address these issues.

14.2 POWER SECTOR STRUCTURE, PUBLIC SECTOR ENTITIES AND ESTABLISHED ROLES

2015 Electricity law of Liberia. The Senate and House of Representatives of the Republic of Liberia approved in October 2015 a bill entitled 2015 Electricity Law of Liberia. The new electricity law sets the guiding principles for the power sector organization and gives some guidance on the roles of the different entities without too much detail. The Law offers sufficient flexibility for different institutional approaches regarding rural energy. The Master Plan study evaluated different alternatives, all with pros and cons, and proposes the one with the potential to be more effective.

Power sector structure. Although now-a-days all power sector activities are provided by Liberia Electricity Corporation, the new Electricity Law structures the power sector in the following different activities which all – except system operation - can now be licensed to the private sector:

- Generation;
- Transmission;
- Transmission system operation;
- Distribution;
- Import and export of electricity;
- Trading of electricity.

Micro-utilities. Micro utilities or operations, such as “Community Current” – common business in Liberia where an entrepreneur operates and distributes power from a small diesel generator – can be exempted from licensing.

LEC. LEC is the State owned Utility which by law continues to be the transmission system operator and the national grid company and is entitled to engage in all other activities at its election. As transmission system operator LEC has to guarantee an instantaneous balance at any given time between the total generation and the total consumption of power taking account of the power exchanges with interconnected foreign systems. The role and scope of the “National Grid Company” is not clearly defined in the Law.

Ministry of Lands, Mines and Energy. Ministry is responsible for the formulation and development of national energy policies and the administration of the Law.

Liberia Electricity Regulatory Commission. LERC is the newly created regulatory agency in charge of licensing activities, issuing regulations to implement the electricity law, approving tariff setting methodologies and to establish, monitor and enforce technical, performance and security regulations and standards.

Rural and Renewable Energy Agency. RREA is an autonomous agency owned by the Government of Liberia with the objective of acting for and on behalf of the Government to promote energy access in rural areas with an emphasis on locally available renewable resources.

14.3 LEARNINGS FROM OTHER COUNTRIES RURAL ENERGY PROGRAMS

Most Sub-Saharan Africa countries (16 out the 20 most populated countries) have created funds or agencies with budgets specifically for the development of their rural electrification (**Table 14.1**).

Table 14.1 - Sub-Saharan Africa countries rural electrification agencies/funds

Country	Rural Electrification Agency/Fund
Nigeria	Nigeria Rural Electrification Agency
Ethiopia	Ethiopia Rural Energy Development and Promotion Center (EREDPC) and REF (Rural Electrification
RD Congo	FDSEL – Fonds de Développment du Secteur de l'Electricité
South Africa	INEP (Integrated National Electrification Program) - DoE and NEF (National Electrification Fund)
Tanzania	REA - Rural Energy Agency - since 1997 and REF (Rural Energy Fund)
Kenya	REA - Rural Electrification Authority since 2006
Uganda	REA - Rural Electrification Agency and Rural Electrification Fund
Sudan	**N/A**
Ghana	National Electrification Fund since 1989 (managed by the Ministry of Energy)
Mozambique	FUNAE - Fundo de Energia de Moçambique
Côte d'Ivoire	**N/A**
Madagascar	ADER - Agence pour le développement de l'électrification rurale and FNE - Fonds National d'Electricité
Cameroon	AER - Rural Electrification Agency of Cameroon
Angola	**N/A (FUNEL was never implemented)**
Niger	**N/A**
Burkina Faso	FDE - Fonds de Développement de l'Electrification
Malawi	Malawi Rural Electrification Fund
Senegal	ASER – Agence Sénégalaise d'Electrification Rurale (since 1998)
Mali	AMADER (Agence Malienne pour le Développement de l'Energie Domestique et de l'Electrification
Zambia	REA - Rural Electrification Authority

These structures were created with the following main goals:

1. Maximization and automation of rural energy funds

Fund creation has, generally, the objective of maximizing and automating funds for rural electrification through government budget, taxes and international financing.

For example, in 1989, Ghana created its national program of electrification, which included the creation of a “National Electrification Fund”, that gathered up to 2013 more than USD 1.5Bi in investments, with more than half originated from external bilateral or multilateral and exporting agencies funding. This fund was initially created with a national electrification levy, a tax in the electricity price. This way, Ghana’s electrification went from 25% in 1989 to more than 70% in 2013.

Another example is FUNAE, in Mozambique, for which funding is channeled from different sources, namely concession rents in Cahora Bassa and a fuel tax to finance rural supply stations.

2. Management/Decision of the rural electrification subsidies allocation

Most funds have dedicated structures, usually under political direction, having the responsibility of managing and allocation the fund’s finances. In almost all of the countries named above, due to its political sensibility, the management of those funds in ensured by the respective Ministry of Energy. That may occur through a department (as in South Africa or Ghana), through an agency or autonomous institute (as in Mozambique or Uganda) or even under the jurisdiction of several ministries (as in Madagascar or Uganda).

In none of the countries mentioned above exists any intervention of the sectorial regulatory entities in the management of the rural electrification. The sectorial regulatory entities are in charge of defining tariffs and regulating the sector independently from the government. The decision of the locations to be electrified is a political process with a strong necessity of coordination with local authorities.

For example, in South Africa, the annual budget of USD 200M of the National Electrification Fund, which is allocated between Eskrom and more than 400 counties, and that ensures electricity distribution, is under the responsibility of the INEP. INEP was created in 1994, having the electrification rates raised from 30% to 75% in approximately 20 years.

3. Rural electrification decentralization and private sector involvement

Although some countries have chosen more centralized models, based on a single utility (as Côte d’Ivoire), in many cases the creation of rural electrification agencies is motivated by the need of avoiding excessive concentration of the national distribution utilities in large urban areas, and by the necessity or interest in involving private initiatives.

Two examples of interest are Senegal and Mali, which have both chosen the creation and contest of public concessions for rural distribution.

In Senegal, the country was divided in 17 concessions for rural distribution, with different tariffs for each concession. In 6 of those, concessionaries have guaranteed 45% of the investment (the minimum requested was only 20%).

In Mali, even though the contest for the 10 concessions did not have such positive results, a simplified program for spontaneous projects up to 1 000 clients (PCASER) was created, which was successful in attracting private initiatives.

4. Other objectives/roles

In some cases, rural electrification agencies, along with banks, have created credit lines for the acquisition of renewable equipment. For example, Uganda's rural electrification agency has created PVTMA, a program that has already enabled the acquisition of more than 2 000 solar home systems. Only companies properly qualified may install and commercialize these systems. In Mali, the PCASER program has been supported by the banks, granting credit lines with special conditions.

In Liberia, RREA has launched a program for solar lantern procurement, storing and distributing to selected retailers. Financial and transport costs are covered by RREA.

In other cases, rural electrification agencies have the responsibility of turning small-scale renewable energy projects more dynamic, such has small hydro or solar PV systems, as well as the national incorporation of these projects. For example, in Mozambique, FUNAE owns and uses a 400 kW solar PV central and operates a PV manufacturing installation.

Finally, several agencies have procurement processes, supporting and supervising the implementation of projects, along with financing entities.

14.4 ALTERNATIVE MODELS AND PROPOSED POWER SECTOR ORGANIZATION

Alternative models for Distribution. Distribution is by Law a licensed activity that can be executed by different companies. Different models for the long term functioning of the Distribution activity were considered (**Figure 14.1**):

- **LEC as the National Grid Distribution Company**, with transitional grids being managed by Local Companies transitorily until they are connected to the National Grid and transferred to LEC.
- **Regional Distribution Companies.** Country being divided into 5 regions with each region awarded to a different regional distribution company. Regional Distribution Companies may operate on decentralized grids or on the National Grid.
- **Local Distribution Companies or Cooperatives**. Transitional grids managed by multiple small Local Companies that would remain as independent Distribution Companies even after connected to the National Grid.

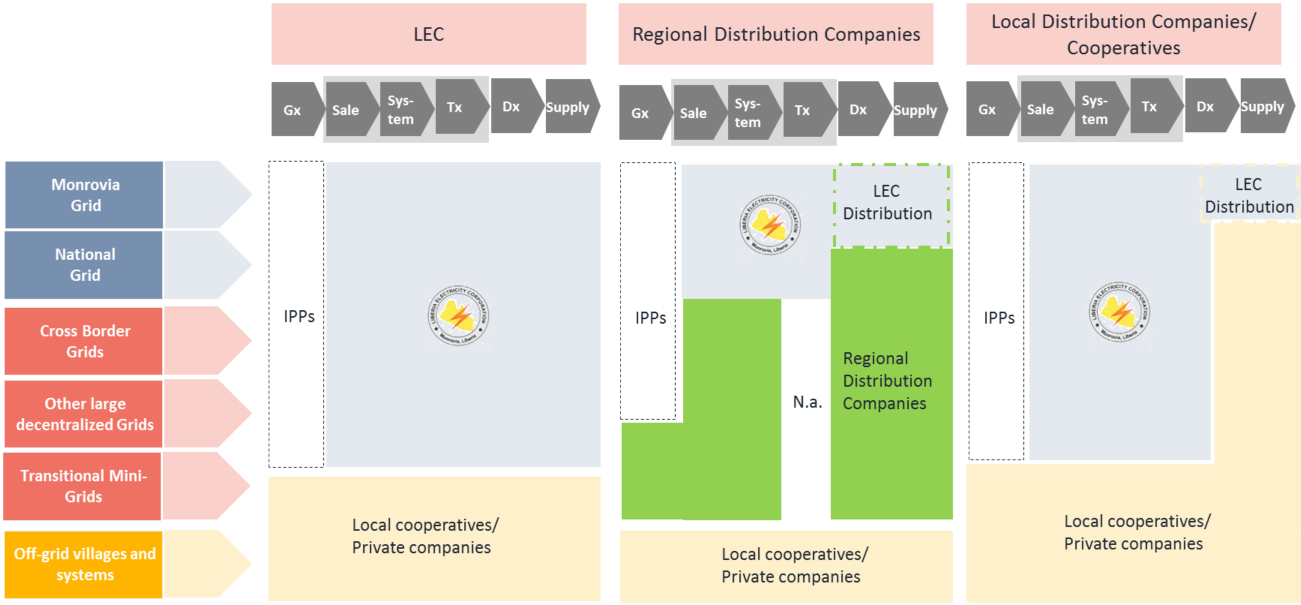


Figure 14.1 – Distribution models activity allocation (illustrative)

Regional Distribution Companies. The Regional Distribution Companies model was selected as it allows for a stronger private sector involvement in the future with a scale that can attract robust private sector companies. LEC model would maintain the more centralized public sector status quo, previous to the new legislation, with a high risk of continued lack of focus on the rural areas and difficulty to implement such a large investment program. The Cooperative model would represent a risk of too many under-capitalized and under-staffed distribution companies without scale or capacity to adequately respond to the challenge of implementing the Master Plan.

Model for Transmission and System Operation: "The National Grid Company or Unit". The Rural Energy Master Plan does not propose any High Voltage Transmission (>60 kV) investment outside the National Grid. The Electricity Law mandates LEC as the "National Grid Company" and transmission system operator. Therefore, all Transmission in the National Grid – except for CLSG which is owned and operated by TRANSCO CLSG - should be operated by LEC. The Medium Voltage infra-structure will be operated by Regional Distribution Companies and LEC will transfer electricity to Distribution Companies in the future Sub-stations that transform energy from High Voltage to Medium Voltage. Conflict of interest coming from LEC being also a Distribution operator recommends that the Transmission and System Operation be set up as an autonomous unit or even company inside LEC – the National Grid Company or Unit.

Alternative models for wholesale activities of trading and import/export. Electricity trading and import/export of electricity are licensed activities under the new Law and normal activities in developed power markets where generation unit dispatch is decided primarily by the market – meaning arrangements between generators and suppliers or clients. However, the Electricity Law awards the responsibility to dispatch generation units connected to transmission to the Transmission System Operator. Several alternative models are possible:

- **Unique Buyer**. Each Grid has a unique Buyer, responsible to procure, dispatch generation in its grid, and guarantee all imports and exports and to sell to Distribution at a regulated price. Model can be applied only to National Grid or also to Decentralized Grids.
- **Regulated or Last Resource Buyer**. A regulated entity is in charge of off-taking renewable Independent Power Producers, and highly subsidized sources of generation in the Grid and resell them to Distribution Companies at a regulated price. However, Distribution Companies are allowed, under certain limits established by LERC, to procure part of their power either in Liberia or West African Power Pool.
- **Multiple Buyers or free market**. Each Distribution Company is free to procure its electricity in Liberia or in the West African Power Pool. Each generation unit is free to sell its electricity. Transmission System Operator manages dispatch after receiving information on bilateral agreements.

Regulated Buyer model. The Regulated Buyer model was selected as it offers security for Renewable Independent Power Producers favoring investment, it allows to share the benefits of grants on generation among Distribution Companies and large industrial clients and it mitigates price differences across the country while offering opportunities to progressively start a more competitive market approach. The Unique Buyer model limits private participation dynamics and the Free Market model brings in the current stage of the Liberian Power Sector too much risk to investors in Generation and Distribution.

The National Grid Company or Unit will be the Regulated Buyer in the National Grid. In each Decentralized Grids – until it is connected to the National Grid - a Regional Distribution Company will be awarded the role of Regulated Buyer.

Model for Generation. Each and all generation units will act under the Independent Power Producer model with a Power Purchase Agreement to be celebrated, after approval of LERC, with either a Regulated Buyer, a large industrial client or the trading unit of a Regional Distribution Company. Agreements with Regulated Buyers – except for own generation - require transparent and competitive procurement processes.

Proposed Power Sector organization. The following **Figure 14.2** summarizes the selected models and proposed power sector organization outlining the responsible entities for each Power Sector activity along the value chain according to the type of grid. The proposed system will not apply to off-grid villages and systems where rural cooperatives will be incentivized to promote higher involvement of local communities, more local job creation and to facilitate more fractioned payments.

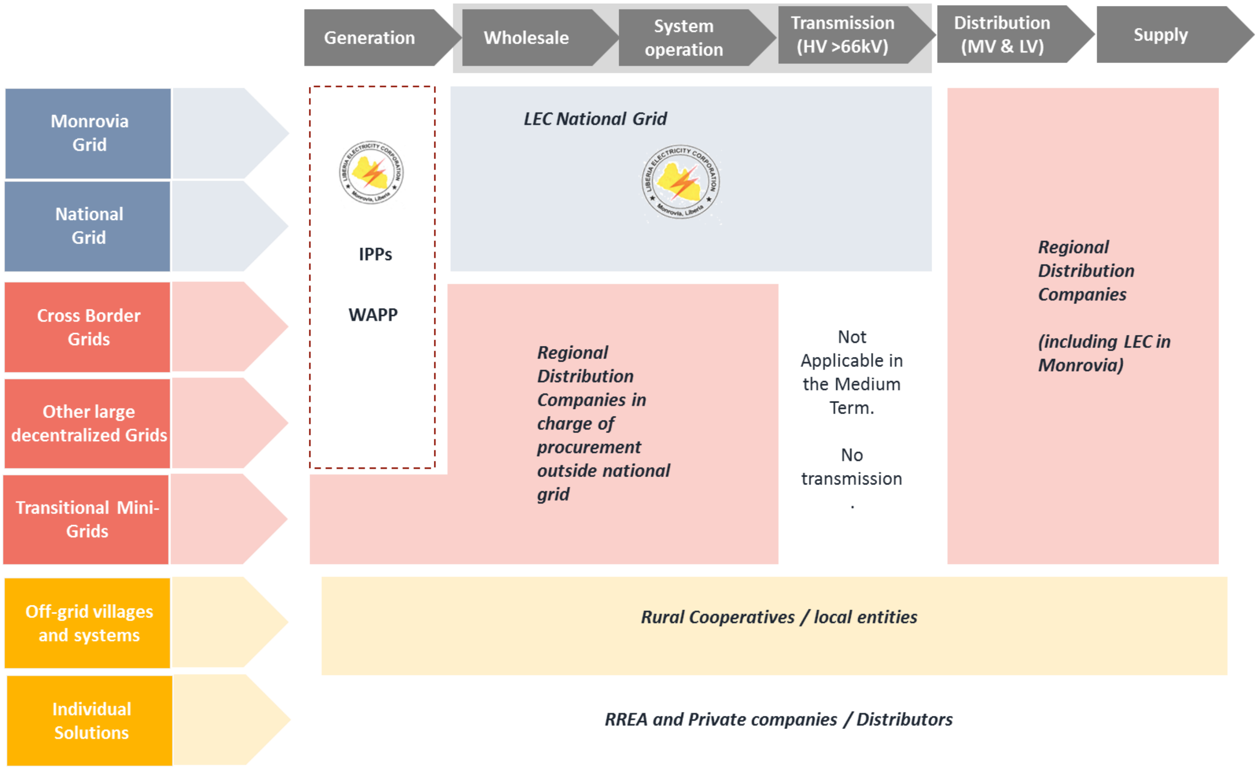


Figure 14.2 – Proposed Power Sector organization

15 PRIVATE SECTOR PARTICIPATION

15.1 PRIVATE SECTOR PARTICIPATION IN THE ENERGY SECTOR

15.1.1 WORLDWIDE

Context. The electricity sector is one of the sectors that attracts the largest quantities of private investment at a global scale, along with the telecommunication, transport and water and sanitation sectors. The approach in this chapter does not include data from developed countries, concerning only medium-high income or lower countries, according to the World Bank classification.

Total investment. According to the World Bank, in 2013, the private sector has invested in more than 200 projects associated to the electricity sector, worldwide, totaling an investment of USD 56.4Bi, of which USD 47.9Bi destined to the development and implementation of new projects. The average investment was about USD 275M per project. Although these numbers are high, the total investment has decreased approximately 25% comparing to 2012.

Regional Distribution. Regarding the regional distribution, the region with most private investment was Latin America, having received roughly 41% of the total private investment. Sub-Saharan Africa has received a total of USD 4.5Bi (8% of the world's total private investment), 19% less than in the previous year (see **Table 15.1**). Apart from South Africa, which received USD 3.1Bi of the total (69%), Nigeria, Kenya and Ghana had one project each that reached financial closure in 2013.

Table 15.1 - Private investment in the electricity sector per region (2013)[18]

Region	Investment (MUSD)	Investment (%)
Latin America and Caribbean	23 400	41%
Europe and Central Asia	15 000	27%
East Asia and Pacific	8 800	16%
Sub-Saharan Africa	4 500	8%
South Asia	3 300	6%
Middle East and North Africa	1 400	2%
Total	56 400	100%

It is important to state that more than 75% of the private investment on the electricity sector in South Africa was in renewable energy. This reflects the credibility attributed by the investors to the renewable energy incentive program (Renewable Energy Independent Power Procurement Program), developed by the South African government.

[18] Source: World Bank database. PPI projects. http://ppi.worldbank.org/.

Distribution in the value chain. Among the three main segments of the electricity sector value chain, generation is the one that attracts more private investment. Indeed, in 2013, 80% of the private investment in the electricity sector was destined to the generation segment, as seen in **Figure 15.1**.

The volume of investments had a wide range, with some investments below USD 10M and others above USD 2.2Bi. The average investment per project was approximately USD 220M.

Distribution received 15% of the total investment in the sector, 14% more than in 2012. Turkey dominated the received investments in this particular segment, having had 8 projects, totaling more than USD 7Bi. Apart from Turkey, only India received investment in this segment, in 2013.

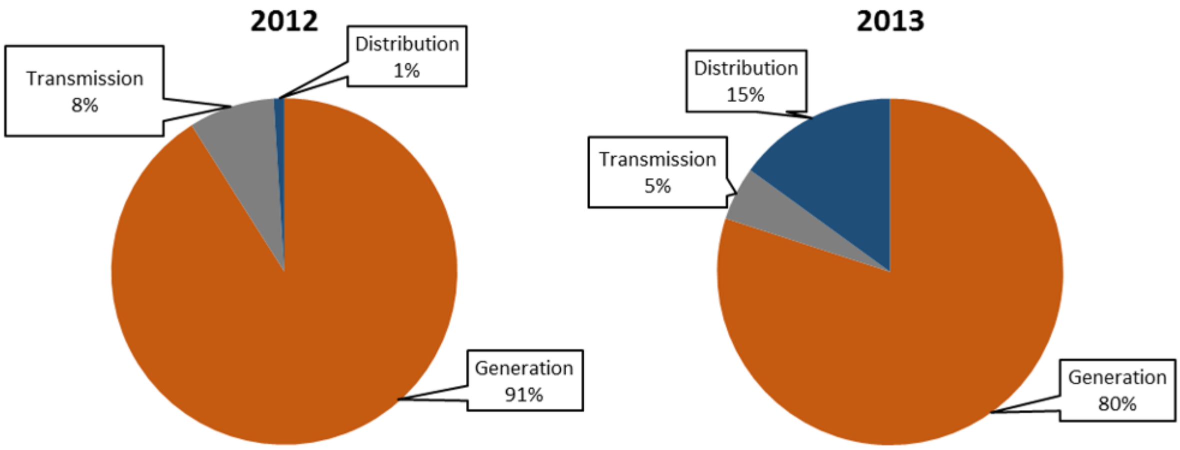


Figure 15.1 - Investment in the electricity sector per segment[19]

Most common contractual models. Public-Private Partnerships (PPPs) are most common model of private sector participation in the electricity sector. In 2013, more than 90% of the electricity sector projects with private investment were developed with different types of PPPs, as seen in **Table 15.2**.

BOO contracts (Build, Own, and Operate) dominated the generation segment, due to its prevalence in renewable energy projects. A BOO contract matches the concept of IPP, as in this type of contractual model the private sector operates under a license and has a contract that allows the delivery and sale of electricity to the grid (Power Purchase Agreement).

Regarding **BOT** contracts (Build, Operate, and Transfer), the private sector uses concessions; that is, assets that are from the public sector. When the concession expires, those assets are returned to the public sector. This model is widely used in hydropower plants, for example. Furthermore, its predominance in transmission reflects the strategic value of this segment to the electricity sector, motivating the preference of governments to hold the assets of this segment once the concession expires.

[19] Source: World Bank database. PPI projects. http://ppi.worldbank.org/.

Finally, for distribution, **ROT** contracts (Rehabilitate, Operate, and Transfer) are the most used. In this segment, the concession of distribution systems to the private sector is used when investment in renovation is needed, in a first approach, or it can be used when investment in expansion is necessary. Again, in these cases, the assets return to the public sector when the concession expires.

Table 15.2 – Most used private investment participation models (2013)

Contract		Generation	Transmission	Distribution	Total
PPP					
	BOO	112	0	0	112
	BOT	50	12	0	62
	BLT	3	0	0	3
	BROT	1	0	0	1
	ROT	0	0	7	7
Management contract		0	0	1	1
Privatization					
	Partial	3	0	0	3
	Total	5	0	1	6
Other		6	0	0	6
Total		**180**	**12**	**9**	**201**

15.1.2 SUB-SAHARAN AFRICA

Context. Private sector investment in the Sub-Saharan African electricity sector started in the early 90's. Back then, with the support of international development institutions, some African countries started to restructure their electrical systems, unbundling generation, transmission and distribution, and providing incentives for private investment in the sector. According to the World Bank [33], between 1990 e 2013 more than 150 projects reached financial closure in Sub-Saharan Africa.

Distribution in the value chain. Similarly to what happens at a global scale, generation was the segment with more private investment in the region, totaling 147 projects which included a generation component, 128 of which were exclusively generation projects.

Distribution was the second segment with most projects: of the 26 projects contemplating distribution, 5 were exclusively distribution projects.

Finally, transmission was the sector that received the least private investment, having had 19 projects, of which only one was exclusively dedicated to transmission.

Participation models. Current practice in Sub-Saharan Africa is not much different from what happens worldwide, as it is shown in **Table 15.3**. The BOO model was also the most used, totaling 63 projects, all of them generation projects. The second most used PPP model was BOT, with 27 projects, almost all in the generation sector.

Table 15.3 - Private investment in Sub-Saharan Africa (1900-2013) [33]

Contract		Generation	Transmission	Distribution	Mixed	Total	Investment (BUSD)
PPP							
	BOO	63	0	0	0	63	11.60
	BOT	24	1	0	2	27	4.00
	BLT	2	0	0	0	2	0.10
	BROT	2	0	1	3	6	1.70
	ROT	4	0	0	4	8	0.52
	RLT	1	0	1	1	3	0.12
Management contract		1	0	1	11	13	-
Privatization		6	0	0	1	7	1.70
Lease		0	0	2	0	2	0.00
Rental		25	0	0	0	25	-
Total		**128**	**1**	**5**	**22**	**156**	**19.74**

In Distribution, the lease or *affermage* model seems to be the most used - also common in water and sanitation. In the water sector in recent years in West Africa, a hybrid *affermage*/concession arrangement has been adopted successfully in Cote d'Ivoire, Senegal, Cameroon and other countries.

Another common model for private investment was rental, with 25 projects. Rental (or operational leasing) consists in a service which is, essentially, providing a power generation unit to a generation entity, encompassing its operation and maintenance and in which the asset's risk remains on the leasing entity's side, thus distinguishing rental from leasing (financial leasing).

Financing structure. Foreign companies have been dominating the private investment in the Sub-Saharan Africa, which reflects the limitation of capital endogenous to the continent [34].

Development Finance Institutions have been playing a major role in the financing of projects in the region. According to a study concerning independent power producers in Africa, by researchers linked to Cape Town University [35], more than half of the independent power generation projects had the participation of DFIs, and the indebtedness index was higher than 70% in most of the projects. Considering that most investors are foreign, most of the projects are financed in strong currency, having the disadvantage of subjecting these projects to currency risk.

Given that only few African countries are considered as investment grade by international rating agencies, most projects have been financed with credit enhancement structures. Credit enhancement corresponds to a specific set of measures designed to lower the credit risk associated to financing, making them more appealing to private investors. The measures used include, among others: political risk insurances, sovereign guarantees, insurances, comfort letters, escrow accounts and partial risk guarantees. For example, concerning power generation projects, which are supported by energy acquisition contracts, buyer's credit might be mitigated through associated sovereign guarantees.

15.2 PRINCIPLES AND OBJECTIVES OF PRIVATE SECTOR PARTICIPATION

15.2.1 OBJECTIVES AND CONSTRAINTS

Public Private Partnership principles. Private sector participation programs are an instrument for the implementation of the long-term vision for the electric sector. In **ANNEX XIX** we can see the potential market actors and stakeholders with core business and capabilities.

Objectives. Among the main objectives are (i) the on-time implementation of an investment program, targeting the increase of electricity access and being fundamental for the economic and financial sustainability of the sector, and (ii) the improvement of the economic efficiency of the sector, with the reduction of technical, non-technical and commercial losses.

Constraints. Constraints that may affect private sector participation include (i) national private sector capabilities, which can be mitigated through the promotion of international partnerships, (ii) funding sources, as internal funding sources are usually limited, meaning that private investors may have to use international funding sources, and (iii) public sector capabilities, as there is a need of adequate assistance from the public sector, thus its capabilities for creating and regulating partnerships (which are complex and multidisciplinary) must be taken into account.

15.2.2 PRINCIPLES RELATED TO THE OBJECTIVES

On-time implementation of an investment program. It is expected that the private sector accelerates the implementation of investment programs for the electricity sector, contributing toward the mobilization of additional financial, human and material assets.

This participation allows to surpass constraints related to public sector capabilities and political budget restrictions, which limit the amounts available for its financing.

To achieve this goal, the program should have a reasonable dimension, both in number and in value of projects, in order to attract a significant number of interested entities. Moreover, such programs should be focused on projects in which the public sector has little to no experience (as projects that involve fairly new technologies) or which implementation would imply a strong dispersion of the scarce public resources.

Improvement of the electric sector's economic efficiency. Additionally, private sector participation should contribute to the improvement of the electricity sector's economic efficiency. This improvement may result, essentially, from the optimization of costs, regarding the life-cycle of the project, or from the maximization of the profits, by reducing the system's total losses.

In order to potentiate this objective, a private sector participation program should be structured to attract a large number of interested entities, favoring competition. It should also include projects that, due to their nature and dimension, allow private investors to present proposals with effective gains, and projects in which the public sector lacks efficiency. Finally, projects' deadlines should be adjusted to the

useful life of investments, allowing private investors to act in a way that minimizes the overall cost of the project in its life cycle.

15.2.3 PRINCIPLES RELATED TO THE CONSTRAINTS

Legal limitations. A countries' legal framework may prevent or limit private sector participation in the electricity sector. For example, Angola's legal framework excludes the private sector from participating in the electricity transmission segment, only allowing it in the generation and distribution segments.

Private sector capabilities. As previously mentioned, in order to obtain valuable and competitive proposals, a competitive environment should be stimulated. On the other hand, the value of a proposal is strongly dependent on the capabilities and experience of the private sector in bringing new methods of implementing projects.

Considering again Angola's example, it can be stated that the private sector only plays a residual role as an operator, being essentially a service provider, mostly as a contractor (building and assembling of equipment), for the government and public entities of the electric sector, both in generation and in distribution. It plays an active role in the attraction of financing for the sector, as some of the contracts have been financed by credit lines discussed with financial institutions from the said contractors' country. Anyhow, when the private sector acts as a service provider, the strategy of investments' implementation is decided by the public sector. However, when projects are managed by the private sector, the responsibility of the projects whole life cycle cost lays on the private sector, thus reinforcing the need for its know-how.

All in all, there is a considerable set of relevant players in the various segments of the electricity sector. Their participation should be incentivized, and it could be of further importance considering that it may guarantee the participation of international financial entities. To attract private sector's interest, there is the need of having (i) transparency and stability in the procedures, as a private sector participation program should set clear and stable rules, namely in the criteria for the adjudication of projects and conditions of contracts; (ii) stable contractual structures, that allow an adequate balance of interests; and (iii) efficient and stable procedures that are favorable to external capital movements.

Financing Sources. Concerning national financial systems, it can be generalized that there is interest in the financing of investments in the electricity sector, as long as these are structured appropriately. However, it is probable that a country's national system cannot finance an entire program, which might condition the financial profile of projects.

In this context, it is desirable to guarantee the access to international financing sources, both from commercial or development banks and from multilateral financial institutions. Access to these sources may be conditioned from several factors, such as (i) exposure limits that each institution sets for itself, (ii) difficulty related to the requisites for the use of these sources; and (iii) credibility from the public contracting entities.

Considering these limitations, previous recommendations are reinforced, namely the transparency of contracting procedures and payment guarantees. On the other hand, considering the probable difficulty associated to large loans, large-scale projects should not be initially included, providing the system enough time for a cadenced absorption.

Public sector capabilities. The establishing of long-term partnerships with the private sector implies several impositions to the public sector during the whole life time cycle of the projects:

- In project creation, as the launching decision for each project of partnership with the private sector should be preceded by a strategic, economic and financial evaluation, demonstrating the ability to choose a certain type of partnership, and where it is quantified its impact on the budget;
- In choosing the partner, since procedures associated to contracting are particularly complex, as it is required for the private partners to develop proposals with a high degree of technical, economic and financial components. These procedures are often lengthy, imposing a high response capacity to the clarification requests by the contestants.
- In contracting, since contracts are often complex, especially when involving external financing entities, regulating a vast set of subjects and establishing measures for several possible events;
- In contract management, as it is important to guarantee an adequate contract management and supervising, ensuring that the payments match the results and that the private operator remains motivated to maintain a high level of performance during the life time of the contract. Furthermore, when rupture events or contract revision processes are triggered, the public sector should have the technical, juridical and financial capability to ensure the safety of public interest.

To sum up, private sector participation should be accompanied by organizational measures and capacity building of the public sector, and the phasing of the projects should be adequate in order to allow the incorporation of the acquired knowledge from successive projects. The existence of limitations should impose an attitude of caution, but should not restraint excessively private sector participation.

15.2.4 INTEGRATED NATIONAL ENERGY PROGRAM – SOUTH AFRICA'S EXAMPLE

Context. South Africa has been implementing measures to increase the access of electricity services in rural areas, using both grid connections and off-grid systems. The electrification rate has increased from about 35% in 1990 to more than 90% in 2013. This progress consisted in two stages: the first stage was based on Eskom's technical and financing abilities, doubling the electrification rate to 70% in 2000. From 2001, the second stage was supported by the creation of programs such as the INEP and a rural electrification fund. INEP's goal is to achieve national coverage of electricity services by 2019, focusing on schools, health clinics and households. Between 1994 and 2011, more that 5 million residential connections were set up, and more than 12 000 schools became grid-connected.

Isolated electrification/solar villages. The electrification program for isolated systems was designed to, temporarily, provide electricity to rural communities far from the grid, until grid-connection becomes economically feasible. When there is not a more economical solution, electrification is based on solar home systems. The concessionaries have at their responsibility the maintenance of the system and should also maintain "Solar Shops", where they sell petroleum-based lighting and paraffin, thus satisfying needs that are not fulfilled by the solar home systems. From 2002 to 2010, connections for more than 3 000 schools, 345 health clinics and 46 000 households were established.

Financing models. Until 2001, the rural electrification program was financed mostly by Eskom, assuming that the investment and capital costs could be sustained by the tariffs charged to consumers. Despite this, in the middle of the 90's, it became evident that the assumed sustainability would not be possible: with reduced tariffs and high investment costs, a household would have to consume, on average, at least 350 kWh per month, in order to cover operational and investment costs. However, most new consumers had low incomes, consuming only 100 kWh on average. This way, rural electrification became a socio-economic integration program. Since 2000, the South African government finances the investment costs and attributes partial subsidies to the management of rural distribution systems. These subsidies allow, on average, to establish approximately 200 000 connections per year, 5% of which in isolated systems. The financial model is based on subsidies and in the charge of tariffs:

- Investment and connections – subsidies cover 80% of these services' cost, with the remaining 20% covered by the private sector. The consumer pays a reduced connection tariff (5%);
- Operation and maintenance costs – these are supported by the concessionaire and subsidized, with the consumer being charged for a base access tariff;
- Free basic electricity – the supply of energy is 100% subsidized, up to 50 kWh per month, being the additional consumption charged.

15.3 RENEWABLE INDEPENDENT POWER PRODUCERS

Growing the Grid Renewable IPP initiative. The Growing the Grid Program includes the "On-Grid Renewable IPP" initiative with 100 MW planned. The IPP model has been selected given the larger size of investments, the ease of integration with the grid – both national and international – and the expected free cash flow that can be generated on the national grid – allowing to obtain funding from Development Finance Institutions and Private sector investors.

Renewable development in decentralized grids. In Decentralized Grids renewable development under a pure IPP model would be challenging in the short/medium term as system size imply smaller projects and potential issues on electricity off-taking due to technical restrictions. Also, the need to balance renewables with more expensive diesel based generation limits free cash flow and the capacity to pay for such investments. Solar/Diesel transitional mini-grids and Hydro generation in Decentralized Grids

are expected to be funded by Grants and therefore should remain property of REFUND to be leased to private operators.

Smaller scale IPPs to replace diesel. Smaller scale investments such as biomass gasifiers to replace diesel could be successfully developed and operated by local entities under a pure IPP model – as long as such operators accept similar dispatch rules as diesel generators.

Renewable IPP contractual schemes. Renewable IPPs are normally supported on a Concession/License agreement and a Power Purchase Agreement. The Concession/License agreement establishes the relationship between the producer and the State, normally authorizing construction, providing fiscal incentives or different types of guarantees and potentially clarifying the transfer of assets to the State after a certain period. The Power Purchase Agreement establishes the relationship between the producer and the off-taker, normally establishing the tariffs by which electricity is sold to the off-taker and the rights and duties regarding dispatch of power plants.

Renewable procurement program. Many options exist regarding the structure of a renewable procurement program. Further studies are proposed to clarify the Legislative, Regulatory and Administrative framework of renewable procurement in Liberia building on best practices and on a correct assessment of Liberia's renewable potential. Such study shall also develop and detail the License and Power Purchase Agreement.

15.4 REGIONAL DISTRIBUTION COMPANIES

Creation of Regional Distribution Companies. The creation of Regional Distribution Companies is a key element of the Rural Energy Master Plan and a major change to the current institutional framework requiring further and more detailed studies. The Master Plan and present chapter outline some of the key elements to be considered.

Initial setup. The initial setup of Regional Distribution Companies can be complex. In Senegal, where the country was divided into several concessions, the setup took many years and still today the model faces significant challenges. The existing cross border grids represent short term concrete opportunities to start developing and testing the contractual structure. Additionally, the need to combine grants with private sector and to have REFUND as an asset ownership platform allows the investment process – supported in owners engineering services - to advance in parallel with the creation of the Regional Distribution Companies.

Local presence and transition from "Community Current". Selection process should give preference to partnerships between Liberian Companies – coming from other sectors – with size and financial capacity together with experienced utilities operating already in other countries. The process should also try to include "Community Current" entrepreneurs as preferred employees of the Distribution Companies as hundreds of such entrepreneurs may risk becoming unemployed and may constitute an obstacle to the new Distribution Companies.

***Affermage* contracts.** The need to have grant funded assets separated makes the use of *Affermage* or Lease Contracts a preferred option for Distribution activities in Liberia. In Lease and *Affermage*

Contracts the operator does not receive a fixed fee but charges a tariff to consumers. In the case of a lease the payment to the authority tends to be fixed irrespective of the level of tariff collection. In the case of *affermage* – the preferred model – the operator has its remuneration guaranteed (assuming that the receipts are sufficient to cover costs) and it is REFUND that takes the risk on the rest of the receipts collected from customers.

Hybrid License/*Affermage* model. Normally in pure *affermage* contracts it is the asset owner that remains responsible for financing and managing investment in the assets based on a rental payment. In the water sector in recent years in West Africa, a hybrid *affermage*/concession arrangement has been adopted successfully – for example in Cote d'Ivoire - where it is the Private Company that assumes the management of the investment process in articulation with the asset owner. The Master Plan proposes a similar hybrid solution to be developed based on LERC regulation that allows Licensees to own and invest in network expansion assets, while limiting demand risk and potentially reducing tariff differentiation among regions.

Demand risk. Rural electricity demand faces still significant uncertainties with impact on private operators. If revenues are significantly below expectations than fixed costs or high running costs such as diesel may be hard to support in a sustainable way – limiting the level of service provided and population's acceptance and adherence. The *affermage* contract with leasing fees to REFUND being dependent on results can mitigate significantly demand risk impact on Distribution Companies economics.

Tariff and service differentiation. Significant tariff and service differentiation between Regional Distribution Companies may not be well understood by population limiting acceptance and adherence. REFUND, through differentiated leasing fees, can act as a balancing mechanism between Distribution Companies – avoiding significant differences in tariffs. The Rural Services Unit(s) in charge of managing the pre-paid meter and billing infra-structure and software can also mitigate differences between Regional Distribution Companies and promote synergies.

Regional structure. Figure 15.2 represents a possible division of the country in 5 Regional Distribution areas based on the existing Region structure and taking into consideration the existing and planned cross border infra-structures. Region 2 because of its size was divided in two different distribution areas: Lofa on one side and Bong/Nimba on the other. Region 3 would be managed by LEC Distribution Unit.

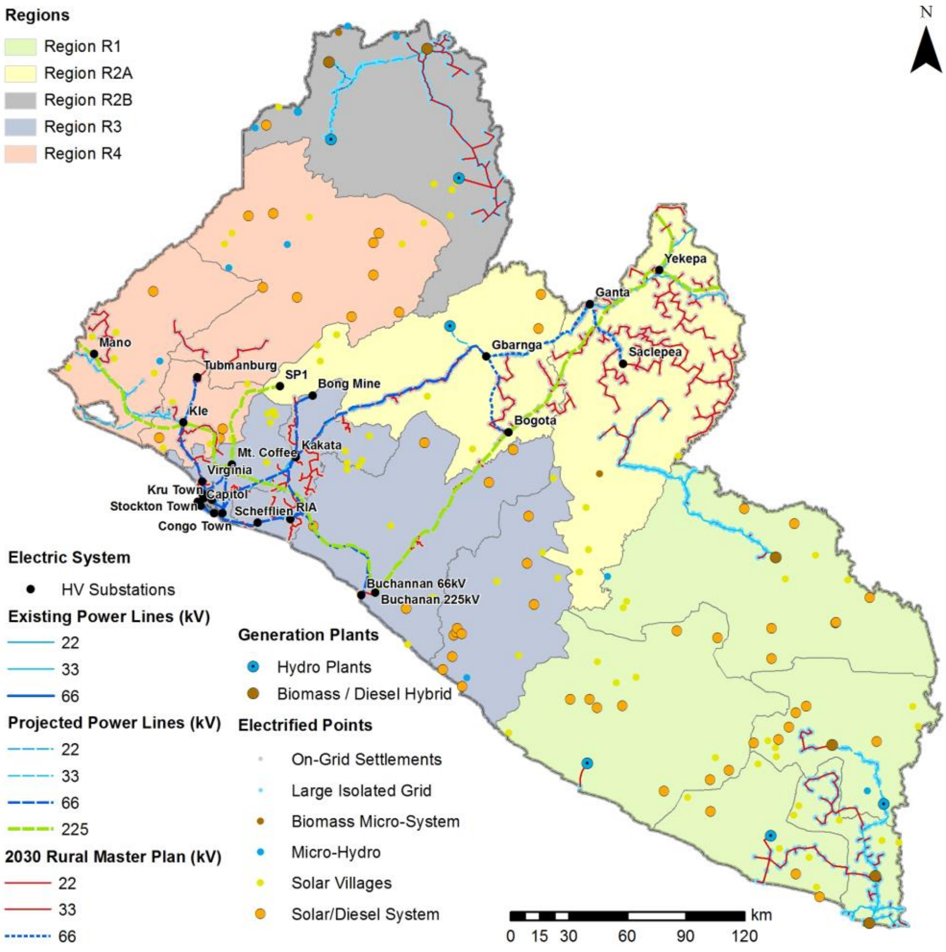


Figure 15.2 – Proposed areas for Regional Distribution Companies

16 CROSS-CUTTING ISSUES

16.1 GENDER EQUALITY

Many benefits of the electrification to women were already discussed in the **Chapter 3.3**. This chapter will have a narrower focus on the specific measures included in the Rural Energy Master Plan which will benefit gender equality.

Biomass as fuel affects primarily women. According to the International Energy Agency (IEA), World Energy Outlook 2015, in Liberia the percentage of population relying on traditional use of biomass for cooking was 98% in 2013. Moreover, this percentage is higher in Liberia than in Sub-Saharan Africa (80%), and indeed Liberia is among the countries with highest percentage of the population relying on traditional use of biomass for cooking in the world. The burden of gathering wood and other types of fuel falls beneath the women's responsibilities which imposes a setback on their education and economic involvement as mentioned above in the chapter regarding the National Gender Policy. Moreover, the use of biomass indoors contributes to respiratory illnesses which affect more women than men. With electricity and promotion of efficient cook stoves the amount wood used for cooking can be seriously diminished, thus decreasing the burden set on women to gather it and also promoting efficiency, meaning that the time consumed in these activities is reduced.

Electric appliances allow women to save time and reduce effort. Other than promoting more efficient cooking fuels and options, by providing electricity to households women are also able to have other appliances which are extremely helpful in their daily activities, such as refrigerators and freezers to conserve food, and in a later phase washing machines for clothes and dishes and electric irons. Allowing women to cook food more efficiently and preserve it for the next day using a refrigerator and powering households with options where they can obtain several appliances enables women to complete their usual tasks in less time and with less physical effort and some of the manual tasks that may be substituted with the use of electric appliances. Hence, by reducing the time women spend on these household activities they are able to employ more time in education and in their economic activity.

Additional ways to promote gender equality. Another way to promote gender equality is to involve women in the decision making process regarding rural electrification, as well as educate women with regards to electrification so that they are able to be part of the construction and maintenance of the electricity grid.

Hence, there is a clear promotion for gender equality and to increase the livelihood of women.

16.2 HEALTH

Health is one of the main priorities. In the beliefs audit it became evident that the most important impact of electrification for the population was health. Indeed, health facilities were given the most priority to electrify first and its target for electrification were extremely high (majority advocated a target above 80%). Given this, the electrification target for health centers was of 100% by 2025 in scenarios 1A and 1B, and in scenarios 2A and 2B this target would be achieved by 2020. Furthermore,

there is a clear program in the Rural Master Plan focused in the health sector in order to provide affordable and reliable energy for health clinics and health centers.

Electricity provides access to better health care services. With electricity, health centers are able to have illumination and hence provide medical services at night but it also enables health facilities to have vaccine refrigeration and ice pack freezing, better communication, more medical appliances, sterilization of equipment and water supply and treatment. These are indeed basic needs for any health facility and hence reliable electricity can have significant implications for providing health care, especially for reproductive and child health.

Using less biomass would contribute to increase public health. More than providing better health care services, electricity also helps to increase public health in other areas. Indeed, as demonstrated above, a great part of the population in Liberia still relying on traditional use of biomass for cooking and the usage of lighting fuel is heavily reliant on kerosene lamps and other polluting alternatives. This use of biomass indoors contributes to household air pollution which emit large proportions of health-harming pollutants in their smoke, further damaging the health of the population. Indeed, in 2013 the percentage of deaths due to household air pollution from solid fuels in Liberia was 7.11% (a rate of 54.23 deaths per 100 000), which is higher than the percentage of total death due to HIV/AIDS (6.59%). Hence, by promoting efficient cook stoves and electricity to several households the health of the population is also improved.

16.3 ENVIRONMENT

Context. Sustainable development depends largely on successfully integrating the environment into economic planning and decision making. This makes environment a part of the fifth pillar – Cross-Cutting Issues. Agenda for Transformation has as strategic objectives for this pillar the development and implementation of clear environmental policies and quality standards, in order to guide environmental management, and those include a National Plan for Low Carbon and Climate Resilient Economy. This all goes in line with the Millennium Development Goals, as one the main messages is the environmental sustainability of energy supply and consumption.

Rural Energy Master Plan. The present Rural Energy Master Plan plays a role on these Liberian strategic objectives, since the energy sector has major influence on the environment. As such, electricity generation was one of the main concerns, and a strong commitment in the environment was taken into account, influencing the penetration of renewable and sustainable energy sources, such as hydropower plants, solar photovoltaic panels and biomass generation units. For example, off-grid solutions contain PV systems, which provide green electricity, not polluting the environment and not needing any fuel.

Hydropower. Firstly, the Rural Energy Master Plan suggests small hydropower plants, which besides providing green energy to rural areas, have several advantages regarding the environmental impacts when comparing to large hydropower plants. One of the impacts mitigated is the amount of water needed, as in small hydropower plants there may be no need of building a dam, if the project is a Run-

of-River hydropower plant. Also, small projects are more suitable for decentralized production where the demand is not as high, thus allowing more small projects rather than less but larger ones.

Diesel and Biomass. Additionally, diesel and biomass generation units for mini-grids were analyzed. Using biomass instead of diesel represents a strong decrease in the emissions of carbon and other pollutants, reducing the environmental impact of electricity generation and also its impact on human health. Moreover, using biomass resources for electricity generation may contribute to the reduction of residues that could damage the environment, especially when considering waste and urban resources. Despite this, a sustainable use of biomass resources is vital, as deforestation remains an issue in Liberia.

Cook stoves. Finally, by using efficient cook stoves and other devices, Liberians can substantially decrease the amount of resources spent in cooking activities, as well as lighting and heating, which contributes positively to the environment.

16.4 INNOVATION

Context. Innovation drives growth and enables change. It is of the utmost importance for a country to be innovative, as it allows the country to discover new and better solutions for existent problems. Even though the results matter, the process of innovation allows people to learn, and enabling learning is the start of the road for development.

Biomass gasifiers. Concerning the energy sector, Liberia's innovative process can be observed in universities such as Booker Washington Institute, in Kakata. There, the use of small biomass gasifiers for power generation has allowed such a remote location to have access to electricity. These gasifiers represent small-scale projects, for demonstration purposes, as the technology itself is not mature yet. In this way, Liberia is contributing to the testing and improvement of gasifiers, while benefiting from the power generation. Furthermore, Liberian people are learning about the technology used, building capacity and acquiring practice with the power generation units and also with the use of natural resources. This is particularly important for the sustainable development and use of resources, raising awareness of these issues.

Off-grid and decentralized solutions. Current innovative processes are focused on off-grid or decentralized production, since grid connections in remote locations may not happen in the near future. The Rural Energy Master Plan encourages innovation in the energy sector, with the use of different and mostly sustainable technologies that represent a step forward compared to the already known diesel generation units.

Gender equality. Concerning learning and innovation, it is imperative to take into account gender equality issues, so as to allow both men and women to handle the devices and technologies used.

17 FUNDING STRATEGY

17.1 FUNDING GAP AND CONSTRAINS

USD 935M investments for rural electrification. **Figure 17.1** shows a summary of the Rural Energy Master Plan investments per Program and type of investment (Generation, High Voltage Transmission, Distribution and other). The GTG and DG Programs represent around 90% of the total investment with significant investments both in generation and distribution. GTG Program by itself represents more than 50% of the Rural Energy Master Plan investments.

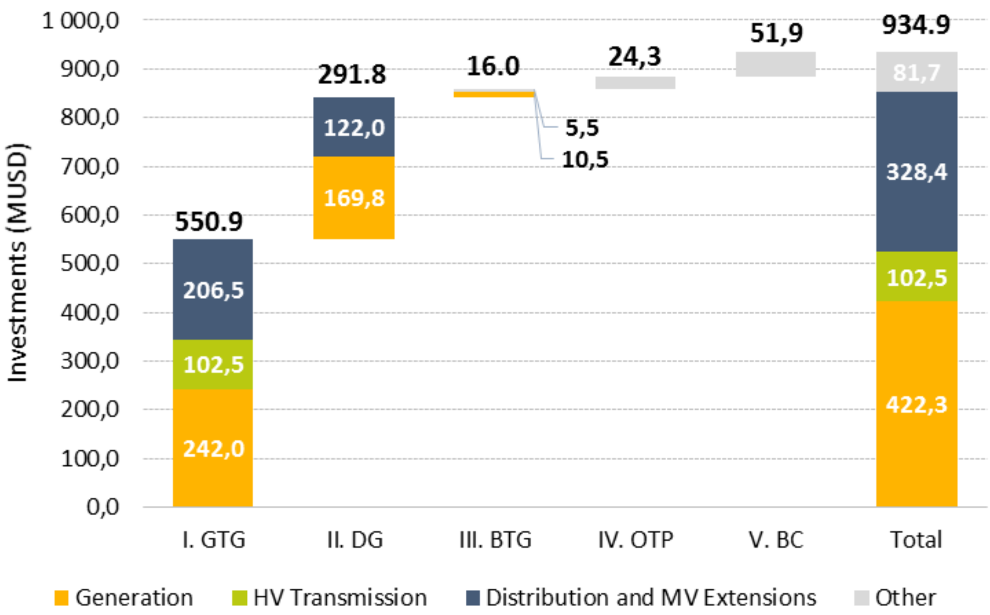


Figure 17.1 – Investment per Program

USD 749M still to be funded mostly for the period between 2020 and 2030. From the required USD 935M, around USD 140M are already committed and an additional USD 45M secured and not yet allocated, representing a total of USD 185M – mostly from African Development Bank, World Bank and European Union (**Figure 17.2**). Most of the secured funding will be deployed in the first phase, representing a significant part of the estimated investment of USD 262M. A gap of USD 746M remains to implement the Rural Energy Master Plan with additional USD 102M being required until 2020, USD 303M between 2020 and 2025 and USD 344M until 2030.

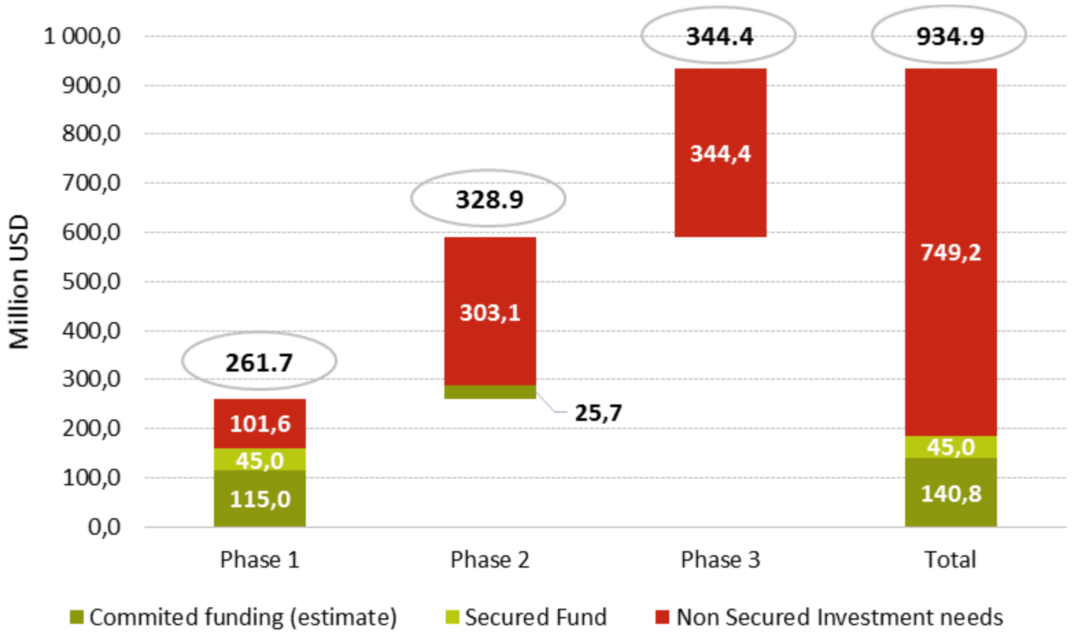


Figure 17.2 – Investment per Phase and Funding gap

Potential sources of funding. Two main types of funding can respond to the USD 749M gap, according to the framework presented in **Figure 17.3** and described next:

- **Country Funding**: Funding by other countries or multilateral institutions which aim to support the development of Liberia. These include Official Development Assistance Grants or Concessional Loans. Grants available for rural electrification are constrained by donors' availability and preferences, and also by Liberia's priorities and the need to share the available funds with other key sectors such as health, education or roads. Concessional loans are available for Least Developed Countries and have very low interest rates and very long maturities, but the available amount is limited by the country's level of income, capacity to repay such debt and IMF policy on acceptable level of indebtedness.
- **Project related funding**: Funding that can be repaid from cash flows generated from the investment. These include Development Finance, Commercial Finance and Equity – each with different requirements in terms of rate of return, tenor and ticket. Development Finance Institutions have been playing a major role in the financing of projects in the region. Potential depends on Free Cash Flows which are constrained by willingness and capacity of consumers to pay, by available generation alternatives and running costs and by capacity of Distribution Companies to avoid losses. Potential also depends on Risk - If debt repayment risk is high than less entities will be available to fund, the funding costs will be higher and less funding will be raised from the same cash flows.

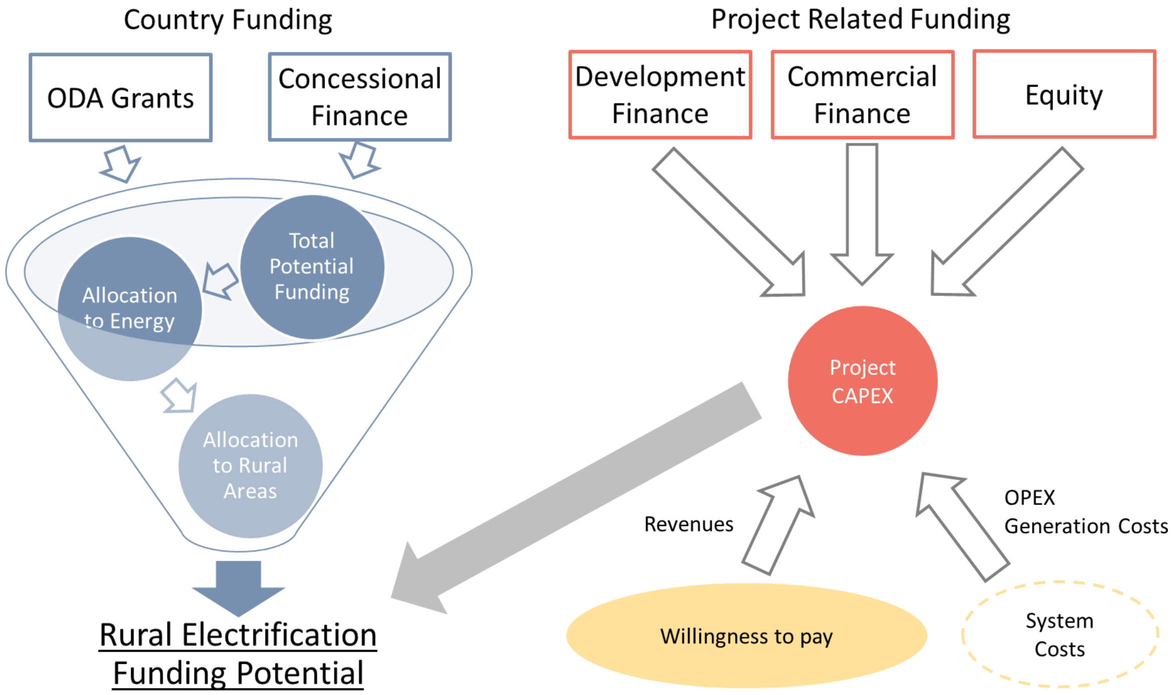


Figure 17.3 – Funding framework

Concessional finance and Project related funding trade-offs and constrains. Given the current situation of the Liberian power sector, the unpredictability of future rural demand and the financial situation of LEC it is difficult to expect in the short term lenders to be willing to fund energy sector investments without some kind of Government repayment guarantee. However, such public guarantee would reflect on the level of publicly guaranteed debt, thus limiting the country's access to additional concessional loans with very attractive conditions. Preference will go to concessional loans and to the implementation of risk mitigation or credit enhancement mechanisms that allow Project related funding without jeopardizing concessional finance. The measures used include, among others: political risk insurances, insurances, comfort letters, escrow accounts and partial risk guarantees.

17.2 TAX POLICY AND GOVERNMENT INCENTIVES

Investment incentive code. Liberia has a liberal business climate intended to attract foreign investment and stimulate economic growth and development. Incentives granted under the Investment Incentive Code include exemption from custom duties, income tax, stamp fees and other benefits to new and expanding businesses, for approved investment projects in manufacturing, agriculture, forestry, fishing, mining, building and construction, transport and communication. Approved investment projects may also be eligible for support in securing loans and guaranteeing credit by the Central Bank.

- **Exemptions from Trade Taxes:**
    - Machinery, equipment, raw materials, semi-finished products and other supplies to be used in a project are exempt from import duty up to 90% of their dutiable value; and
    - Manufactured goods exported from the production of the project are entitled to full rebate on import duties and full refund of both income tax and excise tax.

- **Exemptions from Income Tax:**
  - Reinvested profits are exempt from income tax.
  - Profits not reinvested are exempt from 50% of the income tax otherwise payable.
- **Other benefits:**
  - Approved investment projects may receive certain additional benefits on application to the government, such as the lease of land in government-owned industrial parks at a preferential rate, reasonable tariff protection, purchase of project products by government agencies, etc.

Tax regime for energy. Currently the application of existing exemptions to energy is not clear. Applicable taxes can reach 25% (e.g. in the case of Solar Portable Lamps) and may further increase the already significant investment identified above – which did not include tax. A tax regime for rural electrification and renewable energy investments will be developed to limit import duties and Goods and Services Tax (GST) impact on the total investment and funding required. The future regime will also include tax exemptions for private sector investment on energy in order to incentivize private and commercial funding.

17.3 FUNDING STRATEGY

17.3.1 CONTEXT

Exploring all potential sources of funding. Given the high amount of funding still required, the Rural Energy Master Plan shall explore all possible funding sources, giving always priority to those that generate smaller yearly costs (with lower interest rates and higher maturities).

17.3.2 COUNTRY RELATED FUNDING

Development Assistance. Although Liberia is sometimes seen as a very high Official Development Assistance recipient country on a GDP basis (the first in Sub-Saharan Africa) such fact derives not so much from the level of ODA received but from the very low income of the country – due to one of the most severe and long-lasting civil wars in Africa and, most recently, due to the Ebola outbreak. Considering ODA total value, on average between 2006 and 2014, Liberia was only the 22^{nd} Sub-Saharan African country in terms of ODA received (**Figure 17.4**).

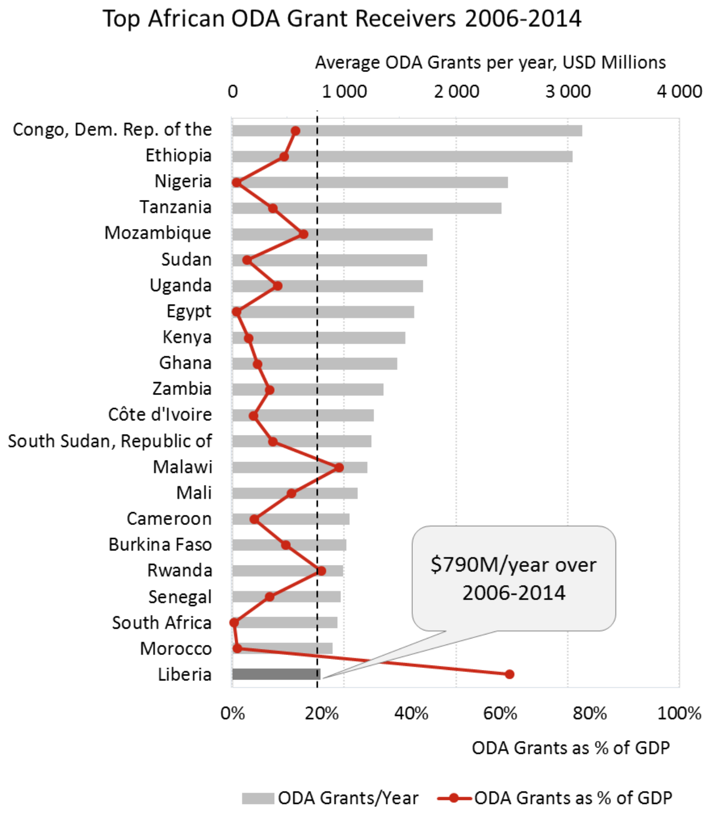


Figure 17.4 – ODA level per country in Africa

Maintaining energy sector as ODA priority may generate funding in excess of USD 474M. ODA has been and is expected to continue being the main source of funding for the needed infra-structure on roads, energy and communications. ODA statistics show that Liberia allocated on average 10.5% of its total ODA received between 2006 and 2013 to the energy sector, much above West African countries average of 3.3%. Considering an intermediate allocation of future ODA to energy (6.9%) and a more balanced allocation of funding to rural energy vs. Monrovia electrification after 2020, ODA funding for rural energy could reach USD 474M until 2030. It could even be higher if priority to energy and rural areas is also higher.

Concessional loans with limited funding potential. While Liberia received on average 60% of its GDP as ODA every year since 2006, its total debt is currently around 41% of GDP – meaning that the total debt incurred over the last years is only a portion of the average ODA received each year and additional debt will be dependent on GDP growth. If we consider IMF policy and limitations on Heavily Indebted Poor Countries and similar criteria to grants on the allocation of country available concessional loans between sectors and, for energy, between rural and Monrovia electrification, the estimated funding potential of concessional loans would be only USD 75M.

A compelling case for Grant and Concessional funding. The Master Plan benefits from a strong initial focus on the electrification of the main cities and towns outside Monrovia (65% of all rural clients in 2030) where there is business activity and some capacity to pay for energy services. The support studies

show that if initial investments have a strong component of grants and if consumers are charged for what they consume based on pre-paid meters and reasonable tariffs, it is possible to create a financially sustainable system that can maintain the assets, pay for running costs and fund a part of the growth investments… potentially leveraging on a robust Rural Energy Fund to mitigate risks and reduce interests.

17.3.3 PROJECT RELATED FUNDING

Free Cash Flow analysis. **Figure 17.5** shows a simulation of the rural energy sector cash flows on an intermediate year (half of 2030). The potential power sector revenues have been estimated considering demand and an electricity price, inclusive of GST, of 0.35 USD/kWh. The revenues are discounted of the Operating Expenditures associated with generation, transmission and distribution of power consumed and lost. On an intermediate year the Power Sector could generate USD 50M of Free Cash Flow. However, with commercial loans and private sector equity required returns such Free Cash Flow would only allow for the repayment of approximately one third of the USD 935M required. This means running costs can be paid by the Power Sector at reasonable prices and some funding could be raised by the Sector, but majority of energy infra-structure investment or CAPEX in rural Liberia needs a significant level of Grants and external support.

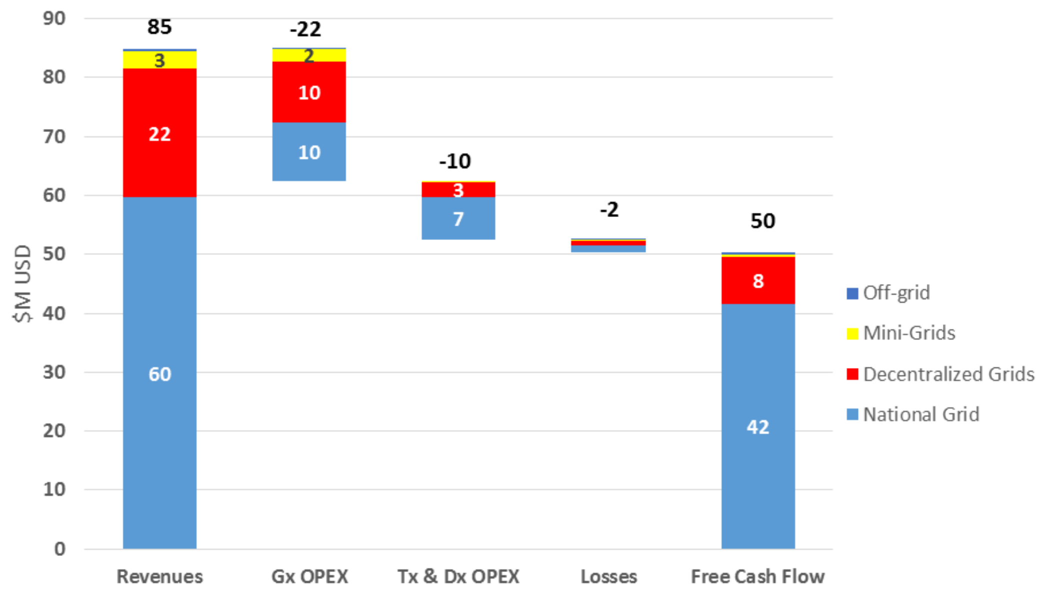


Figure 17.5 – Estimated Rural Energy Sector total Free Cash Flow in intermediate year (half of 2030)

USD 303M Funding potential mostly on the National Grid. The Free Cash Flow Analysis also shows that around 85% of the Free Cash Flow generated would come from the National Grid where generation cost is lower due to regional imports and large scale hydro investments. This offers the potential to have On-grid Renewables and part of the National Grid Distribution investments around Monrovia and the Growth Corridor funded by Development Finance Institutions together with Regional Distribution Companies or Independent Power Producers. An estimated funding of USD 303M could be raised coming from DFI (USD 232M) and Private Sector (USD 71M).

Tariff structure. Demand can have a relevant impact on Free Cash Flow if tariff structure is based only on average costs. Generation units have different marginal costs. As tariffs go below the price of diesel most of the self-generated consumption in National Grid is expected to connect into the grid creating a sudden increase in demand that will require response from expensive backup generation or result in blackouts. The same phenomena tends to happen is smaller Solar/Diesel mini-grids where consumption growth requires more diesel and the response tends to be the reduction in the number of hours of service. Power sector sustainability requires a progressive tariff structure that increases to marginal cost as consumption approaches the available generation capacity.

17.3.4 SUMMARY AND OTHER FUNDING

Funding summary. Figure 17.6 summarizes the potential of the different sources of funding towards the required USD 935M investment (around USD 60M/year). Grants and ODA funding will be the key source of funding. On-Grid renewables and part of the National Grid investments will be funded mostly by DFI, representing the second largest contribution to funding the Master Plan. Concessional loans and commercial lending or equity will have a smaller but still relevant role.

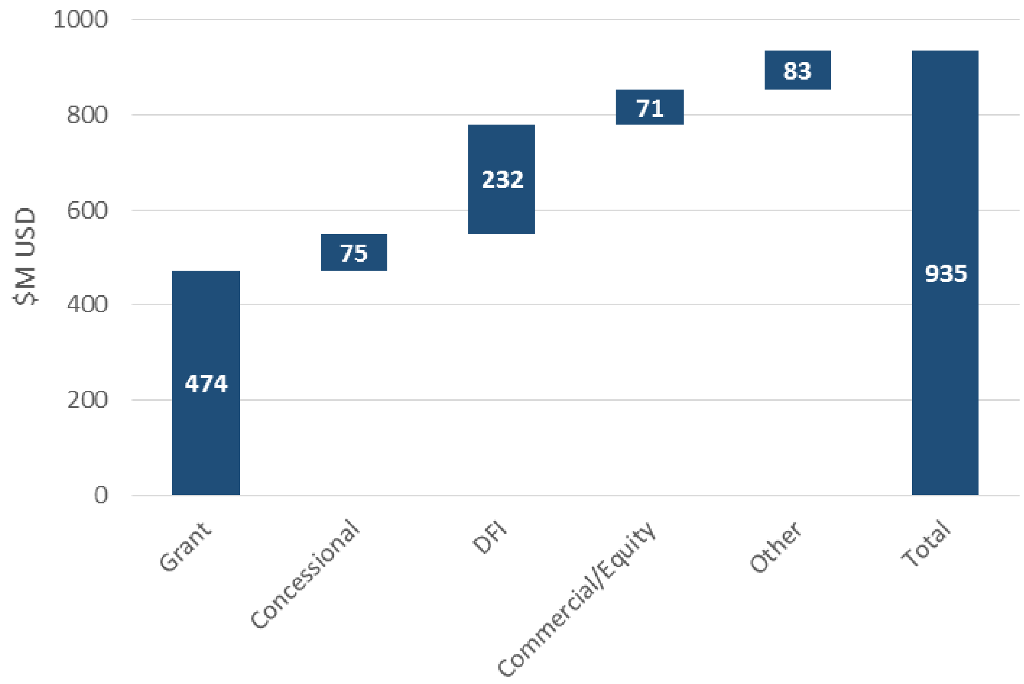


Figure 17.6 – Funding strategy summary

Need for other funding. An additional USD 83M funding is required to reach the USD 935M. The Master Plan proposes the creation of a Power and Petrol Contribution and of Distribution Royalties (DR) that can be directed to REFUND and leveraged with financial institutions to obtain the missing USD 83M.

17.4 REFUND

Objective of the Fund. As per the Act that created the Rural Energy Fund, its objective is to provide for the coordinated and sustainable financing of projects and programs for the development of rural and/or renewable energy projects and delivery of modern energy services for rural development in a manner such that the Fund becomes a channel through which domestic and international financial resources intended for rural and renewable energy delivery in Liberia shall be managed.

Financial management and asset ownership. REFUND is not a single bank account into which funds are paid and disbursed. It is a financial management system for channeling various sources of funding in a coordinated manner. Additionally, given the important role of grant based funding and the fact that many donors can only fund public held assets, it will be necessary for REFUND to own part of the assets and lease them to private Distribution Companies.

Transparency, accountability and use of funds. Transparency and accountability is critical for donors. Also most donors want and need to decide on which investments their contribution will be applied to. As currently the resources of REFUND can be used to pay operational costs and remunerations many donors prefer to manage their grants independently. Towards the future, REFUND shall allow donors to direct their contributions to separate accounts directly linked and only used in specific projects. Moreover, operational costs shall be paid only by Sector generated revenues and not by Donor contributions.

REFUND revenues. REFUND operationalization requires the creation of stable sources of revenue. The Power and Petrol Contribution to REFUND will be created. The PPC consists of a small levy (initially 1% of final price) charged to electricity generators and diesel/gasoline wholesalers. Additionally, REFUND will charge a Lease Fee to Regional Distribution Companies for the assets owned by REFUND and managed by the Regional Distribution Companies. The Lease Fee – to be agreed with LERC - will depend on the calculated tariff level and on the results of revenue collection, mitigating demand risk and reducing tariff differences among Distribution areas.

Credit lines with local banks and Partial Risk Guarantee. REFUND will promote the creation of several credit lines to be made available by local banks to promote acquisition of efficient appliances, financing of grid connections, household internal wiring or other grid growth investments as well as innovative business models and activities. REFUND will reduce risk and will only be used as a guarantee mechanism to support 50% of the defaults.

Risk mitigation for renewable off-taking. The use of REFUND as a means of risk mitigation for renewable off-taking will be explored either through the creation of ESCROW accounts to secure payments or as an interface for Partial Risk Guarantee schemes with multilateral organizations.

18 ACTION: COORDINATION, COMMUNICATION AND MONITORING

18.1 COORDINATION STRUCTURE

Overall coordination. RREA will be in charge of coordinating, supervising and reporting progress of the implementation of the rural Energy Master Plan (see **Figure 18.1**). The Ministry of Land, Mines and Energy will provide policy oversight and monitoring of the Master Plan.

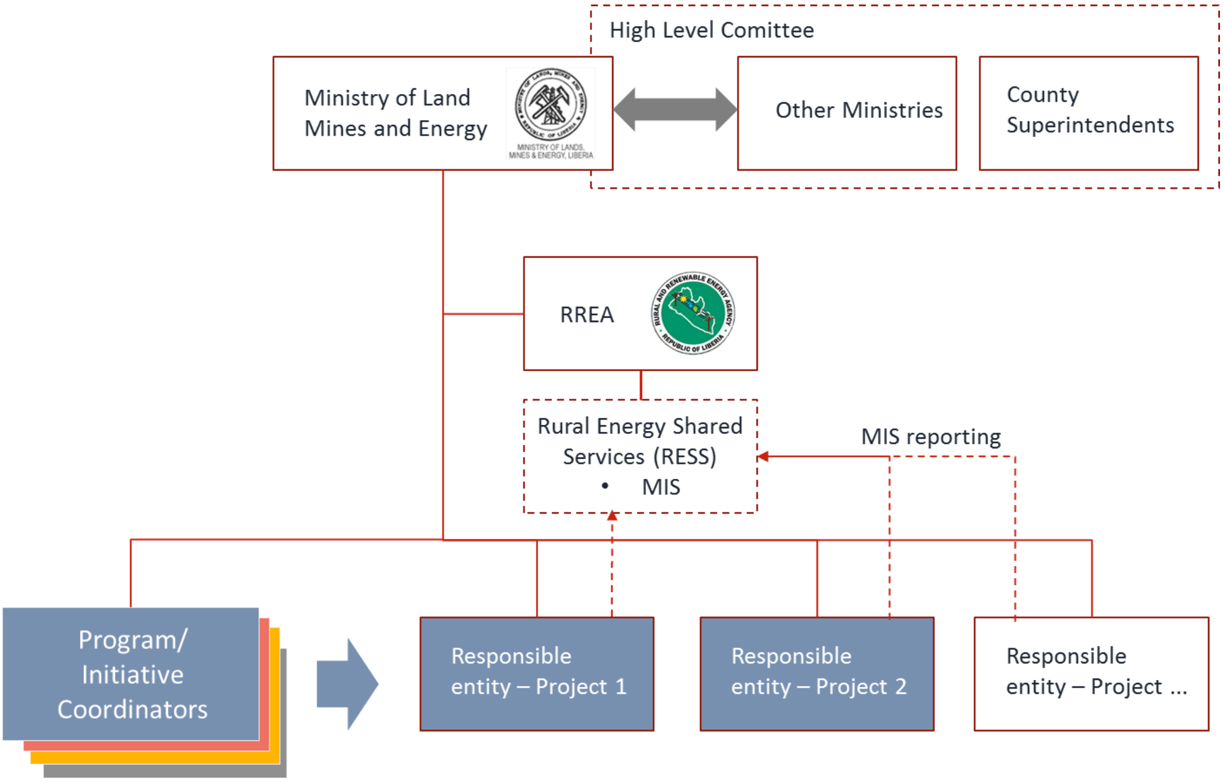


Figure 18.1 – Coordination structure

High Level Rural Energy Committee. A High Level Committee with all relevant Ministries and Superintendents will meet at least once every year to guarantee the involvement of all key entities in the Rural Energy Master Plan and also an adequate articulation between MLME and those entities. RREA will act as Secretariat of the Committee.

RREA and the Rural Services Unit(s). RREA will be the acting agency in charge of the Rural Energy Master Plan and overall coordination, monitoring and communication activities under delegation from Ministry of Lands, Mines and Energy. Additionally, RREA will act as Program Coordinator and, in some cases, as Responsible Entity. The Rural Services Unit(s) will host and manage the Management Information System (MIS) and will support RREA in all reporting activities.

Program/Initiative coordinators. Each Program or Initiative will have a Program/Initiative Coordinator in charge of coordinating and monitoring the implementation of all the projects under that program or initiative. The Program Coordinator will support the implementation but will not have a hierarchical role towards the Responsible Entities for each project. Program/initiative Coordinators will be appointed by the following institutions:

- GTG Program and OTP Program / Efficient Lights & Appliances and Prepaid meters initiatives: LERC
- DG, BTG, BC Programs and OTP Program / Efficient cooking biomass initiative: RREA
- OTP Program / City cooking gas initiative: LPRC

Responsible entities. Each Project will be assigned a Responsible Entity. The Responsible Entity has to guarantee the implementation of the Project. The Responsible Entities will directly respond to MLME on the results of their Projects. They will provide information to the Rural Energy Management Information System and will articulate and require the support, if needed, of the Program/Initiative Coordinator.

18.2 MANAGEMENT INFORMATION SYSTEM

Rural Energy Management Information System. A comprehensive information system will be developed, hosted and managed by the Rural Services Unit(s). The information system will be composed at least of the following key databases:

- **Prepaid meter and Client Connections database**. The MIS will be interconnected with the pre-paid meter database and will have updated information on the number of electricity clients, their consumption and installed capacity, per County, District and Settlement.
- **Funding database**. Information on committed or secured funding in order to identify the remaining gaps.
- **Project database**. Information on the current status of each Project, budget and incurred costs as well as the level of completion and funding sources.
- **Geo-referenced asset database**. Georeferenced information on the existing infra-structure.
- **Procurement database**. Information on all ongoing tenders and status.
- **Generation database**. Information on installed generation.

Information update. In order to minimize extra costs and resources on data collection and processing, the MIS will try to interconnect with existing operational databases and, in some cases, develop useful applications that can support operations and, at the same time, collect the key information.

Transparency. The MIS will not only serve for monitoring and control of implementation, but it will also be a key tool to maintain transparency and promote information exchange with all key stakeholders.

18.3 MONITORING AND CONTROL

Multiple layers of control. Monitoring and control will be developed at all levels, from bottom to top. The Responsible Entity will be the first entity in charge of monitoring and controlling on a day-to-day basis the implementation of the Project and of updating the MIS. The Program/Initiative coordinator also has to control the status of the project, but is only required to do it on a quarterly basis. Finally, RREA will prepare a bi-annual monitoring report to be presented to MLME and to the Rural Energy Master Plan Council.

Information flows. Information will be collected at Project Level under a Management Information System. The information will go directly from Project Applications, Project team or Project Responsible Entity to the MIS.

Rural Energy Master Plan Council. A Council with all Responsible Entities will be chaired by MLME under the secretariat of RREA and will meet twice every year. The Council will review the bi-annual monitoring report with each Program/Initiative Coordinator presenting the status of his Program or Initiative.

Annual High Level Rural Energy Committee and Stakeholder Meeting. An annual report will be prepared by RREA and presented at the Annual Rural Energy Stakeholder Meeting. The annual report will also constitute the basis for the High Level Rural Energy Committee which will meet once every year.

18.4 COMMUNICATION STRATEGY AND PLAN

Communication target audience and objectives. Communication is a key element of the Rural Energy Master Plan implementation with the following key objectives for different target audiences:

For Liberian Population:

- Maximize acceptance by population of electricity services and providers and promote adherence to such services;
- Change habits of consumers on cooking (introduction of city gas and efficient cook stoves);
- Create awareness of available products, services and job opportunities (e.g. Solar Portable Lamps, Credit lines, training centers, …);
- Reduce gender inequality and encourage stronger participation of women on rural energy sector activities and jobs.

For entities directly involved in the implementation of the Master Plan:

- Maximize coordination and information sharing between the implementing entities, namely the Program/initiative coordinators and the Responsible entities;
- Engage public sector institutions and public companies to secure their support and commitment to the implementation of the Master Plan and of the future institutional framework;
- Procure participation of private sector companies in the implementation of the Master Plan.

For donors and other stakeholders:

- Procure and secure the commitment of donors, financial institutions and other international stakeholders to fund the Rural Energy Master Plan projects and investments.
- Engage stakeholders to secure their support and commitment to the implementation of the Master Plan through a clear and transparent communication on progress and involvement/ consultation on key elements of implementation.

Communication mix. Different methods and tools will be applied to communicate the right message to the different target audiences.

Liberian population. RREA communication shall convey the benefits of electricity, efficient cooking and appliances. It will be mostly based on “above the line” media such as billboards, social media, SMS campaigns and radio, but will also include “below the line” communication with press releases and organization of events. Regional Distribution Companies communication will also have a key role in consumer acceptance through its image and of its employees and through the availability of a clear web-site, of local outlets and of a call center where people can ask their questions and present their concerns. All Regional Distribution Companies will be required to approve a Communication Plan and be present at the more populated locations.

Entities directly involved in the implementation of the Master Plan. Communication to this target will start by creating a “Rural Energy” brand and identity. Stationary such as caps or t-shirts will be distributed in key implementation events. Coordination and information sharing will be facilitated by a monthly Newsletter to be released by e-mail to all intervenient. The mailing list will be shared and used also to distribute Progress reports and other key information. The bi-annual Rural Energy Master Plan Council and the meetings of the Rural Energy High Level Committee will further reinforce communication and engagement.

Donors and other stakeholders. A prospectus on the Rural Energy Master Plan will be distributed to key donors and stakeholders. A web-site will be developed by RREA to communicate the results of the Master Plan, the Rural Electrification database and statistics, share the key reports and documents as well as job/procurement opportunities. An international mailing and roadshow to key potential donors will be implemented. A stakeholder annual meeting will be organized by RREA through the implementation of the Master Plan.

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