ECREEE
Towards Sustainable Energy

MAPPING & ASSESSMENT OF EXISTING CLEAN ENERGY MINI-GRID EXPERIENCES IN WEST AFRICA

ECOWAS CENTRE FOR RENEWABLE ENERGY AND ENERGY EFFICIENCY
CENTRO PARA AS ENERGIAS RENOVÁVEIS E EFICIÊNCIA ENERGÉTICA DA CEDEAO
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Abbreviations & Acronyms

AMADER	Agence Malienne pour le Développement de l'Energie Domestique et l'Electrification Rurale
CEMG	Clean Energy Mini-Grid
€	European euro
ADFD	Abu Dhabi Fund for Development
ANPER	Niger Rural Electrification Agency
BOI	Bank of Industry (Nigeria)
CAPEX	Capital Expenditure
DfID	Department for International Development
DPER-SE	Sustainable Development by Renewable Energy - South East Senegal
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
ENERGOS II	European Energy Intervention Programme (Cote d'Ivoire)
EREF 2	ECOWAS Renewable Energy Facility (2nd Launch)
EREP	ECOWAS Renewable Energy Policy
EU	European Union
FCFA	Franc de la Coopération Financière en Afrique Centrale
GDP	Gross-Domestic Product
GEF	Global Environment Facility
GIZ	Deutsche Gesellschaft für internationale Zusammenarbeit (German Development Cooperation)
HDI	Human Development Index
IDB	Islamic Development Bank
IRENA	International Renewable Energy Agency
kVA	kilo-volt-ampere
kW	kilowatt
kWh	kilowatt hour
kW_p	kilowatt peak – refers to PV systems and power supplied at STC
LDC	Least Developed Country
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
OPEX	Operating Expenditure
PCASER	Malian Rural Electrification Programme
PERSHY	Malian Rural Electrification Hybrid System Program
PPP	Public-Private Partnership
PRODERE	Programme Régional de Développement des Energies Renouvelables et de l'Efficacité Énergétique
PROVES	Project de Valorisation de l'Energie Solaire (Beninese Project)
PV	Solar Photovoltaic
RE	Renewable Energy
REA	Rural Electrification Agency
REF	Renewable Energy Fund
RET	Renewable Energy Technology
RREP	Rural and Renewable Energy Programme (Liberia)
SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy for All Initiative
SECO	Swiss Economic Development Cooperation

SHER	Systèmes Hybrides d'Electrification Rurale (Senegalese Rural Electrification Programme)
SHS	Solar-Home-System
SMS	Short Message Service
SREP	Scaling Up Renewable Energy Program
SSA	Sub-Saharan Africa
STC	Standard Test Condition
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
US$	United States dollar
USAID	United States Agency for International Development
WB	World Bank

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Note

- Currencies used in this report are given in United States dollars (US $) or in European euro (€) with the euro rates converted based on www.oanda.com (1st November 2016, Interbank +/-0%) as not all literatures used stated the dates of exchange rates. Nevertheless, I accept all errors that may occur in exchange rate.
- A "." is used as a decimal separator while a "," is used as a thousand delimiter.
- VA (Volt-Ampere) is used for the nominal power of diesel & biofuel gensets, W_p (Watt peak) is used for the nominal power of PV systems, W (Watt) is used for the nominal power of hydropower plants, and W (Watt) is used for the total installed generator power of hybrid systems.
- The term "*universal access*" refers to 100% electricity access.
- The term "*region*" refers to the Economic Community of West African States (ECOWAS)
- Except stated otherwise, the term "*target*" in this report refers to 100% electricity access by the year 2030.
- The ECOWAS member states comprise of 15 countries namely; Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo.

Executive Summary

The benefits of electricity have been well established which brings about socio-economic development and improves the quality of life. However, for the Economic Community of West African States (ECOWAS), having an average of 34%[1] national electrification rate deprives it of the full benefits. Furthermore, if the challenges of the low electricity access are not overcome, studies point to the fact that it will be impossible to achieve the Sustainable Development Goals (SDGs). Recognizing this, the region has committed itself to achieving universal access by 2030. Instrumental is improving the rural electrification rate currently at an average of 18%[2]. Clean Energy Mini-Grids (CEMGs) will be one of the approaches taken to improve rural electrification, which is estimated to cater for 25% of the rural population with a target of 128,000CEMGs.

Although progress is being made, the implementation pace is slow with less than 300 operational CEMGs in the region with very few countries being at the forefront and the others trailing, no country is on track. Achieving significant results will involve all stakeholders, (government, private sectors, development partners, financial institutions), technologies, business models etc.

The report aims to close the wide gap in terms of information and analysis of field experiences. The extracted information is to be used to build the capacities of policy and decision makers, project promoters and investors to improve the enabling environment in order to accelerate CEMG investments in ECOWAS member states.

Not all countries in the region have the right enabling policies and regulatory frameworks to attract private participation. This as well as challenges in access to finances to implement sustainable projects are some of the barriers hampering the scale-up of deployment of CEMG systems. The right financial scheme, management models, technology and customer base are key elements in having sustainable models, but it is also important to state that no single business model provides a universal solution, collectively all models have to be implemented to accelerate rural electrification in the region.

Finally, all stakeholders have major roles to play with the government providing enabling environment in terms of policies and reducing the risks and uncertainties in order to attract private participations, the private operators bringing their experiences and investments, and the populace accepting the change.

[1] This is calculated using the average national electrification rate of the individual countries from the World Energy Outlook 2015 data.
[2] This is calculated using the average rural electrification rate of the individual countries from the World Energy Outlook 2015 data.

1 Introduction

1.1 Objective of the project

The Economic Community of West African States (ECOWAS) region comprising of 15 countries has an average electricity access rate of 34%, the lowest in the world. Consequently, the biggest contributor to its low rate is the rural access accounting for an average of 18%, with over 60% of the population. Figure 1 shows the electrification rate of member states. The United Nations Development Programme (UNDP) ranks 11 of the 15 member countries as Least Developed Countries (LDCs) - a social economic development indicator - and the lack of electricity and modern energy deprives the region of its benefits (economic, social development) which creates a stumbling block to the achievement of the UN's Sustainable Development Goals (SDGs).

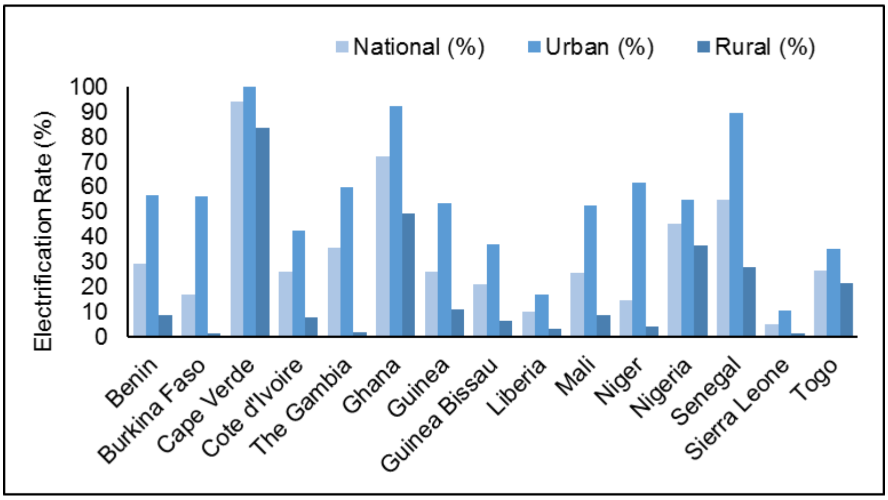

Figure 1. Electrification rate of member states [1]

In 2010, the UN initiative for a Sustainable Energy for All (SE4ALL) was initiated with 3 key objectives of: providing universal access to modern energy, doubling the energy efficiency rate and doubling the share of Renewable Energy (RE) in the energy mix, by 2030 compared to 2010, with at least 40% being Renewable Energy Technologies (RETs), which also contribute to the Sustainable Development Goals (SDGs).

The region's average electricity access had increased by 51% between 1990 and 2010 (20years), corresponding to a population increase of 71% [2]. Committing to the SE4All's goal implies an electricity access of 100%, inferably, means improving access by a staggering 194% (20years). By 2030, the region is estimated to reach a population of 500 million [3] [4], with the rural population accounting for at least 40% [5]. This shows that improving rural electricity access is pivotal to achieving the global goals.

Mini-grids, solar-home systems (SHS), and grid extension will be the 3 main approaches to achieving this goal. CEMGs have proven to be more cost effective and quicker in implementation as opposed to grid extension for remote rural locations, and low density areas. Senegal and Mali leads the region in promoting CEMGs with at least 100 operational systems, with the rest countries lagging behind. Committing, ECOWAS has adopted the ECOWAS Renewable Energy Policy (EREP) which aims to achieve a target of 128 000 mini-grids across the region by 2030 compared to 2012, at a cost of €31.6 billion (US$34.6 billion) to serve 104.3 million inhabitants [6] [7]. To achieve this target an implementation pace of 23 mini-grid/year/1million inhabitants (2010) during the period 2012 – 2030 should be respected. This is expected to address the needs of 25% of the rural population according to the ECOWAS rural RE target.

Not all countries in the region have the right enabling policies and regulatory frameworks to attract private participation. This as well as challenges in access to finances to implement sustainable projects are some of the barriers hampering the scale-up of deployment of CEMG systems.

There is still a wide gap in terms of information and analysis of field experiences and lessons learnt to build capacity of other countries. The overall objective of this report is to contribute to closing this knowledge gap by mapping, assessing and analysing the almost 300 existing operational clean energy mini-grids experiences. The extracted information will be used to build the capacities of policy and decision makers and project promoters and investors, to improve the enabling environment in order to accelerate clean energy mini-grids investment in ECOWAS member states. This is a necessary condition for widespread promotion of CEMGs in West Africa.

This chapter briefly introduces the entire report and looks at the drivers influencing the report, followed by chapter 2 which presents the methodologies applied then chapter 3 presents the literature basis for this report, chapter 4 provides the results of the assessment and chapter 5 discusses qualitatively and quantitatively the results of the mapping and provides recommendations to accelerate CEMG deployments in the region, and finally chapter 6 concludes the report.

2 Methodology

2.1 Overview

This section presents the methodologies applied in this report. Figure 2 shows the work plan generally in the order; review of existing literatures, structuring of questionnaires for data gathering in the official languages, quantitative and qualitative analysis, mapping of data and finally wrapping-up phase, with some sections carried out concurrently.

The EREP baseline targets are the basis for any justifications, calculations and analysis. According to the policy adopted in 2013, if the region is to achieve the White Paper's target by 2020 and universal electricity access by 2030, 60,000CEMGs will have to be implemented by 2020 and an additional 68,000 by 2030 alongside targets for grid connected, and solar home systems (SHS) for rural electrification.

The initial step of defining the information to be collected and analysed is critical for the success of the analysis. A review of the existing literature on CEMGs were combined with inputs from the ECREEE's Rural Electrification team. A balance was sought between the depth of the analysis and the willingness of the stakeholders to provide information.

The methodology for the report involved data collection (using ECREEE's network, both local and international), mapping and finally analysis. The method of data analysed was approached in two levels; quantitative (level 1) and qualitative (level 2). Although, should be the ideal case, the availability of data in the region is still one of the biggest challenges to the full scale deployment of CEMGs, which is what this report aims to resolve. The ECOWAS region comprises of 15 member countries of 3 languages: 5 Anglophones, 2 Lusophones, and 8 Francophones. In order to facilitate quicker responses, the questionnaires were prepared and communicated in the respective languages.

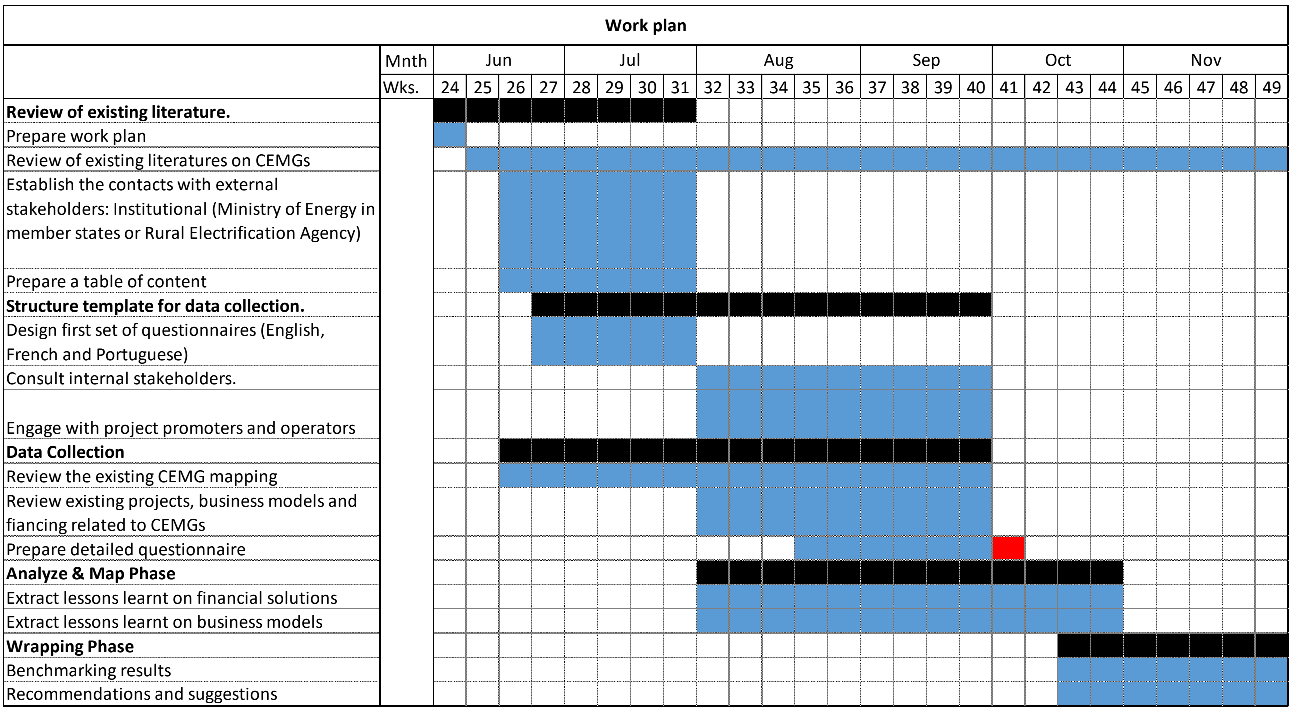

Figure 2. Report work plan.

2.2 Data collection

The approach of data collection was in two steps;

- Level 1: National institutions
- Level 2: Promoters

Level 1: The first level was to request for information on all the existing and known CEMGs from the national institutions (ministries, directorates, agencies etc.) of member countries' in charge of CEMGs deployment in order to gather basic information such as the numbers, locations, sizes and technologies of the existing CEMGs if any. Fifty-one (51) people were contacted in total. These national institutions are the main authorities of the individuals' countries and hence, information received from them are expected to be authentic. In addition, to advance to the second-level of data collection, contacts of promoters (private operators, NGOs, development partners) were requested through the national institutions.

Level 2: The second level involved contacting promoters (NGOs, governments, development partners, and private operators) to require on information requesting technical, financial, management, and performance information of the existing CEMGs, from their perspective. Nine (9) promoters were contacted, with feedback received from four (4), of which three (3) are presented in Chapter 4. Additionally, previous data from ECREEE was also used.

The mode of interview and communication were mainly electronic with few physical interviews majorly with ECREEE's staff in charge of some CEMGs projects. Details on the questionnaires are available in Annex I.

2.3 Analysis

A quantitative analysis was carried out based on the results of the first level to determine the numbers of CEMGs and the distribution across the region, the dominant technology in terms of capacity and number.

A qualitative analysis was carried out for the second level, where both comparative and contrasting analysis were done from data received from the different promoters of CEMGs in the region. The conclusions focus on financial, management, operation and maintenance solutions to be learnt, moving forward to successfully scale-up the deployment of CEMGs across the region.

2.4 Response Rate

The response to requests from the national institutions in a timely manner was low, and this data was key to the success of the report. Three reminders were sent out, after the initial request for data. The 1st, 2nd and 3rd reminders were sent 4 weeks, 2 weeks, and 4 weeks respectively after the preceding reminders. 2 out of 15 (13%) responded within the time frame of the first mail sent, 2 more countries responded after the first reminder, then 3 more countries after the 2nd reminder and by the 3rd reminder, data had been received from 10 countries.

In situations where no data was received, previous data, and information on the internet were used. The number of existing CEMGs in the region hence indicate the minimum numbers and not the exact figures.

Regarding level two questionnaires, none of the promoters provided information within the predetermined agreed time (2 weeks). Hence the deadline was extended for another week, within which 3 responses were received and the fourth response received the following week. In total, response rate was 40%, including the extension.

Currencies are given in United States dollar (US $) or in European euro (€) using www.oanda.com (1st November 2016, Interbank +/- 0%). Any error which may occur in exchange rate is accepted by me.

To determine the total capacity of hybrid systems in W (Watt); the value of solar PV in W_p (Watt-peak), wind generator in W (Watt), biodiesel & diesel generators in W (converted from VA (Volt-Ampere), with a power factor of 0.8) were added-up depending on the hybrid combinations.

3 Literature Review
This chapter presents the literature basis for this report. It consists of definitions of terms, the importance of CEMGs and business models currently in practice.

3.1 Definition of Clean Energy Mini-Grids
The definition of Clean Energy Mini-Grids still seems a bit vague as, while for some, the term mini-grids is collectively used to refer to mini/micro and nano-grids, some definitions make a distinction based on power capacity [8] [9] , and others based on capability and complexity [10]. However, there is no universally accepted definition [11]. What is clear is that, mini/micro/nano-grids are isolated grids (small-scale electricity generation) which serve a limited number of customers (households, businesses, hospitals, schools etc.), through a distribution network, often having no access to the main utility grid, yet capable of offering similar quality of electricity as those connected to the grid. [8]. The term “Clean Energy” differs also relative in its definition, often defined as energy resource that is sustainable (replaced by a natural process at the same or faster rate than it is consumed)[12].

For the purpose of a working definition of this report, the UN’s Sustainable Energy for All (SE4All) definition will be adopted which defines Clean Energy Mini-Grids (CEMGs) as mini-grids which are powered by either renewable energy, or a hybrid of renewable energy and fossil fuel generation, which may include an energy storage technology [13]. In simpler terms, a CEMG is a mini-grid with a source of energy generation being renewables or a mixture of fossils and renewables, termed hybrid. On purpose a classification by quantitative figures (kW installed or households supplied with electricity) is not applied here. However, in chapter 4 some statistics will give an idea on quantitative figures of implemented systems.

3.2 Brownfield and Greenfield
The definition of *brownfield* and *greenfield* are industry specific. Quite a few define a *greenfield* project as one that does not have limitations (present designs, physical structure, land space) imposed by an existing project. This provides wider flexibility in terms of project execution. In contrast, *brownfields* are projects associated with modification (upgrade, renovation, etc.) of existing structures [14] [15].

On this note, brownfields are mini-grid projects that involves modifications (capacity increase of same technology, addition of other RE technologies, redesigning of the existing system to meet the type of costumers etc.) of an existing mini-grid. In this case the flexibility of any modification is limited, as modifications have to be done around the existing structure. On the other hand, greenfield are mini-grid projects (either purely renewables or a hybrid) that involves constructing a mini-grid from scratch, on a bare land. In this case, the flexibility of designing and installing such projects are vast, and not limited to the specificity of existing structure.

3.3 Why Clean Energy Mini-Grids
This section highlights the abundant RE sources in the region, the benefits CEMGs bring and the need to shift from fossil based mini-grids to CEMGs.

3.3.1 Fossil based mini-grids.
Up until recently, the approach to improving electricity access in most West African countries was and is still largely based on the extension of network grids. This approach

had mostly yielded little results[3], mainly due to financial, economic and management hindrances. As a result, some countries like Mali and Senegal embarked on large scale decentralized rural electrification programs, constructing mainly diesel based mini-grids as opposed to RETs, as a viable solution to improving access to the rural communities [8] [16]. Few years down the line, the oil price volatility, transport costs and the reliance on imported fuel sources have made the operation of these mini-grids expensive, non-profitable and unsustainable, and in some cases abandoned. Isolated systems such as CEMGs have proven to be a viable approach when it becomes uneconomical to rely on extension of the grid [17].

3.3.2 Renewable Energy Resources

The region is blessed with abundant and free renewable energy resources. Figure 3 to Figure 5 show the mean solar irradiance, the mean annual wind speed at 80m above ground level, and the mean annual precipitation respectively. Nearly all regions experience an average solar irradiance of 200W/m^2 with little seasonal variation - very ideal for PV installations; some regions have favourable mean annual precipitation and adequate topography for hydro power plants; and some areas where wind energy can be utilized.

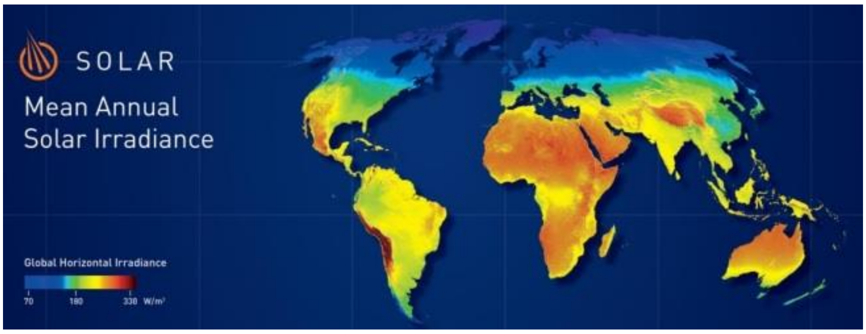

Figure 3. World solar resource map [18]

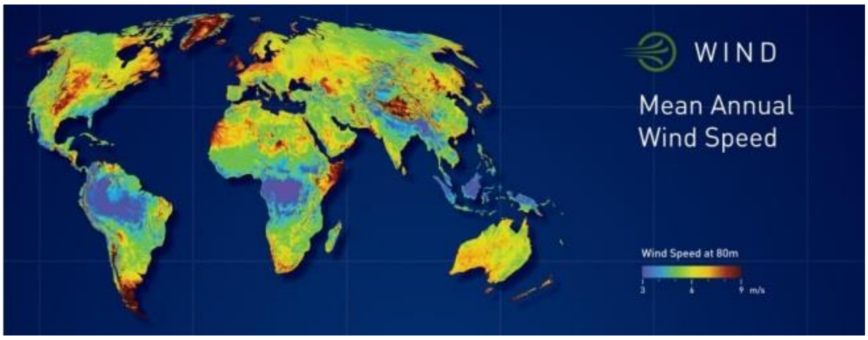

Figure 4. World wind resource map [18]

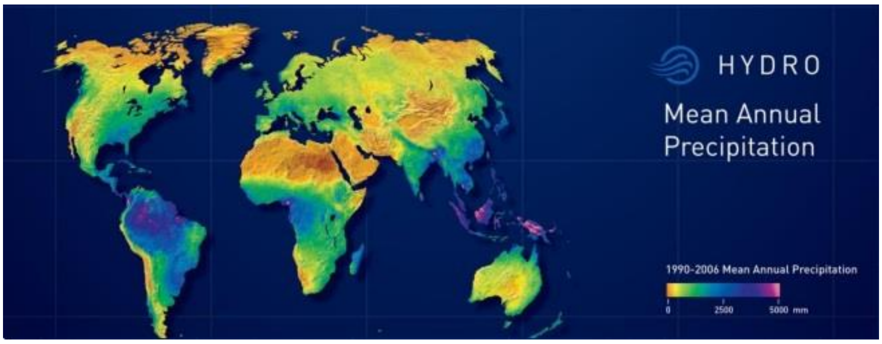

Figure 5. World hydro resource map [18]

[3] With the exceptions of few countries like Ghana, Cape Verde.

High RE electricity prices have been a limitation to its development in the region, however, PV prices have reduced by more than 70% in 6 years (2009-20015) [19] [20], other RETs are not being left out with onshore wind energy reaching grid parity in some countries [20], and PV electricity prices have also been forecasted to reduce by 59% by 2025 from 2015 prices [19].

The reduction in RE prices, abundant resources, challenges of fossil based mini-grids, and challenges of grid extensions have made CEMGs an attractive solution in tackling the region's low electricity access.

3.3.3 The need for CEMGs

ECOWAS accounts for 16% of the estimated 1.2 billion inhabitants without access to electricity worldwide [1]. With an estimated 330 million people, this represents over 60% of the population, with the rural areas accounting for the lowest access rates. Figure 6 illustrates an overview of the rural electricity access of the member states which shows only 2 countries (Cape Verde and Ghana) having a rate greater than 40%, with more than half of the population being rural.

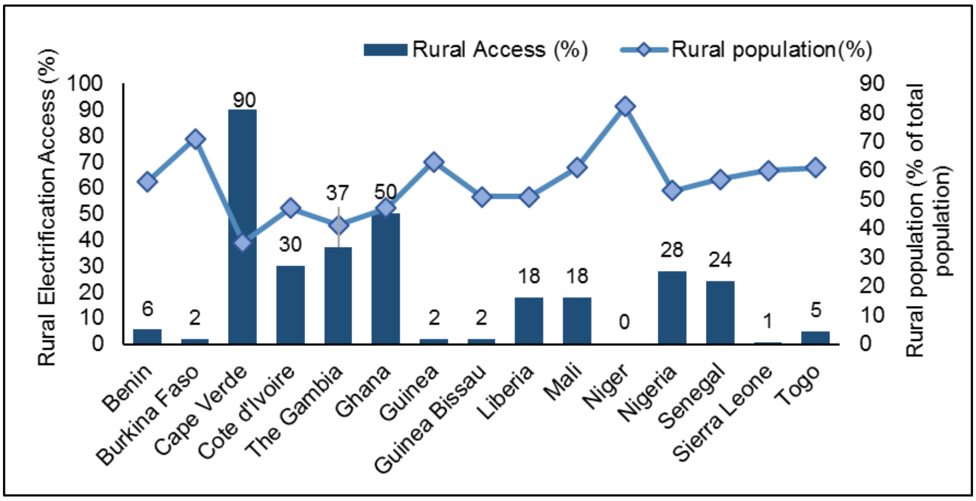

Figure 6. Rural electrification vs population of ECOWAS members. Data source [1], drawn by author.

3.3.4 Benefits of Clean Energy Mini-Grids.

Access to electricity brings about socio-economic development, improve in standard of living etc. Figure 7 shows a correlation between electricity access and the Human Development Index (HDI). According to the 2014 UNDP data, only 3 out of the 15 ECOWAS countries fall above the average HDI for Sub-Saharan Africa (SSA)-0.502, and none falls above the world average HDI - 0.702.[21] (see Annex V). Rural electrification in practical terms will lead to more study times for schoolchildren, springing up of small-scale businesses, safer health and consequently, higher quality of life etc. Studies also point to the fact that it will be impossible to achieve the SDGs, improve on the poverty rate in the region without improving access to electricity.

CEMGs in rural areas provide energy security, cleaner and in some cases cheaper electricity. An estimated 104.3 million people in the region stand to benefit from the 128,000 mini-grids expected to be installed by 2030 [6] [7].

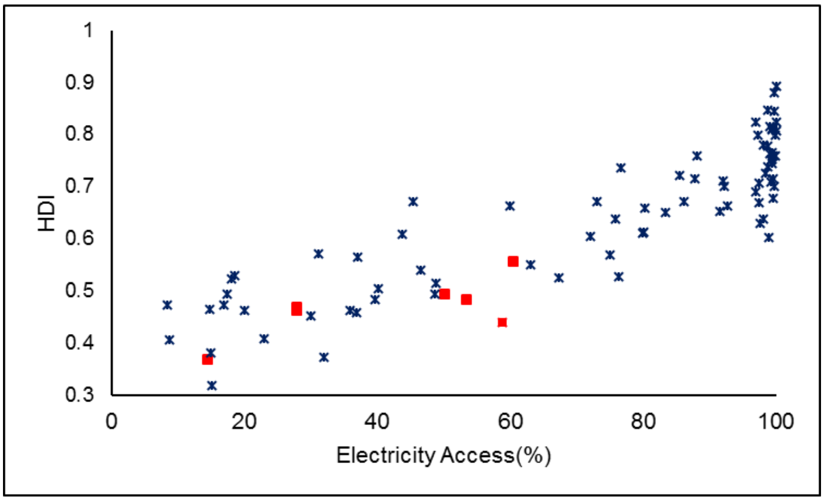

Figure 7. HDI vs electricity access of selected ECOWAS members. Data source [21], drawn by author.

3.4 Business Models

This section covers the common business models, financing schemes and tariffs adopted for rural electrification programs.

3.4.1 The Models

The increase in CEMGs deployment have brought about different business models depending on the local factors. There is no perfect model that works for all, and the local environment has to be critically studied before deciding on the business model approach. The legal and regulatory frameworks if any, acts as the main criteria for selecting which business model to apply.

Classification of models is not as straight forward as thought, nevertheless the important factors considered lies with the roles and responsibilities of the main actors in terms of who invests, owns, develops, maintains, and operates. Several literatures broadly categorise the business models into 4 main types as shown in Table 1

Community based models	*Private based models*	*Government-based models*	*Hybrid based models*
The community owns and manages all aspect of the grid (tariff collection, O&M&R etc.)	A private actor is responsible for all (construction, operation, maintenance) aspects of the grid.	A public institution (national utility company, ministry of energy, rural electrification agency) manages all aspect of the grid.	A combination of any of the other models depending on terms of contracts, with the goal of maximising effectiveness and efficiency.

Table 1. Business models in mini-grids [22] [23]

Traditionally, rural electrification in ECOWAS member states had been handled by the national utility companies but the level of success has been low compared to other regions in the world. Figure 8 shows SSA (which comprises of ECOWAS member states) having the lowest rural electrification rate. Most utility companies lack both the financial resources and the technical know-how to effectively manage these systems. Taking advantage of the private sector in terms of funds, experience, management insight etc. are encouraged if the 100% electricity access by 2030 is to be met by the region. The hybrid based models creates a symbiotic synergy between the private and the public sectors.

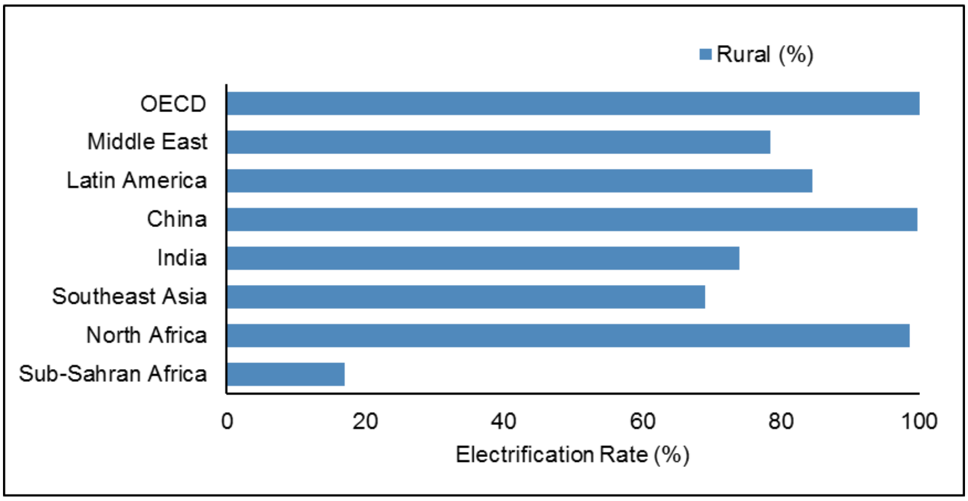

Figure 8. Rural electrification rate of regions. Data source [1], drawn by author.

The hybrid business model encourages a combination of other models most often through public private partnerships (PPP). They can be broadly categorized into two namely [24]:

- PPPs based on contractual PPP (concessions, lease); long term basis, typically greater than 15 years [25], and stating which entity absorbs the investment risks, commercial risks, ownership of assets, operations of the system between the public and the private partners. This model is more common in the ECOWAS region.
- Institutional PPPs: an independent entity formed by both parties, and terms clearly stated on the roles of each party.

The community model (co-operatives, local association etc.) has recorded success in the region in countries like Cape Verde, Burkina Faso, Sierra Leone. This model is more common in areas with low government or private interests[22]. The model encourages ownership and could be very efficient, yet the major setback is the lack of proper technical and business skills to manage rural electrification programs. Community involvements can be in different forms from the entire management of the grids to dedicated responsibilities such as repairs, revenue collection, awareness etc. These models are often supported by NGOs, development partners mostly in terms of trainings, capacity developments.

3.4.2 Financing Schemes

11 of the 15 ECOWAS member states are among the 30 poorest countries in the world in terms of GDP (nominal) per capita. Liberia, the poorest in the region with a GDP per capita of US$474 (41 times lower than the world's average of US$19,463), and Cape Verde, the richest in the region with a GDP per capital of US$3,039 (lower than the world's average by a factor of 6) [26]. The region will require external investment if it is to achieve the target[4], in fact access to finances have been the main obstacle to CEMG deployment, hence the need for external financing partners and financing schemes to eliminate or at least suppress this obstacle. Sources of finance are from international donors, government budget allocations, connections fees, private investors, NGOs etc. through loans, grants, donations, penalties, taxes, private funds etc. Despite the active participation of international donors in the region, many countries have not recorded successes in

[4] By EREP estimation, an average of €2billion yearly is expected to be spent on CEMGs investments to achieve 2030 target. Using 2014 World Bank data, this presents 0.34% of ECOWAS nominal GDP. Nonetheless, Nigeria (oil-dependent nation) whose nominal GDP represents 70% of the regions' allocated in its budget, 59.81billion naira (€178.5m) for its power sector representing 0.07% of its GDP at US$77.5/barrel.

attracting adequate funds for rural electrification programs and also appear to lack the means to achieve this [27].

The evolution of rural electrification programs across the world have resulted in two broadly based financing schemes in Africa namely [27]:

- Rural electrification is implemented solely by the national utility, having strong internal financial support e.g. Morocco, Tunisia
- Rural electrification is implemented by an independent entity (Renewable Energy Funds and/or Agency REF/REA, etc.) comprising of public and/or private parties (NGOs, local associations, development partners etc.) with funding sourced both internally and externally. e.g. Senegal, Burkina Faso, Congo, Nigeria etc.

3.4.3 Tariff Setting

A proper tariff design is an important aspect which has to be given strong attention in terms of legal frameworks and planning [17]. Currently, ECOWAS member states have some of the highest electricity tariffs in the world. In fact, Liberia has the highest electricity tariff in the world [28] as seen in Figure 9. The overall goal in designing and setting tariff is to strike a balance between the willingness, ability of the customers to pay and ability to cover project lifetime cost.

Several tariff structures have been implemented with regards to CEMGs. The option to choose one over the other should depend on localized conditions. Common practices are to design tariff based on energy consumption e.g. Bangladesh, Thailand, Nigeria [29] [30]; based on power demand e.g. Nepal [29] [30]; based on a combination of energy and power e.g. Bhutan, Senegal, Cape Verde [30]; based on per electrical device/node (sockets, bulbs) e.g. India [30]; Time-Of-Use (season, off peak/on peak,) e.g. Brazil [30]; or as a service (per kg, litres etc.) [29].

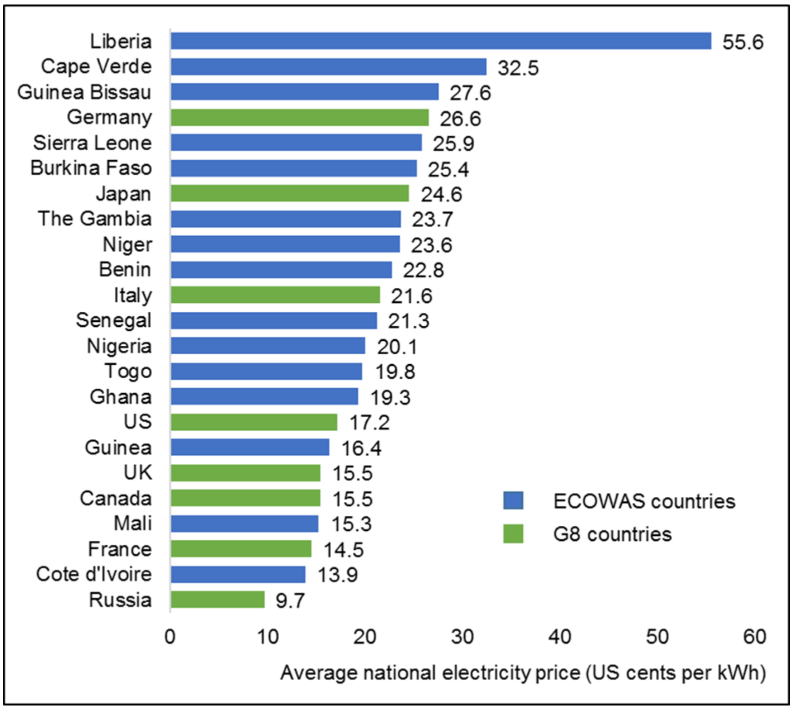

Figure 9. National electricity prices of ECOWAS and G8 countries. Data source:[31], drawn by author

For CEMG projects to be sustainable, tariffs should cover at least the running and maintenance costs, and desirably the investment costs [32] [33]. The issue then lies on either to implement a standard tariff: in most cases, are lower than the actual cost of producing electricity through CEMGs and hence requires some sort of incentives and it is also unattractive to private investors, or a cost reflective tariff; favourable to private investments (enables private operators to recover their investment costs in the long term), but the consumers’ pay more.

4 Results

This sections presents the results of the data collected across the region.

4.1 Mapping

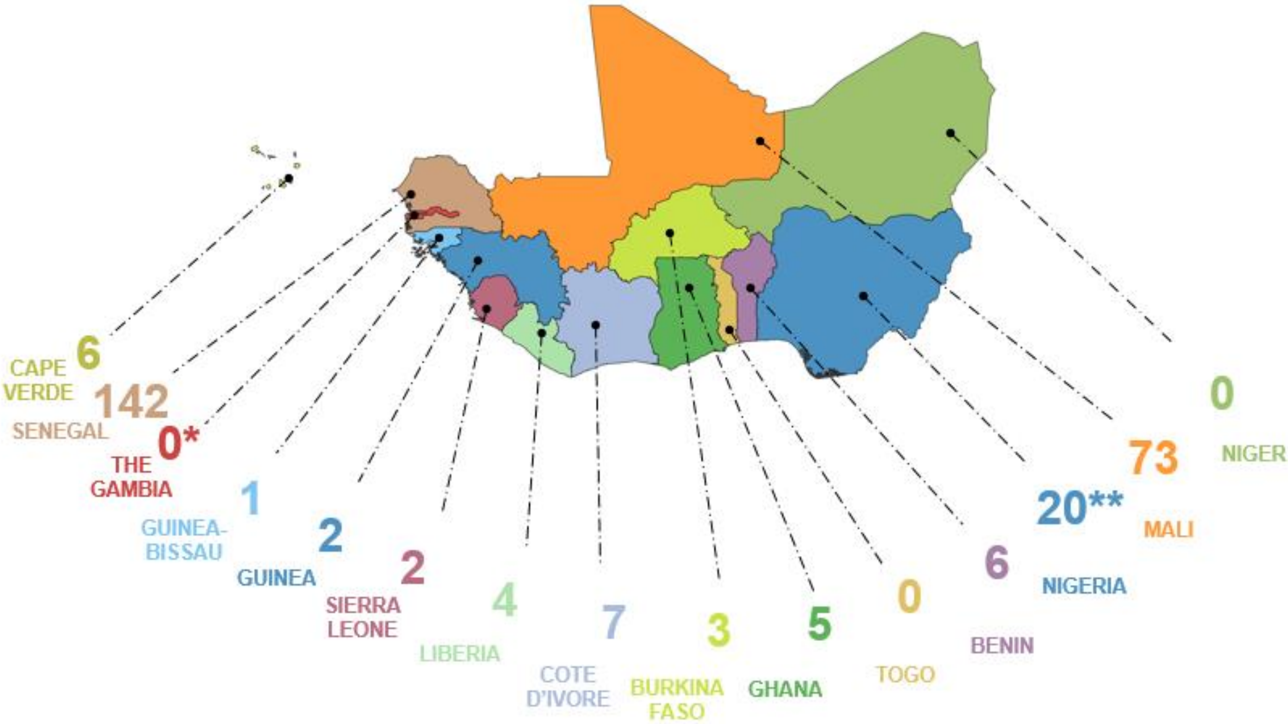

Figure 10. Country wise mapping of existing number of CEMGs in ECOWAS region. Source: Author

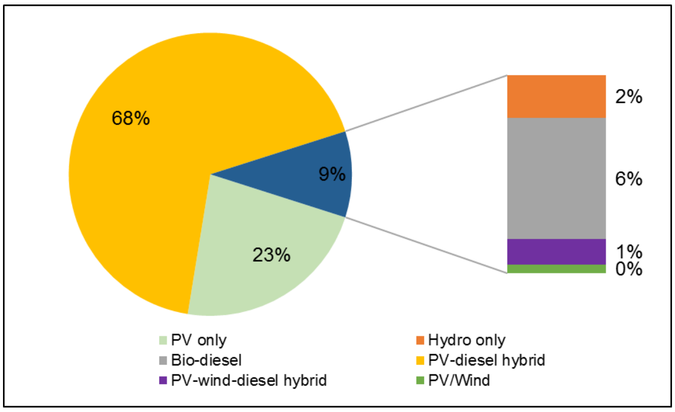

Figure 11. Share by technology Source: Author

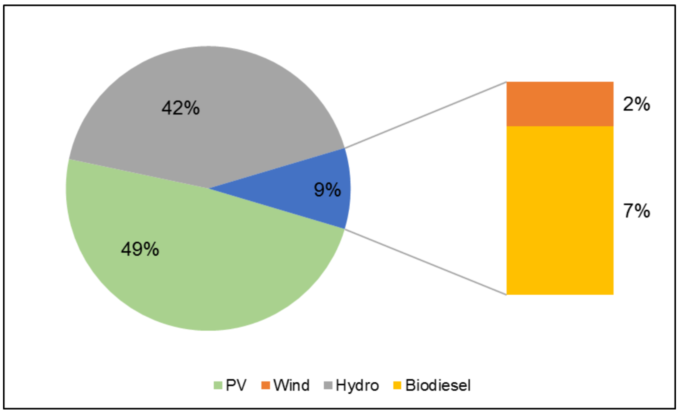

Figure 12. Share by capacity. Source: Author

Figure 10 - Figure 12 provides basic information on the countries with existing CEMGs, their share by technology and capacity. The region has a minimum[5] of 271 existing CEMGs with a total capacity of 11.6MW[6] of which 97% are operational. Also, at the time of writing this report, there are 1,165[7] identified planned CEMGs in the pipeline. (see Annex III). The average size per installation of the existing CEMGs is 50kW.

The top 3 countries with the highest numbers of CEMGs are Senegal, Mali and Nigeria, with the bottom 3 countries being The Gambia, Togo and Niger, all having no existing CEMGs. The Gambia had one existing CEMG (previously an 8.3 kW_p PV-hybrid, but now

[5] Most information for Nigeria were gotten from the internet.
[6] This excludes the capacities of the fossil-based generators in the PV-hybrid systems
[7] Nigeria accounts for 48% of the identified planned CEMGs.

grid-tied through a 20.7 kW_p). Senegal alone accounts for half of the entire existing CEMGs, while collectively with Mali, they represent 80%.

Solar PV is the dominant technology in terms of capacity. This is attributed to the abundant solar resource and its maturity in the region. It accounts for over 50% of the CEMGs installed, mostly occurring as PV-diesel hybrids. Wind energy is the least matured in the region, only accounting for about 2% of the total. This is not unrelated to the fact that not all countries have satisfactory wind speeds, and the technical knowledge for installations and maintenance is still low.

Capacities range from 2.25 kW_p (solar PV plant in Cape Verde) to 4.8 MW (small hydropower plant in Liberia). The largest PV and PV-diesel hybrid systems are in Mali (384 kW_p/675 kVA). Approximately, every 6 out 10 CEMGs are powered by PV-diesel hybrids system (with diesel systems mostly only acting backups) with PV-wind, PV-wind-diesel, mini-hydro plants collectively representing less than 5%. Senegal (142) has the highest number of CEMGs in the region but Mali (73) having twice as less CEMGs, has over threefold more installed total capacity at 4 MW as compared to 1.3MW of Senegal as shown in Figure 13.

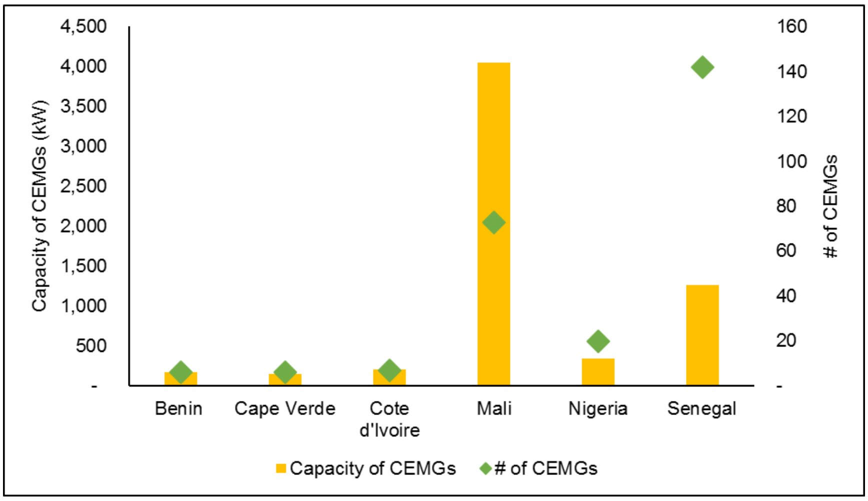

Figure 13. Top 6 countries (Number & capacity of CEMGs)

The two largest PV-diesel hybrids are located in Mali, each having a 384kW_p and a 675kVA installed generator capacity in the villages of Koro and Bankass implemented in 2013 through a collaboration between the national energy supplier (EDM) and a private company (ZED-SA) and the public bank. An ongoing hybridization project by the same partnership when completed will have a capacity of 649 kW_p[8]. It is worth noting that in 2011, Mali constructed a 216 kW_p PV-hybrid system in Ouéléssébougou village, however the demand doubled within a year, leading to an upgrade to an installed capacity of 334kW_p in 2015. This shows the modularity of PV systems, and the importance of future demand considerations during initial design stages.

In terms of total installed capacities at the national level, the biggest PV installations are in Mali with a total capacity of 3 MW_p, while the lowest are in Liberia with a total capacity of 10kW_p. Although very few wind installations exist in the region, the country with the highest total wind installed capacity is Mali with 188 kW, and the lowest is Senegal with 5 kW. Biodiesel plants are still at its infant stage of development in the region with only Mali &

[8] Two projects in the villages of Nara & Diéma of 649 kW_p, 1325 kVA PV-diesel hybrid

Liberia[9] having existing plants. Nonetheless, several countries like Nigeria[10] and Cote d'Ivoire are expressing interests in the technology.

The total installed capacity across the region relating to CEMGs stands at 21 MW[11], including diesel generators, which represent 49%. This is as expected as fossil fuel based generators were used as the energy source in mini-grid installations though the region has lots of RE sources and potential for renewable energy technologies (RETs). Across the region, there are lots of projects ongoing to hybridize other existing fossil-based plants.

The average size of PV-diesel hybrid system is 28 kW_p/60 kVA, with diesel to PV ratio of 2.14. One hybrid diesel-wind exists (Mali) and there are 2 PV-wind-diesel hybrids in the region. The average size of PV-only plant is 16 kW_p.

The small-hydropower potentials have not been fully exploited, as the region has very few plants and ECREEE is taking the initiative to promote small hydropower plants across the region.

The PV installations have been grouped in terms of capacity shown in Figure 14 into;

- small sized (<30 kW_p), average size of 13 kW_p, (197 PVs)
- medium sized (30 kW_p – 150 kW_p), average of 52 kW_p (34 PVs) and,
- large sized (>150 kW_p), average of 327.5 kW_p (4 PVs)

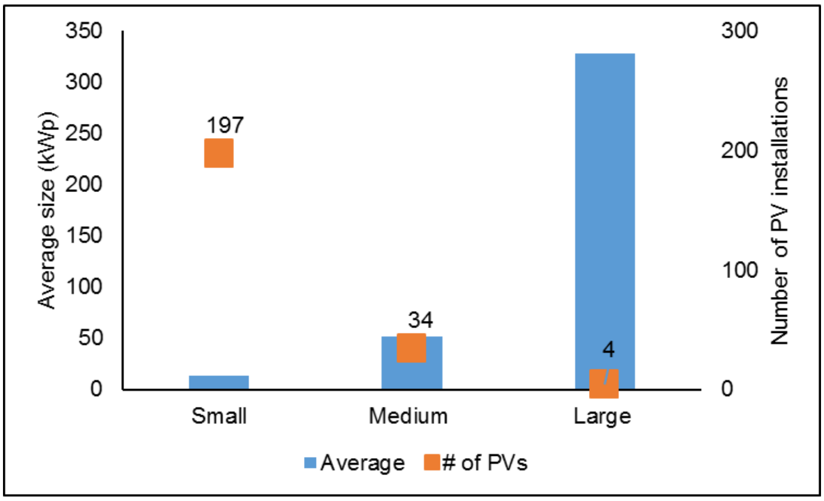

Figure 14. Distribution of PV installation by category.

Table 2 shows the average capacities of the CEMGs by technology mix, Table 3 shows the locations of the largest and smallest CEMG plants and Table 4 shows the locations of the largest and smallest RE generation sources in terms of wind and solar technologies.

Technology	*Average size*
PV-diesel hybrid	28 kW_p/60 kVA
PV only	16 kW_p
PV-wind-diesel	22 kW_p/8.3 kW/30 kVA
Biodiesel	75 kVA

Table 2. Average sizes of CEMG technology mix

[9] With funding from the USAID, another biomass-powered mini-grid is being implemented.
[10] The Nigerian government plans to construct a 5MW biomass mini-grid as a demonstration plant. The objective is to promote biomass based mini-grid as an alternative to diesel based energy generation systems.
[11] This value is calculated including the capacities of the diesel generators (see Annex III)

CEMG plant	Category	Country	Village	Capacity
PV-diesel hybrid	Smallest	Mali	Kandia	6.9 kW_p/8 kVA
	Largest	Mali	Bankass & Koro	384 kW_p/675 kVA each
PV only	Smallest	Nigeria	Uniarho	2.4 kW_p
	Largest	Benin	Kabo	45 kW_p
PV-wind-diesel hybrid	Smallest	Senegal	Sine Moussa Abdou	5 kW_p/5 kW/10 kVA
	Largest	Ghana	Pediatorkope	39.5 kW_p/11 kW/30 kVA
Biodiesel	Smallest	Mali	Sido	9.2 kVA
	Largest	Mali	Garalo	375 kVA
Small-hydro	Smallest	Liberia	Yandohun	60 kW
	Largest	Liberia	Firestone Plantation[12]	4800 kW

Table 3. Location & size of largest and smallest CEMG plants

RE Technology	Category	Country	Village	Capacity
PV	Smallest	Cape Verde	Xaxa - São Miguel	2.25 kW_p
	Largest	Mali	Bankass & Koro	384 kW_p each
Wind	Smallest	Cape Verde	Xaxa - São Miguel	4 kW
	Largest	Mali	Nara	188 kW

Table 4. Smallest and largest PV & wind installations

Also, among the existing CEMGs, no less than 12 owners, 20 promoters and 50 operators were identified comprising of NGOs, development partners, municipalities, local communities & associations and private operators.

4.2 Financing Contribution

Over 50% of the source of funding have been from development partners (European Union(EU), Global Environment Facility(GEF) and other international donors), either wholly or in collaboration with other stakeholders mostly in the forms of grants, soft loans, and debts as shown in Figure 15. The public sector funding alone accounts for less than 10% of the source of financing and the rest coming from both the private sectors, NGOs (including community, associations) in cash and kind e.g. subsidized labour, land donation etc. or as a combination of the different stakeholders. Nonetheless, the member states are now showing interests to promote private investments.

[12] This plant serves the isolated mini-grid belonging to Firestone rubber estate.

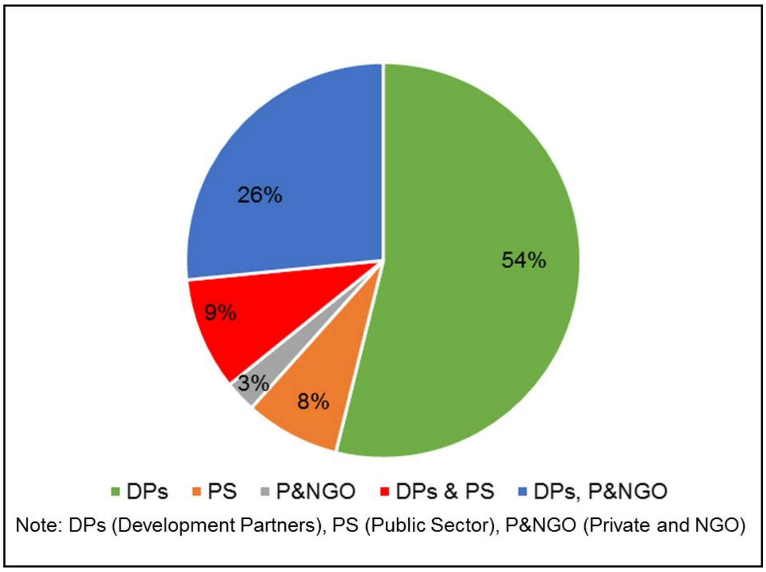

Figure 15. Contribution of financing.

4.3 Analysis of Projects (Level – 2)

The results of selected projects have been analysed in the succeeding sections. The aim is to show the different approaches taken by some countries in the region to maximise on the strengths and to avoid the mistakes of one model over the other. Specific cases have been looked at viewing the projects from the perspectives of different promoters namely: development partner, NGO and the private operator.

4.3.1 Zanzan Project in Cote d'Ivoire – UNIDO (Development Partner)

Background: 15million people with no electricity access. No independent agency, legal framework specific to CEMG or rural electrification agency exists in Cote d'Ivoire. The ministry in charge of energy oversees the entire energy sector, and the public utility implements projects. Cote d'Ivoire aims to achieve the universal access by 2020 with focus on improving the rural electrification access of 30% (2014). 7 PV-diesel hybrids (210 kW_p) in Zanzan region of Northern Cote d'Ivoire (Akwaba Project) under an EU-UNIDO collaboration have been installed in 2016. The villages selected had no electrification plan foreseen in the next decade. The project was implemented from a community based perspective. A standard tariff scheme exists but self-managed grids are exempted. Also at least 30 CEMGs are in the pipeline to be implemented with funding mainly in the form of grants. (see Annex VII)

Management: The community based model is adopted and they were involved in the participation of the projects from inception to completion. The communities of the 7 villages own and manage the grids. A 10-member "user association" with roles such as collection of fees, setting-up of contracts with consumers, being responsible for the running of the grids and decision making, dissemination of information to the locals; and a 12-member monitoring team comprising leaders of the user associations, village officials, local authority, business representatives monitor and assess the performance of the grid.

Technical**:** The PV capacities range from 20 to 40kW_p for the 7 villages, totalling (210 kW_p) with diesel backups ranging from 30 to 45 kVA totalling 255 kVA, inverters rated at 31.2kW for each village, and battery banks 48V each, a total of 36,900Ah C100 as storage backups and are sufficient to meet the village demands including the small businesses. Future demand growth factored based on an increase of population of 1% yearly, was considered with available space for upgrade. The entire grids are managed by the village association (trained in the operation and maintenance of the grids). Maintenance was categorized into 3 namely: basic, preventive and specialized maintenance all carried out by trained staff. This has resulted in 24 hours of electricity availability.

Financial: The project was implemented by UNIDO with major funding from UNIDO-GEF through grants and in-kind contributions. Total investment cost of €2.56m (US$2.8m); 94% by donations & grants, 6% from other sources. To ensure proper accountability, two bank accounts were created, a regular account for the daily running of the grid and a blocked account for unexpected replacement of equipment and extraordinary maintenance. As a way of control, the withdrawal of funds requires certain minimum signatories.

The average utility electricity tariff is 12.7 € cents/kWh but regulations permit cost reflective tariffs, hence in agreement with the community, the tariff was well-designed to match the customers' ability to pay and their energy demands with 7 different levels ranging from residential to religious centres and prices within 13.4 to 14.3 € cents/kWh (see Annex VI). Although higher, the consumers agreed and are paying. Tariff is based on energy consumed and power available with prepaid energy limiters used as metering system. The tariff covers all running, maintenance and replacement costs. The bills are paid monthly and a connection fee of €125 is paid the first time. The average CAPEX (including generation equipment, distribution grid and balance of system components[13]) and OPEX costs are 6,061€/kW and expected to be 88€/kW/year respectively.

Main issues**:** Weak legal & regulatory frameworks, challenges in mobilizing funds and lack of technical know-how by the local technicians.

4.3.2 GVE Ltd in Nigeria – The private operator

Background: An estimated 68million[14] people living in the rural areas do not have access to electricity, with current rural electricity rate at 28% (2015). However, Nigeria aims to achieve rural rate of 60% by 2020. The Rural Electrification Agency (REA) was established in 2006 to manage rural electrification but progress has been slow and most of the existing mini-grids instead have been implemented by private operators and NGOs through funding sourced personally or by development partners in the form of grants and loans. Also an REF is to be established, in which the government will provide subsidies on initial capital costs. Mini-grids of generation capacity below 1MW (cumulative), do not require licences to own, construct or operate and are unregulated. For the regulated CEMGs, cost reflective tariffs are permitted provided they are done in consultation with the prospective consumers with at least 60% acknowledging and accepting.

One of the main actors - GVE Ltd, a private operator has 5 existing CEMGs among the 20 identified in Nigeria upon which the analysis is based on. It also plans to implement 524 more across the country in phases.

Management: GVE Ltd owns, operates and manages all its grids.

Technical: All grids are PV-based with capacities ranging from 5 kW_p to 40 kW_p and having batteries ranging between 615Ah to 5500Ah, this results in electricity availability from 16 to 24 hours daily depending on the sites. All installations are upgradable with foreseen increase in demand.

[13] This refers to all components and equipment, excluding the PV modules in a PV plant which are used to convert the DC power to AC power. It includes switches, inverter, fuses, electrical cables, batteries etc.

[14] Using 2015 World Bank data, total population is estimated at 182million, rural population is at 52%, and the rural access is 28%.

Financial: The average utility electricity price is 18.3€ cents/kWh. Mini-grids under 1MW (cumulated) on-site are unregulated therefore a sustainable tariff was designed based on the customers' willingness to pay leading to different rates for types of consumers with collection methods through a combination of smart prepaid meters[15] with scratch cards. This tariff covers operations management, maintenance support, profit margin, and equipment amortization[16]. A connection fee of US$20(€18.2) is paid once. Source of financing were from development partners, local banks and personal funds through grants (37%), loans (69%) and other sources e.g. subsidized labour, land donation by the communities accounting for the rest. The average CAPEX (including generation equipment, distribution grid and balance of system components) and OPEX costs stood at 6,185€/kW and 124€/kW/year respectively.

Main issue: Importation of equipment& logistics, forex volatility, lack of local skills in the local communities.

4.3.3 Barefoot Women Solar Association in Sierra Leone – The Community/NGO

Background: Sierra Leone is one of the poorest countries in the world and still recovering from a civil war which crumbled the entire electrical structures. Once referred to as "the darkest country in the world", it aims to achieve universal access by 2030 from 12.5% (rural:0.5%) access in 2013. Neither a rural nor a regulatory agency exists. The rural electrification programme is managed by the Ministry of Energy but the only two existing CEMGs have been promoted by NGOs. A new RE policy is in progress and aims to attract private investors and promote private participation. Most recently, with funding from the UN, a rural renewable energy program has been embarked which aims to build fifty (50) PV mini-grids in the smallest and most remote villages by end of 2017.

The first CEMG was inaugurated in 2010. An off-grid PV system in the rural village of Kontaline promoted by the local community, mostly women through an association – Barefoot women solar association with funding from both the government and UNIDO. The entire grid is managed by a group of trained local women.

Management: A rather unique management system which has proven to be a success, although the system was constructed by the government, it is owned, and managed by the local committee (Barefoot Women Solar Engineer Association of Sierra Leone). All maintenance involved are carried out by the women association.

Technical: The system comprises of a $40kW_p$ solar PV with batteries as backup which provide 24 hours of electricity to the community. Consumption is based on power demanded hence energy meters are not installed to reduce the cost.

Financial: The average utility electricity tariff is 23.6€ cents/kWh, making it the highest in the region, however regulations permit cost reflective tariff. As a result, the tariff was designed in agreement with the community and accepted. The people are fully committed as they pay the bills monthly, based on different rates according to the power demanded. Consequently, these rates have been able to cover all repairs and maintenance of the system. No connection fee is paid. The average CAPEX (including generation equipment, distribution grid and balance of system components) and OPEX costs stood at 6,402€/kW and 274€/kW/year respectively.

[15] Smart prepaid meters are energy meters that require that consumers pay for their energy before they are used. This is done with the use of top-up scratch cards, which is inserted into the meters, and the purchased amount credited into the meter.
[16] Amortization is the steady payments of a loan, including interests spread over a period of time.

4.4 Investment costs & household size

Investment cost: Table 5 shows the range of investment costs of some of the existing CEMGs identified. The investment costs include the cost of PV modules, balance of systems and distribution networks. The information is based on 92 CEMGs comprising of ten (10) PV-only plants, eighty (80) PV-diesel plants and two (2) PV-wind-diesel plants. The lower range for the PV-diesel plants are influenced by the large scale systems in Mali ($266kW_p$ – $384kW_p$). (see Annex IV)

Technology	*No of CEMGs*	*Investment Cost (€/kW)*	*Average Cost (€/KW)*
PV-diesel hybrid	80	3,000 - 11,000	6,586
PV only	10	5,000 - 10,000	7,172
PV-wind-diesel hybrid	2	4,500 - 6,500	5,642

Table 5. Range of investment costs of existing CEMGs.

Household size: The average total capacity per household stands at 390W/household which falls into the category of Tier-2 of the SE4All Global Tracking Framework 2015 [34].

5 Discussions & Recommendations

This section discusses both quantitatively and qualitatively the results of the mapping and provides suggestions to accelerate CEMG deployments in the region.

5.1 Actual vs Planned Grids by countries

At 271 existing CEMGs in 2016, this is a long way from achieving the planned targets of 128,000CEMGs by 2030. Complying with the implementation pace of the EREP, the region should be achieving a minimum of 28,000 grids in 2016. This is a far cry from achievement at less than 1% of planned grids. Even countries like Senegal and Mali that represent 80% of the existing grids are lagging from their goals at current 12% and 5% respectively (see Annex II). Achieving the target is a collective effort and countries with no existing grids also need to intensify their efforts to promote CEMGs. Nigeria having the largest number of inhabitants without electricity access will have to implement more than 50% of the expected 128,000 CEMGs.

However, the targets were set with not all countries having the right enabling environments in place. First and foremost, if the region is to hit the ground running, all legal and regulatory frameworks should be in place. As a result of the Paris agreement in 2015, the developed countries have pledged over US$100 billion to clean energy investments in developing nations[35] but if the right environments are not in place, ECOWAS may be left out in the rapid development and implementation of a clean energy economy.

5.2 Finances

This section discusses the main financial contributors, the investments costs and the issue of tariffs.

5.2.1 Funding

Majority of the projects have been funded by development partners in the form of grants, donations and loans from external financial institutions. Although, local and regional financial institutions are beginning to increase interests in funding projects like the case of UNDP/BoI project in Nigeria, and the planned 105 CEMGs to be implemented in Benin (financed by a local bank), efforts have to be beefed up. (see Annex VII)

As one of the main challenge is the high capital investments involved, subsidizing the capital cost of projects will positively impact the scaling up. Mali and Senegal went for this approach with the results being evident, Nigeria is also looking into this option and has included in its mini-grid regulation (draft), and should be considered by other countries in the region.

5.2.2 Investment costs

The investment costs for the CEMG systems vary from 3,000 to 11,000€/kW depending on the type of project (brownfield, greenfield), technology (single or hybrid), country, year of implementation and PV penetration. The lower ranges were observed for the large scale projects and for projects where bulk procurements were made i.e. shipping, tax clearance etc. as compared to when equipment are purchased separately.

Comparing with existing literature, the Department for International Development (DfID) reference costs for Green Mini-Grids puts the cost of PV hybrids (1-150kW) between the ranges of 5,000 and 10,000 US$/kW (4,500 and 9,000€/kW) [11] which are similar with investment costs in the region.

5.2.3 Standard Tariff vs. Cost Reflective Tariff

Mali as well as Ghana among other countries operate a standard fixed tariff across the country but although being at the forefront in promoting renewable energy based mini-grids through private investments and partnership, the pace at which it started has slowed. For example, at the creation of the Malian Rural Electrification Agency — AMADER, it aimed to improve access from 1% in 2003 to 12% in 2010 which it achieved (in 2014, access was 18%) but it had failed on the 2015 target of 55%.

The partially successful feature was achieved by providing favourable conditions for private participation and investments through its World Bank (WB) funded private initiative termed PCASER. A rural electrification fund (REF) was set-up, which was used to support private operators by subsidizing up to a maximum of 80% of the investment cost of projects but AMADER also regulated and set the electricity tariffs which were lower than the true operating cost. The impact is that most private operators are not running profitable businesses which have further discouraged other interested operators. Although, the tariffs were designed in agreement with the private operators and the consumers' capability to pay, it was based on the fact that the consumers will pay on a monthly basis (predictable), which could then cover running and operating costs. In reality, most consumers are farmers and their sources of incomes are dependent on farming seasons and are intermittent. This has resulted in non-regular payments and the inability to cover operation costs.

If the standard tariff is to attract private investors, then the government must commit to paying the difference between the true cost of electricity generation and the standard tariff. This difference undoubtedly will have to come from allocation of funds. However, this should be discouraged because it increases the burden on the government with access to finance being the major challenge in the deployment and development of the system. Alternatively, new tariff models should be designed to capture income variations of consumers.

Then again, like in Nigeria, Cote d'Ivoire, Sierra Leone, regulations permit cost reflective tariffs. In all cases, either managed by the private operators, local associations etc. the flexibility of designing cost reflective tariffs which covers the true cost of the electricity have resulted in sustainable businesses. Although the prices are more expensive than the average utility prices, they were designed and set in agreement with the community-to-be-electrified and the consumers are indeed paying which shows that cost reflective tariffs works. Even if they are more expensive than the utility prices, they are cheaper than the next alternative source e.g. diesel, kerosene lanterns etc. (if one exists). For instance, Sierra Leone has one of the highest utility prices in the region, yet with proper consultation and a well-designed cost reflective tariff (higher than the standard), the PV isolated grid has been running for 6 years and the consumers are paying. Electricity has improved the lives of the people, supported and grown small business in the area. Prior to the mini-grid, no form of electricity was available.

As long as the to-be-electrified community/village is aware of the electricity prices they are to pay and are ready to accept the higher cost in exchange for the electricity services (which was unavailable or unreliable), governments should favour such policies as this is a win-win situation for all.

The impacts of the Zanzan project is yet to be felt but based on the cost reflective tariffs, the project is expected to be sustainable. However, at the time of writing this report, the mini-grids are not in use. One interesting concept of the Zanzan project which should be replicated depending on the size of the projects is the different tariff levels for different lifestyles and markets. The message passed across is that although cost reflective tariffs may seem unaffordable by some consumers, they are workable and the right way to go to attract the needed investments and participations. For remote areas where the consumers are highly underprivileged, then the government can intervene by subsidizing tariffs.

5.2.4 Subsidies

Applicable to all models, part of the investment costs includes the fixed assets e.g. construction of power house, electrical networks etc. and the generation assets e.g. solar panels, meters, batteries etc. which makes the costs high. Since private operators will only venture into businesses that are profitable and considerably of lower risks, subsidizing the capital investments by the government is one way to reduce these risks. Another way will be for the government to be responsible for the distribution networks and fixed assets which will significantly reduce the CAPEX to be invested, and the risks by the private operators. Should in case the main grid extends to the areas of operations, the risks are minimal as the private operators only need to take out their assets.

5.3 Business Models

A wide range of management models have been implemented with various degrees of results as no single model fits all. For instance, Burkina Faso opted for the utility-based model and has so far not been successful (3 PV-diesel systems implemented but not functioning which was attributed to lack of technical know-how, and over demand), Ghana chose the utility model but with good results, Nigeria is open to several models although the successful ones have been private based. Senegal and Mali have implemented the hybrid models of approach with high levels of success although the pace at which they started seems to be dwindling.

The Zanzan project is looking very promising which was designed more on the community models. Community-based models (local associations, municipalities) are dominant in Cape Verde and Sierra Leone and has shown that it is possible. The Zanzan model if successful can be replicated in similar areas of common peculiarities e.g. north of Cote d'Ivoire has similar ecological systems with Mali, Burkina Faso and Niger hence it is possible to replicate similar projects in these areas using the same models with little modifications if necessary.

The approach of Mali, like Senegal to operate using the hybrid based models have been effective, this has increased the participation of local operators and community associations in the management of the grid. Over 30 operators are managing different grids under a concession of 15 years but the inability to recover costs have discouraged more private participations.

In general, major challenges have been encountered in implementation of projects which hamper the development of CEMGs, of such are; access to funds, volatilities in foreign exchange, uncertainties/vagueness and absence of legal and regulatory policies specific to CEMGs, the inability to recover/uncertainty of recovering OPEX and CAPEX, and lack of manpower with adequate skills.

5.4 Recommendations

In no way are the recommendations exhaustive, but after interviews with stakeholders, analysis and also considering the major challenges encountered so far in implementing existing CEMGs, the following recommendations if realised will take the region a step further to advancing electrification access and consequently actualising the universal goals which all countries have committed to.

- Providing enabling policies: Across the region, very few countries have legal and regulatory policies specific to renewable based mini-grids. This creates doubts by investors on the regions' commitment.

- Clearly written regulations: The policies and regulatory frameworks should be clearly spelt out avoiding ambiguities. In terms of business models to be implemented, the ownership, management and operational responsibilities should be clear and explicit from the onset with legal obligations and penalties for violations. It is also important to state what happens when the national utility grid reaches the coverage of operation of a CEMG.

- Make bulk procurements: This reduces the investment costs and subsequently the tariffs to be charged in cases where cost reflective tariffs are permitted.

- Cost reflective tariffs: Scaling up CEMG requires the investment and participation of private operators and they will only participate in businesses that are profitable with low risks. Cost reflective tariffs provide that environment. However, the seasonality of payment by some consumers should be considered in calculations.

- Subsidize capital investment: The high upfront costs in mini-grids are discouraging, however if this cost is subsidized, it becomes more attractive, as the challenges associated with sourcing for funds are reduced. Other subsidies should be avoided or reduced to its minimum.

- Responsibility of fixed assets: The government should be responsible or subsidize fixed assets of projects, most especially the grid networks as eventually when the national grid reaches the areas of mini-grid operations, the infrastructure will already be existing. Connection subsidies should only be provided for the very underprivileged.

6 Conclusion

Progress is being made in the ECOWAS region but the pace is slow. Few countries are at the forefront of promoting CEMGs with the others lagging behind, yet none is on track to achieving the target based on current trends. Achieving significant results will involve all stakeholders, (government, private sectors, development partners, financial institutions), technologies, business models etc.

The majority of the source of funding have been from external development partners. However, the region needs to show commitments by increasing its contribution to funding of projects, and providing the right enabling frameworks to attract more investments and participations.

Large scale PV-diesel hybrids are feasible and have been implemented in the region with good results and should be promoted more as they have tendencies to reach a larger coverage. Notwithstanding, all technologies (PV, small-hydro, biodiesel, biomass etc.) will play their parts and should be promoted.

It is evident that the right financial scheme, management models, technology and customer base are key elements in having sustainable models, but it is also important to state that no single business model provides a universal solution, collectively all models have to be implemented to accelerate rural electrification in the region. Models that have worked well in a region can easily be replicated in other regions having common similarities e.g. similar ecological systems exist in Mali, Burkina Faso and Niger, like the north of Cote d'Ivoire, hence it is possible to replicate similar projects in these areas using the same models with little modifications if necessary.

The benefits of electricity have been well established, and so long as the consumers are willing to pay a higher tariff for reliable and available electricity as opposed to not having electricity at all, then the government should permit cost reflective tariffs, as this is the way to go in order to attract the private sector and accelerate rural electrification in the region.

The approach to rural electrification is entirely different from urban/on-grid electrification, given the intricacies linked with business, management models and financing schemes and therefore should not be approached with the same mind-set.

Finally, ensuring financial sustainability is a key factor, and this is necessary to attract private participation which the region needs. However, in doing so, subsidies should be focused on capital investment since the high upfront cost is one of the biggest challenges for private operators. Governments should aim to reduce risks and assure the private operators of their commitments by taking responsibilities of fixed assets and most especially the grid connection as the networks will still remain even when the national grid reaches the off-grid areas.

7 Annexes

Annex I

Questionnaires (First & Second Level)

First Level

Locations	Size	Others
Department/ (Region)	Fossil (kVA)	Technology
Locality/(Community)	PV (kWp)	Population
Village	Wind (kW)	Promoters
Geographical coordinates	Hydro (kW)	Owners
	Biodiesel (kVA)	Project/Funding/Sponsors
		Operator(s)
		Condition (Operating/Not Operating)
		Status (Existing/Planned)

Second Level

Contact Details
Name of promoter:
Phone number:
Email Address:
Name and contact of person in charge of the project:

Financial information and pricing issues:
a) Financial
Total investment cost of the project [€]
Sources and amount of donation/ grant funds [€]
Sources and amount of concessional loan [€]
Others sources and amount of non-donation funds [€]
Total operation, maintenance and management costs [€/ year]
Diesel expenditure [€/ year]
Tariff collection income [€/year]
Levelized Cost of Electricity [LCOE]
b) Pricing issues
Are the users paying?
Are there different tariffs depending on the type of users/ consumption? Which are they?
Is it a flat rate?
Is the tariff based on energy consumed? Or in the power demanded? Or the service provided? Or in a combination of them?
Does a standard tariff scheme/ table exist at national/ regional or local level?
How was the process to establish the tariff? / Who defines and sets electricity tariff for the users?
Has the tariff been officially approved? By whom?
What is the collected tariff used for?
How often is the tariff collected? Is certain flexibility in the payment allowed to take into consideration seasonal income variations i.e. harvesting season?
Do the users pay a connection fee? If yes, how much in €?

General information
Location of CEMG:
Duration of the engineering, procurement and construction process [months]:
Date of beginning of the operation/ inauguration:
Number of houses in the village:
Number of houses connected to the CEMG:
Number of public institutions connected to the CEMG:
Number of businesses/ commercial connected to the CEMG:
Which electricity service was available before the CEMG was constructed?
Major setbacks/challenges in the whole CEMG process:
Major successes in the whole CEMG process:

Ownership, management, operation and
Who is the promoter of the CEMG? And what kind of organization?
Who has constructed and installed the CEMG?
Who is the owner of the CEMG?
Was the project conceived locally (Bottom-Up) or initiated by an authority and won through competitive bidding (Top-Down)?
Who is managing, operating and maintaining the CEMG?
What is the contractual agreement between the owning authority and the organization in charge of managing, operating and maintaining the CEMG?
Are the promoter, the owner or the organization in charge of the management, operation and maintenance involved in other CEMGs too?

Community involvement and participation
How was the community involved in the project?
Has the creation of economic services been actively promoted by the project? Which activities?
Have the end-users been trained on electricity uses and limits? Which trainings? Before, during or after the construction?

Private sector involvement and participation
Have private companies participated in the project?
Who are they?
Are they local or international?
What have they done?

Performance of the CEMG
Is the electricity service 24 hours/ day, 7 days per week?
If not, explain how many service hours are guaranteed?
Have you already replaced any generation, distribution or metering equipment? Which equipment? Why?
Are there non-technical losses e.g electricity robberies? Which % of the total generated electricity do they represent?
What is the minimum registered State of Charge (SOC) of the batteries? And the monthly average?
How many hours per month is the genset running on average [hours/month]?
How many hours of downtime/ blackout have the CEMG on average [hours/month]?

Technical information	
a) Generation system characteristics	
Solar PV modules	Brand/ model
	Number of modules
	Total Capacity [kWp]
Wind generators	Brand/ model
	Number of generators
	Total Capacity [kWp]
Biomass plant	No of plants
	Total Capacity [kW]
Hydro plant	Number of turbines
	Total Capacity [kW/KVA]
Genset	Brand/ model
	Number of gensets
	Total Capacity [kWp]
Batteries	Number of batteries
	Total Capacity [Ah]
	Nominal voltage (V)
	Type (Lead acid, AGM, Maintenance free etc.)
Inverters	Number of units
	Total Capacity [kW]
Energy Management System:	
b) Distribution system characteristics	
AC or DC	
Line voltage [V]	
Single or three phase	
c) Metering system Characteristics	
Type of meters [pre-paid, post-paid/ credit or current limitation]	
Meter Brand/ model	

Annex II

Planned Implementation pace of CEMG in ECOWAS

Planned Implementation pace of Clean Energy Mini-Grids (CEMGs) in West Africa

Country	Pop (mio) 2010	Year																		2016 (actual)	% of actual
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030		
Benin	9.5	222	443	665	886	1108	1329	1551	1773	1994	2216	2437	2659	2881	3102	3324	3545	3767	3988	6	0.7%
Burkina Faso	15.6	364	728	1093	1457	1821	2185	2550	2914	3278	3642	4006	4371	4735	5099	5463	5828	6192	6556	3	0.2%
Cape Verde	0.5	11	23	34	46	57	69	80	91	103	114	126	137	149	160	171	183	194	206	7	15.5%
Cote d'Ivoire	20.1	469	938	1407	1876	2345	2814	3283	3753	4222	4691	5160	5629	6098	6567	7036	7505	7974	8443	6	0.3%
Gambia	1.7	39	79	118	158	197	237	276	316	355	394	434	473	513	552	592	631	671	710	0	0.0%
Ghana	24.3	567	1133	1700	2266	2833	3400	3966	4533	5099	5666	6233	6799	7366	7932	8499	9066	9632	10199	5	0.2%
Guinea	11.0	257	513	770	1026	1283	1540	1796	2053	2309	2566	2822	3079	3336	3592	3849	4105	4362	4619	2	0.0%
Guinea Bissau	1.6	38	76	114	152	190	228	267	305	343	381	419	457	495	533	571	609	647	685	1	0.7%
Liberia	4.0	92	184	277	369	461	553	646	738	830	922	1014	1107	1199	1291	1383	1476	1568	1660	4	1.1%
Mali	15.2	353	707	1060	1414	1767	2120	2474	2827	3181	3534	3887	4241	4594	4948	5301	5654	6008	6361	73	5.2%
Niger	16.3	380	759	1139	1518	1898	2278	2657	3037	3416	3796	4176	4555	4935	5314	5694	6074	6453	6833	0	0.0%
Nigeria	159.4	3715	7429	11144	14858	18573	22288	26002	29717	33431	37146	40861	44575	48290	52004	55719	59434	63148	66863	20	0.1%
Senegal	13.0	302	604	906	1208	1509	1811	2113	2415	2717	3019	3321	3623	3925	4227	4528	4830	5132	5434	142	11.9%
Sierra Leone	5.8	135	269	404	538	673	807	942	1077	1211	1346	1480	1615	1750	1884	2019	2153	2288	2422	2	0.4%
Togo	6.4	149	298	447	596	745	893	1042	1191	1340	1489	1638	1787	1936	2085	2234	2383	2531	2680	0	0.0%
Total	304.4	7092	14184	21277	28369	35461	42553	49645	56738	63830	70922	78014	85107	92199	99291	106383	113475	120568	127660	271	1.0%

Population in ECOWAS countries source: World Bank

Annex III

Results of Level 1 survey

SUMMARY																
Main Information	Benin	Burkina Faso	Cape Verde	Cote d'Ivoire	The Gambia	Ghana	Guinea	Guinea Bissau	Liberia	Mali	Niger	Nigeria	Senegal	Sierre Leone	Togo	**Total**
PV only	6	-	1	-	-	-	-	-	-	13	-	20	46	1	-	87
Wind only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro only	-	-	-	-	-	-	2	-	2	1	-	-	-	-	-	5
Biodiesel	-	-	-	-	-	-	-	-	1	13	-	-	-	-	-	14
PV-diesel hybrid	-	3	3	7	-	4	-	1	1	45	-	-	95	-	-	159
Wind-diesel hybrid	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
PV-wind-diesel hybrid	-	-	1	-	-	1	-	-	-	-	-	-	1	-	-	3
PV/Wind	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Fossils plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
# of CEMGs	**6**	**3**	**6**	**7**	**-**	**5**	**2**	**1**	**4**	**73**	**-**	**20**	**142**	**2**	**-**	**271**
Size of mini-grids	**167**	**366**	**270**	**465**	**-**	**81**	**-**	**602**	**4,939**	**11,239**	**-**	**343**	**2,304**	**51**	**-**	20,826
PV (kWp)	167	41	126	210	-	40	-	312	10	3,079	-	343	1,256	46	-	5,630
Wind (kW)	-	-	19	-	-	11	-	-	-	188	-	-	5	-	-	223
Hydro (kW)	-	-	-	-	-	.	-	-	4,860	-	-	-	-	5	-	4,865
Biodiesel (kVA)	-	-	-	-	-	-	-	-	54	785	-	-	-	-	-	839
Fossils (kVA)	-	325	125	255	-	30	-	290	15	7,187	-	-	1,043	-	-	9,269
Size of CEMGs	**167**	**41**	**145**	**210**	**-**	**51**	**-**	**312**	**4,924**	**4,052**	**-**	**343**	**1,261**	**51**	**-**	**11,556**
Operating	6	-	5	7	-	5	2	1	3	73	-	18	142	2	-	264
Not operating	-	3	1	-	-	-	-	-	1	-	-	2	-	-	-	7
Existing	6	3	6	7	-	5	2	1	4	73	-	20	142	2	-	271
Planned	105	71	1	37	1	61	-	-	9	90	21	563	150	52	4	1,165

Annex IV
Data of Level 2 survey

SN	No	Country	Location	kW/hh	# of houses connected	Technology	PV (kWp)	Diesel generator (kVA)	Wind (kW)	Total Capacity (kW)	Investment cost (€/kW)
1	1	Nigeria	Umuagwu	0.080	86	PV	6.84	0		6.84	10,000
2	1	Nigeria	Umuokwu	0.089	120	PV	10.62	0		10.62	5,153
3	1	Nigeria	Umuode	0.089	120	PV	10.62	0		10.62	5,153
4	1	Nigeria	Bisanti	0.189	200	PV	37.8	0		37.8	5,308
5	1	Nigeria	Kolwa	0.189	200	PV	37.8	0		37.8	5,308
6	1	C d'Ivoire	Zamou	0.547	137	PV-diesel	39.00	45.00		75.00	
7	1	C d'Ivoire	Solokaye	0.607	73	PV-diesel	20.28	30.00		44.28	
8	1	C d'Ivoire	Kapé	0.646	83	PV-diesel	29.64	30.00		53.64	
9	1	C d'Ivoire	Kakpin	0.493	152	PV-diesel	39.00	45.00		75.00	6,061
10	1	C d'Ivoire	Gansé	0.529	127	PV-diesel	31.20	45.00		67.20	
11	1	C d'Ivoire	Boudou	0.639	84	PV-diesel	29.64	30.00		53.64	
12	1	C d'Ivoire	Kromambira	0.646	83	PV-diesel	29.64	30		53.64	
13	1	Sierra Leone	Kontaline	1.905	21	PV	40	0		40.00	6,402
14	1	Cape Verde	Monte Trigo	0.984	44	PV-diesel	27.3	20		43.30	10,231
26	1	Cape Verde	Vale da Custa	1.148	62	PV-wind-diesel	20.16	45	15	71.16	6,324
23	1	Cape Verde	Porto Novo	0.370	100	PV	37			37	9,212
15	1	Mali	Ouéléssébougou	0.774	1000	PV-diesel	334	550		774.00	3,230
16	1	Mali	Koro	0.924	1000	PV-diesel	384	675		924.00	3,788
17	1	Mali	Bankass	0.924	1000	PV-diesel	384	675		924.00	3,896
18	1	Mali	Tominian	0.806	1000	PV-diesel	266	675		806.00	3,598
19	1	Guinea Bissau	Bambandica	0.544	1000	PV-diesel	312	290		544.00	4,027
20	16	Senegal	ENDEV Project	0.325	40	PV-diesel	5	10		13	5,923
25	51	Senegal	ERSEN 2	0.325	40	PV-diesel	5	10		13	7,015
27	1	Senegal	Sine Moussa Abdou	0.301	67	PV-wind-diesel	5.16	12.5	5	20.16	4,960
21	1	Burkina Faso	Gori	0.317	120	PV	38			38	9,882
22	1	Benin	Sakabansi	0.157	254	PV	40			40	9,125
24	1	Sierra Leone	ENFO	0.279	215	PV	60			60	6,179
	92		**Average**	**0.391**							**6,632**

Annex V
GDP, HDI, population & electricity access

Country	GDP per capita ranking	GDP per capita (US$)	National Population (mio)	HDI Rank	HDI Score	People without electricity (mio)	National (%)	Urban (%)	Rural (%)
Benin	164	780	10.60	165	0.476	7.3	29.2	56.5	8.5
Burkina Faso	174	615	17.59	181	0.388	14.1	16.9	56.1	1.4
Cape Verde	124	3,039	0.51	123	0.636	0	94.1	100	83.6
Cote d'Ivoire	147	1,315	22.16	171	0.452	15	26.1	42.4	7.9
The Gambia	175	451	1.93	172	0.441	1.2	35.6	60	1.6
Ghana	141	1,340	26.79	138	0.573	7.3	72	92.2	49.5
Guinea	182	542	12.28	179	0.392	8.7	26.2	53.4	10.8
Guinea Bissau	178	595	1.80	177	0.396	1.3	21	37.1	6.2
Liberia	186	474	4.40	175	0.412	3.9	9.8	16.9	3
Mali	163	802	17.09	176	0.407	11.4	25.6	52.7	8.7
Niger	185	405	19.11	187	0.337	15.2	14.5	61.8	3.9
Nigeria	127	2,743	177.48	152	0.504	95.5	45	55	36.5
Senegal	162	913	14.67	163	0.485	6.4	54.7	89.8	28
Sierra Leone	176	659	6.32	183	0.374	5.8	5	10.5	1.4
Togo	179	569	7.12	166	0.473	5	26.6	35	21.3
Sub-Saharan Africa					0.502	634	32	59	17
Qatar	1	132,099			0.729				
World (Average)		19,463			0.702	1201	83	95	70
Comments	Out of 189 countries			Out of 187 countries		Electricity Access			
Source:	IMF World Economic Outlook Database April 2016		WorldBank 2014	UNDP, HDI 2013		IEA, World Energy Outlook 2015			

Annex VI

Zanzan project electricity tariff

Tariff Category	Energy (kWh/month)	Costs (FCFA/month)	Costs (€/month)	Norminal power (W)	Tariff (€/kWh)
Economic	8	750	1.14	500	0.1425
Average	17	1500	2.29	500	0.1347
Comfort	33	3000	4.57	500	0.1385
Grand comfort	59	5250	8	500	0.1356
Shops	59	5250	8	500	0.1356
Religious centers	33	3000	4.57	500	0.1385
Youth centers	67	6000	9.15	1000	0.1366
Social halls	100	9000	13.72	2000	0.1372
Gas station	67	6000	9.15	2000	0.1366

Source: UNIDO

Annex VII

Country profiles[17]

Benin

10.60mio
WorldBank(2014)

Electricity Access:

Source: SE4All Action Plan (2015)

National: 32%
Rural: 6%

Target by 2030: **100%**

Existing CEMG: 6

Planned CEMGs	Programme(s)
105	PROVES

Burkina Faso

17.59mio
WorldBank(2014)

Electricity Access:

Source: SE4All Action Plan (2015)

National: 17%
Rural: 2%

Target by 2030: **65%**

Existing CEMG: 3

Planned CEMGs	Programme(s)
45	IRENA/ADFD
10	IDB
1	EREF2

Cape Verde

0.51mio
WorldBank(2014)

Electricity Access:

Source: SE4All Action Plan (2015)

National: 95%
Rural: 90%

Target by 2030: **100%**

Existing CEMG: 6

Planned CEMGs	Programme(s)
1	GEF

Cote d'Ivoire

22.16mio
WorldBank(2014)

Electricity Access:

Source: SE4All Action Plan (2015)

National: 77%
Rural: 30%

Target by 2030: **100%**

Existing CEMG: 7

Planned CEMGs	Programme(s)
7	PRODERE
30	ENERGOS II

[17] Designed by author.

1.93mio
World Bank (2014)

The Gambia

Electricity Access:

Source: SE4All Action Plan (2015)

National: 40%
Rural: 37%

Target by 2030:
100%

Existing CEMG: 0

Planned CEMGs	Programme(s)
1	UNIDO

26.79mio
World Bank (2014)

Ghana

Electricity Access:

Source: SE4All Action Plan (2015)

National: 76%
Rural: 50%

Target by 2030:
100%

Existing CEMG: 5

Planned CEMGs	Programme(s)
55	SREP/IRENA/ADFD
4	SECO

12.28mio
World Bank (2014)

Guinea

Electricity Access:

Source: SE4All Action Plan (2015)

National: 18%
Rural: 2%

Target by 2030:
100%

Existing CEMG: 2

Planned CEMGs	Programme(s)
N/A	

1.80mio
World Bank (2014)

Guinea Bissau

Electricity Access:

Source: SE4All Action Plan (2015)

National: 12%
Rural: 2%

Target by 2030:
80%

Existing CEMG: 1

Planned CEMGs	Programme(s)
N/A	

4.40mio
World Bank (2014)

Liberia

Electricity Access:

Source: SE4All Action Plan (2015)

National: 1%
Rural: 0%

Target by 2030:
100%

Existing CEMG: 4

Planned CEMGs	Programme(s)
19	Sierra Leone Government
6	EU
2	USAID

17.09mio
World Bank (2014)

Mali

Electricity Access:

Source: SE4All Action Plan (2015)

National: 32%
Rural: 18%

Target by 2030:
87%

Existing CEMG: 73

Planned CEMGs	Programme(s)
50	SHER
32	PERSHY
7	SREP

19.11mio
World Bank (2014)

Niger

Electricity Access:

Source: SE4All Action Plan (2015)

National: 10%
Rural: 0%

Target by 2030:
60%

Existing CEMG: 0

Planned CEMGs	Programme(s)
21	ANPER
1	EREF2

177.48mio
World Bank (2014)

Nigeria

Electricity Access:

Source: SE4All Action Plan (2015)

National: 40%
Rural: 28%

Target by 2030:
90%

Existing CEMG: 20

Planned CEMGs	Programme(s)
524	UNDP/BOI

14.67mio
World Bank (2014)

Senegal

Electricity Access:

Source: SE4All Action Plan (2015)

National: 54%
Rural: 24%

Target by 2030:
100%

Existing CEMG: 142

Planned CEMGs	Programme(s)
40	DPER-SE
110	IRENA

6.32mio
World Bank (2014)

Sierra Leone

Electricity Access:

Source: SE4All Action Plan (2015)

NationaAl: 13%
Rural: 1%

Target by 2030:
92%

Existing CEMG: 2

Planned CEMGs	Programme(s)
50	RREP

7.12mio
World Bank (2014)

Togo

Electricity Access:

Source: SE4All Action Plan (2015)

National: 35%
Rural: 5%

Target by 2030:
100%

Existing CEMG: 0

Planned CEMGs	Programme(s)
4	PRODERE

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