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Tackling Energy Poverty:
Improving Affordable and Clean Energy Access

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Contents

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Abstract

With 1.1 billion people without energy access, and approximately half of this figure residing in Sub-Saharan Africa, we are faced with the challenge of addressing energy poverty without causing detriment to the planet. West Africa, and in particular the Economic Community of West African States (ECOWAS), demonstrate high potential for harbouring a regional grid connection for stable electricity supply, and decentralised energy technology to help reach 100% energy access by 2030. Inherent challenges within the ECOWAS region, as well as external barriers and risks, must be addressed. A range of international interventions and business models must be examined to understand such barriers. Economic approaches such as carbon market mechanisms may also be considered as a tool to facilitate the penetration of technology fuelled by renewable sources.

This thesis aims to investigate the barriers that prevent further penetration of small-scale renewable energy for off-grid communities, and the development of regional grid connections powered by renewable energy, particularly through development finance. Different approaches for economising the preparation for renewable energy technology will be evaluated and their suitability for the ECOWAS region determined. Conclusively, this thesis argues that the current penetration of mini-grids and grid connections is insufficient, and that ECOWAS countries must look to sell and purchase electricity from each other. The challenges that stand in the way can be addressed with information sharing and collaboration between the ECOWAS region and international bodies, particularly in Public-Private Partnerships (PPPs), through governmental will. This thesis also argues that carbon market mechanisms may not be the best approach for all countries in the ECOWAS region due to its complexity.

Keywords

ECOWAS, Energy Poverty, Regional Grid Connections, Mini-Grids, Renewable Energy, Carbon Market Mechanisms

1.0 Introduction

The 21st session of the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris is historically known for resulting in all 196 parties deciding to push towards the legal declaration of climate change targets. The parties are required to create their own Nationally Determined Contributions (NDCs), where they outline their Greenhouse Gas (GHG) emission reduction targets post 2020, usually for 2025 or 2030 (short term) and 2050 (long term). Despite there being no legally binding requirements to achieve the goals, the global transparency mechanism has meant that an international review of each countries' mitigation efforts is taken regularly. Should they be failing, the countries will face damage to their reputation. Thus, in many cases, this is incentive enough for them to stick to their targets.

The greatest threat to humankind is often deemed to be climate change. With some governments, such as that of the UK, acknowledging that there is currently a climate emergency, countries must act urgently to stagnate GHG emissions. While some countries are financially and institutionally equipped to gear towards a zero-carbon future, poorer regions tend not to be. Such regions, including countries in Sub-Saharan Africa, South Asia and Latin America, are faced with energy poverty. It is important to note that energy poverty is a "multidimensional phenomenon irreducible to just the types of energy services or technology used" (Olang et al., 2018, p.2). However, it can be considered as communities having no connection to instant and reliable electricity for cooking, lighting and heating when required. Worldwide, this figure stands at 1.1 billion, with 590 million residing in Sub-Saharan Africa. 94% of global growth in Carbon Dioxide (CO_2) up until 2040 is expected to come from non-OECD (Organisation for Economic Co-operation and Development) countries due to the increase in population and energy demand (IEA, 2013 cited in DFID, 2014). Thus, there is a need look to cleaner options to ensure that reliable energy is supplied to all.

Improved electricity access from renewable sources would reduce both poverty and the disastrous effects of climate change. Power outages cost countries in Sub-Saharan Africa 1-2% of its GDP annually (Foster and Briceño-Garcia, 2010, cited in DFID, 2014). 60% of businesses in Africa cite access to reliable electricity supply a constrain on their growth (Walsh, 2013 cited in DFID, 2014). A lack of reliable electricity affects all aspects of life; from neo-natal care and birth care for females as 60% of all health facilities in Sub-Saharan Africa have no reliable electricity access (WHO and World Bank, 2014 cited in IEA, 2017), to the inability for children to do homework and resorting to dangerous substances for energy access. The usage of kerosene, biomass and coal causes 2.8 million premature deaths a year in rural and urban parts of Sub-Saharan Africa (IEA, 2017), both through inhaling whilst cooking and accidental spillage. The detrimental effects of the lack of modern electricity reflects the urgency and importance of the issue at hand. In order to prevent the future spike in GHG emissions, organisations under the United Nations (UN) such as Sustainable Energy for All (SE4All) are striving to ensure that the energy that previously disconnected communities do access, are environmentally sustainable.

In order to improve access to modern energy, particularly in poorer areas such as the Economic Community of West African States (ECOWAS), improving regional grid connections is key. Despite being established in 1995, the Sub-Saharan African power pools remain weak. One of which, the West African Power Pool (WAPP), has not yet played a key part in ensuring electricity access across the region due to capacity shortage. Sub-Saharan Africa could save over US$ 40 billion in capital spending, a reduction in tariffs for the consumer if a regional grid is developed in capacity (McKinsey & Company, 2015). Only 8% of electricity in Sub-Saharan Africa crosses international grids; the majority of this small percentage being in the South Africa Power Pool (SAPP). As some nations experience periods of energy surplus whilst its neighbours experience deficit, there is a need to transmit electricity cross borders to increase energy security. Country leaders must engage in discussions and cooperate to realise the potential of its power pool through interconnections among ECOWAS countries.

If renewable energy is utilised in Sub-Saharan Africa, the region could see a 27% reduction in GHG emissions (McKinsey & Company, 2015). Renewable energy in the ECOWAS region could be further enriched through initiatives such as the International Renewable Energy Agency's (IRENA) WAPP Master Plan (excluding Cabo Verde which is treated as a separate entity) and ECOWAS Renewable Energy Policy (EREP) (IRENA, 2018). Part of this involves acknowledging the falling cost of solar photovoltaic (PV) and wind energy, making non-hydropower more attractive in the region. This renewable energy would be useful to communities that are not connected to the main grid, or are connected to grids with unreliable and insufficient electricity. Thus, utilising decentralised energy, notably green mini-grids (GMGs) or clean energy mini-grids (CEMGs), is key. As a distributed network for a localised community powered by renewables, CEMGs could be a more cost-effective way of meeting the demand of off-grid communities, compared to investing capital in connecting them to the main grid. Indeed, it depends on the distance between the rural area and both the mini-grid and the main grid. Thus, the most cost-effective approach would be to install a mini-grid close enough to households that need them in a community that is far from the main grid.

Despite there being three possible scenarios for the future energy mix of the ECOWAS region, (Reference, Regional EREP and National Targets), all three scenarios show that there is much potential for renewable energy projects, particularly in West Africa (Kaygusuz, 2012). Such projects can be financed through climate finance facilitated by aid and international governmental institutions such as the African Development Bank (AfDB) and Official Development Assistance (ODA). It is in the region's and international donor's best interest socially and economically to gear towards cleaner technology. If nothing is done, the situation will continue to exacerbate as the ECOWAS population grows.

While there is no universal and comprehensive definition of modern electricity, as access to modern electricity can be understood in various dimensions such as the source itself and the scale, the International Energy Agency (IEA) defines it as having access to the minimum level of electricity that is safer and more sustainable than traditional sources, and access that enables economic productivity and is available for public services (IEA, 2019). However, for understanding this thesis, modern electricity is considered in terms of energy supply; that is, it can be understood as grid-supplied electricity that can be consumed through reliable infrastructure. Therefore, sources such as kerosene lamps and firewood, do not qualify, but stand-alone mini-grids, do qualify.

Founded in May 1975, ECOWAS has the aim of integrating West Africa as a tool for accelerating and achieving sustainable development between 15 countries in the region except Mauritania, as depicted in Figure 1.0. The community also acts as a single trading bloc to integrate aspects such as transport, communication natural resources and energy. All members except Cabo Verde, who joined in 1977, are founding members. Although all members are united under the same economic community, the states' economic situation vary quite considerably. Based on annual GDP, although not a comprehensive indicator of development, the region ranges from Guinea-Bissau at US$1,346.84 million to Nigeria at US$375,745.49 in 2017 (The World Bank Group, 2019a). However due to their geographic proximity, there is scope for collaboration with energy infrastructure to benefit all states, especially with regard to sustainably achieving 100% energy access by 2030. ECOWAS is striving for the utilisation of an international grid connection within the region and decentralised energy, such as mini-grids and off-grids, as it is predicted that they will play a role in helping the nations achieve 100% energy access.

Figure 1.0: Geographic depiction of Economic Community of West African States (ECOWAS)

Source: ECOWAS, 2016

Indeed, many argue that there should be an emphasis on providing electricity access, through any means, to areas without electricity, before one can consider making this source of electricity renewable. This is especially the case as renewable energy tends to be intermittent and unreliable, and fossil fuels can provide base load energy. This argument tends to be aligned with the notion that priority should be given to lifting communities out of poverty and realise the immediate (economic) benefits, before addressing climate change. However, it is not only that in many cases, solar energy is cheaper than traditional fossil fuels in the long term (and it is the need to overcome perception of financial risk that is a barrier), but it is better to curb future carbon emissions before it becomes disastrously catastrophic. Therefore, it is necessary to evaluate how grid connections and decentralised energy can economise preparation for clean technology, and how tools such as carbon market mechanisms can increase the penetration of renewable energy infrastructure.

This thesis looks at how to further the penetration of clean technology in the ECOWAS region. After reviewing current literature on the penetration of renewable energy in West Africa, it will first provide an overlook of the energy situation in Sub-Saharan Africa, ECOWAS and West Africa (ECOWAS plus Mauritania). Then, renewable energy potential in the ECOWAS region will be evaluated. Third, the potential of regional interconnections and CEMG projects in ECOWAS through climate and development finance will be examined. Whilst there are a variety of means of providing electricity to communities, this thesis will look at clean CEMGs, thus, other smaller scale clean energy initiatives such as Pico systems or Solar Home Systems (SHS) are beyond its scope. Fourth, subsidy and business and financing options for renewable energy penetration, including the potential role of carbon market mechanisms, will be explored. This thesis will then conclude, ultimately arguing that there are perceived and real barriers to the penetration of renewable energy, but there are ways to overcome them through international cooperation.

2.0 Aims, Objectives and Methodology

The aim of this thesis is to understand how renewable energy can penetrate the energy market of the ECOWAS nations, including examining how international grid connections and mini-grids can economise the preparation for renewable energy technology in the ECOWAS region. It will do this through the following objectives:

1) Analysing the potential for renewable energy in the energy market of ECOWAS region
2) Analysing the potential for furthering the development of CEMGs and a regional interconnection powered by renewable energy within the ECOWAS region
3) Examining subsidy, business and finance options for increasing the penetration of renewable energy, including the potential role of carbon market mechanisms

In order to achieve the objectives, a variety of methods have been deployed. Empirical data from a range of institutions, such as the World Bank, has been used to deepen understanding of the current energy and situation of the ECOWAS region. This research also looks at case studies and the status of current projects from international institutions such as IRENA and the IEA. Empirically, information is provided by individuals from international institutions, embassies and academia obtained through interviews. In particular, interviews with individuals on the ground in Ghana, a microcosm for the situation in communities with a lack of electricity, is utilised to better understand locals' experience with electricity usage and their awareness of small-scale energy. Ghana was chosen due to its particularly dynamic energy development. Using primary data also, visual aids are utilised to portray the situation of the ECOWAS region in an easily understandable manner.

3.0 Literature Review

Literature regarding the analysis of how international bodies are assisting poorer countries shift towards a cleaner economy is abundant. However, it can be argued that when literature looks at developing nations in Africa, there is more of a focus on the activities of international bodies in East Africa and Southern Africa, particularly regarding CEMGs. This may be intuitive as the majority of international governmental develop institutions tend to focus primarily on these two regions. That is not to say that there is little discussion on West Africa, it is to point out the need to support more discussions regarding West Africa, especially new and emerging ones as its energy situation is so dynamic. This thesis hopes to help raise awareness of the potential within West Africa for renewable energy and portray that activities in the region can benefit all parties involved.

The majority of the discussions in literature tend to focus on technological and financial aspects regarding how transmission lines can be built across Africa, rather than the energy source to supply the grids (Blyden and Lee, 2005). What is perhaps surprising is that those that did focus on the energy source itself, acknowledge the plausibility of using renewable sources on a large scale, arguably more so than non-renewable sources such as gas from Nigeria (Yushchenko et al., 2018; Gyamfi et al., 2014; Gnansounou et al., 2007). With renewable energy becoming increasingly dynamic, cheaper and being able to mitigate climate change, there must be more discussions surrounding the rationale for renewable energy to provide electricity on a regional scale within West Africa. However, renewable energy tends to be considered as a group of resources to be implemented on the regional and, although rarely, on a national level as part of a larger grid.

While there appears to be a lack of consideration of various scenarios for estimating the future energy mix of Sub-Saharan Africa, there are some discussions that utilise Geographical Information Systems (GIS) and other empirical modelling techniques to estimate different electricity demand scenarios in Sub-Saharan Africa. Sanoh et al. uses modelling to match annual supply and demand (2014). Although not a commonly occurring issue in literature, it is worth noting that the authors fail to factor capacity into their modelling. By considering installed capacity and annual consumption as one, it assumes that the current infrastructure always runs at full capacity. For poorer countries such as those in Africa, there tends to be a large gap between capacity and actual consumption compared to richer countries, mainly due to a lack of (consistent) energy supply. This thesis acknowledges this difference when assessing the energy situation of the ECOWAS region, and while it does not undertake empirical modelling, it utilises long term and internationally used analyses by bodies such as the IEA and IRENA. In academia, the utilisation of such scenarios in assessing the energy mix and future situation of Sub-Saharan Africa is lacking (such as Mohammed et al., 2013). Some literature focus on the current situation without estimates for the future, and how the prediction might influence possible policies (Gyamfi et al., 2014). Authors that do use predictions, such as Bazilian et al. utilise projections from bodies such as AfDB (2012), they tend to be projects for the whole of the African continent. This thesis will include 3 scenarios that are not widely considered in literature and apply it to the ECOWAS region; the National

Targets, Regional EREP and Reference Scenario. it is not widely acknowledged. In addition, it is important to understand that due to the dynamic tendency of energy markets, particularly in Sub-Saharan Africa where susceptibility to external factors is high, different trajectories for the energy mix must be considered for understanding the potential for the region.

Discussions exists in literature with regard to which approaches can be utilised for developing energy infrastructure in Sub-Saharan Africa (Gnansounou et al., 2007). In top-up approaches, the role of New Partnership for Africa's Development (NEPAD) in pan-African collaboration is often identified, as well as the intervention from institutions, particularly those that are indirectly linked to Sub-Saharan Africa's transmission network such as Europe (connected between Spain and Morocco). The bottom-up approaches tend to evaluate activities in providing communities with small scale renewable energy infrastructure, such as solar panels (Blyden and Lee, 2005). However, there is a lack of discussion regarding how to collaborate and train with locals to ensure that they know how to utilise solar panels within their own homes as prosumers. Most discussions focus on training individuals that are installing the infrastructure, not consuming and helping to maintain it.

One tool commonly sought after to incentivise clean technology development is a carbon market mechanism; namely, assigning a price on emitting carbon through carbon taxes or emissions trading. In literature, discussions of such mechanisms tend to be in relation to more developed regions, and thus tend to leave out poorer countries. Literature that does look at developing nations tend to look at them in term of carbon offsetting. Böhm and Dabhi's criticism of CDM is well known in academia, particularly with transparency issues where bribes have been paid to village leaders or local communities have been displaced due to new energy infrastructure projects (and Böhm and Dabhi, 2009). In addition, in literature where the participation of developing nations is examined, there are no discussions regarding the potential for poorer regions such as those in West Africa, that are beginning to or have been emerging, to develop their own regional carbon mechanisms. Carbon taxes or regional emissions trading scheme that are effective, meaning that permits are priced and allocated relatively efficiently, and that such a market promotes the development of renewable technology is not examined in the context of ECOWAS, for example. Carbon market mechanisms in developing countries are indeed an unconventional approach to explore, and it is thus a gap that this thesis delves into.

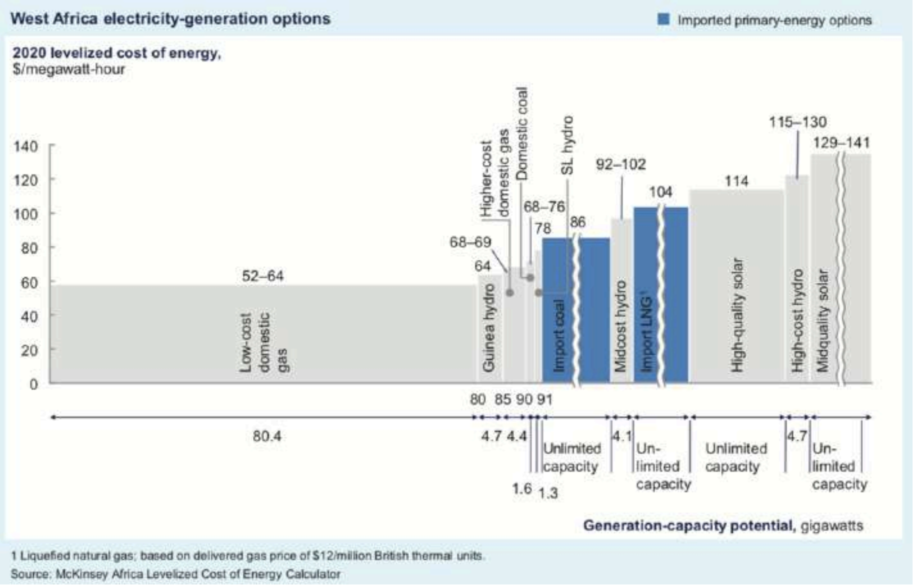
4.0 Energy Outlook in West Africa: Current Situation and Future Challenges

In order to examine how to utilise grid connections and distributed energy generation through climate finance, it is important to first understand the current energy outlook in the region, as well as challenges facing its goals for the future. Obtaining individual data on each ECOWAS region with regard to energy production is a difficult task. On the World Bank's data records alone, individual energy production data on Burkina Faso, Cabo Verde, Gambia, Guinea, Guinea Bissau, Iberia, Mali and Senegal were not recorded. In some cases, if the data is recorded, it may be considered unreliable. Indeed, the fact that data is unavailable reflects the issue of researchers being unable to accurately assess the energy situation of all areas of the countries, including its rural areas. It also highlights issues concerning transparency and publicly available data. Estimates and figures from bodies such as the IEA, however, can still allow one to paint a picture of the energy situation in Sub-Saharan Africa, and what it may look like in the future.

4.1 Current and Future Energy Mix

Following the trend with the rest of Sub-Saharan Africa, traditional bioenergy remains the most predominant energy source amongst ECOWAS members. Not counted in generation capacity, the traditional use of biomass is mainly used for cooking, particularly in rural areas. Currently, West Africa relies on oil-based resources for 60% of its electricity generation, including back-up diesel generators. Solar energy is clearly underutilised in generation capacity, despite its large potential particularly in Mali, Niger and Nigeria (McKinsey & Company, 2015). The potential for wind energy remains low, but in the ECOWAS region, is only significant in the most western areas by the coast. Cabo Verde is the only region utilising wind energy as part of their generating capacity.

Figure 4.1.0: Levelised Cost of Energy per $/MWh in West Africa in 2020

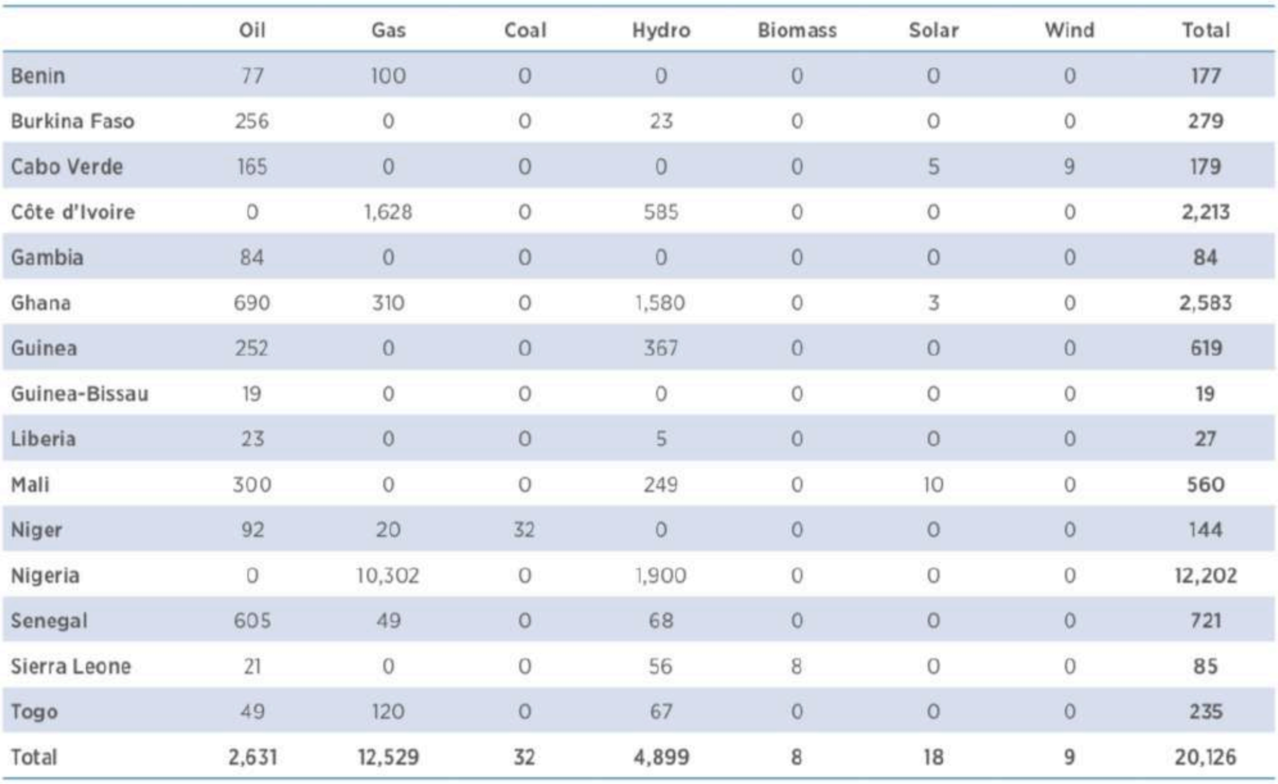


1 Liquefied natural gas; based on delivered gas price of $12/million British thermal units.
Source: McKinsey Africa Levelized Cost of Energy Calculator

Source: McKinsey & Company, 2015.

Nuclear energy plays a significantly low role in West Africa. Despite Niger being one of the top ten largest uranium resource bearers in the world, it only bears small test reactors (IEA, 2014). Ghana has a nuclear research reactor with plans to develop 2 commercial units within the next 5 years with the assistance of Russia and China (Adombila, 2018), while Senegal is looking to develop a nuclear plant with the assistance of France (World Nuclear Association, 2019). Concentrated in more southern parts of Africa, coal also plays a smaller role in ECOWAS as it is more expensive than the majority of domestic gas; coal generated capacity is only evident in Nigeria. Hydroelectric power is not as fully utilised in the ECOWAS region, mainly due to the high levelised cost of generation. The ECOWAS region holds the highest levelised cost of hydroelectric generation, which is up to US$130 per megawatt-hour, as evident in Figure 4.1.0. Diesel is also widely used, particularly for road transport, accounting for 39% of oil consumption in road transport in Sub-Saharan Africa, although this is heavily influenced by outliers such as South Africa with a "comparatively high level of vehicle ownership" and countries where gasoline prices are relatively low, such as Nigeria (IEA, 2014, p.460). Without the outliers, the figure stands at around 45% for diesel usage in road transport.

Table 4.1.0: Existing power generation capacity as of 2015 in Megawatts (MW) in the ECOWAS region



	Oil	Gas	Coal	Hydro	Biomass	Solar	Wind	Total
Benin	77	100	0	0	0	0	0	**177**
Burkina Faso	256	0	0	23	0	0	0	**279**
Cabo Verde	165	0	0	0	0	5	9	**179**
Côte d'Ivoire	0	1,628	0	585	0	0	0	**2,213**
Gambia	84	0	0	0	0	0	0	**84**
Ghana	690	310	0	1,580	0	3	0	**2,583**
Guinea	252	0	0	367	0	0	0	**619**
Guinea-Bissau	19	0	0	0	0	0	0	**19**
Liberia	23	0	0	5	0	0	0	**27**
Mali	300	0	0	249	0	10	0	**560**
Niger	92	20	32	0	0	0	0	**144**
Nigeria	0	10,302	0	1,900	0	0	0	**12,202**
Senegal	605	49	0	68	0	0	0	**721**
Sierra Leone	21	0	0	56	8	0	0	**85**
Togo	49	120	0	67	0	0	0	**235**
Total	**2,631**	**12,529**	**32**	**4,899**	**8**	**18**	**9**	**20,126**

Source: IRENA, 2018.

The future energy mix of Sub-Saharan Africa is expected to become more diverse; this is vital to increasing the robustness of nations to shocks and constraints from one or more energy source. The indicator of diversity can be defined as:

$$\text{SWI} = \sum -p_i \ln(p_i)$$

where p_i is the installed capacity share for resource i (IRENA, 2018). In 2030, the diversity of the energy mix is expected to range from 48% (Nigeria) to 181% (Senegal) under the Reference Scenario, 49% (Nigeria) to 180% (Senegal) under the Regional EREP Target and from 46% (Sierra Leone) to 181% (Senegal) under the National Targets (IRENA, 2018).

While there are a range of scenarios that can predict the future energy situation, to be elaborated further later in the thesis, one scenario is depicted in Figure 4.1. Biomass, as a traditional energy source, will account for the continued increase in bioenergy use in the foreseeable future. For more modern electricity, it is expected that the use of gas in the ECOWAS region will rise significantly to 77% in 2020. Figure 4.1.1 shows the total terawatt-hours (TWh) predicted for each energy source, with gas expected to take up a large share. This is mainly due to the possibility of further gas discoveries in the west coast of Africa, and so by tapping into those sources, the cost of energy production could decrease. In addition, the Jubilee field in Ghana, discovered in 2007, has been identified as a gas and oil hotspot but is still underexplored, and new discoveries in Côte d'Ivoire, Sierra Leone and Côte d'Ivoire have been made. However "further appraisal is required to ascertain their commerciality", (IEA, 2014, p.464), therefore it cannot be suggested that discoveries in oil in West Africa will make a particular difference to the energy mix in the future. Despite this, the share of fossil fuels is expected to decline from 77% in 2012 to 54% in 2040 across Sub-Saharan Africa (IEA, 2014). Coal will continue to play a miniscule role in the energy mix, as well as imported fuel which will have a significant decline in 2030 due to the increased predicted usage of gas. One resource that will play a significant role, however, is solar energy.

After the cost of solar PV becomes low enough, a greater shift towards solar will cause a fall in generation powered by gas; to 72% in 2030 and 65%in 2040 (McKinsey & Company, 2015). Despite the falling price in solar energy, it is not expected to play a role in centralised power until after 2020 (McKinsey & Company, 2015). Therefore, it can be argued that a cheaper and more viable way to further the use of solar energy would be through integrating it into decentralised networks such as mini-grids. However, significant grid connected projects are under construction, such as the 155MW Nzema plant in Ghana which is expected to add to the expected increase in solar in the energy mix (IEA, 2014). While hydropower is expected to increase, its share in the energy mix will slightly decrease due to an increased share in renewables. Large hydropower in particular may expand in countries such as Nigeria, starting with the Mambilla dam which is expected to utilise over 11 gigawatts (GW) (IEA, 2014). In addition, despite being carbon neutral, nuclear energy is not expected to play a key role in increasing energy access in West Africa, especially with particularly complex safety measures and the need for technical knowhow, large upfront investment, and suitable geographical locations for waste storage.

Figure 4.1.1: Share of current and future energy mix in terms of terawatt hours (TWh) in Sub-Saharan Africa

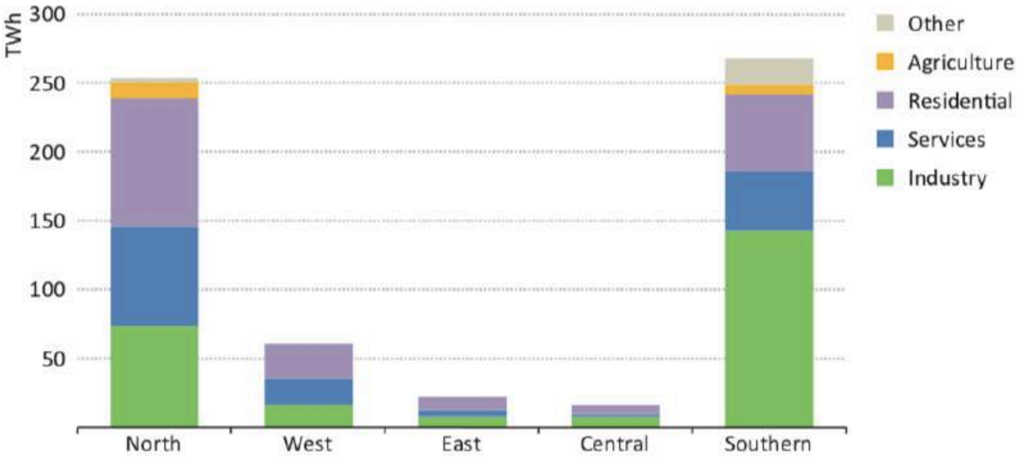
Source: McKinsey & Company, 2015

4.2 Energy Demand and Consumption

While there is much electricity data provided by international organisations, it is important to bear in mind that there is still unmet energy demand in rural areas that is not captured in the statistics, and so it is "difficult to measure electricity demand in a holistic sense" (IEA, 2014, p.39). Thus, like with the IEA, any statistic referred to in this section refers to demand from large or mini-grids, and off-grid sources. As production from back-up generators not recorded in energy statistics, the actual energy production may be higher than reported (IEA, 2014).

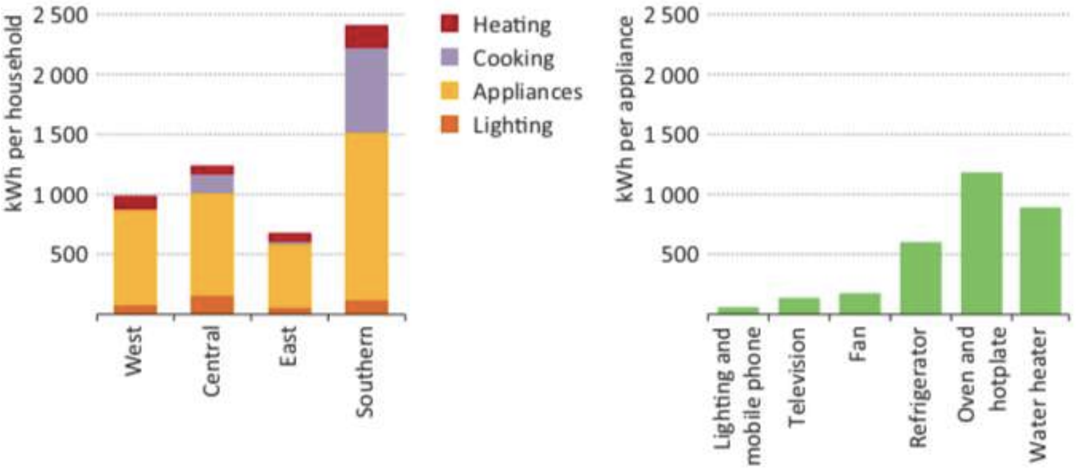
Sub-Saharan Africa accounts for 14% of the global population but "only 4% of global primary energy demand, standing at 739 million tonnes of oil equivalent (Mtoe), with Nigeria being the biggest source of this energy demand at 141 Mtoe or 20% of total demand in Sub-Saharan Africa, as of 2014 (IEA, 2014). Despite having an electricity demand of 605 TWh in 2012, the average Sub-Saharan household consumes 317 kWh per year, which is 20% and 7% of the consumption of Europe and the United States, respectively (IEA, 2014). Intuitively, most of Sub-Saharan Africa's demand comes from urban areas, which comprises of around 50% in West Africa. Urban areas tend to be wealthier and are therefore more likely to use electricity through grid connections or back-up generators, making up 7% of energy consumption in Sub-Saharan Africa. Industry counts for the largest share of energy consumption in Western Africa, which is particularly the case in Nigeria and Ghana (IEA, 2014). In addition, the services industry is increasingly taking up a large portion of energy consumption while households with few and less electricity-consuming appliances take up a small portion (27%). Demand for electricity in tourism and other service sectors, and agriculture is growing, although the service sector accounted for only 20% of electricity consumption in Sub-Saharan Africa (IEA, 2014). Evident in Figure 4.2.0, the majority of electricity consumption, 50%, occurs in industry led by mining and refining activities throughout Sub-Saharan Africa, mainly concentrated in West Africa, namely Nigeria and Ghana, alongside South Africa and Mozambique (IEA, 2014). However, this figure is heavily skewed by Southern Africa. With the exception of Central Africa, the majority of electricity consumption is concentrated at residential levels, not industrial. In West Africa in particular, the service industry is more consuming of electricity than industry. Regarding how energy is used in the household, evident in Figure 4.2.1, the majority of electricity is used for appliances such as cooling systems and mobile phones. Perhaps surprisingly, more electricity is used for heating compared to lighting in West Africa. Compared to the rest of Sub-Saharan Africa, West Africa consumes the second least amount of electricity in Sub-Saharan Africa.

Figure 4.2.0: Electricity consumption in Africa by end-use sector and sub-region in 2012



Source: IEA, 2014

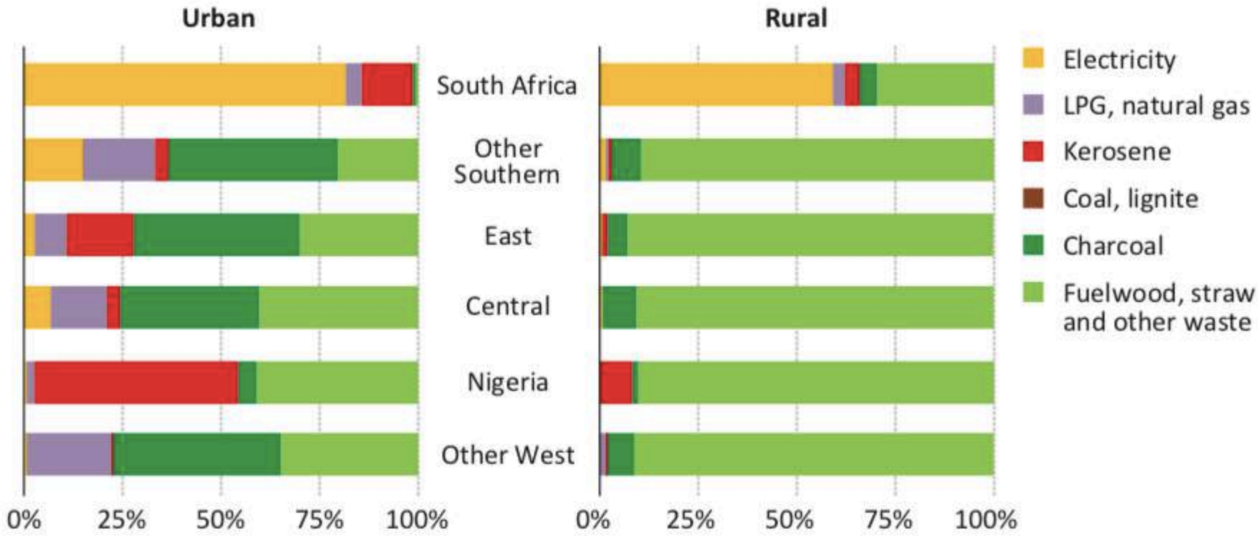
Figure 4.2.1: Average electricity consumption per household in Sub-Saharan Africa, 2012, and indicative consumption levels by appliance



Source: IEA, 2014

In terms of energy source, more than half of the total primary energy demand for communities in Sub- Saharan Africa comprise of solid biomass, mainly for cooking (IEA, 2017). In rural areas, cooking is almost entirely conducted through solid biomass in the form of firewood and agricultural waste. In general, across the ECOWAS region, the usage of charcoal for cooking is slightly higher than the usage of fuelwood, straw and other waste, as shown in Figure 4.2.3. Due to poverty, cooking is the prioritised activity with regard to utilising energy, comprising of around 80% of residential energy demand in Sub-Saharan Africa. Compared to the OECD average of 5%, it is an alarmingly high rate (IEA, 2014). Less than a quarter of households in the ECOWAS region use liquified petroleum gas (LPG) or natural gas for cooking. Indeed, two-thirds of the 4% demand for gas in Sub-Saharan Africa comes from Nigeria (IEA, 2017). Côte d'Ivoire also relies heavily on gas but consumes a smaller volume compared to Nigeria (IEA, 2014).

Figure 4.2.3: Main fuel used by households for cooking in Sub-Saharan Africa in 2013

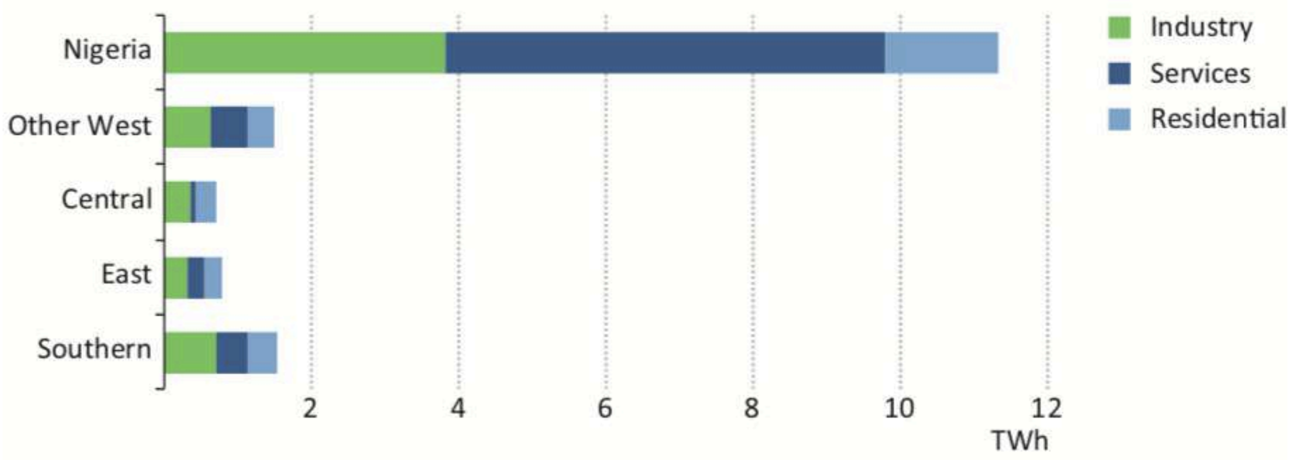


Source: IEA, 2014

However, there is a gap between installed capacity and consumption levels, mainly due to the poor maintenance of power stations and a lack of power supply (IEA, 2014). Grid-based capacity has the potential to grow four times its current size, meaning reaching 100 GW in 2040 (IEA, 2014). Despite some plans for rehabilitation, some plants never restart, thus perpetuating the gap in installed capacity and consumption (IEA, 2014). The plants already existing tend to have the lowest efficiencies as they were initially constructed due to their lower upfront costs. The average efficiency of gas power plants stood at 38% in 2012, as open-cycle gas turbines are used more often in Sub-Saharan Africa instead of the more efficient combined-cycle gas turbines due to the low cost. The unused fuel could generate an additional 21% in electricity (IEA, 2014).

As grid-based electricity cannot meet the demand of all communities, back-up diesel generators are often utilised. Back-up power generation tends to be more expensive than grid supplied electricity, so not all communities can utilise them. Figure 4.2.4 reflects the amount of electricity demand met by back-up generators; they are estimates, as generators are generally not recorded in energy statistics. With the average back-up generator supplying 16TWh in 2012 to Sub-Saharan Africa, one can estimate that total electricity supply was 3% higher than reported at that time (IEA, 2014). However, it is important to note that even with back-up generators, the total demand is still not met. For West Africa, excluding Nigeria, back-up generators are predominately used in industry, with a smaller share in services. Residential generators take up the smallest share. Nigeria is the biggest single consumer of electricity from back-up generators, making up almost 75% of total usage in Sub-Saharan Africa (IEA, 2014). Countries such as Benin, Burkina Faso and Niger that do not utilise many back-up generators rely more heavily on electricity imports.

Figure 4.2.4: Electricity demand met by back-up generators by sub-region in 2012



Source: IEA, 2014

With regard to grid-based capacity, West Africa only achieved 20 GW in 2012, of which more than half was gas-fired and predominately in Nigeria (IEA, 2014). However, even though Nigeria is oil and gas rich, it has little oil generated electricity capacity. Nearly 30% was accounted for by oil and almost 20% by hydroelectric power. This is regardless of the fact that hydropower has been a major source in West Africa, particularly due to the development of Akosombo dam in Ghana.

The demand for energy is expected to increase in the ECOWAS region as population increases. As evident in the Figure 4.2.5, the ECOWAS population growth rate is above the world average. The trend shows that despite the growth rate of the ECOWAS region slowing down, there is still some degree of growth nonetheless, unlike the global average where the growth rate is declining. In addition, as the region becomes more economically prosperous, citizens in both rural and urban areas will have an increased demand for electrical appliances, which would lead to an increase in demand for electricity. This also means transport usage will increase, as more households would be able to afford the already expensive public transport available, as well as purchase cars and develop air travel. Energy consumption in transport usage has been increasing at an annual rate of 4% since 2000 in Sub-Saharan Africa (IEA, 2014). No nations in ECOWAS have at least 500 cars per 1,000 people, spurred on by the high import costs, and air traffic in Sub-Saharan Africa accounts for only 5% of the global airline traffic (IEA, 2014). Despite transport fuel being subsidised in some countries in Sub-Saharan Africa, it is still expensive in relation to income.

Oil made up 15% of demand in Sub-Saharan Africa in 2012, with Nigeria alone comprising more than 20%, and gasoline making up nearly 40% since 2000, with most of the growth being concentrated in Nigeria (IEA, 2014). The demand for LPG increased at a rate greater than kerosene at approximately 60% since 2000, but from a starting point where the latter was used more than the former (IEA, 2014). Evident in Figure 4.2.6, Nigeria makes up more than half of the population size, which may provide an insight into how Nigeria's situation tends to influence the overall statistics for the ECOWAS region, and may also reflect why most of the generating capacity of the ECOWAS region comes from Nigeria.

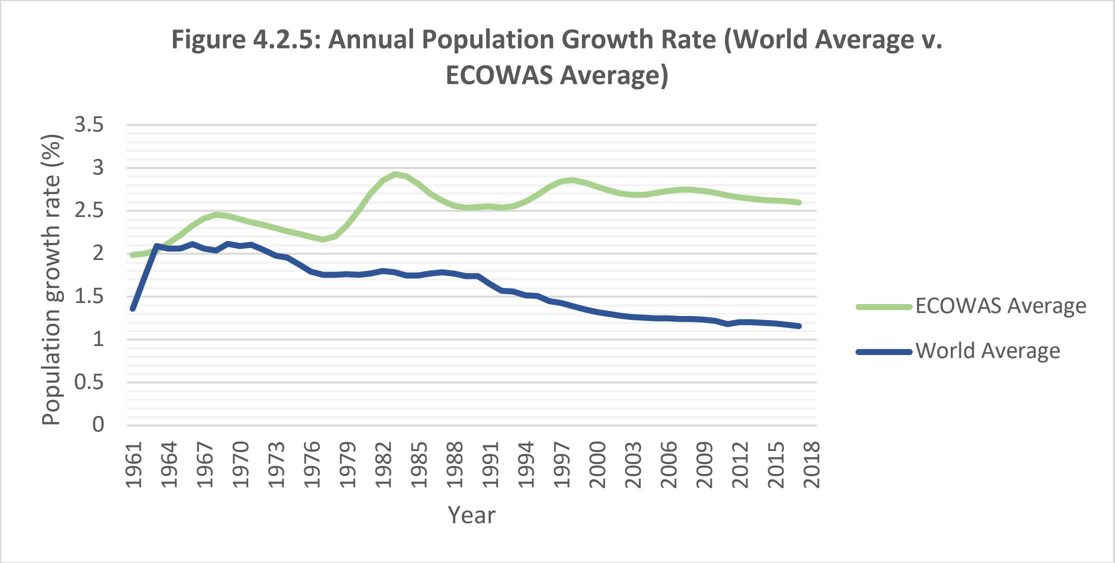


Figure 4.2.5: Annual Population Growth Rate (World Average v. ECOWAS Average)

Source: Author. Data obtained from the World Bank Group.

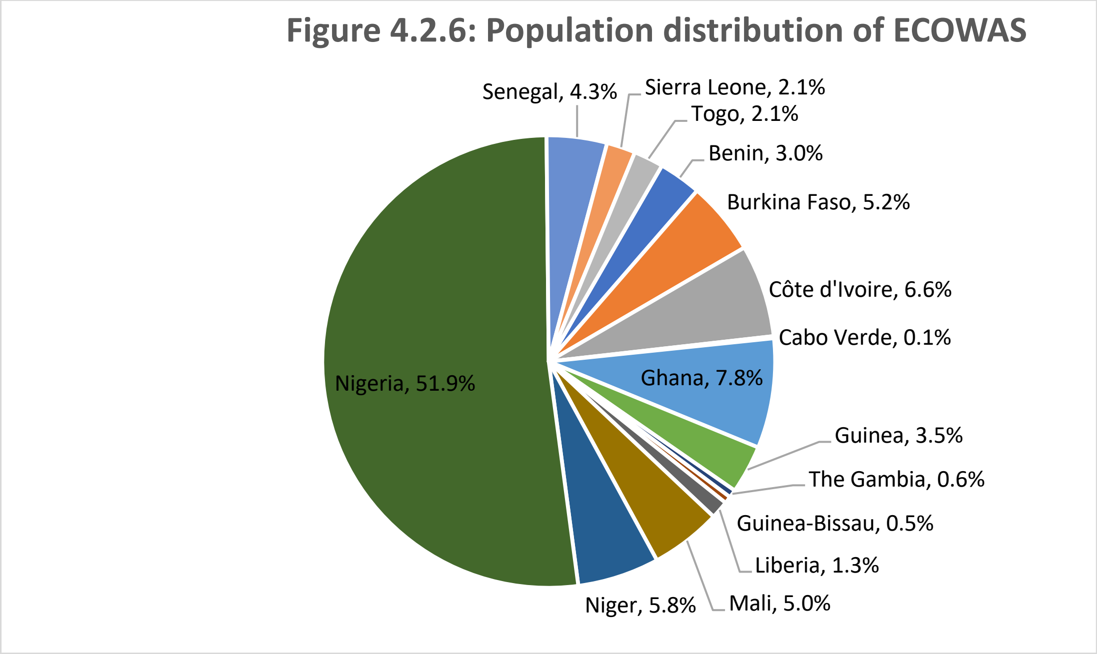
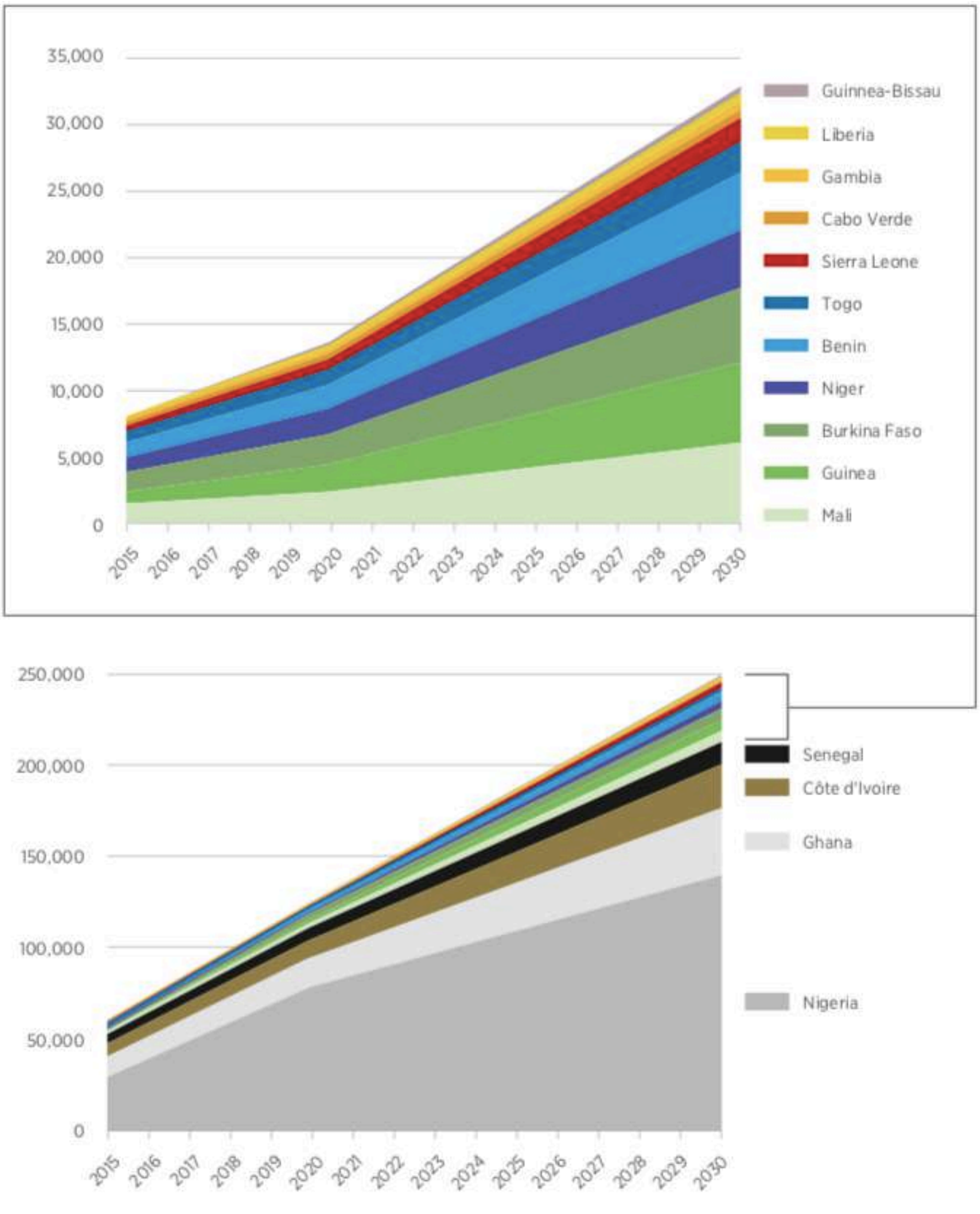


Figure 4.2.6: Population distribution of ECOWAS

Source: Author. Data from: Hobson, 2016

Future estimates depict that by 2040, Sub-Saharan Africa would require a total capacity of 354 GW; 115 GW of this being required in West Africa (McKinsey & Company, 2015). Under the New Policies Scenario (NPS), the future energy scenario based on today's policies, total primary energy demand in Sub-Saharan Africa will increase by approximately 30% by 2030 (IEA, 2017). Figure 4.2.7 reflects the expected growth in demand, with most of this demand coming from Nigeria. This region also has the tightest supply and demand situation in Sub-Saharan Africa, with a ratio of only 1.0 and a demand gap predicted to be 202 GW in 2040 (McKinsey & Company, 2015). There is great base-load potential for the ECOWAS region, standing at 105 GW; most of which will come from solar energy. However, as aforementioned, the demand for bioenergy is set to increase despite the predicted increase in income. In addition, diesel is expected to increase throughout West Africa.

Figure 4.2.7: Secondary electricity demand projects between 2015 and 2030, by country (GWh)

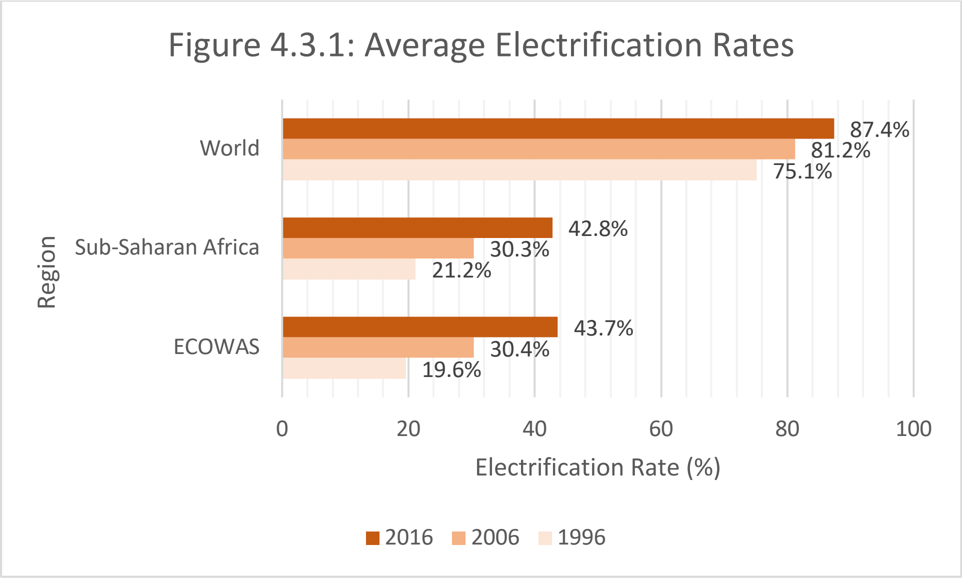


Source: IRENA, 2018

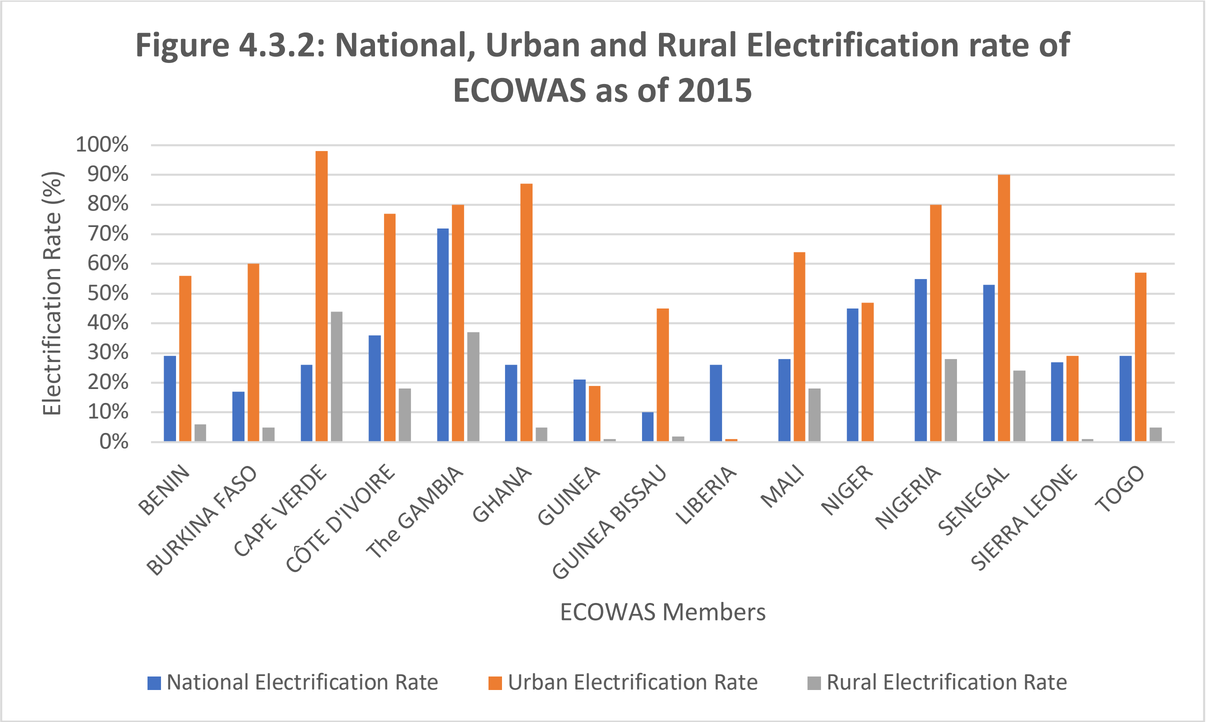
Primary interviews with individuals who grew up in Ghana was conducted to gain an insight into their electricity usage. The discussions were used to paint an overall picture and create deeper understanding regarding first-hand experiences of living in a country with unstable electricity. The situation in the 1970s and 1980s in seem to be similar, with all individuals sharing experiences with having no choice but to use kerosene as there was no electricity. Lanterns were used, both locally made and imported. Communities tended to "put kerosene at the bottom [of the lantern]", which had "wool inside it like a candle to light" (Boateng, 2019). Others had experiences of using makeshift kerosene lamps from a can, much like a tomato tin with the top cut off and wool inside to light. Later, gas lighting became more widely used, where a "shade was put on gas cylinders" (Homiah, 2019). As communities gained more income, small generators were used, until electricity through the main grid was utilised through the main hydroelectric dam, Akosombo, along the Volta River. Although the dam was constructed in 1961, most of the population was still using traditional energy sources in the 1960s. There is evidently a transformation of energy usage over time, however it is only in the urban areas and a few rural areas in Ghana where hydroelectric power through the biggest dam in Ghana is consumed. Some communities still utilise kerosene lamps in Ghana today, especially in the village, but it is still the case in urban areas (Boateng, 2019). One interviewer noted the common usage of kerosene lamps in her hair salon, and others use it in the city to sell food when the streetlights are not bright enough.

4.3 Energy Accessibility

Intuitively, the electrification rate of Sub-Saharan Africa is significantly lower than the world average, as depicted in Figure 4.3.1. Although the electrification rate doubled over the space of 20 years and the number of people without access to electricity in Sub-Saharan Africa has been declining since 2013, it is still far from an economically and socially acceptable level. Sub-Saharan Africa, along with other countries in South Asia and Latin America, is the biggest contributor to the global energy inaccessibility statistic. The biggest difference in the electrification rate, however, is between rural and urban populations, with over 80% of those without electricity in Sub-Saharan Africa residing in rural areas (IEA, 2017). As evident in Figure 4.3.2, with the exception of Gambia, no rural region in ECOWAS has more than 50% electrification. In addition, Côte d'Ivoire, Ghana and Senegal (along with 4 other countries), are the only Sub-Saharan countries that have electricity rates exceeding 50% nationally (McKinsey & Company, 2015). Indeed, discrepancies in data exist also; some records are estimates and extrapolations as the data for some regions may not be record at all. In addition, since the data was taken, the situation may have improved slightly. Nonetheless, the data is a good indicator of the situation facing Sub-Saharan Africa, the progress it has made over time, and indeed the progress it still must make in order to reach full electrification.



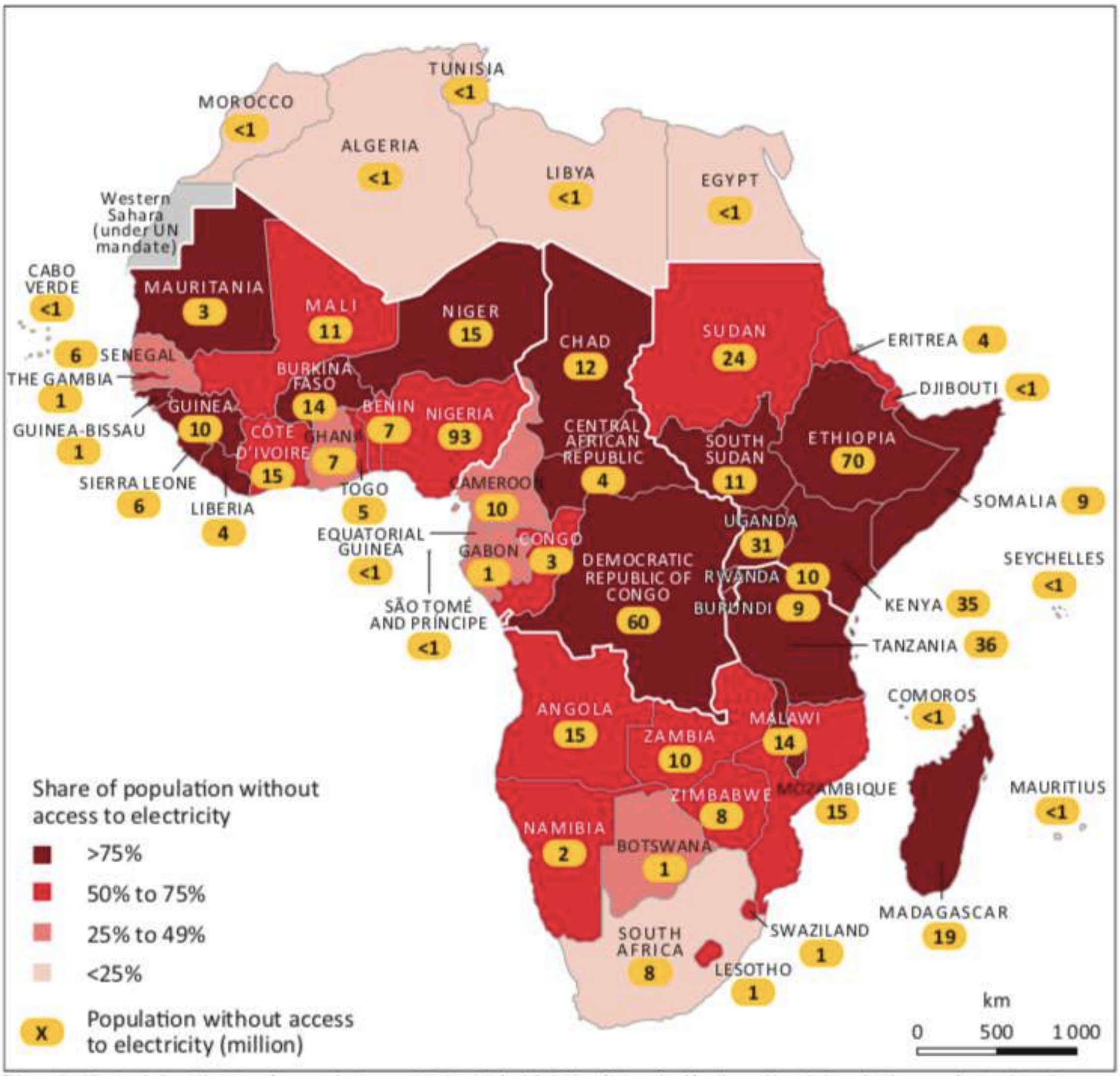
Source: Author. Data from World Bank



Source: Author. Data from AfDB Statistics Department

Evident in Figure 4.3.3, access to electricity across Sub-Saharan Africa varies. Although slightly out of date, the figure represents the dynamics that still exist today. In the ECOWAS region, the range of electricity access goes from 20% (Liberia, Sierra Leone, Niger, and Burkina Faso) to more than 50% with Senegal, and more than 70% with Ghana. Ghana is the only nation in the ECOWAS region on track to achieve universal electricity access by 2030, along with 3 other nations in the whole of Sub-Saharan Africa (IEA, 2017). Ghana now has less than 25% of its population without electricity access. Nigeria is aiming to make electricity reliable to three-quarters of the population by 2020, and reach 100% by 2030. Despite this, Ghana and all the other nations in ECOWAS still utilise back-up generators to increase household energy access.

Figure 4.3.3: National electricity inaccessibility rate in Africa in 2012



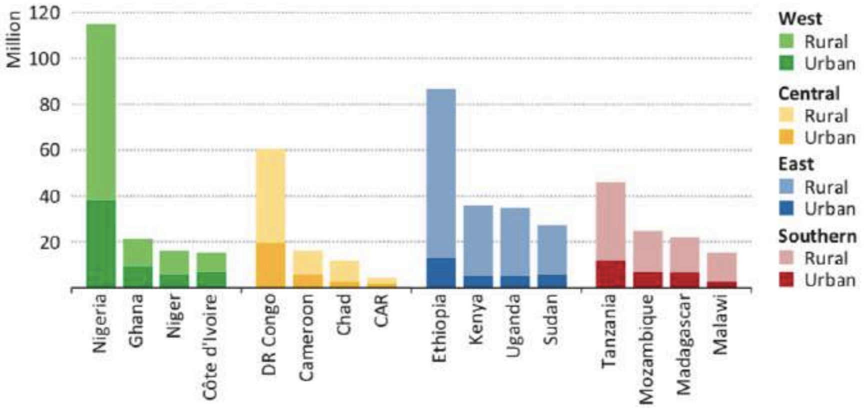
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: IEA, 2014

Traditional yet harmful energy sources are utilised when there is no electricity access, or where electricity is unreliable. Currently approximately 850 million people in Sub-Saharan Africa are using biomass, coal and kerosene (IEA, 2017). Although some communities have access to modern energy courses such as LPG and electricity, they engage in "fuel stacking"; that is, these communities continue to use solid biomass predominately for cultural or affordability reasons (IEA, 2014). Nigeria, along with Ethiopia, the Democratic Republic of Congo (DRC), Tanzania and Kenya, comprise of 50% of the population in Sub-Saharan Africa using solid biomass for cooking, as evident in Figure 4.3.4. Despite this, the usage of biomass is not predominantly concentrated in these countries, as in 42 countries, more than half of the population rely on solid biomass. In Nigeria, Ghana, Niger, and Côte d'Ivoire, the majority of this population reside in rural areas. It is also the case in Ghana and perhaps other countries where individuals are cutting down trees, mixing it with the charcoal and selling it to communities as a way to address the energy shortage (Homiah, 2019). In order to shift away from harmful biomass, several countries have implemented initiatives. Senegal has strong incentives to support LPG usage and as a result, less than a quarter of the urban population use solid biomass. Similarly, Ghana is aiming to put in place incentives to achieve the “ambitious goal of providing 50% of households with LPG by 2016, compared to less than 20% today” (IEA, 2014, p.449).

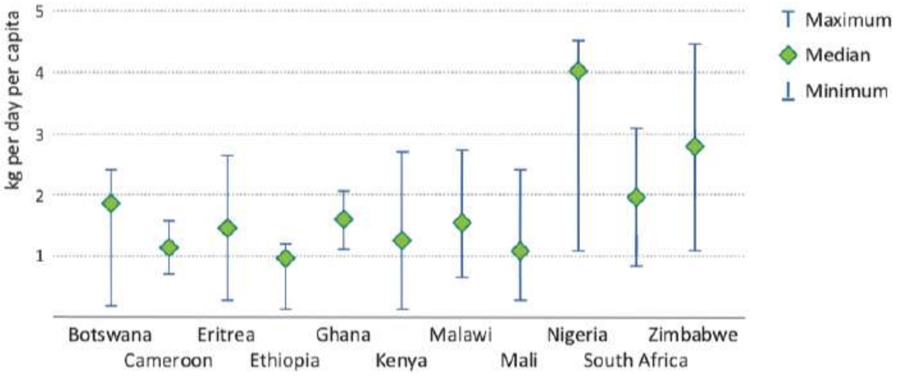
The amount of fuelwood communities can access and utilise varies within Sub-Saharan Africa, as reflected in Figure 4.3.5. Being a large continent, climate and seasonality can affect the moisture of fuelwood, and therefore effects its energy content and how efficient it is for cooking. Household sizes vary among regions also, thus the amount of fuelwood needed to cook a certain amount of food, and therefore population density affects availability and fuelwood depletion. Fuelwood tends in be abundant in some places more than others; in that case, it is greatly utilised and in some cases overused (IEA, 2014). It is clear from Figure 4.3.5 that that Nigeria’s geology variation and geographic size may contribute to the large range in fuelwood usage. Ghana, on the other hand, has a much smaller variation and is geographically smaller in size. In addition, fuelwood is more likely to be widely used in regions where there is no incentive to shift away from it; i.e., no cheaper or free alternatives.

Figure 4.3.4: Largest populations relying on solid biomass for cooking in Sub-Saharan Africa by sub-region in 2012



Source: IEA, 2014

Figure 4.3.5: Fuelwood consumption per capita per day in selected countries



Source: IEA, 2014

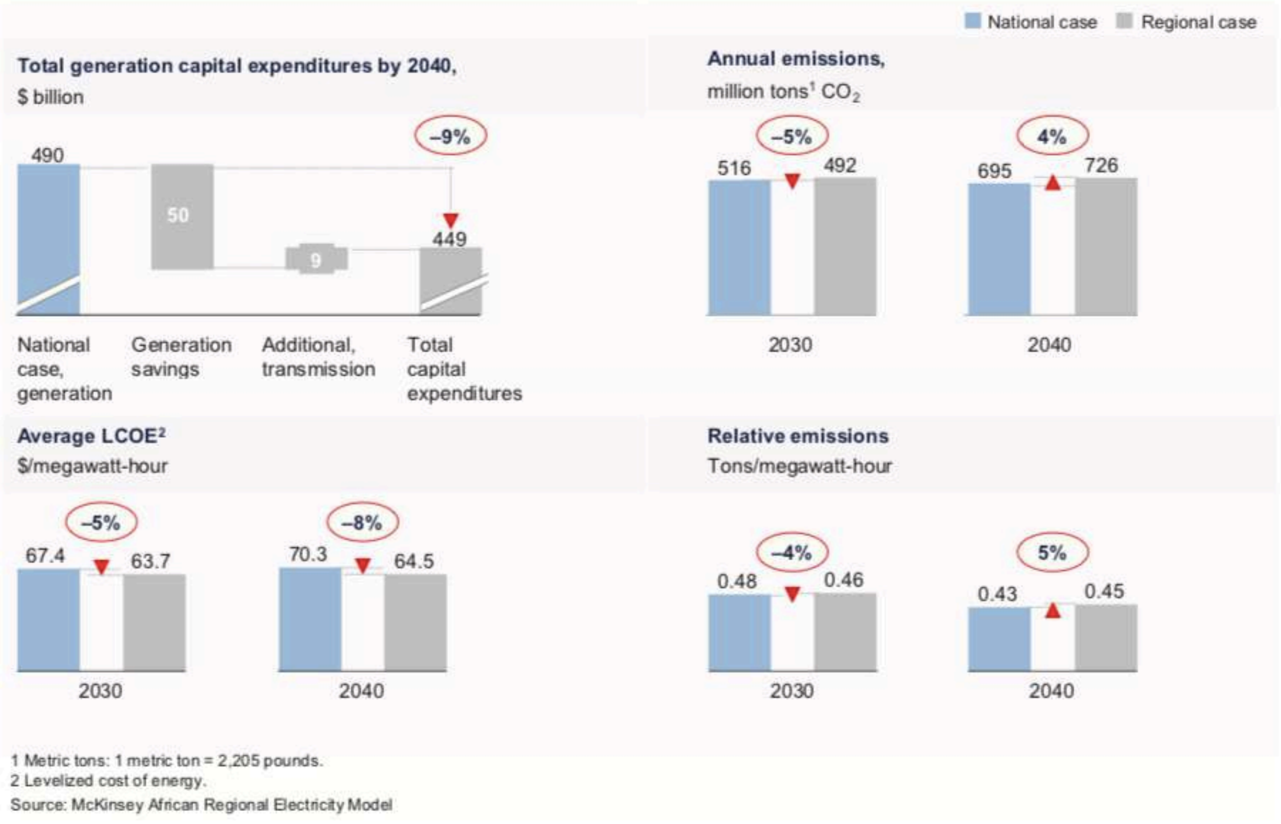
All countries in the ECOWAS region experience power outages due to a lack of power supply. In 2015, Sub-Saharan Africa nations faced an average of 690 hours of outages, with the figure being higher for Nigeria and Guinea (IEA, 2017). Power outages in Ghana are so common that there is a term for it; Dumsor (dum meaning off and sor meaning on). The lights alternate between staying on and staying off, and the period at which the lights stay on is unknown. The occurrence of Dumsor can vary from region to region; areas outside the Greater Accra region may experience Dumsor for longer periods of time. Dumsor often ranges from one hour to several in a day, and communities that are connected who can afford a back-up generator, utilise this when electricity supply is cut off. Throughout April 2019, Dumsor was particularly prominent with some blackouts lasting the majority of the day. In order to help "solve the "dumsorisation", the government has...given or sold the Electricity Company of Ghana (ECG) to the partly privatised Power Distribution Service (PDS)"(Homiah, 2019). However, since Dumsor is still a problem, Ghanaians now call PDS "Proper Dumsor".

Transmission and distribution are intuitively a bottleneck in all communities being able to access electricity; the supply of electricity reduces by more than 18% across Sub-Saharan Africa (excluding South Africa) as a result of inefficient design and poor maintenance (IEA, 2014). As it stands, there is little economic expansion to support the energy demand of the ECOWAS region. However, recently there have been strengthened efforts to enhance inter-regional cooperation for expanding network grids, especially for hydropower throughout Sub-Saharan Africa (IEA, 2014).

5.0 Regional Grid Connections

As aforementioned, regional integration across Sub-Saharan Africa could result in the saving of over US$40 billion in capital spending, as evident in Figure 5.0.0 (McKinsey & Company, 2015), enhance electricity supply through importing at times of deficit, and can substantially reduce electricity costs for the consumer. This is the opposite of the traditional thinking within Sub-Saharan Africa that avoiding reliance on other countries for electricity, and therefore vulnerability that comes with it, would enhance their own energy security. This is in fact counterintuitive; international cooperation is vital to energy security. Furthermore, from regional trade alone, West Africa could gain annual benefits of up to US$1.2 billion by 2025 (USAID, 2018). The need for greater cooperation has been identified by international government institutions, such as the United States Agency for International Development (USAID). USAID has developed a roadmap to 2030 for improving energy access in Africa, which includes a transmission roadmap that evaluates the electricity surplus in various countries, including those in the ECOWAS region.

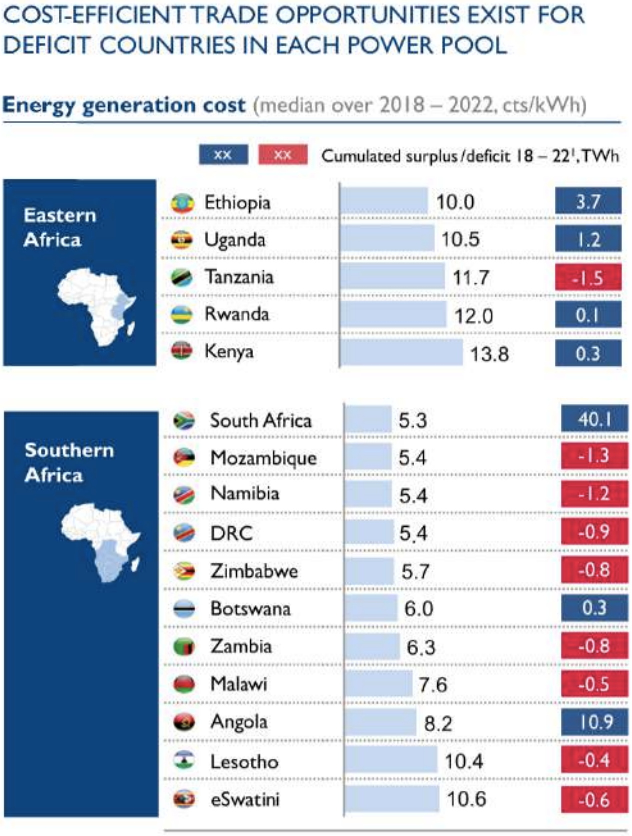
Figure 5.0.0: Potential capital expenditure savings and reduction in the levelised cost of energy in Sub-Saharan Africa

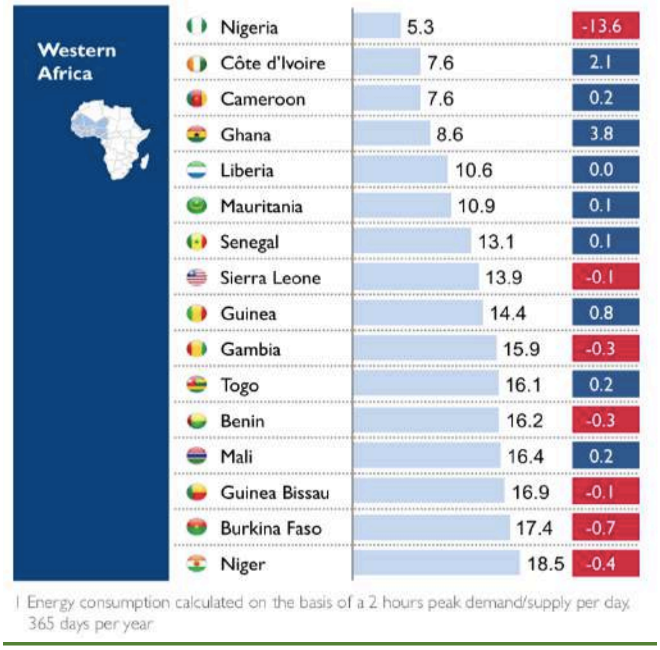


Source: McKinsey & Company, 2015

The varying generation capacity situation in ECOWAS, depicted in surplus and deficits calculated by USAID in Figure 5.0.1, supports the argument that a regional trade system is an efficient option. Ghana, Côte d'Ivoire, Cameroon, Guinea, Liberia, Senegal and Togo are expected to have surplus between 2018 and 2025 (USAID, 2018), where Ghana's surplus between 500MW and 1,300 MW will be partly due to the increase in gas in the energy mix, and Côte d'Ivoire's surplus between 300MW and 1,500MV will be mainly due to hydropower and gas plants. While Benin and Sierra Leone are expected to move from a slight deficit to a slight surplus within that same period, and Mali following the opposite trend, Nigeria bears the biggest deficit in the region standing at 3,400MV in 2018 (USAID, 2018). This deficit is mainly due to a lack of maintenance of existing generation capacity, as well as other factors such as a substantially large predicted population growth (Wakamatsu, 2019). Despite efforts to address this, it is not expected that the nation will see peak surpluses by 2025. The deficit in the region overall is expected to decline, however, countries with a generation surplus should be expected to connect with countries with a generation deficit. Figure 5.0.1 does not include individual generation costs, however, it still paints an accurate picture using weighted average generation costs mapped to each country's expected surplus and deficit. Through this, it can be suggested what type of future connections there could be; for example, Côte d'Ivoire could export electricity to Nigeria.

Figure 5.0.1:





1 Energy consumption calculated on the basis of a 2 hours peak demand/supply per day, 365 days per year

Source: USAID, 2018

5.1 Existing and Planned Connections

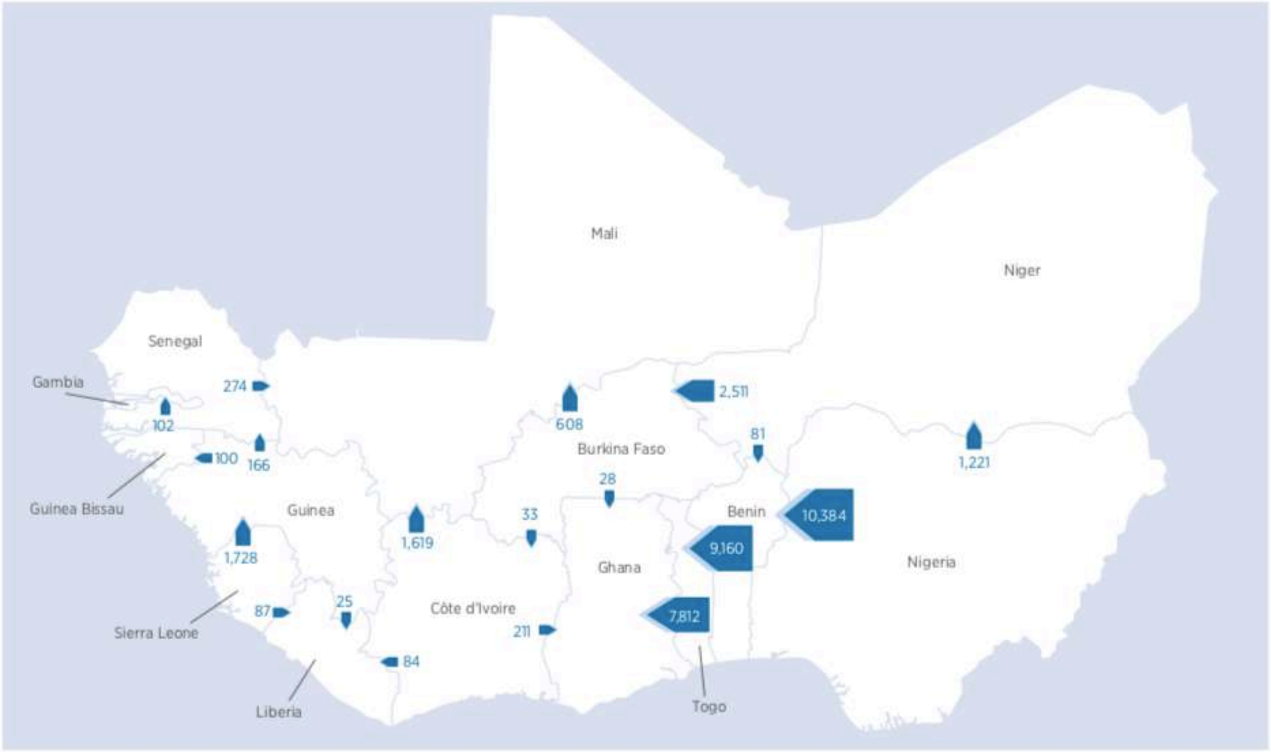
While many argue that cooperation between countries is difficult due to very few nations having significant surplus electricity (McKinsey & Company, 2015), there are plans to utilise connections that are feasible within the ECOWAS region. EREP was adopted by ECOWAS heads of state and government in July 2013, following on from adoption by Council of Ministers, Energy Ministers and validation by the ECOWAS Experts Group. It has the aim of increasing the share of renewable energy and address the challenge of how best to distribute it, and as such, a regional grid as a solution is being discussed. Figure 5.1.0 visually depicts existing and planned grid connections within the ECOWAS region.

Figure 5.1.0: ECOWAS region existing and planning transmission grid network

Source: WAPP GIS database. (Source: Energydata.info, 2018).

There are various projects planned to realise a grid network that looks like that of Figure 5.1.0. For landlocked countries that are particularly hindered with the inability to use coastlines to harbour plants, there are plans to utilise a connection from Ghana to Burkina Faso, Niger and other nations. Another connection planned to utilise Côte d'Ivoire's surplus is a transmission line from Côte d'Ivoire, going through the rest of West Africa, particularly to Sierra Leone and Guinea, through the Gulf of Guinea (CLSG) line (USAID, 2018). The West African Power Transmission Corridor under construction plans to improve interconnectivity particularly through hydropower in Guinea, Guinea Bissau, Gambia, Sierra Leone, Ghana, Liberia and Côte d'Ivoire. With high regional imbalances in the eastern Gulf of Guinea lies the opportunity to utilise a connection from Togo to Benin (with a surplus between 20 and 50 MW, and 50 and 130 MW respectively). There is also the possibility of utilising connections originating in parts of Africa outside of the ECOWAS region. The Grand Igna is a 40 GW hydroelectric dam project planned in Congo to stretch throughout Sub-Saharan Africa; if completed it would be the largest dam in the world (McKinsey & Company, 2015). With the development of WAPP, Nigeria is looking to important electricity from Cameroon. The expansion of the power sector in Nigeria alone would require US$6 million per year in transmission and distribution (IEA, 2014). While analysis of grids beyond West Africa is beyond the scope of this thesis, it is worth acknowledging that such transmission projects in West Africa also involve other parts of Africa.

Figure 5.1.1: ECOWAS Regional trade flows in 2030 under the National Targets Scenario (GWh)

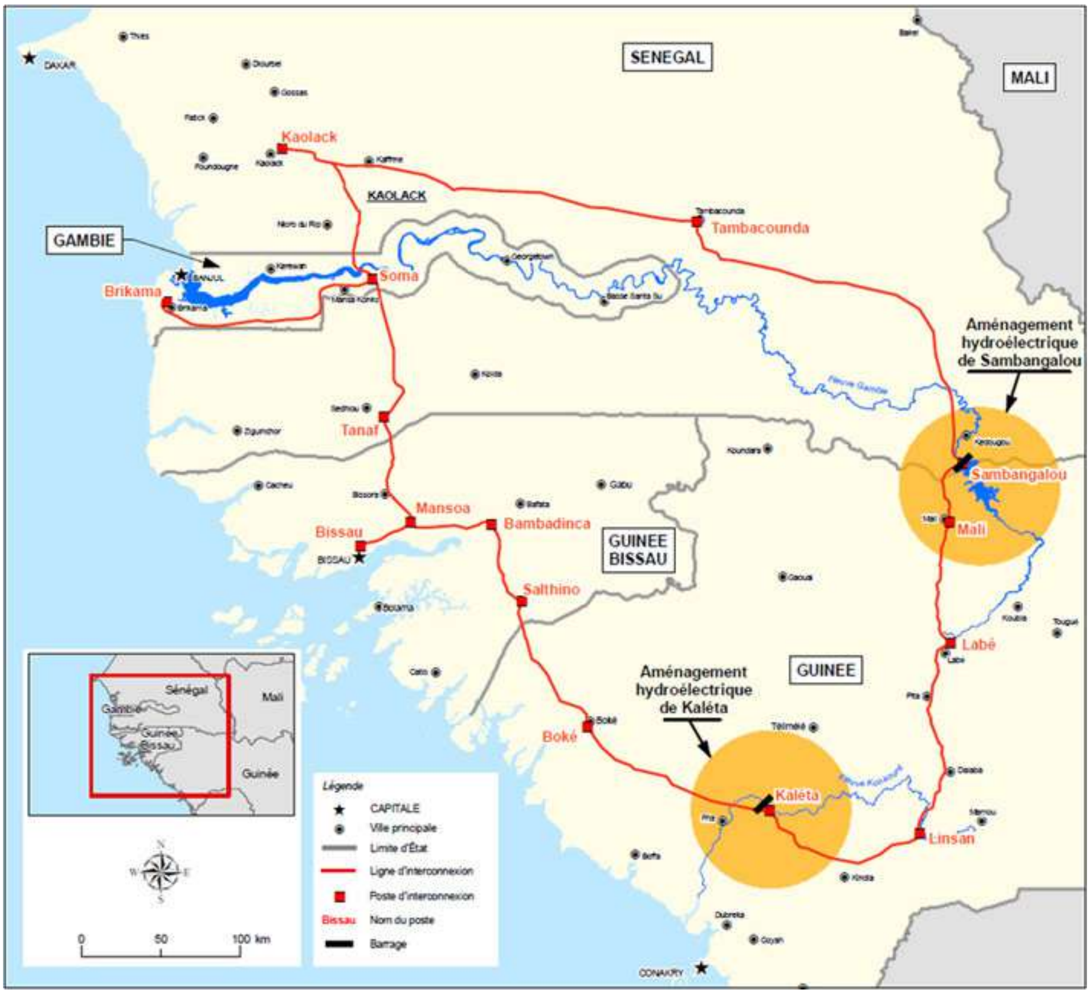


IRENA, 2018

The regional trade flows are presented with modelling techniques in Figure 5.1.1. The greatest net cross-border electricity trade flow, the Coastal Backbone/Dorsale infrastructure going from Nigeria through Benin, Togo and Ghana, is expected to utilise Nigeria's domestic renewable energy generation particularly from hydropower (IRENA, 2018). The next two biggest trade flows lie within the Intrazonal Hub that links Ghana, Burkina Faso, Côte d'Ivoire and Mali, and the North-core (or Corridor Nord) linking Nigeria, Niger, Benin and Burkina Faso. The net trade flow is relatively low for the CLSG and Gambia River Basin Organisation (OMVG) transmission line; they both contribute value in providing revenue and energy security. The details of the OMVG transmission line is looked into in more depth below.

From 29th April 2015, it was decided that an interconnection between Senegal and Guinea, through the OMVG and an extension of WAPP, will be constructed by 2022. Going through Senegal, Guinea, Guinea-Bissau and Gambia, it aims to address the deficit through supplying electricity from Senegal (USAID, 2018). The project comprises of a WAPPP transmission network OMVG interconnection with two components: 1) a 1,1677 km network of 225 kV which will handle 800 MW and 2) fifteen 225-300kV substations (The World Bank Group, 2019c). The extent of the grid network is visually presented in Figure 5.1.2. The transmission lines are particularly expected to utilise hydropower generated in the Kayanga-Géba and Koliba-Corubal Rivers of Gambia.

Figure 5.1.2: Planned OMVG transmission lines, to be completed by 2022



Source: AfDB, no date

Active intervention is required for this project, meaning that the project is considered to be able to "deliver sufficient impact, enjoy the right timing vs. trade needs" but also be faced with obstacles or delays to completion, therefore needing to be "accelerated through concrete, identifiable actions" (USAID, 2018, p. 20). The total project cost is thought to stand at around US$711 million, financed by banks and governments as depicted in Table 5.1.0. Beyond the OMVG member countries (Gambia, Guinea, Guinea-Bissau and Senegal), the governments of other countries, such as Germany, and international banks are assisting with funding. A range of contracts were awarded for procurement to energy and transport bodies in the OMVG member countries (The World Bank Group, 2019c). Although no substations have been completed as of yet, nor have there been any fibre optic networks built, the project management firm in 2018 was considered to be "performing adequately" (The World Bank Group, 2019c).

Table 5.1.0: Financers involved in OMVG transmission line (US$ Millions)

Financier	Investment (US$ Millions)
African Development Bank	134,000,000.00
European Investment Bank (EIB)	106,000,000.00
International Development Association (Ida)	200,000,000.00
Islamic Development Bank	93,700,000.00
Kuwait: Kuwait Fund for Arab Economic Development	23,900,000.00
Germany: Kreditanstalt Fur Wiederaufbau (Kfw)	32,000,000.00
West African Development Bank	53,600,000.00
Borrower/Recipient (OMVG Member Countries)	16,000,000.00
France: Govt. Of [MOFA and Agence Française de Développement (AFD)]	51,800,000.00

Source: Author. Data from: The World Bank Group, 2019c.

Measures were successfully put in place in the early planning stages, such as risk and contingency planning. Impact assessment and consultation with communities affected by the acquisition of land needed for construction has meant that the potential impact of the project on populations were analysed, as well as countermeasures, and their concerns understood. As well as the examples of questions and concerns set out in Appendix I, an example of such concerns being addressed is the resettling of populations due to the construction of the Brikama substation in Gambia, involving reallocating populations and compensating them for their loss of income from losing farmland (The World Bank Group, 2019d). However, the level of female participation in the consultation was low. In Gambia's Soma region, only 1.15% of participants in community meetings for the consultations were female (The World Bank Group, 2019d). Indeed, land owners in Gambia tend to be men, therefore women are not often considered as individuals concerned with land related matters. However, as a lack of electricity is borne heavier on females, as in traditional areas of West Africa they are responsible for cooking, projects should include the concerns females have about grid projects on their way of life. Energy related projects that affect communities should aim to be as inclusive as possible.

5.2 Challenges and Potential Bottlenecks

The utilisation of a regional grid in West Africa is part of an ongoing debate amongst ECOWAS members due to concerns about the regional energy market. One can argue that one of the reasons for concern is political acceptability in both importing and exporting countries. Many communities in ECOWAS are against the notion of their nation exporting electricity to other nations when their own has not yet achieved complete electrification. The counter-argument for this includes the possibility of "incremental national revenue, as well as foreign exchange from saes of power" (McKinsey & Company, 2015, p.28). There also lies unquantifiable social benefits for cross-border immigration; a country that is more economically prosperous and has energy in surplus can improve the energy situation of neighbouring countries, and cause a reduction in immigration from those countries. Indeed, these groups are likely to migrate for a better quality of life with electricity access (N'Guessan, 2019). Another concern communities may have is the potential impact on the environment. Stakeholders involved in the project must consult with communities and produce ways to repair or deter any potential damage.

Another issue is the need for coordination between countries. At the political level, bilateral and multilateral negotiations are required for deciding on power purchase agreements (PPAs). This becomes more complicated when projects need to consider regional and national factors. Political will in the government to succeed the incumbent one is one issue, and political will in the current government is another. Without political will, plans cannot be realised. In addition, in another dimension of required coordination, if solar energy, for example, is utilised for the grid and there are periods of low sunlight in one region, it may need to import hydro generated electricity from another. Diversity in energy source for the international grid is needed to ensure a good complimentary relationship amongst the countries' electricity provision.

Infrastructure is lacking in some areas due to a myriad of factors, including a lack of funds needed to renovate and replace aging transmission lines and build new ones. With regard to developing new grids and trading electricity, however, a few conditions must hold in order to allow the grid to be financial feasibility; this includes " the cost of power in the exporting country…[being] lower than the price in the importing country" (McKinsey & Company, 2015, p.28). Financial regulations should also be put in the place to incentivise trade in power, as well as the need for exporters to receive assurance of guaranteed payment. Connections between countries for energy sources that are intermittent is vital (Esteban, 2019). Although the plans for the international grid connections in the ECOWAS region are still in the planning stage, the financial case for international grid connections will become overwhelming to the point where the region will have no choice but to develop it.

Funds are required at various stages of the project, including early stage development and feasibility assessments. The ability to guarantee future revenue streams affects the ability to obtain funds for transmission projects. Such a guarantee is not always easy to achieve for the ECOWAS region as utilities with whom long term contracts are established tend to have low levels of creditworthiness. Proving bankability becomes even more complicated when revenue is coming from utilities (USAID, 2018). In addition, there are limited private investments available as such investments have historically been focused on power generation instead of transmission.

Financial requirements may be heightened if there is a failure in mitigating risks regarding securing rights for building the transmission line. In such a situation, a third party or political group is needed to facilitate dialogue. Securing long term support from political figures is a challenge in itself. The constructing of grid connections is a long-term project, which typically goes beyond the political lifetime of an incumbent party in a democracy. As aforementioned, the project must have the approval of not only the incumbent government, but the succeeding ones. In addition, the government and other stakeholders must not be involved in transparency issues of any sort, in order to allow resources to be allocated effectively and efficiently.

From connecting housing to ensuring capacity of transmission grids, a range of technical expertise is required. Sufficient generation and cooperation between system operators is lacking in the ECOWAS region and needs to be substantially strengthened in order to utilise a regional grid. For sufficient generation, reliable excess operational capacity, known as a reserve margin, is required. The reserve margin depicts the difference between the "operable capacity and the peak demand for a particular year, as a percentage of peak demand" (IRENA, 2018, p.48). A gradual approach to a minimum reserve margin constraint of 10% is required in the ECOWAS region, where only "firm" capacity is considered to contribute to this margin. The share of capacity regarded as "firm" is noted as the capacity credit, whereby the acceptable level is 1.0 for thermal and hydropower dams, and other dispatchable technologies.

The reserve margin is defined as:

$$\sum_{i=1}^{n} \alpha(i) C_P(i) \geq (1 + RM) D$$

where:

- $a(i)$ is the capacity credit assigned to a plant or technology (i) or the share of capacity regarded as "firm"
- $C_p(i)$ is the capacity of the plant or technology (i) in MW, for centralised grid systems
- D is peak demand, in MV, of a centralised grid
- RM is the reserve margin (IRENA, 2018)

From the definition, the sum of the conditions depict that the capacity credit multiplied by the capacity of the plant, must be greater than 1 plus the reserve margin multiplied by peak demand.

The acceptable reserve margin, which varies for each renewable energy source, is slightly complex. As the definition of reserve margin is an aggregate representation of the load, it must be adjusted to account for the variability in wind and solar power. This is done through 1) a flexibility of dispatch: no allowance for flexibility in when the sources can be dispatched to meet demand because in reality they cannot, and 2) capacity credit: centralised solar plants are assigned an extra 5% capacity credit while wind is not considered as a contributor to the reserve margin (IRENA, 2018). In addition, technical limitations with regard to how quickly a plant can rump up or rump down production is taken into account through de-rating (calculated through 1 minus the available factor). For example, biomass plants are de-rated by the available factor of 50% (IRENA, 2018). The reserve margin can be derived through modelling exercises reliant on statistical analyses of a country's variable resource and its demand (IRENA, 2018). The need to take into account all these factors with regard to feasibility of grid connections is a challenge in itself that the ECOWAS countries need to face, most likely with the help of the international community.

International government bodies such as Japan International Cooperation Agency (JICA) finance interconnected transmission lines in Africa (Wakamatsu, 2019), although they tend to be on a national level, for example in Nigeria and Cabo Verde. There are, however, risks with stability and payment. The risk lies in the fact that a power outage in one country could cause a power surge in another country, thus destroying their current (Wakamatsu, 2019). The issue with payment lies in the fact that since the grid is international, when one party does not pay what is due, it becomes even more difficult to recover the cost, especially as there are different laws in different jurisdictions (Wakamatsu, 2019). ECOWAS members may need external assistance to address these issues.

In addition, the housing situation in many rural communities is one that includes semi-permanent and temporary houses, which may also be technically difficult to link to a grid. Indeed with regard to pricing, these types of accommodation are less likely to be connected to the grid, as it is "more common for utility companies to connect permanent houses" (Olang et al., 2018, p.4). In addition, the price of electricity tends to be more expensive for poorer communities that would want to connect to the (main) grid. Fossil fuels are part of reason for the high costs, standing at around US$140 per MWh (IEA, 2014)). Technical assistance is required first for the regional grid connections in order to drive down the price of electricity and incentivise households to utilise the more affordable electricity.

One barrier some countries must consider is the threat of terrorism and natural disasters to the infrastructure of the grid. Some countries, such as Nigeria, struggle with vandalism and power theft. It can be argued however that a terrorist attack is much easier on a grid relying on oil or gas pipes, and perhaps hydropower, rather than a grid powered by small-scale solar, for example. One cannot easily block the sun from shinning or going to every household and somehow confiscating all solar panels (Esteban, 2019). This is one concern that is relatively miniscule compared to the rest, however, it is still useful to understand that such a threat exists, and that proper maintenance and anti-vandalism measures must be taken to preserve the longevity of the infrastructure.

6.0 Decentralised Energy Infrastructure

Under the IEA's Energy for All Case, a scenario where modern energy for all is achieved, decentralised technology will play a vital role in improving electricity access. This especially applies to rural communities as a reduction in energy poverty would lead to a greater energy demand. Those who "currently lack modern energy services will seek much more than a single light bulb" (Olang et al., 2018, p.2). Thus, "energy access should be the first pillar" (Olang et al., 2018). Mini-grids are most efficient for regions that are too distant or dispersed to be connected to a main grid in the medium-term, but too "densely populated enough to offer economies of scale in power delivery" (DFID, 2014, p.1). In utilising geospatial modelling systems, the IEA suggests that off-grid and mini-grids are the least cost solution for 75% of the additional connections needed in Sub-Saharan Africa (IEA, 2017). The UK Department for International Development (DFID) calculates that CEMGs are the most economical way of achieving the IEA's estimate of 40% of remaining connections in Africa being best achieved through mini-grids (DFID, 2014). As renewable energy is generally becoming cheaper the more Research and Development (R&D) is invested into it, the case for renewables will only continue to grow stronger.

ECOWAS aims to have 22% of its rural population connected by mini-grids and stand-alone systems by 2020, and 25% of that population by 2030 (Elayo, no date). With ECOWAS countries, "104.3 million people…stand to benefit from the 128,000 mini-grids expected to be installed by 2030" (Hobson, 2016, p.17). Despite an increased interest in this sector over recent years, with initiatives implemented by the German Agency for International Cooperation (GIZ), World Bank, AFD, Asian Development Bank (ADB), Norway Energy+ and US Power Africa, mini-grids are the most of off-track component in meeting its projected share of energy provision.

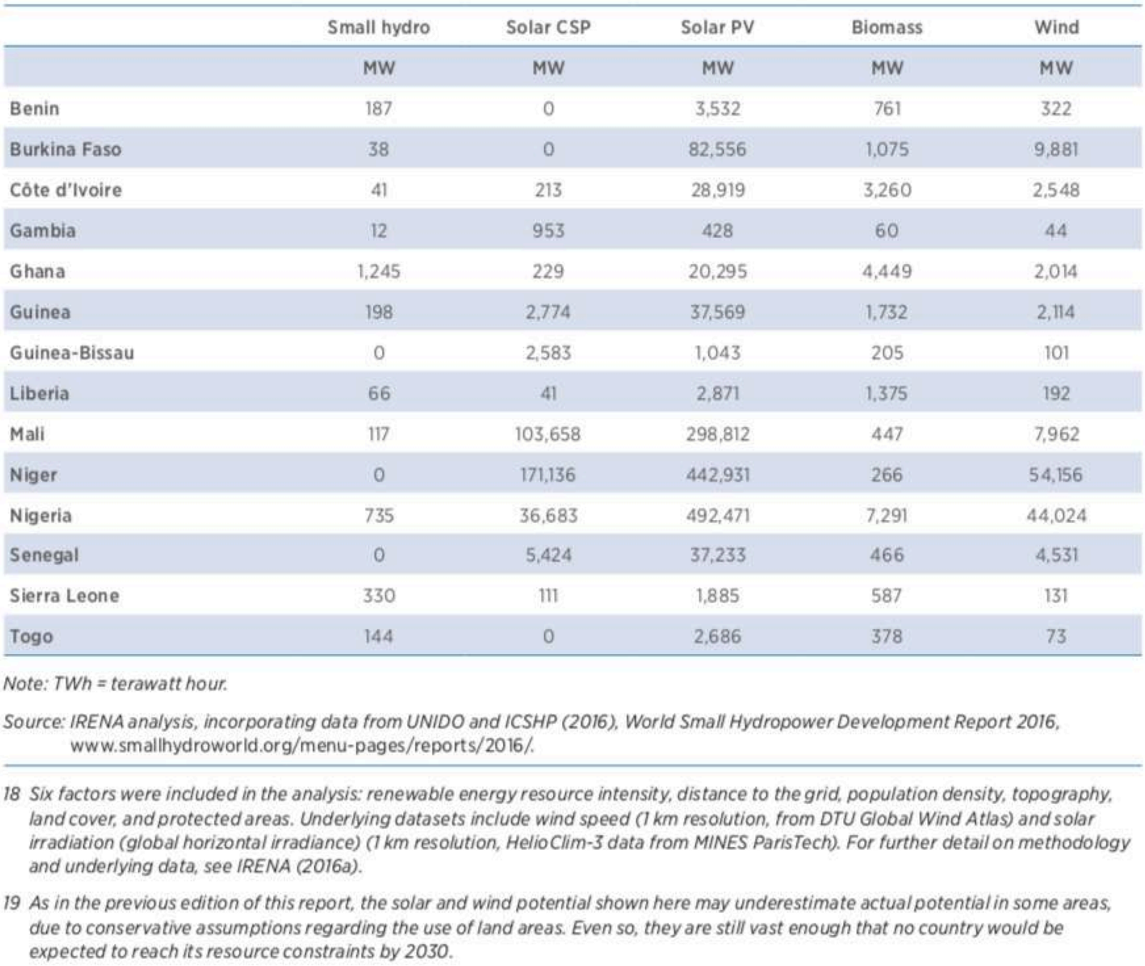
Although there is knowledge on the ground of the existence of small-scale solar grids in communities in the ECOWAS region, through interviewing residents in Ghana, the grids are too expensive for many communities to obtain (Nkrumah, 2019). Residents tend to believe that more should be done to utilise solar energy, due to its high capacity in Ghana. Two type of grids could assist with this; 1) mini-grids that are not connected to the regional networks and are often used for households in distant communities, and 2) off-grid networks that are geared towards households that want to use stand-alone systems. Even with NPS being realised, 600 million people will still be without electricity access in 2030 (IEA, 2017). It is therefore expected that decentralised energy systems like mini-grids should play a part in decreasing this number. As such, this thesis explores mini-grids as off-grids are beyond its scope.

6.1 Mini-Grid Options

There is potential for renewable energy in ECOWAS that has not yet been fully tapped into in. Table 6.1.0 depicts the potential per region based on the 2011 WAPP Master Plan, to be expanded on later.

The potential of each energy type in Table 6.1.0 was based on different analyses. The potential for solar PV and wind is based on IRENA analyses from 2016, which is based on ranking the quality of areas that can be utilised for development, rather than the binary approach where land is either classified as available or unavailable. The small hydropower estimates are based on analyses from the United Nations Industrial Development Organisation (UNIDO) and the International Centre on Small Hydro Power (ICSHP). The potential for biomass was calculated from analyses by IRENA. The type of modelling the analyses are based on is important to bear in mind, as there are discrepancies in each of them. Although the estimates in Table 6.1.0 have come from a range of sources, it paints an accurate picture of the overall renewable energy potential in the ECOWAS region. It is evident that the most potential lies in solar PV. Perhaps unsurprisingly, as the capacity for wind energy is considered relatively low, small hydro potential is much greater than that of wind energy.

Table 6.1.0: Renewable energy potential breakdown in ECOWAS region



	Small hydro	Solar CSP	Solar PV	Biomass	Wind
	MW	MW	MW	MW	MW
Benin	187	0	3,532	761	322
Burkina Faso	38	0	82,556	1,075	9,881
Côte d'Ivoire	41	213	28,919	3,260	2,548
Gambia	12	953	428	60	44
Ghana	1,245	229	20,295	4,449	2,014
Guinea	198	2,774	37,569	1,732	2,114
Guinea-Bissau	0	2,583	1,043	205	101
Liberia	66	41	2,871	1,375	192
Mali	117	103,658	298,812	447	7,962
Niger	0	171,136	442,931	266	54,156
Nigeria	735	36,683	492,471	7,291	44,024
Senegal	0	5,424	37,233	466	4,531
Sierra Leone	330	111	1,885	587	131
Togo	144	0	2,686	378	73

Note: TWh = terawatt hour.

Source: IRENA analysis, incorporating data from UNIDO and ICSHP (2016), World Small Hydropower Development Report 2016, www.smallhydroworld.org/menu-pages/reports/2016/.

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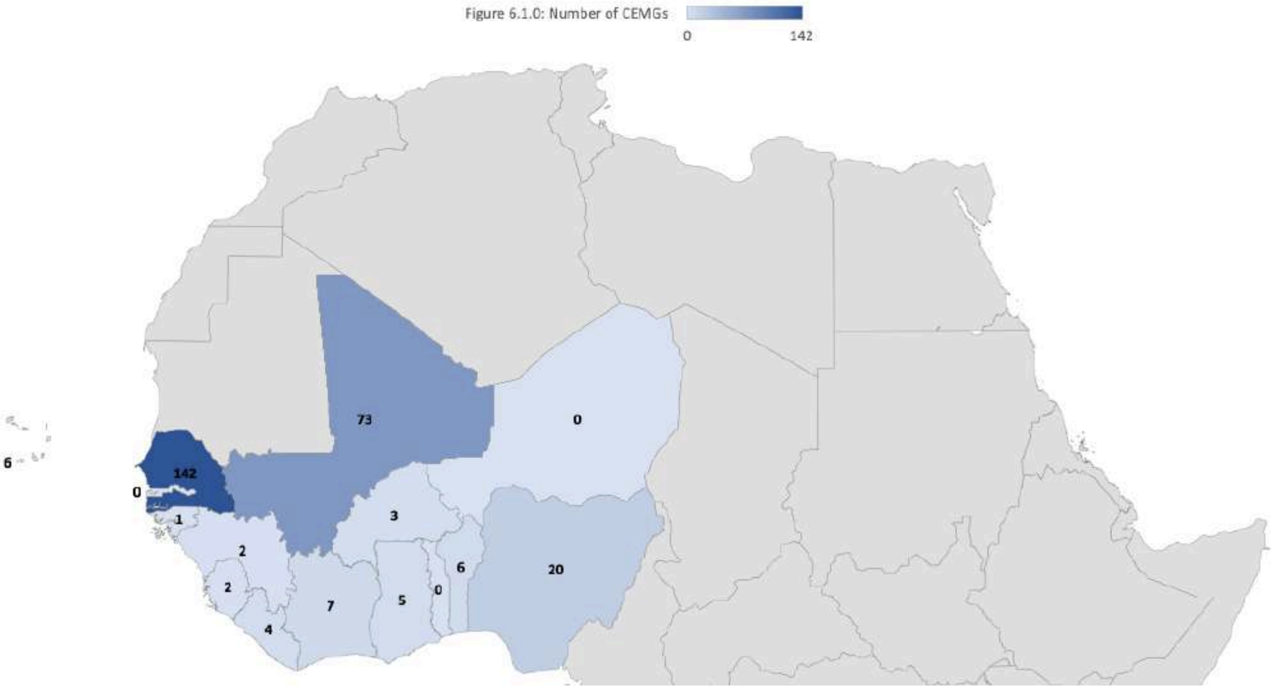
18 Six factors were included in the analysis: renewable energy resource intensity, distance to the grid, population density, topography, land cover, and protected areas. Underlying datasets include wind speed (1 km resolution, from DTU Global Wind Atlas) and solar irradiation (global horizontal irradiance) (1 km resolution, HelioClim-3 data from MINES ParisTech). For further detail on methodology and underlying data, see IRENA (2016a).

19 As in the previous edition of this report, the solar and wind potential shown here may underestimate actual potential in some areas, due to conservative assumptions regarding the use of land areas. Even so, they are still vast enough that no country would be expected to reach its resource constraints by 2030.

Source: IRENA, 2018

In the ECOWAS region, there are at least 271 existing CEMGs, with a collective capacity of 11.6MW. However, 97% of this is capacity is operational (Hobson, 2016). Gambia currently has no CEMGs, as the previous one it did have (at 8.3 kWp) eventually became part of the main grid (20.7 kWp). All nations in the region are either promoting or are already utilising mini-grids (Bugatti, 2015). The ECOWAS region's target of implementing at least 128,000 CEMGs by 2030, however, is ambitious (Bugatti, 2015).

Figure 6.1.0: Number of CEMGs in ECOWAS (as of 2015)



Source: Author. Data from: Hobson, 2016

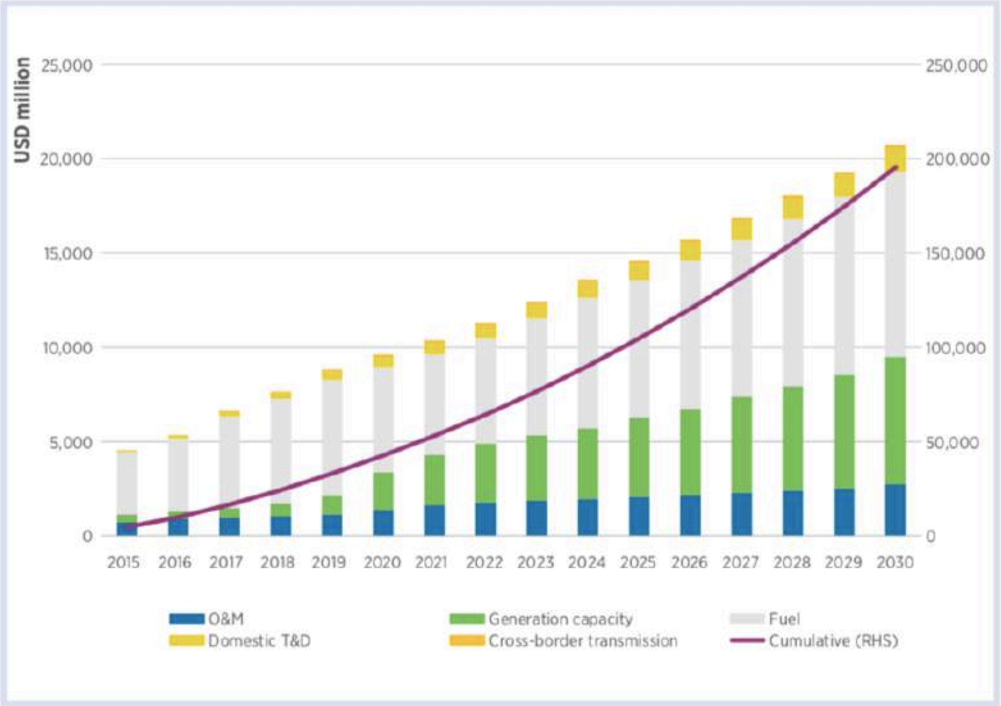
There are three main types of mini-grids: 1) grid-connect networks that are greater than 1MW 2) isolated mini-grids that are between 100kW and 1MW, and 3) very small isolated or micro mini-grids that are less than 100kW (DFID, 2014). All types would be useful in connecting communities to electricity. Evident in Figure 6.1.0, Senegal's CEMGs count for more than of half of the total CEMGs in the region, however Mali has three times for installed capacity at 4MW compared to Senegal at 1.MV (Hobson, 2016). Indeed, Mali is a sparsely populated country about to reach 27% electricity access through mini-grid solutions (IEA, 2014). Furthermore, despite the majority of the region's renewable energy coming from hydropower, for CEMGs, bio-diesel makes up 6% of CEMGs, hydropower alone makes up 2%, PV-diesel hybrids make up 68% and PV alone makes up 23% (Hobson, 2016). There are 1,167 CEMG projects in the pipeline, with an average size of 50kW, as portrayed in Appendix II (Hobson, 2016). Different scenarios and thus the potential for each resource will be looked into at more depth in the following sections.

6.1.1 System Planning Test Model for West Africa (SPLAT-W) and West Africa Power Pool (WAPP) Master Plan

Under different scenarios, the potential of renewable energy expansion in the ECOWAS region can be examined. The WAPP Master Plan, for enhancing the share of renewable technology in the energy sector, is often portrayed in conjunction with the SPLAT-W model. The SPLAT-W model "computes economic implications of a given scenario in terms of investment cost (in generation and [transmission and distribution]), fuel costs and [operation and management] costs" (IRENA, 2018, p.66). WAPP differs to SPLAT-W in that the former depicts the rise of non-hydro renewables and thus a lower hydropower capacity due to drought; the "Dry-year" assumption is considered in the modelling. In the SPLAT-W model, a greater penetration of renewables is expected to be achieved by substituting gas with biomass and solar PV, especially in countries such as Ghana and Côte d'Ivoire (IRENA, 2018).

The sum of the system costs computed under the SPLAT-W model is the costs that the models aims to minimise. Under Figure 6.1.1.0, fuel costs take up the largest share of the total system costs. However, this share is expected to decline as investments in renewable energy increase. The fall in fuel costs is expected to be 25% between 2016 and 2030, whereas the capacity investment system cost is expected to increase by 20% over the same period. In addition, the cost difference in system costs between the National Targets and Reference Scenario only become significant and increasingly large from 2020. ECOWAS regions must take into account the system costs and the extent of impact renewables can have one them, in order to shift towards a cleaner economy.

Figure 6.1.1.0: Total undiscounted system costs under the National Targets Scenario



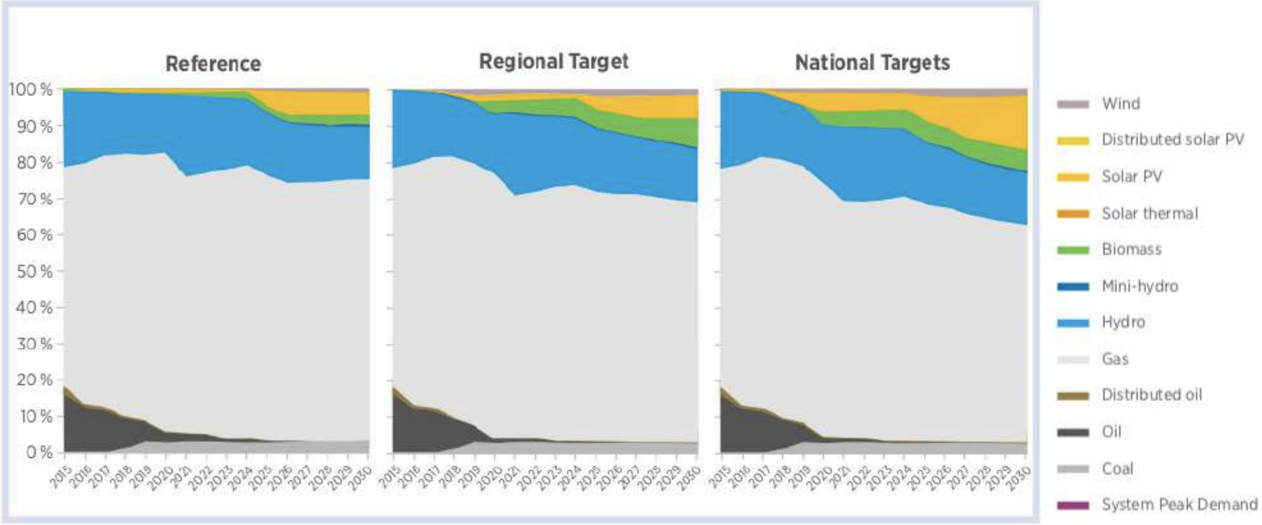
Source: IRENA, 2018.

Despite being able to take into account the system costs, one negative factor of the SPLAT-W model is that it is based on assumptions that may not hold in all ECOWAS countries. There is a need for local experts to examine these assumptions in order to "develop and compare their own scenarios" for analysing "the benefits and challenges of [the] accelerated deployment of renewables" (IRENA, 2018). It is important that in line with SE4All, all households have energy access that is compatible with a decent standard of living for them (Olang et al., 2018).

6.1.2 Reference Scenario

WAPP goes hand in hand with the Reference Scenario and Renewable Target Scenario. The Reference Scenario includes updates on factors such as fuel and renewable technology costs. It also includes an enhanced representation of renewables depicted in the SPLAT-W model.

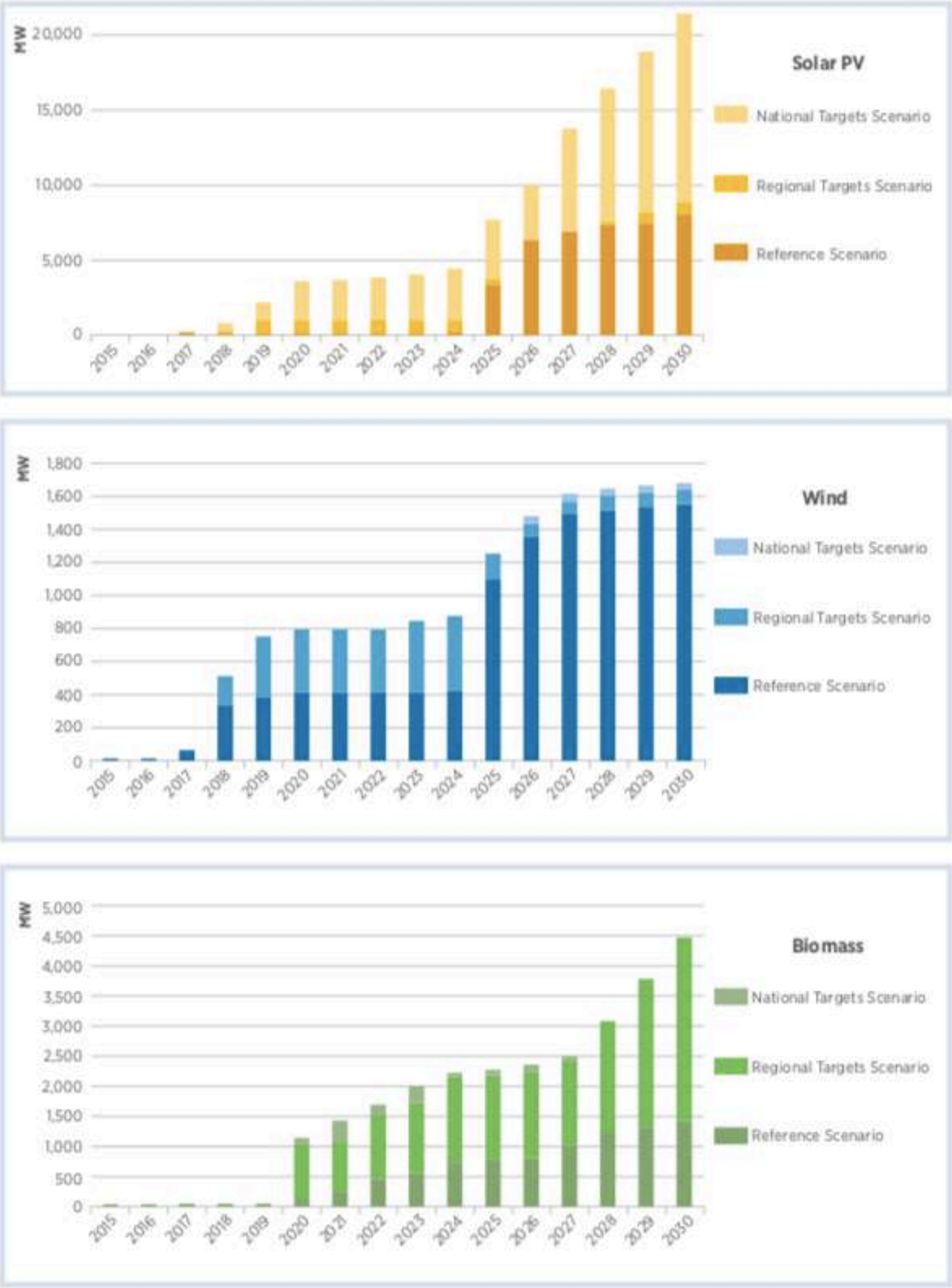
Figure 6.1.2.0: Electricity production in Reference, Regional Target and National Target Scenarios



Source: IRENA, 2018.

The additional capacity in the Reference Scenario is depicted in Figure 6.1.2.1 for solar, wind and biomass. These factors are also shifting; so much so that one update in the competitiveness of solar PV has meant that a 2013 prediction of solar PV and wind power making up 0% of the total grid-connected electricity production increased to 10% in 2018 (IRENA, 2018). In addition, the 20-30% relative fall in oil and fuel costs for 2030 has caused a revised estimate.

Figure 6.1.2.1: New capacity additions under the National Targets, Regional Targets and Reference Scenario

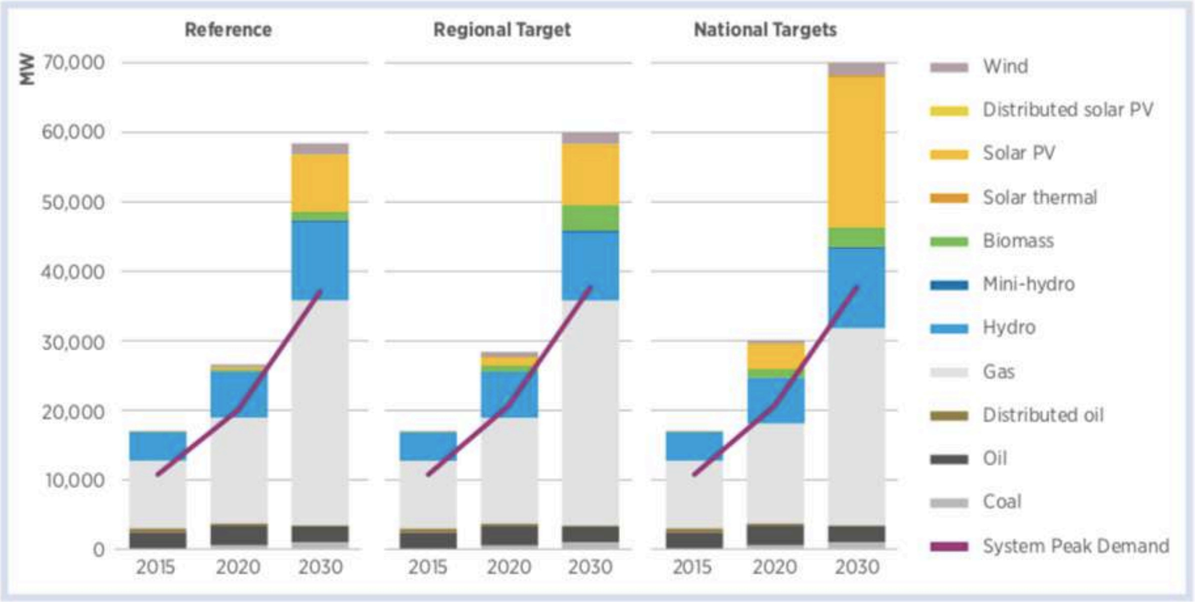


Source: IRENA, 2018.

6.1.3 Regional EREP Target and National Targets Scenario

In the Reference Scenario, there is a 25% total grid connection generation of renewable energy by 2030; for the Regional EREP Target Scenario, this figure rises to 31% (IRENA, 2018). In addition, as evident in Figure 6.1.2.1, the 2030 solar PV and biomass capacity increases by 1 GW and 3 GW respectively under the Regional EREP Target, relative to the Reference Scenario. In the National Targets Scenario, the aggregate share of renewable energy across the ECOWAS region is much greater than the other two scenarios. As evident in Figure 6.1.3.0, more than 12 GW of additional solar PV capacity is expected for 2030 for the National Targets Scenario in comparison to the Regional EREP Target (IRENA, 2018). In addition, the size of the solar PV market is expected to be over 20 GW by 2030 under the National Targets Scenario, compared to over 8 W under the Reference Scenario. One may argue that the more ambitious national targets are due to the individual nations wanting to gain a better reputation on the international stage by being seen as a nation that has great intentions for shifting towards cleaner technology. Despite the aforementioned, similarities do persist throughout the scenarios. For example, under both the Reference and National Targets Scenario, it is predicted that the reducing cost of solar PV and wind generation will cause the share of hydropower in the energy mix to decline.

Figure 6.1.3.0: Electricity Capacity in Reference, Regional EREP Target and National Target Scenarios



Source: IRENA, 2018.

With the future energy mix differing among the three scenarios, there is a nuance in future CO_2 emissions calculations. Under the National Target Scenario, a 12.5 Mt CO_2 reduction is anticipated by 2030, a 15% reduction compared to the Reference Scenario (IRENA, 2018). The level of emphasis placed on the Paris Agreement affects the prediction used in the scenarios.

As the scenarios are based on different modelling tools and assumptions, the scenario referred to by an institution or country could set the course for what kind of projects are developed and how ambitious they are. For example, under the Reference Scenario, the 2030 renewable share of energy falls short of the 31% EREP target by 6%. However, where the renewable share of capacity is considered (percentage peak load), the Reference Scenario exceeds the EREP target of 48% by 17% (IRENA, 2018). This discrepancy highlights the importance of the assumptions that are assigned to different energy sources.

6.1.4 Hydropower

There is huge potential for the ECOWAS nations to utilise hydro mini-grids, as it is relatively cheap in the long-term and has a long operational life-span. Even bigger potential is identified with large hydropower, with 13,371 MW collectively, compared with the potential for small scale hydropower which stands at 3,109 MW collectively (IRENA, 2018). Not all ECOWAS members have the capacity to develop small hydropower; namely, Guinea-Bissau, Niger and Senegal, as evident in Table 6.1.0. In the Reference Scenario, large hydro power is expected to make up the largest portion of the electricity production mix within the renewable energy category. However, by 2030, hydropower will only be slightly larger than solar power in terms of capacity. Despite this, it cannot be denied that hydro mini-grids will be significant in improving energy access and affordability in the ECOWAS region.

The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) is focused on disseminating hydropower plants as a means to reach its aforementioned goals towards a cleaner future. The high initial start-up costs require large investments; obtaining this is often an issue for poorer economies. ECWOAS regions must seek the financial and technical support from international institutions to develop capacity.

Despite the case for hydropower, opposition to its development exists. This opposition tends to consist of concerns over the displacement of citizens, species, and other negative impacts on the environment. Other environmental concerns are linked to caution regarding droughts, which occur frequently in ECOWAS member countries. The ability to produce and store electricity at times of drought is also a point to consider, especially for calculating capacity. Conservative dry-year power generation calculated through modelling can have a “significant influence on national regional energy system evolution” (IRENA, 2018, p.31).

6.1.5 Solar PV

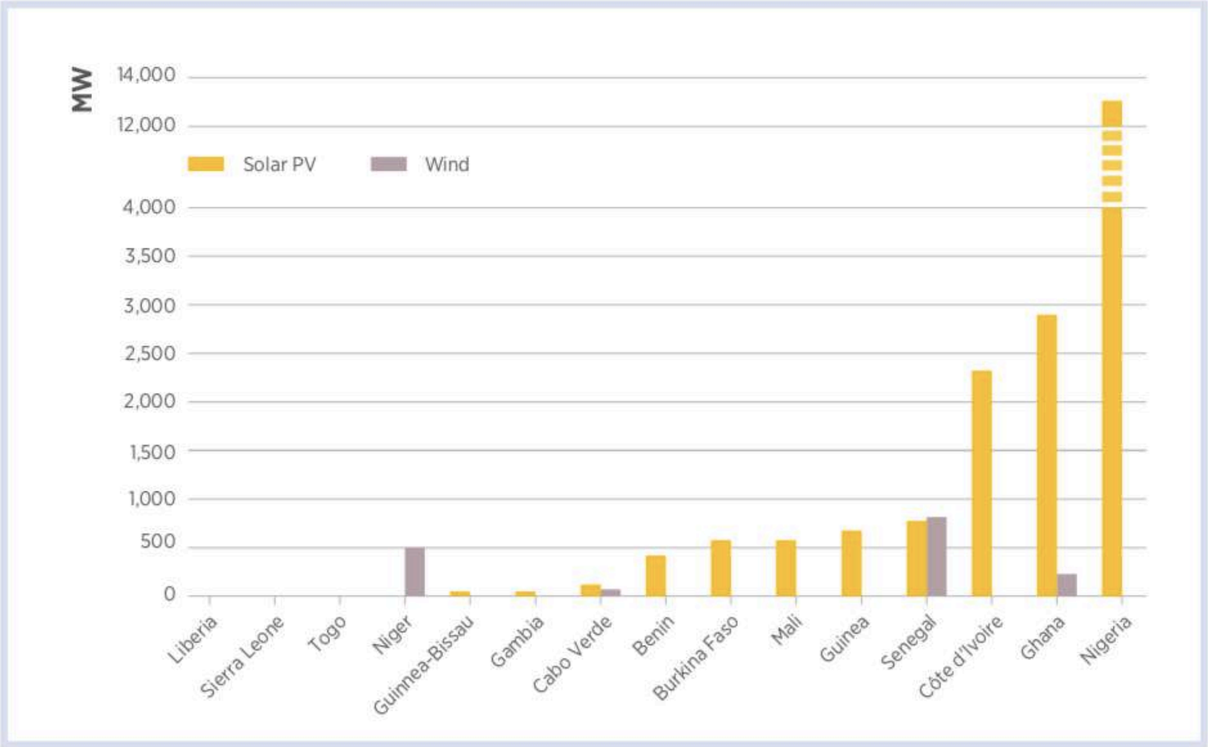
The ECOWAS region has among the highest capacity rates in the world for solar energy. Although there are projects in off-grid small scale systems such as the provision of solar lamps to various retail shops, there is still scope for more solar powered mini-grids in the ECOWAS region. The two approaches for utilising solar energy, as depicted in Table 6.1.0, are solar PV and, the arguably lesser explored option, Concentrated Solar Power (Solar CSP). Solar PV will be explored further in this thesis as there is generally more potential for solar PV in the ECOWAS region compared to the potential for solar CSP. (The exceptions for this are Gambia and Guinea-Bissau).

Solar PV is the most widely used technology for CEMGs. With the largest capacity amongst the renewable energy sources, solar PV as a single source for grids makes up 23% of the CEMGs in the ECOWAS region. The largest solar powered CEMGs reside in Mali (Hobson, 2016). Mali's solar PV installations have a total capacity of 3 MWp, compared to Liberia with 10 kWp in total capacity (Hobson, 2016). Some reports argue, however, that distributed solar energy is more likely to compliment the growth of the energy sector, rather than revolutionise it (McKinsey & Company, 2015). This may be due to their intermittency as there is a considerable gap between capacity and production.

6.1.6 Wind Power

Wind powered mini-grids are not as mature as solar PV mini-grids, as the region's capacity for the former is not as high as the latter, nor is there abundant technical capability for successfully constructing and maintaining wind turbines in all ECOWAS communities. However, amongst those who do harness wind power, Mali has the highest installed capacity with 10 kWp, and Senegal has the lowest with 5 kWp (Hobson, 2016). This is despite the fact that Mali is not be predicted to have any wind capacity under the National Targets Scenario, as depicted in Figure 6.1.6.0.

Figure 6.1.6.0: Wind and solar PV capacity in 2030 by country under the National Targets Scenario



Source: IRENA, 2018

In the case of the UK, wind energy saw a 50% reduction in price due to longer term contracts with guaranteed price on production, and therefore a guaranteed profit (Sharpe, 2019). This would cause a reduced perception of financial risk and a good expectation in industry of the wind market being profitable. This could be replicated in the ECOWAS region with the assistance of international bodies.

6.1.7 Biodiesel

Biodiesel technology is considerably premature for the ECOWAS region. One could argue that part of the reason resides in the occurrence of food scarcity. Parts of the region tend to face food shortages or even famine, therefore utilising food crop for fuel instead of utilising it for communities that are facing malnutrition and starvation is not seen as practical. However, biodiesel originating from animal waste can be utilised for power generation. However, in the interest of capacity, other renewable sources such as solar energy is greater. It is therefore often argued that it would be worth concentrating more focus towards solar and hydropower, rather than on biodiesel. Despite this, even though Liberia and Mali are the only nations in the ECOWAS region with biodiesel plants, Nigeria and Côte d'Ivoire are interested in utilising biodiesel plants also.

6.1.8 Hybrid Energy

In many communities around the world, decentralised energy systems are often hybrid, usually utilising both solar energy and diesel where diesel is used as a backup energy source to increase the reliability of the electricity production. Combining the two is also more cost-effective. This is the case for ECOWAS also, where 6 out of 10 CEMGs are PV-diesel powered. Despite the controversy surrounding its classification, PV-diesel is not holistically renewable, but is often used as solar energy is not 100% reliable. However, in addition to its CO_2 emissions, in order to utilise diesel power, the ECOWAS nations would have to secure access to the resource, which may lead to supply chain related issues. Indeed, renewable energy is free and available, which is a strong advantage for the poorer nations. Many argue that a hybrid system is better than using 100% fossil fuel technology as a reduction in any level of emissions is better than none. This could be a starting point for nations with little solar capacity also, however ECOWAS has much potential, and should seek to implement more fully renewable energy mini-grids. The solar PV and wind power combination is also used, however this only makes up 1% of CEMGs in the ECOWAS region.

The largest two solar-diesel hybrid mini-grids reside in Mali; one in the village of Koro installed with 384kWp generating capacity, and the other in the village of Bankass installed with 675kVA generating capacity (Hobson, 2016). These were constructed in 2013 as a Public Private Partnership (PPP) between a national energy supplier, public bank and ZED-SA, a private company in Mali. Successfully producing electricity to the aforementioned communities, the case for PPP is strong (and will be examined in a later chapter).

Hybrid systems tend to be modular; for example, in 2011, a 216 kWp solar PV hybrid mini-grid was built in the village of Ouéléssébougou in Mali and was subsequently upgraded to 334kWp in capacity to accommodate for the two-fold increase in demand (Hobson, 2016). This is an advantage for the ECOWAS region, as should a mini-grid successfully provide electricity to a community and the demand increases, it can be developed in capacity to accommodate for the new demand. Nonetheless, for ECOWAS nations, future development for repairing aging parts of the grid as well as increasing its capacity is a vital aspect to consider in the initial design stages of procurement.

6.2 Challenges and Potential Bottlenecks

Result-based incentives alone are not enough to ensure the implementation of CEMGs (DFID, 2014). More needs to be done to share information about the economic benefits of increasing the usage of solar energy, as there is a general lack of awareness of commercial opportunities in Africa with private companies globally. With little information on Africa comes a perception of risk (Wakamatsu, 2019). This is something some institutions have realised and are tackling. For example, JICA held a joint seminar with the AfDB in 2017 regarding the commercial opportunities for private companies in Africa in the energy sector. Indeed, more companies are slowly realising the potential of Africa, compared to 5 or 6 years ago, although this realisation is happening at a slow pace. Trading companies, for example, are looking for investment in solar energy, while other international companies are looking to create partnerships with local companies in this arena.

Most attention from international bodies on CEMGs that are in Africa, tend to focus on the Eastern region. Government bodies such as DFID determine that within Africa, the countries with the best combination of enabling environment, opportunity and potential for DFID to play a role in implementing CEMGs, is Kenya and Tanzania (DFID, 2014). Innovation Energie Développement (IED) conducted an analysis in 2013, as shown in Appendix III, assessing various criteria such as stability of the country and min-grid potential amongst Kenya, Tanzania, Rwanda, Uganda, Malawi, Mozambique, Ghana, Somalia, DRC, Ethiopia and Nigeria. While the only two countries from the ECOWAS region were Ghana and Nigeria, their global enabling environment for CEMG percentages were 51% and 41% respectively; not as high as Kenya and Tanzania with 84% and 81% respectively (DFID, 2014). One can argue that this analysis is out of date; indeed, the situation has changed with regard to mini-grid potential over the last 6 years, however it is still prevalent that international attention with regard to renewable energy, especially from DFID, tends to focus more on East Africa. The criteria also shows that whether international mini-grid programmes are already present in a country impacts the decision on whether mini-grids should be deployed in that country. It could be argued that this is a good indicator into the potential success of grids, however this way of thinking may perpetually concentrate projects in one region over another, due to perceived risk. That is not to say that mini-grids should not be developed more in East Africa, but there must be awareness for the potential in West Africa also. DFID has an interest in countries such as Nigeria for developing solar markets, but there is scope for more action beyond discussions and consideration.

There is also scope for sovereign loans and grants for CEMGs, as the grids are so premature in the ECOWAS region (Wakamatsu, 2019) and the up-front cost is high. JICA has been providing loans and equity for these projects, but there is no guarantee. If the private sector can provide guarantees and leverage, a CEMG project is more likely to go from planning to actual implementation. Other than concessional loans there are private loans, which are cheaper 2% better for investors, and could be of relevance to the ECOWAS region.

Contingency planning is also important; an analysis of the risks and how to mitigate them need to be carried out. If there is not enough capacity within the host country to consider the risks, it should receive assistance from international bodies, such as that carried out by DFID in mini-grids in Appendix IV. Though not in West Africa, the analysis of risks is appropriate to the ECOWAS region, and despite being drawn up 5 years ago, is it arguably relevant today.

Developing expertise in the ECOWAS region for handling the development of energy infrastructure in the early stages is a key goal to achieve, as well as the ability to maintain it. A rural electrification agency tends to oversee maintenance, but members of staff are often reluctant to relocate to rural areas. In such cases, technical cooperation projects are often useful. In Sierra Leone, JICA has facilitated formulating operation and maintenance projects using Internet of Things (IoT). In addition, there is a need to focus on the individuals in the community; there is a need to educate communities on how to utilise the grids, and a need to train personnel on how to maintain the systems. On the ground, information spreading could also entail one neighbour seeking to utilise solar energy mini-grids, and inspiring others to do the same.

Indeed, most mini-grids are bespoke as each project varies amongst counties, therefore magnifying the capacity constraints and a “lack of project preparation and delivery experience” (DFID, 2014, p.10) In addition, utilising modern technology is a useful way to make the decentralised systems for efficient. JICA also works towards incorporating this in poorer countries through strengthening sub-stations for energy reliability (Wakamatsu, 2019).

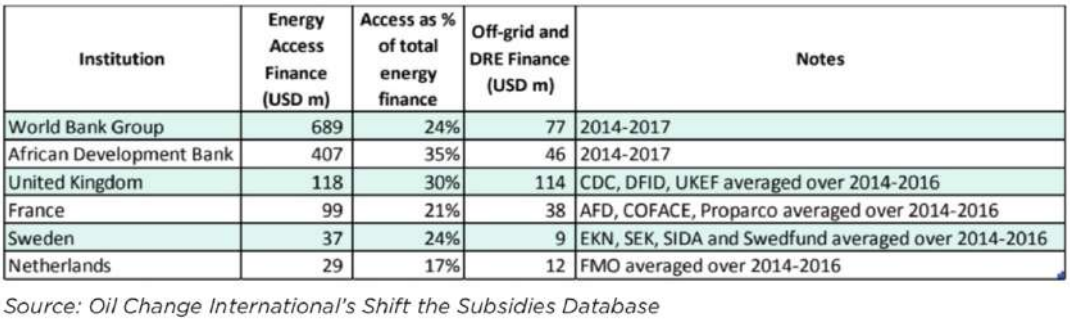
Transparency is needed at all stages to make mini-grid projects a success. Transparency in how planning, implementation and maintenance is constructed is a challenge. International institutions such as JICA are making it their responsibility to provide transparency and place zero tolerance on a lack of transparency (Wakamatsu, 2019). JICA manages their own budget instead of giving funds directly to a government or group. In the case where they do give grants, they provide strict guidelines that the recipient must abide by. Ensuring that such rules are in place is important in realising CEMG projects in the ECOWAS region.

Through an international consultation process led by DFID, DFID found that CEMG specific policies and regulatory barriers exist for the region, as well as for other regions in Africa (DFID, 2014). In addition, early stage market fragmentation has meant that different bodies (such as the technology providers, financers and international developers) each work on different parts of the necessary elements regarding successful mini-grids (DFID). Unmade linkages mean that successful grids cannot be realised. Interventions that should be deployed to counter this, for example market development and coordination, and cross-learning and evidence generation research (DFID, 2014). With regard to the former, market development approaches such as that undertaken within the Lighting Africa programme could help raise awareness to market actors. Such data should be disseminated widely, and perhaps policies of countries with companies interested in the sector could make it easier for them to gain access to the data.

7.0 Development Finance for the Economic Community of West African States (ECOWAS)

In order to realise SE4All, US$52 billion in additional investment is needed per year globally, with 95% of this needing to be directed to Sub-Saharan Africa (IEA, 2017). In 2014, US$12.5 billion or 56% of the total investment in energy in Africa came from Multilateral Development Banks (MDBs) and Development Finance Institutions (DFIs) (AfDB, 2018). In comparison, the private sector invested US$4.8 billion (AfDB, 2018). For Sub-Saharan Africa, the share of funding is depicted in Table 7.0.0. Maximum use of development finance is necessary to realise energy projects in the ECOWAS region, from initiatives such as Official Development Aid (ODA) and International Climate Fund (ICF).

Table 7.0.0: Annual Average Energy Access Finance for Sub-Saharan Africa



Institution	Energy Access Finance (USD m)	Access as % of total energy finance	Off-grid and DRE Finance (USD m)	Notes
World Bank Group	689	24%	77	2014-2017
African Development Bank	407	35%	46	2014-2017
United Kingdom	118	30%	114	CDC, DFID, UKEF averaged over 2014-2016
France	99	21%	38	AFD, COFACE, Proparco averaged over 2014-2016
Sweden	37	24%	9	EKN, SEK, SIDA and Swedfund averaged over 2014-2016
Netherlands	29	17%	12	FMO averaged over 2014-2016

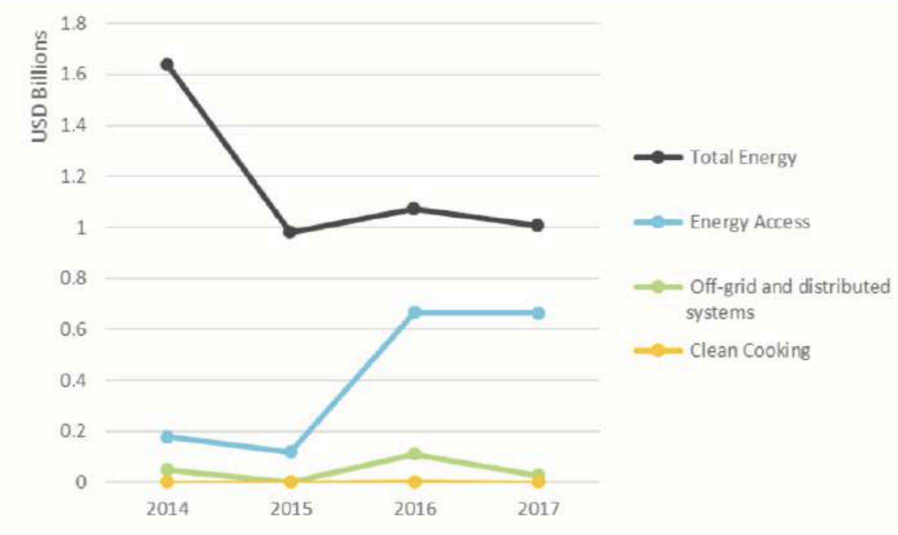
Source: Oil Change International's Shift the Subsidies Database

Source: AfDB, 2018.

Furthermore, the share of rural population in the region to be supplied by mini-grids and stand-alone systems is aimed to be around 22% by 2020, and 25% by 2030, requiring €23.3billion or US$26.17 of investment (Bugatti, 2015; XE, 2019). Despite this, only US$200 million or 1% of international public finance went to off-grid and mini-grid systems in Sub-Saharan Africa from 2013 to 2014 (AfDB, 2018). The off-grid sector has been seeing vast improvement, with a 60% compound annual growth rate globally since 2010, while the mini-grid sector in Sub-Saharan Africa is nascent (AfDB, 2018). This can be attributed to perceived financial risk and an unwillingness for commercial players to invest in low-income rural areas (AfDB, 2018). There must be more finance for mini-grids as it stands at a small figure relative to the amount needed to realise SE4All. As evident in Figure 7.0.0, decentralised infrastructure, as well as clean cooking, received the least funding from AfDB between 2014 and 2017. Funding for off-grid and distributed systems only received 3% of total funding approvals in 2014, rising to 6.6% in 2016. Although it is good news that there is high funding for energy access, the level of funding for decentralised infrastructure fell after 2016. As evident in Figure 7.0.1, almost three-quarters of funding needs to go to decentralised infrastructure in order to realise 100% access by 2025, or US$42 to US$67 billion in additional energy investment annually until 2025. Other estimates based on different assumptions, for example, regarding improvements in energy efficiency and level of service yield, suggest that this figure should be US$14 billion. Regardless, it is undisputable that there is scope for more investment.

AfDB realises its need to increase its funding for decentralised energy as one of its top five recommendations for its ambitious target of achieving 100% energy access by 2025; that is, 100% in urban areas and 95% in rural areas. As such, it aims to provide 130 million new grid connections and 75 million new connections via mini-grids and stand-alone systems throughout the continent, including the ECOWAS region (AfDB, 2018).

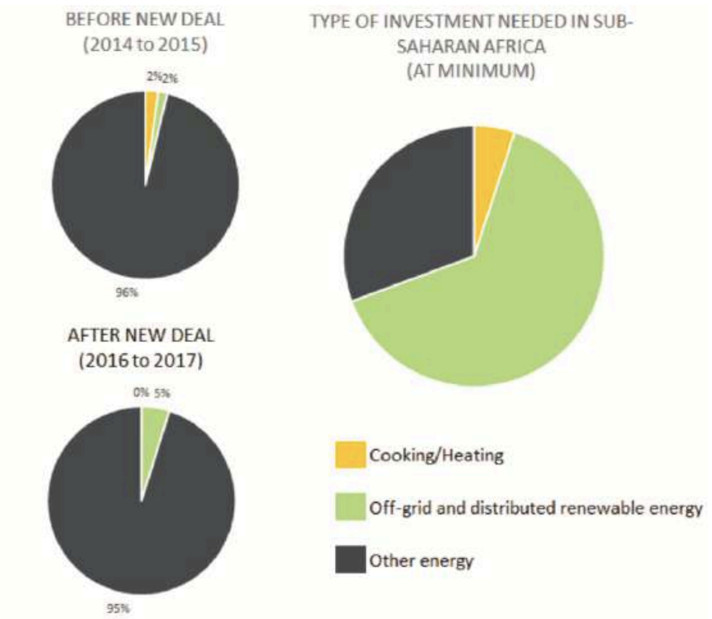
Figure 7.0.0: AfDB Energy Finance in Sub-Saharan Africa, 2014 through 2017



Source: Oil Change International's Shift the Subsidies Database

<u>**Source: AfDB, 2018.**</u>

Figure 7.0.1: Comparison of AfDB's Energy Finance in Sub-Saharan Africa with the Type of Investment Needed for Universal Energy Access

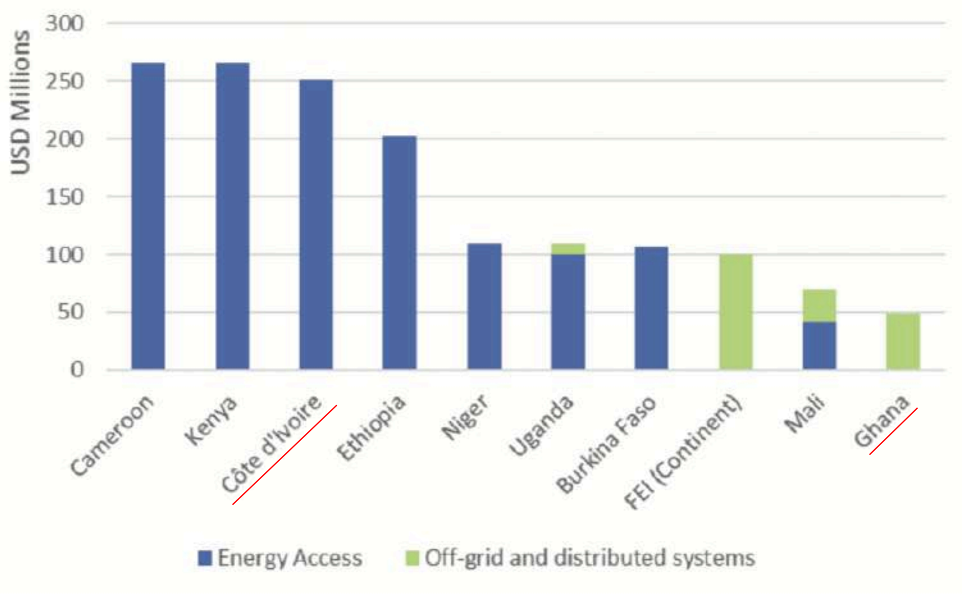


Source: Oil Change International's Shift the Subsidies Database; IEA Energy Access Outlook 2017

<u>**Source: IEA 2017, cited in AfDB, 2018.**</u>

MDBs, DFIs, and other organisations tend to offer loans and grant aid to countries in the ECOWAS region such as Senegal, Ghana and Nigeria. It is often the case where the World Bank co-finances projects with AfDB, with some in the pipeline. AfDB offers hundreds of millions of US dollars in loans that are more concessional than that of the World Bank. Evident in Figure 7.0.2, while Ghana and Mali are key recipients of aid for distributed energy infrastructure from AfDB, the majority of the aid is concentrated in East Africa. Indeed, AfDB's Facility for Energy Inclusion Off-Grid Energy Access Fun (FEI OGEF) for supporting renewable energy access, utilising US$50 million in convertible loans and US$50 million in equity, will "initially focus on East Africa, Côte d'Ivoire, Ghana and Nigeria" (AfDB, 2018, p.11). Regarding other organisations, IRENA performed its first assessment of renewable energy prospects in West Africa, which subsequently led to two key policy developments 1) the adoption of WAPP and 2) EREP, as aforementioned. They aim to "increase the share of renewable energy in the region's overall electricity generation mix to 23% in 2030 and 31% in 2030 (ECREE, 2013 cited in IRENA 2018). In WAPP itself, there are various economic opportunities.

Figure 7.0.2: Top Recipients of AfDB Energy Access and Distributed Renewable Approvals (2014 to 2017)



Source: Oil Change International's Shift the Subsidies Database

Source: AfDB, 2018.

Indeed, not all countries in ECOWAS have the appropriate regulatory framework to attract private investment, nor do they have the right policies to enable this. An enabling environment facilitated through external advisors and technical assistance is required, including "tariff setting, [PPP] framework, procurement processes, operational readiness, [and the] facilitation of cross-country discussions" (USAID, 2018, p.27). Clear policies in the long term for poorer economies such as those in ECOWAS is needed to make renewable energy work. This bottleneck is being addressed by a range of development partners particularly including DFID, World Bank, New Partnership for Africa's Development (NEPAD), European Investment Bank (EIB), International Finance Corporation (IFC) and Millennium Challenge Corporation (MCC). NEPAD, through its seconded mandate by the AfDB, uses its outreach to energy stakeholders on a national and regional level, and to development partners to coordinate the development and implementation of projects (USAID, 2018). They also reach bankability, which is an important bottleneck in transmission grid projects. The OMVG transmission line project, for example, has benefitted from the help of the NEPAD Infrastructure Projects Preparation Facility (IPPF).

Access to financial and transaction assistance is an intuitive barrier for the lower income countries in the ECOWAS region. Indeed, for achieving universal energy access, IEA estimates that finance in all forms must increase, and most of that increase should come from the private sector (DFID, 2014). This is especially the case as with the US$9 billion annual investment globally in clean energy, taking into account population growth, 1 billion people would still be without electricity in 2030 (DFID, 2014). The Sustainable Energy Fund for Africa (SEFA), established in 2011 by AfDB and involving the World Bank's ESMAP programme, is involved in providing funds for sustainable energy projects in the ECOWAS region, as well as ADB, AfDB, European Union (EU), Germany's Development Bank KFW, IFC and JICA. USAID's Power Africa programme provides transaction support to power generation, transmission and distribution projects at their final stages and helps bring them to a financial close (USAID, 2018). By October 2018, Power Africa had utilised a toolbox approach that resulted in the financial close of generation projects totalling over 9,600 MV. This approach, effective for transmission projects in particular, had also seen the OMVG project being supplied over US$200 million collectively by AFD, AfDB and KFW. Although AfDB focus in CEMGs at country levels is weak, it utilised the toolbox approach for transmission lines in other parts of Sub-Saharan Africa (USAID, 2018).

In many cases, sharing best practices, especially solutions to barriers, is an efficient and cheaper way to realise projects. For example, vast technical capacity is required to utilise mini-grids, and it is often the case where adapting "large decentralised power projects…to distributed renewable energy (DRE) systems" is a barrier in its implementation (AfDB, 2018, p. 9). AfDB seeks to overcome this barrier through a help desk to share technical knowledge on mini-grids, especially to West Africa as it acknowledges this region as having a gap in "technical training and skill development for distributed renewable technologies and models" (AfDB, 2018, p.12). Intuitional strengthening and development of labour is also an integral part of this gap. AfDB seeks to provide support not only at an early stage but also throughout the strategic approach development and scaling up access to finance. Despite this will, one arena that AfDB is not active in, is providing support for capacity building to financial institutions (AfDB, 2018). The countries that have made significant progress with mini-grids are those that have been attracting assistance from international bodies including capacity building.

In addition, Power Africa and its development partners are active in providing a platform for sharing best practices at continental and regional levels during workshops dedicated to developing transmission lines (USAID, 2018). They also provide the opportunity for strengthening coordination at a regional and national level, particularly taking into account constraints the projects may face. Not only does this develop accountability and efficiency, but it also helps to facilitate “the adoption of interconnection compliance codes and ease the operationalisation of the cross-border lines” (USAID, 2018, p. 27).

Aid supplied to countries in the ECOWAS region in some cases is still top-down and prevents the regions from becoming self-sufficient. Indeed, the economic situation of the ECOWAS members vary; from states like Sierra Leone still in need of a great amount of external aid, to other states like Ghana deploying the “beyond aid” rhetoric, aiming for self-reliance and graduating from the four-year Extended Credit Facility (ECF) support programme by the IMF. Although the “beyond aid” rhetoric is difficult to implement, external assistance is needed. However, such assistance needs to be one that views the African countries as partners and works with them to develop energy infrastructure that benefits all parties involved, especially in the long term. One barrier to this collaboration is caution by richer countries, of financial risk, as aforementioned. Indeed, in the past decades there was once financial risk regarding clean energy, however the case studies of successful government subsidies had shown that it is very possible to make the market for clean energy profitable.

There is therefore scope for helping PPPs to combine the financial resources and regulatory ability of the government, and the innovation of small companies. Indeed, it is important to consider which governments are in question as some do not have the scope currently to do this due to a lack of transparency. A range of collaboration has come together to address this barrier. AfDB is diversifying its operations to include state-owned enterprises (SOEs), which stood at 0% in 2014/15 and 7% in 2016/17, instead of exclusively government ministries and agencies, which stood at 100% in 2014/15 (AfDB, 2018). Despite this, no finance was given to the private sector. Partnerships between USAID, GIZ and other institutions have led to the provision of technical assistance for planning appropriate business models for countries in Sub-Saharan Africa. In addition, the Lighting Africa programme under the World Bank and International Finance Corporation (ICF) seeks to understanding market barriers and bring awareness of this to market actors who had perceived risk of the region and thus reluctance to enter the market. Another approach, “making markets work for the poor”, or more recently referred to as Market Systems Development, analyses the role of market actors and how to include poorer communities in economic development. It aims to address the market failure whereby the poor is often left out, and instead of facilitating traditional aid where funds run out and long-term impact is not realised, it allows residents on the ground to be part of the market as prosumers. In the light of energy issues, these communities should be equipped with the tools and technical knowhow for producing their own electricity and selling off any surplus to the grid.

8.0 Subsidy Options

Reducing the price of solar PV and other renewable energy installations can be based largely on two characteristics; 1) public sector R&D and 2) market stimulating policies, including private R&D. The price of solar PV has fallen by around 80% in 6 years (between 2008 and 2014) according to the IEA. Indeed, one can argue that a country could wait until the price is at a level they can afford (Sharpe, 2019). This is plausible for states that do not have a big share of the market at the moment, and could include West African states, but not plausible for states that have a large share of the market as waiting to invest in it will not drive the prices down far enough. However, as the energy sector is so dynamic, some argue that it is no longer a question of whether implementing clean energy like solar should be implemented, but rather an issue of how to implement it more (Esteban, 2019). Indeed, solar energy is cheaper than traditional fossil fuels, and is at a break-even point (Esteban, 2019).

It is often argued that in the long run, subsidies would be required for the distribution and connection parts of CEMGs (DFID, 2014). Subsidies are defined by the World Trade Organisation (WTO) as “any financial contribution by a government, or agent of a government, that confers benefits on its recipients” (Whitley and van der Burg, 2015). Speaking with Joss Blamire, Principal Consultant from ITPEnergised and former lead on DFID’s Energy Africa campaign, it was highlighted that mini-grids are expensive and thus there is a market issue when compared to grid connected prices, but this is made more apparent when electricity prices in countries are kept low and essentially subsidised. Giving the same advantage to mini-grid developments can make CEMGs more competitive and helps improve the chances of developments taking place in poorer communities that are disadvantaged by being off the grid (Blamire, 2019). Although not all countries, namely Benin and Burkina Faso, have renewable energy targets, all ECOWAS members cite implementing policies to promote the use of renewable energy. Picking the right mix of policies to suit each country is a challenge (REN21, 2014). With there being many subsidy options for mini-grids and other decentralised technology as depicted in Table 8.0.0, this section focuses on universal tariffs, cost-reflective tariffs, FITs and elimination tariffs.

Table 8.0.0: Renewable Energy Support Policies in ECOWAS Member States

		Regulatory Policies							Fiscal Incentives and Public Financing				
	Renewable energy targets	Feed-in tariff / premium payment	Electric utility quota obligation / RPS	Net metering	Biofuels obligation / mandate	Heat obligation / mandate	Tradable renewable energy credits	Tendering	Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, CO_2, VAT, or other taxes	Energy production payment	Public investment, loans, or grants
Benin	x										x		
Burkina Faso								x		x	x	x	
Cabo Verde	x			x				x		x	x	x	
Côte d'Ivoire	x										x		
The Gambia											x		
Ghana	x	x	x		x	x	x		x		x		x
Guinea	x										x		
Guinea-Bissau	x										x		
Liberia	x												
Mali	x				x						x		x
Niger	x										x		
Nigeria	x	x							x		x		x
Senegal	x		x			x					x		x
Sierra Leone	x												
Togo	x										x		

Source: SE4All, Global Tracking Framework (Washington, DC: 2013), cited in REN21, 2014

8.1 Universal and Cost-Reflective Tariffs

Regarding pricing, the tariffs put in place should cover maintenance costs at the very least. There are often two options for this; either introduce a) a standard or universal tariff that is usually lower than the cost of electricity production and thus requires subsidies, or b) a cost reflective tariff where instead of subsidies consumers pay for investment recovery. The latter higher than the former for the consumer, however, it is attractive to private bodies which are able to recover their investments (Hobson, 2016).

Uniform national tariffs tend to be more politically acceptable, however, many argue that cost-reflective tariffs are needed as without it, there is "uncertainty over if and when the grid will arrive, and what happens if it does" (DFID, 2014). In its Brighter Africa, McKinsey & Company reports that even though governments fear angering citizens over cost-reflective tariffs, cost-reflective tariffs would be effective if is acknowledged that not all residents need to pay the same tariff; the tariff could be differentiated based on the consumption levels of the consumer and the time of day the electricity is being consumed (McKinsey & Company, 2015). This cross-subsidisation would allow poorer communities to pay lower levels of subsidies, while communities that can pay more, will pay more. Again, this should not be met with much opposition as consumers would be more willing to a cost-reflective tariff "to avoid paying even higher amounts for power from diesel generators" (McKinsey & Company, 2015, p.37). In Senegal for example, the Electricity Sector Regulatory Commission "established [cost-reflective] tariffs for the total electrification concession, the Delegated Temporary Managers (GDT) and the Local Rural Electrification Initiative (ERIL) operators" (Bugatti, 2015, p.9). It must be noted that transparency is vital in allowing this system to work.

Universal tariffs can at first seem like a fair option for communities, however the tariff could discourage private investors from participating in the energy sector, as well as hindering the national budget as the government would have to cover the portion of the costs the tariff does not cover. Usually done through a direct subsidy to a power utility, it can cost between 3% and 4% of a national budget (McKinsey & Company, 2015). Therefore, the more electricity used over time, the bigger the burden.

The World Bank is experimenting with the two tariff models in Nigeria and Kenya (although the latter is not in the ECOWAS region, this point of comparison is still relevant). For Kenya, the World Bank is using a universal tariff. Although it ensures that all communities get the same tariff, it means less profit for private sector (Wakamatsu, 2019). This tariff was implemented with the bigger picture in mind; electrification of disconnected areas would improve the economy, and lead to sustainable economic development in the long run. In contrast, the World Bank is using cost reflective tariffs in Nigeria. In this case, even though most homes are connected to a grid, more than half are not receiving power (Wakamatsu, 2019). Thus, mini-grids are being used to supply energy to those areas. Even though one may argue that it is better to find the reason why electricity is not flowing through the grid to those houses, mini-grids could be a temporary but also a more effective solution. For the cost reflective tariff, the private sector can recover the cost and gain a profit. These case studies highlight the two sides of the debate; having cost reflective tariff with the poor communities struggling with electricity prices regardless of the cross-subsidisation or have a universal tariff that may not attract investment and not produce a high profit for private companies. Some believe that there is no straight answer to which one works best (Wakamatsu, 2019). While some argue that the debate regarding which tariff is best is an old discussion as solar energy breaks even (Esteban, 2019), it is clear that with the high initial costs, subsidies can still be beneficial.

8.2 Feed-in Tariffs (FITs)

A large barrier remains in the lack of awareness of the long-term economic benefits of solar energy and other renewables among communities as well as policy makers. Incentives are needed by the government to provide clean energy transitions, such as Feed-in Tariffs (FIT). 2 out of 15 of the ECOWAS members have implemented a FIT; Ghana and Nigeria, while two others, Gambia and Senegal, are developing it.

Looking at Ghana in particular, the region already utilises various mini-grids, as supported by the its FIT established in 2011 and implemented on 1st September 2013, by the Ghana Public Utilities Regulatory Commission (PURC). The long-term contract from renewable energy electricity providers to the grid (homeowners, private companies and so forth) is a good incentive for providers to utilise renewable energy technology whilst guaranteeing they get a price based on the technology used rather than electricity generated. The tariff applies to all renewable energy technology regardless of size, with the level of tariff, which was amended in 2014, depends on the technology. The fix prices are denoted in Table 8.2.0. Intuitively, solar PV is given the highest level of support provided that its grid system is stable. Other than technology, factors affecting the tariff level also include a) costs associated with operation, maintenance and so forth b) consumer and producer interests (striking a balance of interest how between the two) c) reasonable rate of return and so forth.

Table 8.2.0: Feed-in Tariff levels in Ghana Pesewa (GHp) per kWh

Feed-in tariff levels applicable from 1st October 2014

Renewable energy technology		**Capacity**	**Duration of the support**	**FIT levels in GHp/kWh**
Wind	With grid stability system	< 300 MW	10 years	55.7369 (0.108250 (US$))
	Without grid stability system			51.4334 (0.0998939 (US$))
Solar PV	with grid stability system	< 20 MW		64.4109 (0.125103 (US$))
	without grid stability system	< 10 MW		58.3629 (0.113347 (US$))
Small hydropower plants		< 10 MW		53.6223 (0.104140 (US$))
		10 MW – 100 MW		53.884 (0.104643 (US$))
Biomass	using enhanced technology	n/a		59.0350 (0.114646 (US$))
	Using plantation as feed stock			63.2891 (0.0210222 (US$))

Source: IEA, 2015. Conversion based on 100GHp = 1GH¢ = 1US$ (XE.com. 2019)

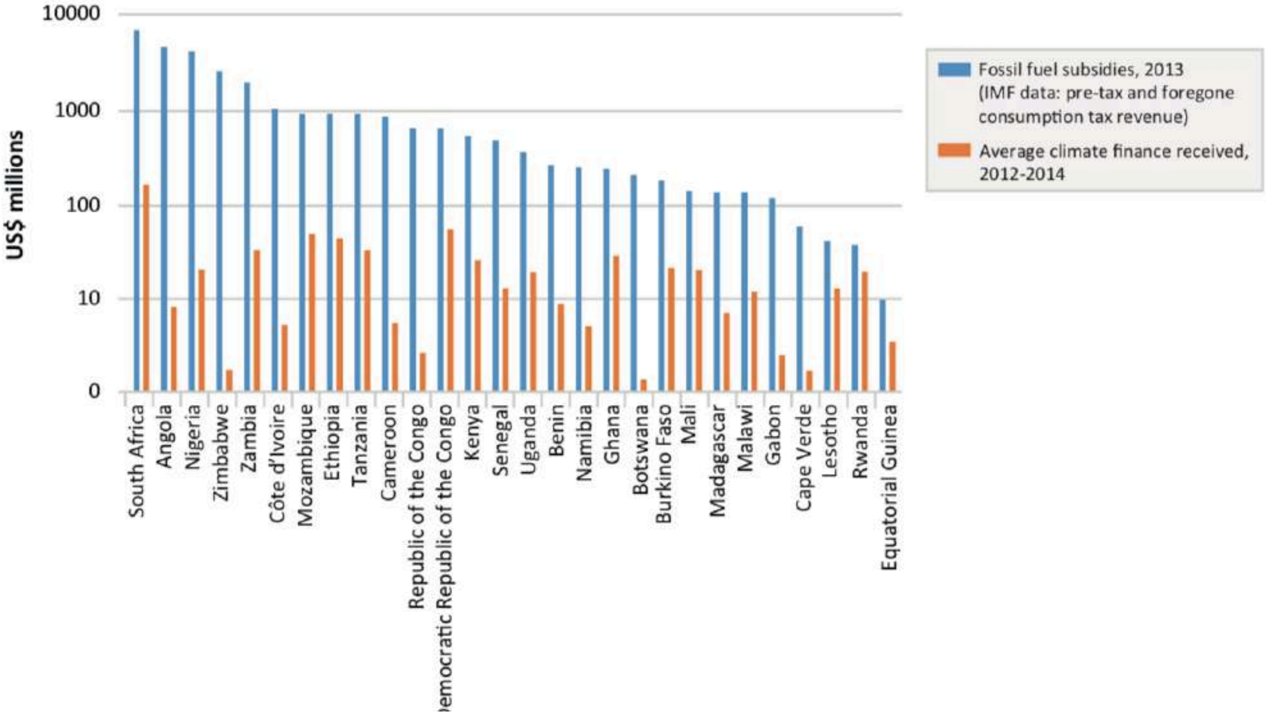
Different bodies are responsible for distributing and generating electricity in Ghana. The FIT was implemented as part of the Government of Ghana's Poverty Reduction Strategy (GPRS), and although there is some uncertainty, especially regarding the price of the FIT after the 10-year flat rate guarantee period, more countries in the ECOWAS region, should seek FITs to increase the penetration of CEMGs. Comparing Ghana's FIT to other countries, the 10-year period is double that of Nigeria's FIT where payments for wind, solar, small hydro, biomass and diesel are revised every five years from 2012 (REN21, 2014). While Gambia adopted FIT support for solar PV, wind, biomass and biogas in 2013, Senegal is drafting FITs for solar PV, solar thermal, wind, hydro, biomass and biogas (REN21, 2014).

8.3 Fossil Fuel Subsidy Reform

From an economic perspective, fossil fuels look cheaper than other options (Ackom, 2019). Fossil fuel subsidies have historically sought to support energy security by providing support to the private sector. They have been implemented in various forms in Sub-Saharan Africa especially with the support of MDBs, DFIs, such as through direct financial transfers, tax breaks and credit (Whitley and van de Burg, 2015). The environmental, social and economic costs of fossil fuel subsidies far outweigh the benefits. The existence of subsidies for fossil fuels is a factor that may prevent the shift to cleaner technology. Reform is required and more action by international bodies such as the World Bank that seldom engage in subsidy reform processes.

Fossil fuel subsidies in 30 Sub-Saharan Africa stood at US$32 billion in 2013, falling to US$26 billion two years later. This fall was due to "reform effects and the falling price of oil, gas and coal" (Whitley and van de Burg, 2015, p.7). Côte d'Ivoire and Nigeria's subsidies were worth over US$1 billion in 2015; this is intuitive as subsidy levels are positively correlated with a nation's economic activity and use of fossil fuels. Evident in Figure 8.3.0, these two countries bear the highest fossil fuel subsidies in the ECOWAS region. Côte d'Ivoire received a guarantee of US$437 million in 2013 for an oil and gas exploration project by the World Bank, while Nigeria received US$395 million a year later for support for its natural gas. In Burkina Faso, low fuel prices due to subsidies have ensured the continued use of fuel-inefficient vehicles.

Figure 8.3.0: Fossil Fuel Subsidies and Climate Finance in Developing Countries



Source: Whitley and van de Burg, 2015.

It is no longer in these countries' interest to continue to utilise fossil fuel subsidies, not least because of public health issues due to CO_2 emissions, a burden on government to manage the subsidies, and a perpetuating inequality where the subsidy benefits do not reach the poorest (Whitley and van de Burg, 2015). There has been a gradual removal of the subsidy in many regions, however. Indeed, Nigeria cut a portion of fossil fuel subsidies in 2012 and Ghana made gasoline and diesel specific subsidy reforms in 2014. However, this is not being undertaken fast enough to address the issues arising from energy poverty and rising carbon emissions. Barriers contributing to a lack of enabling environment include a lack of transparency in understanding the current level of consumer and producer subsidies, a strong belief on the governmental level that economic development is synonymous with fossil fuel exploitation, and special interest in fossil fuel industries by government. Institutional strengthening and more information sharing between and within governments and international bodies, and consultation for the appropriate steps needed for reform in each country is necessary.

8.4 Elimination Taxes

All but two of the ECOWAS members have renewable energy supported through tax. In Burkina Faso, the renewable energy aspects of import duties have been removed; namely, solar PV and solar thermal. Ghana does the same for wind and solar systems, and Mali exempts solar panels, solar lamps and other renewables (REN21, 2014). Nigeria's approach is more holistic and includes a moratorium on all renewables, while at least partial exemptions for renewables exist for Benin, Cabo Verde, Côte d'Ivoire, Gambia, Guinea, Guinea-Bissau, Niger and Togo. Value-added tax (VAT) exemptions have also been established in Burkina Faso for solar PV and sola thermal, and in Ghana for all renewable energy equipment. Mali's VAT has a time frame of five years, and Cabo Verde also utilises a five-year window but at a 50% tax reduction. Senegal's government focuses on the materials needed for the domestic consumption of renewables and gives full tax exemption to them, and Nigeria focuses on exemptions for any investments in the energy sector (REN21, 2014). The government plays a role in supporting the penetration of renewables, despite the perceived and real limitations within its departments. While it is clear that action has already been taking to help make renewable energy a cheaper option, it is also clear that most interventions in the ECOWAS region cover solar power.

9.0 Business Model Options and Planning Tools

One of the barriers identified by DFID in the expansion of CEMGs in Africa is the "lack of proven commercial business models", and therefore the lack of access to long-term finance required (DFID, 2014, p.2). Creating a range of plausible business models is necessary for this as there is no 'one size fits all' model. With (perceived) financial risk, evidence is necessary to reflect the ability for clean energy in Africa to produce "reliable cash flows to support further investment and [provide] private sector leverage" (DFID, 2014, p.10). Private banks and investors are reluctant to lend money to CEMG projects, as there is a greater perceived risk for mini-grids rather than for larger centralised grid connection projects, due to little experience and exposure in the mini-grid energy sector. Creating a business model that works is a challenge, and there are many international development groups that are dealing with the idea. Eiji Wakamatsu, Senior Deputy Director from the Industrial Development and Public Policy Department of JICA, expressed an interest in learning about successful business models for mini-grids in Africa, as JICA is new in the field of decentralised energy in Africa. Plausible business models are therefore examined below and how this could fit in the ECOWAS region.

9.1 Community-based Models

In this model, the community in the host country would have rightful ownership and management responsibility of all aspects of the grid. This management includes tariff collection, and general operation and management. Such duties can be divided in various ways, including dedicated responsibilities to dedicated groups or entire management under one group. This is more likely to occur in countries with low private or government interest in an energy grid.

Such a model would engage local communities in the market, therefore helping to address the market failure where these communities are usually left out. There have been reports of this business model working in Cabo Verde, Burkina Faso and Sierra Leone (Robson, 2016). In an interview with Emmanuel Ackom, Senior Energy and Climate Expert at an international organisation, it became apparent that a community-based model works best in a society with cooperatives. Indeed, the challenge lies in demonstrating capacity and technical knowhow for repairing and maintaining energy infrastructure (Larsen, Ackom and Mackenzie, 2019). This is particularly a bottleneck as much of this expertise resides in urban areas. Despite this, one solution could be recruiting remote repairers to assist in maintenance and repairs.

Due to the important sense of culture and community, many rural areas can assign roles and keep managers of the grid accountable to their fellow community members (Wakamatsu, 2019). Furthermore, whenever there is a problem, whether it is with maintenance or an individual not paying the tariff, the community already has their own set of rules to implement and can take a course of action on their own. However, in some cases, technical and business skills required to manage the energy grid can be a hindrance. In this case, NGOs tend to offer management support. When this is sought, however, it is often the case where the donors bring external approaches that clash with the traditional approaches in the community. For example, a rural community may have a system where regional chiefs oversee problems in the community, and an external governance system that does not incorporate the chiefs but a new and separate committee selected by the external donor organisation may be met with controversy and inefficiency. This alone may stop the true goal, implementing a CEMG, from being realised.

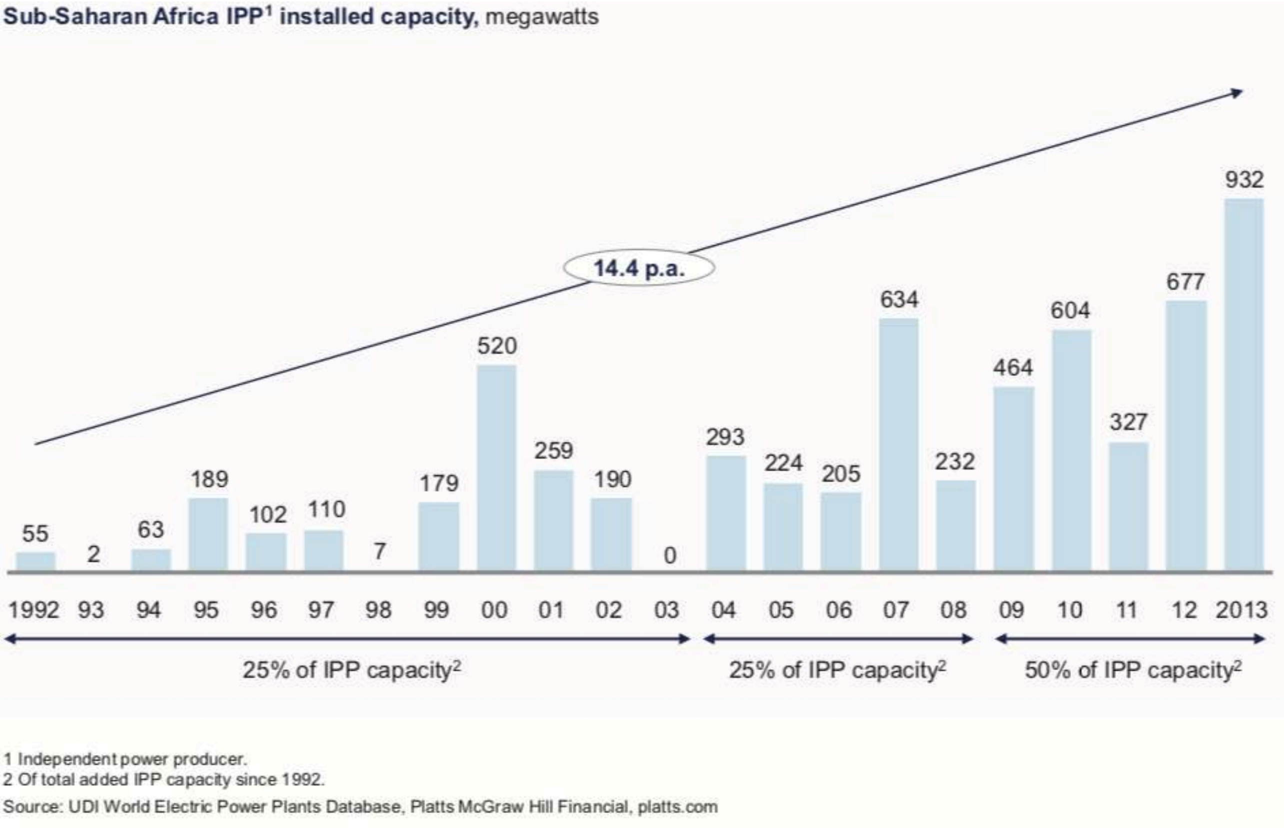
9.2 Private-based Models

In this model, a private company or institution is responsible for all aspects of the grid, including construction, operation and maintenance. In terms of financial assistance, management capabilities and technical knowhow, this approach may work best for many of the ECOWAS countries, provided that they have the capacity to regulate the private sector. Indeed, despite its role remaining relatively low, the private sector must be actively involved if 100% electricity access is to be achieved by 2030 (Robson, 2016). The notion that most private sectors tend to operate less on mini-grids and more on other small scale renewable energy such as solar chargers, must change. The private sector model can be efficient, however, in order for private actors to participate in the energy sector, there must be transparency at all levels. With regard to cost-reflective tariffs, understanding where the subsidies will be and how they will be split along the value chain will make the participation of private investors in the energy market more likely. Therefore, there is a need to diversify the risk or the portfolio. In many cases, the public sector instead has decided to take the lead on this.

Models using private-sector funding rarely result in the growth of energy sectors (McKinsey & Company, 2015). Indeed, many countries in the ECOWAS region initially sought to implement a purely private-based model; this was largely inefficient and prompted the desire for a mixed approach. Other approaches including the private sector but not relying exclusively on their funding, includes incumbent corporatisation. This can help to raise private sector funds by using assets as equity. This would involve "infrastructure binds, and asset sales on equity markets" as well as auctions (McKinsey & Company, 2015, p.40). Nigeria experienced this through a partial privatisation of its distribution and generation assets.

Private actors may also construct plants, or Independent Power Producers (IPPs), and sell the energy generated to the market through a PPA. The Azura-Edo Power West Africa power plant, currently being in constructed in Nigeria, is an IPP with energy and capacity payments outlined in its agreement (McKinsey & Company, 2015). While this plant is an open cycle gas plant, IPPs could be utilised for renewable energy powered plants also, as is the case with other countries such as South Africa. With 50% of IPP capacity in Sub-Saharan Africa being added to the grid between 2009 and 2015, it can be ascertained that there will be more IPPs expected in the future (Figure 9.2.0). However, the current private capacity is miniscule compared to the capacity required. Therefore, mechanisms should be put in place to further facilitate the entrance of private actors in the energy sector.

Figure 9.2.0: The rate of growth of Sub-Saharan Africa's Private-sector investment



Sub-Saharan Africa IPP[1] installed capacity, megawatts

1 Independent power producer.
2 Of total added IPP capacity since 1992.
Source: UDI World Electric Power Plants Database, Platts McGraw Hill Financial, platts.com

Source: McKinsey & Company, 2015.

To facilitate private sector participation and avoid uncertainty, long term transparent, clear and consistent regulations are needed. Regulation is particularly crucial for government ensuring that the prices set by private actors are reasonable. Long term regulations are particularly important as regulations that are constantly changing can cause delays in realising a project. Overcoming this was part of the reason for the success of Nigeria's privatisation programme. Through the Bureau of Public Enterprises (BPE), the government was able to provide vital details to parties involved, such as tariff structure and overall mechanisms for privatisation (McKinsey & Company, 2015). Investors were able to access a public and detailed tariff structure and calculations provided by the Ministry of Power and BPE, which helped with reassuring the investors that their investment would be effectively placed.

9.3 Government-based models

In this model, public bodies such as a state-owned utility company or the energy ministry of a government, manage all areas of the grid. This model may be difficult for the ECOWAS region to implement as its government bodies tend to have weak technical know-how, weak management strategies and a lack of financial resources. In addition, it has been argued that there is less room for the public sector in developing decentralised energy, especially as for poorer economies; subsidies would be needed. However, the public sector may be able to undertake a project faster than a private entity. As aforementioned, in many cases, the public sector has taken the lead of some projects. In Kenya, the private sector entities that developed geothermal took double the time it took for a public company to bring the project to operation (Wakamatsu, 2019). Although Kenya is not in ECOWAS, this example highlights the importance in considering that depending on the region and the project, the public sector may be best equipped to lead a project.

9.4 Public-Private Partnerships (PPPs)

This business model represents a combination of factors from different business models, often sought after to maximise efficiency and effectiveness, and depends on the contract terms and conditions (Robson, 2016). Thus, it is expected that within ECOWAS countries, PPPs can overcome the gap in investment and available budget that is prevalent in the private-based model. PPPs enable the government to hold some ownership of the country's electricity assets, while national utility companies can handle electrification. PPPs can be categorised as contractual PPPs, where obligations are regulated with contracts, and institutional PPPs, where obligations are regulated by the private company's statutes and shareholder agreements between the public and private entity.

Private bodies alone are insufficient for implementing innovation that leads to the realisation of needed sustainable development projects. The origin of innovation, and the true source for allowing innovation to breed, can be argued to be the state (Mazzucato, 2013). Most revolutionary ideas come from the government, working with the public sector. It is often the case where usage of the public sector is rarely identified, the state believes that its role in the market is to set a level playing field and then 'get out of the way', as well as address failures that the market cannot overcome on its own; supporting innovation is missing from this (Mazzucato, 2013). Due to this, in some cases it is often beneficial to include the government in a business model.

The general rule of thumb for PPPs is that the body that is most able to absorb a risk should bear it. The maximised efficiency and benefits lie in the fact that the government can bear some of the risk, which acts as a reassurance for companies and incentivises investment. Private companies are usually wearier of financial risks if they are the only body involved. In some cases, the government is able to provide some financial assistance, as it can purchase loans at a lower interest rates compared to private companies, as a government is less likely to be bankrupt than a private company. Where IPPs are involved, they are often expected to bear the construction and operation risks. The main concern is that the grid is not built on time or does not run effectively; thus, the private company bears the risk as they are often involved directly in its construction. The private sector, however, cannot bear 100% of the risks involved in this such as government supplied environmental permits that can cause delays and issues beyond their control (force majeure). This can be mitigated through performance-based guarantees such minimum load factor quotas that, if not met, could cause revenue loss (McKinsey & Company, 2015). Commercial risks are often borne by the private sector; to overcome concerns such as a lack of funds to pay generation assets, or too much generating capacity causing the need for a plant to be shut down. Contracts are usually implemented in more liberalised markets where the utility is "obliged to purchase the full output from the IPP…[and] ramp down its own production in the event of insufficient demand" (McKinsey & Company, 2015, p.41). Such contracts may not be so viable in the ECOWAS region as the markets are not as liberalised, however it is important that sufficient risk mitigation and risk sharing preparation is undertaken before a long-term contract is signed.

The government is usually expected to bear the foreign exchange, fuel and country risk (McKinsey & Company, 2015). Fuel supply and price risks is best managed by the government when it has a controlling power in the fuel area. Governments can provide guarantee fuel supply or price, however, in countries such as those in the ECOWAS region where the supply cannot always be guaranteed, such a deal would not be bankable or plausible. In the case of country risk, the possibility of grids being nationalised stand; in such a case, termination payment guarantees are usually required. However, when the risk is not as high, it is passed on to the private sector that is not so concerned with the risk. In addition, the government bears the risk of ensuring that electricity sold from the new grid is sold to a credible off-taker that has the balance sheet to buy it. In Nigeria's privatisation case, the Nigerian Bulk Electricity Trader (NBET) was set up to buy such electricity, and the government guaranteed that NBET had the ability to buy the electricity (McKinsey & Company, 2015). With government participation, political stability is required on all levels (Olobo, 2016).

It is often the case where a government will have to seek assistance from international institutions in establishing and guaranteeing risks. Partial Risk Guarantees (PRGs) should be supplied for energy projects in countries such as those in the ECOWAS region. Some governmental bodies, such as DFID, have acknowledged their shortcoming in being unable to provide PRGs, while others such as the World Bank are better able to provide this as "it would require the provision in a separate account of the money required for the guarantee" (DFID, 2014, p.23). AfDB and Multilateral Investment Guarantee Agency, as well as some private-sector institutions, are also able and should provide PRGs.

In addition, seeking assistance throughout the PPP may also be needed for the ECOWAS countries. It is important that knowhow and expertise is developed throughout the process. Nigeria, for example, has been utilising years of rigorous regulatory development and refining frameworks to "appropriately balance government stakeholders, and electricity end users" (McKinsey & Company, 2015, p.43). In doing so, the training of public-sector leaders on running a PPP successfully is facilitated. In addition, as project origination, the first stage of a project, is the most high-risk so private companies are reluctant to pay. JICA's downstream financial department offers feasibility study grants for private companies to utilise for development purposes (Wakamatsu, 2019). The agency also offers financial assistance instead of the private company, to overcome the risk perception. However, many studies do not realise into an actual project, usually due to a range of issues regarding cash flow and risk. How to overcome this or assist the private sector in bridging the gap is a challenge for realising sustainable development projects such as mini-grid infrastructure ones. In addition, the World

Bank and JICA together are working on scaling solar energy (Wakamatsu, 2019). Together they develop contracts for the government of poorer economies and help them through procurement stage, which is a common bottleneck for economies with weak government structures. Any risks pertaining to contract development is then taken away because the World Bank and JICA would have already drawn it up (Wakamatsu, 2019).

The end user of the infrastructure must be borne in mind. As the end user will pay for the infrastructure, it must be ensured that the demand is present (Olobo, 2016). Indeed, demand for electricity is high in the ECOWAS region, however it is important to ensure that the region is large enough to have a demand that warrants the procurement of a project. Continuing to bear in mind the community, environmental and social concerns, such as any damage caused to land or any displacements foreseen, much be considered within a PPP contract (Olobo, 2016). As aforementioned, there were displaced populations in Gambia during the construction of the OMVG. PPPs must mitigate these risks in advanced.

9.5 Market Liberalisation

Market liberalisation points to the induction of the private sector in investing in the power sector and gaining a profit. As the ECOWAS countries are at different stages of development, and it would be wrong to make the same assumption to all countries, it can be argued that most of the ECOWAS countries are not prepared to embark on full scale energy liberalisation. The main reason is that regulation is needed for monitoring electricity prices and ensuring that they are fair for the consumer. Some countries in the ECOWAS region do not have the capacity for regulating private bodies. In addition, due to the lack of constant electricity supply, energy liberalisation, that relies on a consistent supply of electricity, may not be plausible.

Fragile markets, that tend to exist in many of the nations in Sub-Saharan Africa, may mean that it is difficult to see clear benefits of market liberalisation (Bazilian et al., 2012). Market liberalisation can be considered for countries, like those in the ECOWAS region, if their market signals and wholesale prices offer a large enough incentive for the private sector to build energy infrastructure. However, the discussion regarding this plausibility is ongoing, especially as the countries in the ECOWAS region, especially Ghana and Nigeria, have begun to emerge economically.

9.6 Regional and Country-based Approaches

The scale at which mini-grids are implemented is also a factor to consider. The two main ones are regional or sector approaches, and country-based approaches. While neither is better than the other overall, it may be the case for specific countries. The advantages and the disadvantages are depicted in Table 9.6.0 below.

Table 9.6.0: Advantages and Disadvantages of regional/sector and country-based approach to GMG deployment from the view of DFID

	Pros/Strengths	**Cons/Risks**
Regional or Sectoral Facility (such as an MDB programme, or PIDG Facility or CDKN-style tendered facility)	• Maximum programme economy of scale for the implementing organisation • Single point of contact and contract holder for DFID • Single specialist fund manager (eg as PIDG) can manage a multi-country fund • Ability (in principle) to move money between countries more easily if one gets stuck • Easy to co-ordinate with international initiatives like SE4ALL	• Would have to be fully managed centrally, rather than leveraging DFID country presence and ownership • Very hard for regional management agent to have equally good presence, offer and positioning in each target country • Difficulty of incentivising progress in harder countries/sectors • Multi-country funds can be more distant and less responsive to country contexts • DFID central and country reporting lines would be less clear • Governments don't necessarily recognise and access regional funds • Since there is no current facility able to provide this, there would be a tendering and setup time implication
Country-Based approaches (i.e. a series of individual country programmes)	• Strong local ownership and oversight from DFID country offices, governments and leads on the ground • Organisations with maximum functional and geographical specialisation can manage each function • Relatively easy to co-ordinate and position with regards to other programmes in place • Very modular and so scalable since interdependence between funds is limited	• Fund management capacity in countries may be limited or variable • Separate contracts for DFID to manage, and multiple sets of overheads • Possibility of disconnects between the various country funds and participants dropping between them • Harder to achieve cluster benefits and cross-learning between the country programmes • Risk of failure in isolation and lack of access to best international practices • Success may be seen as a pocket, with low visibility

Source: DFID, 2014, p.16).

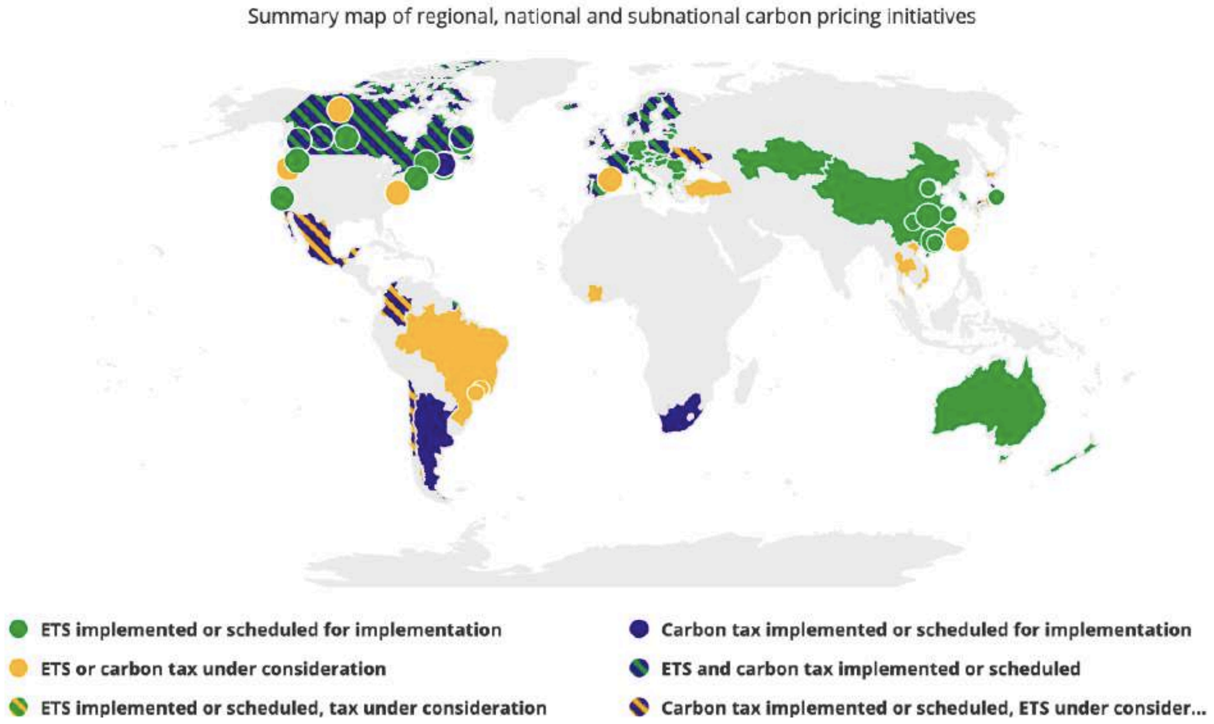
A regional approach to CEMG deployment would mean a top-down approach where largely international firms lead the projects and gain traction in the regions. This differs to a country-based approach that is more bottom-up and facilitates their progress in specific countries with the hope that successful approaches, technology and firms would spread out geographically. It can be argued that the appropriate approach is partly based on the renewable resource being sought, as well as the cooperative structure in the region itself. For example, a regional approach for developing wind energy in Adafua in the Eastern region Ghana may not be effective as the same model in the Western region. It can be argued that working on small scale sub-regional levels would be effective for the ECOWAS region.

In addition, as regional approaches are not country owned, it would be difficult to engage policy processes even though a regional approach can allow bodies involved to share what works between countries and utilise good practice in technology. A country-based approach would be able to link actors in a country but struggle to attract international attention and investment. With the aforementioned points in consideration, it can therefore be argued that some sort of hybrid between the two approaches could maximise benefits. Indeed, a hybrid of country and regional approaches. This ensures that country and international actors are involved in the process (DFID, 2014).

9.7 Carbon Market Mechanisms

As a tool that can incentivise a shift toward a greater use of cleaner technology, carbon market mechanisms can be considered as mechanisms that could help the ECOWAS region tackle energy poverty sustainably. With 57 carbon taxes and emissions trading currently in place globally (42 national and 25 sub-national), 11 GtC02e or 9.6% of global GHG emissions are covered (The World Group, 2019).

Figure 9.7.0:



Source: The World Bank Group, 2019b

While carbon is the initially cheaper option unless it is taxed (Esteban, 2019), it can be argued that it does not make sense to implement a carbon tax in the African region, as it does not pollute much carbon (Esteban, 2019). Academics such as Professor Miguel Esteban from the Faculty of Science and Engineering, Waseda University, argue that it makes more sense to implement policies that make it easier for companies and communities to import renewable energy. In the case of Africa, it makes sense for this to be solar panels (Esteban, 2019). It is no longer a question of whether coal-fired power plants, for example, should be built, but rather a question of when cleaner technology will inevitably take over (Esteban, 2019). However, some see the carbon tax as a business opportunity. Jérôme N'Guessan, Counsellor at the Embassy of Côte d'Ivoire in Japan, counters the idea that small polluting countries do not need a carbon tax, with the need to keep in mind the protection of agriculture. Regardless of CO_2 emissions, utilising non-renewable energy sources is having a detrimental effect on cocoa and other fields. Côte d'Ivoire is the world's biggest cocoa exporter and the first exporter of palm oil, and non-renewable energy infrastructure has been depleting these fields (N'Guessan, 2019). In addition, N'Guessan believes that the carbon tax would be essential in not only building renewable energy infrastructure and generating revenue.

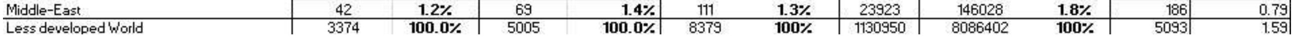
Speaking with Simon Sharpe, Head of Climate Change Strategy and Communications at the UK's Department for Business, Energy and Industrial Strategy (BEIS), it became apparent that in the UK, a carbon floor price has helped to reduce the usage of coal, as it became increasingly cheaper to use cleaner energy resources. Freezing the carbon price floor was undertaken as the price could not increase due to the price of the permits throughout the EU ETS being too low. The interconnectedness of the individual countries' carbon prices hints that regional cooperation is key; there is a need to coordinate policies as one country alone cannot establish a policy, as they would be disadvantaged when trading. Thus, trading within West Africa would be a challenge if one were to think about implementing a regional emissions trading scheme in ECOWAS.

With the dynamics of carbon pricing being one that has negative feedback, one may argue that a tax and dividend together is a better alternative to carbon pricing (Sharpe, 2019). This involves taking revenue and giving it back to the market. This is particularly useful for poorer economies and can help keep the consumer's energy price at an affordable rate, and thus "provide much-needed resources to African countries" (CPLC, 2018a).

9.7.1 Evaluation of Clean Development Mechanisms (CDM)

Clean Development Mechanism (CDM), international carbon offsets in poorer regions through investing in clean energy projects, have been gaining prevalence in recent years. Under the CDM or the EU ETS, a certain number of Certified Emissions Reduction (CERs) are generated or issued to a project by the Executive Board to the CDM Registry Administrator. For example, a clean cookstoves project in Mali and Benin between June 2014 and December 2015 was issued 2,747 CERs (UNFCCC, 2019).

Table 9.7.1.0: Regional distribution of CDM projects, showing that 95% of projects are concentrated in Latin America, and Asia & Pacific.

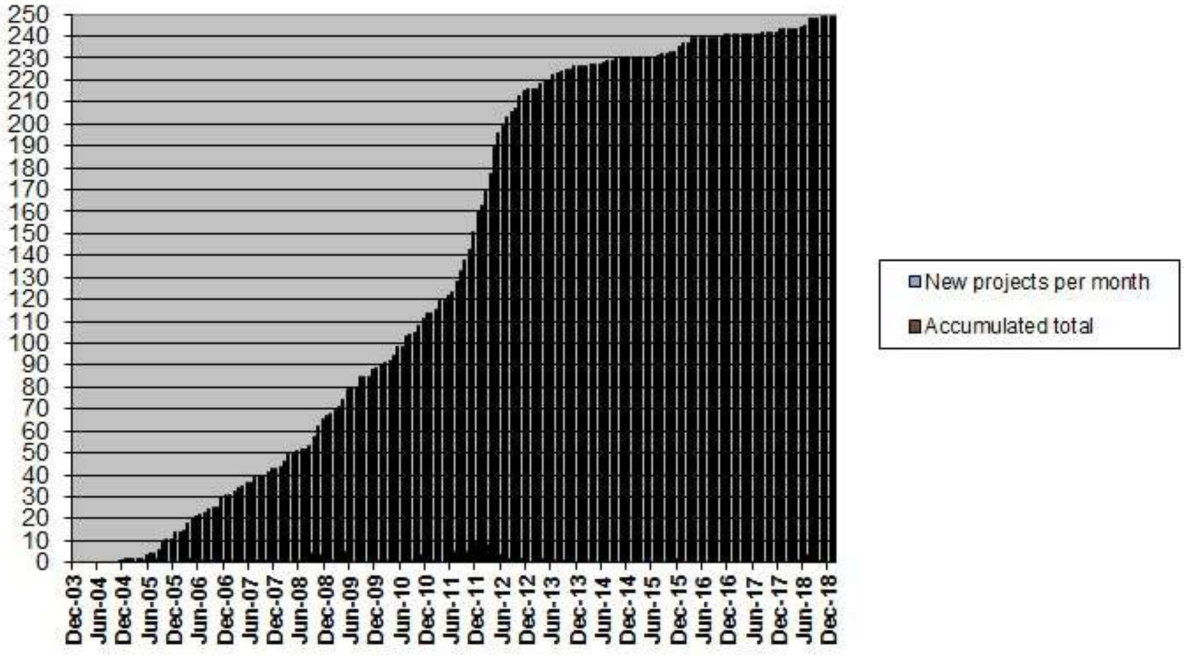


Regional distribution of CDM projects	Number of small-scale		Number of full scale		Number of all projects		kCERs	2020 kCERs		lation	per cap.
Latin America	404	**12.0%**	697	**13.9%**	1101	**13.1%**	144807	965666	**11.9%**	449	2.15
Asia & Pacific	2820	**83.6%**	4014	**80.2%**	6834	**81.6%**	896925	6556712	**81.1%**	3418	1.92
Europe and Central Asia	23	**0.7%**	61	**1.2%**	84	**1.0%**	19503	136604	**1.7%**	149	0.92
Africa	85	**2.5%**	164	**3.3%**	249	**3.0%**	45791	281392	**3.5%**	891	0.32
Middle-East	42	**1.2%**	69	**1.4%**	111	**1.3%**	23923	146028	**1.8%**	186	0.79
Less developed World	3374	**100.0%**	5005	**100.0%**	8379	**100%**	1130950	8086402	**100%**	5093	1.59

Source: UNEP DTU Partnership, 2019

However, there has been a geographical imbalance regarding the concentration of CDM related projects. As evident in Table 9.7.1.0, despite being geographical large, the African continent only attracts only 3.0% of all CDM projects amongst developed countries. Although there are still many projects in the pipeline, there is scope for developing more in the African continent.

Figure 9.7.1.0: CDM Projects in Africa between 2003 and 2018, excluding PoAs



Source: UNEP DTU Partnership, 2019

Figure 9.7.1.0 above reflects the surge in African projects up until 2012, primarily due to the EU's decision in April 2009 to restrict the number of CERs issues for post-2012 projects (Kreibich et al., 2017). This occurred due to the inflow of overly-abundant credits that were pushing down the price of carbon and reducing the incentive to reduce fossil fuels usage. In addition, bottlenecks in project development in Africa could also be a factor in the stagnating project levels; the projects in the region seemingly began to level off around 2012, with the increase thereafter being very slight. This may be why clean energy projects are not penetrating fast enough. It is worth noting that the primary objective of the EU ETS was not to help developing countries develop sustainably, but rather to reduce GHG emissions cost-effectively within the EU.

Reasons for the lack of CDM projects in the African region include 1) lack of capital due to a lack of awareness of commercial opportunities leading to perceived risks 2) the presence of real risks such as a lack of transparency 3) business environment and market barriers such as a lack of incentive for renewables to enter market in the host countries. With the first point in particular, countries that are deemed to be economically stable such as China, are the preferred location of CDM projects. Indeed, the fact that China is establishing its own carbon market in 2020 is a further indicator of its plausibility in utilising renewable energy technology successfully. These risks can be perceived (and ins such case, information sharing is vital), but also very real.

9.7.2 South Africa Carbon Tax

The South Africa Carbon Tax will come into effect on 1st June 2019 for the whole nation and will cover 80% of GHG emissions, or 451 $MtCO_2e$. (The World Bank Group, 2019b). Although South Africa is not a part of ECOWAS, examining some aspects of the carbon tax could be a useful for consideration for West Africa despite its different energy portfolio.

The South Africa Carbon Tax will apply to emissions from "industry, power, buildings and transport sectors irrespective of the fossil fuel used" (The World Bank Group, 2019b). Each tCO_2e will cost R120, or US$8.49 using the current exchange rate of R1 = 0.07076 US$ (XE, 2019). However, taking into the exemptions by firms and tax-free emissions for firms that had invested in efficiency measures, the effective tax would be between R6 and R42 for tC02e, or US$0.42 and US$2.97 (Curran, 2018). Exemption for the South Africa Carbon Tax for many sectors start from 60% up to 95%, where the level is dependent on factors including "presence of fugitive emissions, level of trade exposure, emission performance, offset use and participation in the carbon budget program" (The World Bank Group, 2019b).

Initially, the tax rate would have had an escalation rate of 10% per annum but has now become a more flexible price. The tax rate is expected to increase by the amount of CPI plus 2% per annum up until 2022, and the inflationary adjustments, i.e. only CPI for the preceding tax year as determined by Statistics South Africa will be used to set the tax rate after 2022 (Republic of South Africa Minister of Finance, 2018). Considering the South Africa Reserve Bank's inflation target of 6%, the carbon tax rate will then be 8% (CPI + 2%) until 2022, and then 6% annually after 2022. Set out in the Carbon Tax Bill and shown in detail in Appendix V, the tax base rate is based on formulae calculated from factors such as the fuel combustion amount. This could be useful in Côte d'Ivoire exploration of tax options.

While an escalation rate for carbon tax will allow for firms to make long term investment plans, the tax's dependence on CPI may cause uncertainty within firms as it is difficult to predict CPI in the long term. Technological developments and responsiveness by industry to policies may mean that the price of the carbon tax will change. Predicting future technological developments, which will affect demand for polluting, can be a challenge. In addition, it will also be difficult to assess the effectiveness of the carbon tax in reducing GHG emissions. The Report of the High Level Commission on Carbon Prices, illustrated by the World Bank Carbon Pricing Leadership Coalition (CPLC), suggested a tax ranging from US$40 and US$80 per tCO_2e by 2020, and subsequently reaching between US$50 and US$100 per tCO_2e by 2030 (Curran, 2018). Should West Africa implement a carbon tax, the initial rate may be too low to make a significant immediate impact.

9.7.3 West African Alliance for Carbon Markets and Climate Finance (WAACMCF) and Côte d'Ivoire Carbon Tax

Launched during COP22 in Marrakech in 2016, the West African Alliance for Carbon Markets and Climate Finance (WAACMCF), involving Mauritania and all the ECOWAS nations except Burkina Faso, Ghana, Liberia and Sierra Leone, looks to help the nations develop carbon market mechanisms. Côte d'Ivoire in particular has been engaging with various stakeholders to design its carbon pricing policy; namely, the World Bank's Carbon Pricing Leadership Coalition (CPLC) and Partnership for Market Readiness (PMR), supported by AfDB, UNFCCC and the German Ministry of Environment. Côte d'Ivoire's energy production consisted of 83.3% fossil fuels in 2015, thus it can be argued that a carbon tax could be efficient in facilitating a shift to more renewables, which only made up 16.7% in 2015.

In April 2018, Côte d'Ivoire received US$ 500,000 of funding from the PMR Trust Fund to support its policy design and has been receiving peer exchange and technical assistance from both the PMR and CPLC (CPLC, 2018b). A year later, in March 2019, Côte d'Ivoire confirmed a grant from the World Bank to facilitate the process (N'Guessan, 2019). However, as carbon taxes usually result in an increased fuel price for the consumer, which tends to be borne the heaviest on the poorest communities. Policies could support utilising revenue from taxes to subsidise individual energy costs, however the difficulty lies in deciding who receives the subsidy.

Many believe that other ECOWAS regions should also implement a carbon tax, (N'Guessan, 2019). While Counsellor N'Guessan understands that it is difficult to implement, he believes that when Côte d'Ivoire has the details finalised, Côte d'Ivoire plans to share information learnt to others in ECOWAS in the hopes that they could implement a carbon tax. However, as aforementioned, carbon taxes alone may not be enough of an incentive to ensure a shift to cleaner technology policy intervention is needed. Policy interventions that allow the entrance of new cleaner technology in the market, may be more effective than a tax. In poorer regions, this may be a challenge due to a lack of institutional strength. It may be the case where having subsidies for renewable energy is better than having a carbon price floor for carbon permits, as carbon permits heavily affect the price of other fuels. Indeed, incentives to shift away from coal exist in the ECOWAS region, and to guarantee the use of renewable. Such incentives are already in place, such as the aforementioned FIT in Ghana, as well as a variation of cash grants for purchasing solar panels.

9.7.4 Challenges and Potential Bottlenecks

Carbon market mechanisms are complex, requiring intricate designs and transparency. Establishing a robust accounting system for calculating energy consumption and CO_2 emissions for emissions trading is also necessary. Emissions trading in the power sector in ECOWAS may be a good starting point as not only is it a key polluter, but it is also easier to monitor compared to other sectors. However, due to the complexities in designing and administrating trading, a level of institutional capacity that is required is not present in all of the

ECOWAS countries. Despite being an easier sector to monitor, the ability to assign an emission quota to large emitting facilities, track emissions levels and ensure compliance is not a simple task. Regular checks along the implementation of the carbon tax is necessary to "ensure the rate of emissions reductions…is consistent with the country's overall mitigation strategy" (Curran, 2018). The ECOWAS region may not be at a stage to facilitate this.

One can argue that emissions trading is not effective in reducing pollution as if a nation develops clean technology and no longer has the need for its permits, the decreased demand would cause the price of the permits to go down. This means that the decreased price is not an incentive for nations to switch to cleaner energy, as it may be cheaper to buy cheap permits and use heavy polluting resources. Indeed, renewable energy subsidies would drive down the price of the carbon permits too, but in some cases, it still may be cheaper to buy the cheap permits than to use renewable energy. Assigning the right price is crucial as it directly affects demand and is a challenge any country seeking to implement this mechanism faces. The 2008 Lehman Brothers shock meant that EU Carbon markets fell to £6 (or US$ 7.71) per tonne and was therefore weakening the incentive the develop clean technology (XE, 2019). In the first phase of the ETS, there was free allocation based on emissions in the past, despite the economic situation deteriorated and causing much surplus. Indeed, there are inherent risks in ETS which include economic instability. As some regions are facing this in ECOWAS, such as in Sierra Leone where civil war also threatens political stability, it can be argued that a trading system may not be effective. Perhaps emissions trading could work in the more developed and politically stable countries within ECOWAS such as Ghana and Nigeria, after engaging in knowledge sharing and institutional strengthening.

10.0 Additional Barriers and Recommendations

Barriers being faced are interconnected, however, responses must be tailored to “the market, policy and physical context” (DFID, 2014, p.2). The newest issue facing grids powered by renewable energy sources is the ability in and the cost of storing the electricity at times of peak production but low demand (Esteban, 2019). The intermittency of renewable energy is an issue that can be overcome with international grid connections and mini-grids. Countries such as the UK has utilised an online database called GridCarbon, where the production and demand of different renewable energy sources are displayed. Such can be utilised by regions in the ECOWAS region to monitor energy use and better understand how to make electricity usage more efficient. In addition, “the cost of transporting goods in Africa is among the highest in the world” (IEA, 2014, p.459), which is a barrier to realising grid connection projects.

As aforementioned, some argue that policies must be implemented to support the import of solar panels, and then other renewable energy sources. There are still policies in place in some regions that prevent this from happening**.** Some government owned fossil fuel plants, such as coal-fired power plants, may want to further support the cause for the use of coal, as this would lead to continued profit for them. For example, as a big exporter of oil, Nigeria may be reluctant to implement policies that reduce its export of oil (N’Guessan, 2019). This would prevent other renewable energy sources such as solar from accessing the grid. Some policies committing to mini-grids may also be unclear, including uncertainty over whether the incentives promised will be delivered (DFID, 2014). Furthermore, the policies must be complemented with training individuals on the ground to become experts in maintaining and operating CEMGs, as aforementioned. Once this is done, some argue that economics will take over the rest, and see that such renewable energy is more widely disseminated (Esteban, 2019). One way to overcome the aforementioned barriers is through sector planning and regulatory intervention.

11.0 Conclusion, Limitations and Further Research

Today, in 2019, there are still 1.1 billion people without access to electricity, contributing to millions of preventable fatalities in poorer communities. Access to modern electricity would result in safe cooking methods, improved irrigation practices and cereal resilience, increased productivity and an overall stronger economy. In regions that do have electricity access in poorer countries, blackouts tend to be a common occurrence as energy access is not reliable due to technological shortfalls and/or a lack of energy resources. With most of these communities facing these circumstances residing in Sub-Saharan Africa, and with great potential in West Africa in particular to develop clean technology for sustainable development, it is vital that the international community becomes more proactive in dealing with this aspect of climate change.

In Sub-Saharan Africa, electrification efforts began to surpass population growth in 2014 (IEA, 2017). The number of those without electricity access has been declining, however, the number of people without access to clean cooking resources are increasing. The decline is largely due to businesses taping into decentralised energy grids; however, the statistics show that there is much room for more growth. In off-grid rural areas, traditional energy sources, such as biomass is used for cooking and heating, which is having adverse effects on residents' health and on the environment. While mini-grids exist in the region, there is not nearly enough to keep the nations on track for 100% energy access. 80 million people in Sub-Saharan Africa still cook using biomass (IEA, 2017). A certain categorisation of energy access may class this population as having energy access; however, it cannot be considered modern, reliable nor safe, and not aligned with SE4All.

There is also potential in utilising regional grid connections throughout West Africa, in particular the ECOWAS region. The planned OMVG connection between Senegal and Côte d'Ivoire going through land-locked nations such as Burkina Faso, and the CLSG line from Côte d'Ivoire to the rest of West Africa has much potential for addressing energy deficits (USAID, 2018). The cost of electricity in Africa tends to be expensive, so an international grid could bring down the cost of electricity, as gaps in demand and provision that inevitably occur will be overcome by buying needed electricity or selling off surplus. Many argue, however, that poorer economies such as those in the ECOWAS region should focus on disseminating a grid connection within their countries first before even considering an international grid. This argument does not stand strongly as trade will generate foreign exchange.

Developing the infrastructure for renewable energy in ECOWAS comes with a range of challenges, including (perceived) financial risks, a lack of manpower, information and expertise. Further external support is needed, and indeed is being provided by a range of international government departments, institutions and private companies. However, there is not enough of this. In many cases, there are private companies willing to invest in mini-grid and off-grid technology in rural areas in Africa, but they do not. There is also often the case where there are funds for such projects, but not enough projects existing.

External assistance from MDBs, DFIs and other bodies can help ECOWAS lift itself out of energy poverty, especially through promoting an enabling environment that develops policies, such as subsidies for renewable energy. However, regardless of the external assistance the region may receive, there will be no progress unless the host nations have political will to enable the development of their energy sectors. Different business models can be explored; political will may be further increased through collaboration with other bodies through PPPs. With political will comes the ability for government to manage most of the risks involved in energy projects and increase its chances of success.

Looking at economic tools, while carbon markets can incentivise a shift towards clean energy, they may not be the most effective or plausible tool in all of the ECOWAS nations. Those that are developing institutional capacity such as Nigeria and Ghana, could potentially utilise a carbon tax in the future. However, carbon pricing is not essential as a tool for poorer, less polluting regions. In addition, an emissions trading scheme may not be effective in the foreseeable future as many changes are required in the state of West Africa's current institution in order to handle the complexities in scheme designing, monitoring, compliance and emissions quota setting. If a nation has subsidies for fossil fuels, that subsidy could be gradually eliminated and lead to supporting renewables, without using carbon pricing. Policies that could complement or be in lieu of carbon market mechanisms, include FITs and renewable energy quotas.

While this thesis seeks to address the barriers to tackling energy poverty in poorer regions, with a focus in ECOWAS, there are limitations and therefore scope for further research. Limitations include the age of the data utilised, as well as a lack of reliable data regarding ECOWAS, including each region's energy mix (energy production and/or energy consumption). Further research could seek to obtain or create more up to date and reliable data on the ground. Particularly regarding planned projects that were beyond the scope of this thesis, further research could look into the potential of regional integration that involves other regions besides ECOWAS, such as the integration from Grand Inga.

As mentioned in this research, a combination of different policies and initiatives would best prepare nations such as those in ECOWAS for achieving energy access for all by 2030. Further research could also look into how various climate policies such as FITs and renewable energy quotas affect the demand for carbon, and thus investigate which policies could best complement a carbon market mechanism, if possible, in West Africa. Initiatives can be looked into further to assist this, such as the Lighting Africa Programme and Market System Development, including critiques and room for improvement in helping nations acquire the right toolbox for tackling energy poverty.

This research looks at mini-grids for small communities, however further research could look at the state of Pico energy systems for small individual devices in ECOWAS, investigate the barriers and the optimised utilisation of Pico systems and SHS. Pico systems and SHS would not share some of the barriers mini-grids do (such as those pertaining to utility failures, policy or governance issues, and distribution and business models). There is an issue with preserving the culture of traditional houses in some rural communities, for example. In addition, in communities where makeshift homes are made from scrap metal, SHS could be an option with the right financial assistance and policy framework. Further research could investigate how this can be expanded in the ECOWAS region, in line of the nation's goals for sustainable development. Further research could also look into how regions can utilise solar CSP, especially if there is the case where solar CSP may be more efficient and cost effective in a certain region compared with solar PV.

Despite the barriers that persist, extreme poverty has halved in the last 30 years, and is on track to be eliminated by 2030. Achieving energy access for all by 2030 is very achievable with the right cooperation, political will and changes to the status quo. It is necessary to remove all the barriers that prevent the implementation of renewable energy sources, particularly in poorer regions, in order to realise SE4All and the aspirations of an economically developed and sustainable future for generations to come.

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13.0 Appendices

13.1 Appendix I: Analysis of the questions asked by the participants in OMVG consultation in Gambia

Given the agricultural importance in the villages crossed by the interconnection line, during the various presentations, many important concerns and questions were asked by the participants. A summary of these questions and answer are presented in the table below:

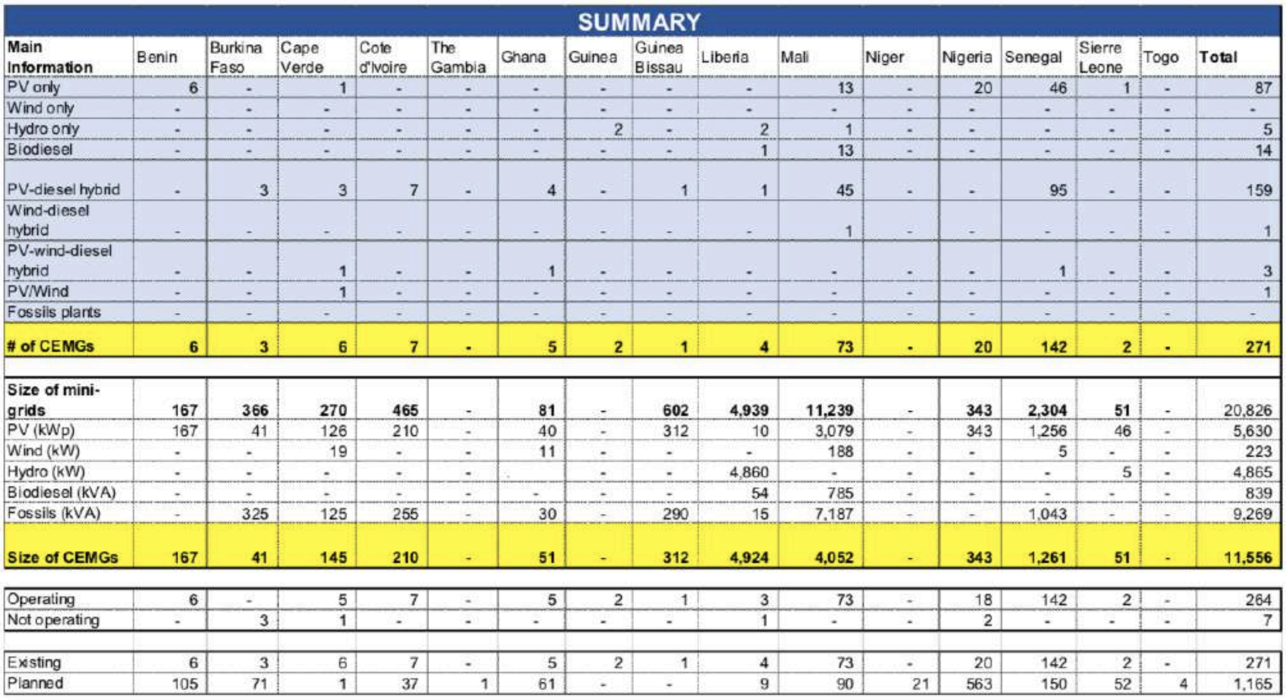
No	Questions	Answers
1	Who will be responsible for connecting the communities to the interconnection line?	The various national electricity companies are responsible for connecting the communities to the line.
2	Since the land is the main asset of the people, will these people be able to access farmland for agricultural work once the construction of the line is complete?	Yes, but, the possible works are: Gardening, food crops and vegetables, livestock, grazing and other compatible activity. However, it is strictly forbidden to build houses, huts, sheds, agricultural buildings, latrines, etc. and to plant trees whose size exceeds 3.5m. The lands under the pylons will be permanently lost (no crops will be allowed).
3	Who will have to identify the location of the pylons?	The location of the pylons will be determined with GPS support.
4	What is NECG's role in this project?	Distribution of electricity from the Brikama and Soma substations.
5	Could interstate conflicts have an impact on this project?	Interstate conflicts should not happen. No member country of the Organization has the right to deprive other country in electricity. The dam and the interconnection line are common property of all member countries of the Organization. This is governed by laws and agreements between States member.
6	Can land or farm owners oppose the installation of pylons in their properties?	From the moment your land or farm is on the interconnection line which is declared to be of public utility by the OMVG member countries, under no circumstances should an owner oppose the installation of the towers on his properties.
7	With the new system, will homes that already benefit from NAWEC service redo their electrical installations and change the "Cash Power" meters (prepaid) made available by NECG?	This case will be duly studied by NAWEC.
8	Will the people directly affected by the project have access to employment under this project?	Populations directly affected by the interconnection line will be favored when hiring during the pre-construction phase and the construction of pylons in accordance with their competence.
9	Is agricultural work possible under the interconnection line?	Under the line of interconnection, the possible works are: Gardening, food crops and vegetables, Livestock, grazing and other compatible activity. However, it is strictly forbidden to build houses, huts, sheds, agricultural buildings, latrines, etc. and plant trees whose size exceeds 3.5m.

10	The impact of the interconnection line on migratory birds?	A study on bird migration corridors was carried out by specialists recruited by AECOM. A first version of the study is available.
11	Management and distribution of electricity in member countries?	In each country the structures responsible for electricity will ensure the distribution and management of electricity. For the specific case of Gambia, it is NECG, for Senegal it is SENELEC, for Guinea Conakry it is EDG and for Guinea Bissau, it is EAGB.
12	Will the villages crossed by the interconnection line benefit from electricity?	The main concern of the OMVG is to ensure the availability of current in quantity and in quality for the four countries in order to meet the demand of the populations by the different national services in charge of electricity.
13	Will the local workforce be used for work at the villages crossed by the interconnection line?	Yes, but according to their competence. Otherwise, labor can be recruited anywhere else in OMVG member countries.
14	What is the expected distance between the pylons?	The planned distance between the pylons is 500 m.
15	How will the surfaces lost after the installation of the pylons be compensated?	First, these losses are classified in the category of surface lost permanently. The compensation will be either in kind or in cash in proportion to the area occupied by the pylons (lost).
16	My land is probably on the interconnection line. But I'm not very sure. My intention is to build a house there. What will you recommend to me?	We recommend that you do not build first. First, make sure that your land is not impacted by the interconnection line before doing anything.
17	If for example my field is crossed by the interconnection line and I lose some or all of my farmland and for compensation I am offered a certain amount for which I do not agree, how will this conflict be resolved?	For the interconnection component, the vast majority of PAPs will fall into the third category (crop, tree or pasture losses). Several proposals exist to resolve this dispute or conflict. - A first method is to provide additional explanations to the complainant (example: explain in detail how the project calculated the compensation of the complainant and show him that the same rules apply to all), - Use elders or respected people in the community to play the role of arbitration. - Make use of the courts according to the laws of each of the 4 member countries of the OMVG. But this process does not seem to be the best way to resolve this conflict, as it often requires lengthy delays before the case is dealt with and this can result in significant costs for the complainant, and requires a complex mechanism, with experts and lawyers, who often can escape the complainant and eventually turn against him.

17 (cont.)		Finally, courts are not expected to hear disputes over untitled properties, which in the case of the interconnection project are likely to constitute the majority of cases. That is why for the OMVG Energy Project, the project manager will set up an extra-judicial dispute resolution mechanism involving the explanation and mediation by third parties. It will comprise two main stages: - the registration by the supervisor of the complaint or the dispute, - amicable treatment, calling on independent project mediators. PAP may appeal to recommendation or decision of this mechanism. Each affected person, as the right to uses at any time the justice system of his country,
18	I own farmland that is operated by a third party and is affected either by the interconnection line or by the substations causing the loss of some or all of the agricultural land. In this case between me the owner and the non-owner operator will be compensated?	For a farmer who does not own a farmland that will lose access to some or all of the land he was farming, it is proposed to pay in kind or in cash the equivalent of an annual harvest according to the cultivated area. - The compensation approach for parcels of land is to focus on offsets in kind to the extent possible. However, special attention will be paid to non-owner farmers who are considered vulnerable. - For the owner, the compensation will be made from the following year in accordance with the affected area. And this compensation can be done either in kind or in cash. Generally, only areas under pylons and substations will be permanently lost.

Source: The World Bank Group, 2019d.

13.2 Appendix II: Survey of existing and planned mini-grids in the ECOWAS nations



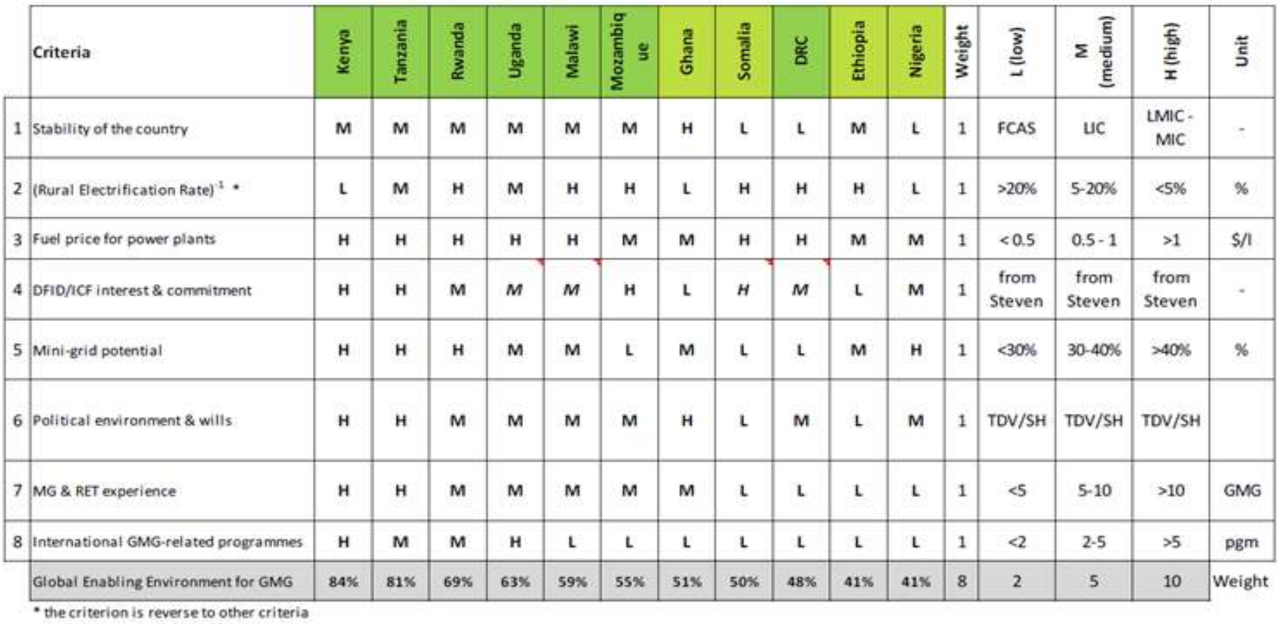
SUMMARY

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

Source: Hobson, 2016.

13.3 Appendix III: Criteria for Country Selection and Preliminary Scores for GMG deployment in Africa by IED

Table 11: Criteria for Country Selection and Preliminary Scores



	Criteria	Kenya	Tanzania	Rwanda	Uganda	Malawi	Mozambique	Ghana	Somalia	DRC	Ethiopia	Nigeria	Weight	L (low)	M (medium)	H (high)	Unit
1	Stability of the country	M	M	M	M	M	M	H	L	L	M	L	1	FCAS	LIC	LMIC - MIC	-
2	(Rural Electrification Rate)[1] *	L	M	H	M	H	H	L	H	H	H	L	1	>20%	5-20%	<5%	%
3	Fuel price for power plants	H	H	H	H	H	M	M	H	H	M	M	1	< 0.5	0.5 - 1	>1	$/l
4	DFID/ICF interest & commitment	H	H	M	*M*	*M*	H	L	*H*	*M*	L	M	1	from Steven	from Steven	from Steven	-
5	Mini-grid potential	H	H	H	M	M	L	M	L	L	M	H	1	<30%	30-40%	>40%	%
6	Political environment & wills	H	H	M	M	M	M	H	L	M	L	M	1	TDV/SH	TDV/SH	TDV/SH	
7	MG & RET experience	H	H	M	M	M	M	M	L	L	L	L	1	<5	5-10	>10	GMG
8	International GMG-related programmes	H	M	M	H	L	L	L	L	L	L	L	1	<2	2-5	>5	pgm
	Global Enabling Environment for GMG	84%	81%	69%	63%	59%	55%	51%	50%	48%	41%	41%	8	2	5	10	Weight

* the criterion is reverse to other criteria

Source: DFID, 2014

13.4 Appendix IV: Risk and mitigation actions acknowledged by DFID for GMGs in Kenya and Tanzania.

B. What are the risks and how these will be managed?

Risks are summarised in the table below with associated mitigation actions proposed:

Risk and cause	Effect	Mitigation Actions
Lack of investable project/developer pipeline	Credit Line fund goes unused because of lack of suitable projects. Private sector leverage not achieved.	ASD options assessment has produced the most detailed assessment of the deal pipeline to date, while TEDAP has a clear pipeline of Type 1 GMGs in Tanzania, while and a statement of interest has been signed by developers in Kenya and Tanzania, co-ordinated by GVEP. Overall potential and pipeline estimates show that more funding will likely be necessary than will be available, although information is less concrete in Kenya. However, funds will not be transferred without demonstrated need, so the risk of stranded funds is reduced. Nationally-managed project development and transaction advisory support is coupled with credit lines to help create viable projects, developers and offtakers. Where possible (especially in TEDAP), existing pipelines of prepared projects with a funding gap are picked up. In Kenya more risks relating to policy blockages exist and the enabling environment for GMGs will have to be monitored, including feedback from IFC's DFID-Supported work in this area through the *Building a Reliable Investment Climate in Kenya* (BRICK) programme.
Customers do not keep up payments to mini-utilities	Loan repayments are not made, firms collapse and electrical service is lost	The primary mitigation is the community mobilisation support and support to create viable business models for mini-utilities, which creates consent to pay for a pre-defined level of service. End-user financing of connections and appliances for productive uses should help consumers manage payments within households budgets, increase incomes and reduce expenditures overall on kerosene and phone charging.
Mini-Utilities do not keep up supply	Service is lost, customers refuse to pay and trust breaks down	The primary mitigation is the project development support which should enable developers to specify a system which is tailored to the needs of the community, and to charge a fee which enables operation and maintenance of the system at appropriate service levels. In some cases it may be possible for other mini-utilities or REA/TANESCO to take over supply in the case that firms run into difficulties.
Communities are not keen to have a mini-grid as they have been promised by politicians that the grid will arrive	There is not consent for a mini-grid from communities even if technically and financially viable	The primary mitigation is clear planning on the part of national governments illustrating the role of mini-grids in serving populations. The secondary mitigation is that mini-grids should be future-proofed against grid interconnection where appropriate and cost-effective.

Off-taker and policy risk reduces willingness of PFIs to support more projects (and PRGs are not provided)	Projects are funded within the credit lines, but there is lower leverage and no replication	In Tanzania, TANESCO has now agreed to pay SPPs in a timely fashion. The financial sustainability of TANESCO is a central focus on the WB DPO and AfDB power sector budget support – including the TANESCO's arrears to ensure it is a financially viable footing as well as setting a strategy to ensure its long terms viability. This will be monitored and Partial Risk Guarantees under SREP will also be explored by WB if TANESCO's payment record does not improve and market soundings indicate that this is a critical barrier. In Kenya, the utility KPLC has a good payment record, but clearer statements from the Government on their interest in mini-utilities will be required to reassure investors. The Mini-Utilities in both countries selling directly to customers will largely make use of pre-payment meters or collection systems not dependent on the national utility.
Additional credit line resources are insufficient to fill the funding gap	Market confidence is lost and deals are dropped	Depending upon the additional time gap, further projects will be asked to delay but not be cancelled, or additional financing may be sought.
Credit line stimulates inappropriate market signals	Banks lend without proper due diligence to bad projects, and private investment is crowded out	Currently the sector cannot grow without long-term financing and the purpose of the credit line in Tanzania is to make it available. Private Banks and lenders must still have between 15 and 25% exposure for credit risk under Credit Line in the case of TEDAP. In general, the risk of crowding out of private financing the 5 year period of the programme is considered low, however after that period it would be hoped that credit facilities are not necessary as developers and banks would have sufficient credit histories and sector experience respectively.
Research not responding to needs and integrated with GMG scaling-up.	Evidence not used effectively to influence future programmes	Research component is linked to existing MDBs active in GMG programming and coordinated through Action Learning Group, linked to HIO initiative on GMGs
GMGs charges to consumers are too high for poorer consumers	Inequality increases as a result of the intervention	Developers will have to consider the most appropriate tariff structure for the proposed schemes, taking equity and regulatory considerations into account in their proposals. Criteria on social inclusion will be included in selection guidelines. Connection incentives and results-based payments should be positioned complementary to the programme support (see Appraisal Case) and end-user financing allowed for under creditlines. Client satisfaction mechanisms will be included as part of the monitoring system from the start.
GMGs will not result in connections or take up of power by health clinics and schools	Health and education co-benefits of the programme are not realised.	Criteria valuing connections for schools and clinics will be incorporated in guidelines for proposals. Connections will be made as appropriate with relevant ministries and local governments (see local government components in Annex 1 and 2) to support the inclusion of public services in GMGs. Where government budgets are a key constraint, REA should seek agreements with the health and education counterparts (or the Big Results-Now Initiative in Tanzania for example) as required to ensure co-benefits are realised.
Additional jobs and employment opportunities do not benefit women and girls	Employment co-benefits of programme are not realised.	As set out in the Social Appraisal, selection criteria will prioritise developers and NGOs who include specific measures regarding developing girls and women's capacity to benefit from the jobs created as part of the programme.

Resources provided to basket funded Trust Funds are retasked to other activities	Resources intended for GMGs are not applied and results are not achieved	Assurances regarding these risks will be solicited and Quested during the due diligence process – including from other donors parties to the MDTFs. Further, the contribution agreements will only be signed in conjunction with an agreed Work Programme corresponding with the activities and results envisaged under the GMGs programme. Disbursements similarly will only be made on the basis of need, linked to a report on activities in the last period and the workplan going forward.
Loan repayments are not properly revolved into new projects or related activities	Misuse of DFID funds	For each loan component a process is set out for the repayment of those funds by the recipients, the final destination of repayments and how the funds will then be used in further projects or related activities. These agreements will be set out in the contribution arrangements with the respective partner, and tracked in the monitoring on the programme.

Source: DFID, 2014, p. 57.

13.5 Appendix V: South Africa Carbon Tax Bill: Tax calculations and allowances

Tax base

4. (1) The carbon tax must be levied in respect of the sum of the greenhouse gas emissions of a taxpayer in respect of a tax period expressed as the carbon dioxide equivalent of those greenhouse gas emissions resulting from fuel combustion and industrial processes, and fugitive emissions in accordance with the emissions factors determined in accordance with a reporting methodology approved by the Department of Environmental Affairs.

(2) If a reporting methodology approved by the Department of Environmental Affairs for the purposes of determining emission factors does not exist in respect of the calculation of greenhouse gas emissions resulting from fuel combustion, and industrial processes, and fugitive emissions the carbon tax must be levied in respect of the sum of the greenhouse gas emissions of a taxpayer in respect of a tax period expressed as the carbon dioxide equivalent of those greenhouse gas emissions resulting from—

(a) fuel combustion in respect of that tax period that is a number constituted by the sum of the respective numbers determined for each type of fuel in respect of which a greenhouse gas is emitted in respect of that tax period which respective numbers must be determined in accordance with the formula:

$$E = (A \times B)$$

in which formula—

- (i) **“E”** represents the number to be determined;
- (ii) **“A”** represents the mass of any one type of the fuel expressed in tonne that is the source of the greenhouse gas emission, other than any fuel utilised for the purposes of international aviation and maritime transport;
- (iii) **“B”** represents the greenhouse gas emission factor in carbon dioxide equivalent per tonne that must be determined in accordance with the formula:

$$X = \{(C \times 1) + (M \times 23) + (N \times 296)\} \times D$$

in which formula—

- *(aa)* **“X”** represents the number to be determined;
- *(bb)* **“C”** represents the carbon dioxide emissions of a fuel type determined by matching the fuel type listed in the column “fuel type” in Table 1 of Schedule 1 with the number in the corresponding line of the column “CO_2 ($KGCO_2$/TJ)” of that table;
- *(cc)* **“M”** represents the methane emissions of a fuel type determined by matching the fuel type listed in the column “fuel type” in Table 1 of Schedule 1 with the number in the corresponding line of the column “CH_4 ($KGCH_4$/TJ)” of that table’;
- *(dd)* **“N”** represents the Nitrous Oxide emissions of a fuel type determined by matching the fuel type listed in the column “fuel type” in Table 1 of Schedule 1 with the number in the corresponding line of the column “N_2O (KGN_2O/TJ)” of that table; and
- *(ee)* **“D”** represents the default calorific value (Terra Joule per tonne) of a fuel type determined by matching the fuel type listed in the column “fuel type” in Table 1 of Schedule 1 with the number in the corresponding line of the column “DEFAULT CALORIFIC VALUE (TJ/TONNE)” of that table;

(b) fugitive emissions that is a number constituted by the sum of the respective numbers determined for each type of commodity, fuel or technology in respect of which the greenhouse gas is emitted in respect of a tax period which respective numbers must be determined in accordance with the formula:

$$F= (N \times Q)$$

in which formula—

- (i) **“F”** represents the number to be determined;
- (ii) **“N”** represents the mass expressed in tonne in the case of solid fuels or the volume of each type of fuel expressed in cubic metres in the case of fuels other than solid fuels, in respect of the greenhouse gas emission; and
- (iii) **“Q”** represents the greenhouse gas emission factor in carbon dioxide equivalent per tonne or cubic metres that must be determined in accordance with the formula:

$$X = (C \times 1) + (M \times 23) + (N \times 296)$$

in which formula—

- *(aa)* **“X”** represents the number to be determined;
- *(bb)* **“C”** represents the carbon dioxide emissions of a fuel type determined by matching the fuel type listed in the column “fuel type” in Table 2 of Schedule 1 with the number in the corresponding line of the column “CO_2” of that table;
- *(cc)* **“M”** represents the methane emissions of a fuel type determined by matching the fuel type listed in the column “fuel type” in Table 2 of Schedule 1 with the number in the corresponding line of the column “CH_4” of that table;
- *(dd)* **“N”** represents the Nitrous Oxide emissions of a fuel type determined by matching the fuel type listed in the column “fuel type” in Table 2 of Schedule 1 with the number in the corresponding line of the column “N_2O” of that table; and

(c) industrial process in respect of a tax period that is a number constituted by the sum of the respective numbers determined for each type of commodity, fuel or technology in respect of which the greenhouse gas is emitted in respect of that tax period which respective numbers must be determined in accordance with the formula:

$$\mathbf{P= (G \times H)}$$

in which formula—

- (i) **"P"** represents the amount to be determined that must not be less than zero;
- (ii) **"G"** represents the mass of each raw material used or product produced expressed in tonne in respect of which the greenhouse gas is emitted in respect of that tax period; and
- (iii) **"H"** represents the greenhouse gas emission factor in carbon dioxide emissions equivalent per tonne for each raw material used or product produced that must be determined in accordance with the formula:

$$\mathbf{X = (C \times 1) + (M \times 23) + (N \times 296) + (H \times 11\,900) + (T \times 5\,700) + (S \times 22\,200)}$$

in which formula—

- *(aa)* **"X"** represents the number to be determined;
- *(bb)* **"C"** represents the carbon dioxide emissions of a raw material or product determined by matching the fuel type listed in the column "SOURCE CATEGORY ACTIVITY / RAW MATERIAL / PRODUCT" in Table 3 of Schedule 1 with the number in the corresponding line of the column "**CO_2/tonne product**" of that table;
- *(cc)* **"M"** represents the methane emissions of a raw material or product determined by matching the fuel type listed in the column "SOURCE CATEGORY ACTIVITY / RAW MATERIAL / PRODUCT" in Table 3 of Schedule 1 with the number in the corresponding line of the column "**CH_4/tonne product**" of that table;
- *(dd)* **"N"** represents the Nitrous Oxide emissions of a raw material or product determined by matching the fuel type listed in the column "SOURCE CATEGORY ACTIVITY / RAW MATERIAL / PRODUCT" in Table 3 of Schedule 1 with the number in the corresponding line of the column "**N_2O/ tonne product**" of that table;
- *(ee)* **"H"** represents the Hexafluoroethane (C_2F_6) emissions of a raw material or product determined by matching the fuel type listed in the column "SOURCE CATEGORY ACTIVITY / RAW MATERIAL / PRODUCT" in Table 3 of Schedule 1 with the number in the corresponding line of the column "**C_2F_6/tonne product**" of that table;
- *(ff)* **"T"** represents the carbon tetrafluoride (CF_4) emissions of a raw material or product determined by matching the fuel type listed in the column "SOURCE CATEGORY ACTIVITY / RAW MATERIAL / PRODUCT" in Table 3 of Schedule 1 with the number in the corresponding line of the column "**CF_4/tonne product**" of that table; and
- *(gg)* **"S"** represents the Sulphur hexafluoride (SF_6) emissions of a raw material or product determined by matching the fuel type listed in the column "SOURCE CATEGORY ACTIVITY / RAW MATERIAL / PRODUCT" in Table 3 of Schedule 1 with the number in the corresponding line of the column "**SF_6/tonne product**" of that table.

Rate of tax

5. (1) The rate of the carbon tax on greenhouse gas emissions must, subject to subsections (2) and (3), be imposed at an amount of R120 per ton carbon dioxide equivalent of the greenhouse gas emissions of a taxpayer.

(2) The rate of tax specified in subsection (1) must be increased by the amount of the consumer price inflation plus 2 per cent for the preceding tax period as determined by Statistics South Africa per year until 31 December 2022.

(3) The rate of tax must be increased after 31 December 2022 by the amount of the consumer price inflation for the preceding tax year as determined by Statistics South Africa.

Calculation of amount of tax payable

6. (1) Subject to subsection (2), the amount of tax payable by a taxpayer in respect of a tax period must be calculated in accordance with the formula:

$$\mathbf{X = \langle\{[(E - S) \times (1 - C)] - [D \times (1 - M)]\} + \{P \times (1 - J)\} + \{F \times (1 - K)\}\rangle \times R}$$

in which formula—

- *(a)* **"X"** represents the amount to be determined that must not be less than zero;
- *(b)* **"E"** represents the number in respect of the total fuel combustion related greenhouse gas emissions of the taxpayer in respect of that tax period expressed as a carbon dioxide equivalent determined in terms of section 4(2)*(a)*;
- *(c)* **"S"** represents the number in respect of greenhouse gas emissions, expressed in terms of carbon dioxide equivalent that were sequestrated in respect of that tax period as verified and certified by the Department of Environmental Affairs;
- *(d)* **"C"** represents a number equal to the sum of the percentages of allowances determined under sections 7, 10, 11, 12, and 13 in respect of that tax period subject to section 14;
- *(e)* **"D"** represents the number in respect of the petrol and diesel related greenhouse gas emissions of that taxpayer in respect of that tax period expressed as a carbon dioxide equivalent, determined in terms of section 4(2)*(a)*;
- *(f)* **"M"** represents a number equal to the sum of the percentages of the allowances determined under sections 7, 12 and 13 in respect of that tax period, subject to section 14;
- *(g)* **"P"** represents the number in respect of the total industrial process related greenhouse gas emissions of the taxpayer in respect of that tax period expressed as a carbon dioxide equivalent determined in terms of section 4(2)*(c)*;
- *(h)* **"J"** represents a number equal to the sum of the percentages of the allowances determined under sections 8, 10, 11, 12 and 13 in respect of that tax period, subject to section 14;
- *(i)* **"F"** represents the number in respect of the total fugitive greenhouse gas emissions of the taxpayer in respect of that tax period expressed as a carbon dioxide equivalent determined in terms of section 4(2)*(b)*; and
- *(j)* **"K"** represents the sum of the percentages of the allowances determined in terms of sections 7, 9, 10, 11, 12 and 13 in respect of that tax period, subject to section 14:
- *(k)* **"R"** represents the rate of tax prescribed under section 5:

Provided that where the number in respect of the determination of the expression "**(E-S)**" in the formula is less than zero, that number must be deemed to be zero.

(2) The amount of tax payable by a taxpayer in respect of the generation of electricity from fossil fuels in respect of a tax period must be calculated in accordance with the formula:

$$\mathbf{X = A - B - C}$$

in which formula—

- *(a)* **"X"** represents the amount to be determined that must not be less than zero;
- *(b)* **"A"** represents the amount of tax payable in respect of a tax period determined in terms of subsection (1);
- *(c)* **"B"** represents the renewable energy premium in respect of a tax period, from the commencement of the tax period until 31 December 2022, constituted by an amount expressed in Rand determined by the Minister by notice in the *Gazette*; and
- *(d)* **"C"** represents an amount equal to the environmental levy contemplated in respect of electricity generated in the Republic in Section B of Part 3 of Schedule 1 to the Customs and Excise Act, 1964 (Act No. 91 of 1964), paid in respect of a tax year, until 31 December 2022.

(3) For the purposes of this section **"sequestrate"** means the process of storing a greenhouse gas or increasing the carbon content of a carbon reservoir other than the atmosphere.

Source: Republic of South Africa Minister of Finance, 2018.